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Cloud Sculpture Final Design Report

Karsten Castillo
Trinity University

Lindsey Lubianski
Trinity University

Talley Withycombe
Trinity University

Jasmine Yang
Trinity University

MEMORANDUM

TO: Stuart Allen, Cade Bradshaw, Bridge LLC

FROM: Karsten Castillo, Lindsey Lubianski, Talley Withycombe, Jasmine Yang

SUBJECT: Final Design Report and Supporting Documentation

DATE: May 6, 2020

CC: Dr. Mehran Aminian, Team Advisor
Dr. Darin George, Senior Design Administor

Executive Summary

The design team has improved the functionality of the paper cloud sculpture, created originally by Bridge LLC, to include a colored response to weather or user-based input. In mid March of this year, the scope of our project shifted in order to comply with the distance-learning protocols put in place by the university. Without access to our materials or prototype, additional work shifted to addressing the weaknesses of our most recent *full* prototype.

Due to the pandemic and lack of access to the labs, the team was not able to implement the final prototype for testing. However, each individual component, namely response to weather conditions in real time, reliable connection to a weather database and fire safety was thoroughly tested and verified. The material used for the cloud is the one suggested by Paper Cloud to make the final product aesthetically pleasing. The facets of the prototype that fall short of our original project plan include ease of maintenance, installation, and ability to transport. While the wire connections in this prototype have little improvement to maintenance ability compared to the original sculpture, we have provided suggestions in the manufacture and structural layout of the weather-adaptive cloud sculpture to address these issues.

Since our team produced a prototype with demonstrable basic functionality, and addressed each weak point of the prototype with specific suggestions, we consider this prototype to be *working.* For thoroughness and safety, we have included detailed instructions for creating the electronic setup in Appendix A, along with the suggestion of welding wire connections for added stability.

1. Introduction

This project is intended to augment and refine the Paper Cloud, an art piece produced by Bridge LLC. Previous work done by the organization involves artistic components of the cloud sculpture design. The original construction consists of a flexible wire frame with LED strip lights woven throughout surrounded by a crumpled butcher paper envelope, which is stapled around the wire-light structure. These original cloud sculptures have two light states: on and off. Some displays of this work exist as standalone clouds, while others contain as many as 150 individual sculptures. Bridge LLC desires the following improvements: updated construction using flame resistant material that maintains the original sculpture's aesthetic, improved maintenance ease, and an additional light-temperature response to local or remote weather conditions. The problem is to design a system with a user-friendly interface that makes the clouds both weather and user responsive while keeping the cost low.

1.1 Project Objective

The main objective of this project is to design, implement, and test a weather-responsive cloud sculpture based on Bridge Project LLC's initial design. The cloud sculpture should accept data from a weather forecast and output different variations of light gradient and color variation based on the temperature and brightness of the corresponding location. These sculptures include materials and components that are fire-safe and suitable for residential, commercial, and artistic use. The successful completion of this project requires a final product that is fire-resistant, has communication that scales for up to 150 clouds, and indicates the weather for some target location in an intuitive way. This final product should fulfill all project constraints, requirements, and applicable codes and standards, as detailed below.

1.2 Project Constraints

Based on discussions with the Project Sponsor, our team has identified the following constraints for the design:

- Total project budget, including all designing and planning shall not exceed $1200
- The cost to manufacture an individual cloud, for Bridge LLC, should be less than $45
- The sculptures must be made of a non-flammable material.
- Any wireless communications must satisfy Federal Communications Commission (FCC) requirements
- Any combination of lights/materials must satisfy the fire codes listed below
- Should be easy to maintain

After Trinity University began distance learning on March 23, the project team lost access to the physical prototype. This unforeseen constraint means that all work after this date consists of tasks that are able to be completed remotely, and has limited our ability to improve the existing prototype.

1.3 Applicable Codes and Standards

Since the sculpture must be fire-safe, the design will be governed by the 2018 International Fire Code, written by the International Code Council, which provides the minimum requirements for fire prevention and fire protection systems [1].

Also, because the sponsor of this design would like to market the cloud sculptures for residential homes, the design needs to follow regulations set by UL Standards; explicitly, the Standard Method for Flame Tests of Flame-Resistant Fabrics and Films (CAN-ULC-S109-14) [2]. According to their website, UL Standards are "used to assess products; test components, materials, systems and performance; and evaluate environmentally sustainable products, renewable energies, food and water products, recycling systems and other innovative technologies" [2]. The National Fire Protection Agency has a method outlined in their standard number 705, which details a "means to determin[e] the tendency of textiles and films to sustain burning subsequent to the application of a[n]... open flame" [3].

Any wireless communications included in the project need to follow the standards set by the Federal Communications Commission, which are listed in the Code of Federal Regulations: Title 47 Telecommunications [4]. The FCC "regulates interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia and U.S. territories [4]."

1.4 Project Requirements

The following project requirements have been adapted from the latest project proposal to reflect two things; the changes in project scope necessitated by our remote learning restrictions, and emphases placed by the sponsor on certain aspects of the design. The full, original list of project requirements is in Appendix J.

Operation Requirements

- Cloud will change color and/or light pattern to emulate a given weather state and update in real-time to weather with a reasonable response time (within 30 minutes).
    - E.g., dim colors for cloudy weather, bright white light for sunny weather
- Able to tune into forecast data from different places, can change based on user input.
- Response based on forecast projections and/or remote weather station data, not actual weather outside location.
- It will hang from a ceiling/raised platform or standalone display.
- Must be made of non-flammable materials in compliance with codes and standards mentioned previously.

- Sculptures will be illuminated using a power source operable on 120 V US mains electricity.

Interface Requirements

- Design shall be lightweight, safe, and allow easy access for repair.
- Prototype components should withstand moving and/or shipping
- Results displayed through coloration and/or light pattern.
- Appearance must be cloud-like and aesthetically pleasing.
- The application/controller shall be intuitive to the user and include instructions.
- Users should be able to pick the location the cloud responds to.
- Users shall be able to set the cloud to their desired settings.

1.5 Design Features

The most recent prototype addresses the project Requirements and objectives by including a variety of capabilities and features. The most versatile aspect of the prototype is the ability that the user has to choose a color for the sculpture to display, or to pick a location that the sculpture will emulate. The sculpture will then take on either the specified color, or the color representing the weather state of the chosen location, which updates once per minute to restrict the number of times the weather API will be accessed. This color or weather-state is set with a client-server model between two Raspberry Pis, or a desktop computer and an RPI. The most recent prototype also features flame resistant housing materials, and a rudimentary electronics housing to protect the electronics from damage during moving or shipping. While this housing is by no means as hardy as the original project specifications require, it represents significant steps in the process to make a more robust prototype.

2. Overview of the Final Design

The overall design is broken into five components; the top-level design, the Raspberry Pi (client) configuration, the Raspberry Pi (server) configuration, the external material, and the electronics housing. The majority of research done in preparation for this design focused on the top-level design, since this portion governs the rest of the design project. While the team considered a number of possible wireless configurations for the communication between the weather database and a given cloud sculpture, the client-server model, with website controller over WiFi, won out due to superior flexibility and accessibility to users.

2.1 Top-Level Design

Our design functions by having a single computer act as a server for a local intranet site. This site functions as the graphical user interface (GUI) where the user can use the form to set the desired color of the cloud installation, or the location from which the weather-data will be fetched. Refer to Appendix B to view images from the intranet site in order to understand how the user would interact with it. Note that we used a RPI as the server in the development of our prototype, but the website code is available on Github so that a more powerful computer can be used in exceptionally large installations.

How the installation functions next depends on whether the color value or the weather location was set. The top-level diagram for what happens when the weather-location is provided by the user is available in Appendix C. The diagram shows that after the weather-location is set in the GUI by the user, a request is then sent to the OpenWeatherMap application program interface (API) to fetch the appropriate data for that location. This process takes roughly one minute. Meanwhile, each RPI client continually makes requests to the server to retrieve this data. This data is then interpreted and the LED strips within each cloud are set to the corresponding color. If the color is set directly through the GUI, then the diagram in Appendix C still applies, but there is no API request, so the process has significantly less delay.

The primary strength of the top-level design is that there is only a single RPI for any given cloud installation that makes requests to the weather API. This reduces the stress placed on the Wifi network as well as the weather API, while also ensuring uniformity throughout the cloud installation. It is important to reduce the stress on the API because OpenWeatherMap provides several subscription models where the cost is dependent on the frequency of the requests.

2.2 Raspberry Pi Configuration - Clients

While all of the code used in this project is readily available in the two Github repositories linked in Appendix D, a number of steps must be taken to correctly configure the RPIs so that each program interacts correctly. These settings are not reflected in the Github.

As the Github indicates, the code base for the clients is quite simple; therefore there aren't many settings that have to be changed for the client to function properly. On startup, the "clients_start_up" script is executed. In order to ensure this, a Cronjob (built-in scheduler for Linux) was configured and appropriate permissions were given so that the script would be available. This script ensures that the Neopixel library is installed correctly on the RPI. The Neopixel library is the Python library that is used to convert the Python code to the appropriate byte streams needed to interface with the LED colors and patterns. Next, the pipeline script is also executed. This script will check the Github for any remote updates and apply them if necessary.

After this, the light_controls.py file is executed via a Cronjob. This file runs indefinitely, and it is used to make requests to the server site to fetch either the color or weather data. After retrieving this data, it is interpreted using boolean logic and the appropriate color is set to the LEDs via the Neopixel library.

2.3 Raspberry Pi Configuration - Servers

Unlike the codebase for the clients, the code base for the server is much more involved and has many more files with interactions between them.

The SD image used for the RPI server uses the lighttpd server. This is a lightweight alternative to Apache and is suitable for the web traffic demanded by this project. All of the files related to the intranet site being hosted by the RPI are stored in a folder outside of the Home directory called "www". For this reason, there is a move_page script in the Github that copies all changes from the working repository into the "www" folder. On startup, the pipeline script is called via a Cronjob (as with the clients). Then move_page is also called such that any changes in the remote Github repository are moved to the appropriate folder so that the webpages are updated.

Because the lighttpd server is constantly running, there is no need for any of the webfiles to be called via a Cronjob. The webpage (shown in Appendix B) uses a combination of PHP and Javascript to permit users to make dynamic changes to the webpage by setting the color or weather-location. Then, any future visits to the site will reflect these changes.

However, when the weather location is set, the weather-data is not immediately fetched from the weather API. Instead, update.php is called via a Cronjob once per minute. While this does cause some lag time before the cloud installation is able to change colors, it helps prevent users from accidentally overloading the server or making too many requests to the weather API. That is to say, regardless of the user's location input, the weather API is contacted once per minute. Using a Cronjob to call update.php rather than embedding it into the webpage also allows for the weather data to be continually be updated, long after the user has set the location.

2.4 External Material

After initially considering a variety of materials as candidates for the external portion of the cloud sculpture, the team was pointed by the project sponsor to use only paper-like materials. Once this restriction was clear, the team conducted research on varieties of fire-proofing sprays and flame resistant papers. This path of research led to the selection of Decorol flame retardant paper in white, to fit the original aesthetic of the cloud sculpture piece.

The structure of our prototype is virtually the same as the original cloud sculptures created by Bridge LLC. A wire frame loosley supports a sequence of no more than 40 WS2812 5V LED pixels, encompassed by crumpled sections of the Decorol Flame Retardant Paper. The cord that supplies power to the LEDs inside the cloud extends to the electronics housing from which the sculpture would be suspended.

2.5 Electronics Housing

The electronics housing, outside the body of the main cloud sculpture, exists to protect the electronic components from damage and upset during regular use and moving. The separation of the electronics from the cloud itself reduces the temperature to which the cloud might be exposed if the Raspberry Pi were contained within the cloud itself, thus minimizing the fire hazard. This separation also makes maintenance of the RPI and internal connections easier and less destructive than accessing a panel within an individual cloud. Our proposed solution is based on the standard and preexisting Raspberry Pi Zero W case shown in Appendix F. Using this case, with welded connections between the pins and power/data lines, would provide sufficient protection to the RPi while improving component stability.

3. Design Evaluation

This section of the report evaluates different components of our cloud sculpture prototype based on the types of project requirements and constraints placed on that portion. Each section will identify the requirement or constraint to be evaluated, then outline tests and their results.

3.1 Flammability Requirements

The primary constraint dictating the flammability of our prototype is that "the cloud shall be made of non-flammable material." In addition to the International Fire Code and UL standards, the external material of the cloud had to pass the field test as dictated by the NFPA Standard 705 [1]-[3].

3.1.1 Test Overview: Cloud Material

This test will determine the flammability of each of our cloud envelope material options and also ensure that they meet the standards set by the International Fire Code, as well as the National Fire Protection Agency [1], [3].

3.1.1.a Objectives

Verify that:

- The material chosen will be considered fire resistant as based on the fire codes mentioned above.
- The material will not allow the fire to spread, if it were to be directly exposed to a flame (worst case scenario).

3.1.1.b Features Evaluated

The feature evaluated in this test was the fire resistance of Decoral Fire Retardant Paper in White. This test also determined if crumpling the paper would impact the fire retardant significantly.

3.1.1.c Test Scope

This test was designed in order to simulate a situation in which the material was directly exposed to a flame. The test was conducted in a draft-free location with no other combustibles present.

3.1.1.d Test Plan and Setup

The procedure done for this test was based on methods listed in NFPA 705: Recommended Practice for a Field Flame Test for Textiles and Films [3]. The materials needed for this test were a kitchen match, a timer, ruler, and a spring clip.According to NFPA 705, the minimum size requirement for test samples is 12.7 mm by 101.6 mm (½ in by 4 in) [3]. We decided for each sample of material to have dimensions of 25.4 mm by 152.4 mm (1 in by 6 in) . After being suspended with the long axis (152.4 mm) perpendicular to the ground, the center of the bottom edge (25.4 mm) will be exposed to a flame for 12 seconds. The material was then timed to see how long it continued to burn, and then, once it had stopped burning, was measured to determine the length of the burnt material, where fire had spread. This procedure will be repeated three times for each of the different material samples.

3.1.1.e Acceptance Criteria

The material will have passed the test if (based on the criteria from NFPA 705):

- During the exposure to the flame, the fire should not spread over the complete length of the sample (101.6 mm) [3].
- There is no more than 2 seconds of afterflame [3]. This means that the material should not continue to burn 2 seconds after the ignition source (the match) has been removed.
- Any portion of the material that breaks or drips off will not continue burning once they have reached the floor [3].

3.1.2 Test Results and Evaluation

The table below shows the average results for the afterflame time, char length, and whether there was material that broke off and continued burning for both the current butcher paper used in the clouds and the fire-retardant paper. The raw data collected during the tests and images of the test materials are listed in Appendix G.

Average of the results for each of the different materials tested.

Type of material	Afterflame Time [s]	Char Length [mm]	Did broken material continue to burn? [Y/N]
Butcher Paper (Not Crumpled)	N/A	152.4	N/A
Butcher Paper (Crumpled)	N/A	152.4	N/A
Fire Retardant Paper (Not Crumpled)	0	49.2	N/A
Fire Retardant Paper (Crumpled)	0	66.7	N/A

During the tests, the regular butcher paper (both crumpled and non-crumpled), had completely burned prior to the completion of the 12s flame exposure, and thus there was no afterflame. Since the paper completely burned, the char length exceeded the 101.6mm requirement, and thus failed the test. There was also no material that broke off of the butcher paper samples, and therefore the last criteria (third column) is non-applicable.

Based on the results above, the fire retardant paper was able to satisfy each of the three test criteria listed in Section 3.1.1.e (both crumpled and non-crumpled), since the afterflame was less than 2 seconds, the char length was less than 101.6 mm, and there was no material that broke off during the test. Therefore, we verified that the fire-retardant paper is significantly more fire resistant than the butcher paper currently used by our sponsor, and thus our test objective has been achieved.

In comparing the crumpled and not crumpled fire-retardant paper, the crumpled seemed on average to have a larger char length compared to the not crumpled paper. However, because the crumpled fire-retardant paper was able to satisfy the acceptance criteria, we determined that crumpling the paper did not affect the fire retardant qualities of the material significantly, and thus can be used to craft the cloud sculptures.

3.2 Cloud Color Representation

Project requirements and constraints regarding the correct color representation of the cloud sculpture are as follows:

- Cloud will change color and/or light pattern to emulate a given weather state and update in real-time to weather with a reasonable response time (within 30 minutes).
  - E.g., dim colors for cloudy weather, bright white light for sunny weather
- Able to tune into forecast data from different places, can change based on user input.
- Response based on forecast projections and/or remote weather station data, not actual weather outside location.
- Results should be displayed through coloration and/or light pattern

3.2.1 Test Overview: Interface and Weather Response

This test used the cloud sculpture desktop interface to test the overall response of the sculpture to various weather and manually-set inputs. This test also incorporated the base number of cloud states, or color changes, to ensure enough variety in light color to reflect weather conditions intuitively.

3.2.1.a Objectives

Verify that:

- A test cloud changes by exactly matching the state given by the desktop interface.
- Color changes driven by weather changes, not manually set, are distinguishable from each other at a viewing distance of 20 feet.

3.2.1.b Features Evaluated

This test evaluated the accuracy of the desktop interface in relation to the color output of an individual sculpture and determined if the variety of colors representing weather states sufficiently reflect the weather conditions.

3.2.1.c Test Scope

These tests used the desktop interface to verify the response of a cloud to manual input, as well as qualitatively determine which colors the LED strip is capable of accurately supporting. These manual inputs included the seven colors of the rainbow at low, medium, and high color saturation. The four basic weather states included night, rainy/cloudy, sunny and hot, and sunny and cold. Likely more states will be included in the final prototype, but for the scope of this first full prototype, only the four states were explicitly tested in order to demonstrate the functionality of the prototype. Each color setting/weather state was qualitatively assessed with a scale of 1-5, with 5 indicating that the color is perfectly represented and 1 suggesting that the color can not be reproduced by the LED strip.

3.2.1.d Test Plan and Setup

The completed cloud prototype is controlled directly by the desktop interface, with the Decoral paper placed over our LED test strip to evaluate the fully diffused color. We used this desktop interface to verify the manual response of the cloud, and record the color changes apparent both directly next to the cloud and at a distance of 20 feet. The manual response included 21 color inputs, shown in a chart in Appendix H. Once the manual response had been verified, we forced the four different weather states by using four different locations depicting the desired weather state at the time of testing. This evaluated the weather location fetching mechanism within the desktop-cloud interface.

3.2.1.e Acceptance Criteria

The current prototype will be considered acceptable based on the following criteria:

- The four base weather states:
    - (1) are distinguishable by the unenhanced human eye at a distance of 20 feet
    - (2) receive an average score equal to or exceeding 3 at 20ft
- The manual color settings:
    - (3) receive an average score equal to or exceeding 3 at 20ft
    - (4) less than 7 settings receive a score of less than 3 at 20ft

3.2.2 Test Results and Evaluation

Appendix H shows that the four base weather states received an average score of 3.50, so it can be inferred that criteria (2) was satisfied. However, the Night setting and the Rainy/Cloudy settings are very difficult to distinguish due to their imperfect scores and similar appearance, so criteria (1) was not satisfied for these states. The table also shows that the manual color settings received an average score of 3.81 and 3.86 at 20ft thus satisfying criteria (3). Additionally, only one setting received a score under 3, so criteria (4) is satisfied.

The scores each color state received varied more than we expected in designing their testing method, and in general, we found that more saturated colors are best represented by the LEDs. We also found that less saturated colors were more prone to distortion through the external material. So, in order to satisfy criteria (1) we should change the weather states to be represented by more distinct, highly saturated colors. With this small change, we will be able to develop a fully functional prototype with clearer weather states.

Bridge LLC conducted their own tests in the spirit of the above test plan to evaluate the color setting further. Their findings coincided with ours; that the colors chosen to reflect weather states should be, generally, highly saturated and bright. There was indeed a gap between the color selected on the cloud sculpture's web app and the portrayed color. To solve this, the sponsors suggested a new set of confirmed weather-states, shown in Appendix I. Furthermore, the number of manual color options was reduced to the seven options reflected in Appendix B1.

3.3 Component Hardiness and User Friendliness

The project constraints list that the final design should be easy to maintain. Bridge LLC also specified in one of our initial meetings that this sculpture should be hardy enough to move within a house, and should be able to be shipped or moved. Another requirement for this project was that the design should be lightweight, safe, and allow easy access for repair. Because we have been unable to work on our physical prototype since roughly March 6th, the following test results were from feedback we received from our sponsors after we gave them our first full prototype.

3.3.1 Test Overview: Hand-off to Bridge LLC

This "test" evaluated whether our first prototype would withstand the transport to Bridge LLC, and allowed the sponsors to evaluate the user interface and electronic configuration first hand.

3.3.1.a Objectives

Verify that:

- Prototype withstands transport
- Cloud construction works with flame retardant material
- The web page landing for the sculpture is user friendly enough for the sponsors to use easily

3.3.1.b Features Evaluated

This test furthers the testing executed in section 3.2, and encompasses the overall design evaluation undertaken by Bridge LLC, but focuses on the connections between electronic components and the accuracy of light-temperature reflecting a weather-state.

3.3.1.c Test Scope, Plan, and setup

As a more informal test, the team decided to hand the first full prototype to our project sponsors to evaluate the overall design. A team member went with the sculpture to the Bridge LLC studio to walk them through the electronics setup, and we trusted the sponsors to recreate a sculpture around the electronics-only frame we provided them. Through this process of moving and constructing the sculpture, the hardiness of the electronic components were tested and evaluated by the project sponsors. Further, allowing the project sponsors to play with and evaluate our user interface gave us valuable information on its user-friendliness.

3.3.1.d Acceptance Criteria

An acceptable prototype will fulfill the test objectives, satisfy the project requirements and constraints, and incite a favorable response from our sponsors at Bridge LLC.

3.3.2 Test Results and Evaluation

We received the following (condensed and paraphrased) comments and concerns from Bridge LLC after a 1.5 to 2 week interval:

- <u>Colors and Color Selection:</u> Sponsors revised the colors based on in-person output. In person, these look quite different, but the hex codes are accurate. See Appendix I for hex codes. A custom color, or weather-state, selector may benefit the user experience to filter out unwanted color behavior.
- <u>Component Hardiness and Setup:</u> In its current state the components are quite fragile. Wires disconnect easily, some connections seem tenuous and easily broken by less than gentle handling. The product must be able to be shipped, and handled relatively easily. Currently the setup is too complex for the general consumer. Ideally, plugging in the system to a monitor is a step that can be skipped. For the final prototype, the physical installation of this cloud should be easy for a consumer to understand - plugging in with a standard US plug or into a can light socket.
- <u>Web Interface General:</u> Can the speed at which this page pushes changes to the cloud be increased? To test the color states took quite some time.
- <u>Flickering:</u> This may be a faulty component on this particular prototype, but there is a constant low level "flicker" in the lights.
- <u>1 Minute Cycle:</u> As already pointed out by the TU team, the cloud "refreshes" every minute, and the lights go out for a brief second.

Although the electronic portions of this prototype survived the move to the Bridge LLC studio, and our sponsors were able to make use of our user interface, their comments prove the insufficiency of our first full prototype. While this prototype was, in fact, nowhere near the commercially viable point, we did gain some insight from these comments. However, since these comments were given to the team before Trinity's shift to online learning, we have not been able to respond fully to these comments, other than suggesting solutions. The team has addressed the bottom three comment sections, and the color selection comment section, by updating the GitHub repositories for this project. Appendix B shows screenshots from the color selection website, which also now satisfy our user-friendliness requirements.

Further streamlining the electronics setup process, and refining the electronics housing, would solve the issues posed by the project sponsors. Appendix A contains electronics setup instructions for initializing the Raspberry Pis. An additional option for increasing component hardiness, is to use RPI Zero W computers without the attached pin headers, and instead manually welding connections to the board. This solution may add a complicated step to the manufacturing process but would overall significantly improve the hardiness of the connections between RPI and cloud.

4. Conclusions

Between the prototype that we delivered in March, the Electronics Setup Guide included in Appendix A, and the updates to the code base made remotely since the March prototype, our design has met the specifications laid out in the most recent project proposal. Although there are still bugs in our prototype that prevent it from being commercially viable, these bugs are to be expected with any software product that has not undergone a period of extensive beta testing. The prototype has room for improvement in its electronic connections, but verification of our suggestions cannot take place because of our restricted mobility and access to our work.

For any future improvements to the prototype, we suggest following the steps outlined in the "Finishing Touches" section of Appendix A. In particular, ample focus should be provided to the beta testing phase we recommend. Having an IT professional who can isolate and correct any reported errors would be paramount to the success of this project in a commercial setting. We also recommend that improvements be made to the electronic connections between the RPI and LED strips.

Based on our most recent project plan, and not our original project requirements, our current modified prototype meets its requirements. Most of our original project requirements and objectives were met, except perhaps the "ease of maintenance" constraint, since our prototype was structurally unchanged from the original sculpture. Although there were a few setbacks and issues due to the current pandemic situation, the team has produced a functional prototype.

Appendices

Appendix A: Electronics Setup Guide

Opening Comments

This guide is intended to outline the electronics setup process for the Weather-Responsive Cloud Sculpture prototype. Due to challenges presented by the Covid-19 pandemic, there is a section that must be completed one time in order to finalize the prototypes. In total there are three discrete sections. The first section outlines steps that should be taken by Bridge LLC *only once* in order to finalize the prototype that the design team delivered in March of 2020. To complete these steps it is recommended that the help of an information technology (IT) professional be sought out. The second section describes the most efficient process to duplicate this prototype such that it can be deployed on a commercial scale. Finally, the third section describes the process that the customer must follow in order to install the cloud-sculptures.

Section I: Finishing Touches

As mentioned before, these steps can be technically demanding, so we recommend the enlistment of qualified help. For a working professional in IT or a related field, these finishing touches can likely be completed in less than a day. However, as with all software products, the cloud sculptures would benefit greatly from a period of beta testing, so that any unknown bugs can be identified.

Update Codebases

1. The first thing to do is to update the code base on the Raspberry Pi server. This can be accomplished by turning on the RPI while it is connected to a keyboard and monitor. After this, load the terminal, and execute the following commands.

   $ sudo git pull https://github.com/kcastil3/Airheads

   $ sudo ./move_page

2. These commands will have updated the server to match the most recent code updates.
3. Now, you will need to update the Client RPI. This is done by repeating the process in step 1, but only entering the following command:

   $ sudo git pull https://github.com/kcastil3/Clients

4. At this point the codebases on both RPIs should be updated to match the github.
5. This is where it is imperative that professional help be enlisted. Because the code changes from the March prototype could not be tested directly, there could be fatal errors as a result of incorrect syntax. However, identifying these errors should not take long considering that the code base is relatively small.

Clone the Github and Establish Update Pipeline

In order to make future changes to the codebase you'll want to clone a separate repository so that any future changes to the codebase can be saved remotely. This can be done with the following command:

$ sudo git push --mirror https://hostname/exampleuser/new-repository.git

Note, this command must be executed for both the server and client repositories.

Now, it is imperative that a pipeline be established in the RPIs so that any updates pushed to the Githubs are automatically pulled down. This way any bugs within the RPIs can be resolved remotely.

In each repository, there is already a file titled "pipeline". First, you should edit these files

such that the line that says "git pull" now pulls down from the new repository. Next, you should execute the following command from inside the appropriate folders:

$sudo chmod 777 pipeline

Finally, you need to configure the Cronjob so that the "pipeline" script is executed on startup. Execute:

$sudo crontab -e

Now you can follow the steps in this tutorial in order to configure this file correctly.
https://www.jessicayung.com/automate-running-a-script-using-crontab/
At this point, the pipeline should be configured. It is recommended that several copies of SD cards from both the client and server be made now to ensure safety in the future. The tutorial for this is linked below.
https://smallbusiness.chron.com/copy-sd-card-another-52692.html

Section II: Production

After completing Section I, the SD cards can be quickly configured for deployment. But first, the Wifi settings must be changed for both the server and the client so that the customer does not have to.

In order to set up the Wifi connections, one the server SD card should be inserted into an RPI, which is connected to a keyboard and monitor. Once the RPI has booted up, access the terminal through the keyboard shortcut CTRL+SHIFT+T. Next, enter the following command:

$**sudo raspi-config**

This command will bring up a menu. Select “Network Options”. From here, you can set the SSID and password for the Wifi network of the customer. Therefore, it is imperative that the customer supply Bridge LLC with their network settings prior to purchase.

Repeat the process described above for a single client SD card. Now, you have a copy of both the server and client as needed for deployment. You can now make as many copies of the client SD card as necessary using the tutorial linked at the end of Section I. Remember that each RPI will require a SD card in order to function.

Section III: Installation

Refer to the diagram in Appendix E to confirm the locations of any pins. And refer to the table in Appendix F to confirm the names of any parts.

The actual installation is quite simple. First, the LED should be cut to the appropriate length, depending on the size of the cloud. We recommend an absolute maximum of 100 pixels be used in a given cloud, as any more may pull too much current from the RPI. Now, you should ensure that the SD card is inserted into the RPI, and the RPI is inside of its case.

Now, a black wire will run directly from Pin 0 (ground) into the black wire connector of the LED strip. A red wire will run directly from Pin 23 (power) into the red connector of the LED strip. And a single white wire will run from Pin 6 (pulse-width modulation) into the remaining connector on the LED strip. The RPI power supply connects directly from the wall socket to the micro usb port.

Appendix B: User Interface

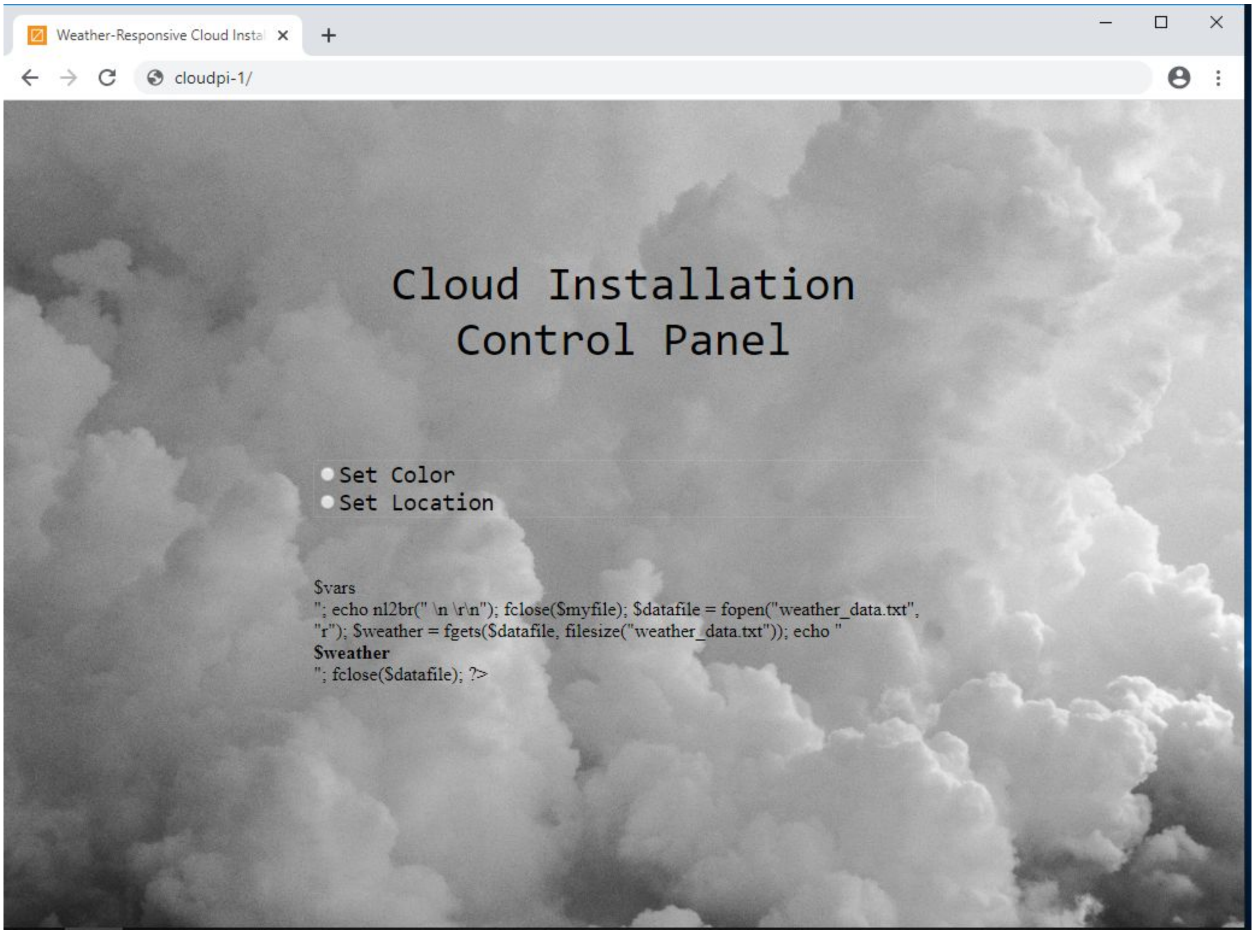


Figure B1. User interface landing page in the Google Chrome web browser. Note that the PHP code at the bottom of the screen would usually indicate the color or weather-data, but this screengrab was obtained from a testing environment where PHP could not be rendered.

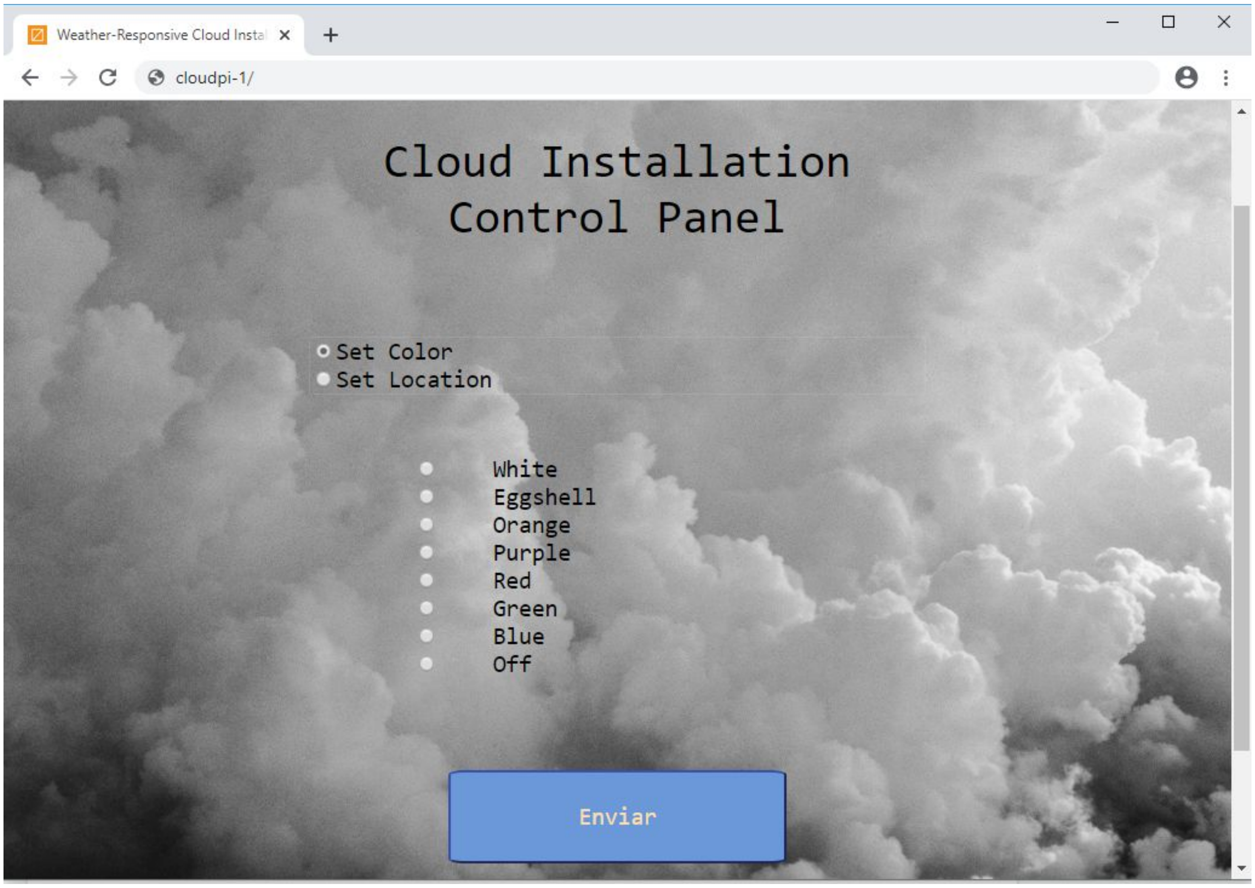


Figure B2. User interface color-selection page in the Google Chrome web browser.

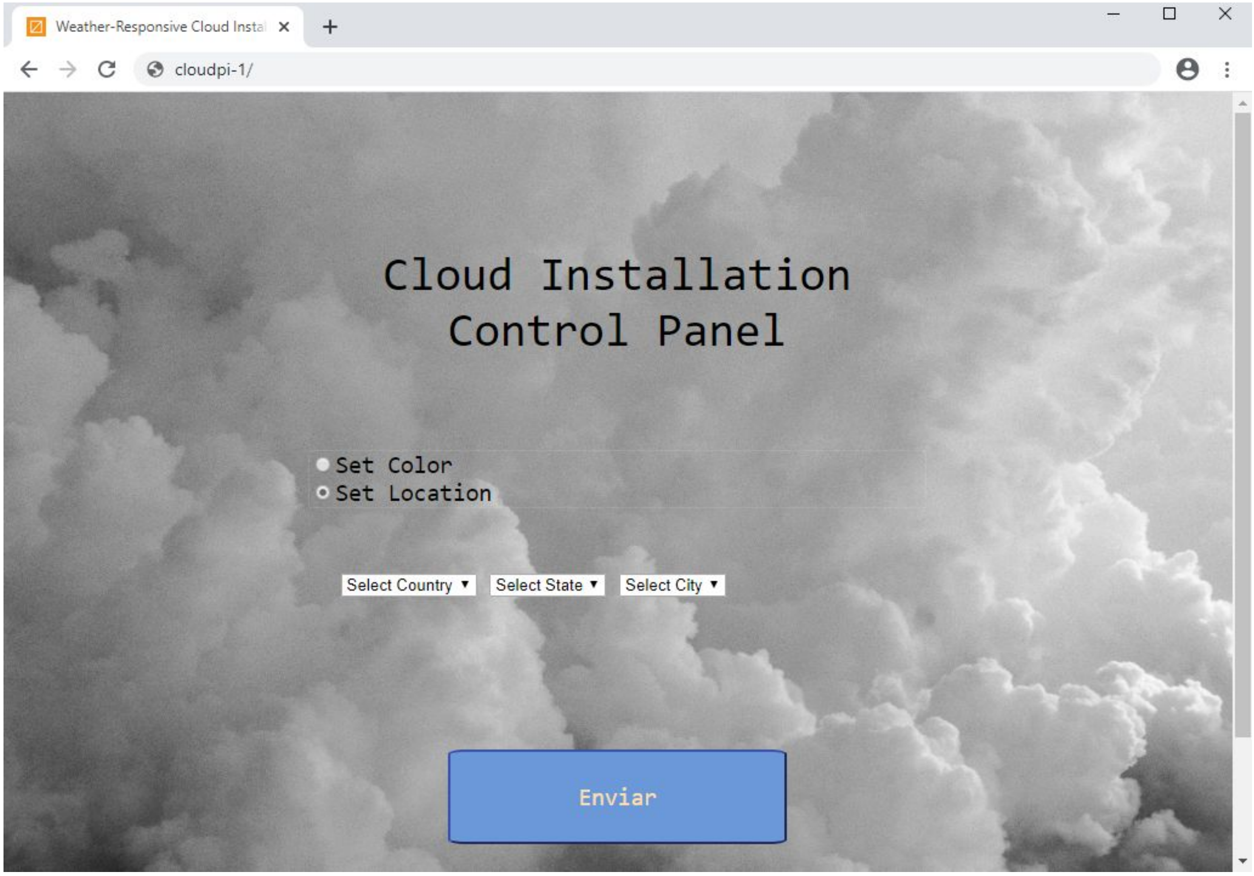
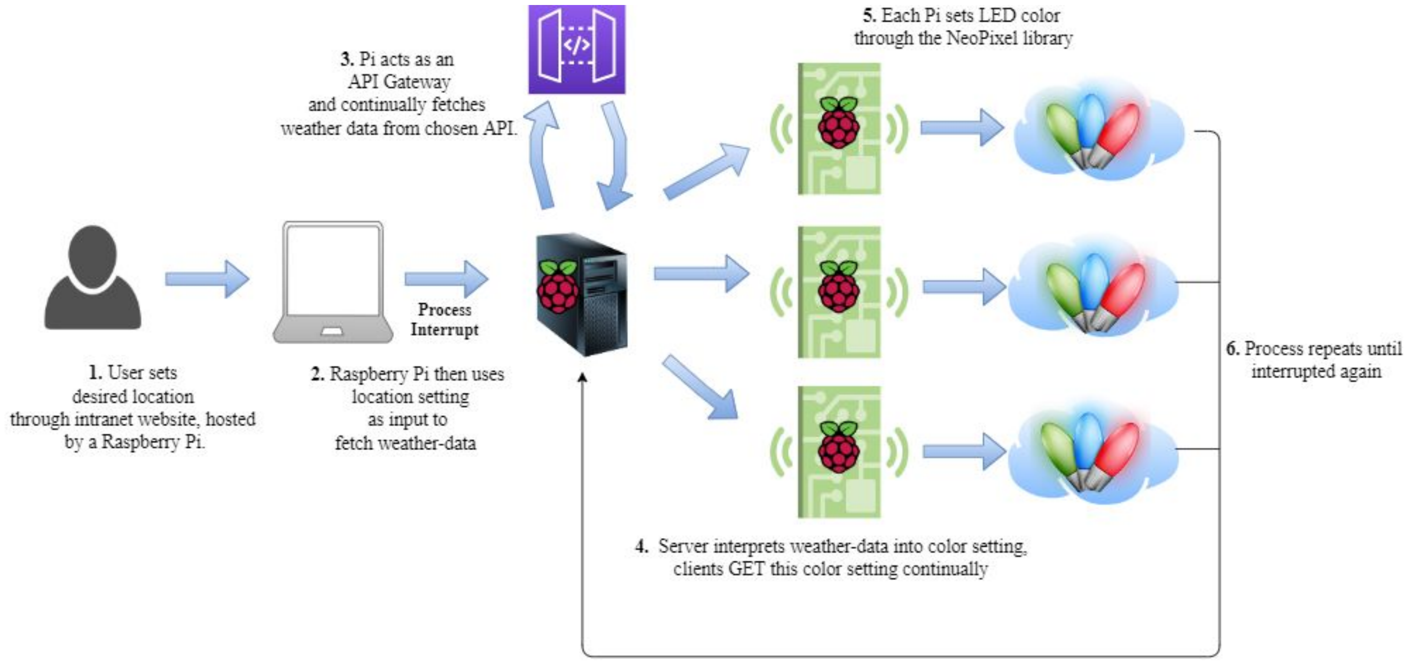


Figure B3. User interface location-selection page in the Google Chrome web browser

Appendix C: Top-Level Design



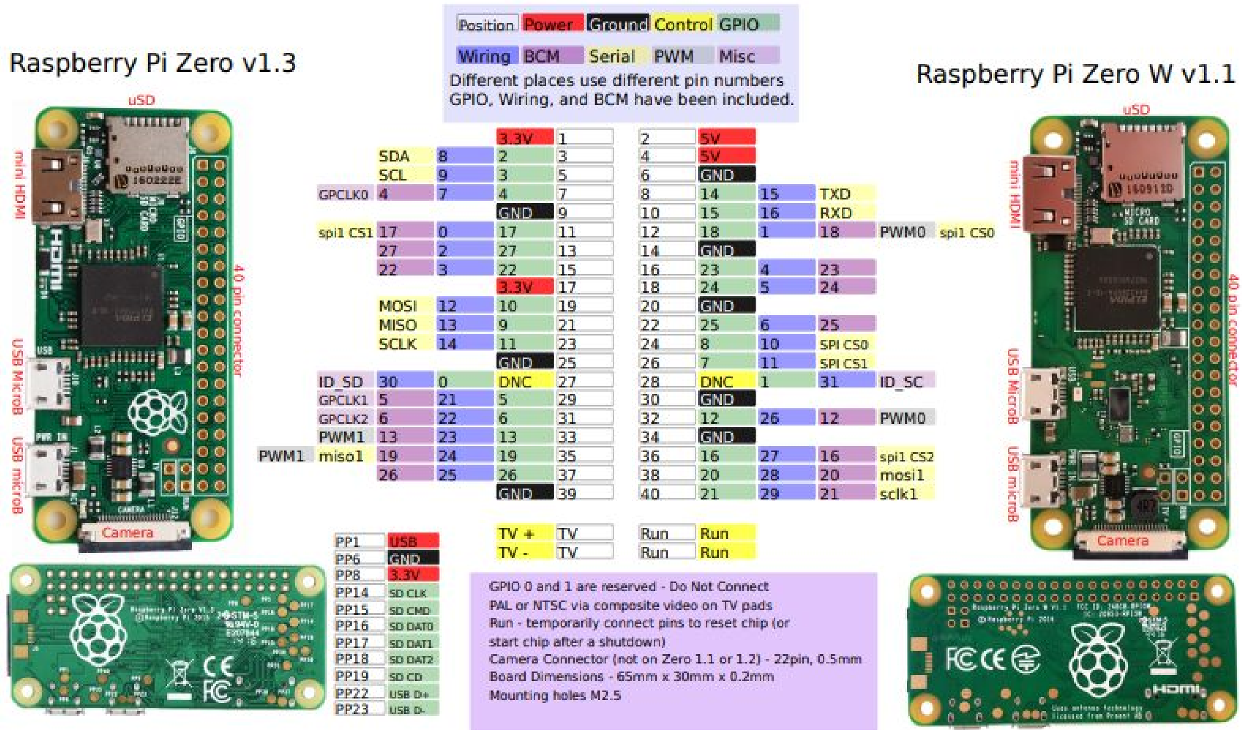
Appendix D: Links to Github Repositories

For the servers: https://github.com/kcastil3/Airheads

For the clients: https://github.com/kcastil3/Clients

For the Neopixel library: https://github.com/jgarff/rpi_ws281x

Appendix E: Raspberry Pi Zero W Layout and Specifications [5]



Appendix F: Electronics Materials

Note, “N” refers to the number of clouds that will be in the installation.

Component	Quantity	Unit Cost	Image
RPI Zero W labelled as “Server” loaded with 8 GB SD Card [6]	1	$14.00 for RPI $5 or less for SD Card	
RPI Zero W’s labelled as “Client” [6]	N	“	"
RPI Zero W Official Case with Space for Headers [7]	N+1	$6.27	
5V 2.5 A Power Supply for RPI with micro-USB tip [8]	N+1	$8.57	
Alitove 16.4ft WS2812B LED Strip [9]	< 1	$23.79	

Appendix G: Fire Testing Data

Type of Material	Trial #	Afterflame Time [s]	Char Length [mm]	Did broken off material continue to burn? [Y/N]
Butcher Paper (Not Crumpled)	1	N/A	152.4	N/A
	2	N/A	152.4	N/A
	3	N/A	152.4	N/A
Butcher Paper (Crumpled)	1	N/A	152.4	N/A
	2	N/A	152.4	N/A
	3	N/A	152.4	N/A
Fire Retardant Paper (Not Crumpled)	1	0	57.2	N/A
	2	0	52.4	N/A
	3	0	38.1	N/A
Fire Retardant Paper (Crumpled)	1	0	77.8	N/A
	2	0	65.1	N/A
	3	0	57.2	N/A

Flame Test Pictures

Figure 1. Fire Retardant sample strips (crumpled) after fire testing.

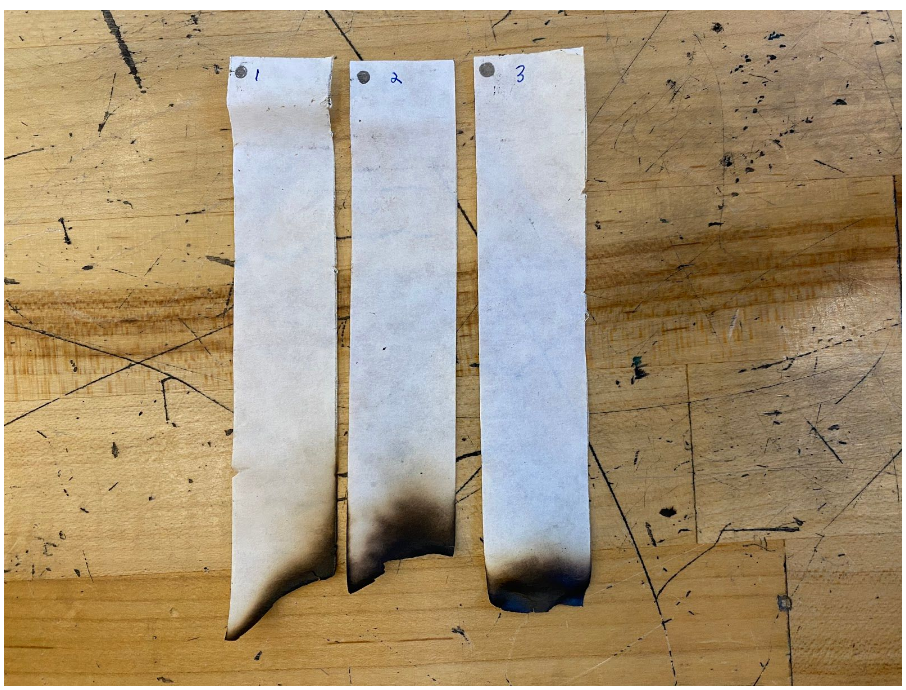


Figure 2. Fire Retardant Paper sample strips (non-crumpled) after fire testing.

Appendix H: Color Quality Testing Results

Test State	Desired Color	Result	View at 20 feet
Night	Dark purple/grey	3	3
Sunny (hot)	Warm bright light, orange undertones	4	4
Sunny (cold)	White light, cooler blue undertones	4	4
Rainy/Cloudy	Medium brightness, grey/blue	3	3
Red 1		2	2
Red 2		2	3
Red 3		5	5
Orange 1		4	4
Orange 2		3	3
Orange 3		2	2
Yellow 1		5	5
Yellow 2		4	4
Yellow 3		5	5
Green 1		3	3
Green 2		4	4
Green 3		5	5
Blue 1		5	5
Blue 2		3	3
Blue 3		4	4
Indigo 1		4	4
Indigo 2		4	4
Indigo 3		5	5
Violet 1		4	4
Violet 2		3	3
Violet 3		4	4
Manual Settings	Numerical Average	3.81	3.86
Weather-States	Numerical Average	3.50	3.50

Appendix I: Final Hex Code Colors

Appendix J: Complete Project Requirements

Functional Requirements

- Cloud will change color and/or light pattern to emulate a given weather state.
  - E.g., dim colors for cloudy weather, bright white light for sunny weather
- It will hang from a ceiling/raised platform or standalone display.
- Will require a program to be able to interface with the weather forecast.
- Will interact with the consumer's app or controller that connects to the program.
- Must be made of non-flammable materials in compliance with UL standards [2].
- Sculpture will use a power source operable on 120 V US mains electricity.
- Will update in real-time to weather.

Non-Functional Requirements

- Able to tune into forecast data from different places, can change based on user input.
- Reasonable responsiveness of cloud after weather change (within 30 minutes).
- Response based on forecast projections and/or remote weather station data, not actual weather outside location.
- Should not need to be repaired/deconstructed for bulbs/lighting source to be replaced.
- Resources are limited to existing, flame-retardant material, and to current research.

Interface Requirements

- Design shall be lightweight, safe, and allow easy access for repair.
- Results displayed through coloration and/or light pattern.
- Appearance must be cloud-like and aesthetically pleasing.
- The application/controller shall be intuitive to the user and include instructions.
- Users should be able to pick the location the cloud responds to.
- Users shall be able to set the cloud to their desired settings.

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[3] *Recommended Practice for a Field Flame Test for Textiles and Films*, NFPA 705, 2018

[4] Federal Communications Committee *Title 47 - Telecommunications*, May 1, 2020. Accessed May 1, 2020. [Online]. Available: https://www.ecfr.gov/cgi-bin/text-idx?SID=1ec13ff9ac07675f7a4b9672463106c7&mc=true&tpl=/ecfrbrowse/Title47/47cfrv1_02.tpl#0

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[8] "5V 2.5A DC Charger Adapter Power Supply for Raspberry Pi 2 3 3B B+, Samsung Galaxy Tablet Huawei Oppo Vivio, Micro USB DC Charger Adapter On Off Switch" Internet: Accessed May 1, 2020 [Online]. Available: https://www.walmart.com/ip/5V-Galaxy-Supply-Adapter-Micro-Off-Pi-Tablet-Charger-Vivio-B-Oppo-USB-3B-2-3-Switch-Raspberry-Samsung-Huawei-Power-2-5A-DC-On/724083841

[9] Alitov, "16.4 ft 150 pixel150 Pixels WS2812B Individually Addressable RGB LED Strip Light Dream Color," Accessed May 1, 2020 [Online]. Available: http://www.alitove.net/product/16-4ft-150-pixels-ws2812b-individually-addressable-rgb-led-strip-light-dream-color-not-waterproof-white-pcb-5v-dc/

SIGNATURES

Project Name: Weather-Responsive Cloud Sculpture

The undersigned agree that the proposed project is realistic and achievable, and that the team can accomplish the stated goals of the project.

	Date Received	Date Approved
Team Members: Karsten Castillo: LIndsey Lubianski: Jasmine Yang: Talley Withycombe:	**May 3, 2020**	**May 3, 2020**
Team Adviser:	**May 3, 2020**	**May 5, 2020**

The undersigned authorize the project to continue, and authorize the construction of a prototype.

Project Sponsor:		
Other signatures required by the Project Proposal:		

Document Change Control		
This section records the revisions to this document.		
Version Number	**Date of Issue**	**Brief Description of Change**
1	5/1/20	Initial Release