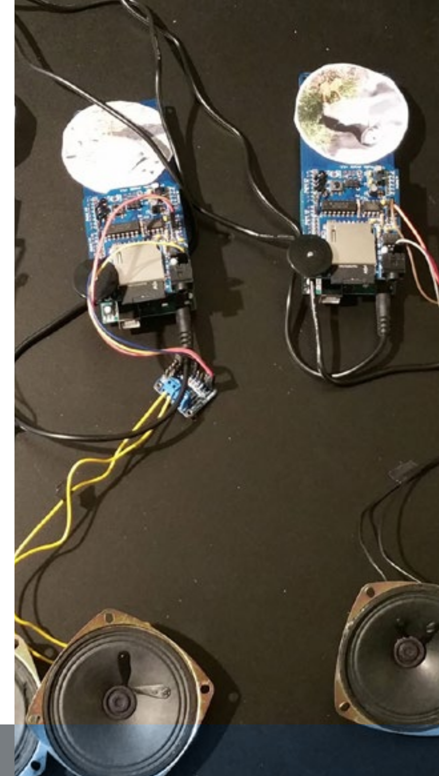
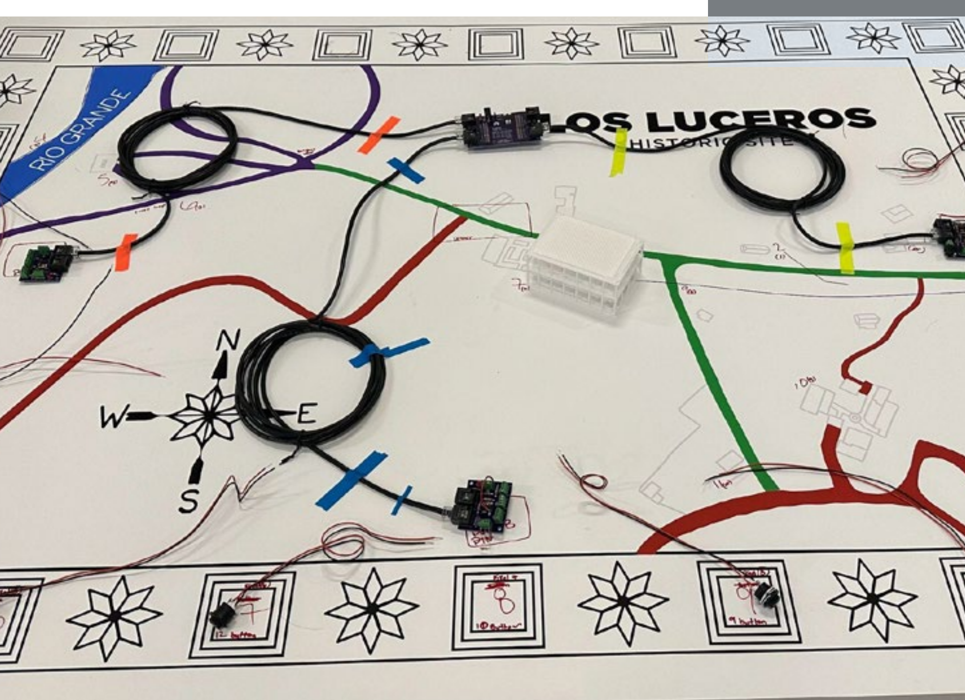


OSHW Case Studies



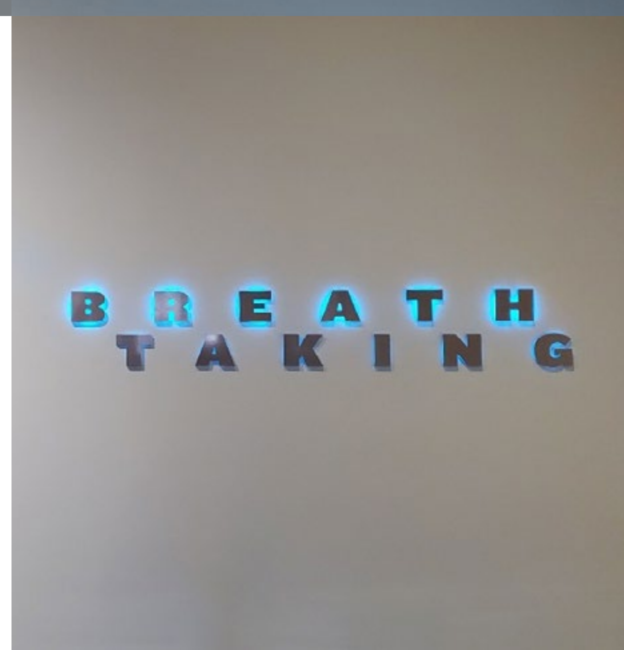


Table of Contents

Introduction to the Museduino and It's Uses; Ideation to Open Source Certification; 2014-2022

The Museduino was born as an idea in late 2014, and we shipped the first sets in mid-2015. I went public with a post on Medium in November 2014, when we had only built and tested the most rudimentary version of what we thought we wanted to do. As anyone who works in hardware knows, creating a one-off is one thing, but creating something documented and shippable is entirely another. Staff and students from the Cultural Technology Development Lab presented a pre-conference workshop at ASTC (Association of Science and Technology Centers) in late 2015. The Museduino was well-received by that group, and we sent each participant home with the 2.0 set and links to the documentation and tutorials.

We hoped to hear back that they were 1) in use and 2) being modified, but other than a few "this is cool!" emails, there wasn't much response.

This dovetailed with a paper I was co-writing with Jason Alderman (author of the included case-study "Full Sails"), called "Open Hardware Belongs in Your Museum", for the Museums and The Web Conference in 2016. This paper was published in the conference proceedings, but the talk was scheduled for the very last time slot of a four day conference - and either the timing or the topic (or both) led to a poorly attended session. Anyway, it's not really a hardware-focused conference or audience. However, it did give Jason and me an opportunity to explore the myriad ways we could pitch OSHW to our museum clients.

Meanwhile, back in New Mexico we were starting to use the Museduino to update exhibits that had been "black-boxed" out of functionality at various of our Department of Cultural Affairs museums. There's a very typical museum scenario, where exhibit technology is developed by third-party agencies or contractors, and when the company pivots, sells, or disappears altogether, the exhibit goes dark when the first component breaks. There's rarely someone with the time and/or skills to open something up and try to reverse engineer it.

The CTDL was created to address these concerns in our partner organizations. We wanted them to have an easier time of developing, installing and maintaining exhibits. Also, it would cost them less in the long run to not have to hire us after the fact to fix an exhibit that was proprietary.

Before the Museduino existed, our team of faculty and students (founding faculty Miriam Langer, Stan Cohen with graduate students Rianne Trujillo (now faculty) and Miles Tokunow) worked in service of these concerns, replacing defunct hardware with Raspberry Pis, Arduinos, and other microcontrollers to get things going. We experimented with many technologies as they came on the market, seeing what would be useful and what could or could not be pushed to an open source modality (Some examples include epaper, xbee and other wireless protocols, Kinect, and more).

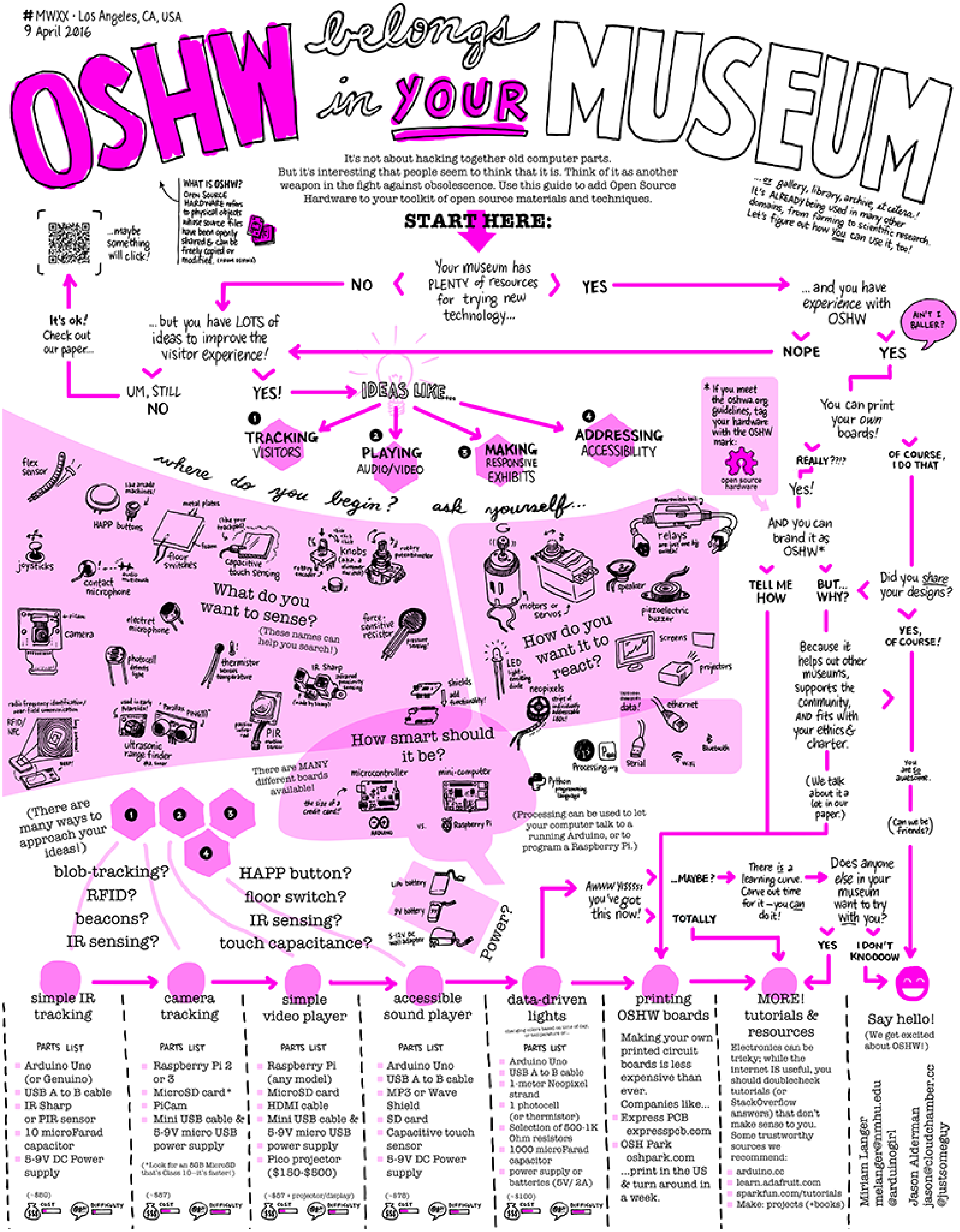
The Museduino brings together two of our long-time loves: the Arduino and its status as the de-facto standard for accessible open source hardware and the sensor/actuator relationship that allows for engagement in an exhibit or art installation.

The case studies included here are demonstrations of open source hardware as installed in museums and historic sites. All of these projects were very low budget, or done with funding related to a PICT (Program in Interactive Cultural Technology) semester project. A Museduino kit costs between \$65-\$120, fits on top of a \$25 arduino R3/Uno and can be used with most off-the-shelf sensors and actuators.

Acknowledgements:

This store of documentation and case study presentation would not be possible without the generous support of the Open Source Hardware Association Trailblazers Program/Alfred P. Sloan Foundation, our fellow cohort members and mentors, Alicia Gibb Seidle and Lecia Ductan. Special thanks to our CTDL founder and member-at-large, Stan Cohen, without whom the Museduino would never have been more than an online quiz.

Rianne Trujillo, Becca Sharp, Miriam Langer



#MWXX · Los Angeles, CA, USA
9 April 2016
OSHW belongs in YOUR MUSEUM
It's not about hacking together old computer parts. But it's interesting that people seem to think that it is. Think of it as another weapon in the fight against obsolescence. Use this guide to add Open Source Hardware to your toolkit of open source materials and techniques.
...or gallery, library, archive, et cetera..! It's ALREADY being used in many other domains, from farming to scientific research. Let's figure out how you can use it, too!
WHAT IS OSHW? Open Source HARDWARE refers to physical objects whose source files have been openly shared & can be freely copied or modified.
...maybe something will click!
START HERE:
Your museum has PLENTY of resources for trying new technology...
NO
YES
...and you have experience with OSHW
AIN'T I BALLER?
NOPE
YES
...but you have LOTS of ideas to improve the visitor experience!
It's ok! Check out our paper...
UM, STILL NO
YES!
IDEAS LIKE...
1 TRACKING VISITORS
2 PLAYING AUDIO/VIDEO
3 MAKING RESPONSIVE EXHIBITS
4 ADDRESSING ACCESSIBILITY
where do you begin? ask yourself...
flex sensor
HAPP buttons
metal plates
joysticks
floor switches
foam
capacitive touch sensing
knobs
rotary potentiometer
contact microphone
What do you want to sense?
(These names can help you search!)
camera
electret microphone
force-sensitive resistor
photocell
thermistor
IR Sharp
RFID/NFC
ultrasonic range finder
PIR
shields
How smart should it be?
There are MANY different boards available!
microcontroller
mini-computer
ARDUINO vs. Raspberry Pi
relays
motors or servos
speaker
piezoelectric buzzer
How do you want it to react?
LED
screens
projectors
neopixels
data!
ethernet
Serial
WiFi
Bluetooth
Processing.org
Python
(Processing can be used to let your computer talk to a running Arduino, or to program a Raspberry Pi.)
LiPo battery
9V battery
5-12V DC wall adapter
Power?
(There are many ways to approach your ideas!)
blob-tracking?
RFID?
beacons?
IR sensing?
HAPP button?
floor switch?
IR sensing?
touch capacitance?
* If you meet the oshwa.org guidelines, tag your hardware with the OSHW mark:
open source hardware
You can print your own boards!
REALLY ???
Yes!
OF COURSE, I DO THAT
AND you can brand it as OSHW*
TELL ME HOW
BUT... WHY?
Did you share your designs?
YES, OF COURSE!
Because it helps out other museums, supports the community, AND fits with your ethics & charter.
(We talk about it a lot in our paper.)
You are so awesome.
(Can we be friends?)
Awwwyissss you've got this now!
...MAYBE?
There is a learning curve. Carve out time for it – you can do it!
Does anyone else in your museum want to try with you?
TOTALLY
YES
I DON'T KNOOOOW
simple IR tracking
PARTS LIST
Arduino Uno (or Genuino)
USB A to B cable
IR Sharp or PIR sensor
10 microFarad capacitor
5-9V DC Power supply
(~$50)
COST
DIFFICULTY
camera tracking
PARTS LIST
Raspberry Pi 2 or 3
MicroSD card*
PiCam
Mini USB cable & 5-9V micro USB power supply
(*Look for an 8GB MicroSD that's Class 10 – it's faster!)
(~$57)
COST
DIFFICULTY
simple video player
PARTS LIST
Raspberry Pi (any model)
MicroSD card
HDMI cable
Mini USB cable & 5-9V micro USB power supply
Pico projector ($150-$500)
(~$57 + projector/display)
COST
DIFFICULTY
accessible sound player
PARTS LIST
Arduino Uno
USB A to B cable
MP3 or Wave Shield
SD card
Capacitive touch sensor
5-9V DC Power supply
(~$75)
COST
DIFFICULTY
data-driven lights
PARTS LIST
Arduino Uno
USB A to B cable
1-meter Neopixel strand
1 photocell (or thermistor)
Selection of 500-1K Ohm resistors
1000 microFarad capacitor
power supply or batteries (5V/ 2A)
(~$100)
COST
DIFFICULTY
printing OSHW boards
Making your own printed circuit boards is less expensive than ever.
Companies like...
Express PCB expresspcb.com
OSH Park oshpark.com
...print in the US & turn around in a week.
MORE! tutorials & resources
Electronics can be tricky; while the internet IS useful, you should doublecheck tutorials (or StackOverflow answers) that don't make sense to you. Some trustworthy sources we recommend:
arduino.cc
learn.adafruit.com
sparkfun.com/tutorials
Make: projects (+books)
Say hello!
(We got excited about OSHW!)
Miriam Langer
melanger@nmhu.edu
@arduinogirl
Jason Alderman
jason@cloudchamber.cc
@justsomeguy

OSHWA Case Study: “Behind the Fence” at Bradbury Science Museum, Los Alamos

Abstract

“Behind the Fence” is a multisensory experience with nine interactive drawers and a 360o video at the Bradbury Science Museum in Los Alamos, NM. This is an open source hardware permanent install that was custom designed and fabricated inside the museum. Behind the Fence uses RFID readers, three custom crafted scents, LEDs and responsive custom audio. This install also includes artifacts from the Manhattan Project to share stories using 360o video of buildings that are no longer accessible to the public including the Slotin Building, Pond Cabin, and Battleship Bunker.

https://vimeo.com/800723340
https://vimeo.com/800723825

The museum had Omar (find last name and title) to help with the construction of the installation, this would include building a new wall for three large monitors and a set of drawers to fit inside the wall so that the electronics may be accessed from the backside. The electronics, scents, and drawer inserts were designed and fabricated by Becca Sharp, Dré Gallegos, Miriam Langer, and Rock Ulibarri. The drawers used three Arduino Unos,

Project Development

Initial Proposal

The Bradbury Science Museum hired the PICT (Program of Interactive Technology) class to design and install various exhibits for the museum. In doing this, Becca Sharp, Dré Gallegos and Miriam Langer proposed an installation using drawers from the Manhattan Project archives to create an interactive exhibit that would feature various open source hardware and artifacts from the Manhattan Project. This project would have a 360o video that would take visitors “behind the fence” where the public was not able to go. The video would instruct visitors to open drawers labeled either “Slotin, Bunker, and Pond Cabin”; three very important buildings to the Manhattan Project. These drawers would have different artifacts and a RFID reader to activate either audio, LEDs, or both simultaneously. These drawers will also contain scents that will be fabricated in house with the help of Art & Olfaction’s Saskia WIlson Brown. Visitors will use a “Secret Pass” designed by the PICT class and fabricated by Becca Sharp and Dré Gallegos. This pass will contain a RFID tag for users to activate the different drawers and to use to discover more exhibits around the exhibit.

Drawers were made of foam core (left) using the original Battleship Bunker image (below) for prototypes

Early Prototyping

Becca started by working with Kerry Loewen (Professor/Chair in Media Arts at the time) to create a script for the videos that would help direct the drawers and what they would contain. Nine drawers would need to be created, three with scent, three with audio and LEDs, and three with artifacts for visitors to touch and see up close and personal.

The first prototype was created with a single LED and a PN532 NFC/RFID Controller Shield on top of an Arduino Uno. This was fabricated inside of a foam core box and once tested with the RFID Shield and multiple RFID scanners we were able to determine this would be the correct direction to go.

The next steps were to determine the story for each set of drawers and what they would contain, what interaction and how to make this a nice multisensory experience. Becca Sharp also began designing the space for the installation using open source software, Unity 3D.

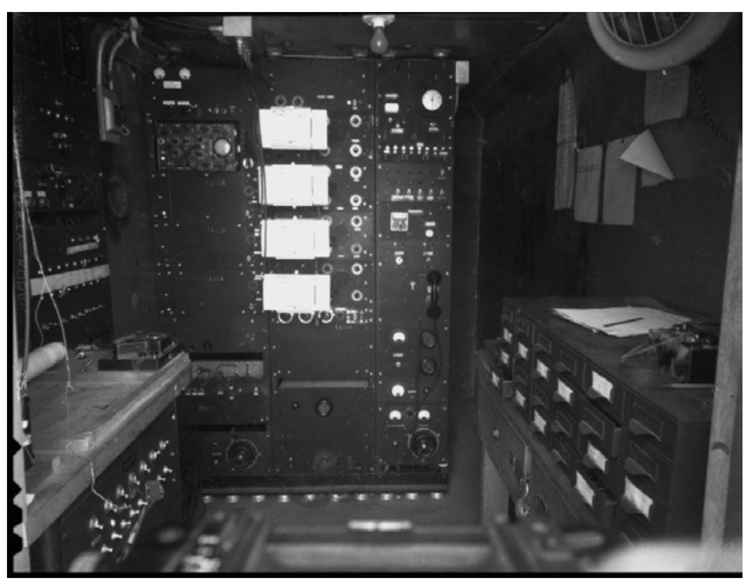


Photo from inside the original Battleship Bunker, the drawers were inspired by the drawers to the right

Buildings:	Slotin Building	Pond Cabin	Battleship Bunker
1st Drawer/ Scents:	Scents: Burning Electronics	Scents: Coffee, Campfire	Photocell Phone & Audio
2nd Drawer/Object:	Metal	Camera	Shot Counter
3rd Drawer/RFID:	Screw Driver & LED	Ruler & LED	RFID & Scent: Gun Powder

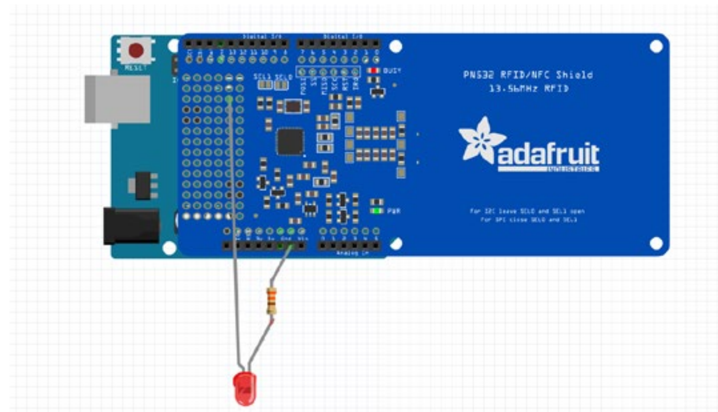
The drawers were then located in the Manhattan Project warehouse that stores archives and important information from the Manhattan Project. The drawers were then taken and fabrication began. The drawers were divided into three buildings: The Slotin, The Pond Cabin and The Battleship Bunker" all three were very important buildings that people would not be able to see in their original state ever again. The electronics and drawers were mapped out in a table pictured above.

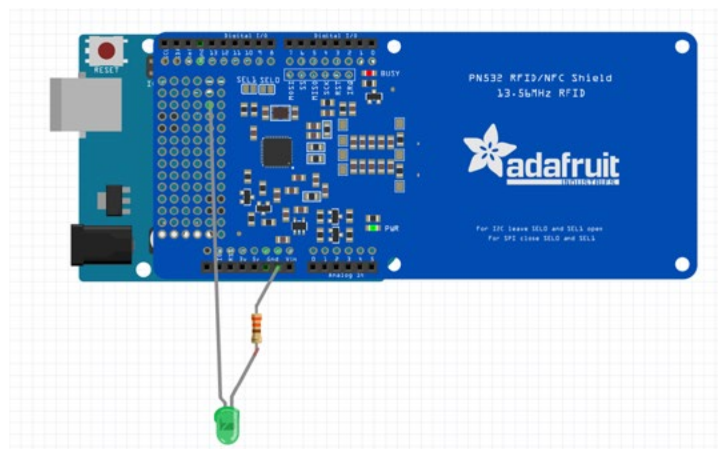
The secret pass was created using a red window for visitors to decode secret messages. The RFID Scanner is located in the bottom right corner. The RFID is adhered using double sided tape and the cards were printed at Media Arts & Technology. These were quickly replaced with larger versions because of the passes going missing so often. (By missing we mean people loved them and took them home)

The second version of the pass is larger and uses the same technology but with a larger thicker pass to hopefully keep them in the museum.

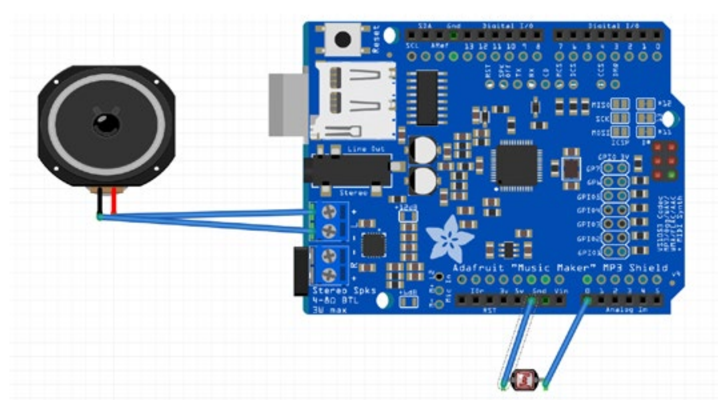
Fritzing Schematic

Prototype Schematic using LED and RFID Controller:



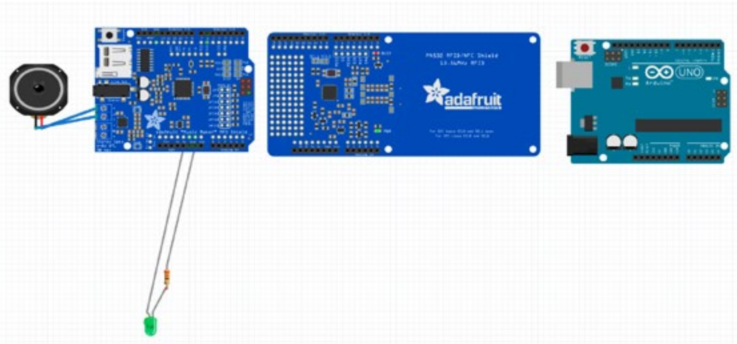


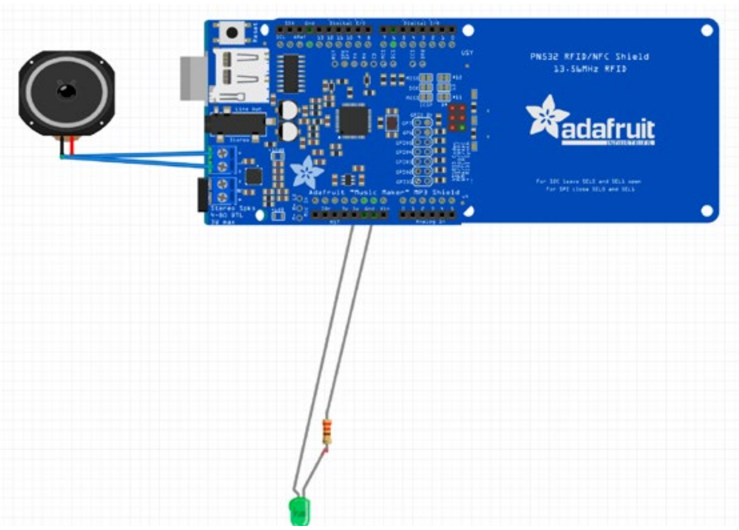
Photocell to Audio Shield and Speaker



RFID Controller w/ Audio Shield (and Speaker) & LED: (Separated)

RFID Controller w/ Audio Shield (and Speaker) & LED:





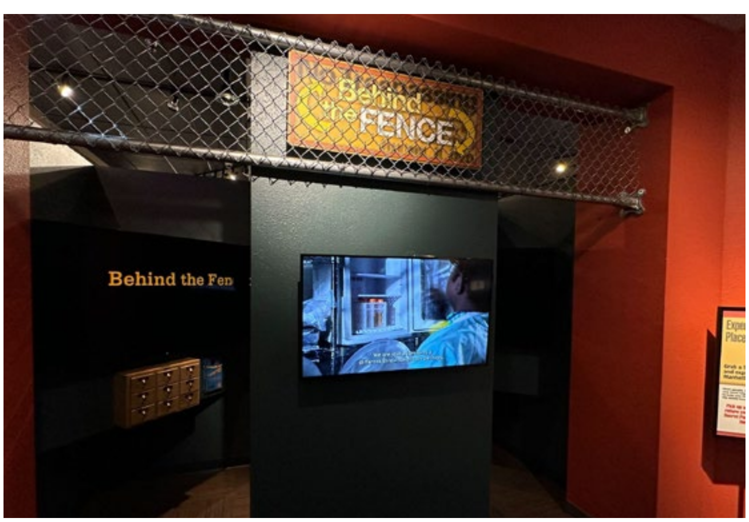
Hardware Used

- The hardware used for each drawer includes the following: Slotin: RFID to LED and MP3 Shield w/ Speakers
- Pond Cabin: RFID to LED and MP3 Shield w/ Speakers Battleship Bunker: RFID to MP3 Shield w/ Speakers
- Adafruit PN532 NFC/RFID Controller Shield for Arduino x 3
- Adafruit "Music Maker" MP3 Shield for Arduino w/3W Stereo Amp x 3 Speakers x 3 (found on adafruit)
- 1 Photocell
- 2 LEDs - 5mm Green and Red w/ soldered 220 Ohm resistor to ground legTroubleshooting and Lessons Learned

Installation

On Site at the Bradbury Science Museum

In May of 2017 the PICT class went to the museum to install. Becca Sharp, Dré Gallegos and Miriam Langer worked with Omar Juveland who fabricated a new spot in the museum for the installation. The drawers were added with all working components and installed with power coming from the backside of the drawers.



Troubleshooting and Lessons Learned

When troubleshooting when installing the drawers were a cm larger than the space provided for them, this required us waiting to install for a few hours on the day of install. The install went well and was relatively seamless. One thing learned was how important documentation is. For this project most of the documentation left with the client or was not archived properly.

Conclusion

Overall, this was a very successful install from concept to installation. The electronics were reliable and as of March 2023 the electronics are still working successfully and have not malfunctioned. The scents created are also still strong and potent. The audio is still very clear and the LEDs are bright.

Case Study 1: Acadia National Park, Mt Desert Island, Maine

The Project

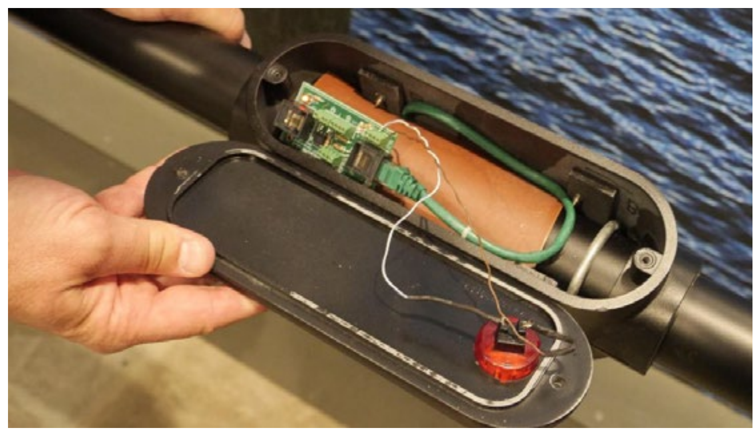
In late 2015 the CTDL was contacted by our frequent collaborator Michael Kelly, who had been hired to design and install an exhibit at Acadia National Park's seasonal visitor's center, the Sieur du Monts nature center. The theme of the new exhibition space was climate change and the effects of rising and warming ocean on the Maine coastline. He asked us if we could build out a few robust interactives that would be able to withstand being turned off during the winter months and easily reactivated when the center opened May-October. We saw right away that this would be a good use case for the Museduino, since his design called for a long run from the sensors to the actuators, and response time with no data delay was a big reason we developed the Museduino.

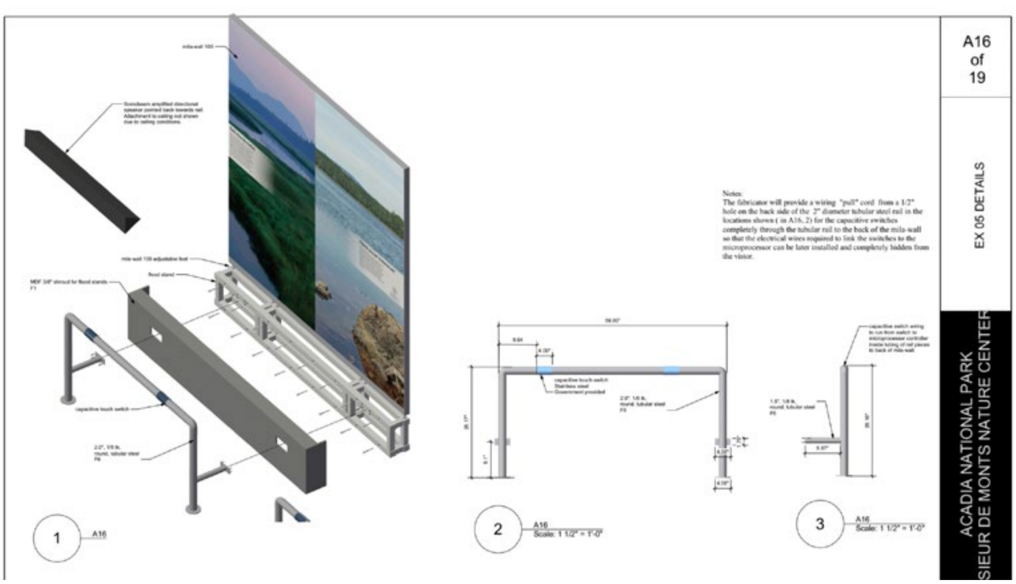
The Space

The Sieur du Monts nature center is a small, old building inside Acadia National Park. It is open seasonally, from May through October, so anything we built had to be easy to shut down and then restart again in the late spring. Easier said than done, as the park rangers, who are brilliant at doing their park-related work, had a fear of the electronics and did not want to be responsible even for plugging things in and switching on a power strip. To reactivate after the first winter, Rianne flew from New Mexico to Mt. Desert Island on a tiny plane to flip a switch. Since then, a new park ranger has been assigned this onerous task each fall and spring.

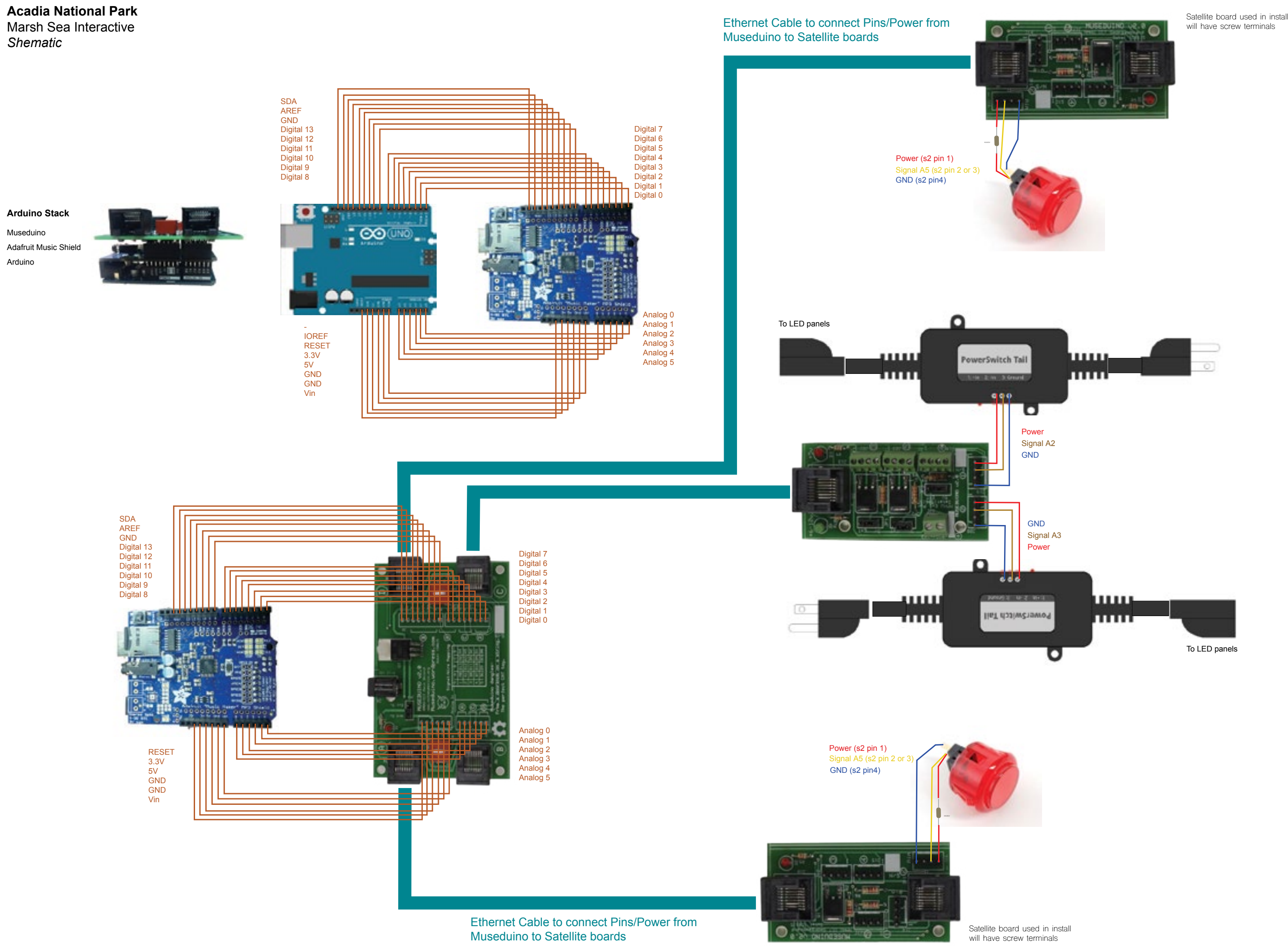
Other issues with the space were that it is an historic building, so installation had to easy to remove, and also the electrical wiring was a little wonky when it came to grounding.

Installation

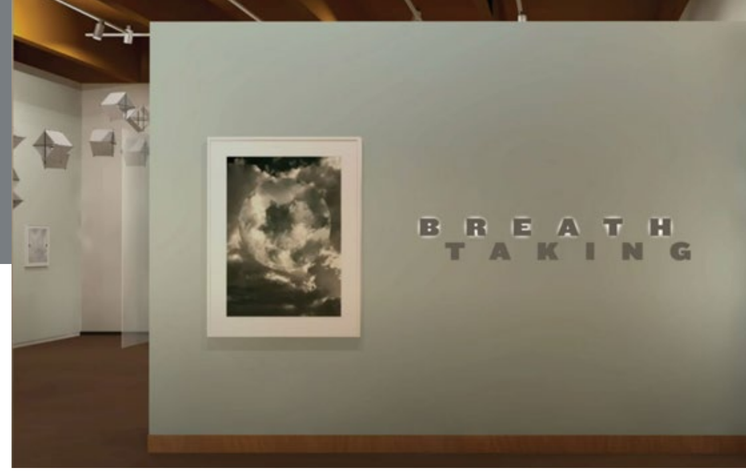




Circuit Diagram



OSHWA Case Study: “Breathtaking” at NMMoA



In this digital mock-up Breath and Taking were to be separated and hung one above the other. Each letter with a minimum of 9 LEDs, this would be hanging on the wall with all electronics hidden.

Abstract

“Breathtaking” is an open source hardware installation built into a wall at New Mexico Museum of Art in Santa Fe NM, which uses RGB LED strips inside custom cut/translucent acrylic letters that are designed to “inhale” and “exhale” at the rate of an average breath. Its purpose was to welcome visitors into an exhibit with multiple New Mexico based artist’s installations.

https://vimeo.com/799324356
https://vimeo.com/799335121

The museum used a local vendor in Santa Fe to cut the acrylic letters to spell out BREATHTAKING and technology fabricator Becca Sharp was hired to solder and test the electronics used in the title wall. Technology fabricator Rianne Trujillo was also hired to help with the installation and creative coding for the LEDs. They used a single Arduino Uno and just over two meters of LED strips from Adafruit. This project was developed and created in two months, however, due to the Covid19 Pandemic this project was shelved and not installed until the following year - almost nine months after prototyping /began.

Project Development

Initial Proposal

Professors Lauren Addario and Miriam Langer have been successfully running a paid summer internship program in Media Arts & Technology for over ten years. Through this internship program they create opportunities for students to use their skills and interests to work with a museum or historic site for an entire summer from concept to install in most cases. They introduced Becca Sharp to Matt, Monica, and Kate from the New Mexico Museum of Art for an interview to take on this project. The install as originally planned would greet visitors as they made their way to an exhibit that would only be available to the public for a short time. The lights illuminated and would slowly dim at the rate in which someone would breathe in and out at an average pace.

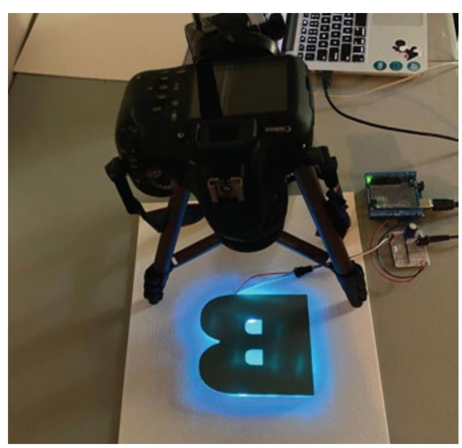
Becca Sharp worked closely with Matt, Monica and Kate to determine the budget of the project and at the time, pre-shutdown, the date of install for a Summer 2020 opening. Becca Sharp worked with Miriam Langer and Rianne Trujillo to develop a parts list and custom circuit using a single Arduino Uno R3 and two power supplies to operate the LEDs and microcontroller. The LEDs would also be daisy-chained together with JST connectors on every letter with an input and output to ensure easy replacement if necessary.

Early Prototyping

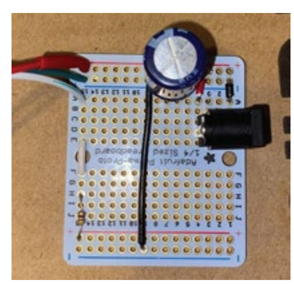
Becca started by creating a custom circuit with the help of Rianne Trujillo to test the LEDs and determine how much power will be needed based on how many LEDs would be used in the install. Becca cut and soldered LED strips to use for testing colors and brightness with a simple strand test using Arduino CC. We decided on using a 5V LED strand from Adafruit (Product ID: 1138). Two power sources were used, one was for the Arduino Uno R3 to power this was a 9V1Amp and the other was to power the LEDs. Due to the amount of LEDs used (2.5 meters at 60LEDs per meter) a 5V10Amp was needed for power.

The requirements were that the top word would illuminate and as it was dimming the bottom word would illuminate seamlessly. This would need to operate from open to close at the museum for (at the time) an undetermined number of months.

Becca was provided with a single acrylic letter ‘B’ to use for prototyping and testing this letter would be the same size and painted with the same top coat of gray paint. The letter was solid and needed to have an area for the LED strip, Becca used a dremel to create an inlay for the LED strip to rest in facing the wall. This would allow for no bright LEDs to be seen through the acrylic letters



During testing, it was decided to flip the LEDs due to the sharpness of the lights.



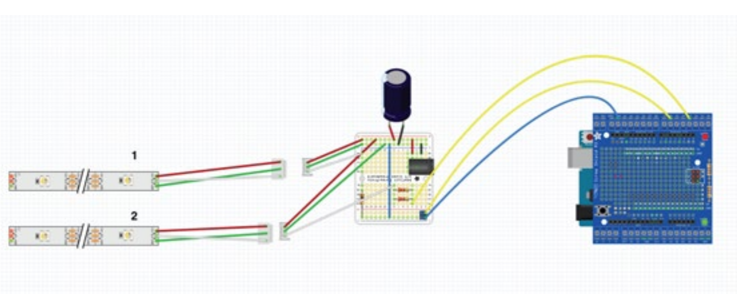
The letters were then all soldered and daisy chained together to further test.

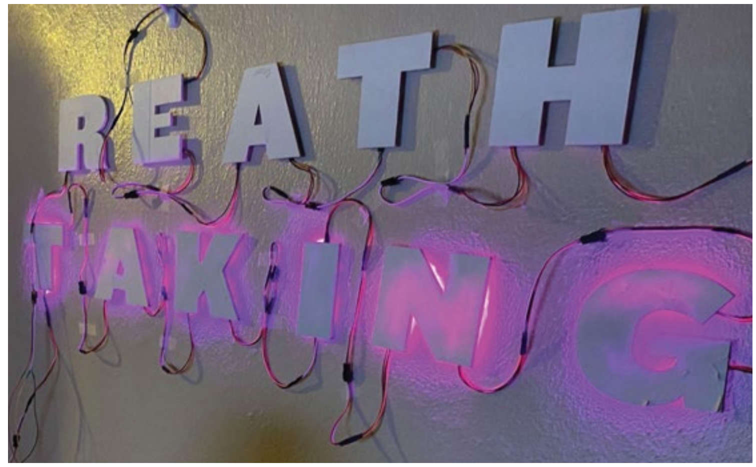
While communicating with the museum staff and giving updates all LEDs were plugged in and tested. This led to the decision to split the two words up by adding on another JST connection to the circuit and allowing the B and T to be the two letters plugged directly into the circuit starting each letter. The number of LEDs per Letter in each word were as follows:

B-13 (0-13)	**T**-11 (78-88)
R-14 (14-27)	**A**-12 (89-100)
E-12 (28-39)	**K**-14 (101-114)
A-12 (40-51)	**I** -6 (115-120)
T-11 (52-62)	**N**-15 (121-135)
H-15 (63-77)	**G**-9 (136-144)
=77 pixels (0-77)	=71 pixels (78-144)

Fritzing Schematic

After this time, when both words were performing as wanted, the project was packed carefully into a box with handwritten notes regarding the project and how it was created.





Installation

On Site at NMMoA

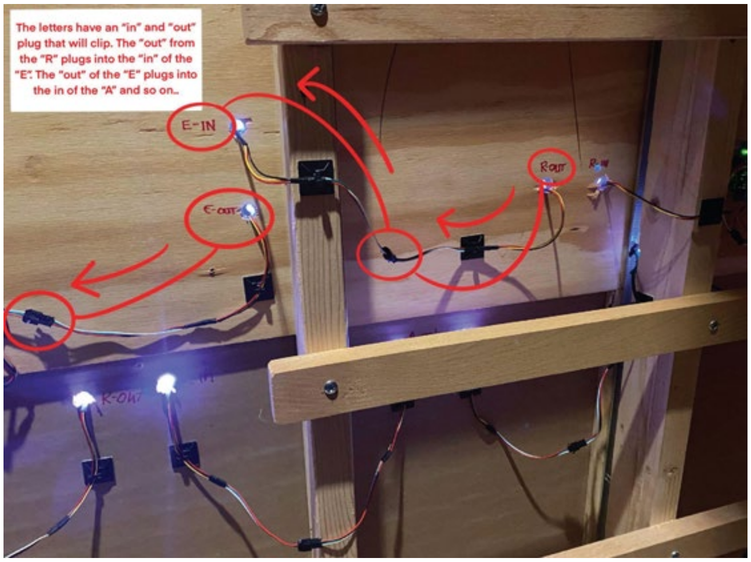
In February of 2021 the museum had contacted Becca Sharp, Lauren Addario and Miriam Langer and said that they were ready for installation. The electronics had been packed up in bubble wrap in a taped box since July of the prior year and needed testing.

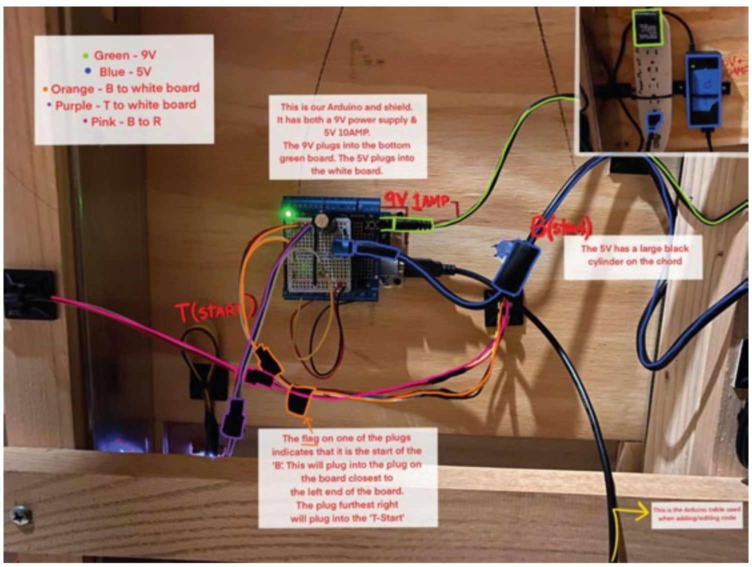
The lights were tested and worked as planned seven months earlier. An installation team with Becca, Rianne, and Daniel Vaughn-Sharp worked at the museum for two days in a one week period. The museum had provided a large moving wall that had an opening on one end for the team to be able to get on the inside of the wall without being exposed in any way.

There was only one thing to still determine with the museum which was the color of the LEDs. The museum was still debating between two colors but ultimately decided on a turquoise (RGB: 10, 210, 180).

The install team worked with the museum curator Kate and (I need to remember his name but he was incharge of doing things like drilling into the walls) to drill holes into the wall to allow the JST connectors to go through and plug in on the inside of the wall.

Documentation Photos for museum





The above photos were left with the museum in case anything needed to be plugged back in. This however was not needed because the cables were managed and secured using zip ties and adhesive squares.

Parts List

- All parts are from Adafruit & SparkFun Electronics:
- 5V10Amp external power supply | Quantity: 1
- 9V1Amp external power supply | Quantity: 1
- 2.5 Meters 60 LEDs perMeter - LED Strip RGB | Quantity: 3 Meters
- JST Connectors: 3PIN | Quantity: 30pcs
- Arduino Uno R3 | Quantity: 1
- Arduino Uno Terminal Screw Shield | Quantity: 1
- Protoboard ¼ Size | Quantity: 1
- 2.1mm DC Barrel Jack | Quantity: 1
- Capacitor 1000uF | Quantity: 1
- 470 Ohm Resistors | Quantity: 2
- 1K Resistor | Quantity: 1
- Zip Ties
- Adhesive Squares

Troubleshooting and Lessons Learned

When troubleshooting to prepare to install one of the connection cables was far too long and was causing issues. While working with the letters we used BHV tape (linked here) to hang the letters and also adhere the LEDs to the inside of each letter. This was a one shot kind of thing and we learned that this BHV was great and held up multiple acrylic letters.

While installing the letter G the LEDs were accidentally bent and needed fixing. Thankfully we had more LED strands as well as JST connectors and were able to clip off the ripped LEDs and replace them on site. This did not slow down our installation but we did notice that when working with small channels for LEDs less is best rather than to try to fit as many as you can.

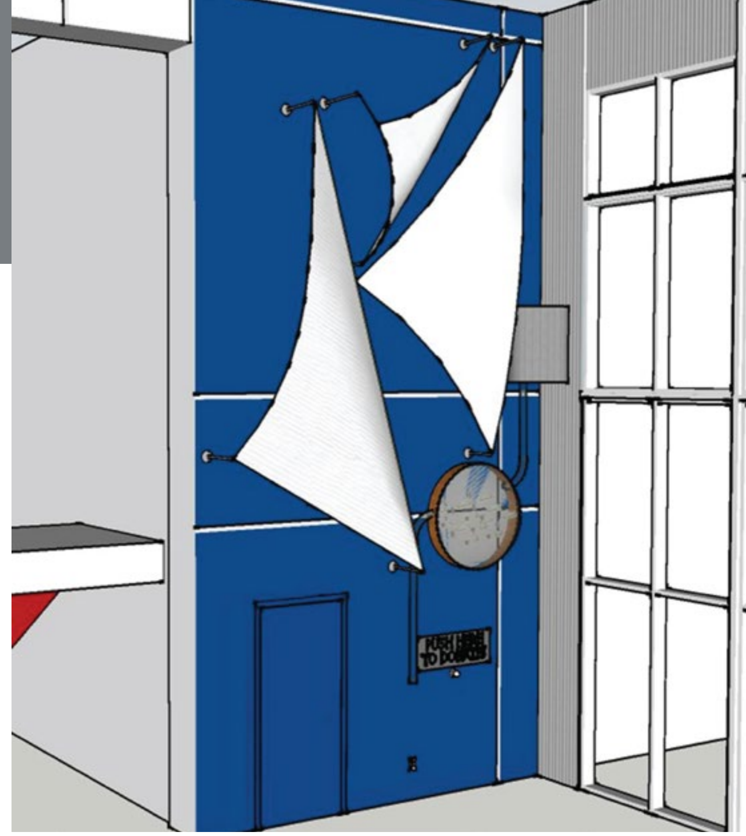
Conclusion

Overall, this was a very successful install from concept to installation. The electronics were reliable and from sources that have been used in other projects from the Media Arts & Technology department at NMHU.

This project was put on hold because of the Covid19 Pandemic and the LEDs were packed away for months, because of the software and hardware used the project was able to pick up right where it was left off when the time came.

By using open source hardware it was affordable and efficient especially when replacing LEDs during install. For this reason, we were also able to reuse these LEDs and letters to spell out "Night Break" for a student project the following Fall Semester.

Museduino Case Study: Full Sails



The original Sketchup file, showing the position of the kinetic sculpture in the atrium, with stairs to the second floor on the left and large bay windows on the right.

Abstract

"Full Sails" is an interactive installation built in the lobby of the Santa Cruz Museum of Art & History, which pulls paper money donations through curved tubing into a glass porthole, and then inflates sails and lights them up as a reward. While its purpose is to accept cash donations to support the museum, it also pays tribute to Santa Cruz's history of sailmaking and shipbuilding.

https://vimeo.com/295454716

The museum commissioned local glass sculptor Biagio Scarpello to design and fabricate the installation and freelance museum technologist Jason Alderman to collaborate on electronic sensors and interactivity, both working with exhibition designer Justin Collins. They used a single Arduino with a Museduino shield and four satellite boards to control three fans, three sets of lights, a dust collector vacuum, a control switch, and two infrared sensors. The project was developed and completed in six months, and has been running continuously since 2017.

Concept Development

Initial Proposal

Justin Collins (exhibition designer) collaborated with Biagio Scarpello (a mixed-media sculptor and glass artist) to plan a kinetic sculpture in the atrium of the Santa Cruz Museum of Art and History that would accept donations and entertain visitors. Loosely inspired by Cash Machine in The New Children's Museum in San Diego (more), the installation (as originally planned) would have visitors push a large button to turn on a vacuum that would suction paper money donations into a large glass dome, and reward visitors by inflating and illuminating ship sails mounted on the wall. As a local art and history museum, the sails and the porthole-like dome in the interactive art installation would pay homage to Santa Cruz's long history of sailmaking.

Justin and Nina Simon (the museum's executive director) referred Biagio to Jason Alderman (a museum technologist who had worked with the museum in the past) to collaborate on the electronics, and Jason and Biagio put together a parts list and a working budget for the project in December 2016. Jason was keen to use a Museduino shield and satellite boards for this project because it would allow the project to be controlled by a single Arduino Uno R3 (and would provide power+ground for every Arduino pin).

After reviewing the proposal, the museum approved it; Nina requested two changes from the original concept:

1. that the sculpture not need a button press to activate, but sense visitors holding a dollar bill and turn on the vacuum, and
2. that color changing LED lights were not top priority for illuminating the sails; standard lights backlighting the sails would be enough, as Justin was overhauling all of the lighting in the museum's atrium.

Given the initial discussions and explorations of types of sensors, the team decided on a Sharp IR sensor for initiating the vacuum, and consumer-friendly relays (PowerSwitch Tail 2) for flipping on and off standard halogen lights and industrial fans.

Early Prototyping

Biagio was near the museum, but Jason was 460 miles south. While they figured out a time that would make sense for both of them to be on-site at the museum for in-person collaboration, Biagio sent a section of tubing to Jason to begin testing sensors.

The initial requirements were for sensors to detect

- when paper money / a hand was at the mouth of the tubing
- when paper money entered the glass dome successfully and actuators

- to turn on the fans
- to turn on the lights
- to switch on the vacuum for a set duration of time.

Jason began making several small Arduino sketches to individually test the sensors and ready the electronics for on-site testing, while Biagio began fabricating and testing physical hardware. During this initial testing, the team found out three important issues:

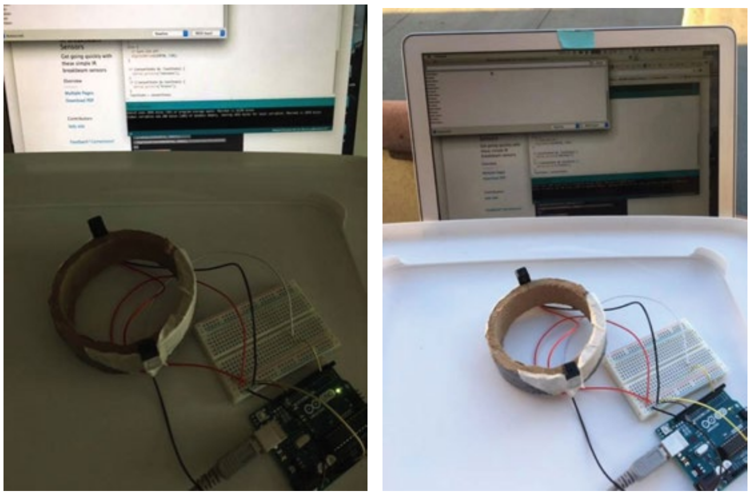


Photo of IR break beam sensor on tubing canister ring, being tested indoors, and then in shade outdoors.

1. IR break beam sensors (the first choice for detecting when money entered the glass dome) performance was unreliable in sunny conditions. The atrium of the museum was flooded with sunlight, especially afternoons, and the installation would be by large bay windows. The sensors would need to be shielded.
2. When would the vacuum turn off? Would it be when the paper money entered the dome? Would break beam sensors (or another sensor) reliably detect that? Would the vacuum need to run for a few more seconds to swirl the money in the dome? The installation would need code for a timer, and it would probably be best to decouple the vacuum timing from a second sensing event — have it run for a set duration every time the Sharp IR was triggered.
3. As Justin and the museum had had further conversations with Biagio, they requested that the installation have a few different modes — that they would be able to turn it off completely, that they could have an autonomous mode that deactivated the donation tubing sensor and cycled the fans and lights, and that they could inflate the sails without the lights to project upon the sails for special events in the atrium. These modes meant that the relays controlling the lights and fans would need to be normally-closed instead of normally-open so that they could be controlled by frontline museum staff with lightswitches, independent of the Arduino. (This would also make sure that the Arduino wasn't a single point of failure!)

On-site Testing

With these things in mind, Jason flew out to work with Biagio in late February 2017. They began to assemble the separate Arduino sketches, crimp wires to connect sensors (since the initial Museduino satellite boards did not have screw terminals), and made a few important discoveries over a weekend of working together and visiting the atrium in person.

- In early tests, loose wires were a frequent culprit when things failed to work. Jason and Biagio were crimping wires by hand, and figuring out how to properly crimp a pin to the end of a jumper wire helped considerably.
- The original timer library in the Arduino sketches, which counted the elapsed milliseconds, was failing. Switching to a lower-level library with callbacks called SimpleTimer fixed these problems.
- Possibly due to fluctuating light levels in the atrium, the Sharp IR sensor at the mouth of the tubing was returning a lot of false positives; Jason updated the code to average over a set of values to smooth the readings.
- The original shop-vac vacuum wasn't powerful enough, so the team returned it and tried a more powerful model. Bills were still getting stuck in the tube (along the sides), so they upgraded to a dust collector for more powerful suction.
- Due to the break beam sunlight issues, the team tried alternatives. Piezo-vibration sensors did not work, likely because of too much noise and vibration in the tubing from the vacuum itself. Ultrasonic sensors relied on the positioning of the paper money, and the sensors on hand didn't work well at such a short range. An IR time-of-flight sensor worked in test sketches, but it required I2C and too much memory when put into a full sketch, so it added constraints. In the end, the IR break beam receiver was shielded by recessing it, putting it at the end of a plastic pen barrel darkened with duct tape, making it more reliable.
- When testing the PowerSwitch Tail 2 relays meant to control fans, Biagio and Jason often used lights, because it was often easier and faster to see that they had switched on or off.

Further Refinement

Having worked together to set up most of the electronics, Jason left it with Biagio; he continued software development remotely on a smaller setup and emailed code updates to Biagio to test.

Biagio continued fabricating and wiring the parts of the installation. He hung the dome on the wall of his house in a spare room (https://www.instagram.com/p/BRybjtaBAgp/), and he experimented with Justin to add internal grates and baffles inside the dome to ensure that the air would circulate well to make the donated dollars spin inside.

Dust collectors — as would be expected with a vacuum that's roughly four times as powerful as a heavy-duty shop-vac — are quite noisy. While the original diagram showed the housing for the vacuum inside the atrium, Justin began working on a housing for the dust collector outside the museum, to help muffle the noise.

Jason continued to work on smaller individual "test" Arduino sketches for each new component. He developed a mode switch for the installation, using a knob from a motorboat dashboard and a voltage divider circuit to switch between three modes (https://www.instagram.com/p/BR6jExLjA9V/), and mailed it to Biagio for installation on-site.

Adding the new switch on a new satellite board using Museduino port D introduced a new issue — the digital pins on port D include 1 and 0, which are the pins that the Arduino internally uses for the Serial communication. If sensors were plugged into those pins, you couldn't upload new sketches, and the Serial Monitor went haywire due to the feedback loop, so the team swapped the satellite boards for the Sharp IR (originally port A) and the mode switch.

These smaller sketches (including the mode switching and randomization for the autonomous mode) were then slowly aggregated into the main sketch as they proved successful. Working in this way helped to isolate (and minimize) software bugs. (Overall, there were a total of 33 sketches —

15 versions of the main sketch and 18 test sketches.)

Final Installation

In early May 2017, Jason flew out again to help with final installation and fine-tuning the sensor code.

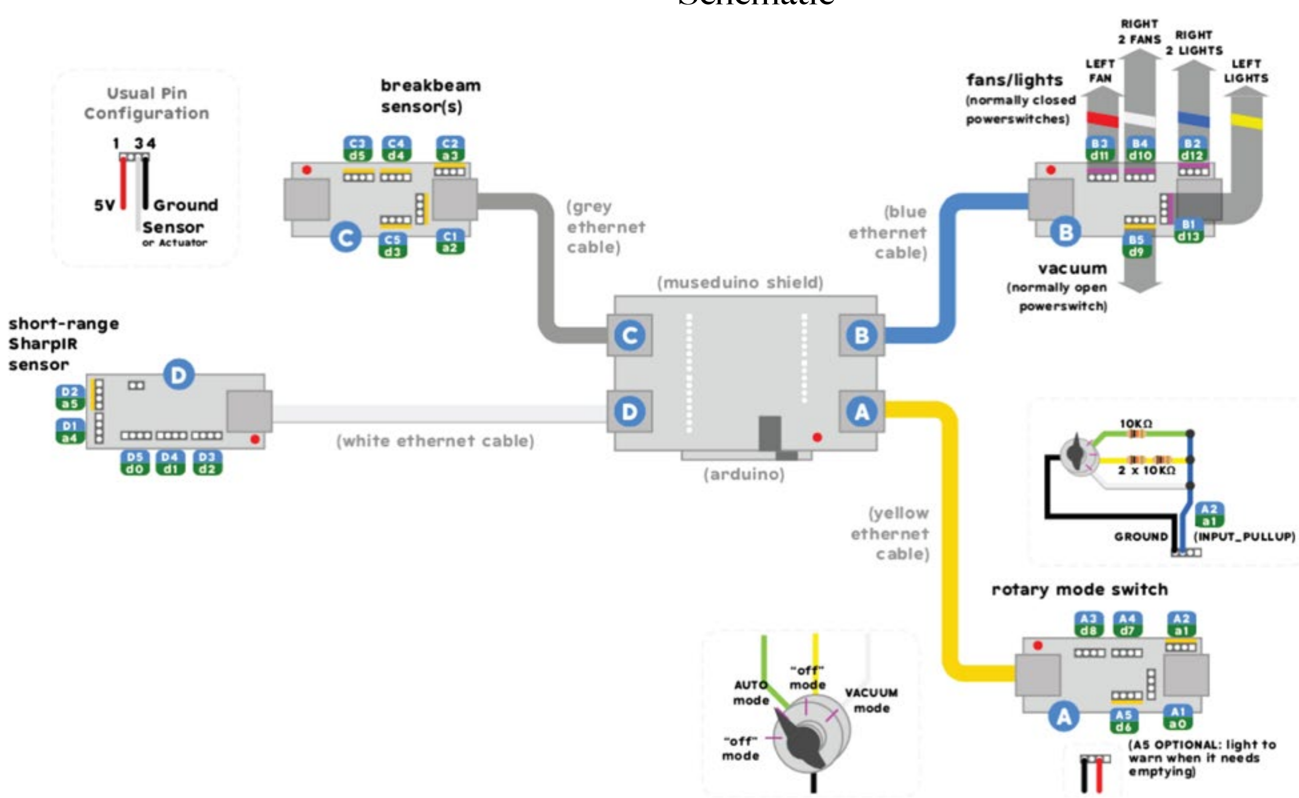
Since the kinetic sculpture in the atrium spanned two floors, Justin and Biagio put the central Arduino, Museduino shield, and PowerSwitch relays on a platform in the drop-ceiling behind the wall of the installation, and left a 10-foot USB cable attached to the Arduino, so that sketches could be updated without needing to have a computer in the ceiling next to the brains of the installation. The team used colored electrical tape and labeled each cord and cable for easier maintenance later.

At the museum's front desk, underneath the stairs, Justin installed a lightswitch panel to allow frontline staff to toggle on the fans and lights separately, and switch modes from OFF (Sharp IR ignored, vacuum never turns on), to VACUUM (Sharp IR triggers vacuum), to AUTO (Sharp IR ignored, vacuum never turns on, fans and lights turn on and off in a semi-random pattern).

"Full Sails" was well received when it launched at a First Friday event in downtown Santa Cruz (https://www.instagram.com/p/BTvKWghDCgw/). In subsequent tests, especially at different times of day, the museum staff found that the IR break beam sensors would not always trigger when paper money rocketed past them into the dome. This bug turned out to be an unexpected "feature," as the unpredictable reward fanfare led people to donate more money to see if they could trigger the lights and fans.

Installation Design

Schematic



Parts List and Budget

If this is something that is helpful for creating any ancillary materials, here was my final budget for only the electronics side of things, including the airfare for two trips out to install.

Troubleshooting and Lessons Learned

- **Keep it simple.** Where possible, this design used relays to switch power on and off to simple electrical devices (fans, spotlights, vacuum). Doing so kept costs down with off-the-shelf equipment and lowered the complexity of the circuitry.
- **"Voltron" together several small sketches.** We tested each component added to the overall system with a separate Arduino sketch (.ino file) before adding it to the aggregate file.
- **Iterate on components.** We prototyped early and often, frequently in the space where the installation would be, and discovered things we could not have foreseen when sketching.
    - A typical shop vacuum did not have enough suction power to pull paper money through the length of tubing. We opted for a dust collector, a vacuum that is four times more powerful. (Keep receipts for quickly returning equipment that does not work for your needs!)
    - We moved the dust collector itself outside the building so that the motor sounds would not be too loud in the acoustics of the museum lobby. This required building an accessible, weather-guarded enclosure for the dust collector.
    - We tested many different sensors to detect paper money at the mouth of the tube and the entry to the porthole, and each had different challenges.
        - Passive Sharp infrared sensors, tuned for different ranges of distance, had to find the right range and then do software averaging to account for the noise from sunlight fluctuations in the space.
        - Piezoelectric sensors couldn't detect vibrations because the paper money was too quiet, and dust collector vibrated the whole apparatus too much.
        - Ultrasonic sensors and infrared time-of-flight sensors were not fast enough and needed more distance, respectively, for paper money that was rushing by.
        - Infrared break-beam sensors were good, but were sensitive to IR in sunlight at certain times of day, and needed to be shielded. (We mounted a darkened ballpoint pen barrel around the sensor to shield it from direct sunlight.)
- **Color code and label your wiring**. The colors in the schematic reflect the colors of ethernet cable and electrical tape on the components, making it easier to track down which wire or relay controls the thing you're looking for.
- **Always doublecheck the wiring.** Use a multimeter and patiently check that your wires are connected properly. Opt for screw terminals over pin terminals wherever possible; pin connectors on wires can be tricky to crimp reliably.

Conclusions

Without a Museduino, this project would have been much more difficult to complete, and would have had many more points of possible failure. Miriam, Rianne, and the Museduino team consulted at several times, helping troubleshoot issues with satellite board power, and recommending simplifications to the design. Overall, using open-source hardware made the experience feasible for a local museum on a shoestring budget, and (due to the standard hardware and well-documented components) made maintenance learnable for museum staff.

OSHWA Case Study: Interactive 3D Map at Los Luceros Historic Site, Los Luceros, NM

Abstract

This interactive 3D map is a CNC engraved 60" x 42" table made from Jemez Pine burned in the New Mexico fires in Spring of 2022. This map has 11 buttons on the border of the map that illuminate different buildings relating to the button. The cut outs feature a square with 3D objects that relate to the building and a button with a braille description. There are 11 locations that are pointed out in the map, and more can be added at a later date if the client wishes. Each location is important to the site and is also a tool for the staff to share about the Historic Site.

(video link to come)

The Los Luceros Historic Site is the newest site in New Mexico and opened in 2019, right before the world shut down during the Pandemic in 2020. This map will be a great tool for the site to use and will be mobile and follows ADA specifications. The map was designed by Becca Sharp and the buildings/objects on the map and buttons were designed and created by Lydia Gonzales and Becca Sharp. The electronics were fabricated by the team as well as with Rianne Trujillo and Miriam Langer. This project is using the Museduino V4 to connect multiple buttons and responsive neopixels using one Arduino Uno.

Project Development

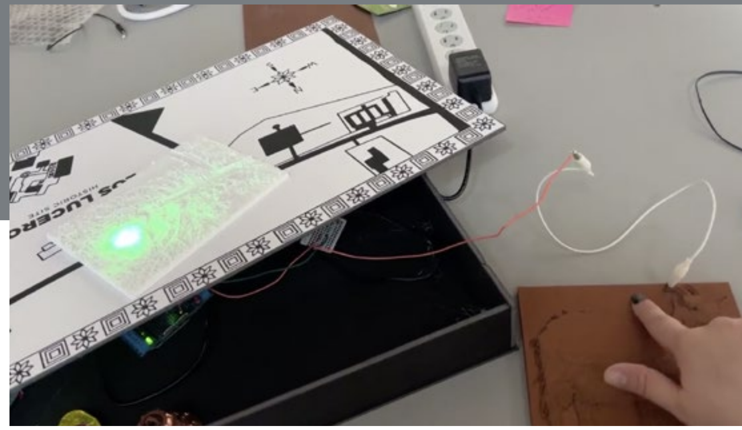
Initial Proposal

The Los Luceros Historic Site hired the PICT (Program Interactive Cultural Technology) class from Media Arts & Technology to create new exciting installations for the site. The class consisted of different teams including the Multimedia Team with Becca Sharp, Lydia Gonzales, Rianne Trujillo and Miriam Langer. The team proposed a large CNC map engraved and resin casted to help as a wayfinding tool for the site. The map will have multiple 3D printed buildings placed in relation to their location around the site. The visitors will be encouraged to press a button that will illuminate the corresponding building/location in the historic site.

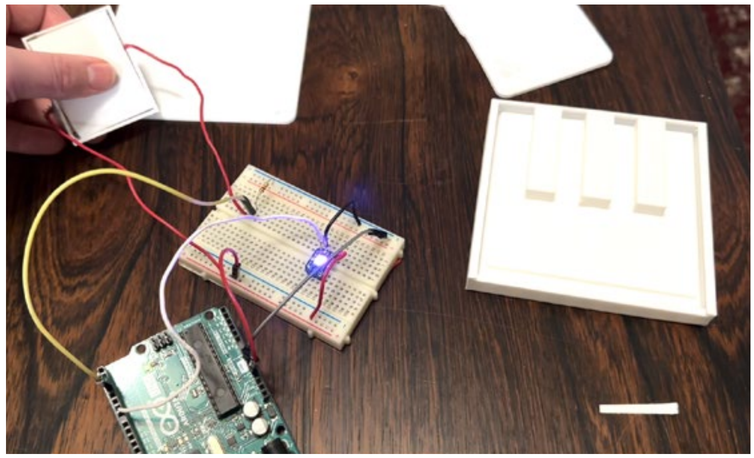
Early Prototyping

The team started by creating a single building from the site and 3D printed the building using different materials such as ABS and PLA. The building is connected to an LED that leads to an

Arduino Uno with a copper tape button that illuminates the



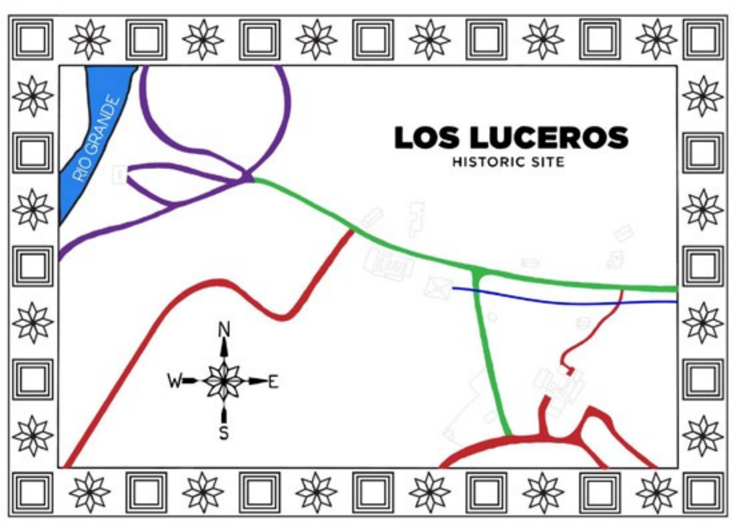
LED illuminating from a switch circuit using copper tape, Arduino Uno, Alligator Clips and a single LED.



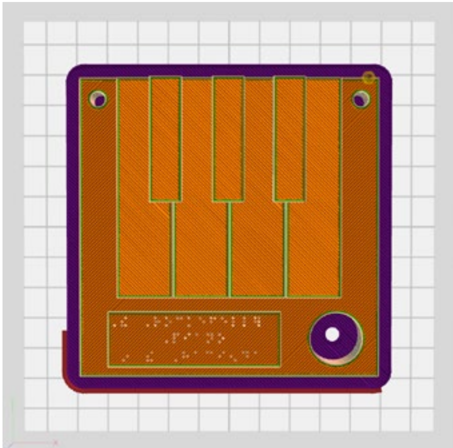
Button prototype Version 1 - A button made from copper tape, foam and springs

LED when touched. The prototype was very successful and did exactly as intended. This then pointed us in the direction to use capacitive touch for the interaction with neopixel LEDs so that we could use different colors for the different locations.

The map design was completed and approved by the site. The team would be working with Old Wood of Las Vegas NM to create the newly designed map with dimensions of 57" x 39". This would allow space between each button and for a large base map to place the buildings on top of.



The buttons will be printed in PLA and went through many different versions, in the final version the button will have a push button, braille for accessibility and an object in the middle of the print.

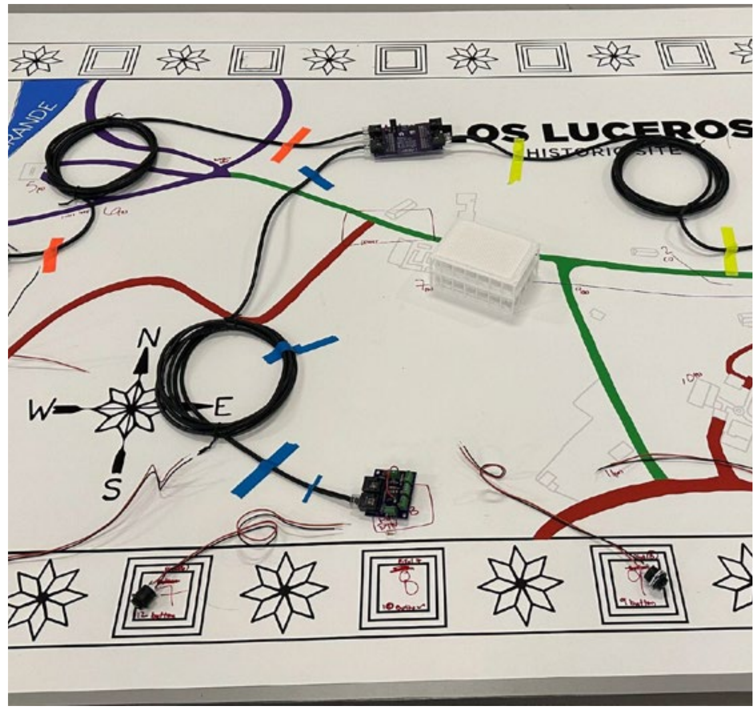


Technology Used

- The technology used for the interaction of the map includes:
- 1 Arduino Uno R3
- Museduino V4 (One Main Shield, 2 Smorgasboards, 1 External Power Board) 11 Push Buttons
- 11 Neopixels

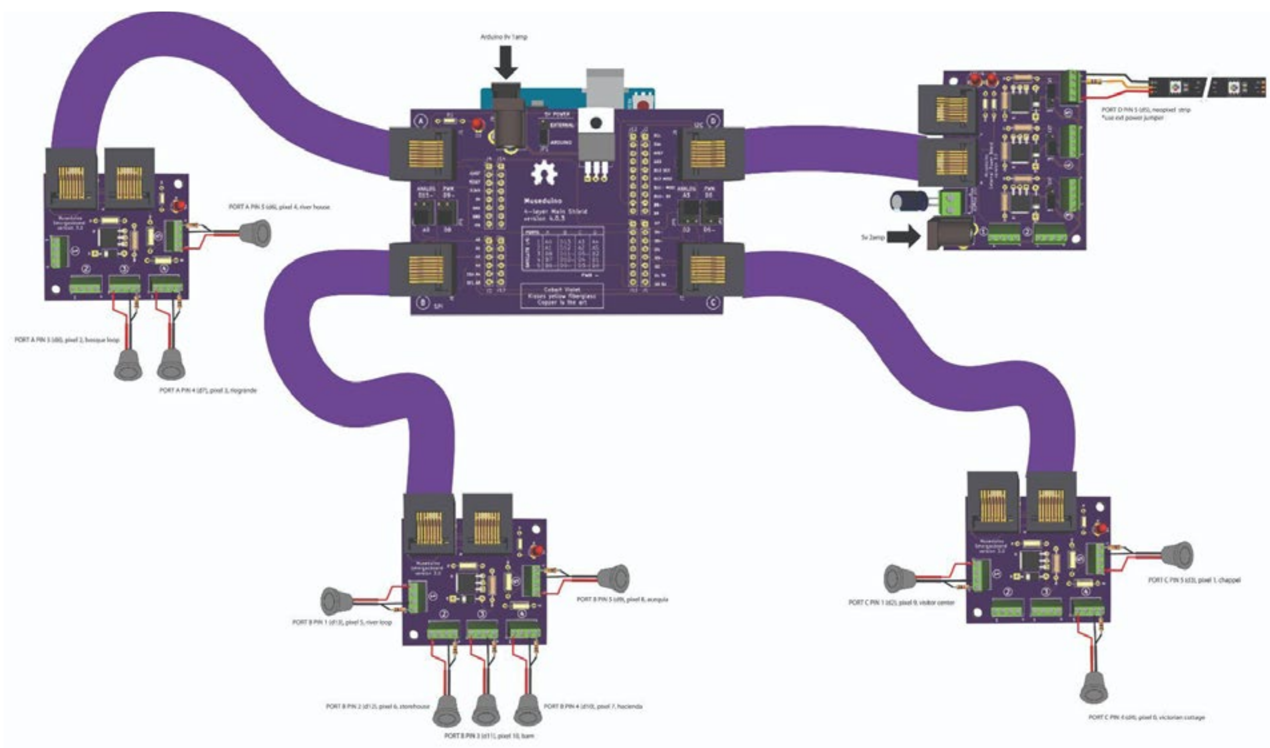
The technology used is all open source hardware and easily accessible for replacement parts if needed. The Arduino Uno will have the main shield on top with the cat5 cables connecting to the external power board that will have the 11 neopixels and 3 buttons attached. The main shield will also connect to the 2 Smorgasboards that will house the remaining buttons.

This will allow the buttons when pressed to illuminate the neopixel that is connected to the corresponding button.



Fritzing Schematic

This schematic shows the Main Shield on the Arduino Uno with the Smorgasboards and External Power Board.



Installation / 3D Model of Install

A 3D model is used in place of the table until installation is complete by July 2023. The table will be created on a 60”x42” wood engraved table. The table will be stained in a dark oak stain and engraved to reveal the natural wood below. The objects created on top of the table are made in PLA with a resin cast. The electronics are housed underneath the table with no wires exposed on the surface of the table. The table will have one power supply that will plug into the floor of the Visitor Center at the Historic Site.

Troubleshooting and Lessons Learned

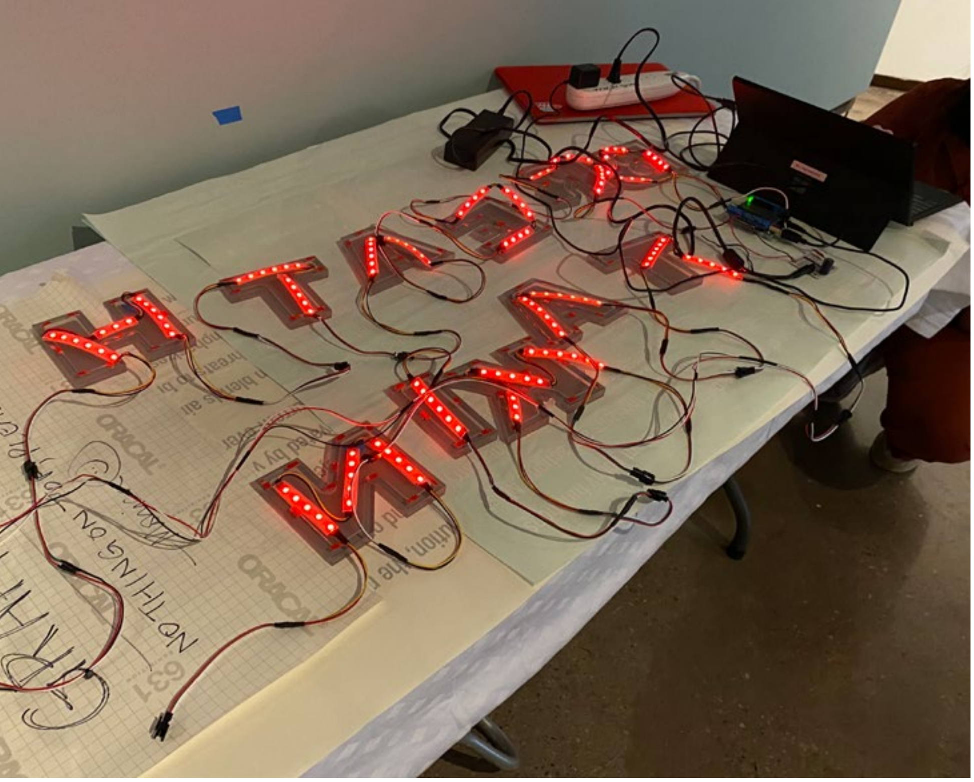
Troubleshooting for this table is still in process but so far it was discovered that the sizing of the table was an issue for a few reasons. It did not give enough room for the buttons to have pressure without breaking the wood edges around the table. The button design took some time to pick the most robust and accessible buttons for the table. The electronics have gone well with the Museduino allowing us to extend the reach much further for the pins needed for the map.

Conclusion

This project is so far very successful and has gone as expected. Through testing the electronics chosen have proven to be robust and the PLA with a light resin cast improves the shine and stability for the prints. The electronics are open hardware and responding just as we wanted. The electronics are straightforward and affordable which allows us to make duplicates for the Historic Site, this will allow some ease in case anything needs replacing (though we rarely need to replace electronics after installation).

References

Appendix




LOS LUCEROS
HISTORIC SITE