MIE 415 Senior Capstone Design

12/10/2018

SolarFi Charging Kiosk

Team 20

Project Sponsor:

Antonio Dixon

Project Team:

Team Lead: Jake Burke

Design Lead: Brendan Byron

Analysis Lead: Daniel Manoli

Fabrication Lead: Paul Leckey

Executive Summary

The goal of this project was to develop a scaled down prototype “technology wall” for Solar-Fi’s solar-powered, phone charging kiosk. The technology wall must include phone charging lockers, a TV for educational programming, empty space for ads, and solar panels to provide power to all the electronic components. Team 20’s prototype provides a flat-packable solution, while implementing all the required components. A locker system for holding and securing phones while they’re being charged was designed such that it can implemented with Solar-Fi’s future mobile payment system. The wall can then be implemented into an existing structure, or a future full kiosk design. The creation of a mock-up kiosk design was included in the scope of this project, with the intention that the design be scaled up, refined, and ultimately constructed by the Solar-Fi team.

Figure 1: SolarFi Concept featuring Team 20’s initial kiosk design

Summary of Impact

Team 20’s contributions to Solar-Fi fall mostly in the realm of conceptual and proof-of -concept guidance. The technology wall prototype is a proof of concept to show that all the needed components can be implemented onto a self-supporting, flat packable wall. The locker design is a prototype and will show that biodegradable materials can be used to fabricate a phone charging locker system. The locker will be 3D printed as part of the final presentation, and will be mounted, and potentially will be used by the SolarFi company in the coming year. The kiosk mockup is a conceptual, scaled design of the final product that Solar-Fi hopes to deliver one day. Once these concepts are fully developed, the solar kiosk will provide a clean and affordable phone charging solution, while promoting entrepreneurship in African countries.

Introduction and Objectives

Access to reliable electricity and business opportunities are in an incredibly short supply in many African countries. Solar-Fi hopes to address both these issues through solar-powered, phone charging kiosks. Phone charging is a huge in issue in Africa, as 70% of the population owns cell phones, yet only 20% have access to reliable electricity. By harnessing the abundance of solar energy in Africa, Solar-Fi kiosks creates a sustainable and reliable source of electricity for phone charging, within a “business-in-a-box” franchise business model. This model encourages local business men and women to lease their own kiosk, and establish steady-flows of income to live off of. Through additional features, such as educational television programming and WiFi access, Solar-Fi hopes to create community-centric environments around the kiosks themselves, and overall, help improve the lives of those the kiosks service.

For Team 20’s contribution to this goal, three main objectives were established: design and fabricate a prototype technology wall, design and fabricate a phone charging locker, and design and 3D print a scale mockup of a conceptual kiosk.

The end goal of the technology wall is for it to support all of the electronic components of the kiosk (i.e. phone charging lockers, TV, solar panels). To allow for easy shipment to Africa, the wall itself must demonstrate the ability to be flat packed. All electrical and software components of the wall are to be provided by SolarFi’s CTO. Based on this, Team 20’s scope for the tech wall was limited to the mechanical components. Thus, we sought to focus our design on flat pack ability, ability to house a TV, phone charging lockers, and advertisement, and support an adjustable solar panel, all while having the ability to be later implemented with a mobile payment system and necessary electrical components. The wall was slightly scaled down (6’ x 4’, instead 8’ x 6’) due to height restrictions at HubWeek, and fabricated out of plywood instead of plastic to simplify fabrication processes and keep costs down. Per request of the project sponsor, this aspect of the project was to be completed by mid-October in support of the company’s crowdfunding kickoff at Boston’s HubWeek conference.

Each phone charging locker will be large enough to house most cell phones, have a hole drilled out of the back to thread a charging cable, and be easily mountable to the technology wall. A rail mounting system will be designed and permanently bonded to the technology wall, to allow for easy mounting and dismounting of the lockers. The locker will also house a small solenoid locking mechanism that will have the ability to be implemented with a mobile payment system. For the final design presentation, a single locker and mount will be 3D printed and mounted to the technology wall.

The scale mock-up of the kiosk will serve as a conceptual representation of a flat-packable solar kiosk. It will be approximately 1:12 scale model, and illustrate various components of a final kiosk design. The technology wall aspect will be shown to have the ability to face either inside or outside of the kiosk by rotating on pins. It will also show how components, such as the TV and lockers, will be easily mounted through an integrated mounting system.

It is important to note that no electrical components were included in the scope of team 20's efforts. The team was specifically directed to design mechanical components that would be able to be integrated with electrical components and software provided by SolarFi's CTO, Glenn Butler. Team 20 communicated with Glenn as needed to make sure that all designs were integratable with his software and components. Overall power generation and consumption was not considered as all electrical components were approved by the CTO before implementation, under the impression that Glen knew how much power the system would require and how it would be generated. However, as Glenn has no obligations to meet team 20's deadlines, there was always the possibility that Glenn's components would not be ready in time for the final design competition.

Contributions of Each Team Member

Jake Burke (Team Lead):

- Concept generation for HubWeek prototype
- Created schedule and kept up-to-date
- Primary point of contact with project sponsor and software engineer
- Negotiated and finalized requirements with project sponsor
- Assisted in gathering material for, and fabricating prototype
- Attended and presented prototype at HubWeek event
- Evaluation of completion of project specifications and goals
- Final Design review presentation

Jake's contributions were vital to having a functioning group, without Jake's guidance and leadership the team couldn't have functioned as well as it did. Jake also kept a detailed schedule that kept each member organized and on track.

Brendan Byron (Design Lead):

- Concept generation for HubWeek prototype
- Initial design concept modeling
- Assisted early stages of HubWeek prototype fabrication
- House of Quality
- Preliminary Design Review PowerPoint presentation
- Attended HubWeek, assisted setup, helped crowdfund during event

- Final kiosk design CAD model (2nd iteration)

Brendan's contributions were vital to the design of the full kiosk, as well as having a scaled model of the final design.

Daniel Manoli (Analysis Lead):

- Concept assistance with HubWeek wall design
- Assistance with HubWeek fabrication
- House of Quality
- Functional Decomposition
- Locker Design
- Preliminary Design Review PowerPoint presentation
- Attended HubWeek, assisted setup, helped crowdfund during event
- ANSYS simulations to determine how strong the design would be

Dan's contributions were vital to the development of the final design, as well as evaluating if the design would function properly.

Paul Leckey (Fabrication Lead):

- Concept generation for prototype
- Assessment of feasibility of fabrication
- Research of Building standards
- Bill of materials generation
- Assisted in acquisition of materials
- Fabrication of prototype
- Final Design review presentation
- Estimated cost of final product

Paul's contributions were vital to constructing a working prototype as well as determining the cost of assembly.

Functional Decomposition

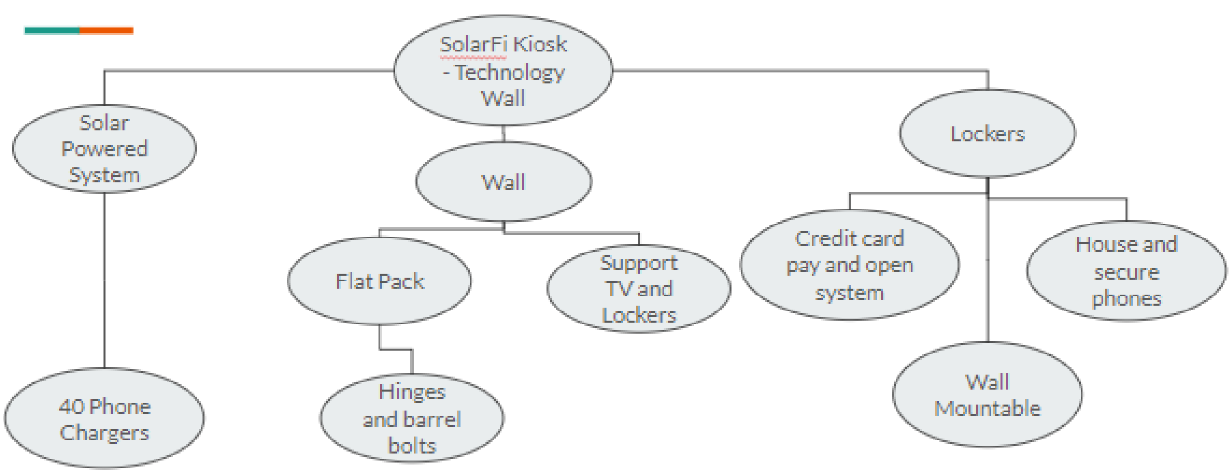


Figure 2: Functional Decomposition

I. Solar Powered System
    A. 40 Phone chargers
        1. The Solar Kiosk must have the capability to charge up to 40 phones simultaneously via Solar power.
II. Wall
    A. Flat Packable
        1. Hinges and Barrel bolts
            a) To achieve the criteria that the wall must be flat-packable, the design of the wall incorporates a system of hinges and bolts such that the wall can fold on itself and reduce the area it occupies.
    B. Support TV and Lockers
        1. While the Hubweek Tech wall was supported by the lockers themselves, the full scale tech wall would be part of a self-standing structure
III. Lockers
    A. Credit Card Pay and Open System
    B. Wall Mountable
    C. House and Secure phones

Engineering Standards

Any engineering standards applicable to the SolarFi kiosk fall in the realm of structural integrity of the kiosk itself, or the implementation of the solar electrical components. As neither of these aspects were part of Team 20’s scope, no engineering standards were considered.

Specifications

Table 1: Target and acceptable specification values

	Target	**Acceptable**
Kiosk	1:12 scale	1:18 scale
	Rotating Tech Wall	Fixed Tech Wall
Tech Wall	Support 40 Lockers	Support 30 Lockers
	Adjustable Solar Panel Angle	Fixed Solar Panel Angle
	Folded thickness: 5”	Folded thickness: 7”
Phone Charging Locker	House all sized cell phones	House all non-XL cell phones
	Electronic locking mechanism with mobile payment system	Electronic Locking mechanism
	Biodegradable and resilient material	Sustainable and Resilient Material

Target specifications were mainly given by the project sponsor, Antonio Dixon. Antonio took ideas he thought of (such as the inclusion of the television to add the community aspect) and merged them with concepts of already existing products on the market (such as the flat-packability and ease of assembly from Solar Kiosk) to create the specifications for the SolarFi kiosk. Antonio specified he would ideally like the kiosk to be roughly 6’ x 6’ x 8’, have the ability to charge 40 phones at once (of multiple different models), have a television display between 32 and 40 inches, and have the structure be flat-packable for shipping and ease of assembly. Antonio also discussed including free space on the tech wall for advertisements of both SolarFi and its sponsors. These specifications were applied to the various components of team 20's project scope.

It is important to note that the project sponsor's specifications frequently changed throughout the semester, such as the number of phones to be charged at once and the existence of a fridge in the kiosk, as shown in the SolarFi concept in Figure 1. While design changes in the future could allow for these specifications to be achieved, they were not considered to be part of the initial scope of the task, and were thus not added when the sponsor requested such.

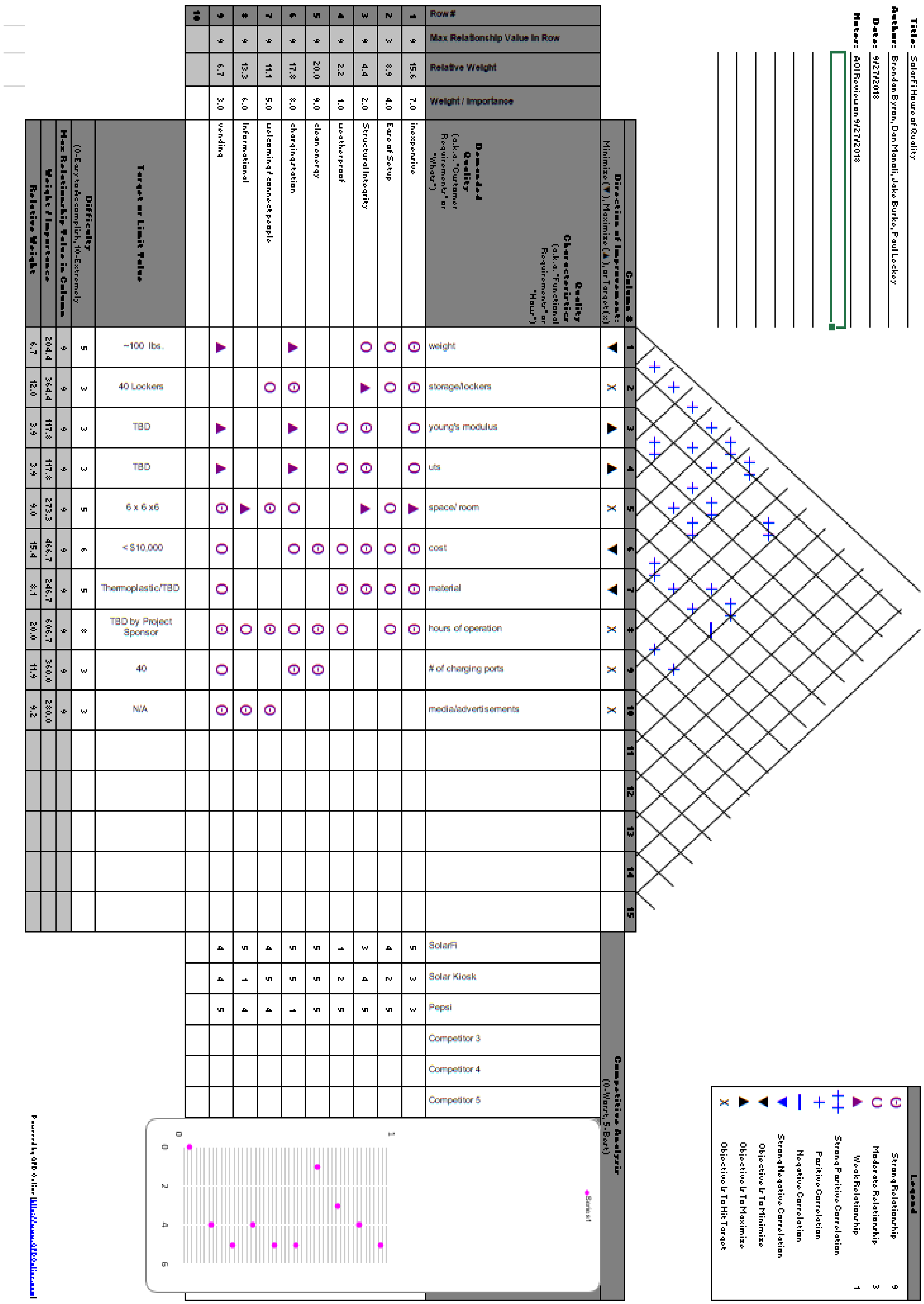


Figure 3: House of Quality

Design Selection and Solution

The large scope of this project made identifying the most important components of the design difficult. It was quickly realized that the initial idea of a fully-fledged solar powered kiosk was beyond the scope of this class. Instead a proof-of-concept prototype for HubWeek, detailed design and prototype of a stackable and automated locker, and a possible design concept for the full kiosk were provided to the project sponsor. Initially, Antonio provided some design concepts and proof-of-concept prototypes which the company had already fabricated and/or created using an image editor. Two of these initial concepts can be found in figures 4-6. Figure 4 is an image of the “lemonade stand” concept which the company used at a previous event. This rudimentary proof-of-concept aimed to exemplify the function of the services SolarFi aimed to deliver-- most notably solar-powered phone charging and empowering and educating communities. Figures 5 and 6, also provided by Antonio, show his vision of what the final kiosk may look like. Both of these kiosk designs were considered when designing the final CAD concepts to deliver to Antonio.

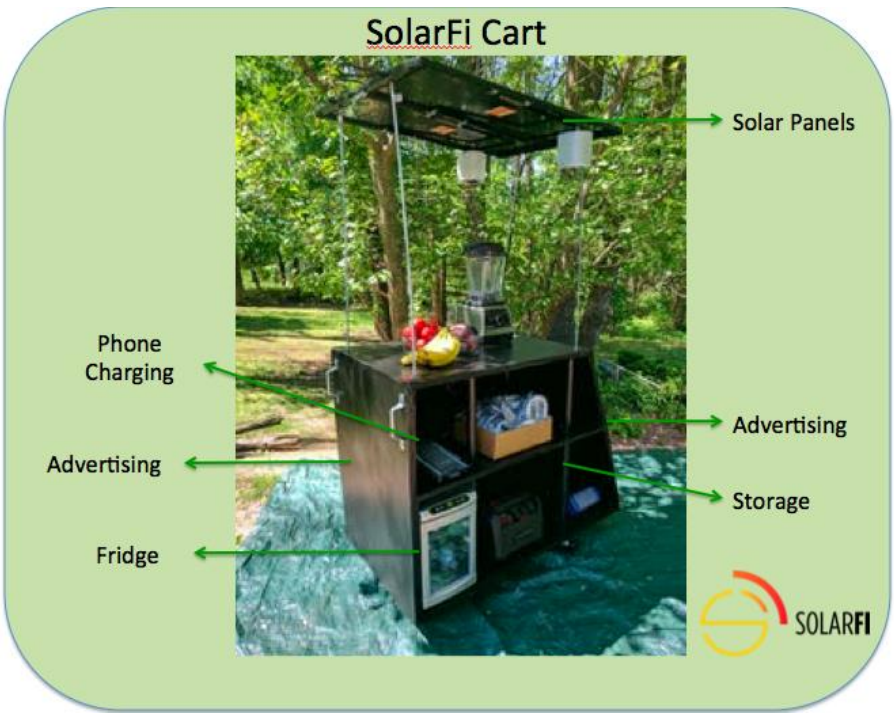


Figure 4: “Lemonade Stand” SolarFi Cart Proof-of-Concept

Figure 5: Initial Kiosk Concept 1

Figure 6: Initial Kiosk Concept 2

A major competitor of SolarFi is SolarKiosk. SolarKiosk is further along in development of their product, with some kiosks already implemented throughout the world. Some inspiration for the SolarFi kiosk design concepts draw from the SolarKiosk product. Antonio emphasized that while being a fundamentally similar product, SolarFi kiosks aim to improve communities by empowering and educating in addition to the phone-charging capability. He also required that the SolarFi kiosk be more easily shipped and assembled. An image of a SolarKiosk can be found in Figure 7.

Figure 7: SolarKiosk

Scope creep was a major concern in this project, considering that the final product SolarFi aims to deliver is a full solar powered kiosk. Instead of attempting to design and fabricate a structure of this magnitude, we agreed to design three major deliverables for our project sponsor: a locker with a mechanical locking system to house cell phones while they are charging, a proof-of-concept prototype for HubWeek (which we also attended), and a CAD model for a possible full kiosk design.

The locker design was modeled to be similar to the lockers purchased for the HubWeek prototype, but more optimally sized to fit different phone and hand sizes. The full kiosk concept is designed to incorporate the requirements laid out by the sponsor including flat pack ability, security, and the ability to be implemented on existing structures. These designs are discussed further in sections 10 and 12.

Detailed Design

This section is divided into three sections, each detailing the design of the three deliverable items which were provided to the project sponsor this semester: a stackable 3D printed locker, a "tech-wall" prototype for HubWeek, and a final kiosk design concept.

HubWeek Prototype:

In the early discussions with Antonio, he expressed that he would like our team to provide a proof-of-concept prototype for HubWeek, an event on October 13th. It was determined that a "tech wall" prototype would be best suited for this event given the purpose of the event (crowd-funding and marketing the brand/proof of concept) and the limited time available for fabrication. Antonio provided materials/products to utilize in our HubWeek prototype including a television, television mount, lockers, phone chargers, a solar panel, and advertisements (all of which can be found in the bill of materials in appendix A.) With this in mind, the tech wall design was first created in SolidWorks then fabricated using materials purchased at Home Depot. The initial design of the tech wall which was presented at HubWeek can be found in Figure 8.

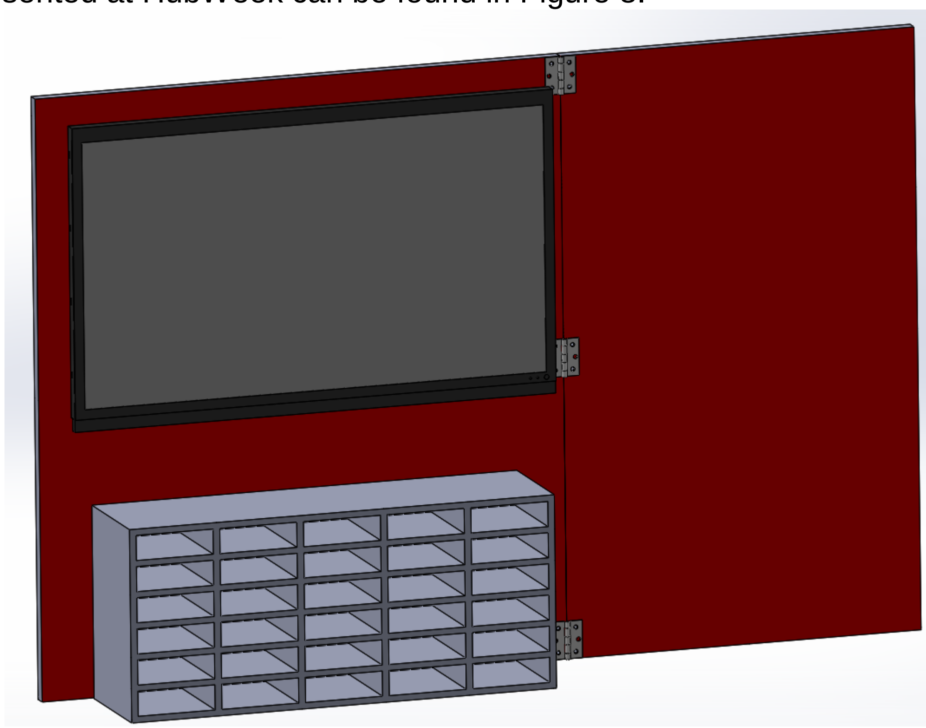


Figure 8: Initial HubWeek Tech Wall Design

Since time was a major factor in the fabrication of this design, the remaining materials were determined based on what was available at Home Depot (which can be found in the Bill of Materials.) The aim of this design is to exemplify the goals of SolarFi effectively. The sponsor emphasized that the purpose of the tech wall prototype was not to have a perfectly functioning product, but a proof-of-concept that would entice customers and those attending the event. The tech wall design had a vertical bend axis with the TV to be mounted on one side, and the lockers beneath it. This design left the entire other panel open to ad space, which the sponsor also wants to maximize. This initial design would give support to the wall with the lockers resting on the ground. The width of the two panels making up the wall were determined by the width of the TV to be mounted, which was specified to be 43", leaving a 29" space for the other side. This design could then be optimized with spacing and adjustments to solve any mechanical issues. The solar panel was outfitted above the top right fold using hinges and hydraulic door closers. Further discussion of this prototype, as well as figures of the final design presented at HubWeek, can be found in section 12: Final Design.

Locker:

The first locker design came from the lockers purchased for HubWeek, being 6.3”x2”x8.3” (Figure 9). This design worked for HubWeek, as the depth was large enough to fit any phone inside with additional room, and the same goes for the width of the locker. The problems for this locker design primarily had to do with its dimensions, as the depth and width were much more than needed to fit the phone, yet the height wasn’t sufficient for easy access. The lockers were also made out of metal, making them very heavy and cumbersome, and did not align with SolarFi’s goals for sustainability. The lockers were secured with a lock and key, rather than an electric locking system, thus they would not be able to integrate with the mobile payment system. Also, there was only one hole to thread all 30 charging cables through, which meant that every cord had to be painstakingly threaded from the single hole. Lastly, the lockers could not be individually mounted, but rather had to be mounted as the full 30 phone unit. Antonio expressed to us that he wanted the lockers to have the ability to be individually mounted, such that a kiosk franchise owner could customize their respective kiosk with any number of lockers. He also wanted the mounting system to be adaptable to other potential components in the future, such as larger lockers for tablet charging or package receptacles.

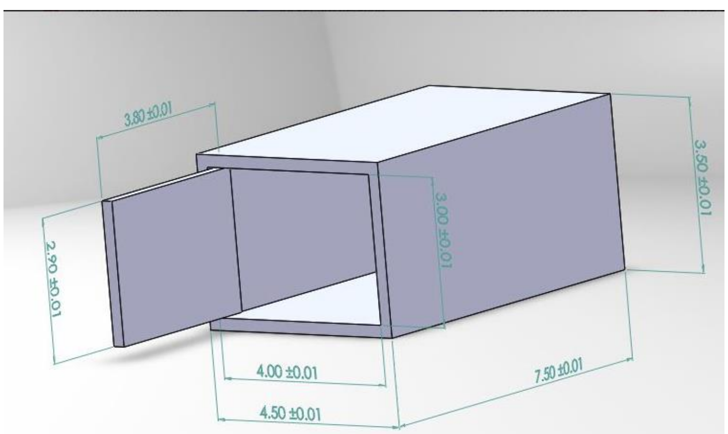


Figure 9: Locker design - 1st iteration

The second iteration of the locker design (Figure 10) changed the orientation of the phone while charging, such that it was now upside down, with the right side of the phone adjacent to the wall. This reduced the amount that the lockers stuck out of the wall quite a bit, while still being able to fit the majority of the phones on the market today and being very easily accessible. A four toothed mounting plate was designed to support the locker. However, the downwards opening door drew concerns about how fast the door would open upon unlocking, and the resulting force that the door would experience. There was also some concern about how people would perceive charging their phones upside down. Lastly, the number of support teeth per locker was deemed to be a bit extraneous for such a light load.

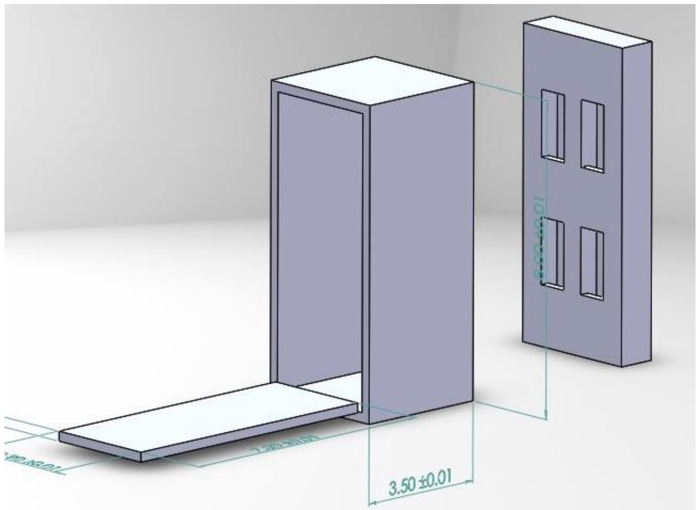


Figure 10: Locker design - 2nd iteration

The final design of the locker (Figure 11) solved the problems of the 2nd iteration design by rotating the locker 90 degrees. This allowed for the phone to lay flat, or on its side at an angle, a much more desirable orientation for the customer. A lip was added near the inner edges to provide a better interface between the door and locker, and a small knob was added to allow for easier opening and closing. A hole was drilled out of the back to thread the solenoid and charging cable through, and a small notch was placed in the right inner wall for the locking mechanism. A small platform was added to the door to support the solenoid, as the mount it came with did allow for proper orientation with the walls of the locker. PLA was chosen as the desired material, as its corn starch base makes it highly sustainable compared to similar plastics.

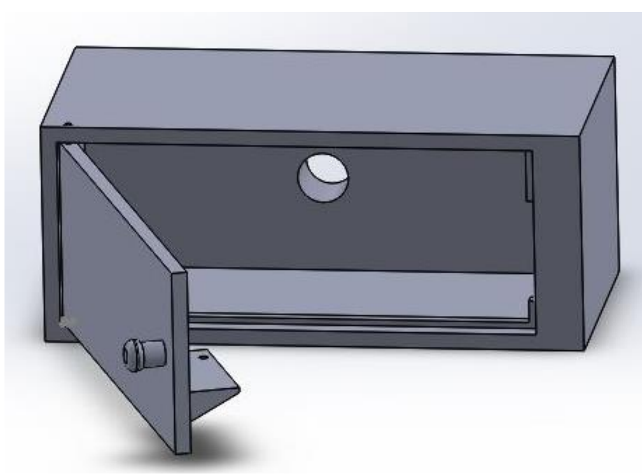


Figure 11: Final locker design

The new mounting system (Figure 12) was created to ease setup of lockers and the wall. The idea came from adjustable shelving, having two mount pegs on the locker itself, and then fitting holes on a mount to be fit to the tech wall. In the full scale kiosk, the mounts will act as a rail system, spanning the full height of the wall and allowing for maximum modularity for each kiosk.

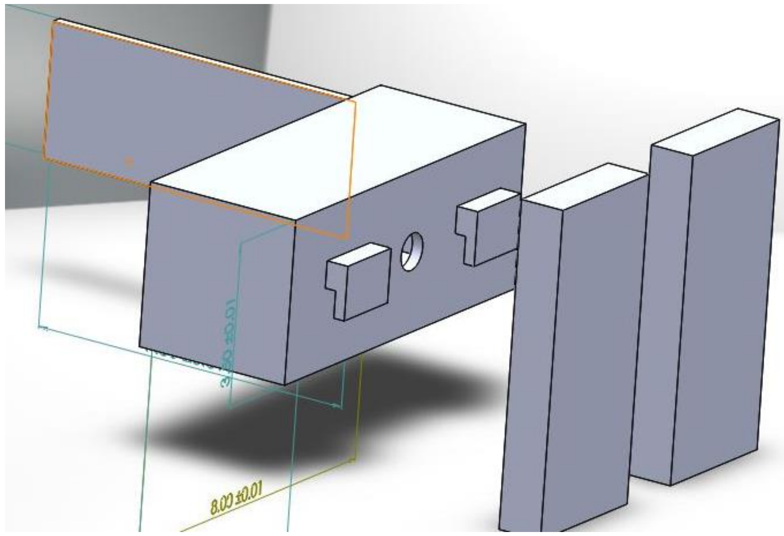


Figure 12: Final locker design with mounts

Kiosk:

The initial kiosk design idea came from our project sponsor, Antonio, and has since been optimized and changed to go along with his needs and the team's ideas. Utilizing some of the original design concepts which were proposed by Antonio and can be found in figures 5-6 in section 9, the kiosk design has since been updated to be flat packable and be outfitted on an existing structure such as a shipping container. An initial kiosk design, which was provided to Antonio per his request in early October for marketing purposes, can be found below in figure 13.

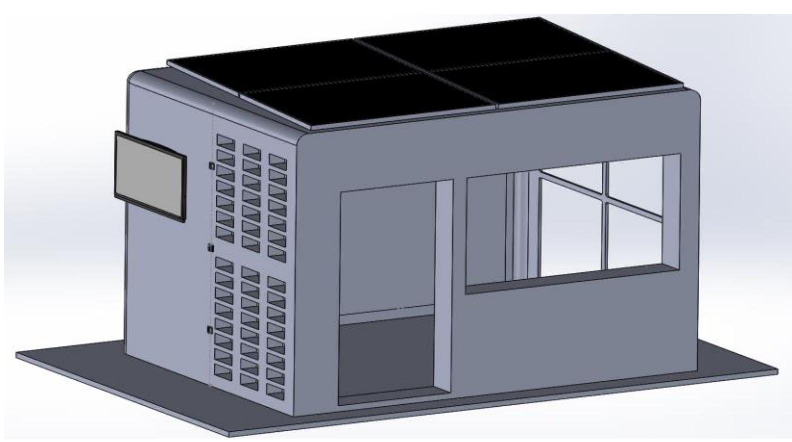


Figure 13: Initial Kiosk design

This first kiosk design was created to be similar to those presented by Antonio initially with the addition of concepts from the “tech wall” prototype. This kiosk design features a tech wall which is designed to be foldable along the vertical axis--something which Antonio had discussed for ease of assembly and shipment. This kiosk design measured 8’x11’x9’. After further discussion, it was determined that the final design should be 3D printed in many pieces to display flat-packability, utilize the locker design in a matrix, feature a tech-wall which could rotate along the vertical axis (for security purposes), and have walls which are similar to those found on common existing structures such as shipping containers. The second concept is similar to the first in that it is designed to be manned by a SolarFi employee and includes space for additional services (such as a refrigerator, necessary hardware for internet and backup power, etc.) but includes the improvements mentioned above. The ability to be flat packed is one of the major requirements set forth by the project sponsor, and by breaking the design into many parts which can be easily assembled/disassembled; the final kiosk design meets that requirement. The tech wall, which houses the television and lockers, is updated to be able to rotate along its vertical axis by bolts in the roof and base and could be outfitted on existing structures. This second and final iteration of this design can be found below in figure 23 and further discussed in section 12: final design. It is worth noting that this is merely a suggested design to be used for marketing and possible further kiosk design to be used by SolarFi and is not a finished product. The material, cost, stability, and feasibility of manufacturing and fabrication of this structure are beyond the scope of our project.

Detailed Engineering Analysis (Selected Design)

Static structural ANSYS analysis was performed on the phone charging locker to model the response of the locker to the weight of the phone and solenoid. For this analysis, a “worst-case” scenario of charging the heaviest phone on the market, the iPhone 8 plus (202 grams), was assumed. The team also chose a 147 gram solenoid to satisfy the sizing constraints of the locker door. The resulting 2 N force was applied at the base of locker, and a 1.5 N force was placed on the locker door-shelf (Figure 15). Compression-only supports were applied to the bottom, inside surface of the locker’s teeth to simulate the mount supports, and a remote displacement constraint was applied to the back surface of the locker to simulate the wall. A compression-only support was also applied to the bottom face of the locker pin. Although the prototype locker was printed with ABS, ideally the final product will be printed with PLA. Therefore, the analysis was done assuming PLA.

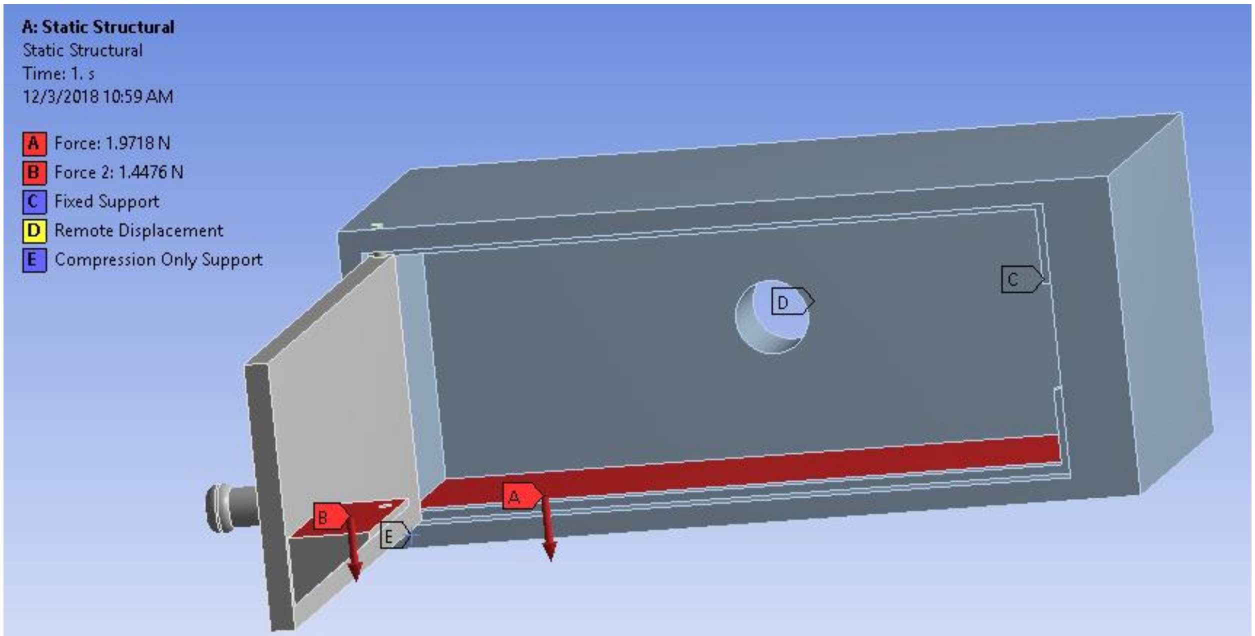


Figure 14: Application of fixed support and remote displacement boundary conditions

The goal of the analysis was to show that the locker would not yield under worst-case loading conditions, as well as not deform any noticeable amount (i.e. less than 1 mm). To show this, results of the static structural included Equivalent Stress, Max Shear Stress, and Total Deformation. Max equivalent and shear stresses were 0.0212 MPa and 0.0122 MPa (Figures 15), respectively, which were both significantly below the yield strength of PLA (54 MPa). Total deformation was also miniscule, as the maximum deformation experienced by the locker was 0.0041 mm (Figure 16).

ANSYS analysis was done on the locker to find the deformation and stresses on certain points of interest in order to verify the structural integrity of the materials chosen. These points of interest included the locker mounts and the pin for shear stress, and the bottom face of the locker and the end of the extended door for deformation. The small forces applied from the phone and solenoid show that these stresses and deformations are negligible, and that the thickness of the locker is suitable. ANSYS was performed on these lockers using the material properties of PLA (Polylactic Acid) for the locker body, and structural steel for the locker pin. With the forces expected on a day to day basis, being that of the phone and solenoid, the expected life will be infinite. The materials chosen, and others that have been discussed in terms of potential use (namely polyethylene and polypropylene) perform well in any weather conditions seen normally in Africa. These materials will not react when in contact with anything seen in the environment.

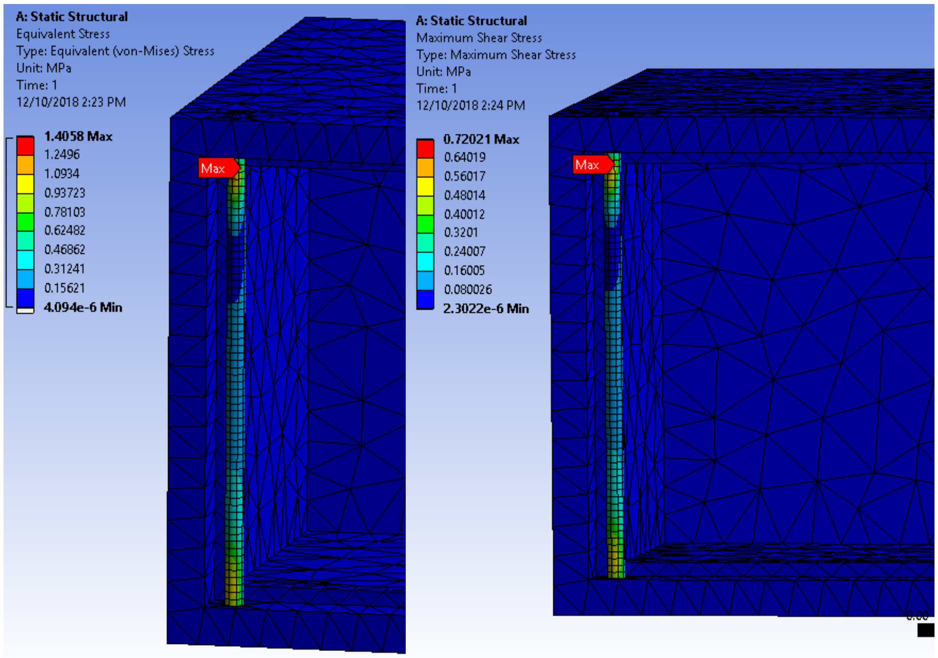


Figure 15: Equivalent stress and maximum shear stress results of locker analysis

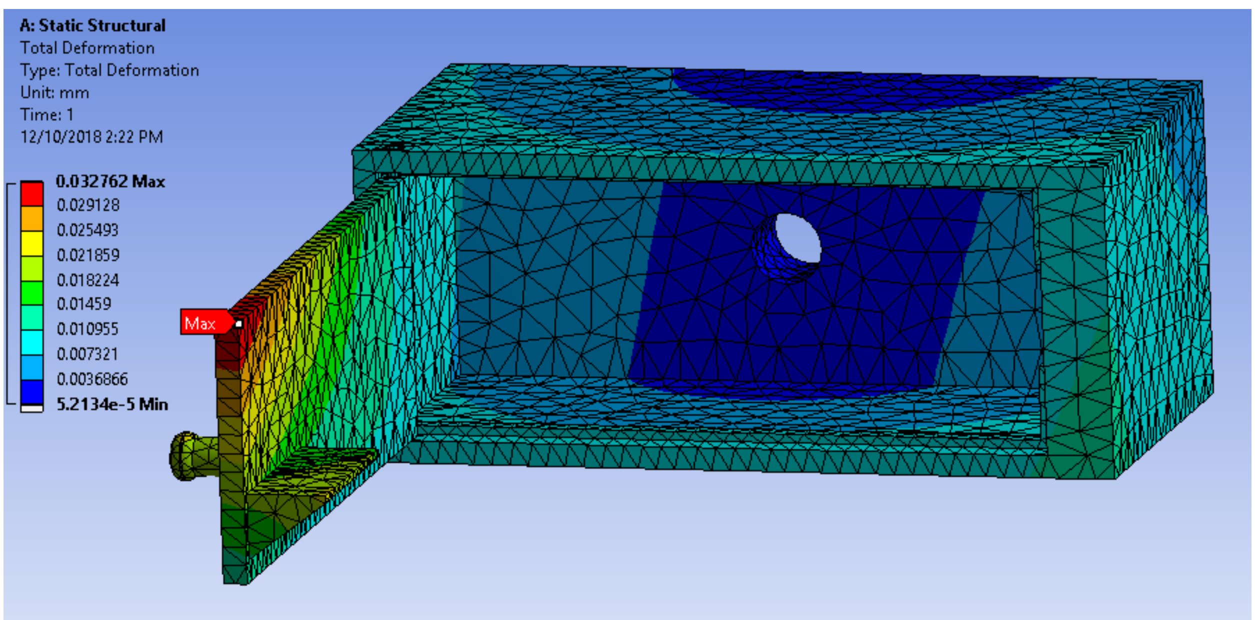


Figure 16: Total deformation results of locker analysis

The team then decided to find the stresses and deformations that an individual locker might experience under a maximum force using the properties of PLA. This maximum force analysis serves more as a justification of structural integrity measure than anything else, as there will be other safety measures employed for theft protection. For example, an individual locker will not be accessible, for the idea is to have all of the lockers within the tech wall grouped together. Also, the tech wall will be turned to the inside during off-hours when the kiosk is not being run by a worker. The following Figures (17-22) show the forces and supports, deformation, and stresses on the locker.

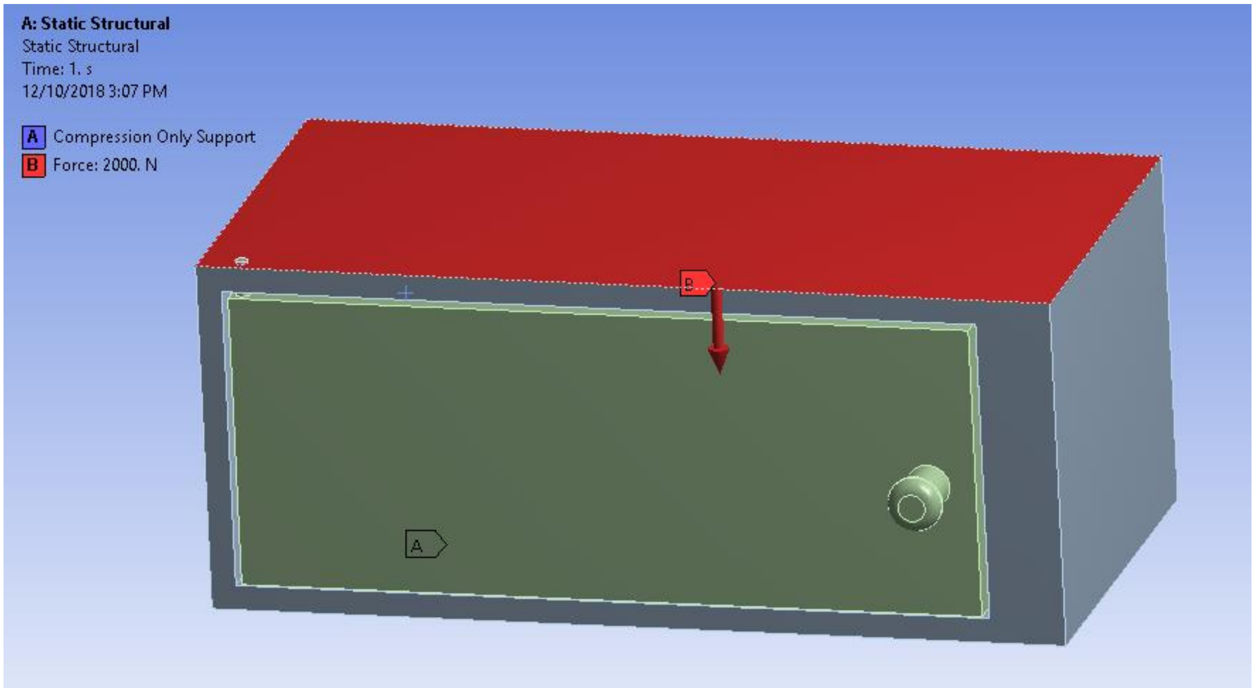


Figure 17: Application of worst case scenario force

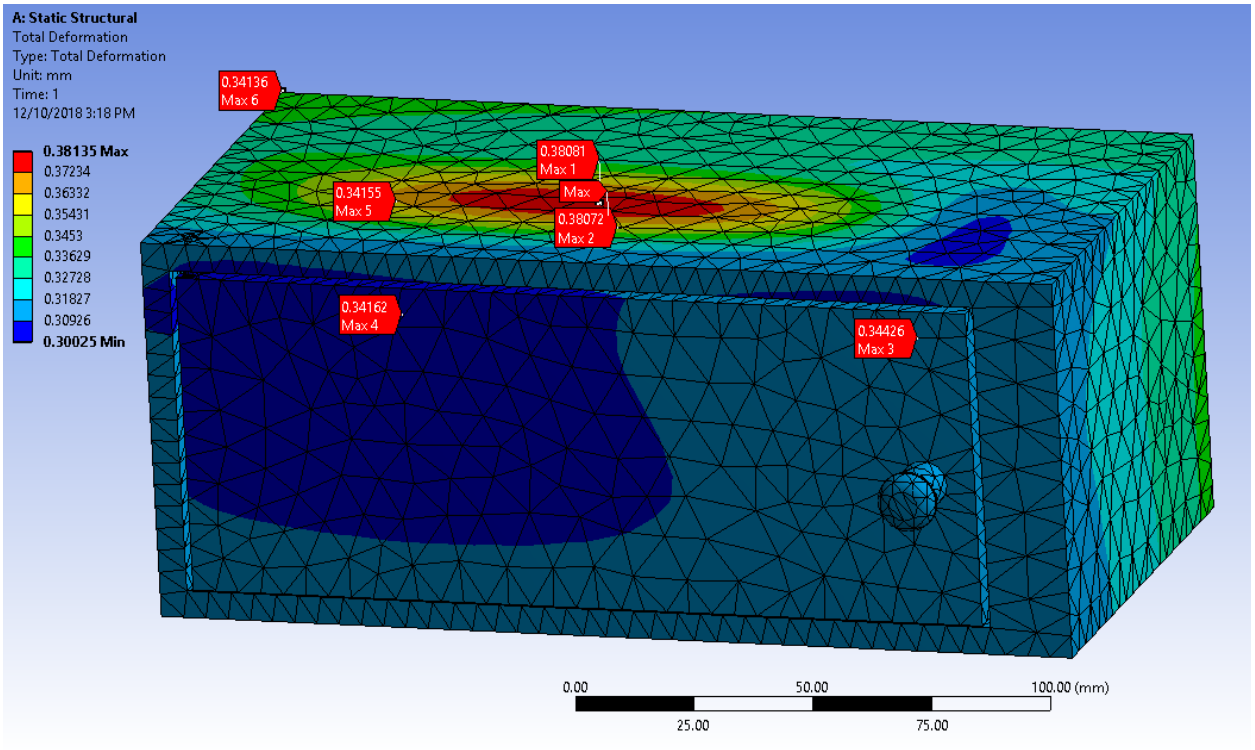


Figure 18: Total deformation results of locker analysis

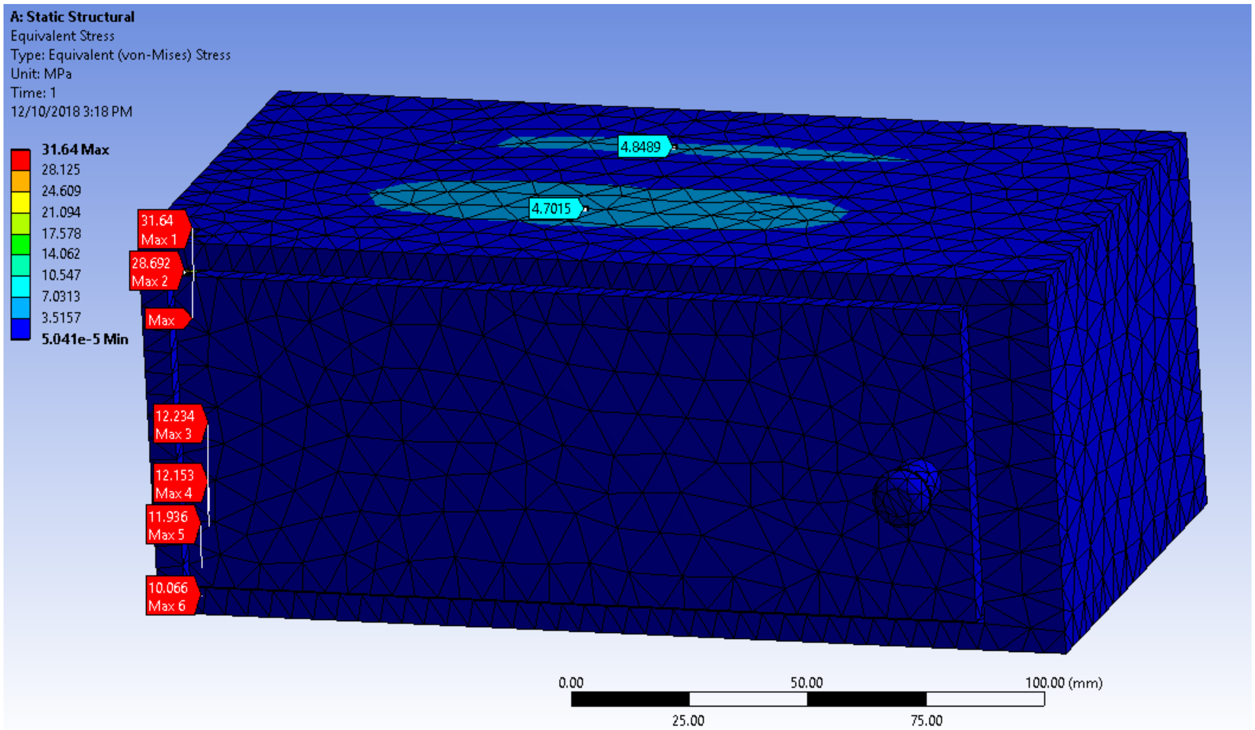


Figure 19: Equivalent stress results of locker analysis

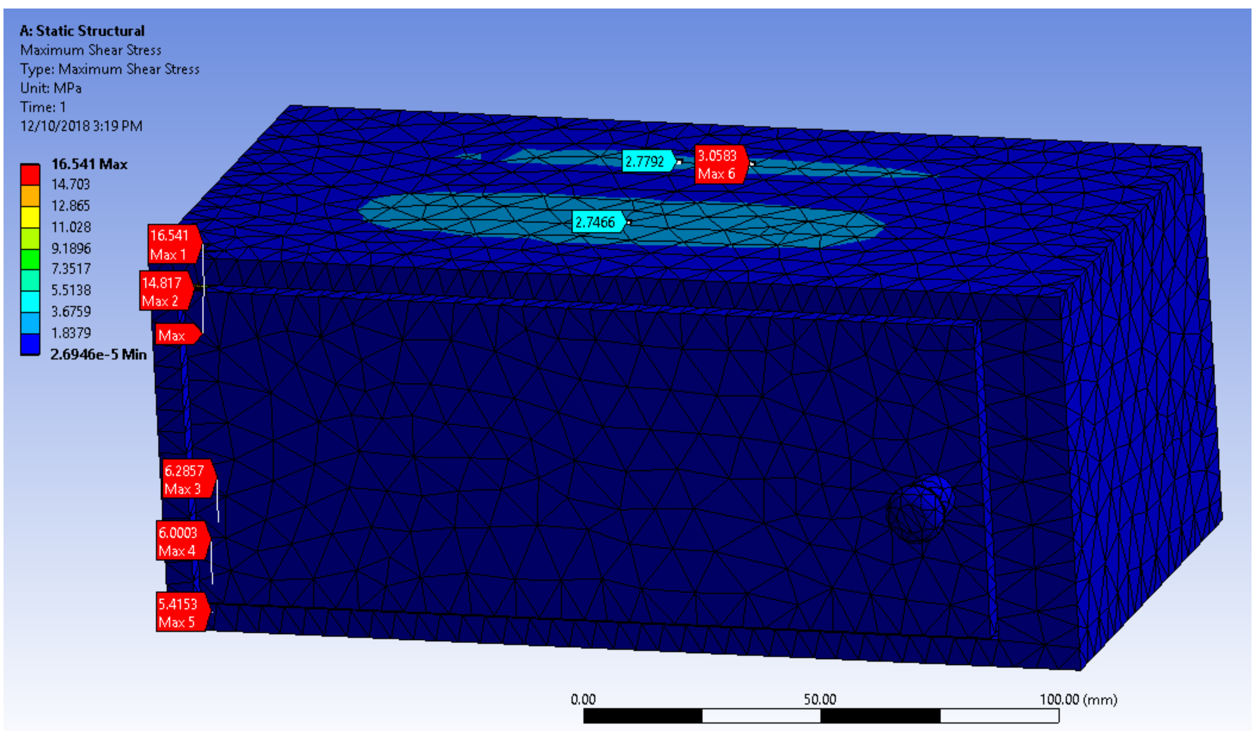


Figure 20: Maximum shear stress results of locker analysis

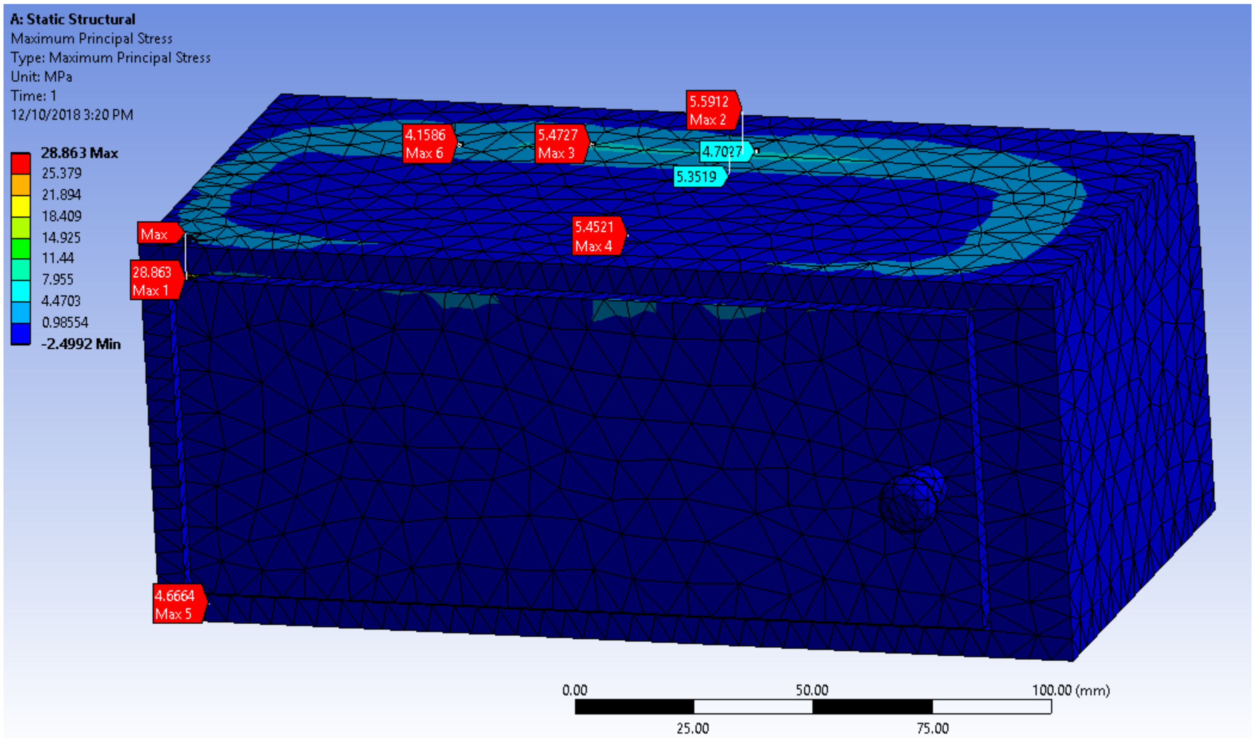


Figure 22: Maximum principal stress results of locker analysis

A 2000 N downward force was added to the top of a closed locker to simulate a maximum force theft protection measure. This force was chosen to show the force of 200 kg, being a significant force exerted by an individual. The resulting stresses and deformations showed that the locker would hold up when facing such a force. The max shear stress shown is at the pin with 31.64 MPa, and the yield strength of structural steel is 250 MPa. The stresses on the locker itself don't come close to yielding either, with a max of 5.59 MPa (Figure 23), and material yield strength of 54 MPa. The deflection under this maximum force was minimal as well, coming at 0.34 mm on the top of the locker where the load was placed, which remains below the target value for deflection of 1mm..

Even though Team 20 was told not to consider how the design of the electrical systems, a simple "power-in, power-out" analysis was conducted. The results showed that the kiosk would indeed be able to support the power demands of all of the components. Note that the analysis was done under the assumption that only one solenoid would be activated at a time. Also note that the full scale kiosk would have a battery for power storage, and an inverter for converting DC to AC current. It is worth mentioning that Team 20 fully understands that there will be inefficiencies within the electrical system. But again, as this was not considered to be part of our scope, we were directed to not do any further analysis than what is shown below.

Table 2: Basic power consumption analysis of full scale kiosk

Device	Quantity	Power (W)	Total Power (W)
Solar Panel	2	265	530
Solenoid	1	-7.8	-7.8
Phone charger	40	-5	-200
TV	1	-88	-88
Net Power			**234.2**

Final Design

Having passed all of the structural analysis, the final locker design was sent to be printed. The locker however was too large to be printed in the available printers, and thus had to be printed to 9/10ths scale. Despite this, the locker still could fit an iPhone 6S with a case. The solenoid was chosen based on recommendation from Glenn. It is powered by a 12 volt battery back. When off, it successfully prevents one from opening the door, and when activated, allows for one to easily open the door. The mounting system was also printed. This can be seen mounted to the tech wall later in the report (Figure 30).The production locker, door, and mounting system will be injection molded from PLA.

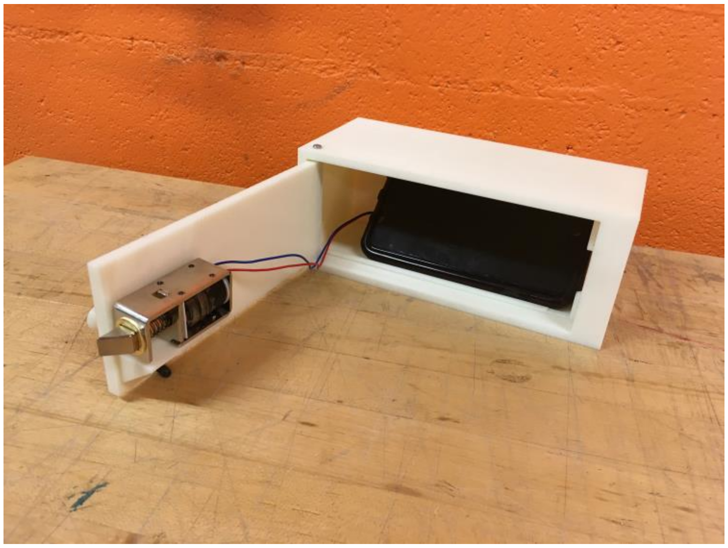


Figure 23: Final Locker Design Depicted with IPhone 6s (cased)

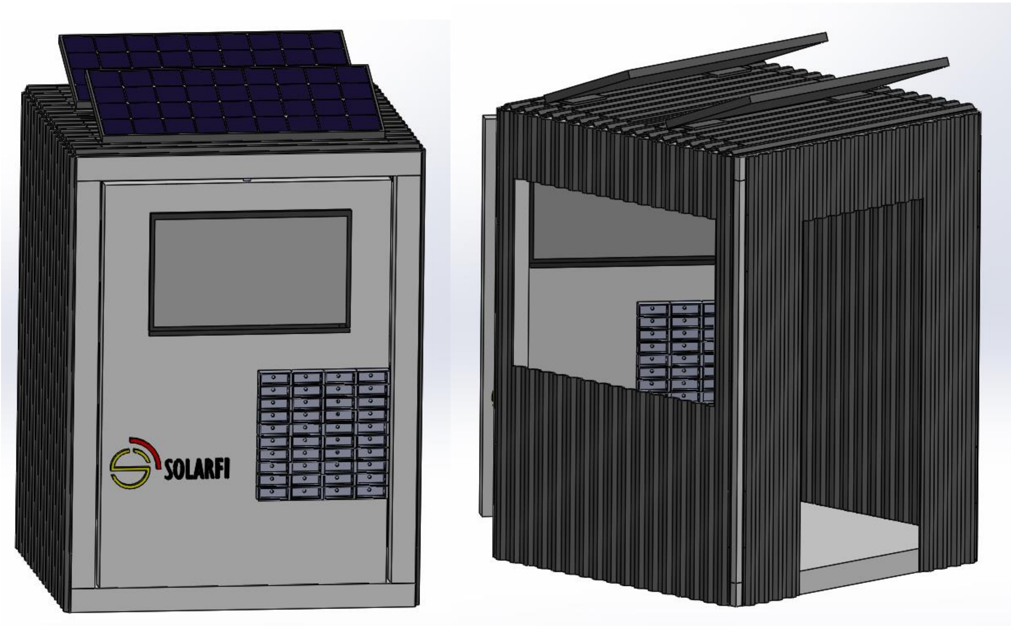


Figure 24: Final Kiosk mockup design - CAD

The above kiosk design incorporated all of the components required, including the TV, 40 phone charging lockers, rotating tech wall, solar panels, and the requested 6’x6’x8’ dimensions. The lockers depicted were given the same dimensions as the final locker design. The team desired to 3D print the design to 1:12 scale, however the model was slightly too big for the available printers. The design was thus scaled to 1:13, and printed in multiple parts, shown below.

Figure 25: Final Kiosk mockup design - Printed, disassembled

The wall thickness proved to be so thin that one wall actually cracked in the post-printing bath. The team will try to mend this before the final design presentation. It was also realized upon printing that there was no way to mount the walls. To fix this, new supports were designed with lips for the walls to slide into, see below.

Figure 26: Kiosk supports - lipped (top) vs. unlipped (bottom)

The final printed parts demonstrated ease of assembly, and a functional rotating tech wall. The corrugated walls warped slightly upon final assembly due to the addition of the lips on the supports, but were considered slight enough to not required redesign or reprinting.

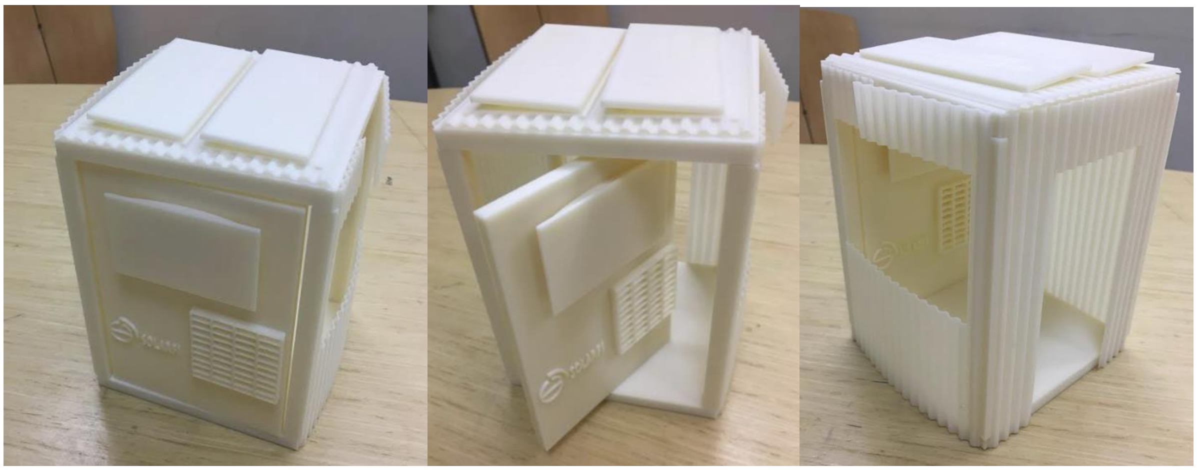


Figure 27: Final Kiosk mockup design - Printed, assembled

The HubWeek tech wall prototype was requested to be completed 10/13 so that it could be presented at the HubWeek conference. Therefore, major design components were limited to the wall itself and the adjustable solar panel mechanism. The wall had to demonstrate portability, as the final product would need to be easy to ship. Through the use of door hinges and barrel bolts, the 6’ wide, 6’ high (with solar panel) wall was reduced to 4’ x 3’ 7” when folded. Hydraulic door closers were utilized to make the solar panel adjustable, while being robust enough to support the panel. Supplier provided lockers were used as the conference was too early in the semester to have a functional locker design complete.

Figure 28: HubWeek tech wall - partially assembled

Figure 29: HubWeek tech wall - fully assembled at HubWeek

After HubWeek, it was decided to reuse and modify the HubWeek tech wall, rather than create a new one for the final presentation. To accommodate the custom locker, one of the ads was removed, freeing up 2 square feet of space. The printed mounts were fastened to the tech wall with nuts and bolts. A hole was drilled through through the wall to accommodate the solenoid wires and charging cable. Unfortunately, Glenn Butler was not able to provide the requested mobile payment software, so the final prototype was simply locked and unlocked by a switch.

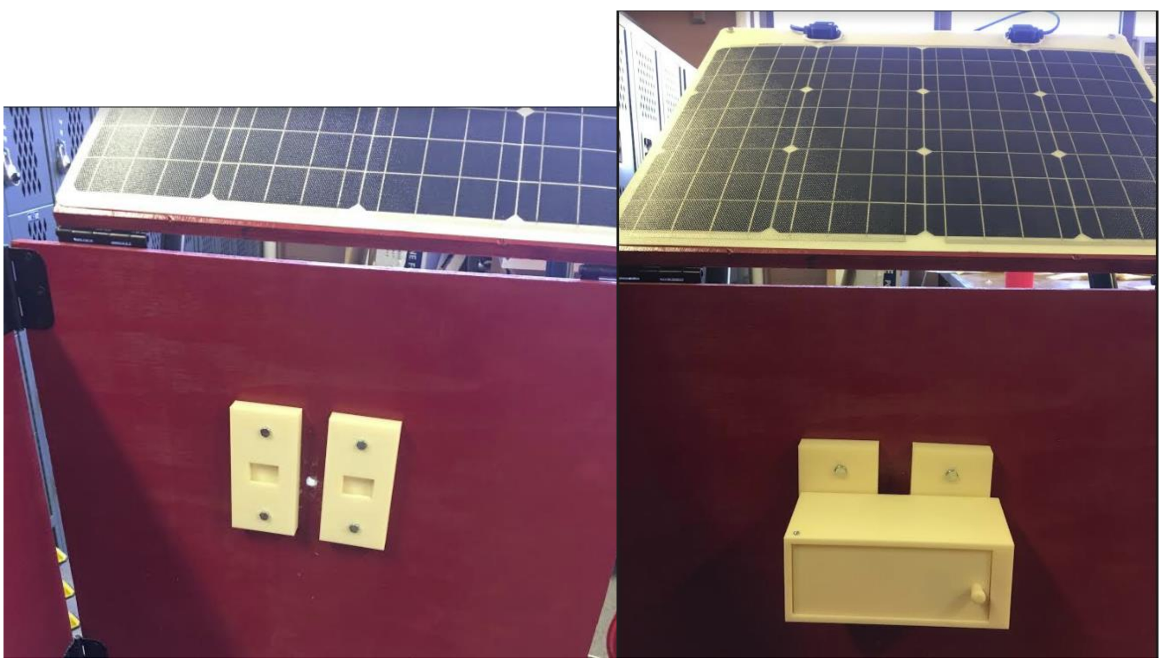


Figure 30: Final tech wall - locker mounted to wall

Design Evaluation

Table 3: Evaluation Metrics and Results

	Target	**Acceptable**	**Actual**
Kiosk	1:12 scale	1:18 scale’	1:13
	Rotating Tech Wall	Fixed Tech Wall	Rotating Tech Wall
Tech Wall	Support 40 Lockers	Support 30 Lockers	30 sponsor Lockers 1 custom locker
	Adjustable Solar Panel Angle	Fixed Solar Panel Angle	Adjustable Solar Panel Angle between 0° and 30°
Phone Charging Locker	House all sized cell phones	House all non-XL cell phones	2.73’’ x 7.5’’ x 3” fits all non-XL phones
	Electronic locking mechanism with mobile payment system	Electronic Locking mechanism	Electronic Solenoid Locking Mechanism
	Biodegradable and resilient material	Sustainable and Resilient Material	PLA: sustainable and resilient

There were three aspects of the project that required evaluation; the scale model of the kiosk, the tech wall and the phone charging lockers. The tech wall had to be able to support 30 lockers, a TV, and our 3D printed locker. The locker needs to be able to support cell phone while also keeping them safe while they charge.

The scale model was targeted to be a 1/12th scale model. However due to size restrictions on the available 3D printers, it was made to be a 1/13th scale. The tech wall was also able to rotate about its center axis.

The tech wall needed to be able to support 30 lockers, a 43” LED TV, and the solar panel used. The angle at which the solar panel was standing also needed to be adjustable. These two metrics were evaluated by attached all the necessary equipment and standing the wall upright. The wall was able to stand successfully. The solar panel was attached to two storm door closers such that the angle the panel is resting can be adjusted with relative ease from 0° to 45°.

The 3D printed lock needed to be able to house a cell phone, as well as support the weight of the solenoid that was used. Initially, the design for the locker was designed to fit all standard cell phones. However, the model had to be scaled to accommodate the 3D printers that were available.

Discussion

The original sizing parameters for the locker were based off of the largest phones on the market, without needing to house a tablet. The ideal inside parameters were a 3 inch height, a 3 inch depth, and a 7 inch width with a ¼ inch thickness throughout. The final design parameters of the locker ended up being 2.73 inch width, a 7.5 inch width, a 3 inch height, and a varying thickness. The thickness of the final design is ¼ inches for all of the locker shell except for the right side, being ⅗ inches to house the solenoid plunger. The final specifications vary from the target due to a change in scope. Originally, the idea was to make the locker large enough to house any phone size, but as the project progressed the sponsor wanted to make the locker smaller with an idea to eventually incorporate larger lockers intended for the biggest phones and tablets on market. The deformation and stresses experiences on a daily basis ended up being negligible with 0.03 mm deflection, and 1.4 MPa on the door pin. These values are well under the allowable stresses of the materials used (Yield Strength for PLA is 54 MPa, and 250 MPa for steel), and the deformation will not cause any permanent deflection. The team's target value for deformation was 1mm, and the material yield strength for stress. The maximum force shown on a single locker made out of PLA was chosen to be 2000 N. This maximum force to break gave values under the target numbers as well, with a deformation of 0.38 mm, and a maximum stress on the steel pin and PLA locker body of 31.64 MPa and 5.6 MPa, respectively. The main lesson learned is that it is very easy to over-manufacture with a simple design. With all of the stresses and deformations hitting well below the allowable marks, the design proved to have more material than necessary for its application. However, the design and fabrication require a certain amount of material in order to complete the intended locking and holding purpose and mold.

Conclusions and Recommendations

By the end of the semester, team 20 had completed all of the goals we had set-out to achieve to the best of our ability.

The tech wall met all of the specifications for HubWeek, despite the short amount time allotted to complete. It was also able to support the custom locker prototype for the design competition. Had we had more time, we would've also designed a foldable support structure for the wall, so that it could be implemented into an existing structure.

The locker, despite size restrictions in regards to 3D printing capabilities, demonstrated the ability to hold all non-XL cell phones without yielding or deforming. The mounting system proved to be simple and effective, and the solenoid locking mechanism performed as hoped for. The one negative for the locker was the fact that we never heard back from Glenn regarding the mobile payment system. However, as the solenoid was handpicked by Glenn, we fully expect this design to be easily implemented with the payment system once complete.

The kiosk, while not printed to the exact scale we had wanted, still displayed a feasible concept for SolarFi to scale up. The components were easy to assemble and the rotating tech wall was effectively demonstrated. Ideally, a full kiosk prototype would've been constructed, but the large size of the kiosk, combined with Team 20's lack of construction knowledge, simply made this idea impossible.

The SolarFi kiosk is still very early in the development stages, and will require the efforts of multiple engineering disciplines to see to completion. Team 20 suggests that SolarFi hire more electrical and computer engineers to assist Glenn in the implementation of the solar electrical systems, and in further developing the mobile payment software. SolarFi should also look to hire civil engineers to scale the kiosk model and design a suitable foundation, and industrial engineers for human factors analysis.

References

"Find Your Power Inverters." *Wholesale Solar Blog*, www.wholesalesolar.com/power-inverters.

"PLA vs ABS 3D Printer Filament." *ProMolt 3D*, promolt3d.com/blogs/filament-info/82919619-pla-vs-abs-3d-printer-filament.

"SOLARKIOSK ." *SOLARKIOSK*, www.solarkiosk.eu/.

APPENDIX A: Bill of materials and cost analysis

Prototype Bill Of Materials

Quantity	Description	Price (Include shipping)	Vendor Info. (website or phone #)
1	23/32 4X8 Radiata Pine Plywood	37.98	Home Depot
4	2.5” Barrel Bolt Black	2.97	Home Depot
16	12 in W Large Packet Pal	16	Home Depot
1	Sharp 43” class 1080p LED TV-LC-43Q3000U	229	Antonio through Sam’s club
1	28-55” TV Wall Mount	50.00	Antonio through Sam’s Club
5	Door Hinge	3.28	Home Depot
2	2X4-96” Burrill Premium Fir Stud	3.90	Home Depot
3	Painters Touch 2X Gloss Colonial Red	11.94	Home Depot
2	Medium Duty Hydraulic Door Closer	19.98	Antonio through Home Depot
1	30-slot cell phone storage station	454.99	Antonio through Amazon
1	Renogy 50-watt 12 Volt Flexible Solar Panel	119.99	Antonio through Amazon
10	6 ft micro USB charging cables	59.94	Antonio through Amazon
10	6 ft iPhone charging cables	119.94	Antonio through Amazon
10	6 ft USB-C charging cables	29.99	Antonio through Amazon

3	Plugable 10-Port USB 3.0 SuperSpeed Hub	160.77	Antonio through Amazon
2	Command Picture Hanging Strips, White, Medium, 3 Sets of Strips/Pack	8.40	Antonio through Home Depot
2	Advertisements	N/A	Solar-Fi
2	Lock-style Solenoid - 12VDC	39.67	Adafruit.com
1	3D Printed Locker	127.77	UMass Amherst

Prototype Budget

Quantity	**Description**	**Price (Include shipping)**
1	23/32 4X8 Radiata Pine Plywood	37.98
4	2.5” Barrel Bolt Black	2.97
16	12 in W Large Packet Pal	16
1	Sharp 43” class 1080p LED TV-LC-43Q3000U	229
1	28-55” TV Wall Mount	50.00
5	Door Hinge	3.28
2	2X4-96” Burrill Premium Fir Stud	3.90
3	Painters Touch 2X Gloss Colonial Red	11.94
2	Medium Duty Hydraulic Door Closer	19.98
1	30-slot cell phone storage station	454.99

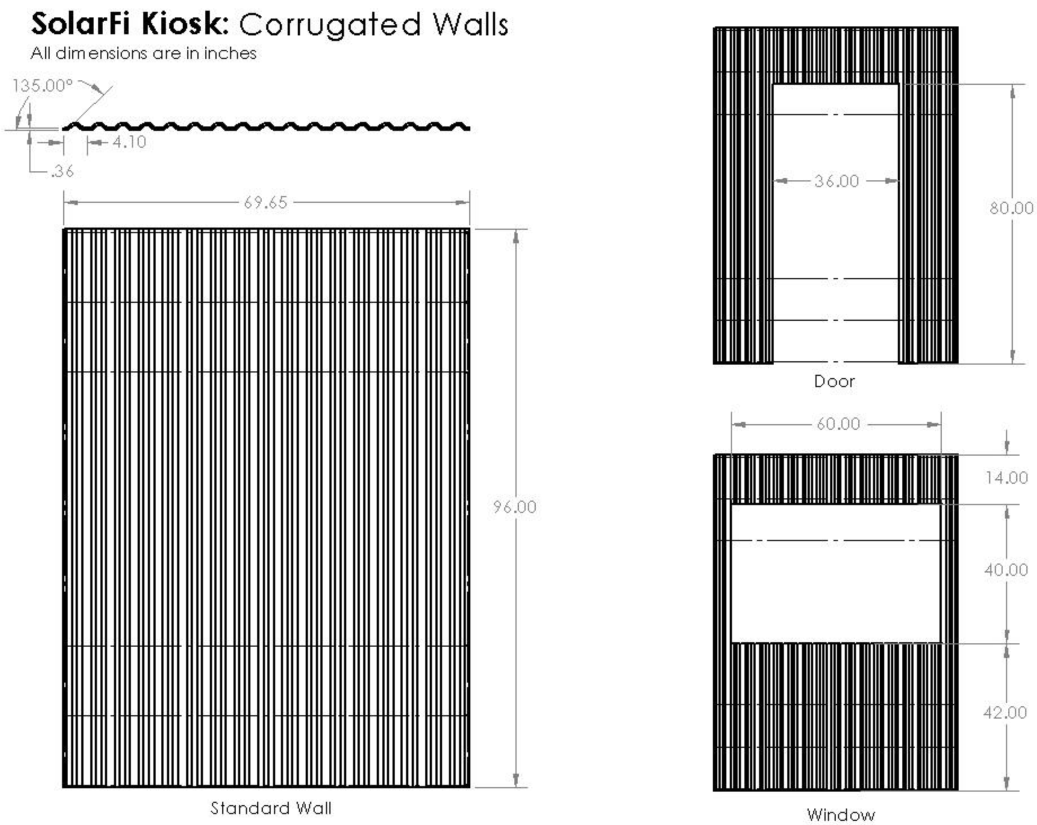
1	Renogy 50-watt 12 Volt Flexible Solar Panel	119.99
10	6 ft micro USB charging cables	59.94
10	6 ft iPhone charging cables	119.94
10	6 ft USB-C charging cables	29.99
3	Plugable 10-Port USB 3.0 SuperSpeed Hub	160.77
2	Command Picture Hanging Strips, White, Medium, 3 Sets of Strips/Pack	8.40
2	Advertisements	N/A
1	Lock-style solenoid - 12VDC	14.95
1	3D Printed Locker	127.77
Total Cost		$ 1329.07

Estimated Production Kiosk Budget

Quantity	Description	Price ($)
8	4 in. x 4 in. x 8 ft. Untreated Kiln-Dried Douglas Fir Dimensional Lumber	89.2
1	265-Watt Polycrystalline Solar Panel (4-Pack)	1379.34
10	6 ft micro USB charging cables	59.94
20	6 ft iPhone charging cables	239.88
10	6 ft USB-C charging cables	29.99

3	Plugable 10-Port USB 3.0 SuperSpeed Hub	160.77
40	Lock-style Solenoid 12VDC	598
1	Sharp 43” class 1080p LED TV-LC-43Q3000U	229
1	28-55” TV Wall Mount	50
15	8"x24' Galvanized Steel Corrugated Roof Panel	257.55
1	Quikrete 80lb Concrete mix	4.7
1	Magnum Energy MicroGT 500 ME-GT500 500W Micro Inverter	285
1	UPG UB-4D AGM Battery	200
40	3D Printed Lockers	5111.11
Total		$8694.48

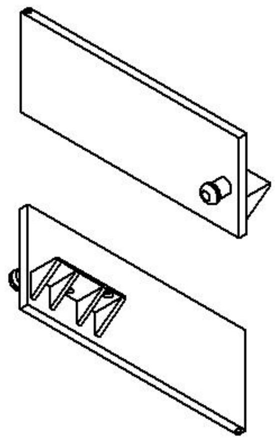
APPENDIX B: Engineering Drawings

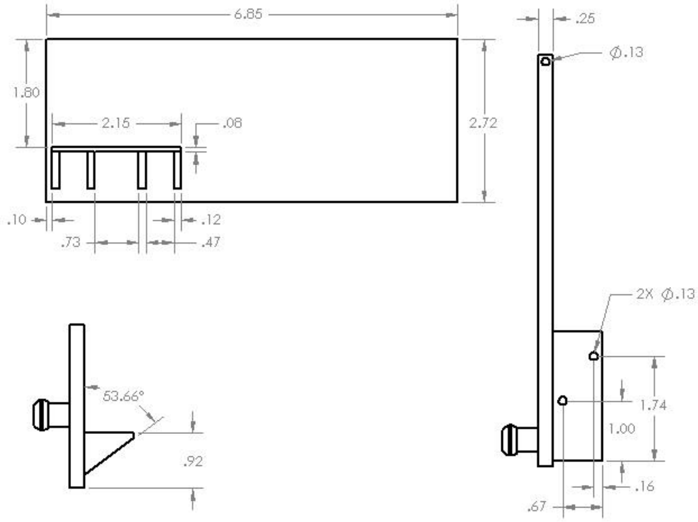


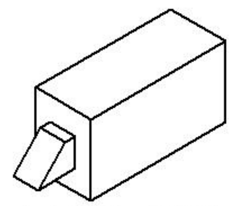
SolarFi Kiosk: Locker Door

All dimensions are in inches

- Dimensions made to be fitted on locker model with appropriate tolerances and 3D printability
- Shelf on door created to house lock-style solenoid 12VDC with appropriate M3 hardware
- Door attached by pin





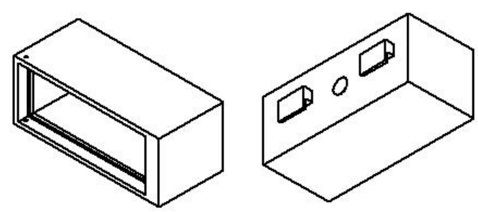


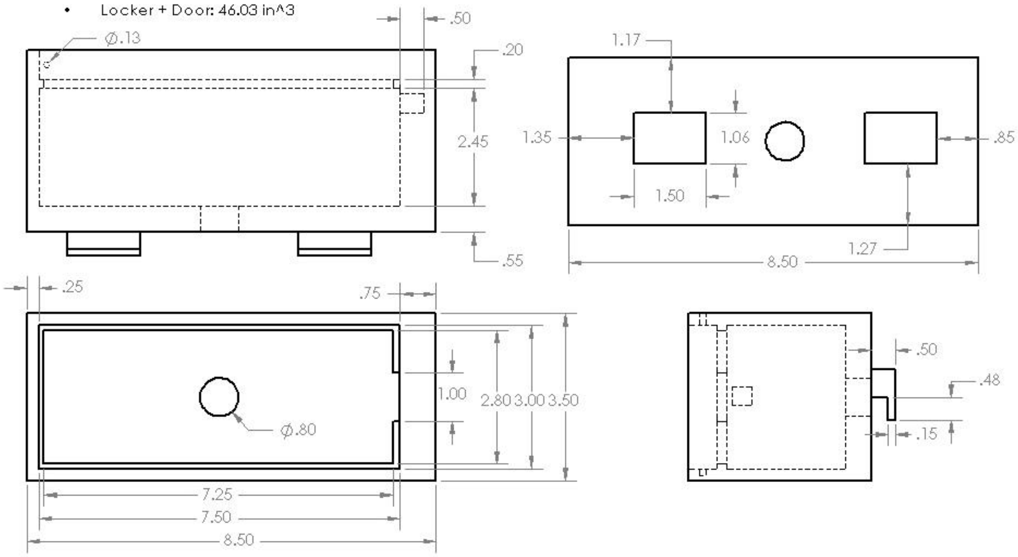
Lock-style Solenoid 12VDC

SolarFi Kiosk: Locker

All dimensions are in inches

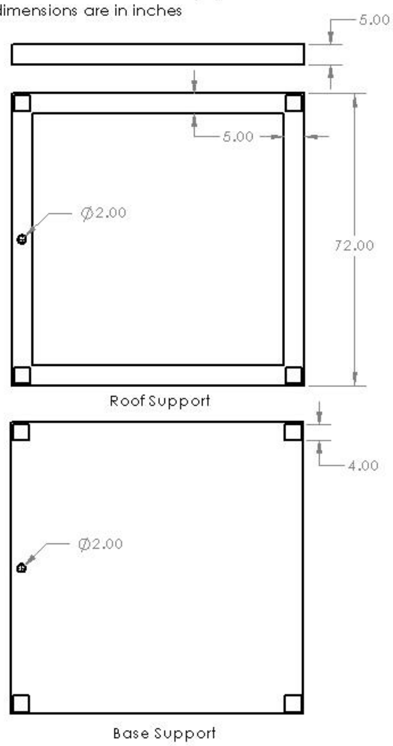
- Dimensions optimized for all non-XL sized phones and 3D printability
- Suitable to house electronic payment/opening system
- Door attached by pin
- Material: PLA
- Volume:
  - Locker: 41.06 in^3
  - Locker + Door: 46.03 in^3

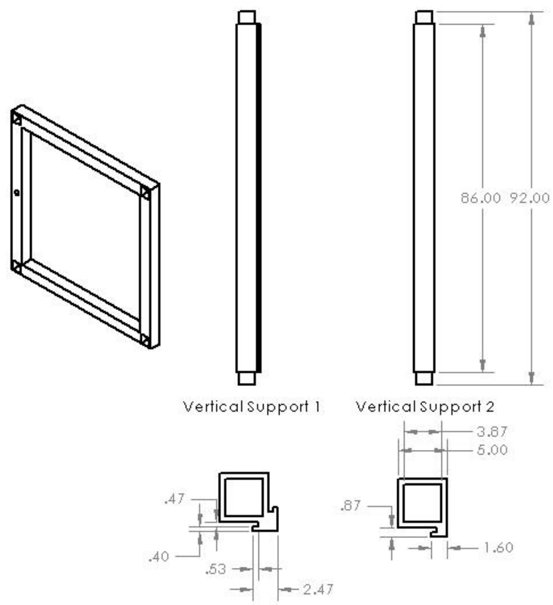




SolarFi Kiosk: Supports

All dimensions are in inches





Vertical Supports include flanges which support and house the corrugated walls for stability while still providing ease of assembly

SolarFi Kiosk: Tech Wall

All dimensions are in inches

- Includes matrix of 40 phone-charging lockers
- Includes 48" tv with mount
- Bolt along vertical axis so tech wall can be turned around for security purposes
- Space open for SolarFi logo and other advertisements