Solar XO Laptop

APSC-100 Project Proposal

By

Group Number: 213 E

Eric Ross
Adam Hall
Alex Pierratos
Alexander Monahan

REPORT PREPARED FOR:

Faculty Sponsor:	Dr. Pearce
Project Manager:	Nabeil Alazzam
Community Sponsor:	Queen’s Applied Sustainability Research Group
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Executive Summary

The "XO Laptop," from the "One Laptop Per Child Foundation" is an inexpensive laptop intended to help children in developing countries express themselves for educational purposes. Unfortunately, the average household in these developing countries do not have access to electricity to charge these laptops . In order to allow these children to bring these laptops home to be used, a solar panel laptop charger must be designed.

Because the main consumers of the laptop charger are children, the design for the charger must be durable, practical and easy to use. In addition, because this design will be released to developing countries, it must be inexpensive and affordable. The final design must meet all of these requirements and must also be fairly simple to build.

The final design resembles an 'L-shaped' book and encompasses all necessary design criteria. When the charger is closed, the solar panels are protected from all sides and stays closed with Velcro. When opened, the user is intended to prop the design up against an object so an optimal efficiency angle is met. The design includes a 'shadow stick' holder that allows one to find the optimal angle of power generation. The design will use a total of six solar panels that will output 12 watts of power at maximum efficiency. The prototype lies within the $80 budget given while the design when mass produced may be made for under $30.

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1.0 Introduction

The One Laptop Per Child program opens up educational opportunities for children in undeveloped countries by equipping them with an inexpensive, reliable, and efficient XO laptop [5]. These laptops are filled with amazing software that is able to grow with the child and includes advanced hardware such as mesh networking capabilities and flash memory [5]. However, these laptops cannot function without electricity and therefore must incorporate a solar panel as an additional power source.

Solar panels are capable of converting energy into power by utilizing impure crystalline-silicone called negative type and positive type. By putting these two separate pieces of negative (N) and positive (P) silicone in contact with one another an electric field forms. This makes the N side electrons rush over to the P side to fill the empty holes, but at the junction a barrier is formed. As a result, it becomes harder for N electrons to cross over to the P side. Once equilibrium is reached, an electric field acts as a diode, allowing P electrons to flow to the N side, but not the other way around. When energy, in the form of photons of light, hits a solar panel the photoelectric effect takes place and electron-hole pairs are freed. This disrupts the electric field equilibrium and N electrons do work as they flow to the P side. A current is created by this flow while the electric field causes a voltage resulting in power [7].

The designs for the solar panel range from a simple yet expensive notebook to a more complicated yet affordable book style. The end result is a mixture of different concepts, which reduces rapid prototyping material cost, fits within the budget and is able to supply at least 10 watts of power to charge the XO Laptop.

2.0 Problem Formulation

The XO laptop requires an off-grid electricity source. The project objective is to outfit one of these laptops with a solar panel charger that can provide the electricity required for under $80.

The design must possess several qualities. It must be durable as to ensure that it can be used for a long time and must protect the solar panels and wiring when dropped or impacted. Second, it must be lightweight and portable because some children travel long distances back and forth to school. Third, the design should be able to be built in any rapid prototyping machine. These machines are able to build the plastic casing for the charger very easily and locally for just the cost of the plastic. Finally, it must be inexpensive as to not increase the total cost of the XO laptop by a significant amount.

Because the XO laptops require approximately 10 watts of power to be charged, the solar panels used must have a maximum output of at least 10 watts. One must also consider ways into ensure that when the charger is being used, it must be able to be propped at the optimal angle. Additionally, it would be convenient to allow the children using this charger to find this optimal angle in a very simple manner.

3.0 Design Considerations

Table 1 summarizes what features are required for an effective design. The three categories (cost, practicality and durability) are rated out of ten, and weighted to help determine which design is most practical. The overall rating will be found by multiplying the score of the design by the weight factor and then adding all the weighted scores together.

Table 1: Design Criteria

Criteria	Specifications
Cost (60% weight factor)	• Meets the $80.00 budget • Can be rapidly prototyped in a cost effective manner
Practicality (20% weight factor)	• Should be lightweight and portable • Must be able to be built by any rapid prototyping machine • Has to charge the laptop efficiently • Able to be set up easily • Can optimize angle of sunlight
Durability (20% weight factor)	• Must withstand abuse • Waterproof • All wires should be protected

3.1 Design One: Cover

The first design incorporates a cover for protection and a stand to maintain optimal efficiency (Figure 1.1).

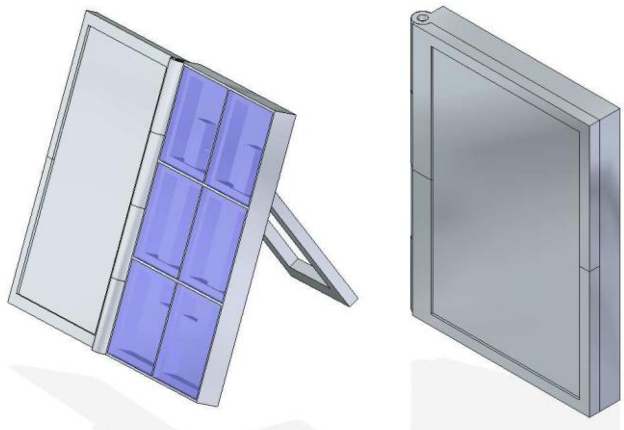


Figure 1.1: Design One

The main criterion behind this design is simplicity. It involves a base that will hold six solar panels, a cover to protect the solar panels and a stand that will allow the solar panel to be tilted (Figure 1.2). The base is trimmed down so that minimal material is required. It will be divided into two halves, so that it can be produced in a rapid prototyping machine. One half will have a region of slightly smaller dimensions so it can be inserted into the other half. Two screws and silicon sealant will join the halves of the base.

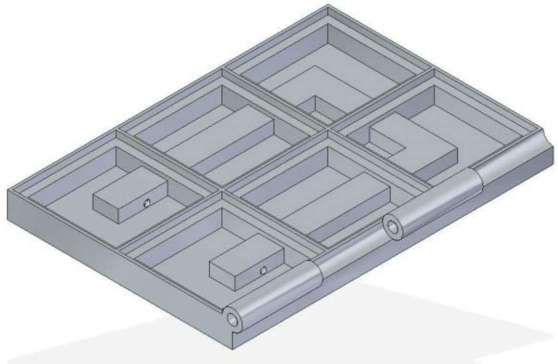


Figure 1.2 : Design One Base

A protective foam layer will be placed beneath each solar panel to prevent the solar panels from breaking. Each solar panel will then be placed in its proper position. The six solar panels will produce twelve watts of power and will be connected in a parallel fashion to ensure cloud cover will have a minimal effect. If one panel is covered by a shadow, the other panels will continue to perform [4]. The cover is made from a frame, which will be produced by the rapid prototyper in two halves, with a plastic sheet that will be inserted into this frame (Figure 1.3).

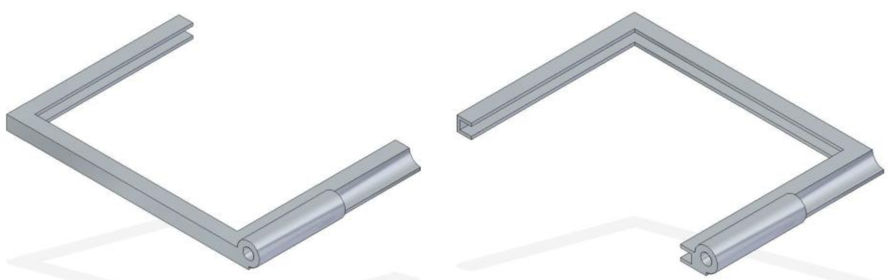


Figure 1.3 : Design One Cover

Sheet plastic is much more inexpensive than rapid prototyping and will reduce the overall cost of the design [3]. The stand is attached to the back of the base in the area allotted for it (Figure 1.4) .

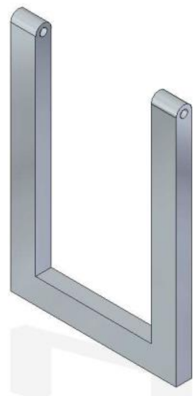


Figure 1.4 : Design One Fixed Stand

An ultraviolet protected acrylic sheet will be placed over the solar panels to increase their lifetime. This protects them from weathering such as scratches and water damage. A silicon sealant will be used to affix the acrylic sheet.

The rating for cost is 6 out of 10. This is because this design replaces parts that could be rapidly prototyped with cheaper options. The rating for practicality is 6 out of 10. Although it is multifunctional, it is awkward to carry. The rating for durability is 4 out 10. This is because there are many parts, such as the stand and cover, that could break apart. Thus, the overall rating for this design is 5.6 out of 10.

3.2 Design Two: Stand

Design 2 was thought of due to its multifunctional capabilities. By making the cover also act as a stand it was hoped that less materials would be used (Figure 2). However, this design turns out to be equally as expensive as the other designs because of the complicated hinge construction.

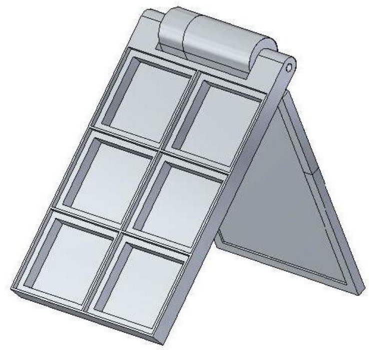


Figure 2 : Design Two

As well, the hinge in the picture would be almost impossible to make using the rapid prototyping machine. Therefore, the design would require a redesigned hinge, which would reduce time spent on the overall design.

This design cut cost by featuring a plastic frame fitted with acrylic sheeting. However, this might require supporting material to be used when making these parts, which would increase overall costs.

For these reasons, this model in theory would work very well, but does not abide by all required criteria for this project (Table 2).

Table 2 : Design 2 Rating

Criteria	**Rating**
Cost	3/10
Practicality	9/10
Durability	8/10
Overall	5.2/10

3.3 Design Three: Book

The open book design contains two columns of three solar panels which fold into each other when not in use (Figure 3). This allows for maximum durability when the solar panels are not in use. In addition, this design is compact; it is half the size of the other designs when folded. It is much easier to transport than the other designs, and much easier to store.

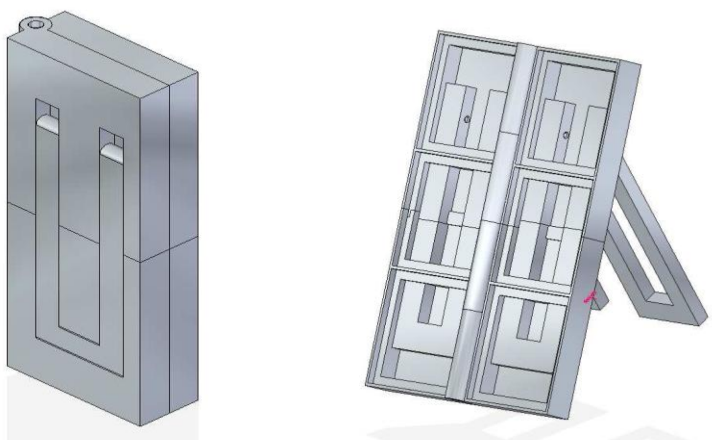


Figure 3 : Design Three

Unfortunately, it is more difficult to change the angle of the solar panel with the open book model than the others and more plastic is used in the rapid prototype. The two solar panel columns must be connected outside of the design therefore leading to a greater chance of the wires being damaged.

The design uses approximately 18 cubic inches of plastic when rapid prototyping and costs approximately $120.00 [6]. Foam is needed to hold the solar panels in place and provide cushioning to protect them. UV protected acrylic will also be used to protect the solar panels. Hinges will connect the panels together and holes will be drilled in the sides of the casing to allow wires to pass through and connect the panels to the laptop. A sealant will also be needed to waterproof the design.

Criteria	Rating
Cost	3/10
Practicality	7/10
Durability	9/10
Overall	5/10

3.4 Final Design: L-Book

The L-Book is extremely similar to the book design, but with each side of the 'book' having three solar panels in the shape of an 'L' (Figure 4). It has all the benefits of the book design, but can be made in the rapid prototyping machine in two plastic parts instead of four (the machine can only make parts in a 10 by 10 inch box) [6]. In order to fix the problem of changing the angle of the solar panels a shadow stick may be inserted into a hole in the design to help the user find the optimal angle for the solar panel at any time of day. The large base also lowers the center of gravity of the design and makes it sturdy when placed up against a rock or the side of a house for support.

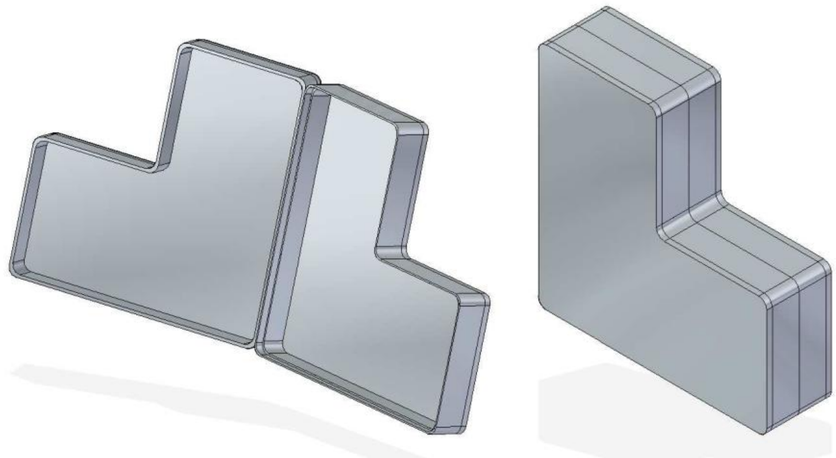


Figure 4 : L-Book Design

One of the visible downsides about the design is that two sides of the book must be connected externally. This poses a potential problem as it is much easier to sever the circuit, rendering half of the solar panels useless until repaired. In order to solve this problem the connecting wire must run from one panel to the other through the hinge. This solution was too expensive for the prototype, but from a mass production standpoint it would be a viable solution.

Cost – 10/10

Extremely cheap; approximately $40.00. Uses least amount of plastic during prototyping. Other materials used in the design are very inexpensive when bought in larger quantities.

Practicality – 8/10

Easy to use and charges the laptop effectively. Could be considered large and somewhat bulky.

Durability – 9/10

Extremely durable when in casing. Wires have a small chance of being severed.

4.0 Design Implementation

The following are materials that were used in the building of the prototype.

The table includes all specifications and reasoning behind choosing the parts (Table 3: Parts).

Table 3 : Parts

Part	**Specs**	**Reasoning**
Solar Winds USA Silicon Solar Panels (6)	-4 by 4 inches -2 watts -2 volts -1 ampere	Supplies the right amount of power (12 W), while fitting within the budget.
Prototyped Plastic (2 frames)	-6 cubic inches	Used for the frame, which provided enough strength to the prototype.
Acrylic	-transparent -UV protected	Provided a strong case while reducing costs. Allowed sun to hit panels.
Laptop Charger Plug	-Digikey 6mm Plug	Compatible with XO laptop.
Piano Hinge	-7 inches	A strong hinge that allowed the panels to open smoothly.
Insulated Wire	-6 inches -2-prong	Connected both sides in series.
Cardboard	-moving box cardboard	Provided a strong base for the solar panels. Contained some cushioning properties.
Black Foam	-packing foam	Reduced damage from side impact
Bubble Wrap	-packing wrap	Was thin enough while reducing impact damage.

4.1 Tools

Jig Saw
Drill
Soldering Gun + Solder
Sandpaper
Box Cutter
Wire Cutters
Electrical Tape

4.2 Simplified Construction Process

The following is a simplified construction of the L-Book in order to get an idea of it's overall design.

1. The bottom of the prototyped plastic frame was to glued to an acrylic piece.
2. Two layers of bubble wrap were placed within the frame on top of the acrylic.
3. A L-shaped layer of cardboard was placed on top of the bubble wrap.
4. The solar panels were glued to square pieces of cardboard, which were then glued to the L-shaped layer of cardboard.
5. The panels were soldered together.
6. An acrylic sheet was fitted and glued within the frame.

4.3 Detailed Construction Process

The following is the in-depth step-by-step instructions for the construction of the L-Book.

1) Prototyped Frame

1. A rapid prototyping machine was used to produce the frame.
2. The frame featured a sunken down lip so the top acrylic piece could fit within the frame without making contact with the solar panels.

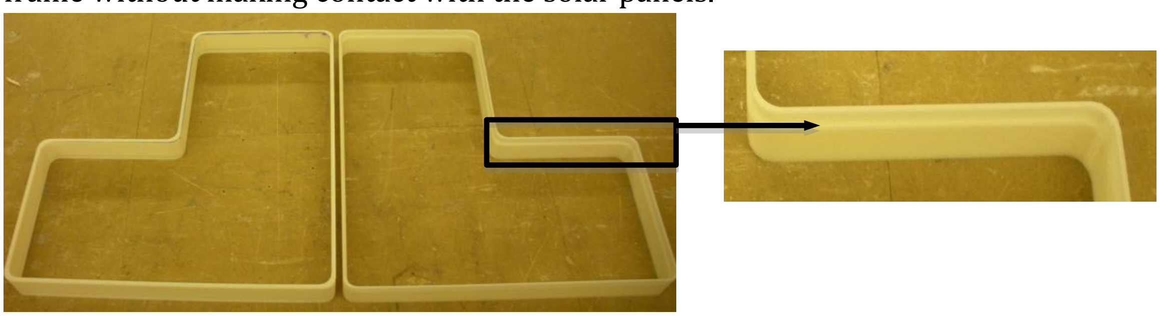


Figure 5 : Prototyped Frame

2) Acrylic Bottom Pieces

1. The two bottom acrylic sheets were produced by placing the plastic frame on an acrylic sheet and tracing it.
2. A jig-saw was then used to cut out the piece.
3. It was then sanded down to fit the plastic frame.
4. The pieces were then glued to the bottom of each frame.

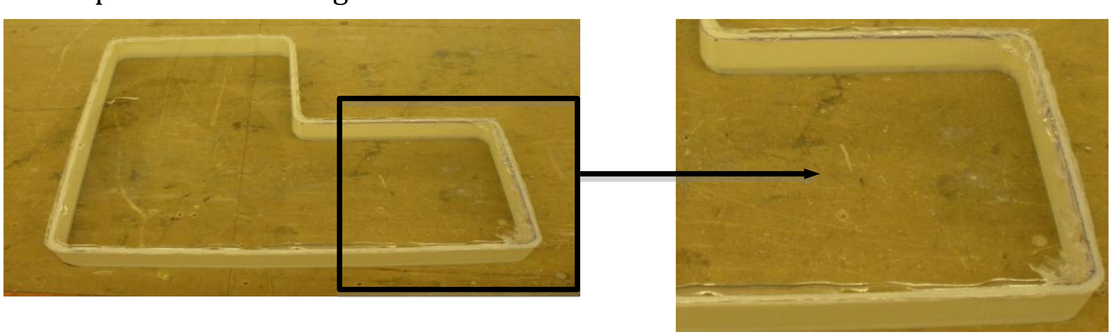


Figure 6 : Frame and Acrylic

3) Cardboard ad Bubble Wrap

1. Four pieces of bubble wrap were cut to fit within the frame (two for each frame).
2. Two pieces of cardboard were cut to fit within the frame (one for each frame).
3. The two layers of bubble wrap were then glued to the cardboard piece.

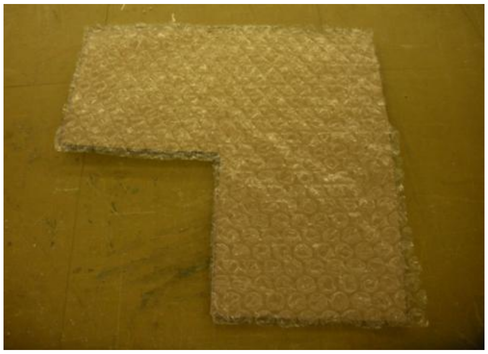


Figure 7 : Cardboard/ Bubble Wrap

4) Drilling

1. A hole was drilled at the bottom corner of each frame so that wires could attach the two frames together to complete the circuit.

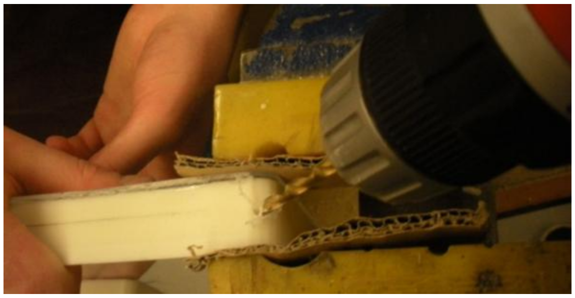


Figure 8 : Drilling Hole

5) Shadow Stick

1. Two pieces of acrylic (l=1 inch, w=0.5 inch) were cut out.
2. A square piece of acrylic (w= 0.5 inch) was cut out.
3. The two pieces of acrylic was glued together at the corner of a frame.
4. The square piece was glued to the other pieces to form the base.

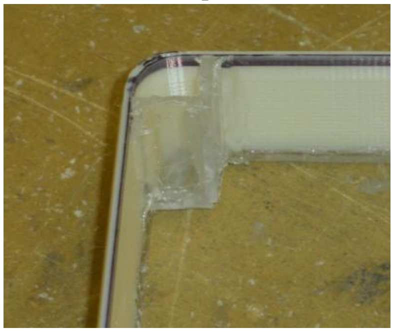


Figure 9 : Shadow Stick Holder

6) Hinge

1. The two frames were placed on top of each other and taped together. The hinge was placed on the frame and traced out to ensure that it was glued in the right place.
2. Hot glue was added to one of the frames and half of the hinge was attached.
3. Hot glue was added to the other side and then other half of the hinge was attached.

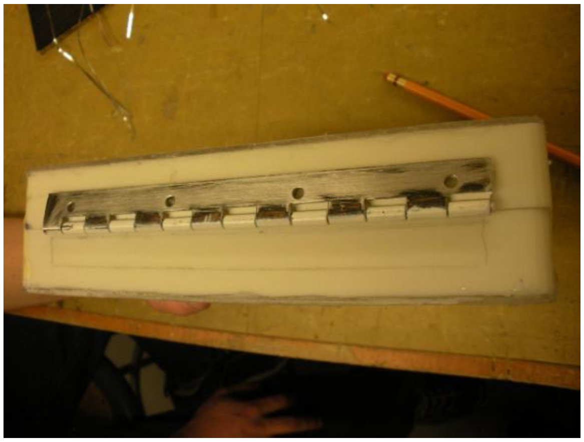
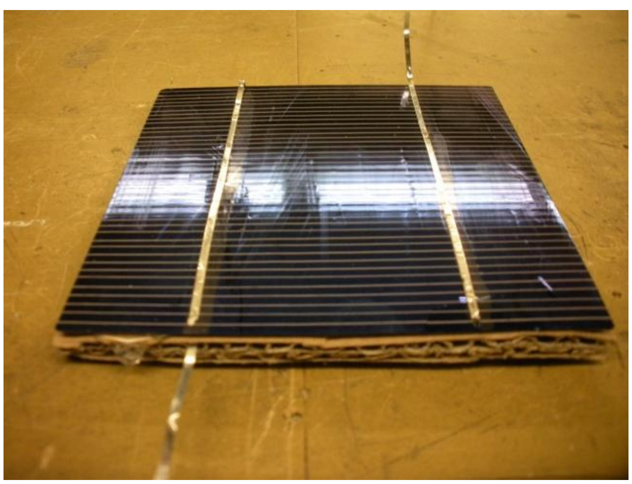


Figure 10 : Hinge Attachment

7) Solar Panels

1. A solar panel was traced out onto cardboard.
2. The cardboard square was cut out and carefully glued to the bottom of the solar panel to provide extra strength. This was done for all six panels.
3. Two of the solar panels were glued to the L-shaped cardboard cut-out.



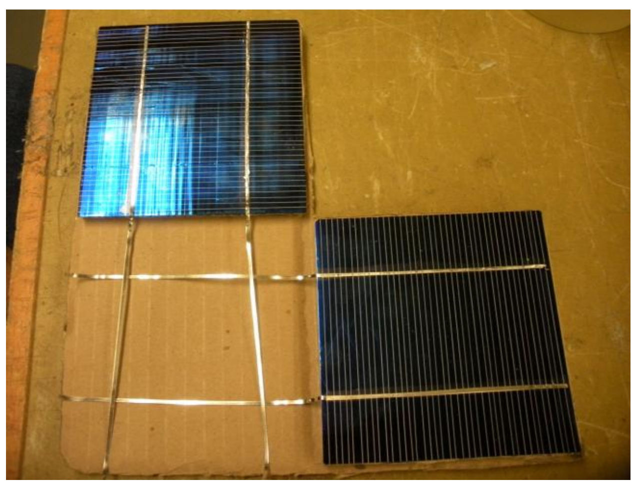


Figure 11 : Solar Panels/Cardboard Backing

8) Assembly/Soldering of Right Frame
1. The layers of cardboard, bubble wrap, and solar panels were laid within the frame and permanently glued to it.
2. The insulated wire and charger wire was fed through the hole into the frame.
3. The insulated wire was soldered to the first panel's negative lead (circled in red).
4. The first panel's positive lead was soldered to the second panel's negative lead (circled in blue).
5. The black charger wire was attached to the third panel's positive lead, which was bent under the backing and looped to the other side of the panel (circled in pink).
6. The third panel was glued down and the second panel's positive lead was soldered to the third panel's negative lead (green circle : panel two lead).

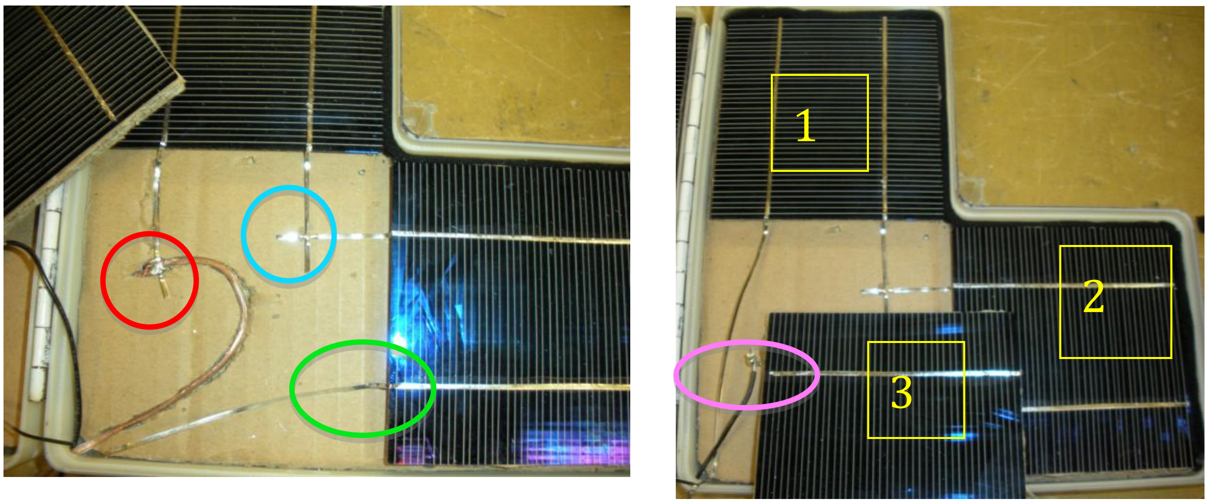


Figure 12 : Right Frame Soldering

9) Assembly/Soldering of Left Frame
1. The layers of cardboard, bubble wrap, and solar panels were laid within the frame and permanently glued to it.
2. The insulated wire and positive black charger wire end was fed through the hole into the frame.
3. The first panel's negative lead was soldered to the black charger wire (circled in green)
4. The first panel's positive lead was soldered to the second panel's negative lead (circled in red).
5. The insulated wire was soldered to the third panels positive lead under the cardboard (circled in pink).
6. The third panel was glued down and the second panel's positive lead was soldered to the third panel's negative lead (blue circle : panel two lead).

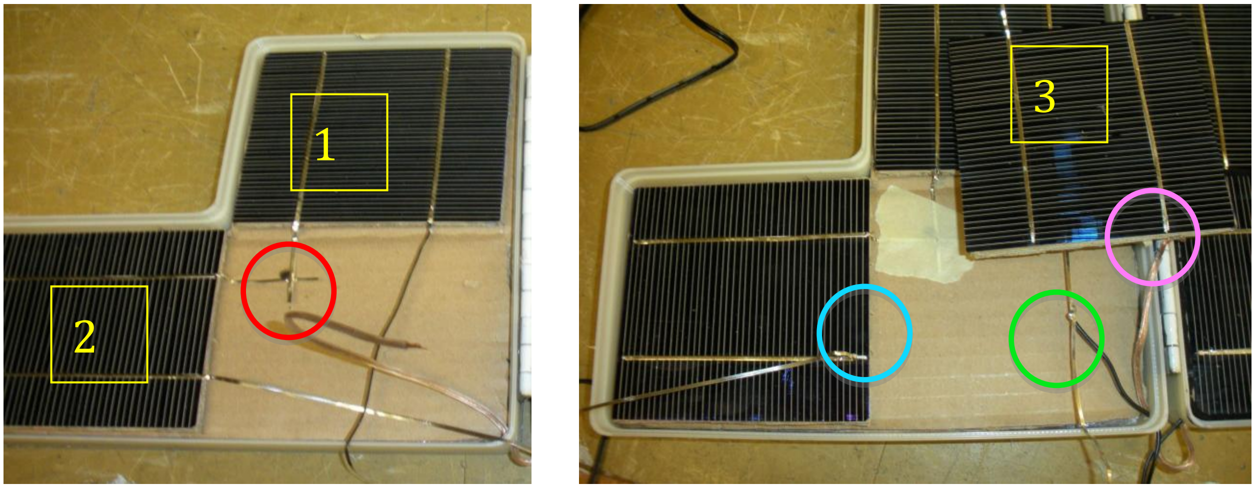


Figure 13 : Left Frame Soldering

10) Foam

1. Black foam was stuffed around all solar panels to provide extra support from any possible impact (green arrow).

Figure 14 : Black Foam

11) Acrylic Top Pieces

1. The two top acrylic sheets were produced by placing the plastic frame on an acrylic sheet and tracing it.
2. The jig-saw was used to cut out the inside of the trace line because the acrylic had to slide within the frame and sit on top of the lip.
3. It was then sanded down to fit within the plastic frame.
4. Hot glue was placed on top of the lip and the acrylic sheet was pressed strongly down.

12) Finishing Touches
1. All excess glue was removed
2. All holes were caulked to prevent water damage.
3. Velcro was attached to prevent the panels from opening up unexpectedly.

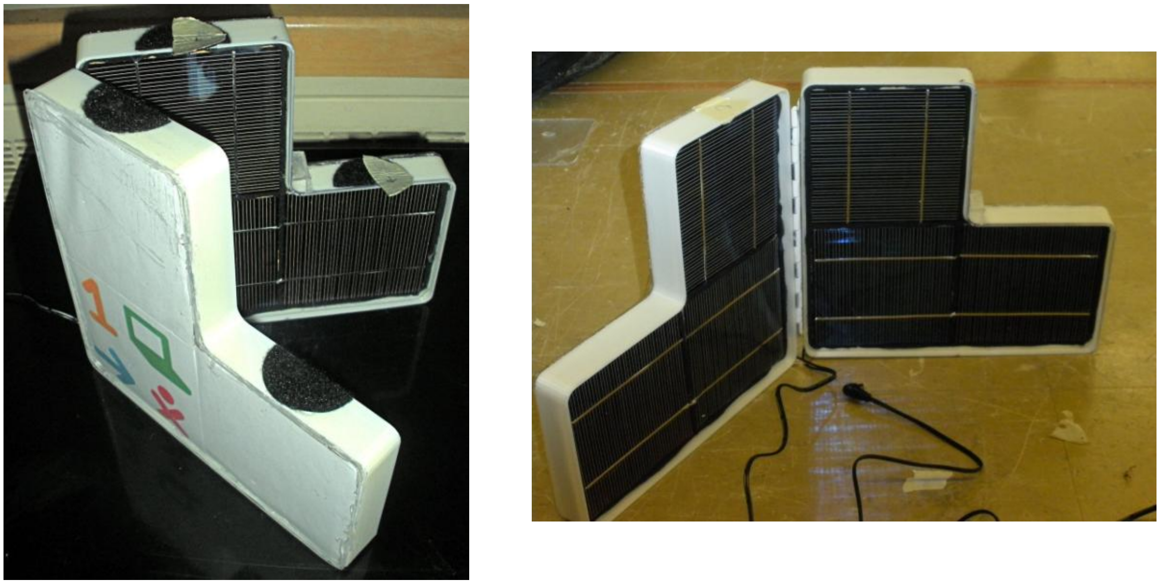


Figure 15 : Final Product

5.0 Experimental Testing

Testing on the charger would involve hooking it up to the XO laptop and placing it in the sunlight. If the laptop starts charging, then the laptop produces enough power to run the laptop. However, due to undesired weather, the prototype has not been able to be tested. However, the prototype was tested to see if a current would travel through it. This test confirmed that it did have a completed circuit and adds to the validity that it will work.

6.0 Discussion

As was earlier stated, the charger was never tested due to uncontrollable circumstances. This causes uncertainty in whether the charger would actually produce enough power for the laptop. However, the charger theoretically produces 12 watts of power. This is more than enough power to run the laptop. The only other cause that would prevent the prototype from working is if the circuit was incomplete and, as said earlier, this was already tested and it was indeed complete.

The chosen design ended up being very easy fast and easy to construct. This can be proven by looking over the design process as there were no problems during construction and the charger was able to be built in a matter of hours. The longest part of the construction process was the rapid prototyping of the shell and this is the part that would hold up the construction process. This allows the design to be very feasible for mass production if put into production.

7.0 Economic Analysis

Table 3 outlines the materials used in this project and their associated costs

Table 4: Materials and Cost

Material	**Cost ($)**
Prototyping Plastic	36.00
Hinges	2.00
Foam Padding /Bubble Wrap/ Cardboard/Velcro	2.00
Acrylic Sheet	10.00
Glue	2.00
Solar Panels	24.00
Total	**76.00**

The total cost of the production of our prototype was $76.00. This cost was under our total budget for the project, which was $80.00. However, one particular thing to notice is that the materials we have chosen to use can be easily mass produced, specifically using a RepRap machine.

A RepRap machine is a self replicating manufacturing machine. These are machines that can manufacture custom plastic moulds using CAD software, and can manufacture up to 50% of their own parts. An example of a current RepRap machine, seen in figure 4, is able to manufacture every plastic part incorporated into its frame.

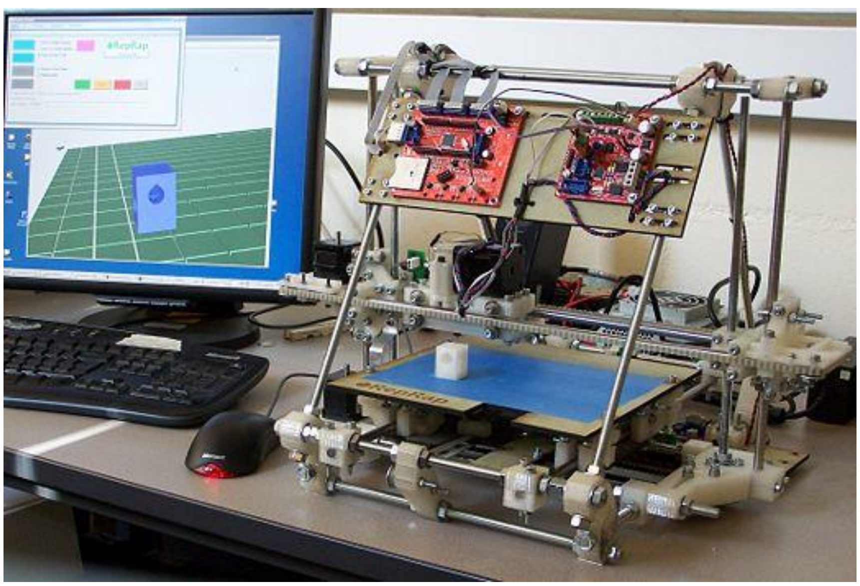


Figure 16. An example of a current RepRap machine. All the white plastic parts can be manufactured by the machine itself.

The other parts of the machine, like the metal supports, motors and circuits, can be purchased for approximately $500.00. Although the RepRap design is still being perfected, it is a unique and efficient tool that will decrease the cost of the mass production of our product. [8].

A possible implementation strategy is that a community in a developing country would produce their own RepRap machine. They could then use this machine to produce other machines and the rapidly prototyped plastic shell. Using figures found online, the calculated price to manufacture the prototyped shell reduces to only $1.76 [8]. This is a little over $34.00 cheaper than performing the operation at Queen's University. Not only is it cheaper, but once all the shells have been made, the community can use the RepRap to make anything they require. This could include coat hooks, toys and other accessories for a low cost. The RepRap machine allows the parts to made locally. This eliminates the need for a complex transportation system and the marked up costs due to distributors. Not only that but only one person needs to be trained in how to operate and build the machine to help the whole community.

Table 4 outlines the costs of parts if they were mass produced and the RepRap machine was used. We have seen from the websites of manufactures that the prices of materials drops as you buy more at once. These costs have been estimated to best predict the cost of our design.

Table 4. Materials and their Associated costs using if they were massed produced

Material	**Cost ($)**
Prototyping Plastic	1.76
Hinges [3]	0.50
Foam Padding /Bubble Wrap/ Cardboard/Velcro[3,1]	1.00
Acrylic Sheet[3]	7.00
Glue[3]	0.50
Solar Panels [8]	18.00
Total	**28.76**

Overall this design could cost under $30.00 per unit using the method described above. This is a very affordable cost for the developing countries where the design is intended to go to.

8.0 NEXT STEPS

Although the current prototype is a very effective model, some improvements could be made before it is mass produced to ensure a quality product. The first item that should be changed is the naked wire that connects the two L's. This wire could easily be tugged on by children, or caught on something in the surroundings and rip off. It is an integral part of the design and it must be fixed. A solution to this would be to create a hinge, that is incorporated into the rapidly prototyped shell, that allows the wire to pass from one half to the other. This would ensure the wire does not become damaged or ripped off. Also, the hinge that is currently being used is simply glued onto the frame. This hinge should either be built into the rapidly prototyped shell or screwed in to the frame to increase stability and durability

Another problem is the current lip on the prototype. When it was dimensioned, the thickness of the acrylic was unknown. Thus, extra height was allocated to the lip to ensure the acrylic would fit. However, this extra height yielded a lip that is too large. This lip should be smaller so that it is flush with the top of the acrylic panelling.

A third change that could be made involves removing the bottom acrylic sheet and creating a shell that not only outlines the product, but encloses it on the underside. This will reduced weak points where the acrylic has been glue.

9.0 Conclusion

The XO laptop has a high demand for an alternative power source despite its amazing features and durability. Since these laptops will be exported to areas without access to electricity an external solar panel is a simple solution.

The device must be easily prototyped at a cheap cost, durable, and simple to use. It must be inexpensive because the product is being shipped to undeveloped countries. The design must also be easy to rapid prototype since in the future these machines can be exported to countries and the people could replicate the design themselves. Last of all, it must be durable and simple to use since children are the main users of this product.

The prototype has a durable design that is also cost effective. With some simple changes, the prototype is ready for implementation. A method for implementation of the design, using the RepRap machine, has also been explained. This method has the potential to greatly reduce the cost of the product and help communities in developing countries.

10.0 References

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11.0 Individual Contribution

Everyone contributed equally to the creation of the designs and the reasoning behind the designs. The contributions are divided into who did what for the proposal report and for the final report. This is because, in many circumstances, built off what was already written to complete the final report.

11.1 Adam Hall

Proposal report:

I wrote up the Executive summary and the explanation of design 1. I also helped with the overall formatting of the report including the table of contents, referencing, and the title page. I also help organize meetings, record what was discuss in each meeting, and communicate these recordings over Facebook to the rest of the group

Final Report:

-Updated Economics, Conclusions and references wrote Next Steps

-Put final report together

11.2 Eric Ross

Proposal report:

So far in this project I have helped research background information on solar panels and the XO laptop. I also contributed to potential, researched the economics and helped set up a prototyping cost analysis for most of the designs. For the proposal presentation I covered the economics, short and long term, and the design criteria of the project. As for the proposal report I wrote the Introduction, Problem Formulation and the Conclusion.

Final Report:

- Wrote Design Implementation

11.3 Alex Pierratos

Proposal report:

I wrote up the Economic Analysis, the explanation for Design 3, and the explanation for our Final Design.

Final Report:

-Updated Executive Summary, Introduction,

11.4 Alexander Monahan

Proposal report:

I created all the solid edge models seen in this report and others that were not used. I also wrote up the explanation for Design 2.

Final Report:

-Wrote Discussion and Experimental Testing