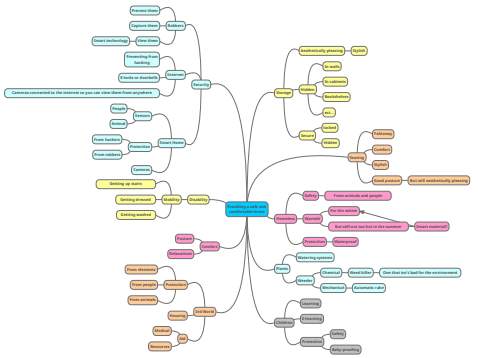
Name : Harry Watkins
Candidate No. : 5039
Centre No. 62403
AQA – GCSE Design & Technology
Specification – 8552
Summer 2020

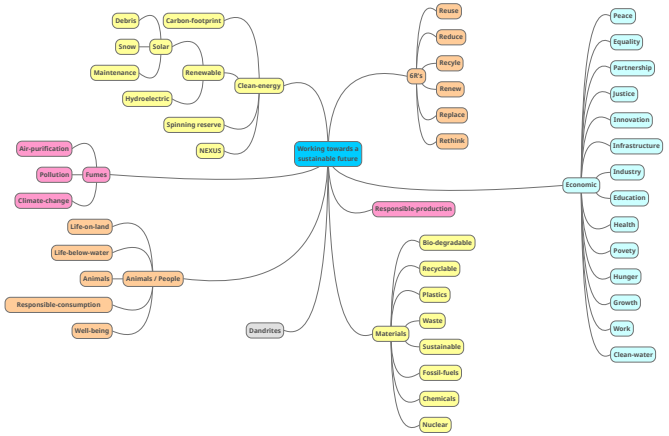
GCSE Design & Technology

After much consideration between two of the design briefs I chose to answer the design brief 'Working towards a sustainable future'.

Once I had decided to focus on 'Working towards a sustainable future' I created a word cloud so that I could see my ideas more clearly. It also helped me to analyze my ideas. I decided to focus on clean-energy and then solar panels. I chose this for a multitude of reasons. One of these was that I find solar energy fascinating, as we are harnessing the natural energy from the sun and converting it to electricity that we can use in our every day. Also, solar energy is one of the cheapest forms of renewable energy, which is a great advantage. After doing some research into the current problems with solar panels I decided to focus on the problem of solar panels being covered in debris, in particular, snow. I chose this because solar panel farms in countries such as Japan suffer a lot from the snow which can lead to a loss of production. Furthermore, the cost of one crew to clear the panels is the same amount that the whole farm would make in one day. Although it is expensive, it is worth it but it would be very advantageous if there was a cheaper, simpler option to clear the panels and that is the problem that I am going to try and solve. I will make an automatic system that will clear solar panels from snow and other debris, enabling the solar farms to save a lot of money.



I brainstormed the brief 'Providing a safe and comfortable home' so that I could further understand the brief and try to decide possible design ideas. I narrowed it down to nine key categories; security, disability, comfort, 3rd world, storage, seating, homeless, plants and children. After this, however, I chose to work on the design brief 'Working towards a sustainable future'.



I created a mind map to try and brainstorm the brief 'working towards a sustainable future'. I decided that there were seven key parts; clean-energy, fumes, animals / people, materials, economics, materials, 6R's and responsible production. I decided to focus in on clean-energy and in particular solar production.

Introducing my client

I decided that my client would be Andreas Mustad, co-founder and ex-CEO of a well known renewable energy company, Sonnedix, as he has many yeas of experience in the field. I then decided to ask him about the current problems with renewable energy (all text is paraphrased):

Q1: What would you say is the biggest problem currently in the renewable energy industry?

A: The biggest problem and challenge facing the renewable energy industry,y is that most renewables are dependent on their environment, except for hydroelectric dams, which are very valuable, because they are the only way you can store 'energy' in a large quantity because you can store the water. With the other methods, once the electricity has been created, it has to be used instantly and cannot be stored or slowed down efficiently. So if there was an efficient way to slow down or store electrons then that would be very helpful. Also, even if you could find a rechargeable battery big enough to be able to store the spinning reserve then dendrites would build up and then the battery shorts out. If there was a way to have a battery where the dendrites are broken off automatically then that would be really great.

Q2: Is maintenance a big problem?

A: Overall panel maintenance is not a large problem because they have drones which fly over the solar farms with infrared cameras on them and look for hot spots on the solar panels. If there is a hot spot then you can tell that there is going to be a maintenance problem soon and therefore a maintenance crew is sent out to fix the panel and you are then effecting around 0.001% of the solar production as there are so many panels.

Q3: What about debris like snow, is that a big problem?

A: Snow is an issue in some parts of the world. Whenever you have snow on a panel you can loose days, weeks even a month of production if you don't clear it early. You don't actually have to clear the whole panel from snow but only a little corner as the sun will shine on that spot and will heat up and will melt the snow around it. Throughout the day, the panel will clear itself. If there was something that could keep snow from accumulating on the panel so that as soon as the sun comes up all of the panels would be clear and that would be awesome. If it used a small amount of power it could just run constantly and if there was a way of turning it off then that would be great.

Q4: Is it worth clearing the whole or just part of the panel from snow?

A little bit would be enough but the whole panel would be really great

sonnedix

*audio from the interview with Andreas (will auto play on presentation)

After my interview with Andreas I understood that the main problems were:

Problem 1 – Improving the efficiency

- Apart from hydroelectricity, most renewables rely on their environment which can make them in-efficient.
- One option is to use any spare energy to pump water back to the top of a hydroelectric dam but with transfer losses, you can loose 50% of your energy.
- Most battery's are 85-95% efficient, so if you had a 95% efficient battery, then it is 5x more efficient than recycling water at hydroelectric dams.
- One current problem with batteries, is that dendrites can build up and when they touch, the battery shorts out.

SOLUTION – CREATE A BATTERY THAT AUTOMATICALLY CLEARS THESE DENDRITES

Problem 2 – Improving solar maintenance

- Solar panels currently produce 350w/h which is 15,000w / per day on average.
- Renewables countries loose 1-2% to soiling which doesn't sound very much but for a lot of companies that is a loss which can easily be over £6-8m loss of revenue which is a lot
- You also don't need to clear the whole amount only a small segment of maybe ¼ and then the sun will take care of the rest.
- One crew cleaning all of the panels costs the same as the amount that the plant would make in a day so it's worth it.

SOLUTION – CREATE AN AUTOMATIC SYSTEM THAT CAN SENSE DEBRIS OR SNOW AND CAN THEN CLEAR IT

Problem 3 – There is no current way to efficiently store the 'spinning reserve'

- Renewables can only put energy into the spinning reserve which is there incase one of the plants on a line goes down.
- If you could find a way to store enough power efficiently so that if one plant went down you could then just turn on this 'battery' and for say 15 minutes it would then be able to produce power whilst the utility brings another plant online.
- One option would be to use the large batteries on electric cars so that you could plug in wherever you stop and then contribute to the 'power pool'.
- Also, renewables are now almost able to supply more than 10% and therefore some plants are even having to turn off temporarily but if you could slow down or store the electrons and release them later then that would be very helpful.

SOLUTION – FIND A WAY TO SLOW DOWN ELECTRONS SO THAT THEY CAN BE USE WHEN THEY ARE NEEDED

Task analysis + Research Plan

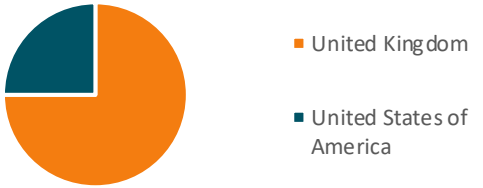
What do I need to know?	Why do I need to know this?	Primary or / and secondary sources?	Answer:
Function	So that I know what I am making.	PRIMARY – I will speak to people in the industry .	- This will clear solar panels of snow by using a heated scraper. - This will clear the panels regularly (especially overnight) so that the snow and ice doesn't have a chance to build up.
Key Features	In order to integrate them into my design.	PRIMARY – Questionnaire sent to everyone I know who owns or works with solar panels.	- It will be automatic. - It will use a little amount of electricity. - It will have a heated element. - It won't need much if any maintenance.
Environment	So that I can try to reduce any environmental impact caused by the product and also use as environmentally friendly materials as possible.	SECONDARY – By doing online research.	- I will try to avoid non environmentally friendly plastics. - I will try to only use materials that come from a sustainable source.
Cost	I need to know the ideal price that both the commercial and personal consumer so that I can focus on one and then choose my materials accordingly.	PRIMARY – Questionnaire sent to everyone I know who owns or works with solar panels.	- Commercial : £1 - Personal: N/A
Construction Materials	So that I can influence my design so that it can be manufactured.	PRIMARY – I will conduct research by analyzing the properties that will be needed by each material.	- See next slide.
Size of panel	So that I can design the product with correct measurements.	SECONDARY – I will find a technical drawing which states their dimension.	- 1956 x 991 x 45 mm (length x width x depth). - More info on 'solar_panel_dimensions.png'.
Current Maintenance methods	So that I know what, if any competition and I can also learn from their mistakes. It also gives me more insight into what people currently do and if they have an effective solution currently.	PRIMARY – I will search online and try to find any products that are similar to my concept.	- 'Take it off the roof and wipe it clean' - 'Hose and sponge' - 'Rain' - 'Mother nature'
Aesthetics	So that when I design my work I need to know which pieces will be exposed and will therefore be seen by the public and will then make them aesthetically pleasing.	PRIMARY – By looking at and analyzing my design.	- This will be very aesthetically pleasing - It is all going to be visible bar a couple of parts so it must all look appealing.

Further Research

I also sent out a questionnaire to everyone I knew who is involved with solar panels (all responses may be paraphrased)

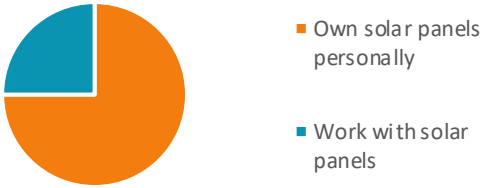
Q1: Please state you country (I asked this in order to try and ensure I get as diverse responses as possible from a multitude of countries)

A:



Q2: Do you own solar panels personally, work with solar panels or own solar panels corporately? (This was so that I could differentiate between people who were enlightening me with their personal or corporate opinion)

A:



Q3: How many solar panels do you own or work with? (This was so that I could understand the background of the participants)

A:

Q3: What is the model and make of your solar panel? (so that I could try and make my product compatible with any popular solar panels)

A:

- SolarWorld

Q12: Is there anything else that you would like to say regarding the current problems with solar panels? (so that I could try and add any requested features).

A:

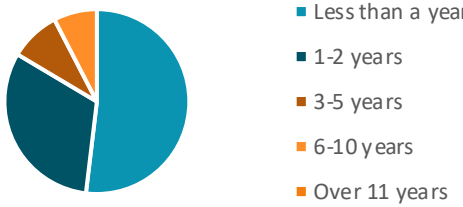
- 'It would be useful if the system was automated such as my automatic vacuum and automatic lawnmower'
- 'It would be good if you didn't have to access the panels as they are on the garage roof, and I am not great on ladders!'

Q4: What type of solar panels do you have? (So that I could understand whether people generally had tracer or fixed panels)

A:

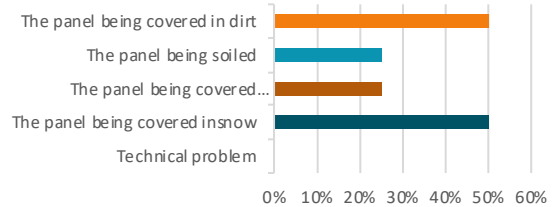
Q5: How long have you had your solar panels? (So that I could understand how much experience they had with solar panels)

A:



Q6: What problems have you had with your solar panels? (So that I could understand what problems they had and whether any of them had struggled with snow, however, none of my participants were from my target countries, which are countries like Japan who have an immense amounts of snow)

A:



Q7: How do you currently maintain your panel(s)? (So that I could understand peoples current solutions to their maintenance problems)

A:

- Take it off the roof and wipe it clean
- Hose and sponge
- Rain
- Mother nature

Q8: If I were to create a system that could (for example automatically clear snow and debris off panels in countries that get a lot of snow in the winter) what sort of price range would you want the product to be per panel? (So that I could further understand the price that the corporate potential customer would want)

A:

- £1 (corporate customer)
- £20 (personal customer)

Q9: What key features do you think would be essential for this product? (So that I could understand what they would like to see in the product)

A:

- Be maintenance free
- Light weight and ease of use

Q10: Do you have any key advice for me regarding the production of this product? (This was only asked to commercial users of solar panels so that I could learn from the experts in this area)

A:

Find someone who speaks Chinese and works in production in China who can advise you on how to get something mass produced (and human error proofed) in China. 90% plus of all panels are being manufactured there. If you cannot integrate or complement your product with their product offering you will struggle to get to market.

(Andreas Mustad)

Q11: If I made an effective, cheap solution to this problem would you be interested? (so that I could try and find any potential customers)

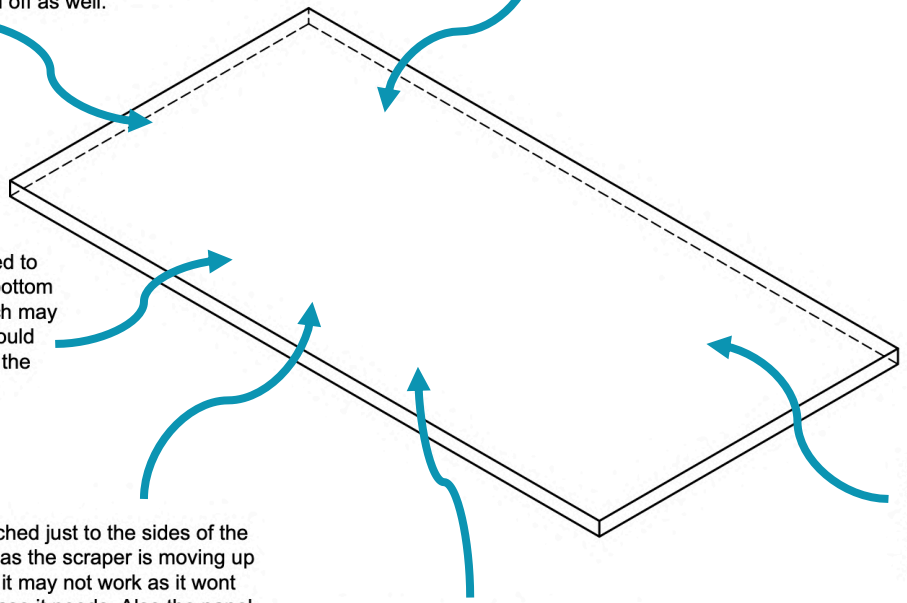
A:

This survey shows many things but the most obviously of which is the overwhelming want for the product from the customer.

Sizes and Dimensions

It could just be attached hanging from the top of the panell however as the scraper will be moving up and down the panel it is likely that it will fall off. Also if it faced any bad weather then it is likely to fall off as well.

It could be attahed to all four sides which si what I am going to do. This makes it as secure as possible and I will use springs in the frame in order to make it that it locks onto the panel easily.

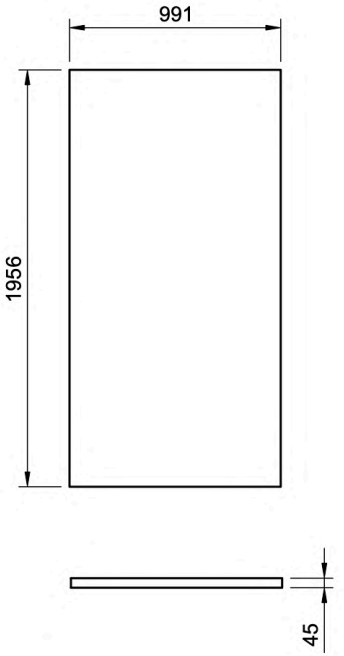


It could be attached to both the top and bottom and one side which may work however it could still be pushed off the panel with harsh conditions.

It could be attached just to the sides of the panel however as the scraper is moving up and down then it may not work as it wont have the purchase it needs. Also the panel is sloped which means that it could slip off of the bottom.

It could be attached with suction cups on the back of the panel. This would probably be the easiest but there would be the risk of the suction cups coming off of the panel especially in bad weather.

It could be attached to both the top and bottom of the panel however that would mean that it is not prevented from moving sidewards and could fall off the sides.



Dept.	Technical reference	Created by: Harry Watkins 11/09/2019	Approved by
		Document type: Technical Drawing	Document status
		Title: 350W Solar Panel	DWG No.
			Rev. / Date of issue / Sheet: 3/4

Current solutions on the market (see source page at end)

Using a Automatic Window Cleaner

PROS:
- Automatic
- Less labour
- Quicker
- Does not waste water
- Cleans to a high standard
- Safer than having people up there
- Cheaper in the long term
- Works in most conditions

CONS:
- Expensive in short term
- Big and heavy
- Uses a lot of electricity
- Probably produces fumes
- Probably produced using cheap labour as it's made in China
- It is not very aesthetically pleasing
- Wheels could mark the windows

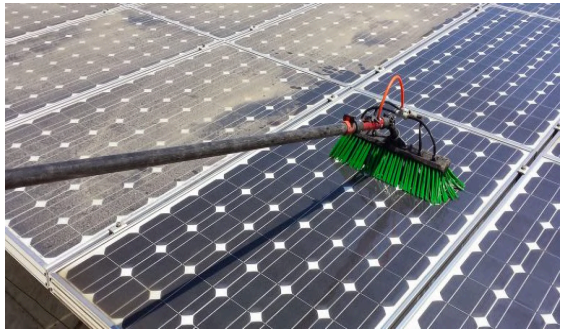
This cleaner is automatic which means that there is less labour and as it also quicker, it also means that it will waste less water. However, because it is automatic, it is more expensive in the short term and uses a lot of electricity. It also probably produces fumes but it will clean to a higher standard than a human. Although the wheels might mark the windows.

Cleaning Solar Panels with a brush that automatically releases water and product

PROS:
- More water efficient
- Equipment is cheaper

CONS:
- Could leave water marks
- Requires labour

This is more water efficient than just using a simple brush and hose and the equipment it cheaper. However, it could leave water marks and requires labour.



Using an Electronic, Heated, Ice Scraper to clear Ice and Snow off Cars

PROS:
- Heat will help melt ice
- Handle is very ergonomic, making it easy to hold and use
- Has an LED for ease of use
- Has an easy switch to turn on and off.

CONS:
- Metal could scratch window
- Requires electricity
- The handle and wiper are probably made out of rubber/silicone which is bad for the environment.

The heat will help melt the ice and an ergonomic handle means that it is easy to old. The metal could scratch window but it does require electricity.

Using a Hose and Brush to Clean Solar Panels

PROS:
- Doesn't need much electricity
- Equipment is cheaper
- Equipment isn't specialist, just everyday items
- Brushes are extendable for long reach

CONS:
- Requires a cleaning crew which could be expensive
- Hard working conditions
- Could be using cheap labour
- Wastes water
- Brushes could damage panels
- Manual labour
- Cannot happen if there is bad weather
- Takes a long time
- Very labour intensive
- Could leave water marks
- In a hot country the water could have evaporated by the time the cleaners get there

Using a hose and brush doesn't need much, if any, electricity and it very cheap, as it requires very standard equipment. However, it does require a cleaning crew which could be expensive. Brushes could also damage the solar panels. This would also take a very long time and is very labour intensive.

Using a Plastic, Ice and Snow Scraper to Clear Ice and Snow off Cars

PROS:
- Cheap
- Easy to use
- Scraper will be very effective on snow
- Easy to store

CONS:
- Made of plastic which is bad for the environment
- Does not have a very ergonomic handle
- Would not handle ice or thick snow very well
- Could scratch the glass
- Short handle which means that there is a short range and it could be hard to clear the middle of the windscreen.

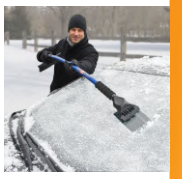
This scraper is cheap and easy to use as well as store. It is also made of plastic which is bad for the environment. The short handle which means that there is a short range. It could also scratch the glass.

Long Handled Ice Scraper to Clear Ice and Snow off Cars

PROS:
- Long handle for ease of reach
- Has another head which has a brush on it
- Could get through thick snow and possibly ice

CONS:
- The scraper could scratch the glass
- Could be hard to stow away
- Might struggle getting through ice
- Made of plastic which is bad for the environment

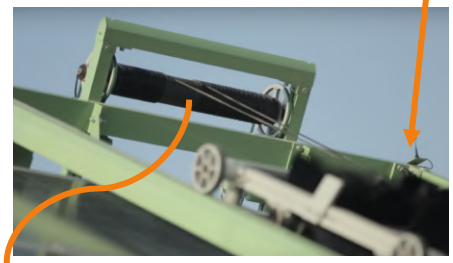
It has a long handle which means that you can reach the other side of the windscreen easily. It could also get through thick snow and probably ice. However the scraper could scratch the glass and it might struggle getting through ice. Also it is made out of plastic which is bad for the environment.



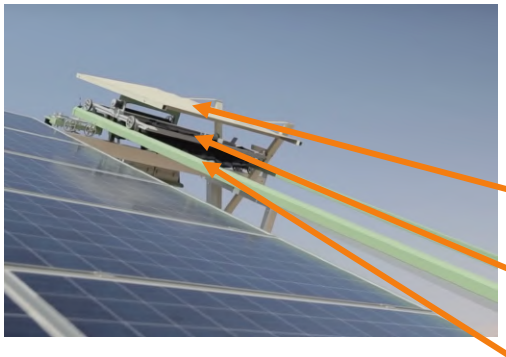
Detailed Product Analysis – E4 by Ecoppia

Wheels mean that there is little or no load on the solar panel surface

RF antenna to communicate with the E4 hub



2 flexible silicone coated wires ensures secure and reliable upwards and downwards movements



Provides shelter from wind and UV rays

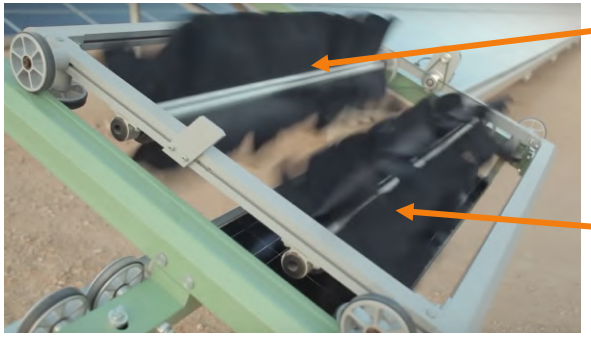
Secure docking station

Performs an additional self-cleaning routine at the end of the cleaning cycle

All of the components are built either on site or from tier-1 suppliers and have passed through rigorous stress tests in high temperatures (over 65 °C) and desert conditions to ensure stability over time.

The onboard solar panel charges up the robot with a full battery lasting 3 cycles

The robots recover energy whilst descending the panel

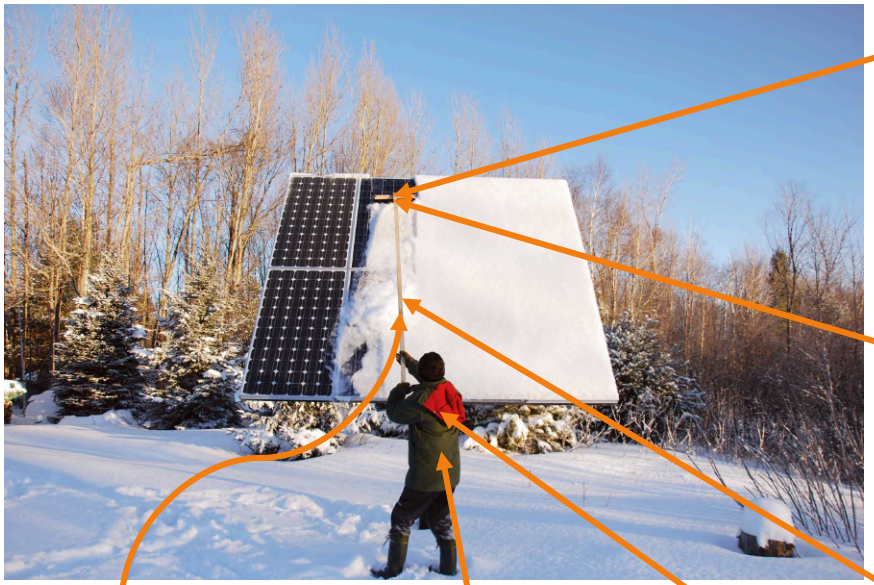


It performs a rapid auto clean of it's microfiber elements before ascending the panel again

Microfiber brushes enables gentle but strong cleaning to remove 99% of all the dusk without damaging the panel

E4 by Ecoppia is an ingenious automated cleaning system fixing a very big problem in solar farms in desserts. The microfiber brushes clear the panels effectively whilst being gentle and, furthermore, the machine performs a rapid auto clean which cleans the microfiber elements before it ascends the panel. The brushes are also on wheels which means that there isn't a load on the panel surface which is lowered by two flexible, silicone coated wires which ensures a secure and reliable upwards and downwards movements. As well as this all of the components are wither made onsite of from tier-1 suppliers and have passed through very rigorous stress tests to ensure stability over time. When the robot is not cleaning the panels then it is stored in a secure docking station which provides protection from the wind and UV rays. When the robot has finished cleaning all of the panels it has been assigned to, the robot performs another self-cleaning routine. Also, the solar panel that is onboard charges throughout the day and a full battery lasts three full cycles which means that when there is cloudy weather the robots still work. When the robot descends the panel, is recovers energy which makes it even more efficient. The onboard RF antenna communicated with the central E4 hub which enables plant workers to control all of the panels from one place, anywhere is the world. Although this robot is effective, it is very expensive and the microfiber brushed mean that it couldn't clear much bigger or heavier debris other than dust and sand.

Detailed Product Analysis – Using a brush



The brush would get through light snow but not ice or thick snow

The brush is not very long so it would take a long time to do large panels

Only requires a brush which is cheap and a common household item.

Long handle enables a long reach so that the person cleaning the panel can reach the top of the panel easily

Requires a human to operate

Would take a very long time to clean an entire solar farm

Using a brush to clean solar panels is a very common method however there are some major drawbacks. The fact that the brush has a long handle means that the person operating the brush can reach the top of the panel easily without having to use any other apparatus such as a ladder. This does also require a human to operate which means that is would take a very long time, and a very large team to clean an entire solar farm. Furthermore, using people is very expensive and could encourage cheap labour. One plus is that this method only uses a brush which is very cheap and a common household item so for smaller, personal, users this could be a very appealing solution. The brush itself is not very long, however, which means that to clean an entire, large panel would take a long time and require a lot of labour. The brush would definitely get through light snow but it may struggle to get through thick snow or ice.

A summary of all the methods

In order to clean snow off of windows or windscreens etc… all of the methods are manual, which means that they are all very labour intensive. This is very expensive and time consuming if you scale this up to a large solar farm. One of the methods that I analyzed used a heated element which means that it would be much more efficient and easier to get rid of ice and thick snow. Without this heated element, a humble scraper cannot do much more than scrape thin layers of snow and ice off of a window. These scrapers are also not very wide which means that it would take a very long time to clear a large panel. One of the scrapers that I analyzed had a very long handle which means that you can clean the whole panel, from top to bottom, very easily.

One current common method for clearing snow and other debris off of panels is using a brush as seen to the left. Using a brush means that there is a very long handle so you can reach the top of the panel very easily. Also I analyzed one solution which was a brush connected to a hose which means that you could pour antifreeze on the panel and remove the ice and snow very easily.

Both of the automatic solutions which I analyzed were effective at what they were designed to do however neither of them were designed to clear snow. E4 is better than the automatic window cleaner as it is more environmentally friendly and is also designed for solar panels. Furthermore, E4 by Ectopia utilizes smart technology allowing it to be controlled and monitored anywhere in the world.

I think that I will base my machine off of E4 by Ecoppia, however, instead of there being a microfiber brushing unit there will be a heated snow and ice scraper which will clear the panels of snow and ice.

Design Brief and Specification

Design Brief: I will design and manufacture a device which will clear snow from a solar panel periodically in order to stop it from building up in the first place. This will enable the solar panels to benefit from the great sun rays that they could be harnessing and turning into electricity as they will not be covered in snow. This will both help people in countries such as Japan to make the most of their panels and also will encourage people to buy solar panels and use renewable energy as they will be able to make energy all year round.

Function
- This will clear snow off of solar panels in the winter.
- This is designed for countries like Japan which get colossal amounts of snow in the winter with some areas receiving up to 6 meters of snow .
- The current solution is to send out a maintenance crew in order to manually clear the panels however one callout to a crew costs the same amount that the entire plant will make in a day so it is very inefficient, but better than nothing.

Appearance
- This must be sleek looking as it will be on view.
- It must also suit the high tech look of a solar panel but although appearance is important it is second to performance.

Environment
- As this is a product designed for snow, then it will need to be able to withstand the winter environment.
- This means that it must both be able to withstand cold temperatures and harsh conditions such as strong winds.

Construction
- As much as possible of my design with be made by 3D printing using PETG as it has the strength of ABS but is recyclable.
- Also, the fact that it will be 3D printed means that people that own a 3D printer can easily change parts if they break or print upgraded parts.

Materials
- I will use PETG for all of my plastic parts as it is recyclable
- I will used rubber seals in order to seal my product from the elements outside.

Performance
- This will be very effective and will use a heated scraper in order to clear the snow in order to stop it from building up in the first place.
- It will clear more regularly in the night so that it does not affect the energy production as much. (However, this may only be part of the second iteration as the first version is to just get it working, and second is to get the timing correct).

Ease of use
- This will be very user friendly and even if something does go wrong, then they will either be able to 3D print a replacement part or if they don't have one / it isn't able to be 3D printed they will receive a replacement as soon as possible.
- One set up .

Cost
- This will be as cheap as possible however it will be made with quality materials in order to ensure that it is as hard wearing, maintenance free and long lasting as possible.

Safety
- As it will be in the winter and there will be rain and snow so the electrics must be insulated in order for the user not to be electrocuted.

Size
- This will be designed to fit a standard 350W solar panel which has the dimensions of 1956x991x45 mm (length x width x depth).

Product Lifespan
- This product will have a very long lifespan as it will be as uncomplicated as possible and every part (with a few exceptions) will be very upgradeable and changeable.
- The main limiting factor of the lifespan of this product is when the technology has improved so much that the customer decides to buy a new machine and they will get a product discount on all future purchases as they are part of the *Panel Clear* Family.

Servicing
- This will be very easily serviceable because as mentioned above it will be designed to be as simple as possible with as few moving parts as possible.

Installation
- Installation will be as simple as possible using as few bolts as possible.
- This could be achieved by using a spring.

Manufacture
- As much of my product as possible will be 3D printed in PETG as it has the strength of ABS but is not as bad for the environment as it is recyclable.
- I will make the leadscrews out of C35E stainless steel as it is corrosion resistant but tough.

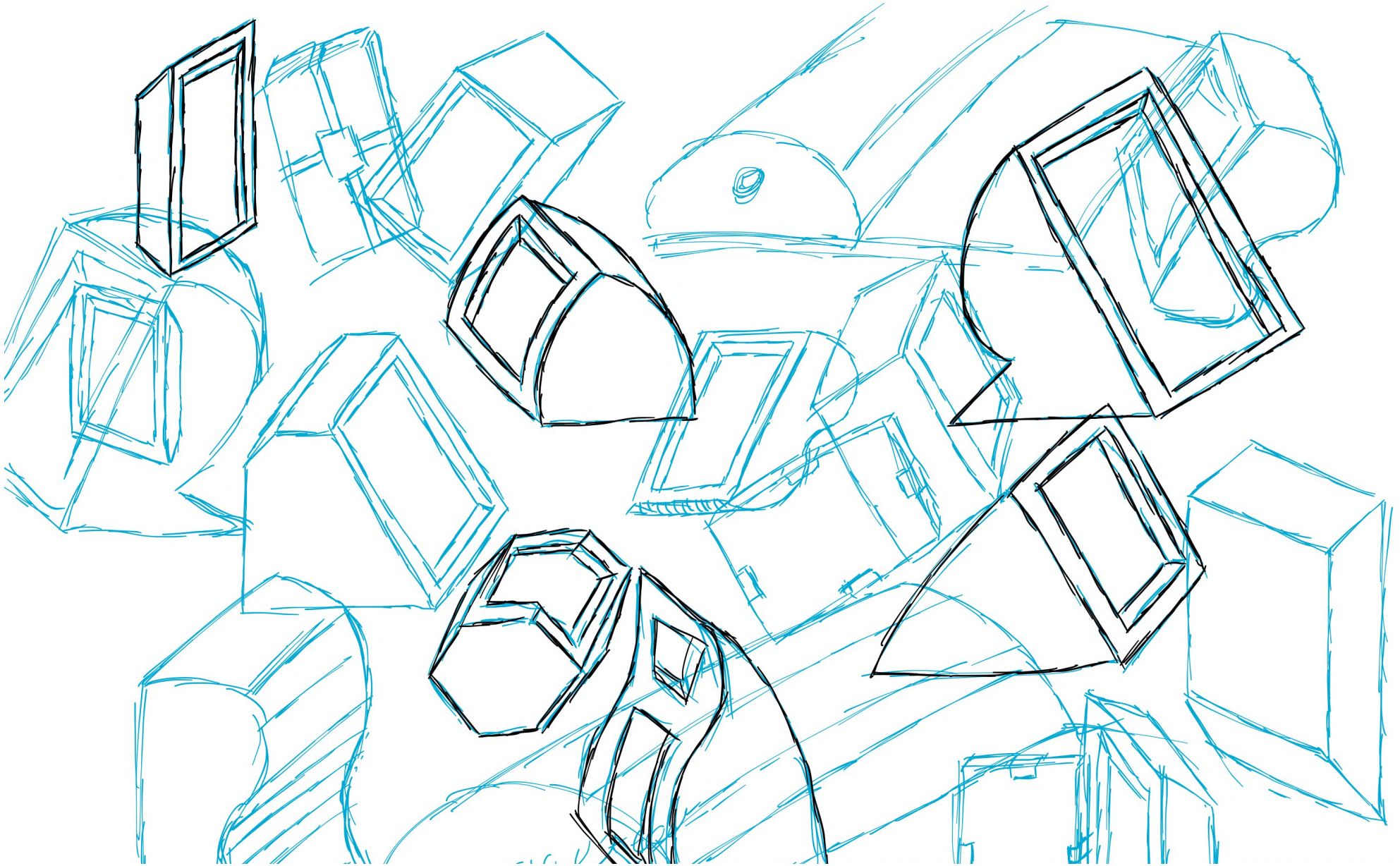
Features
- Electric, heated scraper to get rid of ice and snow easily.
- All electric – no manual labour required.
- Maintenance free.
- Good for the environment.
- Future-proof as a lot of parts will be 3D printed and easy to upgrade especially as 3D printers are becoming increasingly popular and cheaper.

Customer
- My customer is going to be the personal consumer as the commercial consumers had targets which were unrealistic for the first iteration with regards to cost and function.

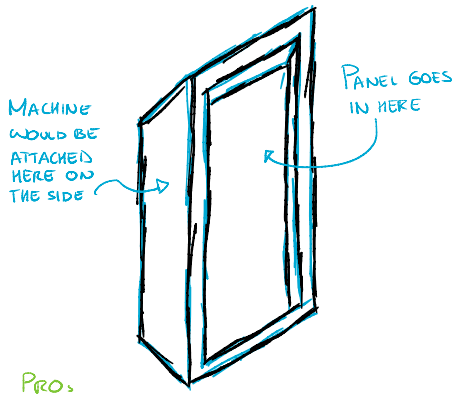
Competition
- There is no real competition at the moment as I could not find a single other machine that does the same thing.

Electronics
- There will be two main motors, one on either side and a motherboard controlling them. The motors will both be standard 50mm motors.

A quick brainstorm of ideas on how to mount the solar panel

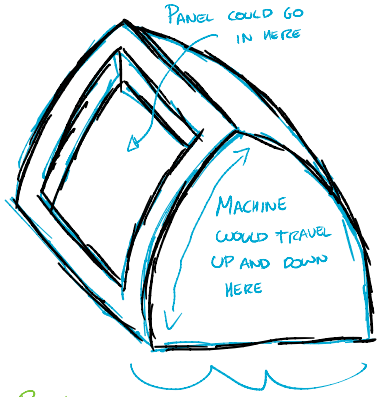


Further analysis of some sketches



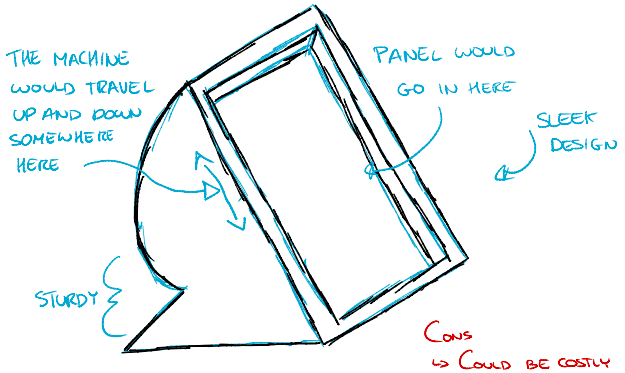
PROS
- SLEEK AND SIMPLE LOOKING
- FAIRLY SOLID

CONS
- COULD BE UNSTABLE
- WOULD BE HARD TO MANUFACTURE
- NOT SURE HOW I COULD ATTACH THE MACHINE



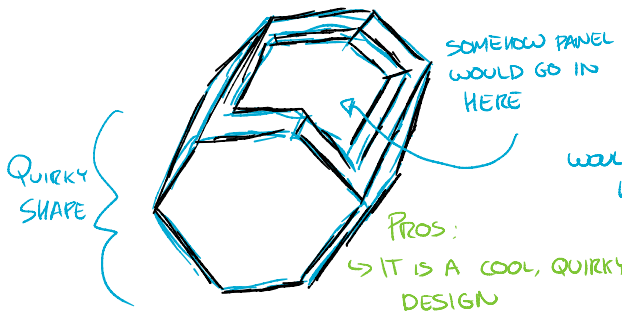
PROS
- SOLID BASE
- SOLID IN GENERAL - QUITE STURDY

CONS
- STILL NOT SURE HOW THE MACHINE COULD BE MOUNTED
- NOT SURE HOW I COULD MANUFACTURE IT



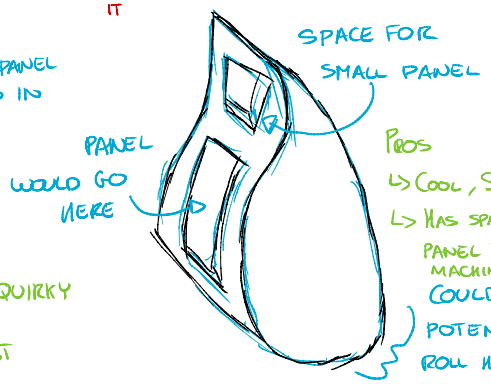
PROS
- STURDY BASE
- SLEEK DESIGN

CONS
- COULD BE COSTLY B/C OF AMOUNT OF MATERIAL NEEDED
- NOT SURE HOW THE MACHINE COULD BE ATTACHED
- NOT SURE HOW TO MANUFACTURE IT



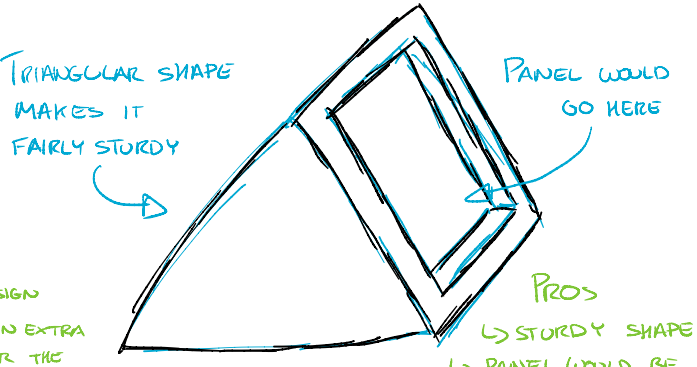
PROS:
- IT IS A COOL, QUIRKY DESIGN
- IT WOULD BE ROBUST

CONS
- IT COULD ROLL
- WOULD BE VERY COSTLY
- I DON'T KNOW HOW I COULD GET A PANEL AND MACHINE ONTO IT.



PROS
- COOL, SLEEK DESIGN
- HAS SPACE FOR AN EXTRA PANEL TO POWER THE MACHINE. COULD HOWEVER, POTENTIALLY ROLL HERE

CONS
- WOULD PROBABLY ROLL
- NOT SURE HOW TO MOUNT THE MACHINE.



PROS
- STURDY SHAPE
- PANEL WOULD BE ANGLED TOWARDS SUN

CONS
- WOULD BE COSTLY AND HARD TO MANUFACTURE
- PANEL WOULD ONLY GET SUN FOR A SMALL PERIOD OF TIME BECAUSE OF STEEP ANGLE
- NOT SURE HOW I WOULD BE ABLE TO ATTACH THE MACHINE.

CONCLUSION - IN CONCLUSION, NONE OF THESE IDEAS WORK WITH MY SPECIFICATION, THEREFORE I HAVE DECIDED TO MODEL OUT A FEW OF THEM WHILST STILL THINKING ABOUT ANY OTHER POSSIBLE SOLUTIONS.

Models and further analysis of Idea No. 7

Client Feedback

I spoke to my client about this idea and he liked the overall premise but he also brought up the problem of how the machine would attach easily and suggested that I took a look at some other options

To further investigate how well idea number seven would work, I decided to model it out of cardboard. My aim was to be enlightened as to how the aesthetics would look, and also how well it would function at actually holding the panel.

From the model, I concluded a number of things. Firstly, I learnt that it was too thin, and therefore it was quite flimsy, this would be something that, if I decided to carry on with the design, I would have to adjust. My plan was for this to then be attached to an arm, so that it would not require much ground-space However, this turned out to be impractical and trying to mount the machine onto it would also have been extremely difficult whilst keeping its sleek look. It would also need a very exact fit and therefore manufacture would be extremely hard as it would have to have extremely low tolerances. There would also be nothing to actually hold the panel in the holder apart from the sides. Furthermore, it would not be very easily adjustable from model to model of solar panel.

One of my main aims, at the beginning of the project, was for the majority of the parts to be able to be fixed, or repaired using a 3D printer, so that repairs would be relatively cheap, especially as 3D printers are becoming more and more popular and common. Not one part of this would be able to be 3D printed, which would mean that it would probably be made from plastic or metal which would not be very good for the environment.

This design would be good and reliable in the snow and cold as it is quite robust thanks to its shape. However, the electrics would be a major problem, this is because, as it is so sleek and thin, there in no obvious place to put the electronics such as the motherboard and also no easy way to protect the motors. Furthermore, the power output cables are on the back of the panel, so making it so that those cables could be accessed but weatherproofing the access point would be extremely difficult as water always finds a way to get through.

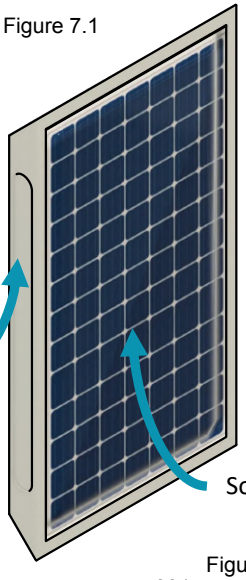
Furthermore, there would be no easy way for the machine to travel up and down the panel and things like dirt or debris could just end up being squished into the microscopic gap between the panel and the holder, and if this continued being forced in and building up, then it could lead to a major issue with the electronics or the panel itself.

For this model to work, I would have to make it so that the back of the panel could be easily accessible and also so that the motors could be mounted and protected very easily.

In conclusion, this model did help me achieve my original aim of figuring out the aesthetics and functionality of the model but unfortunately it did fall a little short and therefore I will not be using this model for my final product.

Fusion Render and Drawing, along with sketch of Idea No. 7

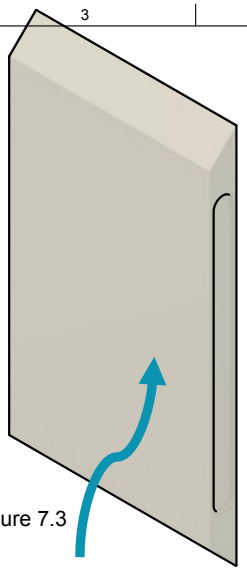
Figure 7.1



Insert for scraper to move up and down on rails possibly?

Solar Panel

Figure 7.3



Panel Holder

Figure 7.5

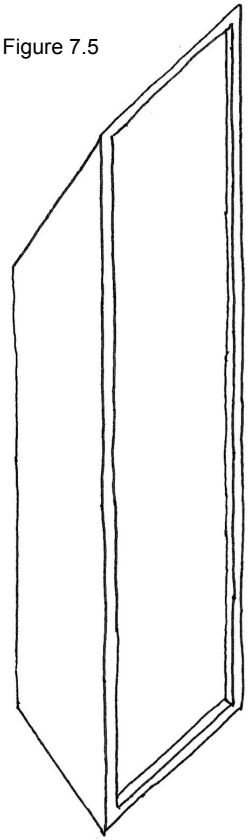


Figure 7.6

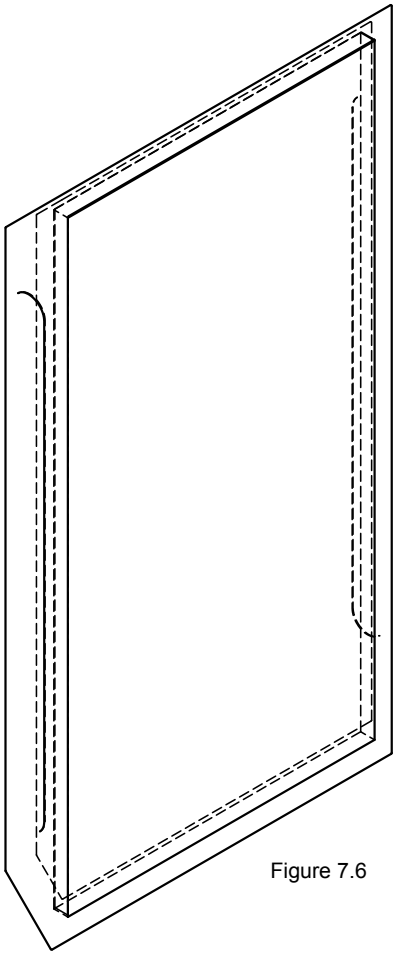
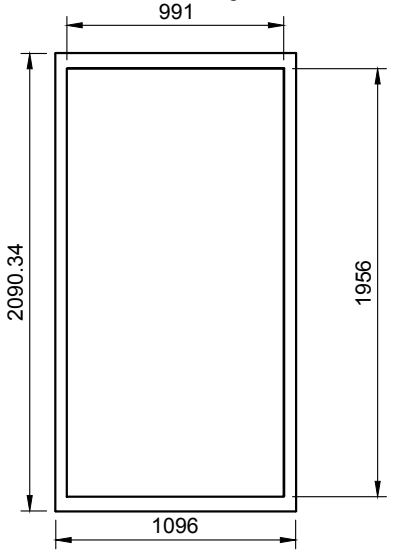


Figure 7.2



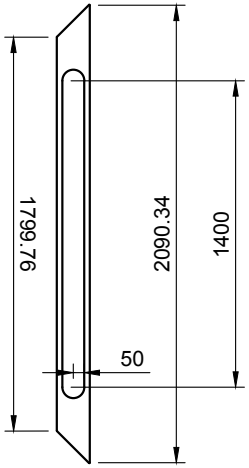


Figure 7.4

Dept.	Technical reference: D7.V1	Created by: Harry Watkins 25/09/2019	Approved by
7.1 - overall render from front (isometric NE) .7.2 - Line drawing from front 7.3 -overall render from back (isometric NW) 7.4 - line drawing from side 7.5 - Isketch 7.6 - overall line drawing of entire design (NE)		Document type: Technical Drawing	Document status
		Title: Solar Panel Clearer Idea 7 7.1-7.6	DWG No.
			Rev. / Date of issue / Sheet: 1/1

Models and further analysis of Idea No. 8

As one of the shortlisted ideas, I decided to make a model of idea number eight. One of the first things that I discovered, was just how flimsy the top panel was, but I was able to fix this very easily by adding in supports (as can be seen on the photos). I also found that creating the angles without supports was very hard as well, so I added supports there as well. However, the overall structure, once complete, was extremely strong and robust. The angles in the card gave the model so much more rigidity and helped it to function well as a strong model.

This model would definitely function well in the stormy and cold weather, furthermore, the large inside cavity would mean that there would be a lot of storage space for electronics.

Still, one problem would be that because of the large borders, it would be hard for the machine to actually travel up and down the frame. It would also be hard to attach any motors to it, especially to the side if I decided to go down the leadscrew route. Also, there is nothing keeping the solar panel from falling out and the panel is only held by the side.

This frame would also require an awful lot of material and would not be very economical because it would not be very diverse due to how snug the fit would have to be. There would have to be a completely different one from panel to panel. Moreover, due to the fact that it would need to be such a snug fit, the machining tolerances would have to be extremely low as there would have to be little, to no room for error.

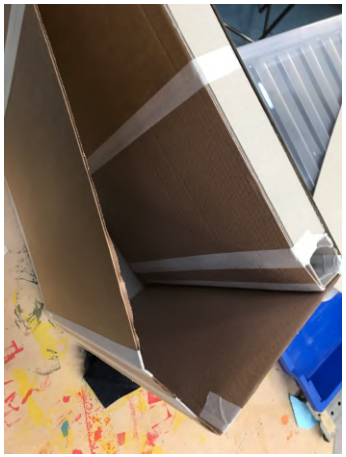
One similar problem that it would share with frame no. seven, is that if there is any gap between the sides of the panel and the holder, then any dirt or water or other debris, could end up being squished down there and could eat away at the holder or at the panel itself. Any water that may congregate there, would probably manage to find a way to get to the electrics and could damage those. Another, shared problem with frame no. seven is that one of my main aims was to make it so that most problems or breakages could be fixed with a 3D Printer and not one bit of this frame could be 3D printed.

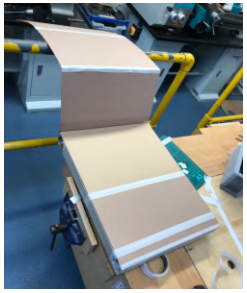
Although it is very rigid, this frame is extremely light, and would therefore still need to be bolted down to the ground or the roof, or wherever the panel will be put. In addition to that, due to the fact that the area of this holder that actually touches the ground is very large, it would take up a lot of space, especially with certain bigger panels.

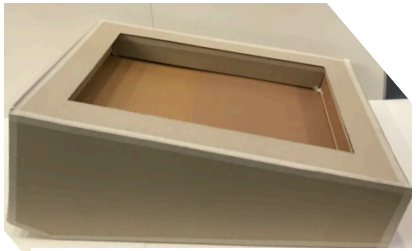
In conclusion, although it is better than frame number seven, it is still not the solution due to the fact that it would use a lot of material, and take up a a lot of unnecessary space.

Client Feedback

My client really liked the idea of this model but agreed with me that it could be very difficult for me to attach a scraper and the whole machine to the model. He suggested that I should try to find some more possible solutions to this design brief.







Fusion Render and Drawing, along with sketch of Idea No. 8

Figure 8.1

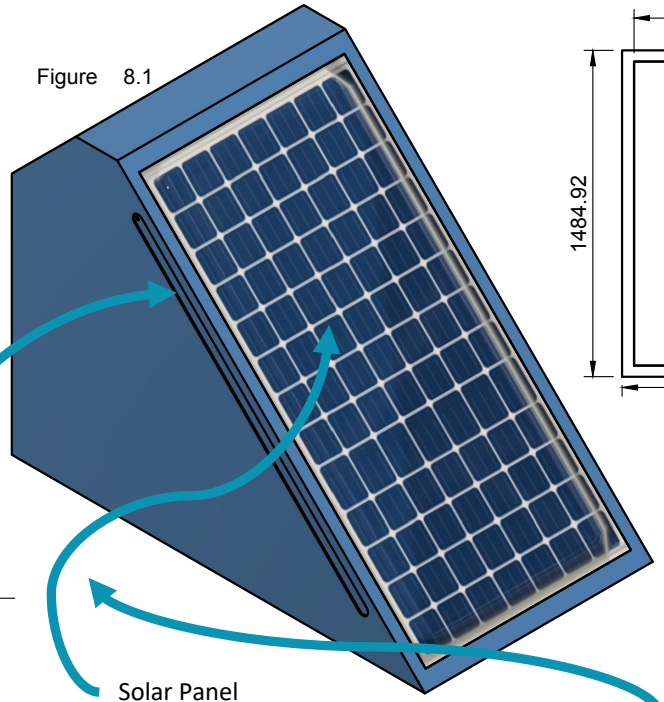


Figure 8.2

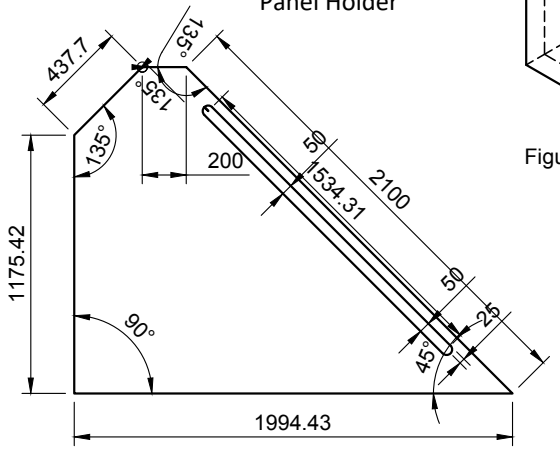


Figure 8.3

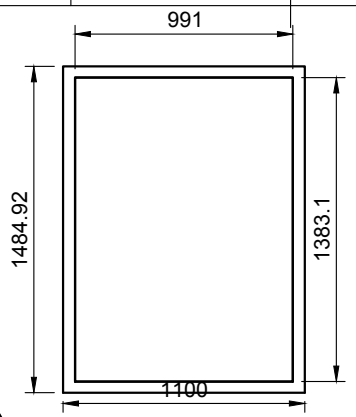


Figure 8.4

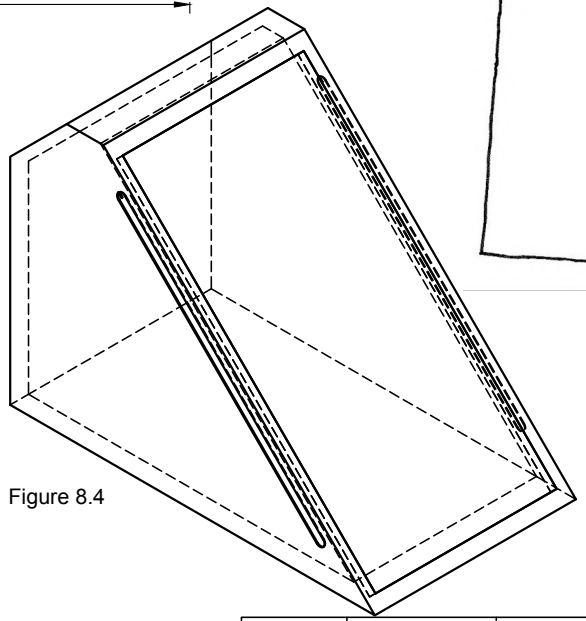
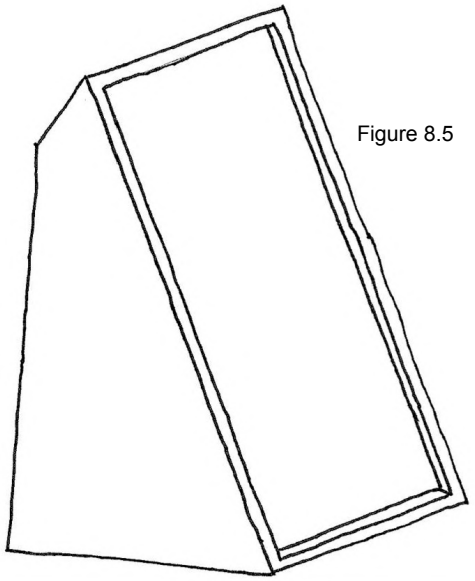
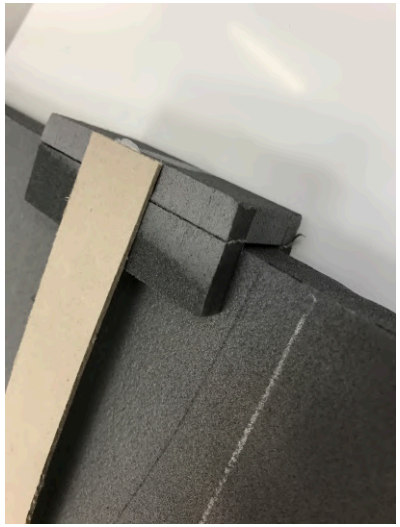


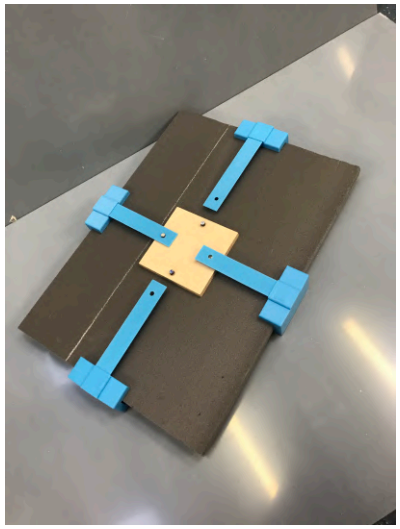
Figure 8.5

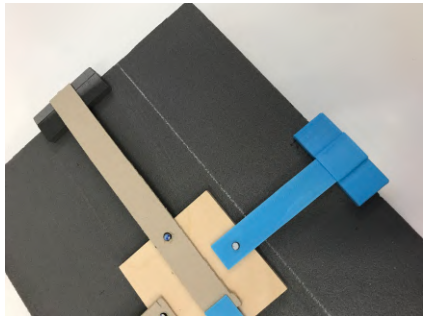


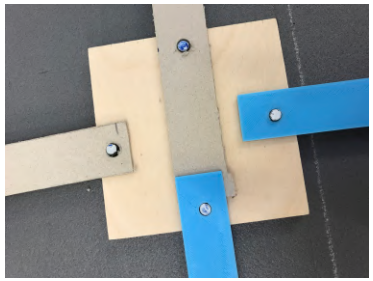
Dept.	Technical reference	Created by	Approved by
	D8.V2	Harry Watkins 25/09/2019	
8.1 - overall render from front (isometric NE) 8.2 - Line drawing from side 8.3 - line drawing from front 8.4 - line drawing (NE) 8.5 - quick original sketch	Document type		Document status
	Title: Solar Panel Clearer Idea 8 8.1-8.5		DWG No.
		Rev. / Date of issue	Sheet: 1/1

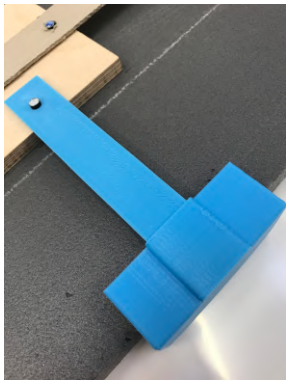
Models and further analysis of Idea No. 11

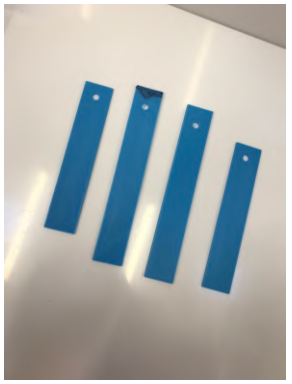












One solution to the problem of the frame not being diverse, was frame no. 11. It solved the diversity issue by using 4 clamps that were each going to be spring loaded. Frame no. 11 went through many, many iterations.

It started off with some cardboard, a piece of ply and some laser cut circles. I used a pencil and drill to estimate the holes and it must have taken me at least three times to get it perfect. However, there were two big problems. One was that the circles were 3mm tall and that was not tall enough to keep the cardboard in place. This was was easy to fix as all that I had to do was laser cut the circles out of 6mm acrylic not 3mm. The second problem, was that my cardboard and foam 'clamps' kept on breaking as the foam or the cardboard would come apart from each other. I solved this solution by using Fusion, to quickly 'CAD' them up and then get them 3D Printed. However, it still took me two attempts to get them perfect because the first time, the measurements were off. This was okay, though, because I designed it so that the 'head' of the clamp and the long stick bit had a friction fit, so I could adjust the lengths very quickly and easily.

You can see in the photos the difference between my first and my last versions of the model.

This model solved the problem of the holders not being able to be used from panel to panel without being redesigned however it still had a host of problems. One big one was that it did not provide any space for electronics, however, this could we worked around by simply adding a junction box to the back and using as many weatherproof devices as possible. Then those devices that weren't weatherproof, I could create a waterproof enclosure for. All of this could then simply be added to the frame.

This frame would function very well in the cold and bad weather as I would plan to print the final version in PETG which would be extremely strong. It would also almost completely be able to be replaced or upgraded by the user if they needed or wanted to.

In conclusion, this frame was a huge leap towards the right direction but it still held the question of how if would hold the motors and the device. I did figure out a solution (see next page) however it is very overcomplicated and could lead to many technical difficulties which I would like to avoid as I want the machine to be as simple and as user friendly as possible.

Client Feedback

I spoke to my client about his opinions on this idea. This was his favourite idea so far as it had the biggest potential to add the machine to this. He still thought that there would be some flaws to this such as the potential to weatherproof the components and thought that there could be almost too much that could go wrong. Therefore, he encouraged me, once again, to try and find an alternative solution.

Fusion Render and Drawing of Idea No. 11

Figure 11.1

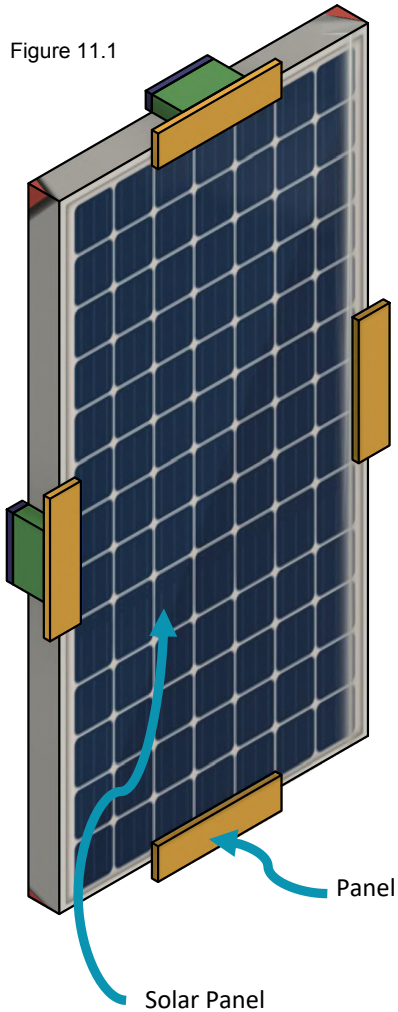


Figure 11.2

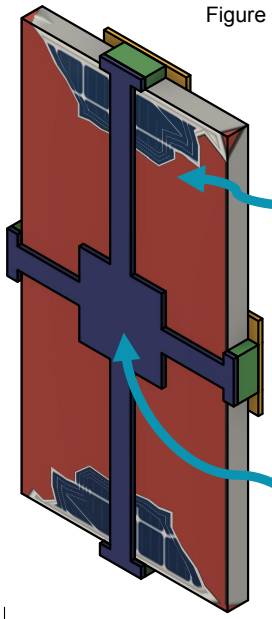


Figure 11.3

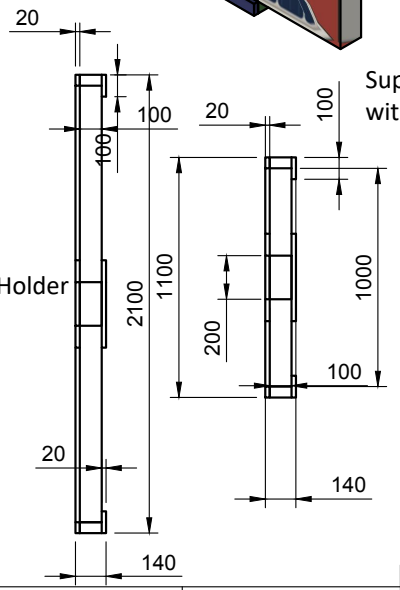


Figure 11.4

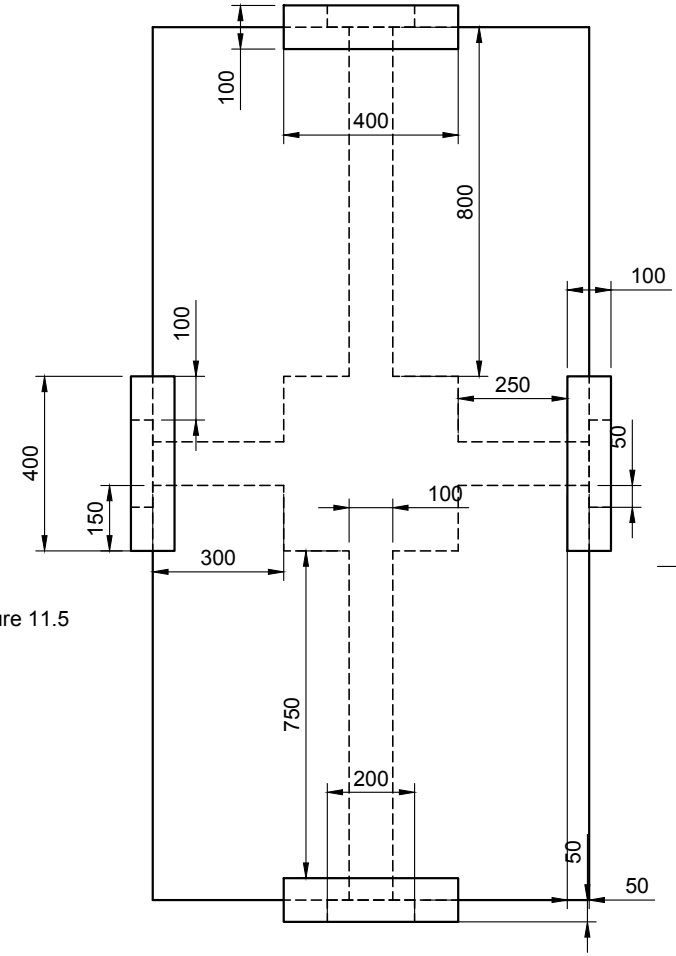


Figure 11.5

Dept.	Technical reference: D11.V2	Created by: Harry Watkins 27/09/2019	Approved by
11.1 - overall render from front (isometric NE) 11.2 - overall render from back (isometric NW) 11.3 - line drawing from side 11.4 - line drawing ffrom bottom 11.5 - overall line drawing of entire design from front		Document type: Technical Drawing	Document status
		Title: Solar Panel Clearer Idea 11 11.1-11.6	DWG No.
			Rev. / Date of issue / Sheet: 1/1

Fusion Render and Drawing of Idea No. 12 with Idea No. 11 as frame

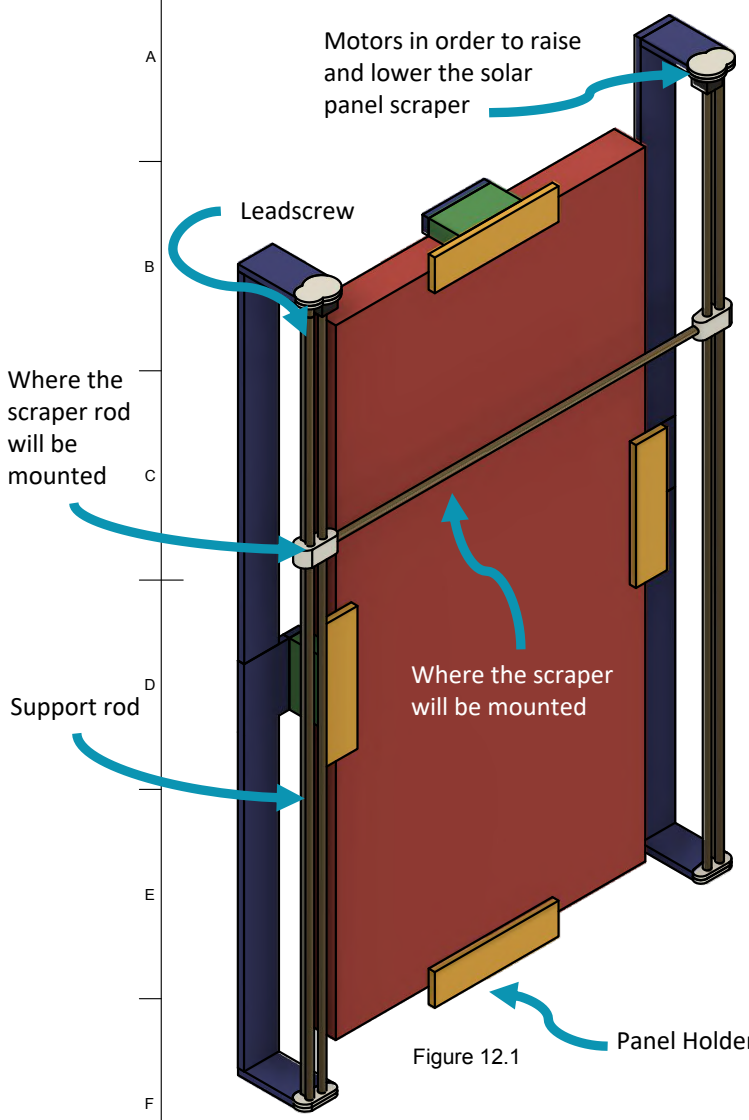


Figure 12.1

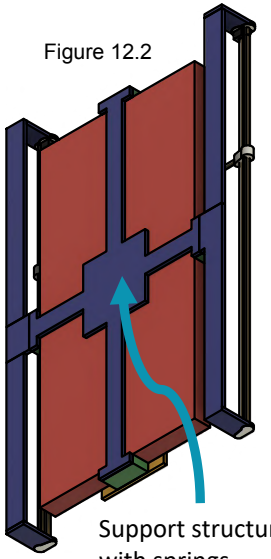


Figure 12.2

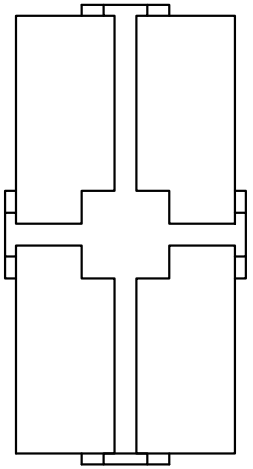


Figure 12.3

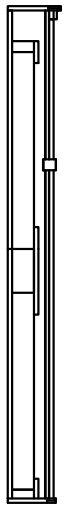


Figure 12.4

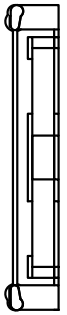


Figure 12.5

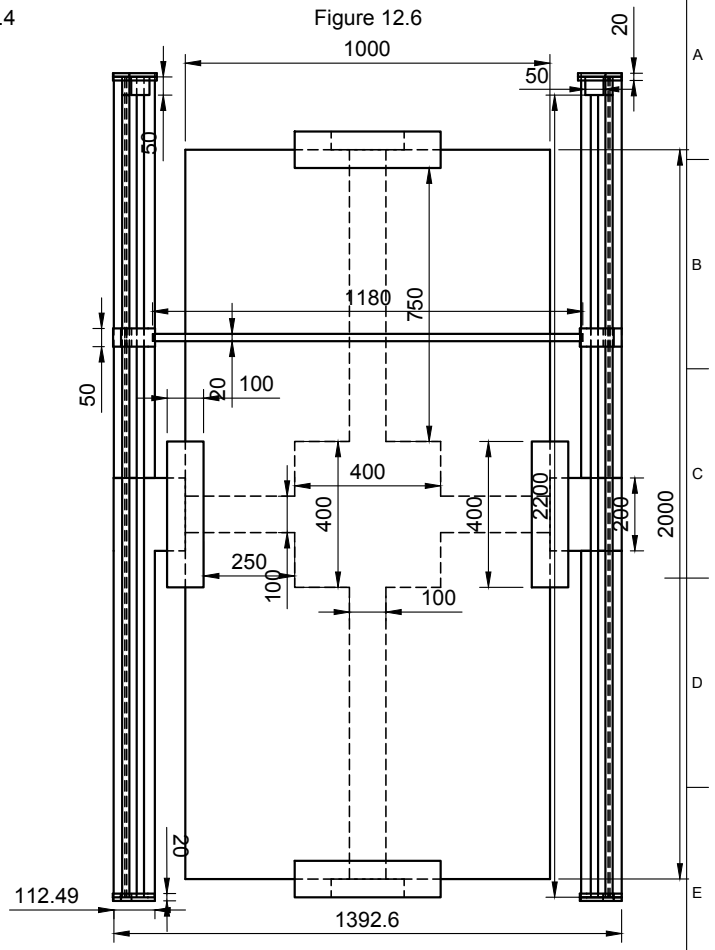


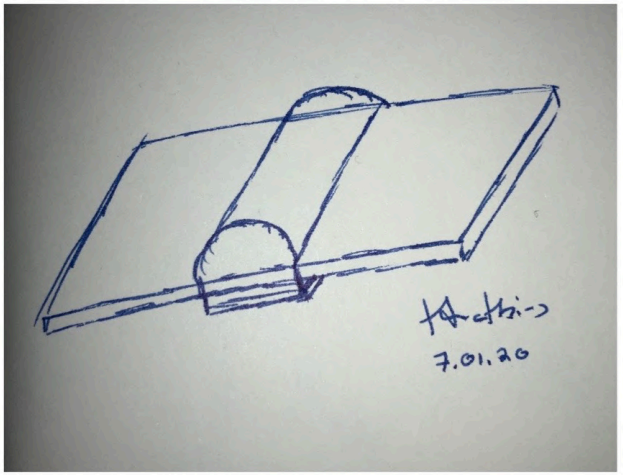
Figure 12.6

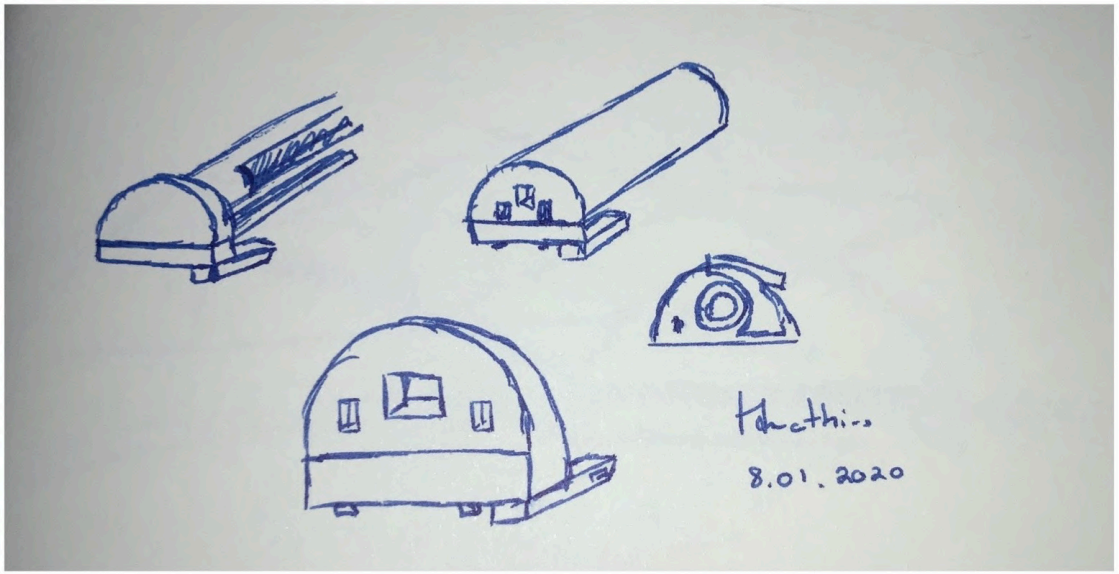
Dept.	Technical reference: D7.V2	Created by: Harry Watkins 25/09/2019	Approved by:
Notes: 12.1 - overall render from front (isometric NE) 12.2 - overall render from back (isometric NW) 12.3 - Line drawing from back 12.4 - line drawing from side 12.5 - line drawing from bottom 12.6 - overall line drawing of entire design		Document type: Technical Drawing Title: Solar Panel Cleaner Idea 12 12.1-12.6	Document status: DWG No. Rev. / Date of issue: 25/09/19 / Sheet: 1/1

I STILL DIDN'T REALLY HAVE AN IDEA I WAS HAPPY WITH SO I CONTINUED TRYING TO THINK OF AN IDEA THAT WOULD WORK.

I HAD ALWAYS HAS THIS SORT OF 'FAR FETCHED' IDEA IN MY HEAD OF MAKING A MACHINE THAT WOULD BE ONE, SEMICIRCULAR UNIT, THAT COULD TRAVEL UP AND DOWN THE PANEL ON EITHER A BELT OR 2 LEADSCREWS.

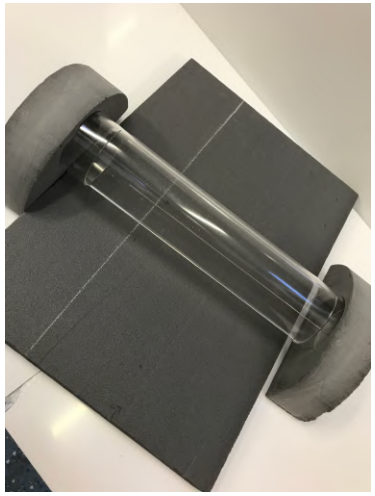
I DECIDED I SHOULD TRY AND INVESTIGATE THIS IDEA FURTHER SO I DREW UP SOME SKETCHES AND COMPLETED SOME CAD 'MOCK-UPS'





AS SOON AS I HAD THESE IDEAS I IMMEDIATELY SKETCHED ONE DOWN IN MY NOTEBOOK AND THEN, THE NEXT DAY, I TRIED OUT A FEW MORE.

Models and further analysis of Idea No. 13



At last, with idea no.13 I found my solution. It started off when I saw the ‘Geva bot’ which is a brand new machine that clears dust and dirt off of solar panels. It took me many modelling attempts to finally get the final model (as seen on the previous page). The first version was created using an foam piece the exact size of the panel and another semi-circular piece that I cut using the router. This was used so that I could have a rough feel of how the model could work and I would therefore brainstorm how to make it do that it could move up and down the panel. I used a piece of acrylic tube to simulate the brush, and out of it I used the laser cutter to cut a window for where the brush would push out.

The second stage was for me to design the model on CAD so that I could start making more specific models. I went through many, many iterations to get to the model on the previous slide. The first few, worked by going along a slide that would be attached to the panel, however, I realised that it would be much better and easier for the machine to just travel up and down on the borders of the panel. However because there had to be a big gap, the easiest way to manufacture it would be in two pieces. This then enabled me to have a slight protrusion as the border is around 1.9mm above the panel. This meant that the brush and the scraper on the machine would be able to touch the surface of the panel without exerting too much force on the panel.

This would still need to be adapted for each panel as the widths would be different however a lot of it could be 3D Printed which was one of my main aims. Thanks to the semi-circular blocks at either end, there would be a lot of space for electronics and it would be very easy to weatherproof them. It also looks incredibly sleek and would be very good in a cold, stormy environment as, thanks to the fact that the two parts of each end screw together, essentially slipping themselves to the panel, it would be hard to break or damage it.

I would plan to use a belt system to move the machine up and down the panel which could present problems both with the electronics and because the belt could slip off of the pulley.

In conclusion this is the idea that I will pursue as I think that (at least for the first prototype) it is the best solution available.

Fusion Render and Drawing of Idea 13 - I chose to make this my final idea after the client feedback and initial modeling

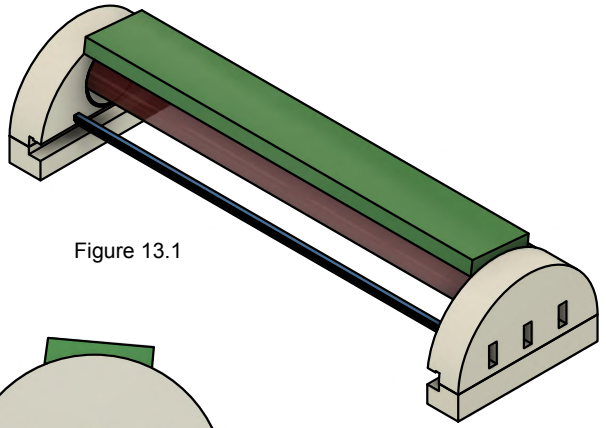


Figure 13.1

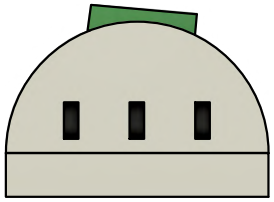


Figure 13.2

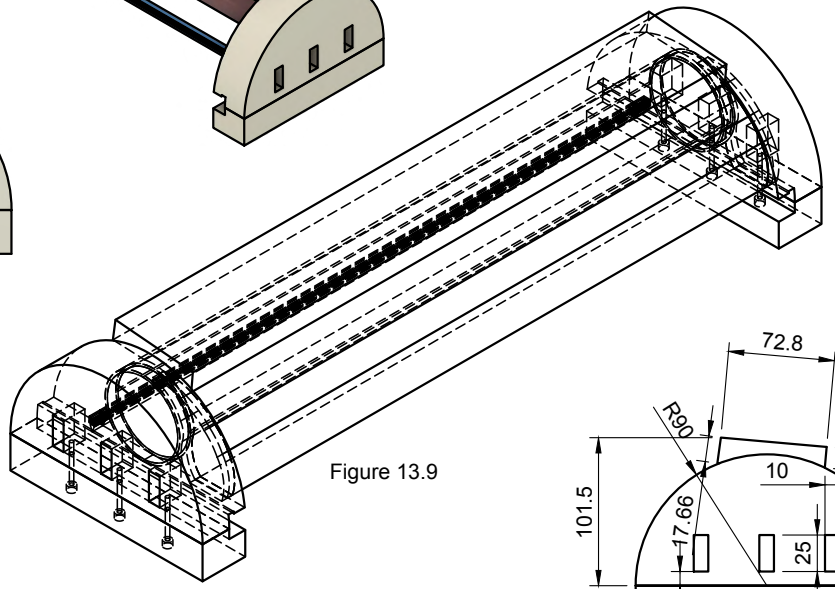


Figure 13.9

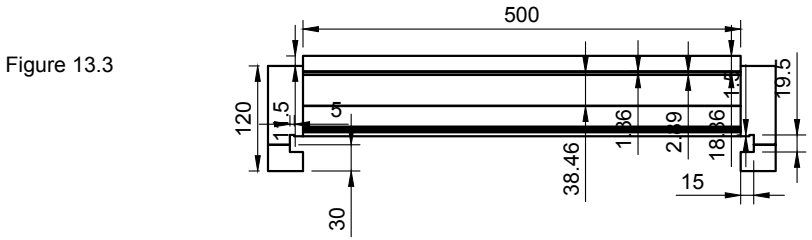


Figure 13.3

Figure 13.7

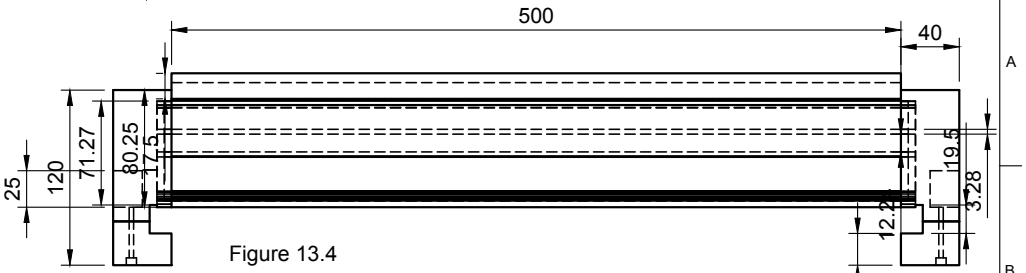


Figure 13.4

Figure 13.8

Figure 13.6

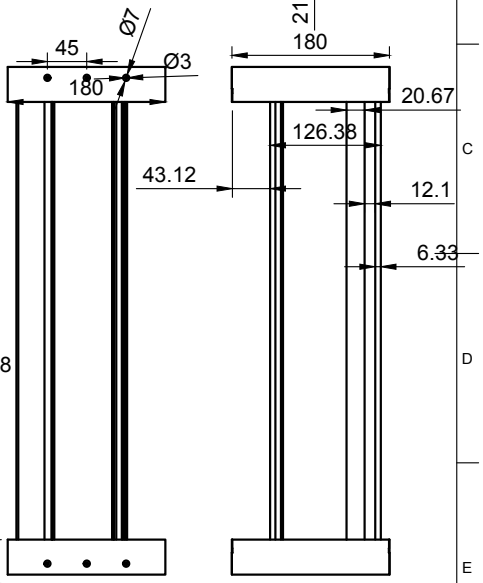
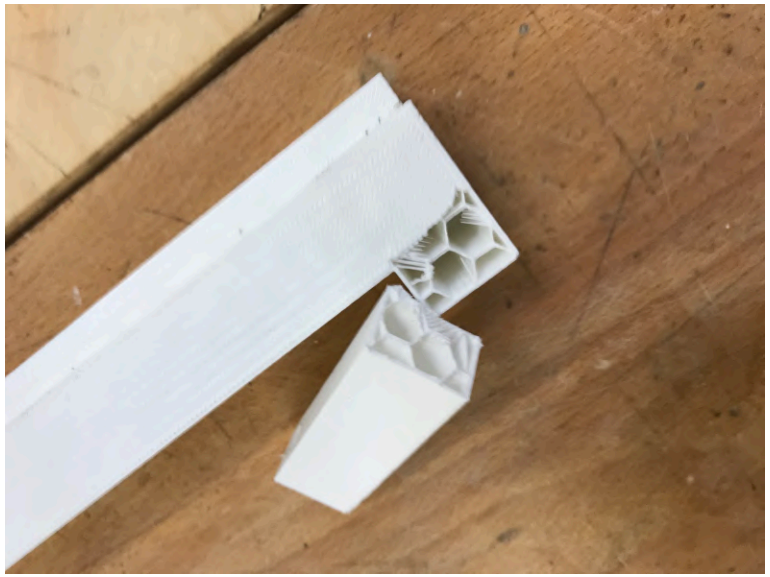


Figure 13.5

Dept.	Technical reference	Created by	Approved by
	D13.V6	Harry Watkins 15/01/2020	
13.1 - overall render from front (isometric NW) 13.2 - render from Left 13.3 - render from isometric NE 13.4 - overall line drawing of entire design 13.5 - line drawing from top 13.6 - line drawing from bottom 13.7 - line drawing from front 13.8 - line drawing from left 13.9 - overall line drawing of whole machine		Document type: Technical Drawing	Document status
		Title: Solar Panel Cleaner Idea 13 13.1-8	DWG No.
			Rev. / Date of issue: 15/01/2020 / Sheet: 1/1

Models and further analysis of Idea No. 13 – Final Idea

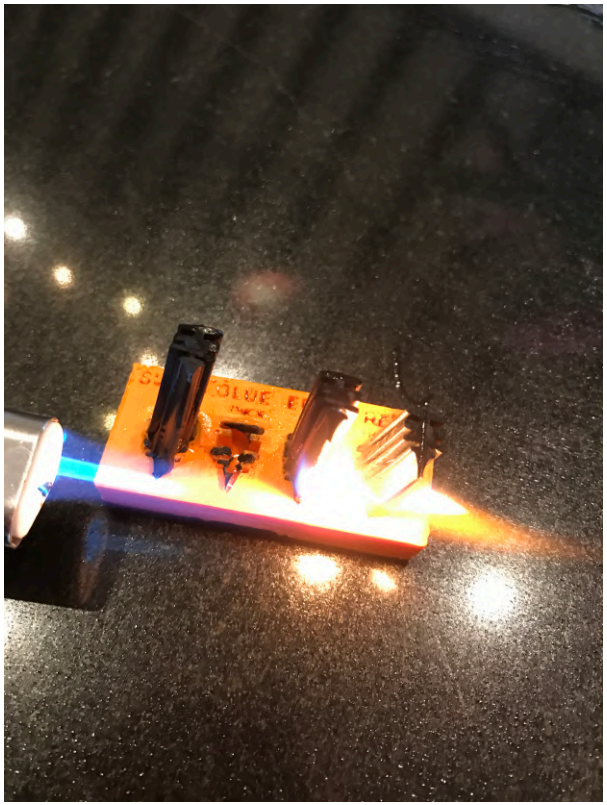


Modelling the bottom piece

I created numerous models of the bottom but eventually I got to the one above. What I found when I tested was that it was weak on the arm where the belt attached to it. I found that when put under pressure the arm simply snapped off. This made sense because it was all one piece of low infill plastic.

One solution to this would have been to have printed the model in a different orientation so that the lines of weakness would be different however there would still be a low infill which would not be very advantageous.

The other option was to change the design. I changed the design so that the belt was attached to a separate part made out of resin. This part was then bolted onto the bottom piece meaning that any tension put on it would not actually effect the bottom piece.



Solvent testing

I decided to test multiple solvents in both the cold and hot. To do this I printed off a basic holder with four slots. I narrowed it down to two solvents; super glue and epoxy resin. I used two slots for epoxy resin and slots for super glue. I put different amounts in each hole. I let it dry for 24 hours and then used pliers to try and remove each piece. The piece that was stuck down with a thick layer of super glue came out immediately.

I used a bowl of ice water to cool the plastic solvents down but the remaining three still remained in when I tried to remove each piece with pliers.

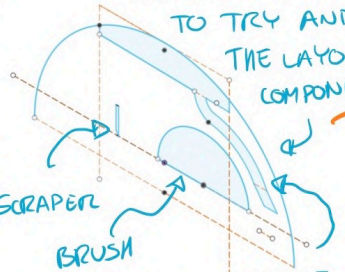
After this I used a blowtorch to heat the plastic pieces and I then used pliers again to try and remove the pieces. The remaining one with a light layer of super glue then came out.

In the end I decided to use a thick layer of epoxy resin to attach the scraper to each end.

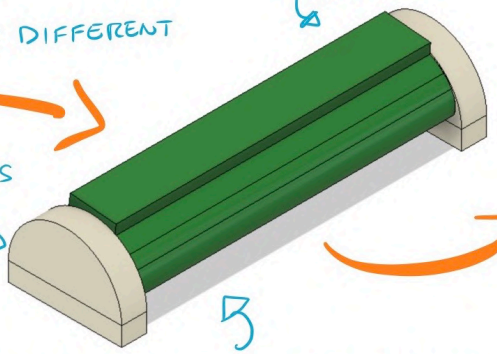
Idea No. 13 CAD Progression

I STARTED OFF WITH THIS BASIC EXTENDED HALF-CIRCLE SHAPE.

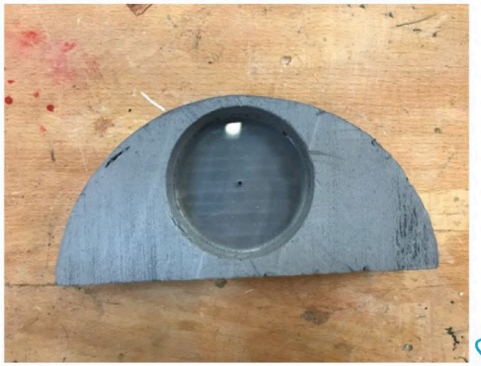
MY IDEA WAS FOR IT TO SOMEHOW TRAVEL UP AND DOWN THE PANEL



I THEN CAME UP WITH A SKETCH TO TRY AND DESIGN THE LAYOUT OF THE DIFFERENT COMPONENTS.

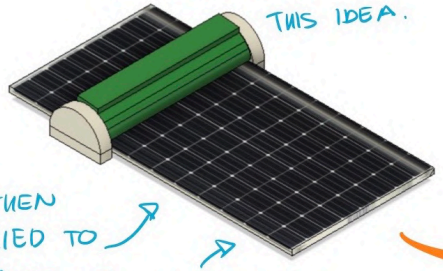


I THEN CREATED MY FIRST MOCKUP FOR THE WHOLE MACHINE WITH EACH COMPONENT.

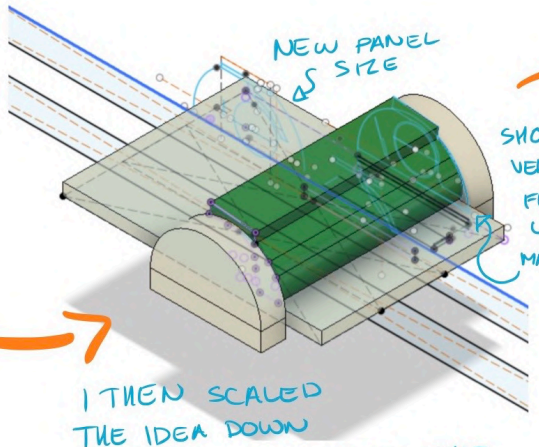


I THEN CREATED MY FIRST MODEL OF THIS IDEA WITH JUST A SIMPLE CUT OUT FOR THE BRUSH. THIS WAS SO THAT I COULD GET A BETTER IDEA OF THE FUNCTIONALITY OF THIS IDEA.

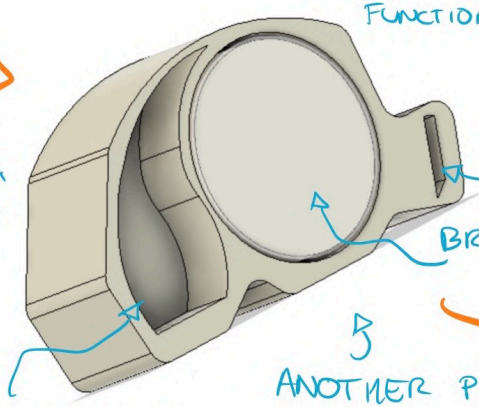
I LIKED WHAT I SAW IN THE FIRST MODEL AND THEREFORE DECIDED TO PURSUE THIS IDEA.



I THEN TRIED TO FIGURE OUT WHAT IT WOULD LOOK LIKE ON A PANEL AND I COULD THEN DO SOME BRAINSTORMING OF HOW IT COULD ATTACH TO THE PANEL.



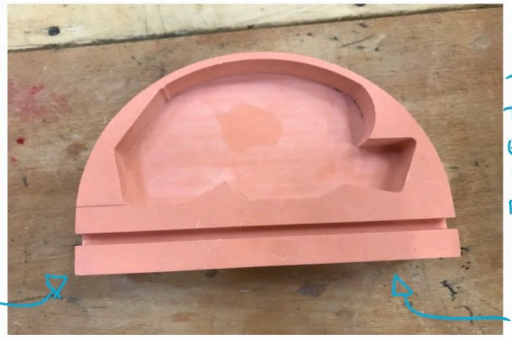
I THEN SCALED THE IDEA DOWN TO THE SMALLER PANEL THAT I DECIDED TO MAKE THIS PROTOTYPE ON. I IMMEDIATELY NOTICED IT LOOKED SLIGHTLY OUT OF PROPORTION SO I HAD TO ADJUST THE SIZES



ANOTHER PROBLEM ON MY MIND AT THIS POINT WAS HOW I WOULD DESIGN THE END PIECE. MY LATEST IDEA WAS TO 3D PRINT AN INSERT THAT WOULD SLOT INTO A PIECE WITH A HOLE CUT OUT ON THE CNC ROUTER.

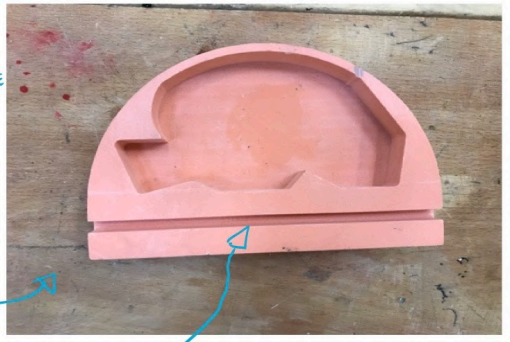
Idea No. 13 CAD Progression

3D PRINTED INSERT OF CAD MODEL FROM PREVIOUS SLIDE.

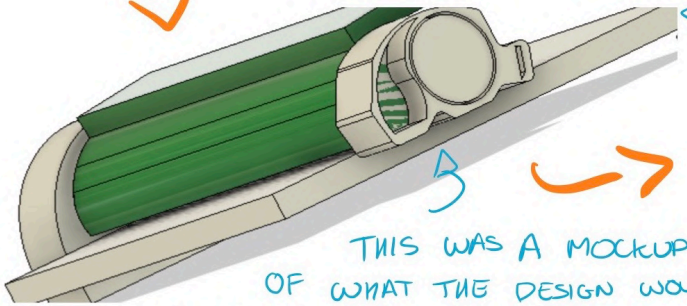


I MADE SURE THAT THE HOLE CUT OUT HAD A LARGE ENOUGH TOLERANCE SO THAT THEY WOULD FIT TOGETHER

THESE WERE THE TWO ENDS WITH THE SLOT FOR THE INSER CUT OUT WITH A CNC ROUTER

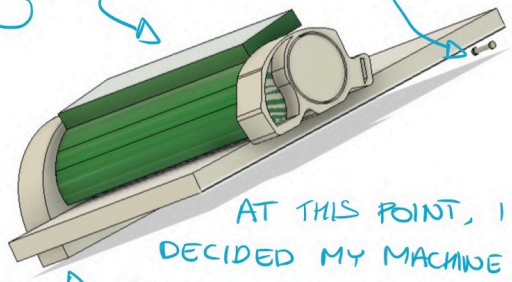


THIS SLOT WAS CREATED AS MY SOLUTION TO THE MOVEMENT PROBLEM WAS FOR IT TO MOVE UP AND DOWN ON A RAIL THAT WOULD SLOT IN HERE.



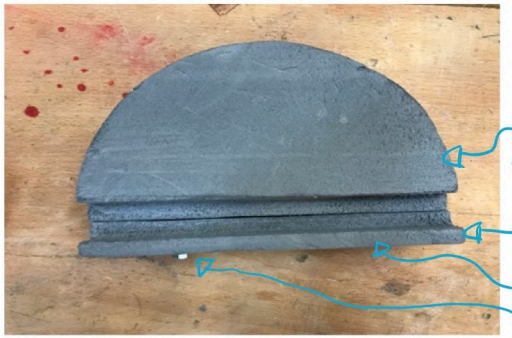
THIS WAS A MOCKUP OF WHAT THE DESIGN WOULD LOOK LIKE IF I CHOSE TO USE THE INSERT.

I ALSO CHANGED THE SIZES TO MAKE IT MORE IN-PROPORTION



ROLLERS

AT THIS POINT, I DECIDED MY MACHINE WOULD TRAVEL BACK AND FORTH ON A BELT SYSTEM SO I ADDED A SET OF ROLLERS TO THE DESIGN

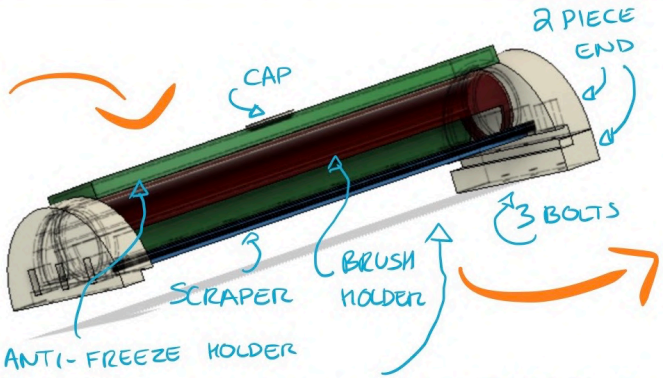


TWO PIECES

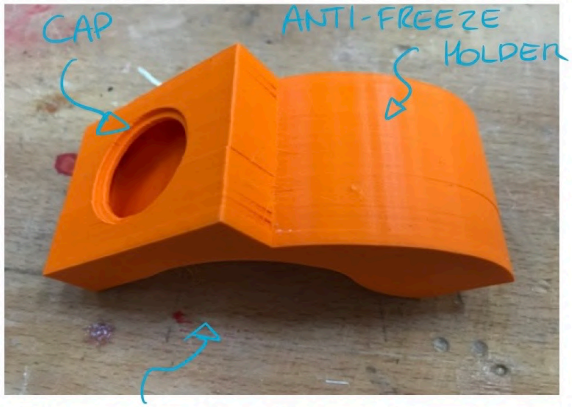
BOLTED TOGETHER

I NEEDED TO FIGURE OUT A MORE PRACTICAL WAY OF THE MACHINE TRAVELING UP AND DOWN THE PANEL THAN THE SLOT AND RAIL. TO DO THIS, I CUT A PIECE OF FOAM TO SIZE AND SPENT SOME TIME TRYING TO FIGURE IT OUT.

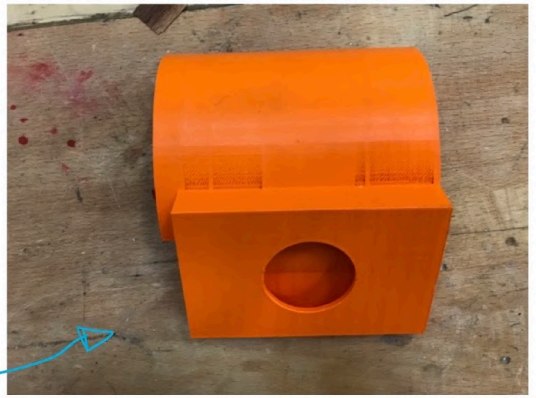
Idea No. 13 CAD Progression Continued



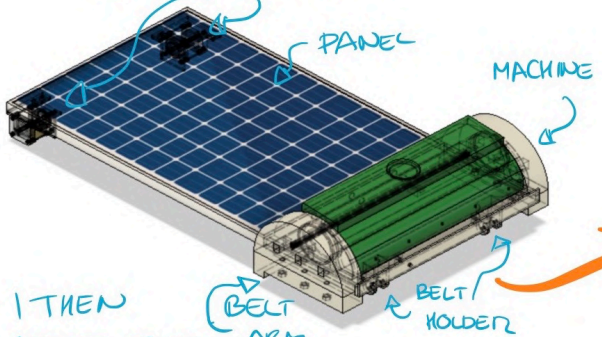
I THEN DECIDED TO MODEL UP THIS IDEA ON FUSION TO SEE HOW I COULD INTEGRATE IT WITH THE REST OF MY DESIGN.



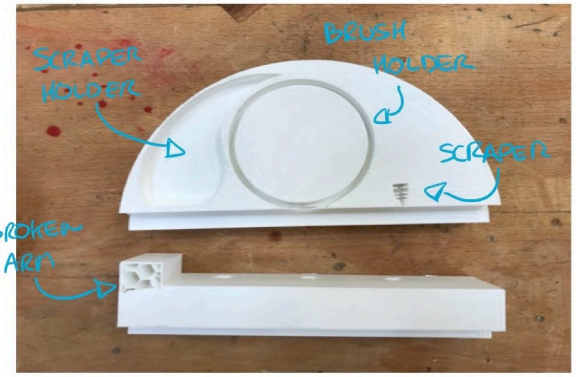
THIS WAS MY FIRST MODEL OF THE ANTI-FREEZE HOLDER WHICH I USED TO TEST OUT THE HOLES AND ALSO HOW THE CAP WOULD FIT.



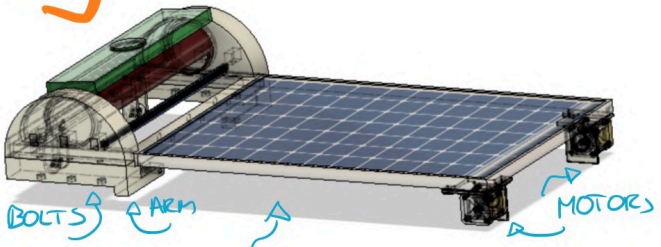
I THEN USED THIS SECOND MODEL TO TRY OUT THE END AND SEE HOW WELL IT WOULD FIT IN THE END.



I THEN ADDED TWO MOTORS TO THE BOTTOM OF THE PANEL AND UPDATED THE BELT PULLEY SYSTEM ADDING TWO ARMS

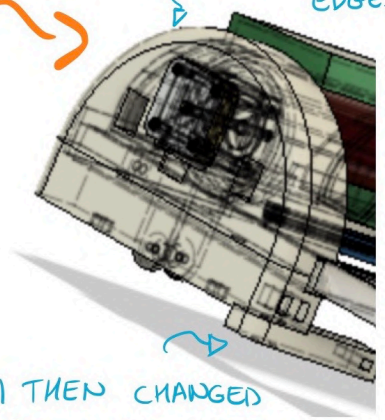


I THEN PRINTED OUT A NEW VERSION OF THE END HOWEVER I QUICKLY DISCOVERED A WEAKNESS IN THE ARM.

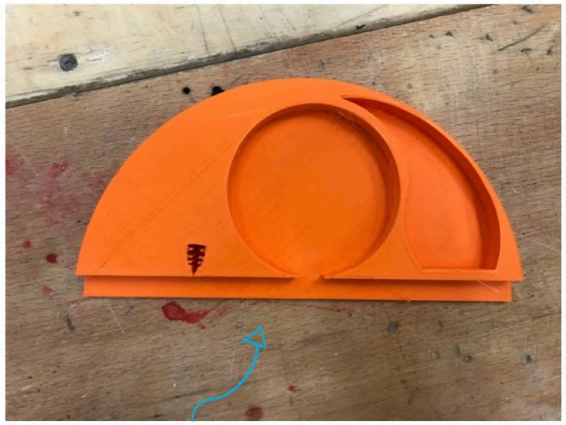


I THEN MADE SOME IMPROVEMENTS TO THE END PIECES MAKING THEM CLAMP ON BETTER TO THE PANEL.

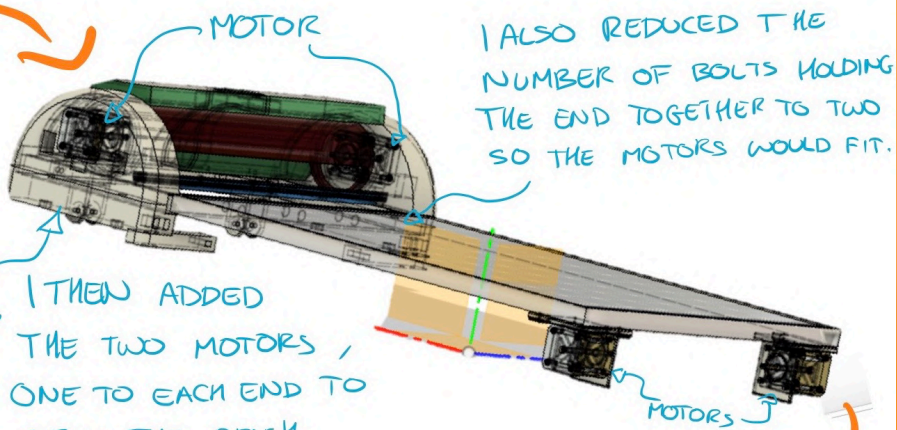
Idea No. 13 CAD Progression Continued



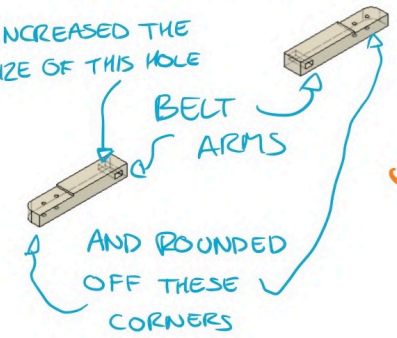
I THEN CHANGED THE ARMS SO THAT THEY WERE BOLTED IN AND COULD BE MANUFACTURED WITH A HIGHER INFILL

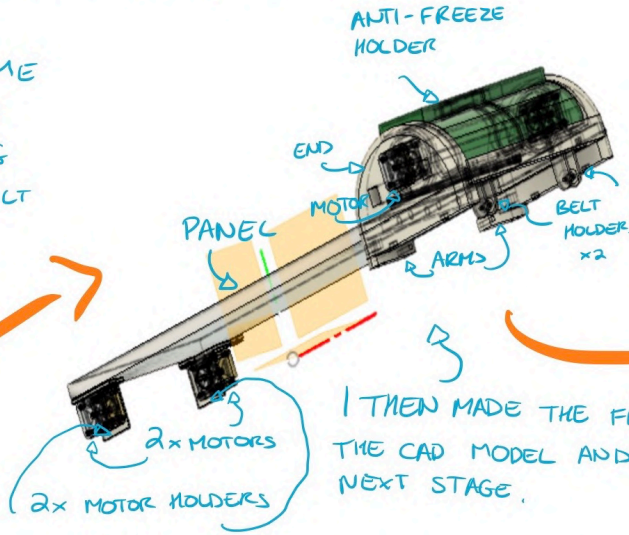


AFTER THIS, I PRINTED OFF ANOTHER VERSION OF THE TOP END TO CHECK AGAIN THE SIZES OF EACH COMPONENTS

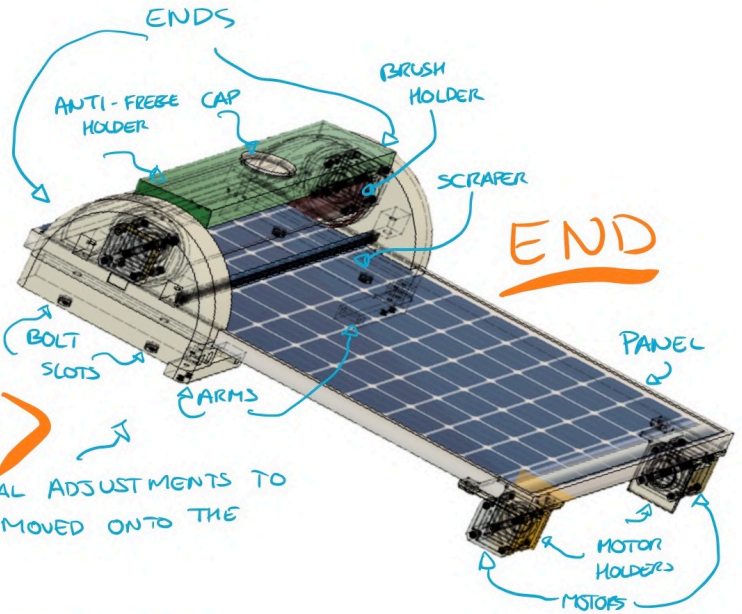


I THEN MADE SOME ADJUSTMENTS TO THE ARMS HOLDING THE BELT



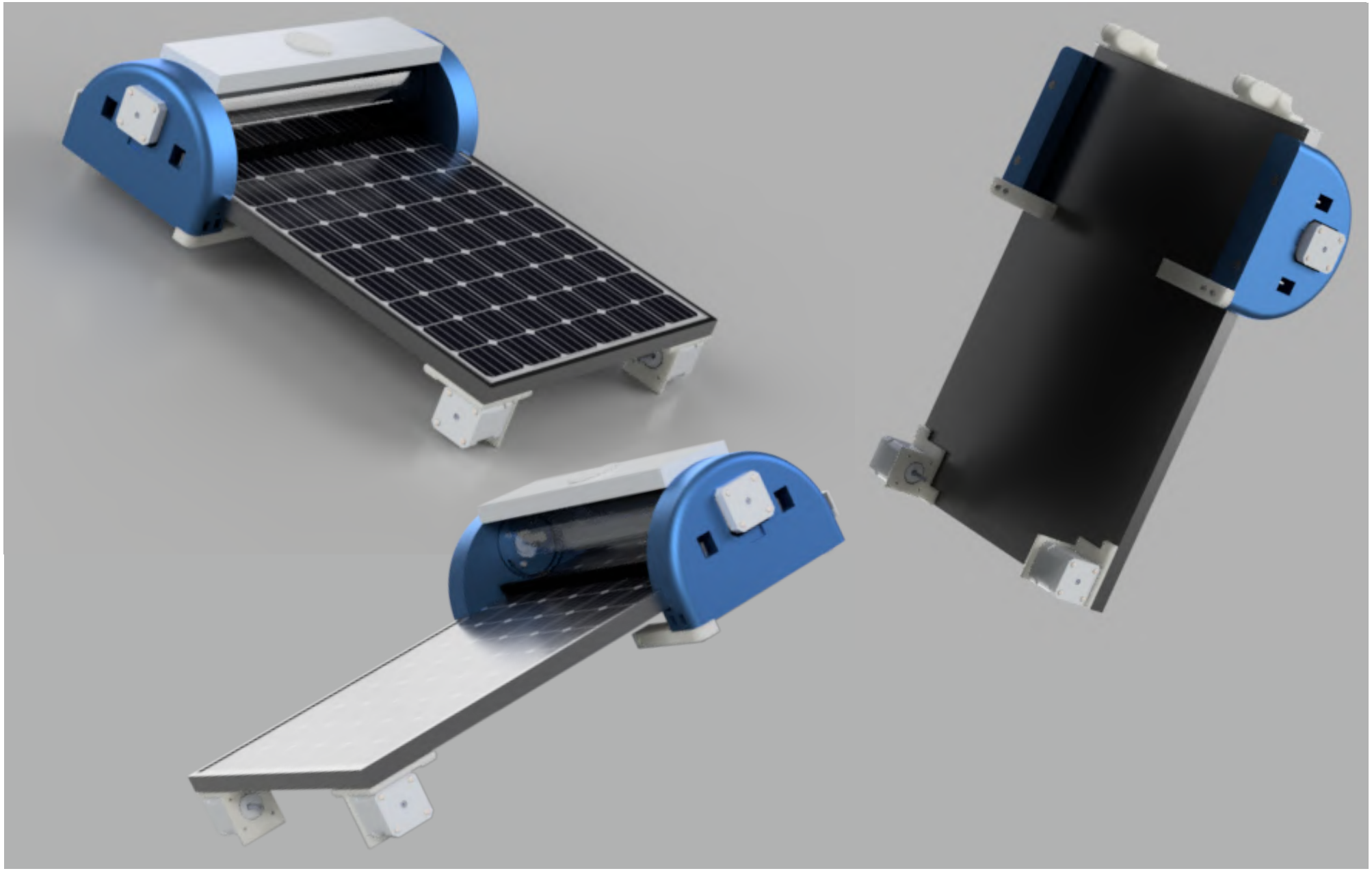


I THEN MADE THE FINAL ADJUSTMENTS TO THE CAD MODEL AND MOVED ONTO THE NEXT STAGE.

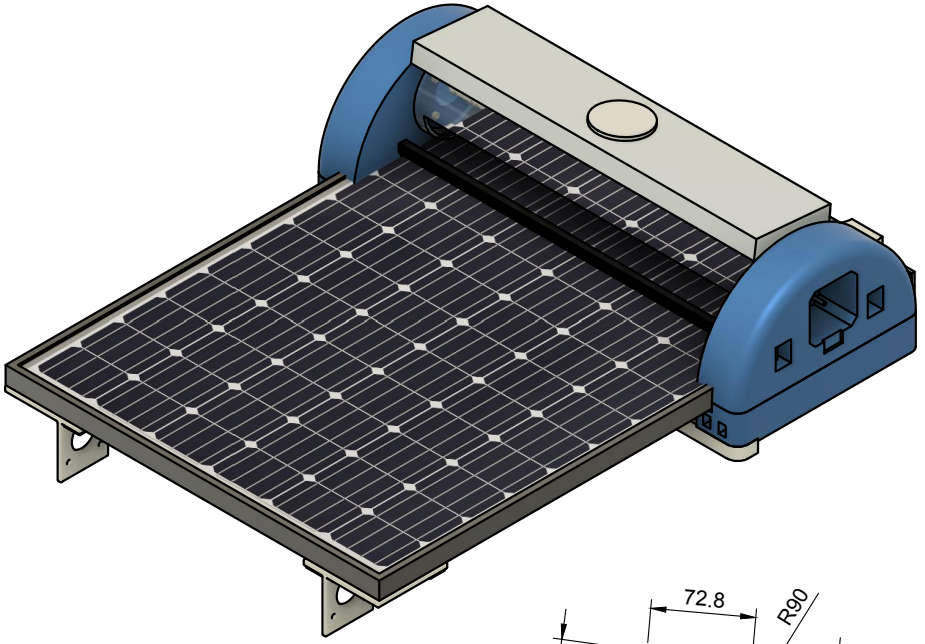


There were 84 versions in total for this idea alone

Idea No. 13 - Final Version – Full Renders

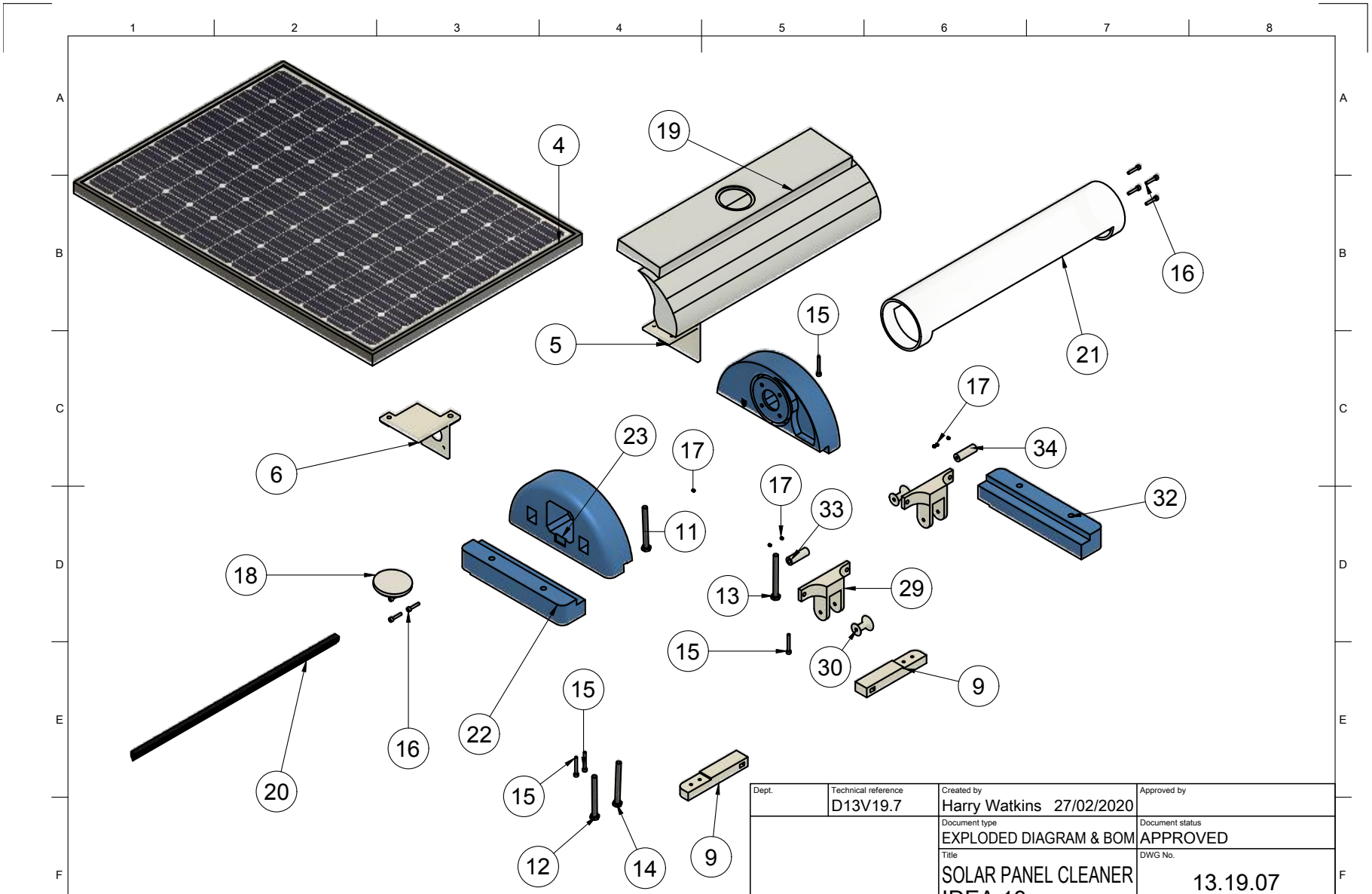


Idea No. 13 – Technical Drawing



Dept.	Technical reference	Created by	Approved by
	D13V19.8	Harry Watkins 27/02/2020	
		Document type: TECHNICAL DRAWING	Document status: APPROVED
		Title: SOLAR PANEL CLEANER D13 V19.8	DWG No.: 13.19.08
			Rev. / Date of issue: 27/02/2020 / Sheet: 1/1

Idea No. 13 – Exploded Diagram



Dept.	Technical reference	Created by	Approved by
	D13V19.7	Harry Watkins 27/02/2020	
		Document type: EXPLODED DIAGRAM & BOM	Document status: APPROVED
		Title: SOLAR PANEL CLEANER IDEA 13 V19.7	DWG No.: 13.19.07
			Rev.: 197 / Date of issue: 27/02/2020 / Sheet: 1/2

Idea No. 13 – Bill of Manufacture

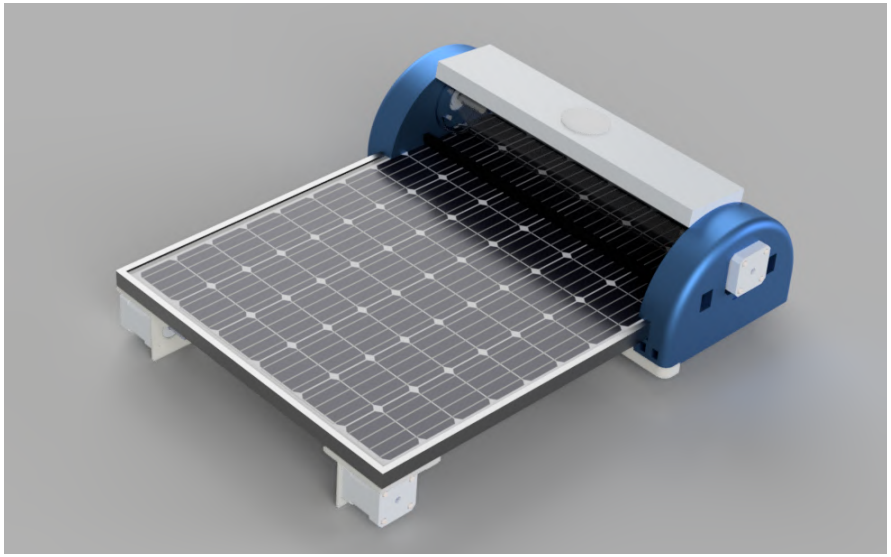
Parts List				
Item	Qty	Part Number	Part Name	Material
4	1	Actual solar panel dimen	Actual solar panel dimen v7	Steel
5	1	NEMA 17 Stepper Motor Assembly L	NEMA 17 Stepper Motor Assembly L v8	Acetal Resin, White
6	1	NEMA 17 Stepper Motor Assembly R	NEMA 17 Stepper Motor Assembly R v11	Acetal Resin, White
7	1	NEMA 17 Stepper Motor	NEMA 17 Stepper Motor v3	Steel
8	1	NEMA 17 Stepper Motor LEFT	NEMA 17 Stepper Motor LEFT	Steel
9	1	17 for arm	17 for arm v13	Acetal Resin,
10	1	NEMA 17 Stepper Motor RIGHT	NEMA 17 Stepper Motor RIGHT	Steel
11	1	Hex-bolts_asm	Hex-bolts_asm v2	Steel
12	1	M6x^) HEX RIGHT 1	M6x^) HEX RIGHT 1	Steel
13	1	M6x60Bolt 1 LEFT	M6x60Bolt 1 LEFT	Steel
14	1	M6x60 Bolt 1 Right	M6x60 Bolt 1 Right	Steel
15	5	DIN_912-M3x25	DIN_912-M3x25 v1	Steel
16	7	DIN_912-M3x16	DIN_912-M3x16 v1	Steel
17	6	Grub Screw	Grub Screw v1	SOLIDWORKS Materials|AISI 316 Stainless Steel Sheet (SS)
18	1	Cap	Cap	Rubber

Parts List				
Item	Qty	Part Number	Part Name	Material
19	1	Anti-Freeze Holder	Anti-Freeze Holder	ABS Plastic
20	1	Scraper	Scraper	Rubber, Black
21	1	Brush holder	Brush holder	Acrylic, Clear
22	1	Left End Bottom	Left End Bottom	ABS Plastic
23	1	Left End Top	Left End Top	ABS Plastic
24	1	Panel End	Panel End	Aluminum
25	1	Rotating piece R	Rotating piece R	Acetal Resin, White
26	1	COMPONENT	COMPONENT	
27	1	Pulley holder right	Pulley holder right	Acetal Resin, White
28	1	COMPONENT (1)	COMPONENT (1)	
29	1	Pulley holder Left (1)	Pulley holder Left (1)	Acetal Resin, White
30	1	Rotating piece L (1)	Rotating piece L (1)	Acetal Resin, White
31	1	Right End Top	Right End Top	ABS Plastic
32	1	Right End Bottom	Right End Bottom	ABS Plastic
33	1	Motor - brush adaptor Left	Motor - brush adaptor Left	Steel
34	1	Motor - brush adaptor Right	Motor - brush adaptor Right	Steel

Dept.	Technical reference: D13V19.7	Created by: Harry Watkins 27/02/2020	Approved by:
		Document type: EXPLODED DIAGRAM & BOM	Document status: APPROVED
		Title: SOLAR PANEL CLEANER IDEA 13 V19.7	DWG No.: 13.19.07
			Rev.: 197 / Date of issue: 27/02/2020 / Sheet: 2/2

Idea No. 13 – Materials List

Part No.	Description	Material	Quantity	Unit Cost	Total Cost
4	Solar Panel	Stainless Steel	1	20	20
5	Left Motor Holder	Resin	1	5.20	5.20
6	Right Motor Holder	Resin	1	5.20	5.20
7,8,10	Stepper Motor	Multiple	4	5	10
9	Arms for belt	Resin	2	2.08	4.16
11,12, 13&14	M6x60 Bolt	Stainless Steel	4	0.10	0.40
15	M3x25 Bolt	Stainless Steel	4	0.05	0.20
16	M3x16 Bolt	Stainless Steel	4	0.05	0.20
17	Grub Screws	Stainless Steel	6	0.02	0.12
18	Anti-freeze holder cap	Rubber	1	1.16	1.16
19	Anti-freeze holder	PLA	1	9.49	9.49
20	Scraper	Rubber	1	0.50	0.50
21	Brush holder	Clear Acrylic	1	5	5
22	Left End Bottom	PLA	1	1.54	1.54
23	Left End Top	PLA	1	2.99	2.99
25, 30	Rotating Piece Right	Resin	2	0.46	0.92
27, 19	Pulley Holder	Resin	2	6.85	13.7
31	Right End Top	PLA	1	2.98	2.98
32	Right End Bottom	PLA	1	1.54	1.54
33	Motor Brush Adaptor Left	Stainless Steel	1	1	1
34	Motor Brush Adaptor Right	Stainless Steel	1	1	1



Idea No. 13 – Plan for Manufacture

Part Name // Material	Process, tools and techniques	Start Date	Time Allowed	End Date	Risk Assessment	Quality Control	Progress Report
Motor Holder Left // White Resin	Form Labs Form 2 // SLA Printing	24 Jan 2020	8 Hours	24 Jan 2020	I will be careful as the Form 2 has hot moving parts. To ensure I stay safe I will follow all safety precautions ensuring that all safety lids are shut.	I will make sure that the resin is in date and the bed was flat.	Took two attempts but COMPLETED
Motor Holder Right // White Resin	Form Labs Form 2 // SLA Printing	25 Jan 2020	8 Hours	25 Jan 2020	I will be careful as the Form 2 has hot moving parts. To ensure I stay safe I will follow all safety precautions ensuring that all safety lids are shut.	I will make sure that the resin is in date and the bed was flat.	Took two attempts but COMPLETED
Bottom Left // Matte Blue rPLA	Makerbot Replicator 2, 3D Printing	11 Feb 2020	6 Hours 8 Minutes	11 Feb 2020	I used PLA to avoid producing fumes. There are hot moving parts but to ensure I remained safe, I used a Perspex acrylic screen.	I made sure that the filament was fresh and dry and the bed was level.	COMPLETED
Top Left // Matte Blue rPLA	Makerbot Replicator 2, 3D Printing	10 Feb 2020	12 Hours	10 Feb 2020	I used PLA to avoid producing fumes. There are hot moving parts but to ensure I remained safe, I used a Perspex acrylic screen.	I made sure that the filament was fresh and dry and the bed was level.	COMPLETED
Bottom Right // Matte Blue rPLA	Makerbot Replicator 2, 3D Printing	11 Feb 2020	6 Hours 6 Minutes	11 Feb 2020	I used PLA to avoid producing fumes. There are hot moving parts but to ensure I remained safe, I used a Perspex acrylic screen.	I made sure that the filament was fresh and dry and the bed was level.	COMPLETED
Top Right // Matte Blue rPLA	Makerbot Replicator 2, 3D Printing	3 Feb 2020	12 Hours	3 Feb 2020	I used PLA to avoid producing fumes. There are hot moving parts but to ensure I remained safe, I used a Perspex acrylic screen.	I made sure that the filament was fresh and dry and the bed was level.	COMPLETED
Anti-Freeze Holder // White rPLA	Custom built 3D Printer, 3D Printing	19 Feb 2020	16 Hours	20 Feb 2020	I used PLA to avoid producing fumes. There are hot moving parts but to ensure I remained safe, I used a Perspex acrylic screen.	I will make sure that the resin is in date and the bed is flat.	COMPLETED

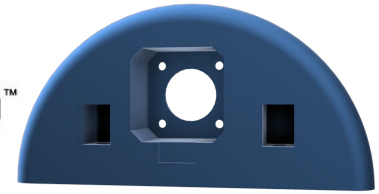
Idea No. 13 – Plan for Manufacture

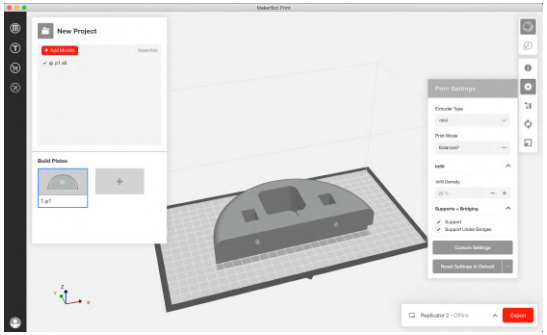
Part Name // Material	Process, tools and techniques	Start Date	Time Allowed	End Date	Risk Assessment	Quality Control	Progress Report
Anti-Freeze Holder Cap // Grey Rubber	Form Labs Form 2 // SLA Printing	10 Feb 2020	8 Hours	10 Feb 2020	I will be careful as the Form 2 has hot moving parts. To ensure I stay safe I will follow all safety precautions ensuring that all safety lids are shut.	I will make sure that the resin is in date and the bed was flat.	COMPLETED
Brush Holder // Clear Acrylic	Cut with Laser Cutter	10 Feb 2020	1 Hour	10 Feb 2020	I made sure that I did not look directly into the laser and that the extractor fan was turned on.	I focussed the laser and calibrated it to make sure it cut accurately.	COMPLETED
Brush // Guttridge	Trim with secateurs	19 Feb 2020	1 Hour	19 Feb 2020	I was careful to ensure that I did not cut myself by accident with the secateurs.	I used a ruler and precision cutters to trim the Guttridge to the correct length.	COMPLETED
Brush and Motor adapter Right // Aluminium	Use a lathe	14 Feb 2020	20 Minutes	14 Feb 2020	I made sure that there was good lighting and that I wore safety glasses as well as adjusting the safety screen so that it was covering the metal.	I used a pair of callipers to ensure the tools were the correct size.	COMPLETED
Brush and Motor adapter Left // Aluminium	Use a lathe	14 Feb 2020	20 Minutes	14 Feb 2020	I make sure that there was good lighting and that I wore safety glasses as well as adjusting the safety screen so that it was covering the metal.	I used a pair of callipers to ensure the tools were the correct size.	COMPLETED
Belt Holder Left // Blue Resin	Form Labs Form 2 // SLA Printing	30 Jan 2020	10 Hours	30 Jan 2020	I will be careful as the Form 2 has hot moving parts. To ensure I stay safe I will follow all safety precautions ensuring that all safety lids are shut.	I will make sure that the resin is in date and the bed was flat.	COMPLETED
Belt Holder Right // Blue Resin	Form Labs Form 2 // SLA Printing	31 Jan 2020	10 Hours	31 Jan 2020	I will be careful as the Form 2 has hot moving parts. To ensure I stay safe I will follow all safety precautions ensuring that all safety lids are shut.	I will make sure that the resin is in date and the bed was flat.	COMPLETED

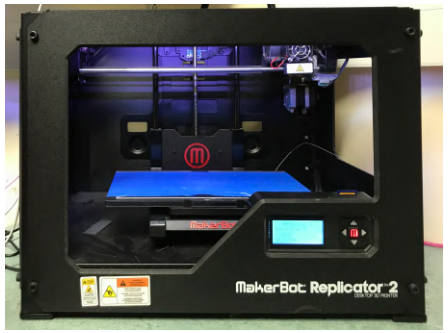
Idea No. 13 – Plan for Manufacture

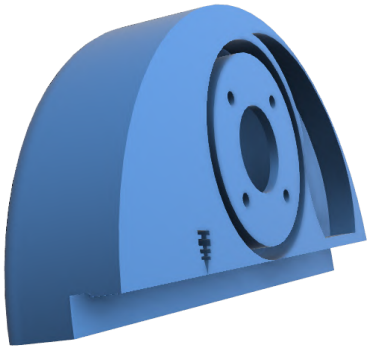
Part Name // Material	Process, tools and techniques	Start Date	Time Allowed	End Date	Risk Assessment	Quality Control	Progress Report
Belt Attachment Left // White Resin	Form Labs Form 2 // SLA Printing	7 Feb 2020	8 Hours	7 Feb 2020	I was careful as the Form 2 has hot moving parts. To ensure I stayed safe I followed all safety precautions ensuring that all safety lids were shut	I made sure that the resin was in date and the bed is flat.	COMPLETED
Belt Attachment Right // White Resin	Form Labs Form 2 // SLA Printing	8 Feb 2020	8 Hours	8 Feb 2020	I was careful as the Form 2 has hot moving parts. To ensure I stayed safe I followed all safety precautions ensuring that all safety lids were shut	I made sure that the resin was in date and the bed is flat.	COMPLETED
PCB 1	Solder with Soldering Iron and drill holes with hand drill	20 Feb 2020	1 Hour	20 Feb 2020	The soldering iron was very hot but I make sure there was good lighting and airflow to remove any fumes from the solder.	I tested it with a logic probs after soldering each chip.	COMPLETED
PCB 2	Solder with Soldering Iron and drill holes with hand drill	20 Feb 2020	1 Hour	20 Feb 2020	The soldering iron was very hot but I make sure there was good lighting and airflow to remove any fumes from the solder.	I tested it with a logic probs after soldering each chip.	COMPLETED
Code Arduino	Code with Arduino software	20 Jan 2020	5 Hours	24 Feb 2020	N/A	I tested the motors after every change to ensure that it worked.	COMPLETED
Belt Left	Trim with wire cutters	18 Feb 2020	5 Minutes	18 Feb 2020	I was careful to ensure that I did not cut myself by accident with the wire cutters	I used a guitar tuning app to ensure the belt was the right tightness.	COMPLETED
Belt Right	Trim with wire cutters	18 Feb 2020	5 Minutes	18 Feb 2020	I was careful to ensure that I did not cut myself by accident with the wire cutters	I used a guitar tuning app to ensure the belt was the right tightness.	COMPLETED

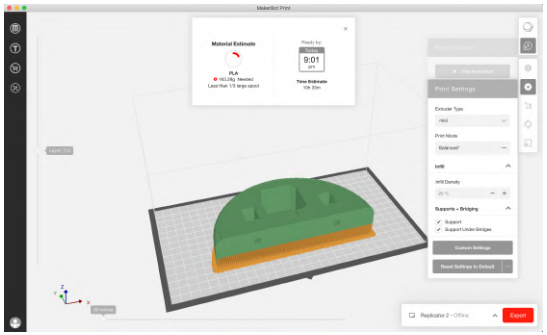
Diary of Manufacture - Step 1 – Print off all FDM 3D Printed Pieces











I had to print five objects on the FDM 3D Printer. This part Is the Left Top piece

Step 1.1 – I designed the model on Autodesk Fusion 360. It went through tens and tens of changes and updates but eventually I landed on this design

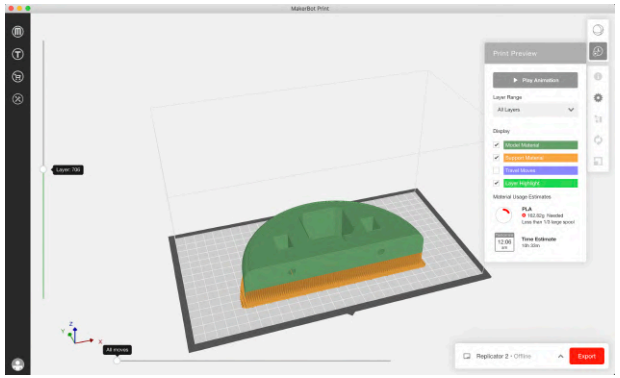
Step 1.2 – I imported it into 'MakerPrint' which is the slicer favoured by Makerbot printers. One of my main challenges was that the edges were filleted, but to ensure that I got a good surface finish I orientated it so that the side with a filleted edge was on top. This orientation also minimised the amount of support needed and therefore minimised the amount of waste. I used a raft to ensure that it was a level print and that there was a good adhesion to the print bed. I made the infill only 20% because I wanted this piece to be lightweight but strong. This piece did not have to be that strong though, which is why I only made the infill 20%.

Step 1.3 – I exported the .x3g file to an SD Card and inserted it into the printer

Step 1.4 – I started the print by going 'M' > 'PRINT FROM SD CARD' > 'HW END LEFT TOP'. I printed it in blue matte PLA from Filamentive which means that it was rPLA. This means that it is recycled and it therefore better for the environment.

Step 1.5 – The print took just under 12 Hours. After it printed, I removed the raft and support. The print turned out very well so I was very happy with the overall piece.

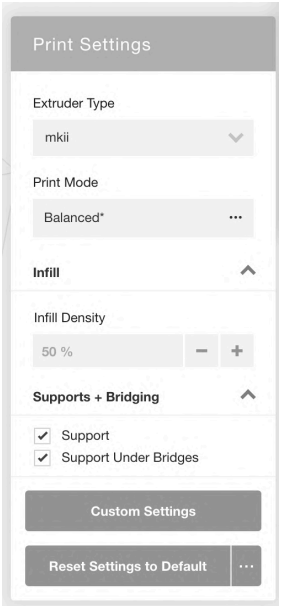
Diary of Manufacture - Step 1 – Print off all FDM 3D Printed Pieces



Left Top
Stage 1.6-1.10

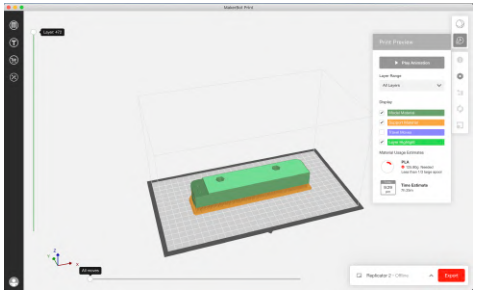
I repeated stage 1.1-1.5 for this object. I still used an infill of 20% because I found that it was the sweet spot where the model was both strong but light.

On this print, the supports and raft were slightly more difficult to remove therefore I had to use a Stanley knife and metal ruler to fully remove them. Despite this, it still emerged well from the printer with a very nice, smooth, surface finish.



Right Bottom
Stage 1.11-15

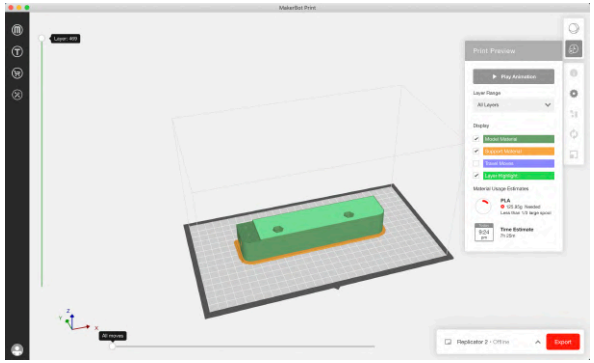
I repeated stage 1.1-1.5 for this object, however, I changed the infill to 50%. This is because it will have a lot of tension on it because of the belt. I printed it in this orientation because I wanted it to be strong in the X direction so that it wouldn't tear apart under tension.

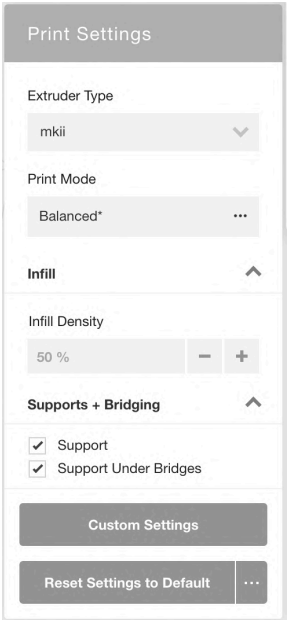


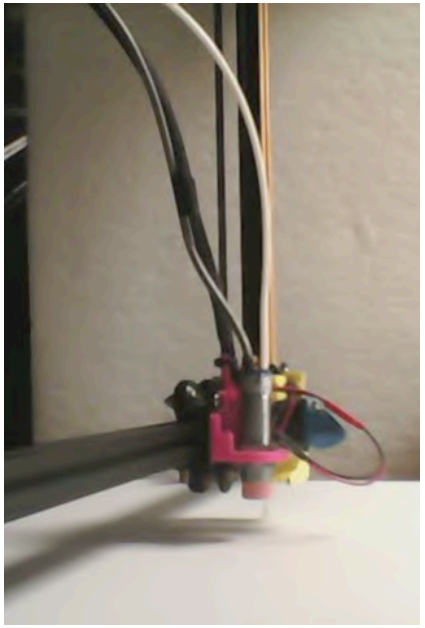
The supports and raft came off very easily and left the print looking clean and smooth. I was overall very happy with this.

Left Bottom
Stage 1.16-20

I repeated stage 1.1-1.5 for this object however I changed the infill to 50% along with the print for the right bottom. The supports did not come off very easily for this print especially the ones in the hole for the screws but these parts will not be seen so it was okay.





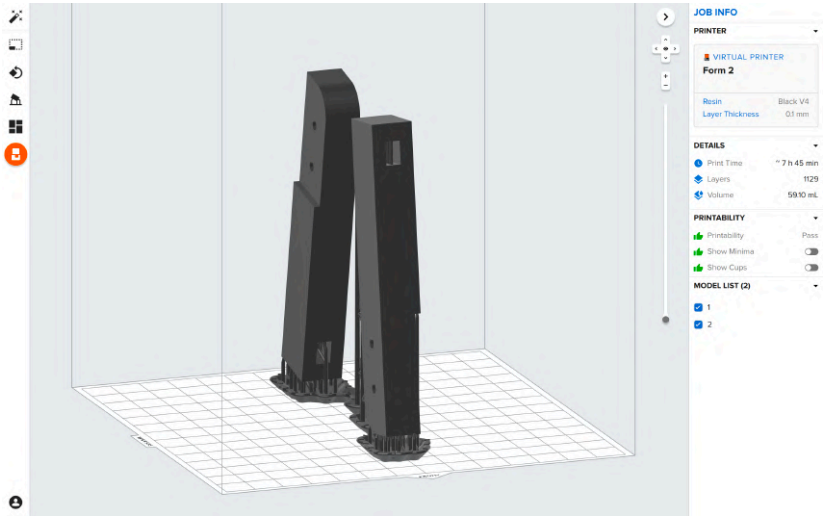


Anti-Freeze Holder
Stage 1.21-25

This wasn't printed on a Makerbot but instead a custom printer which had the height needed to complete this large print. I changed the speed in this one at two points in the print. I started off with it being really slow for the first few layers to make sure that the bottom got a really nice adhesion. I then increased the print speed for the next 2/3 thirds of the print. For the final part of the print I slowed down the print speed because I didn't want the layers to get too wavy with the printer movement. However, this did not work as well as planned but actually made the print a little bit wavy but I still think that it is better than it would have been if the print speed was faster.

Diary of Manufacture - Step 2 – Print off all SLA Pieces

formlabs



I had to print 6 objects on the SLA printer, I used the Form 2 by Form Labs

Step 2.1 – I designed the model on Autodesk Fusion 360. It went through tens and tens of changes and updates but eventually I landed on this model. This model is the belt attachment for both sides.

Step 2.2 – I imported it into 'PreForm' which is the software used to prepare a model to be printed on a Form Labs. I had to make sure that there was adequate support so that it would print in high quality

Step 2.3 – I exported the file straight to the printer from the laptop and started it remotely

Step 2.4 – The print took around 8 hours and I printed this piece using standard white resin

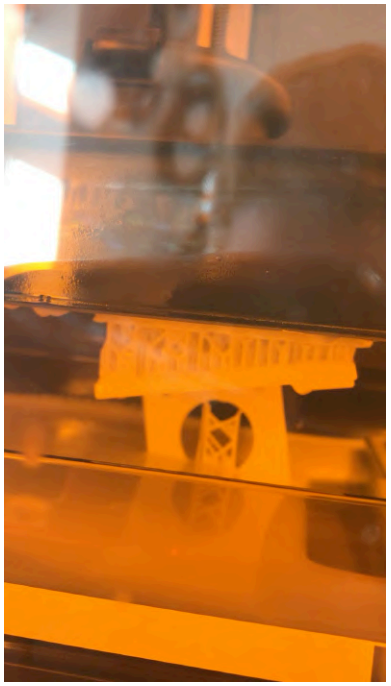
Step 2.5 – After the print was complete, I had to put it in the curer for 20 minutes in order to remove any waste residue or resin on the model

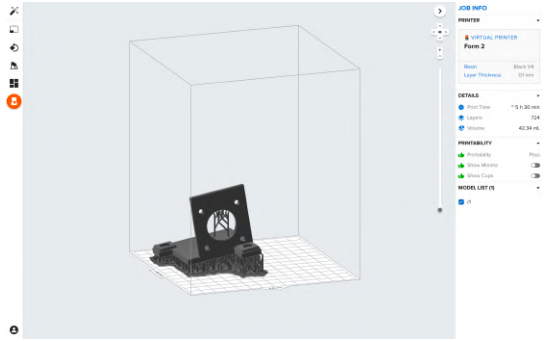
Step 2.6 – I then had to bake it in the FormLabs oven for a further hour. This baked the resin and solidified it.

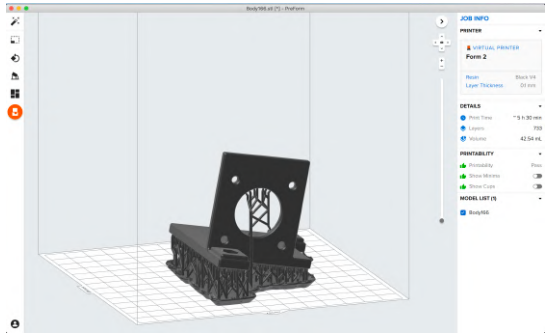
Step 2.7 – After the print was complete, I then had to remove the raft and all of the support. This then left some dimples all over the model which I then had to sand out with both sand paper and wet and dry paper.

Step 2.8 – I then had to repeat this process for all of the other prints

Diary of Manufacture - Step 2 – Print off all SLA Pieces







Anti-Freeze Holder Cap

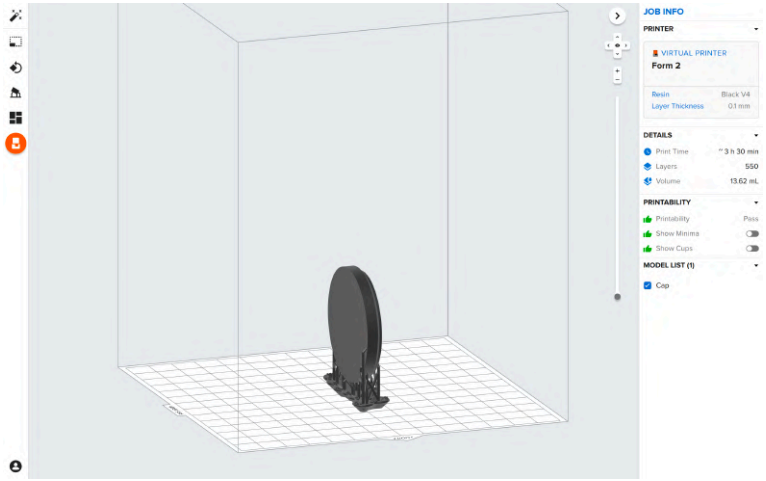
Step 2.9-2.16

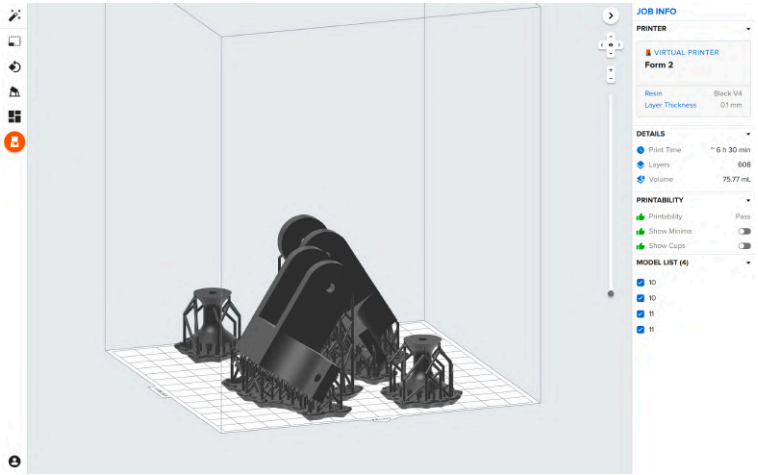
Repeat step 2.1-2.8 however I changed the resin to a flexible rubber resin. I still had to wash and heat it, however, it meant that the supports did not come off as easily. It took me a lot longer than expected to get the model up to a good finish standard, because as well as sanding down the piece I also had to use needle files to remove some parts of the support. The final piece was not quite as good as I would have liked it to be but all of the bits that were slightly rougher were hidden as they were inside the Anti Freeze Holder. Overall, however, I was very happy with the part because it was slightly flexible but still maintained its firm shape, perfect for a cap.

Other Form Labs Pieces

Step 2.17-2.42

Repeat 2.1-2.8 for the remaining pieces that needed to printed on a SLA printer. The remaining parts that needed to be printed were the belt holder for both the left and the right side along with the motor holders. The belt holders were made using engineering resin which is a little bit stronger. They would need this extra strength because of the tension from the belt. The motor holders were printed using standard white resin because they did not need any specialty features





Diary of Manufacture - Step 3 – Build ‘other’ parts

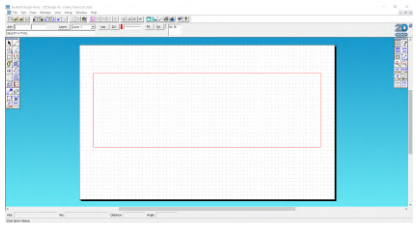
Brush Holder - Stage 3.1-3.6

Stage 3.1 – I designed the model on 2D Design (you can see the design below). It was very basic because I only needed it to cut a slot in the tube

Stage 3.2 – I removed the cutting bed and replaced it with the rotary attachment.

Stage 3.3 – I then placed the tube in the attachment and focussed the laser onto the tube.

Stage 3.4 – After that I set the laser cutter to show a light where it was going to cut to ensure that it was going to work correctly.



Stage 3.5 – I then cut the tube by pressing the green button

Stage 3.6 – I then sanded down the edges and got it ready to be assembled with the rest of my product.

Brush

Stage 3.12-3.15

Stage 3.12 – I used a ruler to measure the length of brush needed, I then used a pair of secateurs to cut it down to size

Stage 3.13 – I then used a blow-torch to melt both ends to remove all plastic bristles so it could be inserted into the adapter

Stage 3.14 – I then used electrical tape to push the bristles in their natural direction so it could be trimmed easily

Stage 3.15 – I then trimmed the bristles to 65mm in total length with a pair of scissors

Brush and Motor Adapter Left and Right

Stage 3.7-3.11

Stage 3.7 – I measured the width of both the Guttridge and the motor with a pair of callipers

Stage 3.8 – I then used a 3.5mm drill bit to drill the smaller hole on the centre lathe for the Guttridge

Stage 3.9 – I used a centre punch first, which is short and wide so that it didn’t wobble when drilling the initial hole. I then created a 5mm hole on the centre lathe to be attached to the motor

Stage 3.10 – I then used 2.5mm drill bits to drill three holes for grub screws

Stage 3.11 – I centre punched the aluminium using a machine vice and the pillar drill and drilled a 2mm diameter hole (the correct size for then 'tapping' with a M3 or 3mm thread)

Stage 3.12 – I then tapped a M3 thread - The tap is held in the tap wrench and using a cutting compound rotated clockwise, for every one full turn, I turned back a half turn to clear out any swarf. Ensuring the tap is vertical to avoid a 'drunken thread'

Diary of Manufacture – Step 4 - Motors

PCB 1 and 2

Stage 4.1 – 4.7

Stage 4.1 – I started off by using a breadboard to figure out the circuit I needed for this project

Stage 4.2 – I then designed the circuit board using the software ‘EasyEDA’ which is linked to JLCPCB

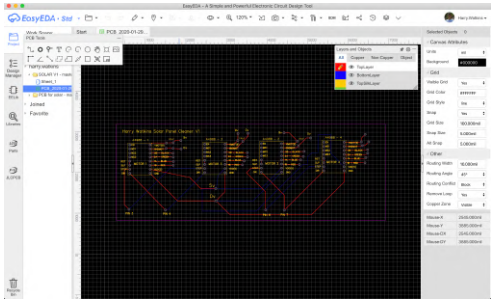
Stage 4.3 – I then had the circuit boards printed by the company JLCPCB. I had five printed.

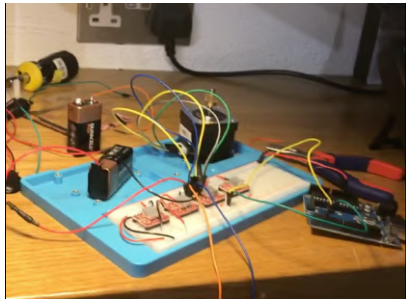
Stage 4.4 – I then soldered the components to the circuit board

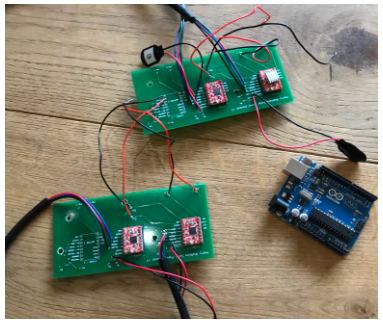
Stage 4.5 – I used a logic probe to test each part of the Printed Circuit Board to ensure that it would work

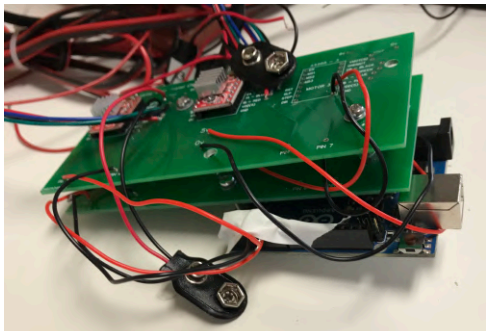
Stage 4.6 – After this, I drilled 4 M3 holes using a hand-drill on a space PCB to create a stencil.

Stage 4.7 – I then used the stencil to drill holes in the other PCBs being used so that I could use M3x20 bolts and nuts to bolt them together.









Code Arduino

Stage 4.8 – 4.13

I used Arduino to code the stepper motors

Stage 4.8 – I started off by coding for one motor which would do one turn forwards, one turn backwards

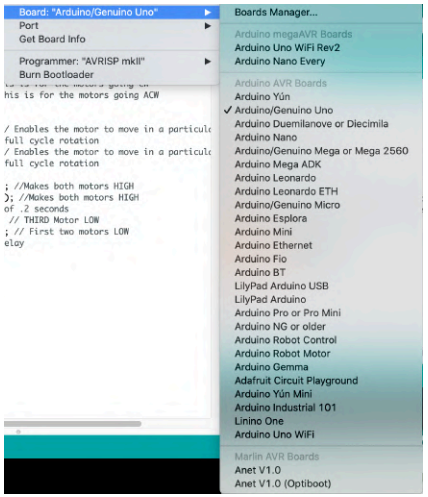
Stage 4.9 – When I got this working I changed the code so that it would continuously turn one way

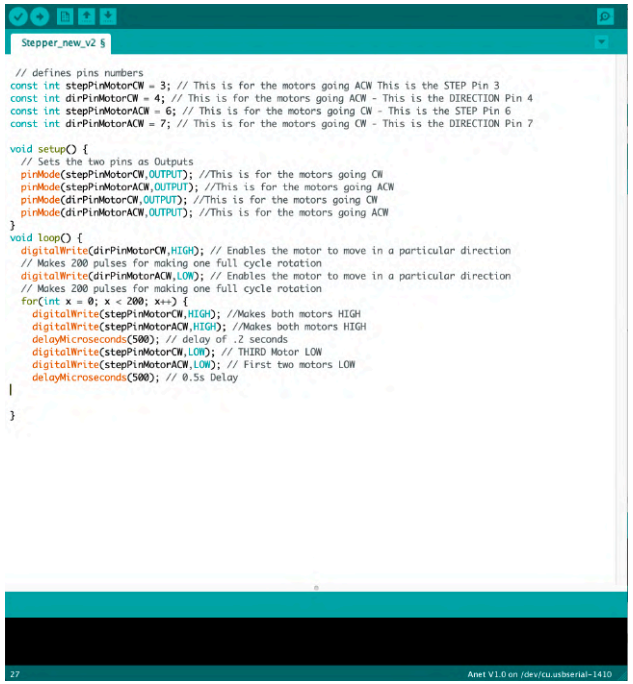
Stage 4.10 – I then made it so that it worked for two motors, each one going in a different direction. This is because each axis has two motors but each motor is the other way around from its companion. This way each motor in a pair will work together well

Stage 4.11 – I then cleaned up the code and added in notes so that it’s easier for a novice to read or adjust it

Stage 4.12 – I then had to select the board ‘Arduino genuine’, programmer ‘AVRISP mkII’ and the correct port.

Stage 4.13 – I then compiled the code, ran an error checking program on the code and uploaded it to the Arduino Board.

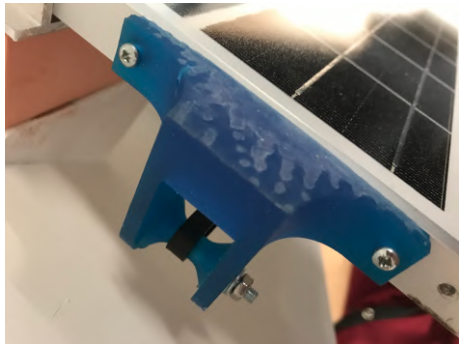




Diary of Manufacture – Step 5 - Assemble

Step 5.1-5 – Glue the Top Half Together

Step 5.1 – Mix the resin and the hardener together on a 1:1 ratio.
Step 5.2 – Use Epoxy Resin to attach the anti-freeze holder to the Left end along with the scraper and the brush holder. Make sure that the brush holder is rotated correctly.
Step 5.3 – Let it set overnight
Step 5.4 – Now use Epoxy Resin to attach each part to the Right end. Ensure that both ends are perfectly straight
Step 5.5 – Let it set again overnight



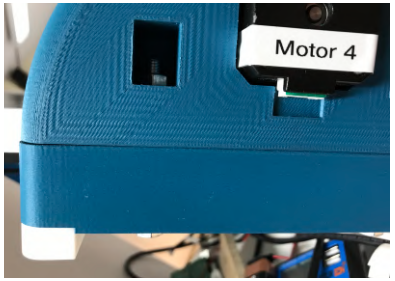
Step 5.10-15 – Attach the Belt Holder and belt

Step 5.10 – Drill two M4 holes on each side of the top of the panel
Step 5.11 – Attach the belt holder using two M3 Philips head bolts and nuts per holder
Step 5.12 – Add the spinning part to the top with a long M3x30 Bolt and two washers on each end.

Steps 5.13 – Now attach the M3 belt so that it goes through the belt holder using two zip-ties and use a guitar tuning app tighten the belt so that when you ping it, it makes the sound of a G – string of a guitar.
Step 5.15 – Attach the toothed idler with grub screws to each motor and move it along the shaft until the belt is straight.

Step 5.6-9 – Screw the bottom part of each end onto the top part along with the belt attachment

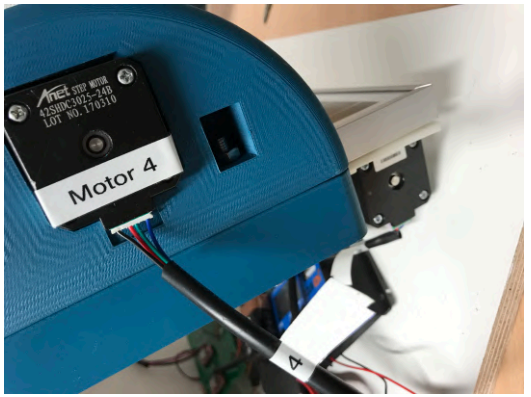
Step 5.6 – Use two M16x60 bolts and nuts to screw the bottom part of each end to the top part. Use a washer on each end to ensure that the pressure is evenly spread out on the part.
Step 5.7 – Use a 10mm spanner and a flat-ended screwdriver in order to tighten the bolts.



Step 5.8 – Now use M3x20 Bolts and nuts to attach the belt attachment onto each end
Step 5.9 – Lastly attach all four motors with 4 M3 bolts with a washer on each between the bolt and the plastic to ensure that it can be tightened without damaging the part.

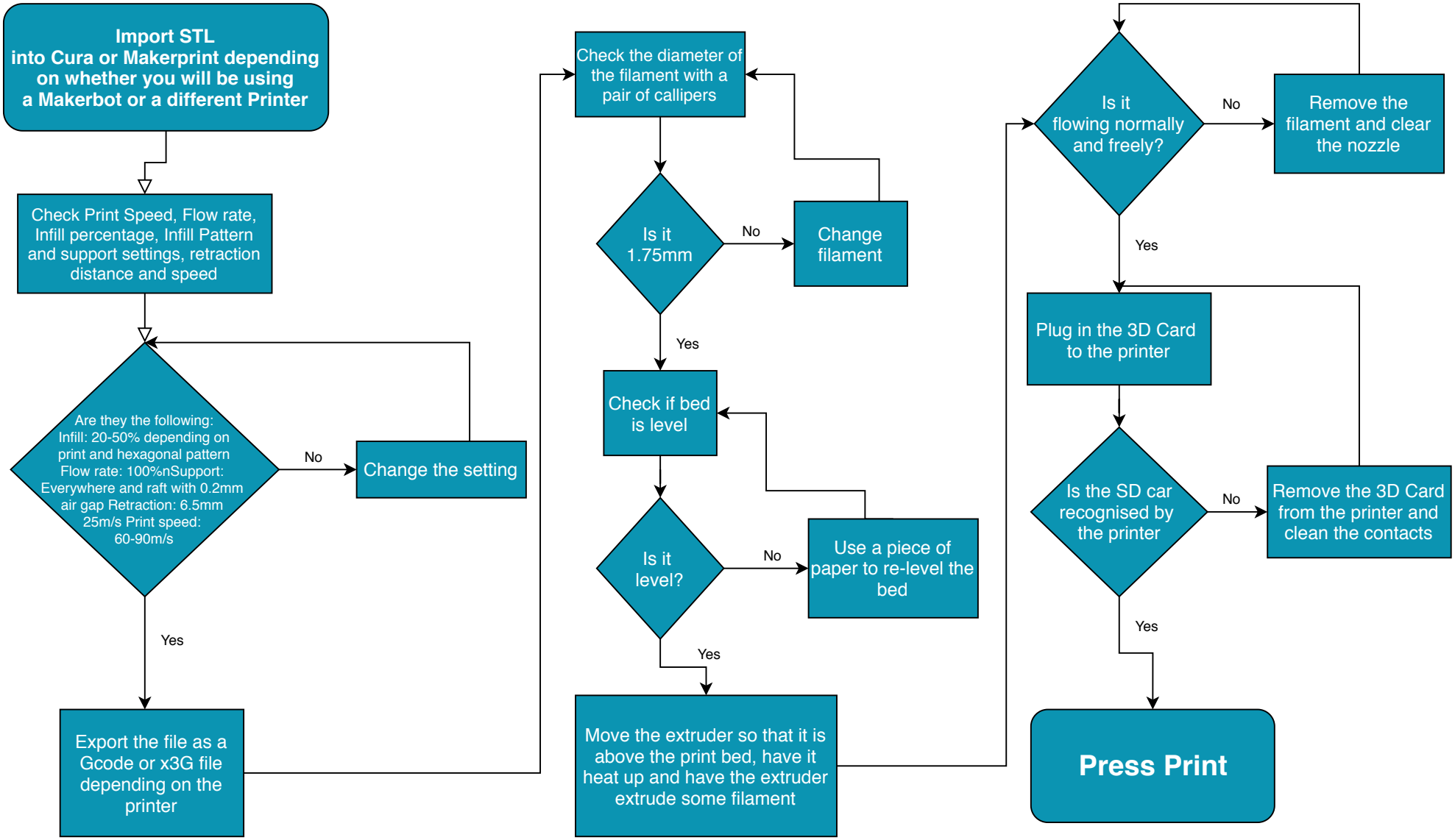
Step 5.16 – Plug in all four motors to the main PCB and attach the motor-brush attachment

Step 5.16 – Plug in each motor to the correct wire. Make sure that the Left Motors are plugged into the drivers from pin 3+4 and that the Right motors are plugged into the drivers from pin 6+7.
Step 5.17 – Attach the motor – brush attachment to the motor shaft on each side. Make sure that the grub screw goes onto the flat edge of the motor. Tighten it up with an Allen key.
Step 5.18 – Now attach the brush, one side at a time. Once one side is in and the grub screws have Both been tightened, attach the other end and tighten both of the grub screw on that side as well.



Quality Control

I used multiple different methods to ensure quality control, here is an example of what I did to ensure that my 3D Prints went as planned



Design Specification Comparison

Specification Point	Specification Point	Strengths	Weaknesses	Overall Achieved?
1	Clear snow off solar panels	Yes it does do this every effectively	N/A	YES
2	Must be sleek looking	The smooth curves and filleted edges provide this with its sleek look although it still has a few sharp contemporary shapes such as the one of the holder provide it with its sleek look	The wiring and the PCBs do detract from the overall sleekness but they are held neatly on the back	YES
3	Must suit the high tech look of a solar panel	The sharp corners and sleek edges suit the solar panel well. The general design follows the ethos of less is more and simpler is better, as seen with the basic colour scheme of matte mid blue and white along with the sharp shapes	N/A	YES
4	Must be able to withstand the winter environment	The motors and belt system would work in a cold environment and the solvents will stick.	The motors and PCBs are not currently weather protected	MID
5	As much as possible must be build with PETG	Everything that was 3D printed using a FDM printer was printed using rPLA	I decided to not use PETG because this was only a prototype and PLA is more familiar to me	NO
6	As much as possible will be 3D Printed	All of the main parts bar one are 3D Printed	N/A	YES
7	I will use rubber seals to protect the machine from the outside	N/A	This did not happed because I decided to not include this in the first version	NO
8	I will use a heated scraper to clear the snow	N/A	This also did not happen because I decided to not include this in the first version	NO

Design Specification Comparison

Specification Point	Specification Point	Strengths	Weaknesses	Overall Achieved?
9	The motors will move it up and down the panel	Yes this works	Because of how heavy the machine is, it does not work as smoothly as was planned	YES
10	This will be very user friendly and most parts should be able to be 3D printed by the consumer	This is very user friendly as it is easy to put it together and easy to turn on as you just have to plug one cable in	N/A	YES
11	This will be as cheap as possible whilst still using good quality, responsibly sourced, materials	All of the 3D Printed objects were made out of recycled PLA (rPLA) or good quality, responsibly sources resin depending on the printer type	N/A	YES
12	The electrics must be insulated from the rain	N/A	I did not insulate the electrics because I decided to focus this on the second gen model	NO
13	This will be designed to fit a 350W Solar Panel	N/A	I decided to make this prototype on a much smaller panel because of ease	NO
14	This product will have a very long lifespan	This product is built using strong components and strong nuts and bolts	The PLA could eventually wear away and either crack or break but it should be fine	YES
15	This will contain as few moving parts as possible	This has a few moving parts as I designed it to be as simple as possible	The moving parts are quite small and can be fragile such as the motor which could suffer from water damage ect…	YES

Design Specification Comparison

Specification Point	Specification Point	Strengths	Weaknesses	Overall Achieved?
16	Installation must be as simple as possible	To install the device you simple have to use four bolts and attach the belt	The belt could be a little bit challenging to people not used to it especially as you have to get it tight	YES
17	It will be all electric without any manual labour	It is all electric and fully automatic	It still needs to be turned on manually but this will be changed for gen 2. The new software will be able to be downloaded from the internet and uploaded themselves	YES
18	It must be good for the environment	Everything that is 3D Printed using FDM Printing will be printed in rPLA which is recycled PLA so it good for the environment	Plastic still isn't very good for the environment but is the best material for this application.	YES
19	It must be future-proof	This is incredibly future proof because updates can be downloaded from the internet and then either 3D printed or downloaded to the Arduino	There are some parts that can not be 3D Printed and will eventually break	YES
20	There will be four motors and a simple PCB controlled by an Arduino	They all work and the Arduino makes them easily codable	N/A	

Savings

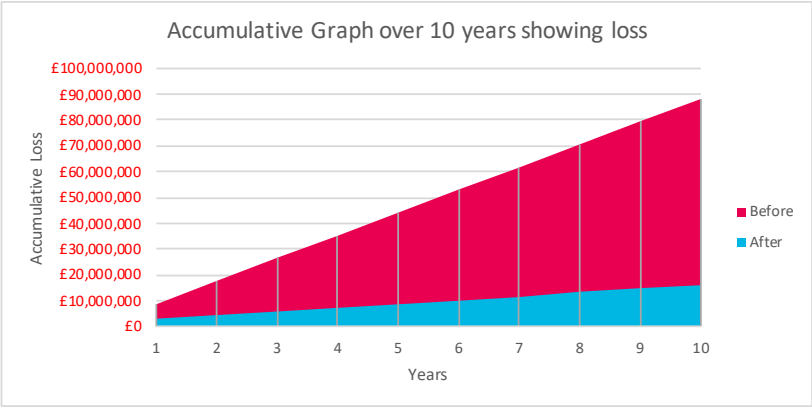
I produced a data sheet and graph of the possible savings that could be made if the client chooses to switch to my new solution.

Amount of power generated from one solar panel / hour	0.350	kWh		
Amount of power generated from one solar panel / day assuming 6 hours of use	2.100	kWh		
Feed in Tariff	33.000	yen/kWh		
Plug in' per panel Total tariff for one panel / day	69.300	yen/kWh		
Number of panels	14,000.000	panels		
Total tariff for a farm / day	970,200.000	yen/kWh		
Conversion rate for USD to Yen	1.000	Yen	0.01	USD
Total Tariff for a farm / day	9,702.000	USD		
Number of snow days in Japan	60.000	days		
Number of weeks	8.571	weeks		
Round to	9.000	weeks		

Cost to get it cleaned		
Fee for cleaners	9,702.000	USD
Missed amounts from panels not being cleaned	970,200.000	USD
TOTAL	979,902.000	USD
Assuming panels have to be cleaned once a week during snow week	9	times / season
Total cost	**8,819,118.000**	**USD**

My Machine				
Start off costs				
	87.300	GBP		
TOTAL for start up	112.710	USD		
Refill cost				
Liquids	100.000	USD		
TOTAL for Refills	100.000	USD		
Energy Cost				
27v	27	Watts		
5 mins	135	Watts	0.135	kWh
However many days	8,100.000	Watts	8.1	kWh
Cost	267.300	Yen		
	2.673	USD		
Total Cost for one panel	215.383	USD		
Total Cost for all	3,015,362.000	USD		
Total yearly cost for one panel yearly after start up	102.673	USD		
Total yearly cost for all panels yearly after start up	1,437,422.000	USD		

Comparison		
Total cost Before	8,819,118.000	USD
Total cost afterwards	3,015,362.000	USD
Total saving in FIRST YEAR	5,803,756.000	USD
Accumulative saving in SECOND YEAR	14,622,771.327	USD
Accumulative saving in THIRD YEAR	23,441,786.654	USD
Accumulative saving in FOURTH YEAR	32,260,801.981	USD
Accumulative saving in FIFTH YEAR	41,079,817.308	USD
Accumulative saving in SIXTH YEAR	49,898,832.635	USD



Testing and Evaluation

Micro Testing and Evaluation

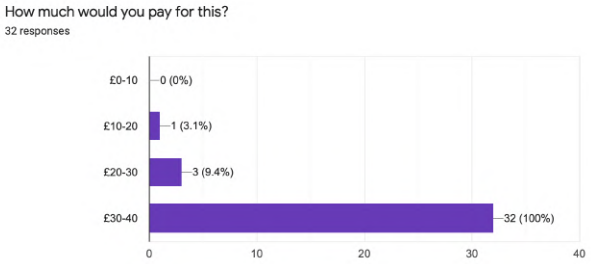
The anti-freeze holder worked very well as the holes gave just the right amount of liquid to get rid of any ice on the panel. The motors that take the machine up and down the panel worked fairly well as they do bring the machine up and down however, as the machine is very heavy, it sometimes get stuck or jams etc... which was not ideal. The scraper also worked very efficiently. It cleared any snow or debris off of the panel during testing. Furthermore, the motors which control the brush worked extremely well. However, one part that let the machine down slightly was the brush. The brush's bristles were slightly too long which meant that they got stuck on the panel or the brush holder. The brush holder also worked very well, it slotted into each end perfectly and fit the brush nicely. The PCB's which control the motors worked perfectly. When triggered from the Arduino, each motor performed exceptionally. The motor holders worked well and fitted all of the motors exceptionally, furthermore, the belt holders and belt attachments to the end pieces worked well as the belt fitted perfectly onto each piece and they allowed the tension of the belt to be extra tight. The cap did not work great at the start because the lip was slightly too thick but when I filed it off slightly, it fitted perfectly.

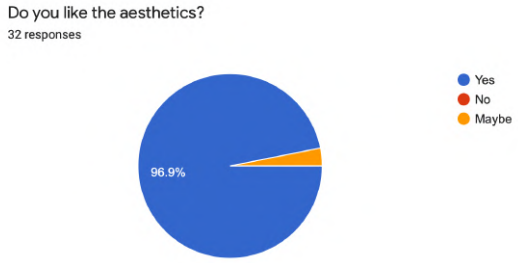
Macro Testing and Evaluation

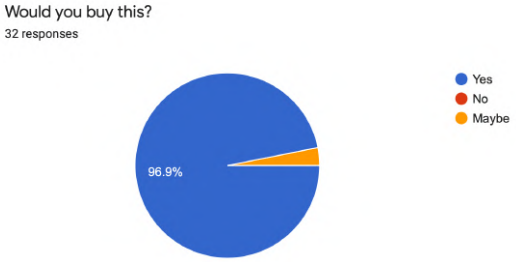
In general, the machine worked very well. As soon as I placed the machine on the panel, in it's environment I noticed that one possible problem was that the wires going to the motors on the bottom can get squeezed a bit onto the bottom frame, which over time could damage the contacts. This problem could be easily fixed, however, by simply rotating the motors, so no new work would need to be done. However, on the plus side, the machine fitted the panel perfectly. The slight indent in the machines sides fit the bezels of the panel perfectly keeping the machine in the centre of the panel. When, the screws have been tightened and the machine is almost 'clamped' onto the panel, it is very secure, and it would be extremely hard for things such as bad weather to take it off the panel. Thanks to the strength of the parts linking each end together, it won't come off the side, and thanks to the bezel on the top of the panel, and the belt system, it would be extremely hard for the machine to fall off either the top or the bottom. Furthermore, thanks to the wide space between the two belts and due to the entire back of the panel being free, it allows a vast amount of different mounting choices. This allows it to be very diverse and used on many, many different panels with different mounting systems. All in all, I am very pleased with this device as it works very well especially for a prototype.

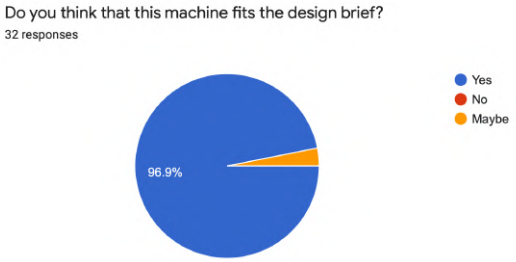
Peer and Client Feedback

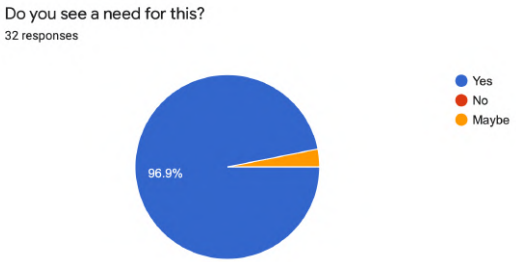
I selected 32 random peers and sent them a questionnaire asking them what they thought of my solution.

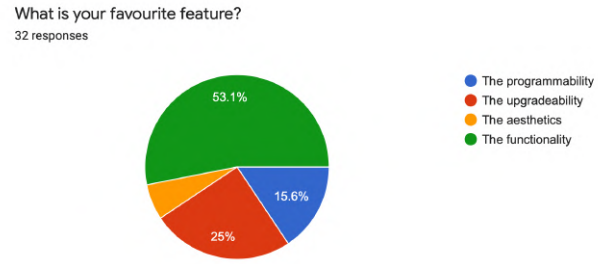












Peer Feedback

I sent a questionnaire to 32 random peers and the results were overwhelming. 96.9% of all people believed that this fit the design brief which means that only one person thinks that I didn't. Almost every single person; saw a need for this product; liked the aesthetics and would buy it! The functionality of the device was most peoples favourite part but a lot of people also enjoyed the upgradeability, the programmability and the aesthetics as well.

Client Feedback

I had another phone call with my client and he was absolutely amazed with my product. He said that he was amazed that I was able to find such an effective solution. I went over the improvements with him and he agreed with them, saying that he felt they would greatly improve the product.

He agreed with me that it is a bit annoying how the machine can get a bit stuck or move slowly at some points due to how heavy the machine was. However, he agreed with me that if I made the proposed improvements on the next page then the machine would run much more smoothly and easily.

He said that the cost was a little higher than he would ideally want but that if I made the improvement where one machine could be used for multiple panels, then the cost would decrease significantly.

The main negative that he brought up was about the weather proofing but it would be a simple thing for his engineering teams to breakthrough, and therefore, currently, at this prototyping phase, would not be a big problem at all.

He loved the aesthetics of this machine along with how user friendly it was especially with it's ability to be re-programmed and/or have parts replaced.

All in all, though, he was very positive about it and was very impressed that I was able to come up with a solution as complex as this one was. He's having me pitch the idea to his board and a group of lead mechanics at his firms.

Modifications

If I was to make this again, I would make five main modifications

Modification Number One: I would make the machine out of PETG not PLA

- This is because PETG is better for the environment than PETG and is also a lot stronger. This would be a very easy adjustment to make as all I would have to do is slightly adjust the print files and change the filament in the 3D printer.

Modification Number Two: I would make the machine more weather protected

- This was probably the biggest Specification point that I did not meet because I decided to focus on other parts of the machine for this first prototype.
- In order protect the parts I will use a number of different methods. These would include a waterproof wrap covering the wires and then the connections between the wires and the motors as well as a junction box with the circuit board inside. Lastly, I would use O-ring seals and plastic bushing in order to protect the motors.

Modification Number Three: I would make the scraper heated

- This was one of my original aims that unfortunately I was unable to meet due to the lack of technological advancement, however, this is a key part of allowing the device to melt and cut through ice, therefore it would be a key stepping stone to improving the device.

Modification Number Four: I would adjust the design to fit a standard 350W Solar Panel

- This is the device which the Panel was originally meant to fit, however, under advice, I decided to make this first prototype on a slightly smaller panel. This is because of a multitude of reasons, one of which being that it is much easier to manufacture the pieces without having to create professional molds or tools.
- However, this is the panel which the device was designed for and the panel that this device will be sold with so it is essential to adjust the design in this way.

Modification Number Five: I would rotate it and make it move on the Y-plane not the X-plane

- This is because it would make it easier for it to clean multiple panels in a row. This would make it cheaper as, then, there would not have to be a separate machine for each panel.

Modification Number Six: I would put it on a leadscrew not a belt

- This is because on a leadscrew it is easier to move heavier loads and the machine is fairly heavy.
- This would also make the machine more robust and reliable. It would also make the machine more easier, putting less pressure on the panel.

Modification Number Seven: I would add a frame on the end

- This is because, if the panel has to ‘live’ on the top of the panel, then it will prevent a number of cells from picking up light from the sun.
- Adding a frame, although may increase the startup cost, it would be worth it in the end, in terms of the amount of energy that can be created.

Reflections – What I learnt…

I learnt a lot from the process. One of these is that I learnt a lot about the current problems in solar panels. My talk with Andreas was absolutely eye-opening, I also managed to talk to a person called Olivier Renon who is the Executive Vice President for Business Development. I learnt about the main problems in the renewables industry today, which I found fascinating, especially, the physics part, learning about the spinning reserve, optimum running speeds, optimum sun levels and also, about the restrictions on renewables companies. These really surprised me because we have this thought that the government and other companies are trying to be as renewable as possible, but a lot of them, especially in America, aren't. This is because of the politics of renewable energies, people like Trump are funded by oil companies and therefore they don't actually want to use much renewables, as the politicians don't want to lose their funding. I found these politics especially fascinating.

Olivier Renon

Another thing that I learnt, was about using international manufacturers. I used JLCPCB to produce the PCBs for my design and it was a very eye-opening process to go through the design, communication, manufacture and delivery. The design process was fascinating as I got to use some brand new software and the quality control process was really interesting. The communication with the manufacturer was also very interesting especially as we had to deal with the COVID-19 outbreak so it was fascinating to see how the manufacturers dealt with this problem.

All considered, I am very pleased with how well the entire design process went and I am very proud of my final product. Throughout the design process, my ideas and product fluctuated greatly with my final product being completely different from my original idea. The design process taught me even more tricks on CAD especially Fusion 360. I also learnt to use a CNC Lathe for the Aluminium Brush-Motor Adaptor. It was fascinating to also learn the 'tricks of the trade' on how to effectively make certain incisions and holes.

One time consuming part was working out the end pieces and how to make them. I went through countless models and versions along with different ways to actually manufacture the piece as well as hold the different parts. One of my thoughts was to 3D Print a piece what would slot into a piece that could be cut on the CNC Router, however this did not go to plan. In the end, after many many models, I decided to just 3D print the entire piece because of the intricate design of the scraper.

When it came to testing the model, I was overcome with satisfaction as it actually worked! I was obviously slightly disappointed that it did not necessarily move as smoothly as I may have wanted, but I was very happy that each part performed exactly as designed apart from that.

Overall, I thoroughly enjoyed the entire process of designing this product from the beginning to the end. The research was fascinating and the modelling process was rewarding as I learnt new methods and techniques to get the final product that I desired from the beginning. It was very satisfying and rewarding to see this product go from a small idea in a dream, to a concept, to a model and then to a prototype.

Sources

Picture 1 - Page 2 - ‘Solar Panels in Desert’ - https://cdn.vox-cdn.com/thumbor/jfNeex8Gr4d6Vk6awLYnnLrWrZU=/1400x1050/filters:format(jpeg)/cdn.vox-cdn.com/uploads/chorus_asset/file/13457847/510728016.jpg.jpg
Picture 2 - Page 3 - ‘Picture of Andreas’ - https://www.crunchbase.com/person/andreas-mustad
Picture 3 - Page 3 - ‘Soneddix Logo’ - https://lh3.googleusercontent.com/_zShndiwnJ7_r93JWv-jVT0K0kMCPvxKqJ0WnSpAtlK6cHp4dNTS9ZpZGwKx3N_ISBSLsf0=s170m
Picture 4 - Page 7 - ‘Automatic Window Cleaner’ - https://lh3.googleusercontent.com/DYUTze7pKkHAm9xsz7uyBn940vkWxKotPwd08lWoNeAQc_fZadwkx-K9aZCmAZU1UHPxLBY=s85
Picture 5 - Page 7 - ‘Electric, Heated, Ice Scraper’ - https://lh3.googleusercontent.com/zicYHpDlvtadQEuUbNOIUT7uPt4pE7H1cvoKnnV3FCFfpWIErDquq_YMph23LNcXNBB1ag=s103
Picture 6 - Page 7 - ‘Plastic Ice Scraper’ - https://lh3.googleusercontent.com/IoGIHgZlg9vAkAXfMgesbwlekrXWIo6V9Tb_li5zGG_woW_4WqfPWgQL7aUhNVVhDpTtmQ=s128
Picture 7 - Page 7 - ‘Automatic Brush’- https://lh3.googleusercontent.com/-qQi8VtrG1wXrKZw7D7dt16_GXMA0jWnEkffncUTBN7nf6UnBaXLnsDJC3WC7n0sL2hhsg=s144
Picture 8 - Page 7 - ‘Hose and Brush’ - https://lh3.googleusercontent.com/dKPmTI0GwX_6wlGCdMvhN9itURJSZJjiD8SoBTfVIoWcnyOjiE_-AuL-xp1rp_yNIgvwUQ=s169
Picture 9 - Page 7 - ‘Long Handled Ice Scraper’ - https://lh3.googleusercontent.com/ZGpbFZTf_upqojedSHRbo4c7iWbAETgUeDd3O0yW6d6UUD2ymNCXVzcOgQuyiwJm3b_x=s85
Picture 10 - Page 8 - ‘Ecoppia Top Left’ - https://lh3.googleusercontent.com/qhyq8mHl6jkVPloLJgFJQA9JYZzJoVgbjs-QqPme9NAy2zrkE0cb3ZqemGmP5SIE65kTtg=s127
Picture 11 - Page 8 - ‘Ecoppia Middle Left’ - https://lh3.googleusercontent.com/c_ekvMMkCuVqeOJu13LD3oabn4j3Aq_pG1NPq1p-zlV2L0Rytsn4Cb5p57nZl0eq2NjC=s126
Picture 12 - Page 8 - ‘Ecoppia Bottom Left’ - https://lh3.googleusercontent.com/8SeFxk-LmVzpuxzdglqeRGhHSMoa72Pjnv8IBpzphJW3-83wrLIfp16Apfk-Y7kyhWG9_Sw=s149
Picture 13 - Page 8 - ‘Ecoppia Middle Top’ - https://lh3.googleusercontent.com/Hv6J9-HNtzLsysmEYaWrBhg1J2O-ILymX_ZnWbsZQYIJV2F2y-a4W1pwKEe7cMyMf1_4gA=s149
Picture 14 - Page 8 - ‘Ecoppia Right Top’ - https://lh3.googleusercontent.com/GcMpnzAUUhbxknmemGgDFnS8bJLzMg7fM5_g0UGSoz-hcNr51_Zp1YSwGEjQCpB-_snctA=s127
Picture 15 - Page 9 - ‘Using a brush’ - https://lh3.googleusercontent.com/77wK1FbLfACZSF78yWE490Zexx1jkAZel5hifqvZhsIEdOlCoKg5dO6kSzMeGbr2lNGk_Mg=s127
Picture 16 - Page 20 - ‘Top Left 1 machine’ - https://lh3.googleusercontent.com/prE2hUlCVgZwX2znoU_RuWS5HDrvRVrVXtYri4w3qYsSGOeVgF_hlTWdk4rh8tnAq7rsjg=s170
Picture 17 - Page 20 - ‘Middle Left Drone shot’ - https://lh3.googleusercontent.com/VHMMUTqLEKHb4EkZHpYmPJVO93bmCZblxEj-r7T8D7WGAuv1zrj9lXsfFk8RuTVCayBINw=s152
Picture 18 - Page 32 - ‘Autodesk Fusion 360 logo’ - https://lh3.googleusercontent.com/HsvlQ24jvHGeIYfLrarlicwlDvBlJYdKh64EAcJ3MaafIis2R7uERxSWTBRo5FQ_nGc7Nw=s170
Picture 19 - Page 32 - ‘MakerBot Logo’ - https://lh3.googleusercontent.com/i-IMjvjrojgSj8WdCBETKs28KPRh3WdddGeQFwIsAo3jgc0-9AK9ylzSyEdNs5_HezHq=s85
Picture 20 - Page 32 - ‘Filamentive Matte Blue Filament’ - https://lh3.googleusercontent.com/qkSZOxFjynkBW8zqZIZdNH8XL7q5ZWMzTjXE7H7OgQJDaOUnz5cECqh1LBayWmKSri1F=s85
Picture 21 - Page 34 - ‘FormLabs logo’ - https://lh3.googleusercontent.com/F5axGtMi99V-05uKYeSLzTKdWbG3AtXwLSVzxT88wv2-uZoTmmY3VppwCqN6MuFjVKBDgMA=s85
Picture 22 - Page 34 - ‘Curers’ - https://lh3.googleusercontent.com/FyH0SstF11xZpu6NKNq-9DxVYJFimr4ttZXPr6n1v7IXsQL_iLf16Xu1BKdF9husvImNKA=s136
Picture 23 – Page 46 – ‘Olivier Renon’ - https://lh3.googleusercontent.com/EFiKOzpdB4mHa7hvNPDQ-MYiz35rEJYfzjW7K3f4Q3soh3Z7M-kZdCJyiRHSHNrB9NmGyg=s85