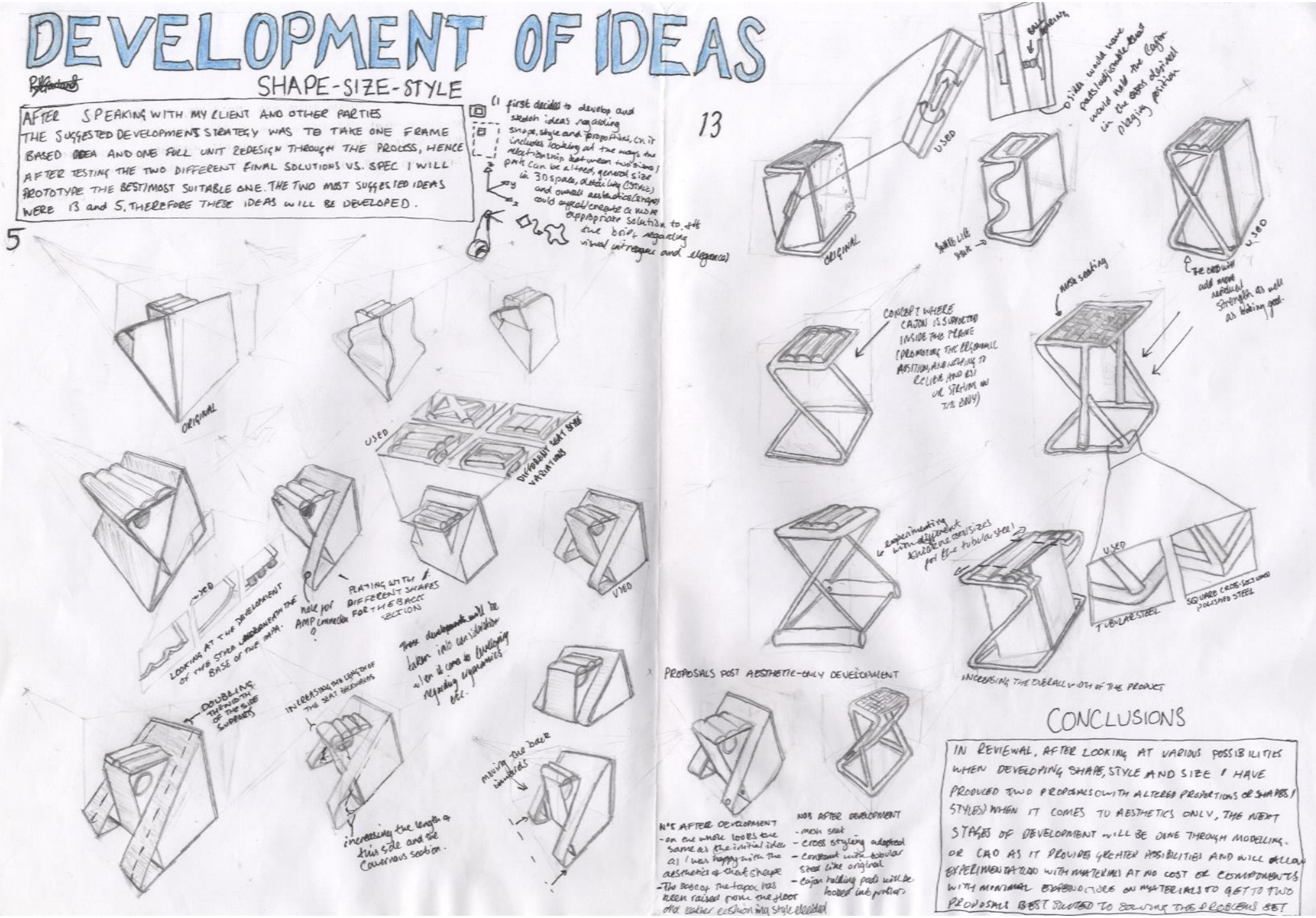
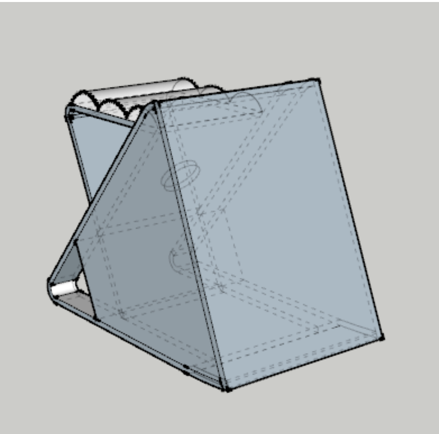

DEVELOPMENT OF IDEAS
SHAPE-SIZE-STYLE
AFTER SPEAKING WITH MY CLIENT AND OTHER PARTIES THE SUGGESTED DEVELOPMENT STRATEGY WAS TO TAKE ONE FRAME BASED IDEA AND ONE FULL UNIT REDESIGN THROUGH THE PROCESS, HENCE AFTER TESTING THE TWO DIFFERENT FINAL SOLUTIONS VS. SPEC I WILL PROTOTYPE THE BEST/MOST SUITABLE ONE. THE TWO MOST SUGGESTED IDEAS WERE 13 and 5, THEREFORE THESE IDEAS WILL BE DEVELOPED.
(I first decided to develop and sketch ideas regarding shape, style and proportions, as it includes looking at the ways the relationship between two sizes / parts can be altered, general size in 3D space, detailing (style) and overall aesthetics (shape) could affect/create a more appropriate solution to fit the brief regarding visual intrigue and elegance)
13
5
ORIGINAL
USED
DIFFERENT SEAT STYLE VARIATIONS
LOOKING AT THE DEVELOPMENT OF THE STEEL UNDERNEATH THE BASE OF THE ARM.
hole for AMP connection
PLAYING WITH DIFFERENT SHAPES FOR THE BACK SECTION
These developments will be taken into consideration when it comes to developing regarding ergonomics etc.
DOUBLING THE WIDTH OF THE SIDE SUPPORTS
INCREASING THE LENGTH OF THE SEAT BACKWARDS
increasing the length of this side and the Cavernous section.
moving the door inwards
sides would have pads/adjustable pads would hold the Cajon in the correct playing position
ORIGINAL
USED
USED
CONCEPT WHERE CAJON IS SUPPORTED INSIDE THE FRAME (PROMOTING THE ERGONOMIC POSITION, AND HELPING TO RELIEVE AND BE ... STRAIN ON THE BODY)
mesh seating
The cross will add more rigidity/strength as well as looking good.
experimenting with different cross-section sizes for the tubular steel
USED
TUBULAR STEEL
SQUARE CROSS-SECTIONED POLISHED STEEL
INCREASING THE OVERALL WIDTH OF THE PRODUCT
PROPOSALS POST AESTHETIC-ONLY DEVELOPMENT
N°5 AFTER DEVELOPMENT
- on the whole looks the same as the initial idea as I was happy with the aesthetics of that shape
- The base of the taper has been raised from the floor and seat cushioning style decided
N°13 AFTER DEVELOPMENT
- mesh seat
- cross styling adopted
- constant with tubular steel like original
- cajon holding pads will be looked into further
CONCLUSIONS
IN REVIEWAL, AFTER LOOKING AT VARIOUS POSSIBILITIES WHEN DEVELOPING SHAPE, STYLE AND SIZE I HAVE PRODUCED TWO PROPOSALS (WITH ALTERED PROPORTIONS OR SHAPES/STYLES) WHEN IT COMES TO AESTHETICS ONLY, THE NEXT STAGES OF DEVELOPMENT WILL BE DONE THROUGH MODELLING OR CAD AS IT PROVIDES GREATER POSSIBILITIES AND WILL ALLOW EXPERIMENTATION WITH MATERIALS AT NO COST OR COMPONENTS WITH MINIMAL EXPENDITURE ON MATERIALS TO GET TO TWO PROPOSALS BEST SUITED TO SOLVING THE PROBLEMS SET

Ergonomic Development



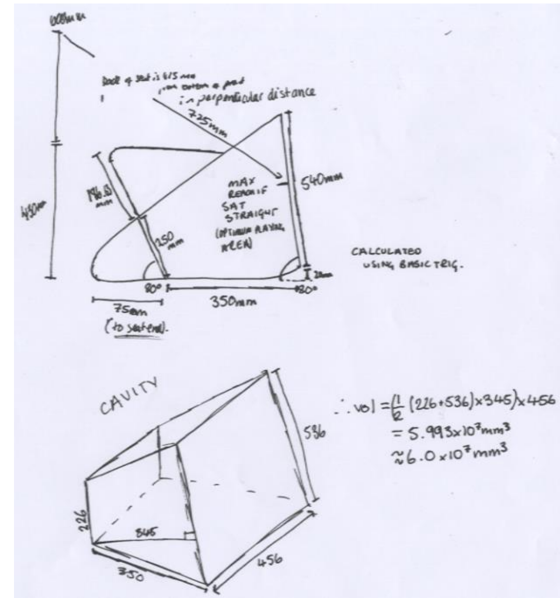
Idea 5 (CAD Drawing post initial development) (un-rendered)

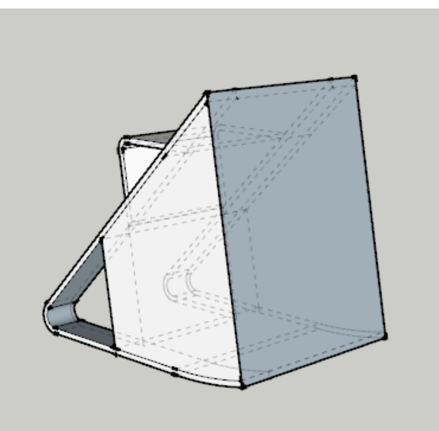
SketchUp

Table of Anthropometric data that must be used to develop the Cajon in order to make it as ergonomic as possible.

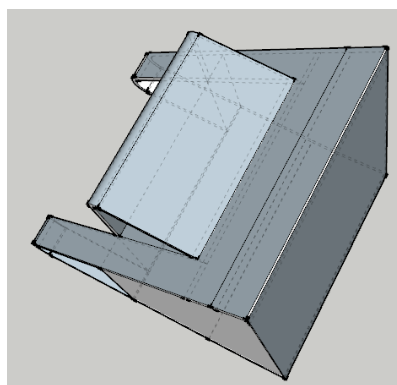
MEASUREMENT	VALUES
DEPTH (tapa - back of seat)	460mm max
WIDTH (seat)	375mm max. (340 suggested)
HEIGHT (seat from floor)	430mm (50th percentile)
IDEAL DISTANCE FROM SHOULDERS-MIDDLE OF TAPA	775mm (50th percentile)
VOLUME OF CAJON	5.0-6.0x10^7 mm^3

I measured the dimensions of Will's current Cajon and 6 others, that produced a desirable sound to get an average volume, this must be used to get the desired sound. (NOTE- *surface area of side parallel to tapa must be as close to that of the tapa itself*)

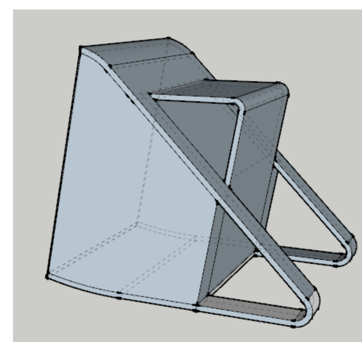




Altering the side of the product to fit the depth, height and distance from shoulder sizes.

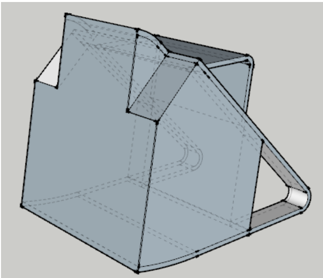


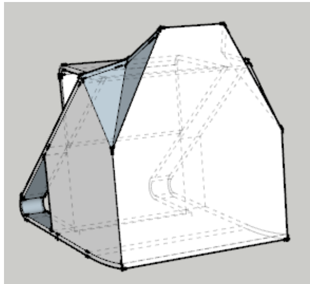
Increasing seat width to accommodate all (340mm) and full width of product (480mm) to create the correct volume of cavity.



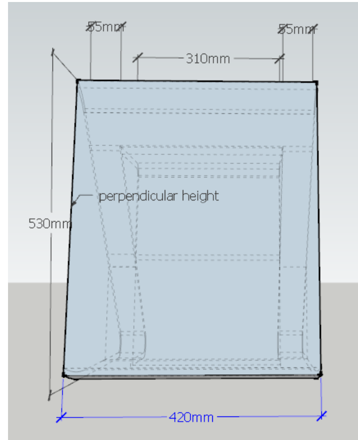
Curving the top edge in order to increase aesthetic appeal.

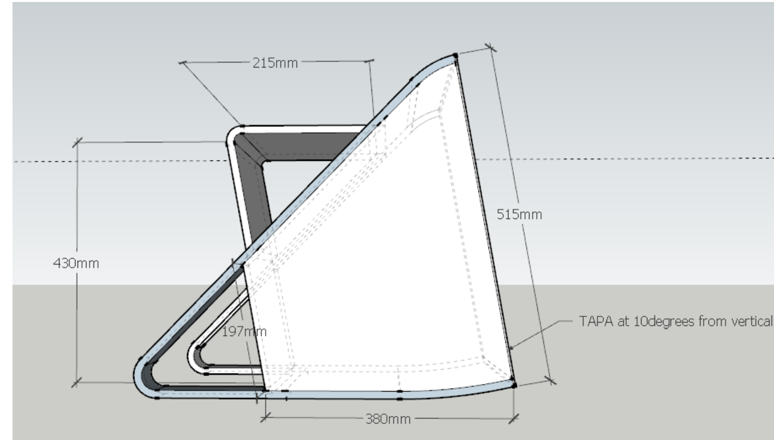
On the following side are variations of the product that take into account ways to make the legs more comfortable and reduce strain on the groins that may occur when stretching around the product.





A range of variations stem from this principle of taking out corners, however this affects the volume of the Cajon and although it sometimes looks aesthetically pleasing the playing surface is reduced and altered and thus the final sound produced..





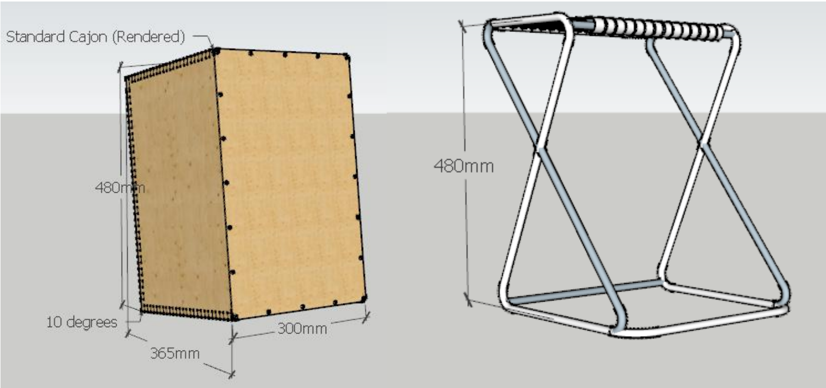
After realising this, I took the initiative to reduce the width of the total product by 40mm, in order to help with reducing strain on the groins. I balanced this for volume by increasing depth of the cavity by 30mm to 380mm, this both looks more aesthetically pleasing and compromises style and function. Top Right show the revised dimensions, which I believe are a great compromise from those desired and those attainable without loss in aesthetics.

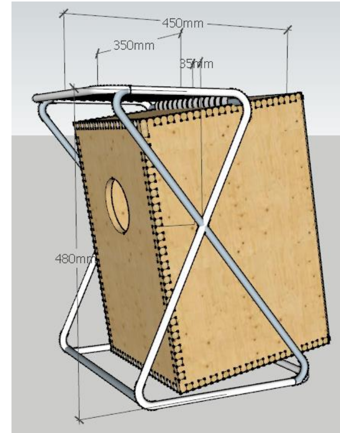
Idea 13 (CAD Drawing post initial development) (un-rendered)

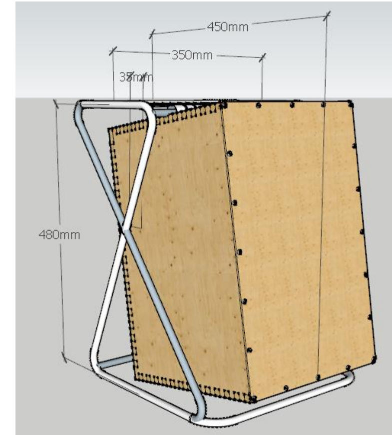
Table of Anthropometric Data and Useful Sizes

MEASUREMENT	VALUES
HEIGHT/WIDTH/DEPTH OF STANDARD CAJON	460mmx300mmx350mm
WIDTH (seat)	375mm max. (340 suggested)
HEIGHT (seat from floor)	430mm (50th percentile)
IDEAL DISTANCE FROM SHOULDERS-MIDDLE OF TAPA	775mm (50th percentile)
IDEAL PLAYING ANGLE	110° CCW from horizontal

After the Drawing in proportion to the sketch on slide 17 was complete, I scaled the seating position down to 430mm, the ideal sitting height, with knees at right angles.







However, the height at which the seating position of a standard Cajon and distance from the middle of the tapa to shoulders, (Cajon at 10° CCW from vertical), is approximately 480mm, so for practical purposes, the height of the frame should be increased by 50mm to 480mm.

Following this, I then took into account sizes such as the width of the standard Cajon and the width of the seat, I decided to give a 35mm gap either side in order to allow for variations and to keep the seat width just below 375mm. And created a depth below 460mm for ergonomic reasons, and to keep proportions.

Idea 5 Final Sizes

MEASUREMENT	IDEAL VALUE	FINAL VALUES
DEPTH (tapa - back of seat)	460mm *max	
HEIGHT (seat from floor)	430mm	430mm
WIDTH (seat)	340mm	310mm
TOTAL SPACE OCCUPATION	n/a	530x420x455mm
CAJON VOLUME	$6.0\text{x}10^7$ mm^3 *max	$5.6\text{x}10^7$ mm^3
DISTANCE FROM SHOULDERS-MIDDLE OF TAPA	775mm	775mm ±20mm *depending on shoulder position

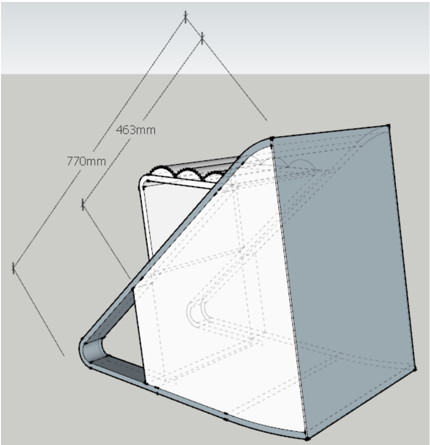
Idea 13 Final Sizes

MEASUREMENT	IDEAL VALUE	FINAL VALUES
DEPTH (tapa - back of seat)	460mm *max	450mm
HEIGHT (seat from floor)	430mm	480mm
WIDTH (seat)	340mm	310mm
TOTAL SPACE OCCUPATION	n/a	500x400x410mm
PLAYING ANGLE	110° CCW from horizontal	110°±5° CCW from horizontal

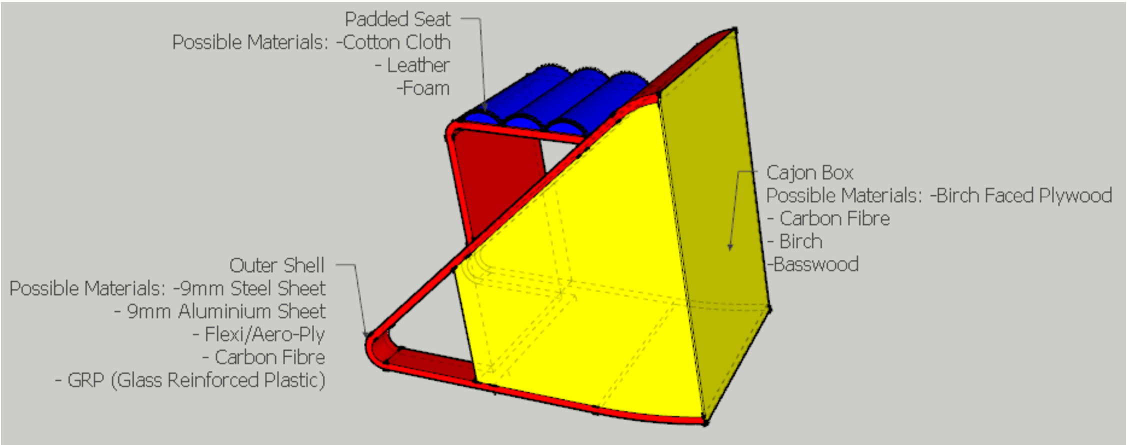
Above are the final sizes of each idea after ergonomic development, some sizes are different to the ideal ones due to impracticalities but I have attempted to keep them as close to those suggested in order to make my solution as ergonomic as possible.

Materials Development

Materials used to make the product must be considered and compared, both aesthetically and regarding their properties.



Idea 5 with a padded seat added for comfort as specified by client, to overcome poor options available currently.



Above is a colour coded version of Idea 5 to show where the different materials are located, and which materials could be used for each section.

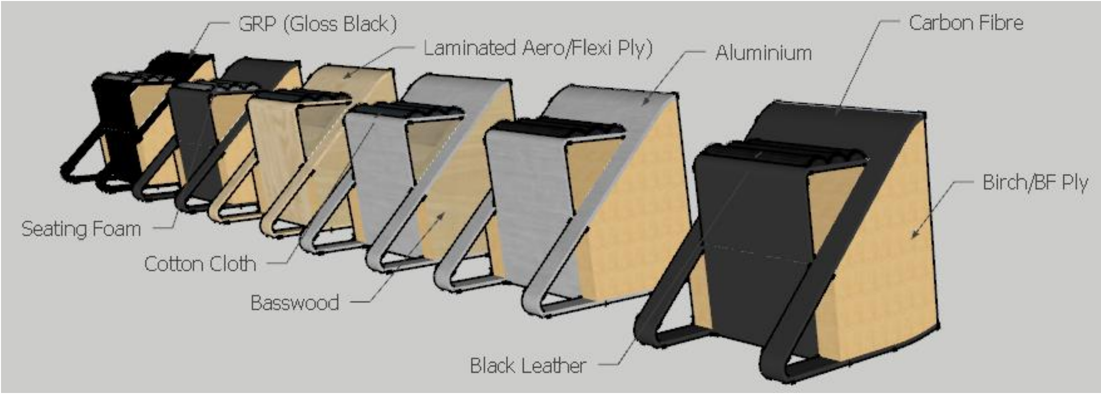
Cajon box part of the idea

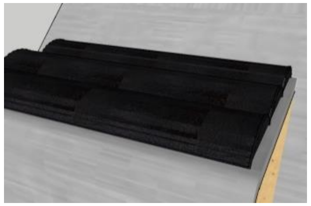
Padded seat

Outer shell supporting seat and creating the overall shape.

I then took a sample of each material and examined their properties, and hence which would become the most suitable for my product in order to create a solution that conforms to spec as well as possible. Below is range of textured CAD models of the product to show the aesthetic qualities of a range of material combinations.

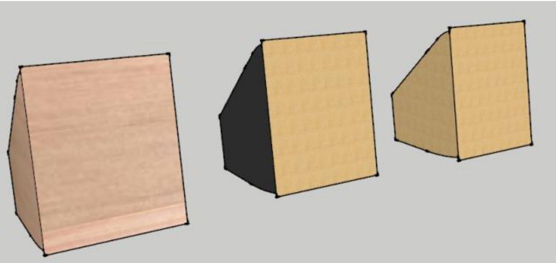
SEAT MATERIAL	EVALUATION
Black Leather	Tough wearing material, good for regular use. Fits with any outer shell material.
Cotton Cloth	Thin, but easy to work with and inexpensive compared to leather, similarly fits with most other materials.
Seating Foam	Quick and easy to apply with an adhesive, however not hard wearing or fit the aesthetic as well as leather or cloth.

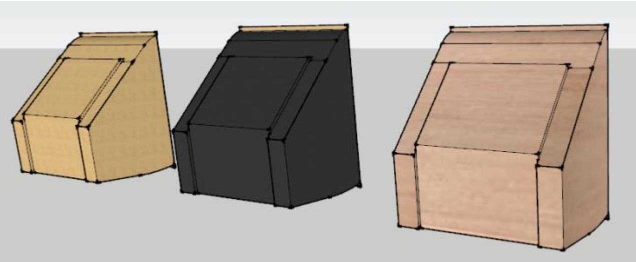




EVALUATION OF SEATING MATERIAL: I should use back leather stuffed with synthetic fill in order to create the most comfortable solution it is both hard wearing and aesthetically pleasing. And works well with a range of material combinations.

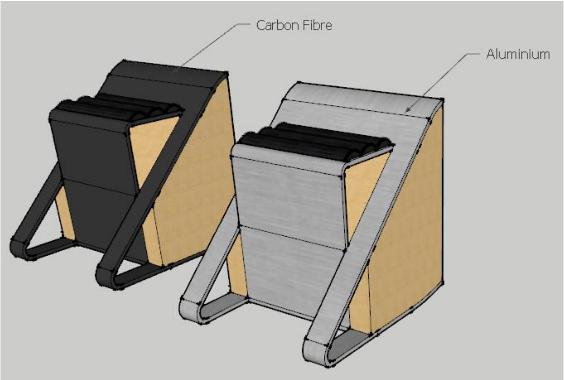
EVALUATION OF CAJON BOX MATERIAL:
A Carbon Fibre backed Cajon would reduce weight and perhaps make improvements to the final sound heard. However the Cost effectiveness of this material in this part of the product is low, compared to a more traditional Birch Faced Plywood construction, which would be the material of preference, due to ease of manufacture, and cost compared to alternatives. A traditional sound was reproduced when I tested the materials together.





Above are three different iterations of the ways the possible materials for the box could be combined using CAD. Left is Birch/BF Ply, Middle is a carbon fibre box with BF Ply for the Tapa, and right is a basswood version.

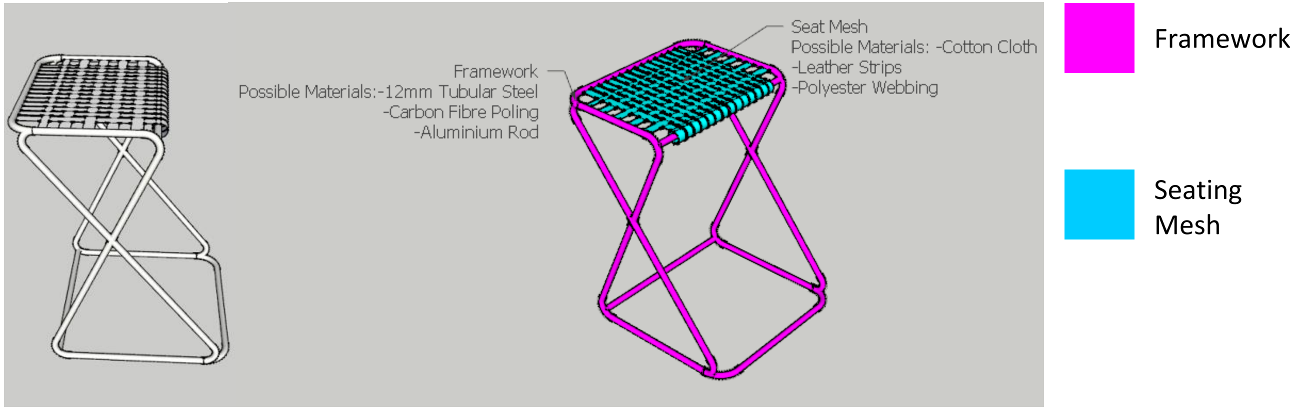
CAJON BOX MATERIAL	EVALUATION
Basswood	Aesthetically appealing material and nature of material means that acoustically it performs well but it can be quite costly to use and more difficult to acquire than other options.
Carbon Fibre/Birch/BF-Ply Combination	In this iteration, the tapa was a traditional wood, and to mix modern and traditional materials together I decided to research and experiment with the properties of carbon fibre. The acoustic reproduction of carbon fibre means that the sound produced is much clearer to the ear due to a larger range of frequencies being resonated. Its lightness also means that the final product is much more portable as it is lighter than its wooden counterpart. Disadvantages include cost, and the need for a full mould in the desired shape of the backing of the Cajon.
Birch/Birch Faced Ply	Many traditional versions of the Cajon incorporate Plywood., in particular birch faced. It is inexpensive, comes in a wide range of thickness giving options regarding the replication of frequencies . Standard birch is more uniform as a material and good for working with, and has similar properties to basswood, when tested, its aesthetic is similar to BFP however the cost would make BFP the preferred option of the two materials.



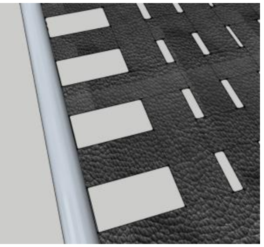
EVALUATION OF OUTER SHELL MATERIAL: Both Carbon Fibre and the 12mm Aluminium option after a comparison of all of the suitable materials have come out on top, the use of either material would achieve the desired aesthetic and presence of the instrument, although they are not the easiest of the four to construct, they are the strongest and have the most desirable properties. This means that they are both suitable for a proposed solution to the clients problems, Further testing should ensue once I have tested both developed solutions vs. spec in order to decide which material to use to complete construction of my prototype. (Above are the final models of this idea after materials development.

Right is a colour coded version of Idea 13 to show where different materials will be located, and which materials could be used for each section.

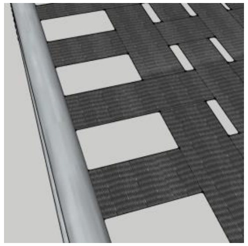
OUTER SHELL MATERIAL	EVALUATION
Carbon Fibre	The material adds a futuristic aesthetic, it is modern, lightweight, has high residual strength, and can be shaped and set easily, making it suited to the function of the shell, and strengthening the seating position.
Aluminium	Aluminium is lighter than its steel counterpart however a much cheaper option than Carbon Fibre or GRP, 9mm is not strong enough for the holding the user, however 12mm aluminium was, and the contrast between it, leather and birch-ply is very elegant, as asked for by the client. Holes could be cut into the base to reduce weight however.
GRP (Gloss Black)	Similar to Carbon Fibre in weight, however, not as strong, But the Gloss black finish, as shown on p22, is very aesthetically pleasing, and the way GRP is formed makes achieving the complex shell shape very easy.
Flexi-Ply	Another light material, and the lamination process means it can be formed easily, in terms of cost it is inexpensive in comparison to other suggestions. However, its strength is questionable, and does not create variation in my design like aluminium or Carbon Fibre.



Using the same technique as idea five, I took samples of the materials, looked at their properties and compared the tests using tables of evaluation and CAD modelling to come to a conclusion as to which materials would be most suitable for use in idea 13.



Example of proposed leather strips (CAD)



Example of proposed polyester webbing(CAD)

Example of proposed Cotton Cloth (CAD)

The proposed idea 13 (12mm Tubular Steel with Polyester Webbing)

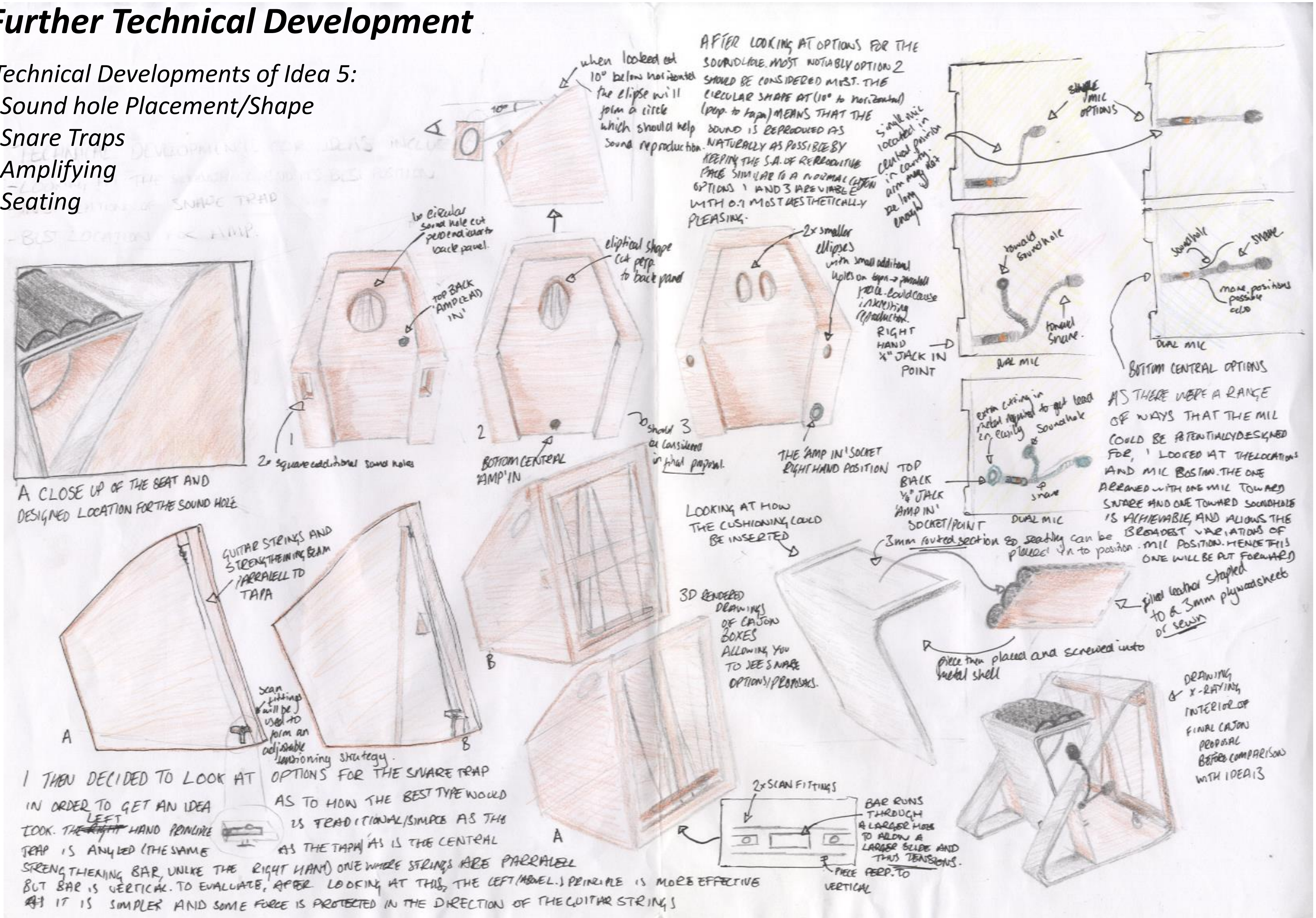
FRAME MATERIAL	EVALUATION
TUBULAR STEEL	Tubular steel is widely accessible, and the 12mm variation I found to be very residually strong, whilst being light, along with this it can be bent cold, and welded to create the desired frame.
ALUMINIUM ROD	Aluminium Rod is heavier, as it is not hollow, but his makes thinner versions stronger, or the same thickness as tubular steel very strong with a similar aesthetic created.
CARBON FIBRE	A carbon fibre poling option, would look futuristic, and although strong, I found my test piece very brittle, so it may be unable to take the same weight tolerances as tubular steel or aluminium rod.

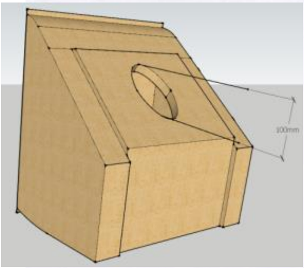
MESHING MATERIAL	EVALUATION
LEATHER STRIPS	Extra stress can cause the strips to stretch and they would have to replaced a lot, however the idea is simple, and the contrast between the poling options looks like it is intended for a range of environments.
POLYESTER WEBBING	This material is found in car seatbelts, and because of this it is very strong and very suitable for taking the weight of humans in a mesh, it doesn't stretch and transfers the weight acting on it to the points supporting it meaning it can be placed in a range of patterns. The movement the material does allow improves comfort. The plain black look means it its any of the framework materials suggested.
COTTON CLOTH	The material looks appealing, however to create any sort of strength, the material must be layered up and even then tearing can still occur. The manufacture is much more difficult than the Polyester webbing option for example.

EVALUATION OF IDEA 13 MATERIALS: Tubular steel is the most suitable option for the framework, as it is light, strong, and much easier to manufacture than carbon fibre, which is only marginally lighter. I should use polyester webbing for the seating mesh, due to its suitability in the scenario where there is no additional support underneath the seating position as highlighted above. These material developments should make the solution as effective and improve how it is sited to specification.

Further Technical Development

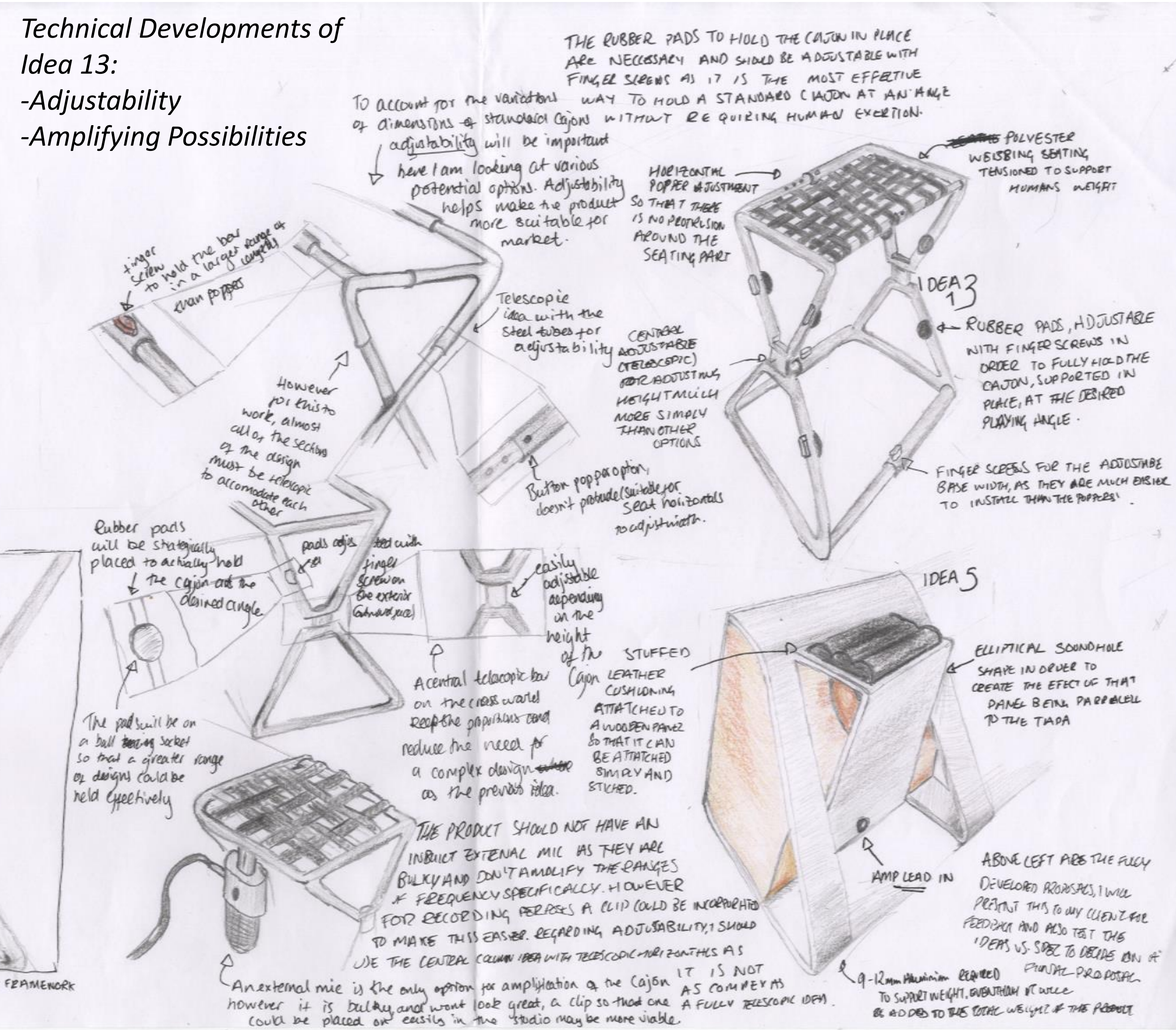
Technical Developments of Idea 5:
-Sound hole Placement/Shape
-Snare Traps
-Amplifying
-Seating





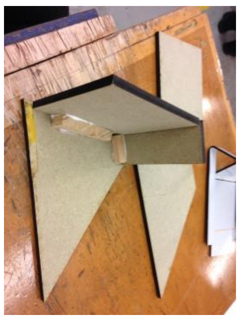
CAD Rendering of the box of idea 5, showing that the size of the hole seen at the 10° angle

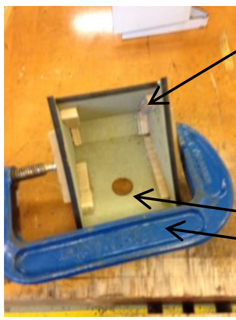
Technical Developments of Idea 13:
-Adjustability
-Amplifying Possibilities



Construction Testing and Development

I then decided to test how I would manufacture the products using method of scale modelling, I chose this technique as it allows me to see first hand how a design transfers into reality and thus gives me the best basis to base the according developments to the product upon, as problems that occur in scale modelling, will no doubt also occur in the full manufacture, hence scale modelling saves cost, and means that problems that occur during manufacture are reduced. I used a 1:4mm scale as the materials would still behave in very similar to manner as they would at full size. I was content with how Idea 13 could possibly be made, using cold bending of the tubular steel, and drilling cutting and welding , reducing the various required slots and holes in order to form the desired shape..



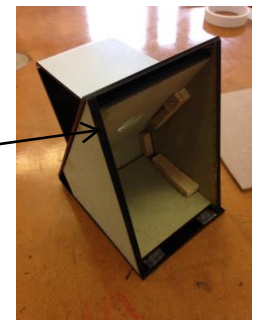


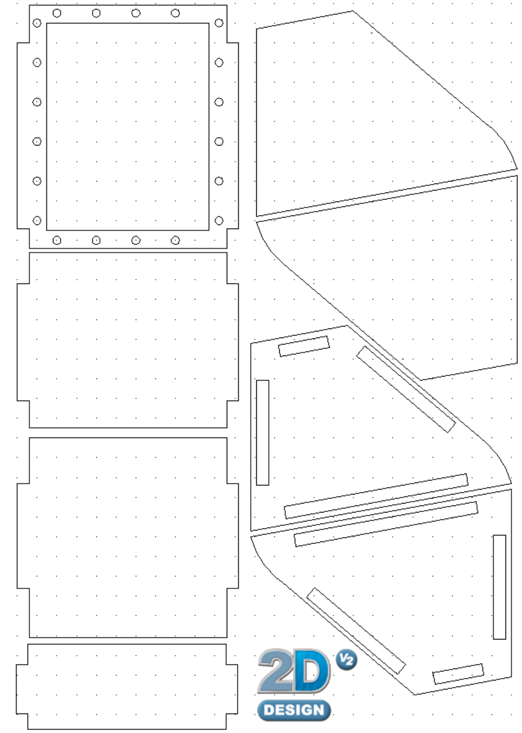
Infills are made from offcuts of the panels

This type of construction means that a lot of pressure will be put through the top panel, this means that manufacturing the real Cajon in this manner would risk snapping the box apart.

A simple circular sound hole for modelling purposes.

G-Clamps were required in order for the Cajon box to set as desired

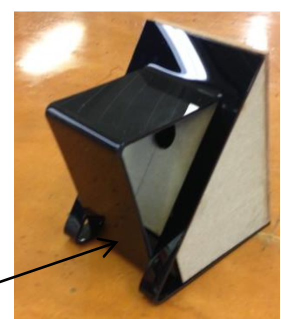




Above is the 2D file which was exported as a .dxf and sent to a laser cutter in order to cut the panels for my example housing model with increased accuracy.

Initially, I began looking at the Cajon box construction for idea 5, using the research that I collected, I created the box using butt joints with the infill, simply using PVA glue to hold the pieces together. The construction as simple, however, to get the angles it took trail and error, this was time consuming. Finger joints were inappropriate for this type of construction although they would have added the extra strength that the construction required.

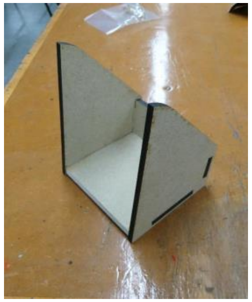
With 3mm acrylic at this scale the seat took 50kg of weight with ease

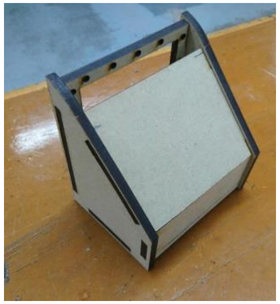


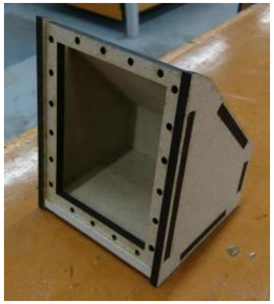
Not shown in the model, however the aluminium shell will be attached to the wooden box using a suitable number of countersunk screws.

Experimenting with he manufacture of the aluminium shell, I chose to use and line bend 3mm acrylic, cut using a single net created on Techsoft 2D Design. The process worked well, and I believe that this could be achieved using aluminium, and cold bending. However 4mm aluminium would have to be used. Not only would this make manufacturing simpler, it would also reduce the weight of the shell by 2/3. The effect created by this is very aesthetically pleasing.

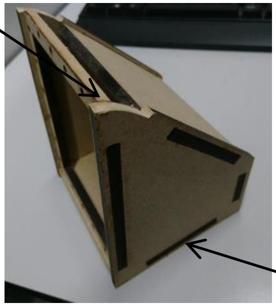
As problems were with my initial plans for how the box could be constructed, I began to think of alternatives, one of which is shown below, it is the use of half housing joints which consisted of a lug slotting into the cut outs on the side panels. I used 6mm Medium Density MDF. I then took the pieces, and simply slotted them together, filing and sanding down in order to achieve the angled corners.





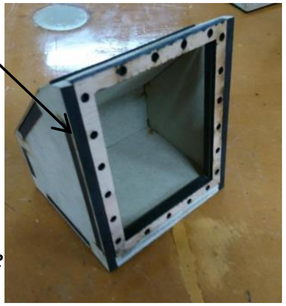


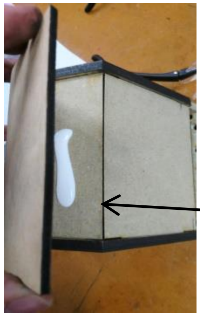
The design has the curves section cut out, so that flexi ply can be laminated to fully close the box construction rather than a more time consuming steam bent piece.

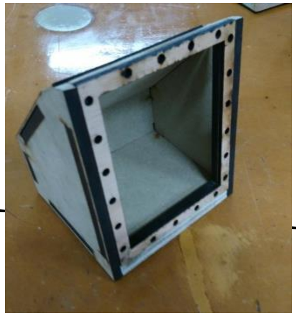


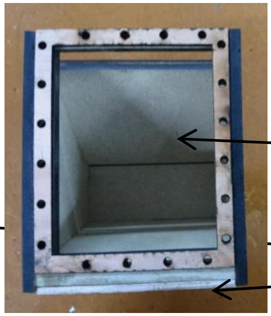
Tapa connecting 'frame' is also housed into the side panels for ease of construction.

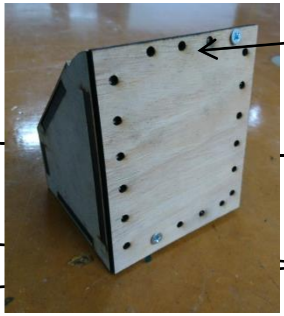
Cut outs will be offset 3mm from the edge of the side panels.









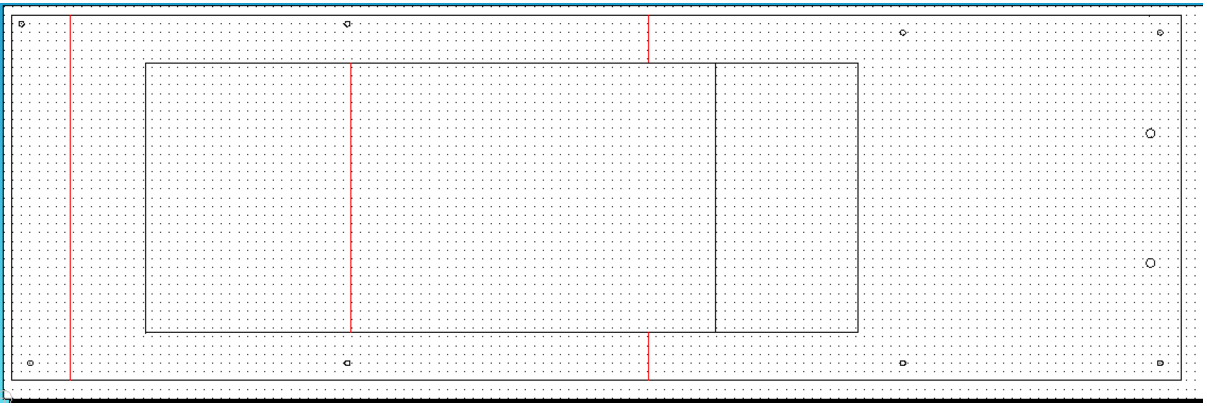


6-8 screws will run up either side of the vertical on the tapa, 4-5 screws will also run at regular intervals across the horizontal edges as seen here.

No sound hole was cut out or snare installed due to this box being a direct scale model of the final box.

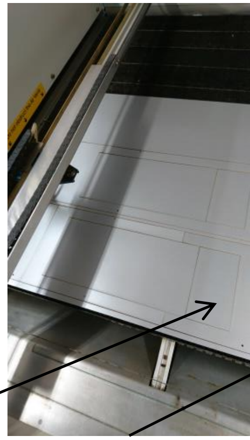
As seen here, decorative 3mm birch faced play will be placed in the indent left by this type of construction, to achieve a desirable flush finish.

In order to achieve a flush edge with the side panels, and aluminium shell, I decided that the best method was to use 3mm Birch Faced Ply for purely decorative reasons, so that the user would not be able to see the unappealing cut outs. Hence this will be the case with the final product. As can also be seen here, the frame connector must also be brought flush, which will result in the associated 'snap' sound created by the tapa.



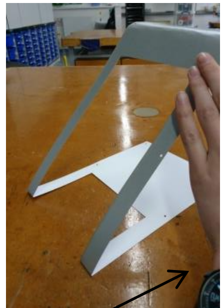
As my material development suggested the shell should be made out of aluminium. I did not have the tools available in the workshop, hence I would have to look at commercial processing. I tested a card model to look into how the part should be processed commercially and if this was the most effective technique.

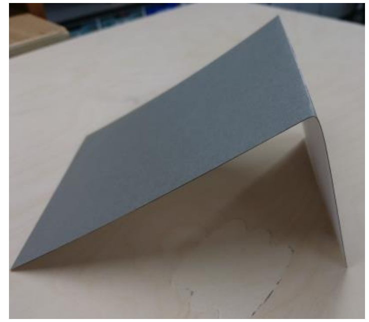
Left is the 2D file which was exported as a .dxf and sent to a laser cutter in order to cut the two sections for my proposed outer shell/seating design

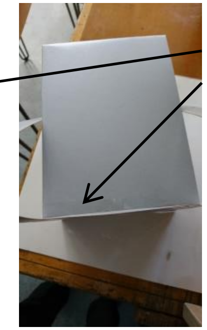


Laser Cutting the scale model from dxf to thin card into two sections (Seat and Shell).

Each section was then bent along an engraved line to angle.

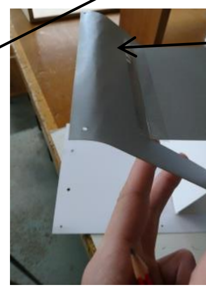




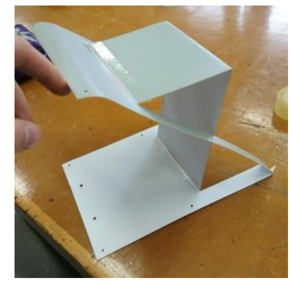


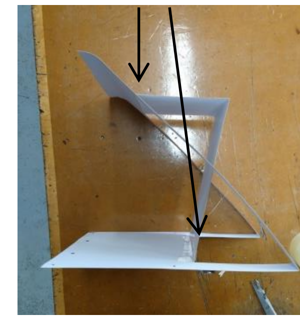
Sections were then taped together to express where the weld would be.

The completed outer shell scale model side on, to express the shape. ***WELDS***

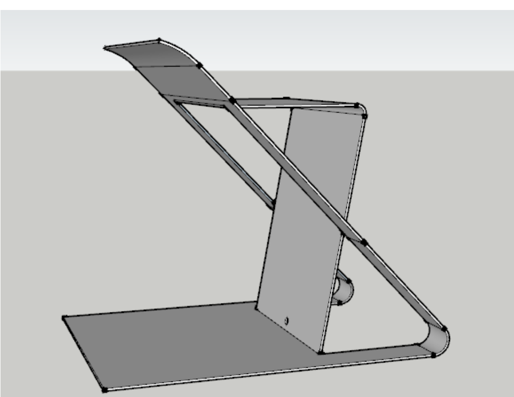


A radiuses bend would be required to form the top curve. I chose no to have one on the bottom face (left). Tensioner access and connecting holes in base.





To create the shell, a range of processes would be needed. I evaluated the most time efficient ones and chose these to form a priniciple scale model (3:1) from thin card, this would also give me a feel as to how to inform others of how it should be made. In the model, I laser cut one sheet of thin card, with connecting holes, into two panels, I then bent them individually, and conjoined them into the desired style using selotape to represent a weld.



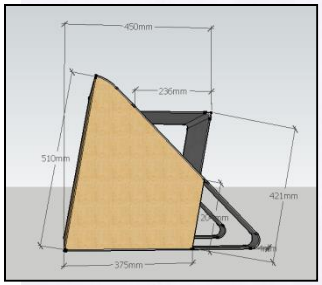
CAD Model of Resultant Outer Aluminium Shell Using the successfully tested methods above and industrial processes.

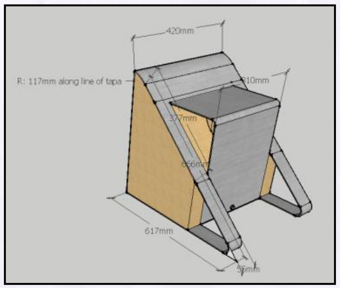
RESULTANT CONSTRUCTION DEVELOPMENTS OF IDEA 5

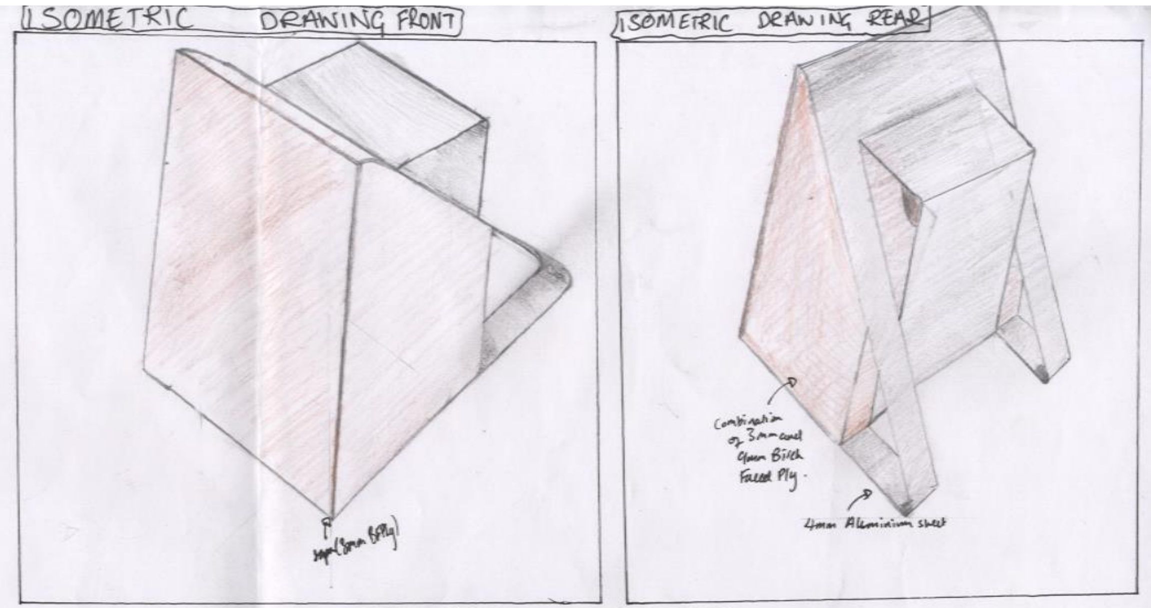
- *Half housing, with lug/slot principle applied for construction of Cajon Box, as this simplifies the existing box construction, with decorative panes to create flush edges.*
- *Curve on bottom face removed from design due to added complexity for little practical gain*
- *Flexi-Ply Lamination used to complete box construction on top curved edge*
- *4mm Aluminium sheet will be used for the final shell construction (reduction of weight, and complex shape can be achieved using cold bending/welding with ease)*
- *Shell manufactured in two parts and cold bent separately, then welded together*

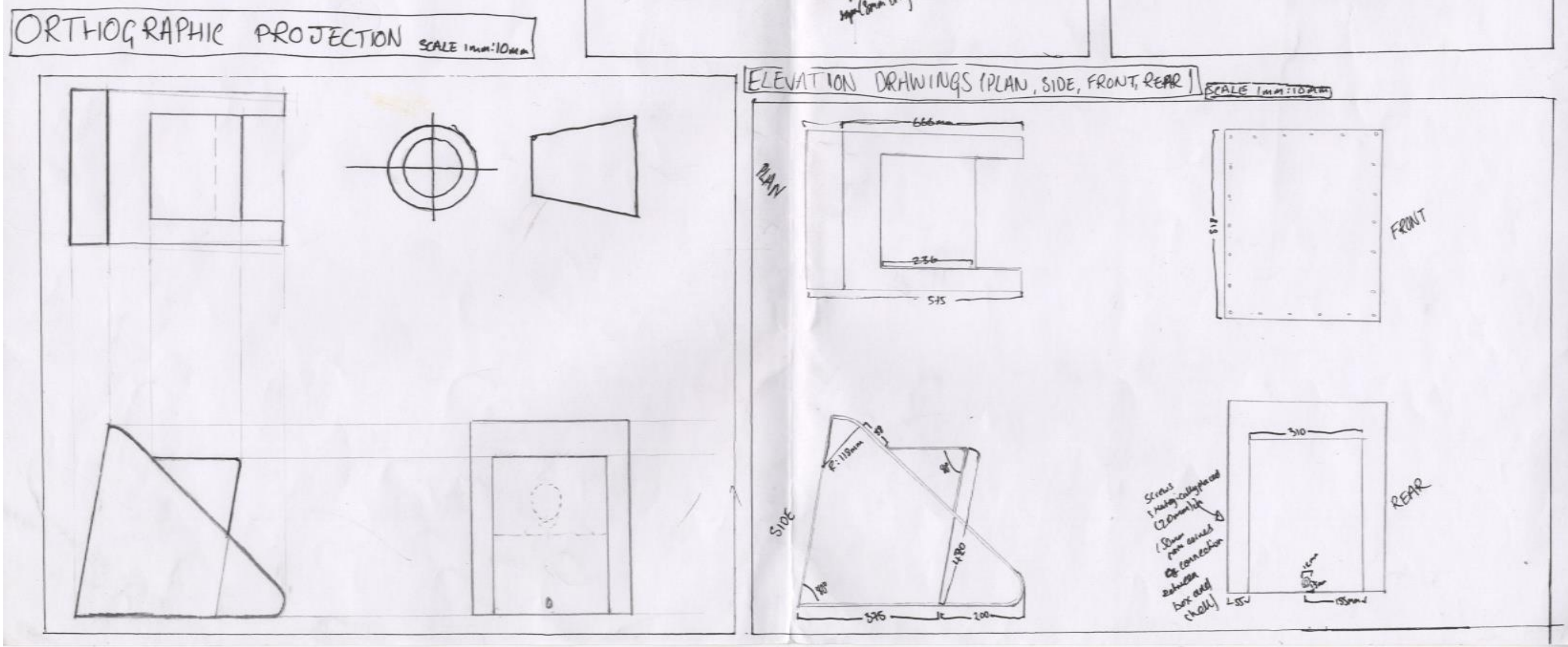
Manufacturing Specification

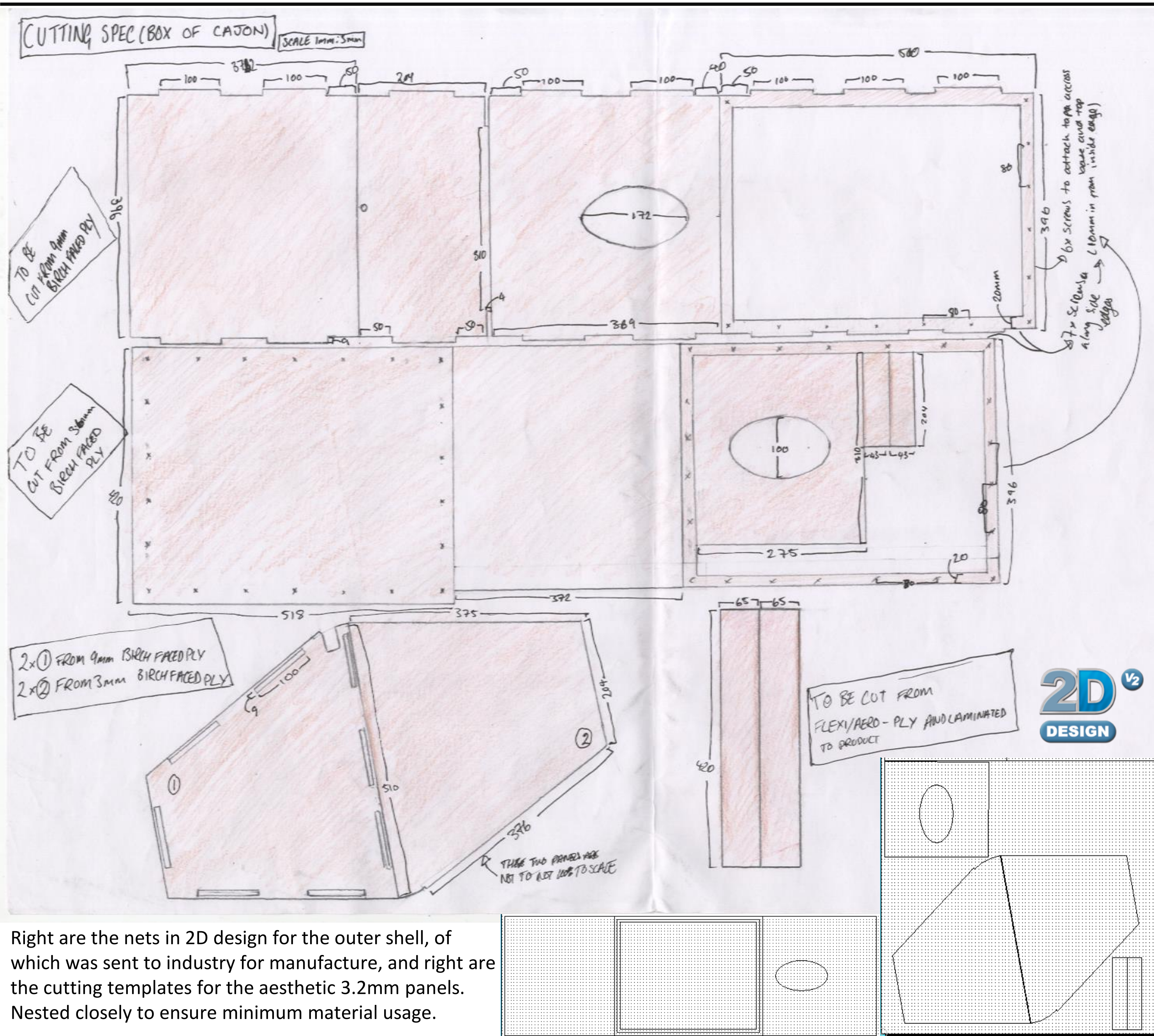
- Orthographic Projections
- Elevation Views
- Isometric Drawing
- Nets/Cutting Specification

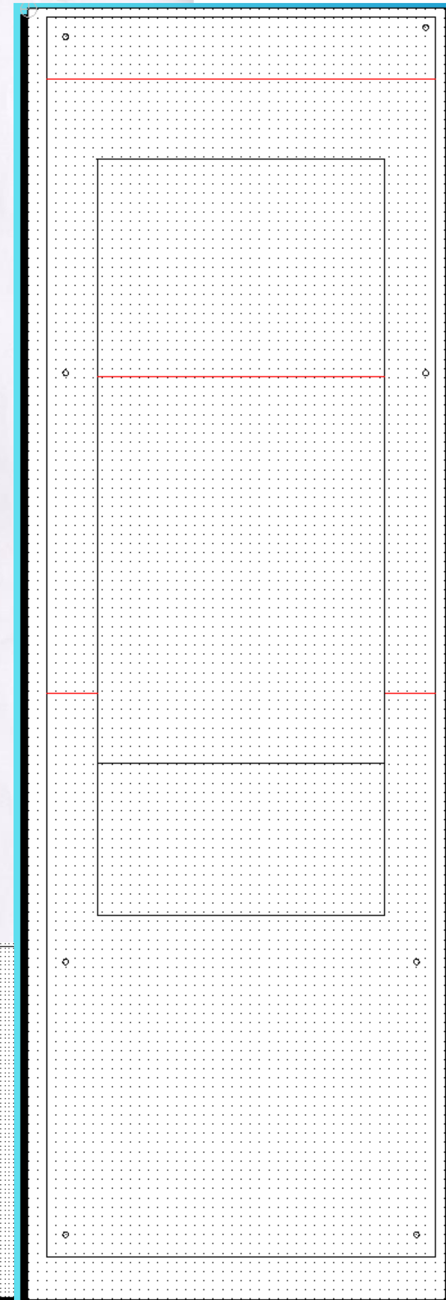








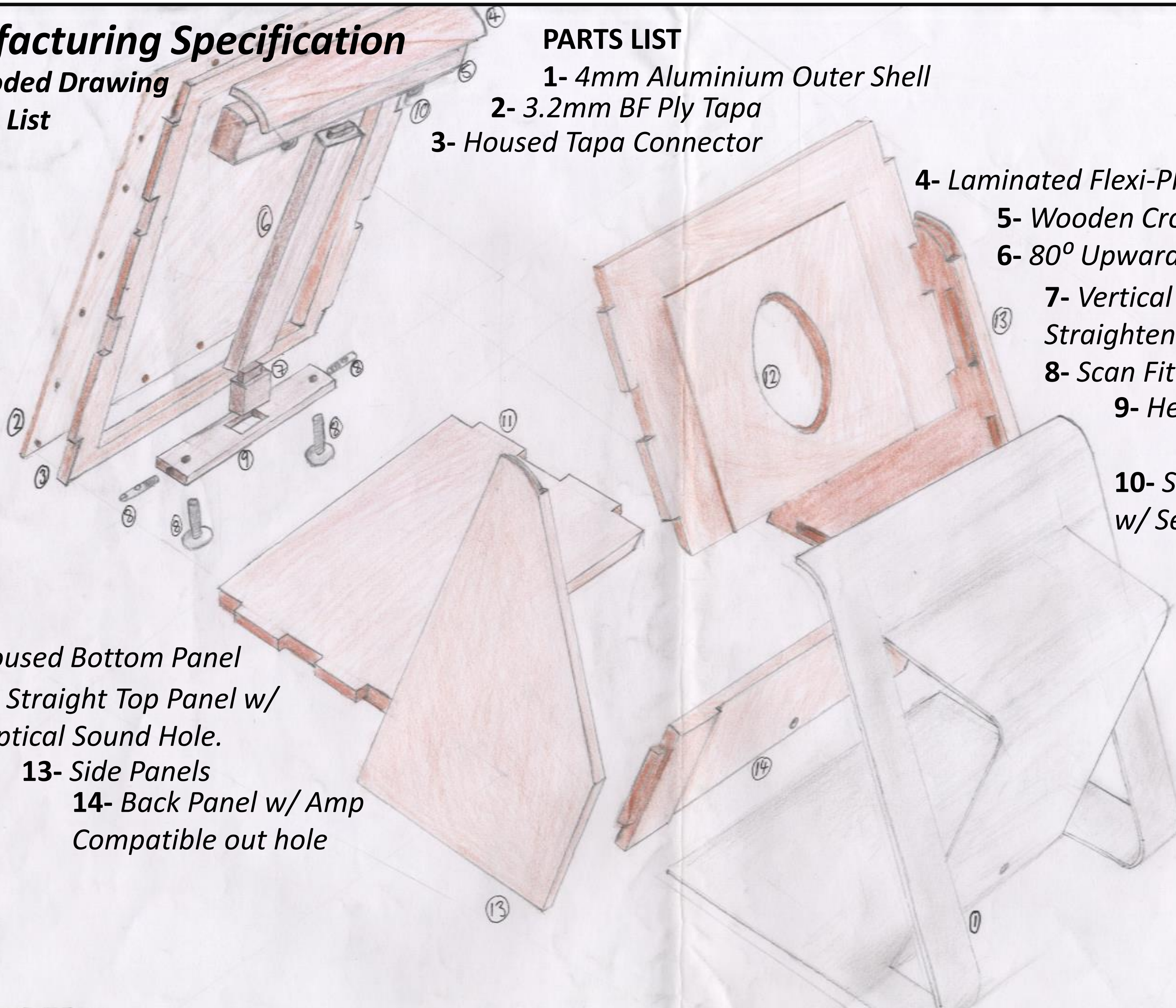




Right are the nets in 2D design for the outer shell, of which was sent to industry for manufacture, and right are the cutting templates for the aesthetic 3.2mm panels. Nested closely to ensure minimum material usage.

Manufacturing Specification

- ***Exploded Drawing***
- ***Parts List***



PARTS LIST

1- *4mm Aluminium Outer Shell*

2- *3.2mm BF Ply Tapa*

3- *Housed Tapa Connector*

4- *Laminated Flexi-Ply Top Curved Panel*

5- *Wooden Cross Beam*

6- *80^o Upward Strengthening Beam*

7- *Vertical Strengthening Beam Straightening Section*

8- *Scan Fittings*

9- *Hex Bolts (for Snare Adjustment)*

10- *Snare Guitar Strings w/ Securing Hooks.*

11- *Housed Bottom Panel*

12- *Straight Top Panel w/ Elliptical Sound Hole.*

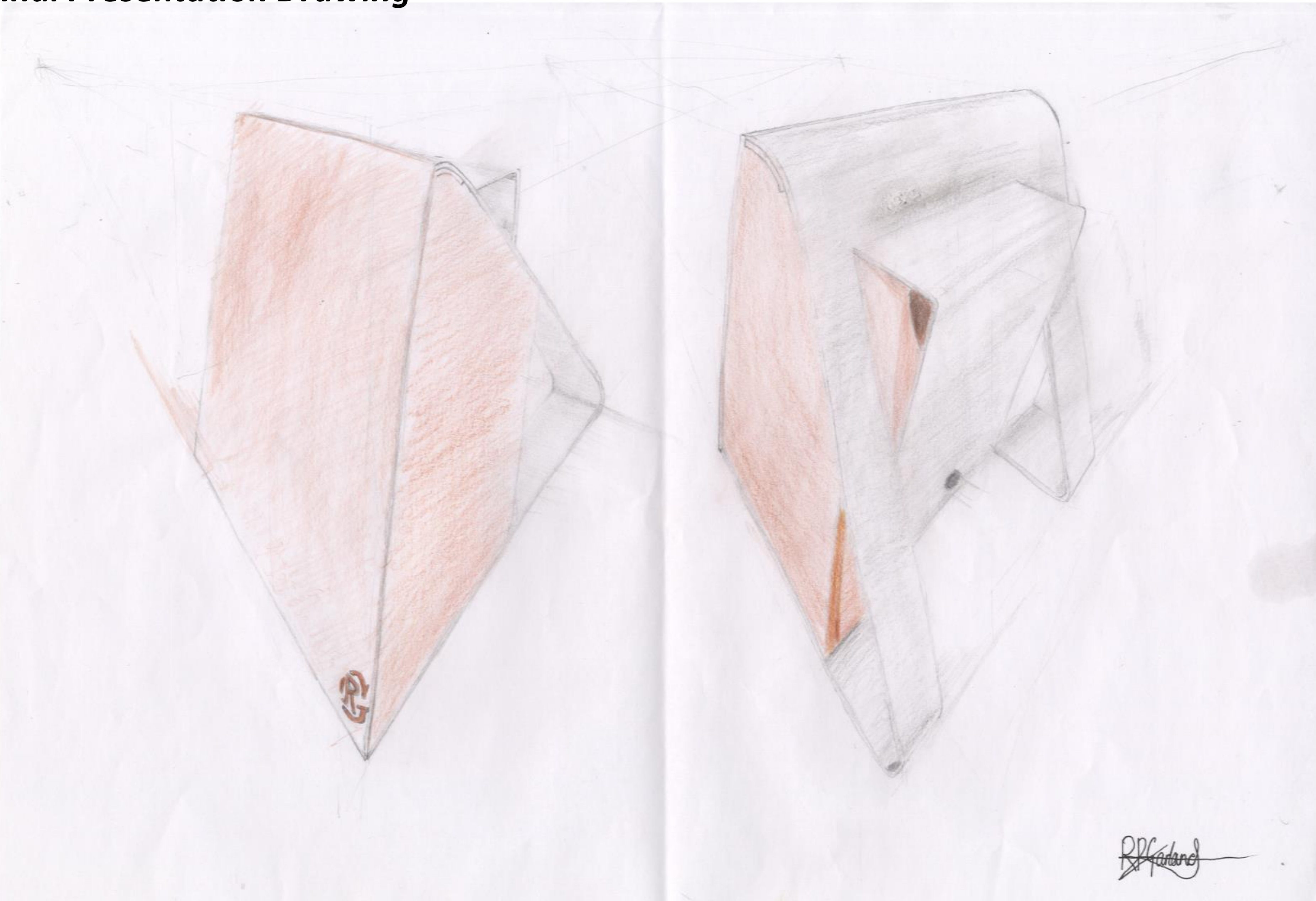
13- *Side Panels*

14- *Back Panel w/ Amp Compatible out hole*

EXTRUDED DRAWING IN ISOMETRIC PERSPECTIVE

NOTE: *All parts highlighted here should be sized and cut to the standards of the manufacturing specification and cutting spec on the previous slide.*

Final Presentation Drawing



Plan of Manufacture

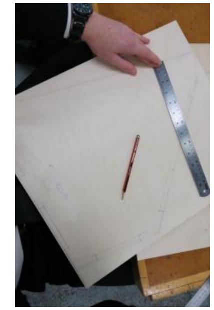
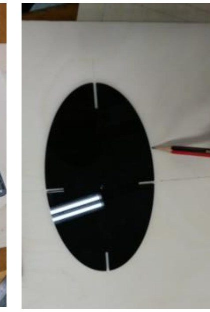
STAGE 1	DIRECTIONS	PROCESSES USED	EQUIPMENT REQUIRED	RISKS	AVOIDANCE	QUALITY CONTROL	TIME PROJECTED	TOTAL TIME
Mark out box onto plywood sheets.	Mark out (onto the correct thickness of BF plywood) the panels required for the Cajon Box, as specified in cutting specification.	Marking Out	Pencil Rule Tri-Square Pair of Compasses	Splinters from rough sawn edges. *Magnitude of Risk*: 2/10	Keep fingers away from edges of wood, and care when working with them. If a splinter is received carefully remove it with pliers, rinse wound, apply plaster.	Ensure that Tri-Square is used for perpendicular edges, check and redraw inaccurate edge measurements until they match the specification entirely.	1hr30	1hr30
STAGE 2	**DIRECTIONS**	**PROCESSES USED**	**EQUIPMENT REQUIRED**	**RISKS**	**AVOIDANCE**	**QUALITY CONTROL**	**TIME PROJECTED**	**TOTAL TIME**
Cut out panels and pieces required for the box	Using the appropriate saws, accurately cut out and drill the required holes of all of the marked pieces for the Cajon Box.	Cutting Drilling	Tennon Saw Coping Saw Pillar Drill Morticer	Trapping Fingers in saw, of trapping material/hair to pillar drill. Offcuts going into eyes. *Magnitude of Risk*: 8/10	Tie all loose Items of material/hair back, use protective eyewear, keep fingers as far away from cutting edges of machine saws as possible.	Use Clamps to hold wood in place on drills, and fence is used to get a straight edge, leave a minimum of 2mm from cut to markings.	1hr	2hrs30
STAGE 3	**DIRECTIONS**	**PROCESSES USED**	**EQUIPMENT REQUIRED**	**RISKS**	**AVOIDANCE**	**QUALITY CONTROL**	**TIME PROJECTED**	**TOTAL TIME**
Route housings on side panels	Using a router take out material in the side panels to form the cut outs in which the lugs of top, back and bottom pieces will sit.	Routing	Router	Trapping loose items in the spinning blade in the router. *Magnitude of Risk*: 8/10	Tie all loose items back, wear protective goggles, ensure fingers are kept well away from cutting blade	Similar to above, cut so that there is a minimum of 2mm from the cut lines to ensure the cut does not cause any inadequacies, which would cause material wastage and add to the total expense	1hr	3hrs30

STAGE 4	*DIRECTIONS*	*PROCESSES USED*	*EQUIPMENT REQUIRED*	*RISKS*	*AVOIDANCE*	*QUALITY CONTROL*	*TIME PROJECTED*	*TOTAL TIME*
File and sand all pieces to size/ angle	Using varying abrasiveness of files, sand paper, and the sanding machine bring the edges of all panels and pieces down to the specified dimensions and marked edges, sand to angle by fitting the existing parts together, and use mark/sand method gradually to bring pieces to size.	Sanding	Files Sandpaper (both of varying abrasiveness) Sanding Machine	Sawdust being inhaled or caught in the eyes. *Magnitude of Risk*: 2/10 Fingers caught by sanding belt. *Magnitude of Risk*: 7/10	Wear a Facemask, and protective goggles to ensure no sawdust is inhaled as it causes long term problems. Keep fingers as far away from sanding belt as possible.	Take Care when sanding, steadily bring each edge down, measure every time more sanding is done, to ensure the size of the panel is the same as the sizes measured.	2hrs	5hrs30
STAGE 5	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Apply decorative 3mm Birch Ply to structural panels	Using F and G Clamps, using a strong adhesive, join the panels together individually, to reduce problems that would occur if it was done later.	Lamination	F Clamps G Clamps PVA Glue	PVA glue is unhygienic. *Magnitude of Risk*: 1/10	Wear gloves when applying the glue, wash hands after completion.	Ensure the decorative and structural panels have been set so that there are no innacuracies.	1hr 30	7hrs
STAGE 6	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Fit the basic Cajon box together	Using the Specification of the box, fit the panels together, using an adhesive to ensure the joins hold together. Laminate the Flexi-ply part during this stage also. Then allow the adhesive to set. (Do not attach the tapa)	Assembling Lamination	PVA Glue Sash Clamps	N/A	N/A	Ensure that all of the pieces sit square to each other using a spirit level and tri square.	30mins	7hrs30

STAGE 7	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Install the 'snare' trap system	Install the pieces and parts for the snare part of the Cajon. Crimp the Guitar string ends into hooks, and tension them between the top and bottom beams, using the scan fittings, install the tensioning mechanism, and tension the guitar strings.	Assembly	Ferules and Wire Crimper Screwdriver	String is over tensioned and breaks, with harmful effect. *Magnitude of Risk*: 6/10	Use protective eyewear. Ensure strings and all parts are correctly installed before tensioning the wire.	Use an accurate tensioning screwdriver to ensure that the screws have not been over tightened. Use marking tools to ensure that pieces are installed right before moving on to the next.	1hr	8hrs30
STAGE 8	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Cut out Leather pieces for seating.	Using marking chalk and textile scissors, draw out, match, and cut the leather pieces to size Ready for stitching.	Marking Out Cutting	Marking Chalk Scissors	N/A	N/A	Mark leather using a wooden cut out for a template, to ensure that they are cut to the same size.	30mins	9hrs
STAGE 9	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Sew Leather seat	Using the black leather purchased, sew the leather seat together and stuff it with cushioning before attaching it to a thin wooden panel.	Stitching	Sewing Machine Staple Gun	Fingers Caught the needle. *Magnitude of Risk*: 6/10	Keep fingers away from sewing needle, and ensure proper machine set up.	Ensure that the stitch is in line with what needs to be sewn at all times, proceed to stich slowly, and accurately	1hr	10hrs
STAGE 10	***DIRECTIONS***	***PROCESSES USED***	***EQUIPMENT REQUIRED***	***RISKS***	***AVOIDANCE***	***QUALITY CONTROL***	***TIME PROJECTED***	***TOTAL TIME***
Cut out outer shell aluminium	Cut out the outer shell, as specified by the net created as two parts	High Intensity Laser Cutting (Industrial)	High Intensity Laser Cutter	N/A	N/A	Ensure laser is calibrated and aligned correctly.	30mins	10hrs 30

STAGE 11	DIRECTIONS	PROCESSES USED	EQUIPMENT REQUIRED	RISKS	AVOIDANCE	QUALITY CONTROL	TIME PROJECTED	TOTAL TIME
Bend and weld aluminium shell	Using a powerful cold bending machine, and TIG welding, bend each section at the correct points, as specified, and weld the two parts together to form the final outer shell.	Cold Bending MIG welding (both done by industrial manufacturer)	Cold Bending Machine MIG Welding Bay	High intensity light from the electrostatic arc formed damages eyes, or burns to skin occur.	Wear Welding Gloves and mask, along with protective suit to help to prevent any bodily harm.	Check Bending machine is calibrated correctly, and that resultant piece is accurate. If not, re- cut bend and weld the piece, until it is correct.	1hr	11hrs 30
STAGE 12	**DIRECTIONS**	**PROCESSES USED**	**EQUIPMENT REQUIRED**	**RISKS**	**AVOIDANCE**	**QUALITY CONTROL**	**TIME PROJECTED**	**TOTAL TIME**
Attach Seating to shell	Using Counter sunk screws that will not harm to user when sat on the cushioning, attach it to the outer shell.	Assembly	C/S Screws Screwdriver	N/A	N/A	Ensure that the holes aligns before screwing, and that the cushioning sits square, if not, repeat the construction of the seat.	15mins	11hrs 45
STAGE 13	**DIRECTIONS**	**PROCESSES USED**	**EQUIPMENT REQUIRED**	**RISKS**	**AVOIDANCE**	**QUALITY CONTROL**	**TIME PROJECTED**	**TOTAL TIME**
Attach Outer Shell to Cajon Box	Again using the strategically placed screw holes, align the box and shell up, then attach the two together.	Assembly	C/S Screws Screwdriver	N/A	N/A	Ensue the entire box sits flush, as desired by specification. If not, make adjustments and realign beforehand.	20minutes	12hrs 5
STAGE 14	**DIRECTIONS**	**PROCESSES USED**	**EQUIPMENT REQUIRED**	**RISKS**	**AVOIDANCE**	**QUALITY CONTROL**	**TIME PROJECTED**	**TOTAL TIME**
Add Tapa	Attach the tapa to the product.	Assembly	C/S Screws Screwdriver	N/A	N/A	Ensure tapa sits flush and square, and all holes are aligned before attaching it.	25minutes	12hrs 30

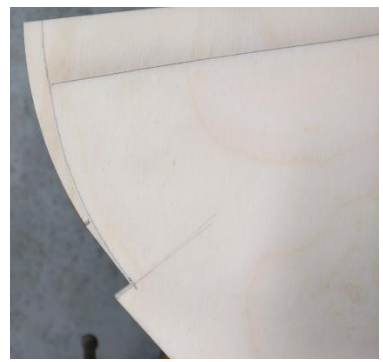
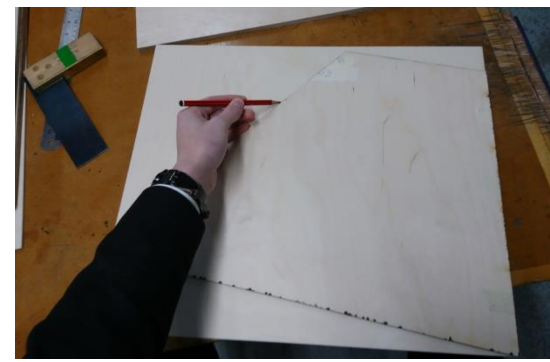
Production Diary

These pictures show the various templates and them being laser cut, and a selection of parts being marked out

STAGE 1: In order to make my marking out as accurate and repeatable as possible, I initially created a cutting list so that a 1220x2440mm sheet could be moderated to a more usable size, also minimizing waste. I also made .dxf files to cut out, the side panels, of which are of a more intricate shape, and an oval template for the rear sound hole. Hence, my 3.6mm panels were already cut for the sides, and I used these to template onto 9mm panels. I felt my level of accuracy was high however some parts, were slightly out which meant that I had to adjust this later on which reduced the quality of the final outcome. The process took slightly longer than scheduled, even with the templates. Approx. 2hrs
Improvements: If I were to conduct this process for large scale manufacture, it would be very time consuming, hence, if I were to conduct this stage again, I would use a more powerful laser cutter, so that all of the panels could be cut more accurately than by hand, and more quicker and more repeatable manner, as i would only have to create one file, and no marking out at all would be required.



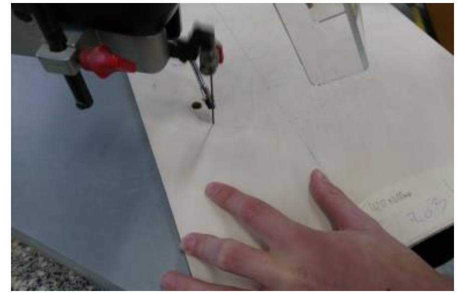





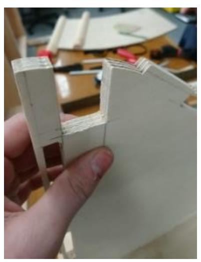
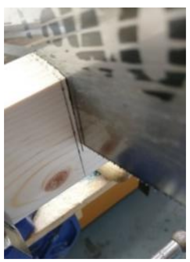
Using a Tennon saw to cut the back panel.

STAGE 2: Once marking out was complete I began to cut my components using conventional hand tools, (Tennon/Coping Saw) and machine tools such as a scroll saw, and pillar drill and morticer for the strengthening column to support the box from the tension within the snare system. I cut the panels and housing fingers to size, I encountered no real problems when doing this, and conducted it to a high level of accuracy, as the panels matched the 3mm ones of which were laser cut closely. The 'T' column and tensioner were also conducted to specification, and a strong mortice and Tennon joint was a result. It took approximately 2hrs to conduct the entire process of cutting of all parts and panels required, of which was longer than scheduled.
Improvements: I would use more accurate and more repeatable method of cutting, as stated above, (CNC) or a high powered laser cutter, otherwise, I would use a band saw to improve speed and accuracy further.





The above photos show me taking out the sound hole ellipse using a pillar drill and threading a scroll saw blade through the hole drilled in order to cut the ellipse. And the completed 9mm top panel. Below are further examples of me cutting further details into the panels. Using a Tennon saw and Morticer to fabricate the basis for the 'T' strengthening column. I drilled further holes in the cross beam, and front face panel to provides support for holding the tapa on to the box. Along with this, I cut a further square out of the bottom 9mm panel using a coping saw to provide a slot to hold the 'T' in place.




Drilling the holes that would connect the tapa to the box, in the front 9mm panel.

STAGE 3: Once the general panels and shapes were cut, I routed the female part of the housings into the side panels, along with this, I used the router to take the centre from the front face also. I found routing to be a time effective, and accurate process. Having cut the male fingers on the front panel, I had to nail a straight edge for the router to run along, to get a clean and straight cut. Even with the added time, the process took approximately 30mins.

Improvements: I would choose to laser cut the panels if possible, so that there was no need for routing, and the panels would sit perfectly when assembled. Or if I had to route, I would leave cutting the male fingers in the front panel until I had routed the centre out. This would save time, as the router guide would be used.

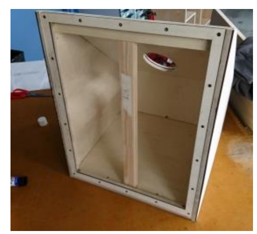

The front face being routed, edges that needed to be added, and the results, with the centre removed


STAGE 4: As the router leaves a circular end for each housing, the next step was to file and square up the housings in the side panels, and using the belt sander sand sown the edges and inaccuracies from cutting, and to neaten the mortice joint using a chisel. I matched the panels and then filed together so that each part was as close to the manufacturing spec as possible, to help make assembly easier. This step took approximately 1hr30, as the belt sander helped me bring the panels to the marked dimensions with a good level of efficiency.

The 9mm side panels after routing was complete, and any shavings were sanded off.

The above images show testing of the assembly before applying the 3mm panels, I did this to find and adjustments that may have need to be made in the 9mm pieces as no further adjustments would be able to be made once the 3mm pieces were applied.

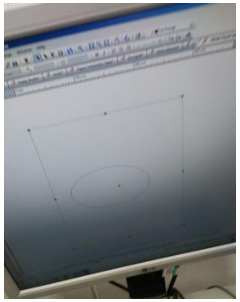
Examples of the side panels completed, filing the sound hole and using a chisel to neaten the mortice joint

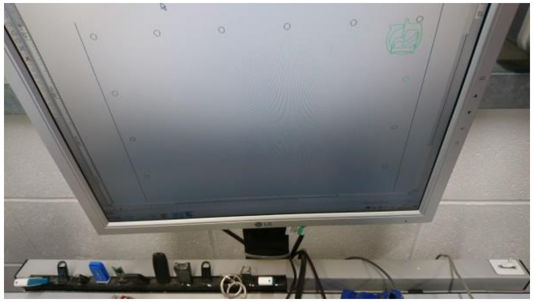


STAGE 5: Once I was happy with the assembly of the box, I then had to apply the 3mm panels. Unlike my models, where I applied them to the completed construction, here I applied them separately, applying and even surface covering of PVA glue on one of the panels then aligning the laser cut 3mm with the 9mm. Using predominantly G Clamps, to apply pressure to ensure the bond was strong and secure, I then left the panels to set. This took just over 3 hours, adding time to the construction of the product. The images show how the clamps were applied along with the glue, for the side panels, They also show dry version of the box.

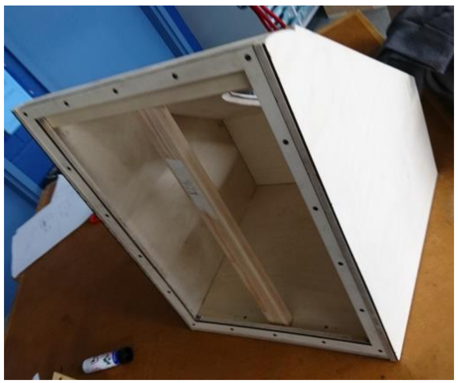
Improvements: I could use a faster setting adhesive to improve this process, as it would reduce the total time of the construction. A stronger adhesive may also improve this stage, as less adhesive would have to be used overall.

A close up of the completed mortice joint, and the two of the 3mm decorative panels required



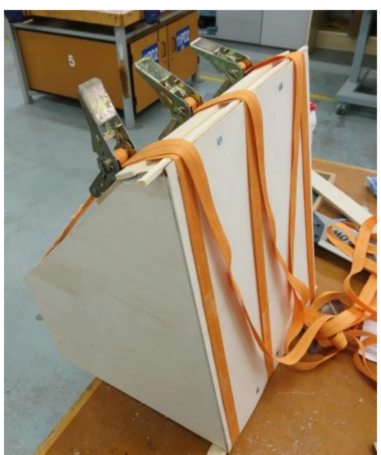


One of the 3mm panel templates along with the Tapa template in Ethos, a laser cutter driver software.



STAGE 6: Once the panels had set, the next step was to construct the basic box, this involved slotting the housings together. It took approximately 15 minutes to put PVA glue on the contact areas and also put the box together. Using sash clamps as seen in the images to the left to provide the pressure needed hold the box strongly together once the glue had set. The setting took approximately 3 hours, I also installed and set in place the strengthening ‘T’ section in this process. Along with this, I used tensioning straps and rods to bend and laminate in that form 3 layers of flexi-ply as seen below during the time period, across the top curved section, in order to close the box off. I anchored it with 2 screws in the corners, and then secured the bend using rods across the length of the section. The actual flexi-ply was slightly too small width wise, and doesn’t quite fit. I also applied a varnish to seal the box and protect it from marks or excessive warping.

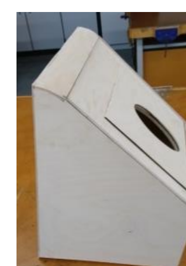
Improvements: I could have used a stronger adhesive such as an epoxy resin, not only would it set quicker, it would provide a greater residual strength in the construction. To make the process of lamination quicker, I could manufacture a mould out of Styrofoam, this would reduce the strain on the box, and also make the process repeatable and more accurate. I would perhaps also hide the flexi-ply with the 3mm side panels, so that the finished product has a cleaner outside appearance.



The above shows the flexi-ply was formed around the top curve.

Applying the water based protective varnish.

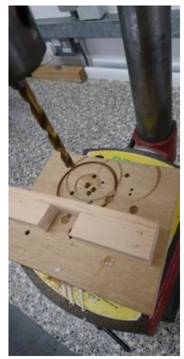
The box after stage 6 was complete.



STAGE 7: This stage involved the installation of the snare trap, and its tensioning system, the followed the basic system researched and specified. Initially, I cut the tensioner to size, and drilled the holes for the scan (cross-dowel) fittings to slot into. Then threading 50mm (M6 thread) C/S screws through the base to install the tensioning system, I had to use a lubricant to make screwing the screws smoother. To get the bass strings as close to the tapa as possible, I used wire staples to secure them to the front panel. I then used a screw with washer to secure it at the other end, instead of using hooks and ferrules. I then steadily tightened the screws in the tensioner, to tighten up the strings. I noticed that due to the utilisation of a soft wood in the tensioner, the strings were digging into the wood, which means the tension would decrease over time. The process was conducted to schedule took approximately 1hr.

Improvements: I should use a metal corner bracket, or simply a metal plate, to protect the tensioner, and help prevent tension loss over time.

Below shows the snare once completed, and how it is secured.



Using a Vernier calliper to measure the diameter of the cross dowel, and hence the size of hole needed to be drilled

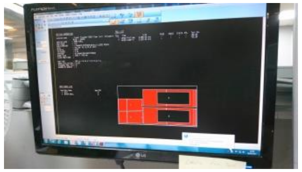
The fitting, secured into the tensioning piece

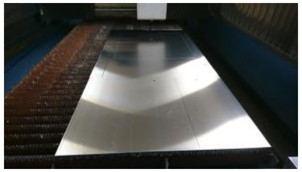
The tensioner installed before the strings were added

STAGES 8,9,12: As I was manufacturing my product, at the point it came to creating the seat, I realised, due to the length of time it took to glue my parts together, that I was quite far behind schedule for the time I had used, hence, in order to still create a solution that matched specification, as closely as possible, I chose to not manufacture the seat out of leather as planned however if I was selling the product, would produce, and install the amp, of which I chose to leave out of this prototype due to cost. Leaving the process out, saved 1hr45, which was a large chunk of the 3hours lost to assembling, and laminating the parts of the product. I approached the client as asked if this was a major issue, he responded saying no, however It would have been nice, and if the could be added at a later date, it would make the product much more desirable, and that the cushioning already in production would be used on a temporary basis.

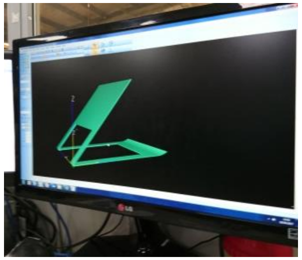
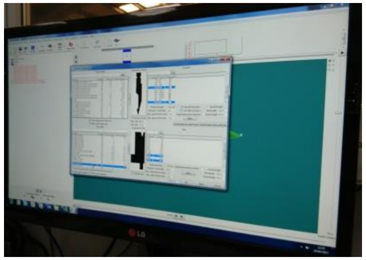
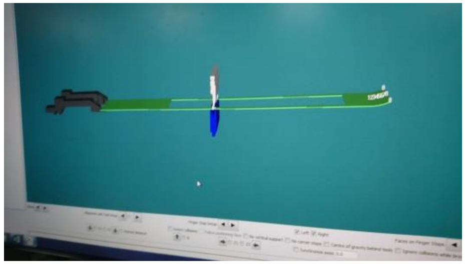
Improvements: If I were to manufacture this for market, I would plan more time to allow for the setting and laminating of the construction and the individual panels. So that ample time was available for making and adding the seat to my product. As it would make the product more aesthetically pleasing and fit for purpose.





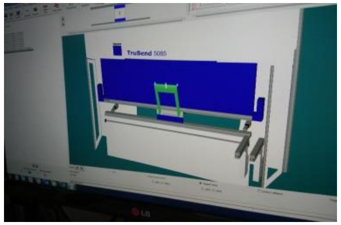


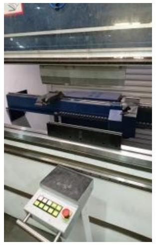
STAGE 10 (industrial manufacture): Once the basic box was complete, stage 10 was to create the outer shell, to help me do this, I went to a local sheet metal development company, to gain an insight into industrial processes, and how they are designed for. After completing my dxf in 2D design, I presented my manufacturing specification, along with the dxf and a cad drawing of how I wanted the outer shell to appear. Then, using the professional program Radan, produced a specification for the high intensity laser cutter to use to cut my shell from 3mm aluminium sheet. Right shows the specification, and how I nested the parts into one 2440x1220mm sheet. The laser cutter, industrially, is loaded from a storage tower, meaning that the sheet is always set square, for quality and accuracy. The programme is taken from a central server, and then used by the cutter as a template. For quality reasons, and potential variations later in my production, I nested two shells from one sheet so that if one went wrong, there would be no need to recut. The process was conducted to schedule. And accuracy was high. The programme, also allows for the programming of the radius at the top along with standard bends, so that you can view how the processing chosen will affect the resultant shape of each part.

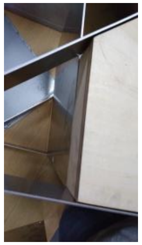





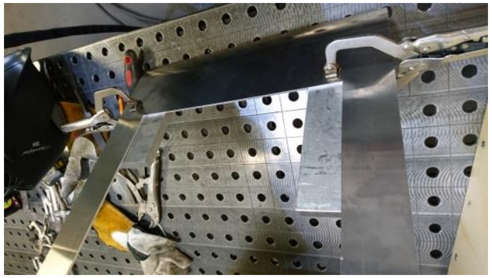
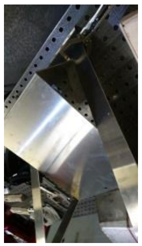
See Right, final parts of the shell cut to size. (seat was given 0.5mm clearance either side so that it didn’t rub against the outer structure).

STAGE 11 (industrial manufacture): Using Radan again, in order to accurately bend the sheets to the shape desired, locations for bending the radius were marked at eight 3° increments (this part was step-bent), and then a single bend (set to 46°), the case was the same for the seat part (one bend was required (80°)). Once this was set, the program allowed me to view how the product would look after this was completed. I was happy with the shape. The next step was to programme the correct tooling for the bending machine operator to use, and how the part would be bent. I used tools that were 500mm in width, and allowed for all of the bends for both parts could be done, without having to change them. Once happy, the process was put through a simulator, so that the part could be tested, reduce material wastage if wrong, and save time. Once happy, my aluminium was taken to the bend machine operator and bent to fit my box, the 3° increments were changed slightly, because they were an estimated, in order for the radius and shell to fit my product accurately. Continuously testing the shaping against the box as shown to the left allowed me to achieve the flush edge on the rear, along with the fit of the radius. Once happy with the shape, the two





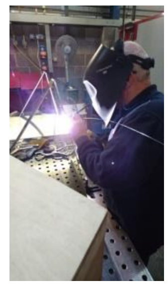


Above shows how the shell was clamped up so that the two sections could be rested making welding easier.

STAGE 11 (continued): parts had to be welded together for the final shape to be achieved. TIG welding was used. This is the use of an electric 'gun' of which has a heated tungsten tip of which is non consumable, at the temperature to melt the aluminium along with an inert shielding gas to prevent the weld from contamination, and zinc rod used as filler to secure the weld, which hardens as it cools and self oxidizes with the air, strengthening the join. The process of conjoining the two parts, consisted of setting up metal rests to hold the metal in place when welding, the pieces were then tacked, and then when set properly, welded to form the final shape. This was repeated on both sets to produce two shells, one spare, and to allow for any variations. The weld was then blended and polished. The stage took approximately1hr, which was to schedule.

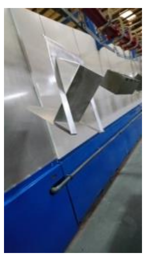







Above displays the welding process, the first picture tacking, the next two of a professional welding the product, the complete welds, the resultant shape of the shell, and myself blending the weld.

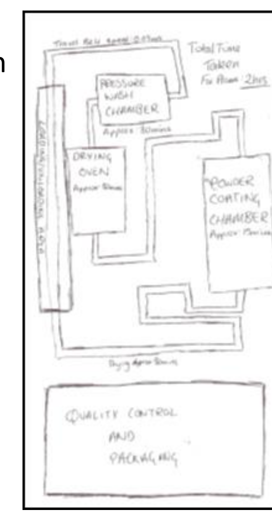
STAGE 11 (additional process (Powder coating on an industrial production line)):
During the manufacture of the shell, I had the opportunity to consider another industrial practice, this was powder coating. I chose to do this to add another option to the finish of the shell, I chose a gloss white paint. Powder coating is the process through which a one particle thick even coat of paint can be applied to a metal by electrically charging the object and the paint, (one positively the other negatively) and hence an even coverage. The production line (as shown right) consisted of a main belt that charged the object moving along, initially through a pressure wash chamber, then a drying oven, once passed through here, the object was sprayed using a hand gun (to coat parts that would be missed by the auto guns) and then by a hand gun on the opposite side of the automatic sprayers, to clean up the coat. Then the piece was left to set by air for about 30mins, before being taken off the belt, quality checked to ensure a total coverage and no patches, and packaged. The images to the left show myself using the hand gun, and the process described.











STAGE 13: This stage involved attaching the shell to the box. Having had the shell bent to form around the box built, very little adjustment was required in order to fit the two major components together. Using countersunk self tapping screws also, there was no requirement drill additional holes into the box. I only had to drill a hole in the box where the amplifier would go. However, I had forgotten to plan into the laser cutting of the shell, access holes for tensioning the strings, these holes had to be drilled into the shell post its manufacture. Because of this, the stage took 10minutes longer than anticipated. Using my quality control checks the stage was completed accurately.
Improvements: Ensure that care is taken to all aspects of the product, forgetting the adjustability access holes added time to the fitting together, hence, to improve, I should ensure that these are accounted for in the program used for the shell. Also, perhaps add a few more holes for the attachment screws to further secure the connection between the box and shell.

STAGE 14: The final step was to add the tapa to my product, using C/S machine screws (M6 thread), I used the laser cutter to cut it, and it sat perfectly flush with the edges of the metal and box. I had to use a hand drill to create a hole in the central strengthening beam in order to get the bottom cental screw in, however this did not affect the outcome structurally or aesthetically when tested. *Overall I was pleased with the outcome, and quality control helped me to make the product as accurately as possible, for example, if the tapa was not flush, I would have to cut it again etc. In my opinion it ti is fit for purpose, and complies with specification, and provides a solution to the problems set out by my client and the market.*