



School of Engineering

**Product Design and Management
Individual Project Report**

ENGG660

**Conceptualisation Design and
Development of an Innovative Hot
Tub Surround**

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1.0 Summary

The goal of this project is to conceptualise, design, and develop a modular hot tub surround system that will enable customers to affordably create custom surroundings. By providing more features that enhance the hot tub experience even better, the surround will assist the user in improving its functionality. The product is made of modular components so that customers can customise and build the surround system to suit their needs. The increasing rise in popularity of inflatable hot tubs in the UK opens market opportunities for this product.

The project covers the identification and evaluation of the products marketplace, consumer, user, and place of use to develop design concepts providing different unique selling points. A Product Design Specification is established in accordance with the design development process, and then several concepts are investigated to satisfy the product demand. The most efficient concept is chosen for detailed design through concept variant analysis. The design's aspects are then thoroughly examined and improved upon using in-depth research and engineering science. To make the product feasible for production, the detailed design is finalized and developed.

The report discusses the modular surround system's thorough design along with the reasoning and supporting information for design choices. The ethicality and sustainability of the design is also evaluated. For the purpose of manufacturing the product, 2D technical drawings and a BOM are provided. Whenever possible, calculations and analysis are used to support the design decisions. To model and display the finished product, various tools are utilised to complete the task. This is accomplished using CAD, VR, Photoshop software, and sketching media.

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4.0 Introduction

Aim: To Design and Develop Modular Surround for Inflatable Hot Tub.

Objectives:

1. Create range of Conceptual Design ideas for surround system.
2. Sketching and Drawing Concepts.
3. Develop Product Design Specification (PDS).
4. Model the Detailed System in Creo Parametric Software.
5. Generate 2D Technical Drawings and Bill of Materials (BOM).
6. Visualisation and Rendering of the product for Demonstration.

This innovative design project focuses on the conceptualisation, design, and development of the surround system for an inflatable hot tub. To create the ideal environment for the hot tub, the product to be developed should be modular. Additionally, the surround system needs to be compatible and interchangeable with the current inflatable hot tub versions sold in the UK. The project's goal is to improve the hot tub experience by adding extra features to the inflatable hot tub while allowing customers to customise the surround to their liking.

In essence, the surround system is an additional device placed around the hot tub that adds capabilities to enhance its usability. The project's goal is to create a modular surround system that can easily fit in with the spa theme while preserving or improving the hot tub's aesthetics. The system should be easy to use and reliable in a variety of settings. The design aims to be simple to use and put together, as well as painless to move if necessary. The product's design aims to enable cost-conscious customers to purchase a unit or module of the surround system at a time.

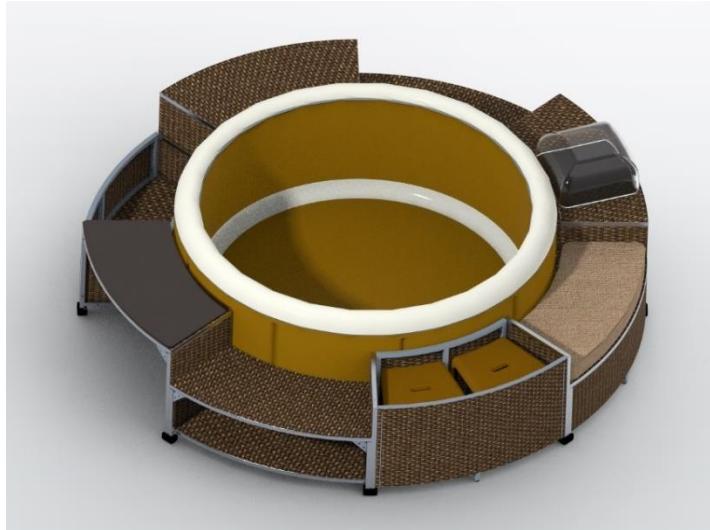


Figure 1 - Arrangement of different modules to make surround system for Hot tub.

Inflatable hot tubs have started to become popular purchases for UK consumers. Due to their traditional features at low cost and easy set-up process and low maintenance, inflatable hot tubs are trending in the UK market for leisure activity. Many families and groups of youngsters prefer to spend their time in the

hot tub for relaxation or enjoyment purposes. The UK home water leisure market is now worth billions and it's a sector that is projected to grow as more and more people look spend more time outdoors, providing greater scope for inflatable hot tubs and surround products. According to data sources, 227,000 total new hot tubs were sold in year 2020, marking about 10% increase from previous year. According to 2021 survey, 63.3% of current hot tub owners are seeking for products to enhance their experience of the hot tub. By concentrating on creating eco-friendly products and cost-effective products, a larger portion of market could be targeted.

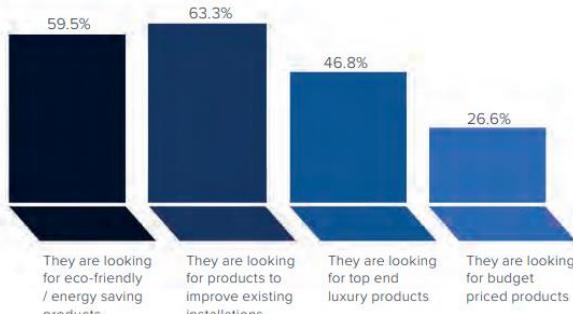
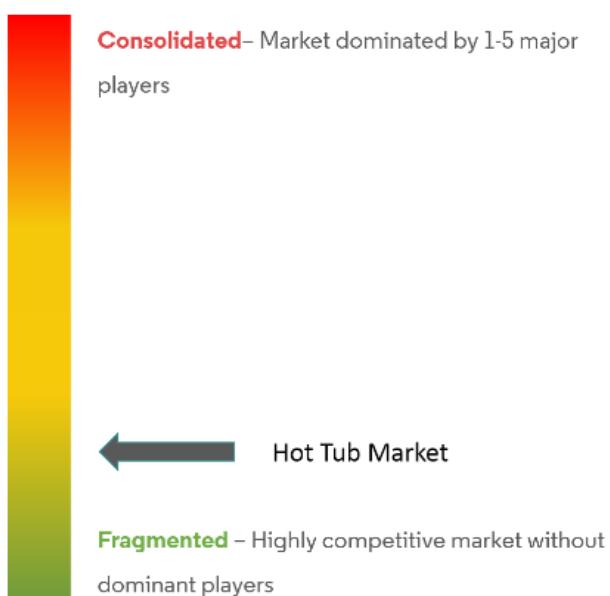


Figure 2 - Data of Market Requirements for Hot tub Accessories, 2021.

Available surrounds are, however, provided 'as is' meaning that there is an opportunity to develop products that surround the hot tub and provide enhanced functionality. The available inflatable hot tubs are marked as an economical and portable option for indoor spas, so they are just inflatable tubs with heating and air-jet functionality. The current hot tub market is not consolidated, means there is room for new product which is modular in nature to fit to the variety of the models of round inflatable hot tub. So, modular surround systems for these hot tubs to provide an enhanced experience could be best solution.



Source: Mordor Intelligence



Figure 3 – Global Market Concentration of Hot Tub in last 5 years.

In order to construct the desired surround system for an inflatable hot tub, the proposed model of the surround system is designed with a focus on modularity and its various functions. The showcased surround system (fig) can be purchased and installed as a whole and includes the recommended seven surround modules with attachments. The system is simple to install around the hot tub and enriches its attractiveness. The modular design lets customers build the fitting surround they want to create in space around the tub. Additionally, since the buyer can repeat the system's modules or even just purchase the necessary module pieces, the consumer is free to construct the surround system as wanted. Due to the product's lightweight nature, its design makes it simple for users to swap out, replace, or reposition the module's component pieces. Overall, the layout allows customers the flexibility to develop a personalised surround system for their hot tub. The product can be easily fabricated and put together on a commercial scale. To assist the consumer in the installation process, assembly instructions are supplied.

For the project to be a successful, a variety of resources are required. The project requires the formulation of a product design specification; to effectively do this, several online and library resources, including Mintel reports, are used. CAD software is essential to continue developing these conceptual designs. Creo Parametric software is used in this project to model and detail the concepts refined through a repeating design process. The success of the product depends on the final materials and methods employed, which is why software for selecting materials and processes is needed. Ansys Granta EduPack is resourced to get the material information required. Finally, the presentation, marketing, and sale of the finished product will all be done using visualisation software. For this purpose, Blender software is used to showcase the product.



Figure 4 - Visualisation of the Hot tub Surround Product.

5.0 Concept Development

The aim of the project is to develop a modular surround system that can provide additional features to inflatable hot tub experience while being cost conscious. The surround system of a hot tub us basically a structure around it which provides different supplementary features and add aesthetic to the inflatable hot tub. With the modular nature of the surround system, customers are able to create the bespoke surround for their round inflatable hot tub. These module parts of the system can be interchanged or exchanged in position as per the user need without any excess cost. The system is still able to provide different features to enhance the hot tub experience while maintaining the hot tub aesthetics. The product should be cost conscious and provide the freedom to the customer to buy a piece at a time. This is the brief and underlying characteristics for concept of product to be designed and developed.

To develop the different concepts of the product, current market and customer is to be studied. As per 2021, round shaped inflatable hot tubs for 4-6 people are popular and people are willing to spend money to buy surround systems. According to market analysis of 2021, small and medium sized round inflatable hot tubs dominate more than 50% of the hot tub market and there are many products available around these hot tubs in market. Small circular hot tubs are prominent- due to their shape, easy and uniform inflation. The design of a round inflatable hot tub offers a more traditional hot tub feel. Hot tubs were generally made to be round so a round inflatable hot tub will give a more classic spa experience. There are few already existing surround systems in the market which are not dynamic. Currently, the customers have to buy the complete surround system for their hot tub which cannot be customised according to the requirement. The surround systems in the current market cost around £1000. This cost is not necessarily the amount a potential customer is willing to pay hence the modular surround system facilitates modular parts with unique features, providing choice and freedom to the customer as a cheaper option.

The available surround products in market come in single unit or some external service is required to assemble it together. The size is quite big to adjust it around the hot tub after the installation or anytime further in lifecycle. The surround system to be designed should provide freedom and ease to adjust and change the arrangement of surround system. There are variety of small accessories available in market which provide one or two features to hot tub experience and these products are expensive compared to standard version of them, as they are slightly modified to fit in the hot tub user environment. Also, user need to purchase them from different sellers and most of them are not compatible with diverse inflatable hot tub models. Incorporating all of those accessories at a time is complicated and expensive. The surround system which can provide these features will be best solution for user so creating system with different features is crucial.

With the market and customer research, basic customer requirements are listed for concept development. The customer requirements based on the demanding features, suggestions, reviews and complaints from customers are considered. Some of them being that the product should be light investment, comfortable and simple to use, customizable, safe and reliable, aesthetically pleasing and easy to install around the hot tub. Some of the popular required features were sitting area, platform, tabletop, storage, space to keep plants, area to safely keep valuables away from water and more. Considering these basic characteristics and research data, few crude concept designs were formed. Each of the concept is inspired from different modularity or customization aspect. The basic different concepts also have different use of materials and features. The combination of different features and modular parts are used to create further concepts.

The inspiration for the concepts is from different modular structures. Modularity subdivides a system into smaller parts called modules which can be independently created, modified, replaced, or exchanged with other modules or between different systems. While keeping this at centre, concepts are developed and modified using different materials and features. The modular parts differ in shape and use also. Some of the modular units are used as building blocks to support the whole tub, arranged around the tub, or used to create parting features. The concepts are then evaluated based on few important criteria to select one concept for development of the design in following stages.

Nº	Parameter	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10
1.	Modularity	1	1	1	1	1	1	1	0	0	1
2.	Portability	0	0	1	1	0	1	1	1	0	1
3.	Ease of Installation	0	0	1	1	0	1	0	1	0	1
4.	Stability	1	1	0	0	1	0	1	0	1	0
5.	Compatibility	1	1	1	1	1	1	1	0	0	1
6.	Synergy	1	1	1	0	0	1	1	0	0	
7.	Space Utilisation	1	1	1	0	0	1	0	1	1	0
8.	Accessibility	1	1	1	0	0	0	1	0	0	0
9.	Reliability	0	1	1	0	0	0	0	0	1	1
	Total	6	7	8	4	3	6	6	3	3	5
	Rank	3	2	1	5	6	3	3	6	6	4

Scheme	Value	According to the analysis, the concept with the highest rank is shortlisted for the further design stage.
Good	1	
Bad	0	

Figure 5 - Concept Variation Analysis

The above table shows the Concept variation analysis done to select the best concept design. The criteria selected are based on the customer requirements and design objectives. Satisfying all the criteria is difficult task. Although some concepts appear to be good, proper evaluation indicate the

lacking parts in them. The round shape of the selected surround system concept compliments the round inflatable hot tubs and benefits to the modular nature of the system. The highest rated concept has arc shaped modules which can be arranged around the hot tub to create desired surround system. These individual modules have different features which can be purchased separately and located around the hot tub.

These modules are made up of metal frames and rattan is wrapped on them. Compared to other type or material for hot tub, rattan goes best with the spa theme and enhances the aesthetics. Also, rattan is weather resistant and can require lower maintenance compared to wood and metal. These different rattan modules are held together by interlocking pockets. These locking systems make easy to assemble and rearrange the modules around inflatable hot tub. The concept provides freedom to customer to build surround of their liking. This is taken further for refining and detail designing.

6.0 Detailed Design

The modular nature of the design allows use of recurring parts to make the complete surround system. There are 7 basic suggested module designs to assemble to make complete surround set around the hot tub with maximum features. Each module is constructed by assembling various panels using the supplied screws. These panels come in a range of shapes and sizes, and they can be put together in certain ways to create a number of modules with various functions. These panels also have a few repeating components that must be welded together to form the final shape of the panel. The product's modularity is based on the panel's design, which creates distinctive modules that can then be combined around the tub to create the desired surround system.

Individually assembled module is in arc shape to snug fit to the wall of inflatable hot tub. This aids modularity since several arcs can be placed on the circle's circumference in numerous ways while maintaining the spaces between them. Maximum eight modules are intended to fit around the hot tub. In essence, each unit covers a 45° angle. Each module is the same size in length and width but has two different heights. The general chord length of arc is one meter and width is just a short than half meter. In accordance with the hot tub height, there are two height options that are suitable for interacting: 600mm and 350mm from the ground. The further detailing of the design is discussed in parts as follows,

6.1 Frames

The core structural part of the system are frames. They carry the load and are connected to the other frames of different shapes. Here, the Box section bars are used to construct the frames. The box section is selected over other options because they have good strength and bending resistance compared to filled sections. Another quality of box section is that they can be stacked or fitted parallel to each other and can be firmly screwed with less tolerances. It is also easy to machine the box section, compared to channel or I-beam sections. Box sections are simple to align and weld together firmly, saving the extra tasks in manufacturing process.

Only box sections are used to ease the process of welding of bars and assembling to the other frames, instead of using combination of one or two different sections. Additionally, utilising a confined structure like a box makes it easier to wrap and weave rattan around it securely. If an open section like a channel is employed, there is a chance that polyrattan will eventually become damaged or tear over the sharp edges. Compared to round or curved parts, box sections have flat faces, making it simpler to drill a hole and taper it. Box sections are also easier to bend, or curve compared to other sections as well as simple to form different shapes of frames as they can act as simple connecting blocks. Box section bars are preferred over other types of bars or panels for this reason.

The material selected for making the frames is aluminium. Although the frames of the surround system are the major load-bearing components,

aluminium was chosen because of its many additional benefits. Because aluminium is a lightweight material, constructing furniture from it will enable it to move about with ease, enhancing the modular character of the surround system. Additionally, compared to stainless steel or coated mild steel, aluminium is more corrosion resistant. Simple coated aluminium is a much better option than steel for this product since it is always used outdoors in open area. As a result, the system is weatherproof and simple to maintain. To enhance durability of aluminium, it is power coated. Polyester is the most used powder coating. It is found on most outdoor furniture because it's very durable against corrosion, UV weathering and most cleaning chemicals. In addition, it can provide good finish and aesthetics.

Aluminium is currently more affordable than steel here on market. Aluminium recycling uses less energy and resources, is more readily accessible, and increases the sustainability of product. The weldability and machining properties of aluminium 6082 T6 allow for a quick and easy manufacturing process without a lot of finishing and grinding. The selected box section of 25x25x2mm can be extruded and can be curved to required arc with cold ring rolling. Aluminium is weaker than steel in terms of strength, however the strength it lacks can be comprehended by stacking two beams on top of one another and employing box section. The strongest aluminium grade is the newest alloy of aluminium, 6082T (containing Mn, Mg, and Si).

6.2 Polyrattan

To cover the frames completely Polyrattan material is used. The panel is made by weaving the lengthy polyrattan strands over the aluminium frame. Polyrattan is a synthetic material that is simple to make in a factory. It mostly consists of poly chain polymers and has all the advantageous characteristics of plastic. To cover the frames, polyrattan was chosen over wood or ordinary plastic slabs mostly due to how it appears and feels. The weaving of the material gives it a rough texture, which produces a non-slippery surface close to the water body, which is good by regulations. Discontinuous pieces or rough surfaces should be used on wood or plastic slabs to prevent skidding and water from accumulating on them. Water can easily seep through polyrattan weave and easy to maintain in all weather.

Compared to natural rattan, polyrattan is quite commercial. Although polyrattan is more resilient in all weather conditions, including snow, natural rattan is stronger. Natural rattan carries the risk of fungi or bacteria growing, however polyrattan is made of plastic and is therefore resistant to these factors. It is easier and less expensive to weave polyrattan. Some sections can now be woven on a machine as well. Since polyrattan is a common industrial material and can be recycled, it is a sustainable choice.

The polyrattan is also available in a variety of materials due to the market's varied needs and purposes. Although they are fundamentally a blend of various polymer plastics, they are categorised according to the primary plastic component. Here, Polyethylene (PE) polyrattan is chosen over other accessible

options due to its overall superior qualities. Although PVC and PU polyrattans are less expensive, they are less robust than PE rattan. Compared to the other two, PE has a more authentic look of rattan and is weather resistant. It is UV resistant and has a high tensile strength of 75 to 85 MPa for a single stand. Also, it comes in a range of colours and finishes. The production of PE rattan is more environmentally friendly and recyclable.

Based on their cross-sectional area, rattan strands can also be classified into many varieties. The three main types are full round, flat, and half-moon. Because it is easily woven and commonly accessible in PE material, flat polyrattan is chosen in this case with thickness of 1.2mm. Rattan that is spread flat saves space while enhancing the strength of the covering surface. the Wicker Style weaving technique. It is widely utilised and most popular in the rattan industry. Machines may also be used to accomplish this out. With less material, this type of weaving pattern offers comprehensive coverage of the area and good strength.

6.3 Panels

Panels are made by weaving polyrattan material in wicker style on welded aluminium frames of different shapes and sizes. The technique differs from shape and needs to be done covering whole frame. Precaution should be taken that excess polyrattan weaving is not done and functional features of frames like holes or box section gap are not covered. Panels are to be shipped in one piece, so it should be securely attached to the frame.

There are some assemblies to be done on some panels before packing them for shipment. The Rivet nut inserts are to be fixed in the holes before weaving the rattan and rattan should not cover these holes. After weaving the rattan, the leg inserts are to be inserted securely into the box section gaps of vertically used panels. The leg screw is also to be assembled into leg insert before packaging. Panel should be ready to assemble with other panel without performing any additional assembly or joining.

The joining methods and design decisions of each panel is discussed in detailed below. Also please refer the Pack 3 in appendix for nomenclature of parts and assembly drawings.

6.3.1 Side Panel - Tall:

The side panels are vertically at the end arc section of each module. The Tall side panel is 575mm in height and 450mm in length. The thickness of this panel is almost same as width of box section with $\pm 2\text{mm}$ tolerances due to polyrattan and inserts.

The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 1. All the weld joints are butt weld joints. The horizontal top bar (sp_h_top_450) is rested on the top of box section of vertical side bars (sp_v_side_550) and welded at the end with butt weld joints. This structure will allow load to transfer onto vertical bars directly and completely, while preventing the shearing of the weld joint. The miter joint can be used but

the element of downward acting force on top bar is applied on the weld joint for shearing and special cutting is required. The bottom horizontal bar is placed between two vertical bars keeping 50mm distance from ground. It is also butt welded between face of vertical bar and edge of box section. Although, there no direct load on this bottom bar, it provides closing edge to wrap the rattan around, providing rigidity and reducing buckling.

There are six 9mm diameter holes on the side of tall side panel for inserting and fixing the rivets. They are blind holes and are 385mm apart. The distance between them is long enough to transfer vertical load correctly and prevent shearing of the sheet. They are also away around 70mm away from the edges so that fixing the screw can be convenient in assembly. Holes on top bar are through holes for M6 bolt. They are also 70mm away from edges so that bolt can be assembled easily. Legs are inserted into open bottom end of the vertical bars. Legs are slide in interference fit, so they will not come out during normal operations.

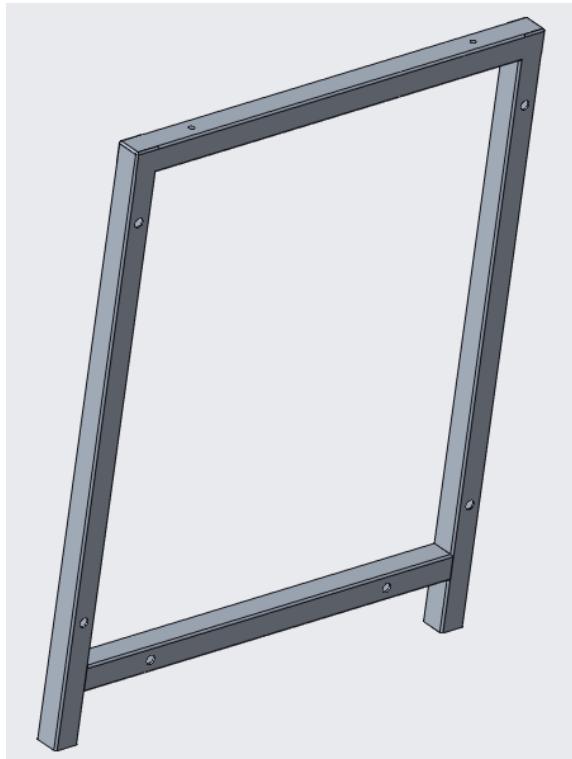


Figure 6 - Assembled frame structure for Tall side panel in Creo.

6.3.2 Side Panel - Short:

This panel is very similar to the Tall side panel. All the joining, welding, assembly and prominent features are the same. Only difference is that the side bars used are short. The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 2. Here, the horizontal top bar (sp_h_top_450) is rested on the top of box section of vertical side bars (sp_v_side_375) and welded at the end with butt weld joints. The height of this side panel is decided considering the ergonomics and anthropometrics for sitting.

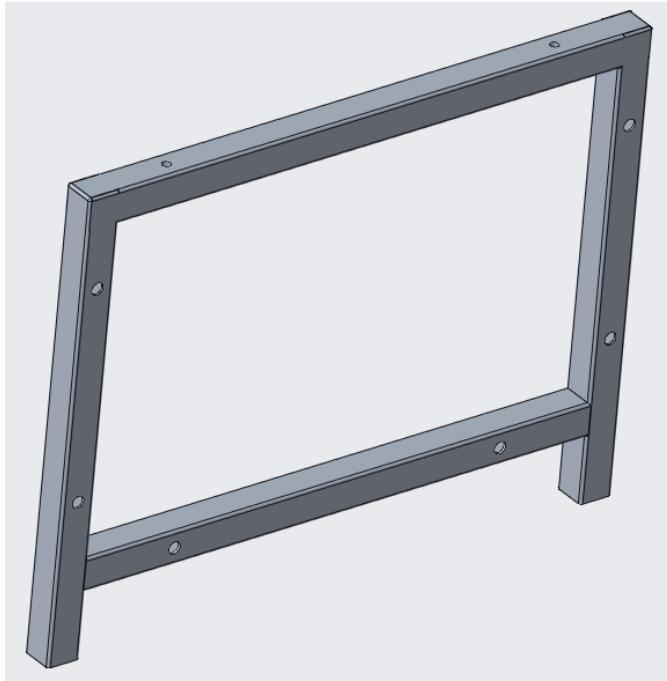


Figure 7 - Assembled frame structure for Short side panel in Creo.

6.3.3 Top Panel:

The top panels are to be horizontally assembled as the top of each module. It is shaped like a thick arc. It has inner and outer diameters of 2000 and 2900mm and spanned over 45°. The width of the sides is 450mm. The thickness of this panel is almost same as width of box section with ±2mm tolerances due to polyrattan and inserts.

The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 3. All the weld joints are butt weld joints. The outer arced horizontal bar (tp_h_outer_1090) is placed between two side horizontal bars (tp_h_side_450), also inner arced bar (tp_h_inner_735) is placed between the other end of side bars and welded. The three middle horizontal bars are welded between the frame equidistantly from the side horizontal side bars.

The outer curved arc is 1090mm in length and middle straight bars are used to support and hold it together. Also putting these bars in middle increases the strength of top panel by reducing beam length and providing support structure for distributing the load. There are blind holes on the bottom surface of the side bars. They are 9mm in size and for panel for inserting and fixing the rivets. The distance between them is long enough to transfer vertical load correctly and fixing the screw can be convenient in assembly.

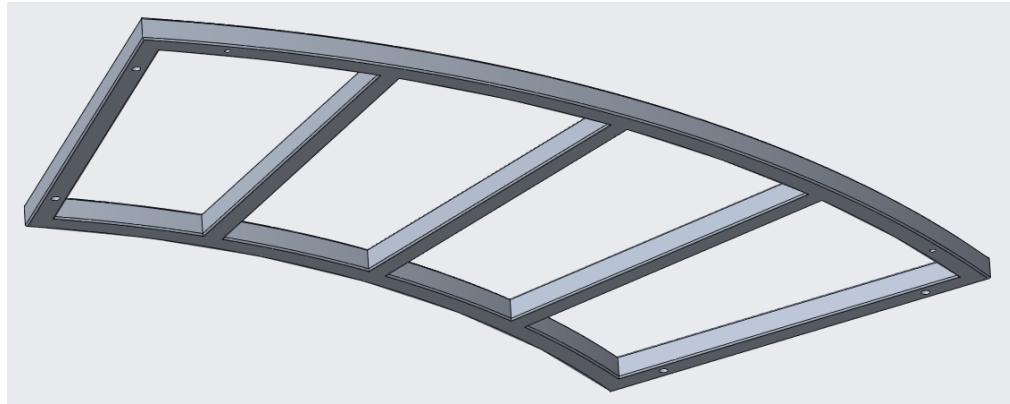


Figure 8 - Assembled frame structure for Top panel in Creo.

6.3.4 Bottom Panel:

The bottom panels are to be horizontally assembled in the bottom part of each module. They are not touching to the ground. The shape of this panel is similar to top panel, but the dimensions and holes are different. It has inner and outer diameters of 2050 and 2850mm and spanned over 42°. The width of the sides is 400mm. The thickness of this panel is almost same as width of box section with ±2mm tolerances due to polyrattan.

The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 4. The total 4 holes on the bottom panel are located on the inner surface of the end side bars with 2 on each. They are through 9mm in diameter for rivet nut insert and 260mm apart. This allows equal distribution of the load kept on bottom panel safely. Rivets also provide more pitch area in contact so force per unit area is decreased. So, bottom panel can securely carry the load if applied and hold the legs together.

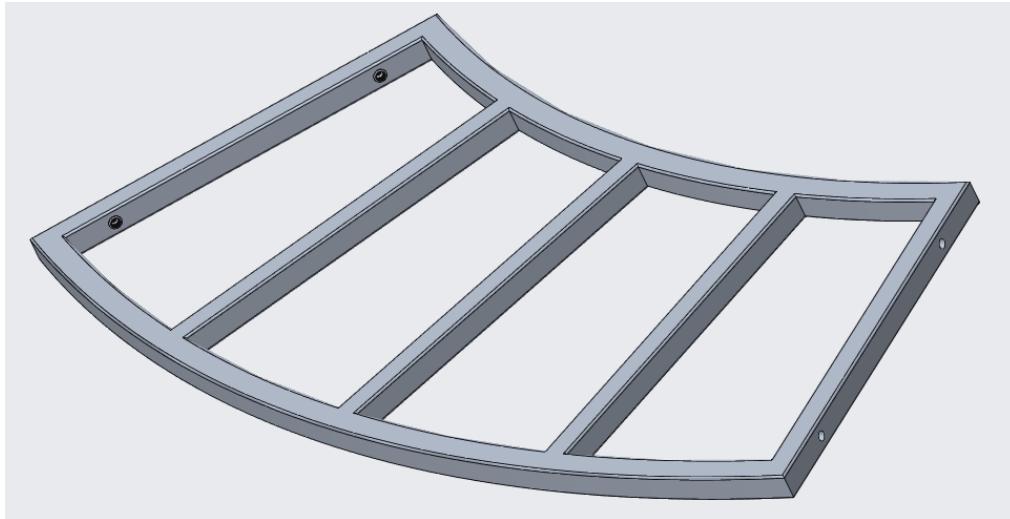


Figure 9 - Assembled frame structure for Bottom panel in Creo.

6.3.5 Front Panel - Tall:

Front panels are the curved vertically assembled panels which are at the front of each module and connected between two side panels. The Tall front panel is of the same height as Tall side panel. It is 575mm in height and curved on 1005mm over 42°. The thickness of this panel is almost same as width of box section with ±2mm tolerances due to polyrattan.

The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 5. All the weld joints are butt weld joints. The horizontal top curved bar (fp_h_top_1086) is rested on the top of box section of vertical side bars (fp_v_side_500) and welded at the end with butt weld joints. Then the long middle vertical bar (fp_v_middle_550) is welded at the midpoint of top arced bar to its box section and parallel to other side bars. Finally, the two bottom bars (fp_h_bottom_505) are butt welded between side and middle bar at the end of side bar. Leg is inserted into open bottom end of the middle bar. Legs are slide in interference fit, so they will not come out during normal operations.

The side bars of the front panel do not reach the ground they are connected to middle bar through top and bottom bars. The load on top curved bar is directly transferred to middle bar mainly and also to the side bar joints. There are four through holes on the outer surface of the side bar for M6 bolts. The holes are 383mm apart. As front panel is connected to side panel via horizontal bolts, downward load acting on the top bar of the front panel is also transferred in fractionally on these bolts. As the middle bar is attached to ground, top bar of front panel is in contact with curved bar of top bar and side screws, front panel can stand the normal loading conditions upto 220 kg. The calculations are presented in the Appendix Pack 4 under beam calculations.

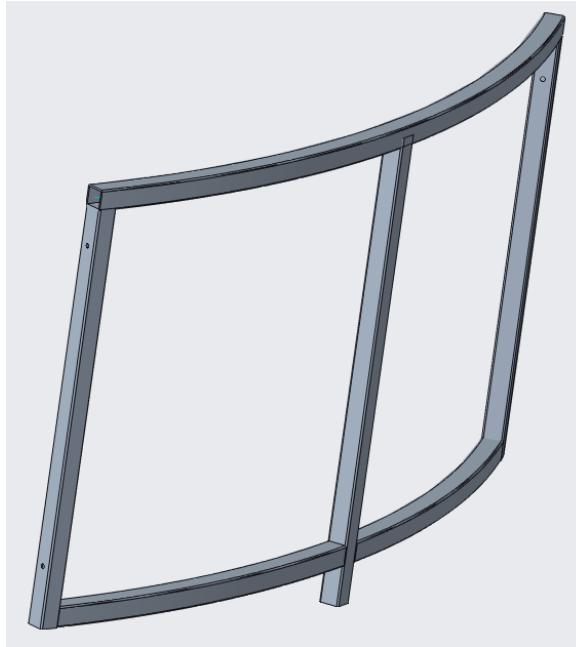


Figure 10 - Assembled frame structure for Tall front panel in Creo.

6.3.6 Front Panel - Short:

The short front panel assembly is similar to the tall front panel. Even the structure and hole features are same only the height of the panel is short. Here, short side bar (fp_v_side_273) is used instead of tall bar (fp_v_side_500) and short vertical middle bar (fp_v_middle_323) instead of tall middle bar (fp_v_middle_550). The structural design remains the same and leg is inserted into open bottom end of the middle bar.

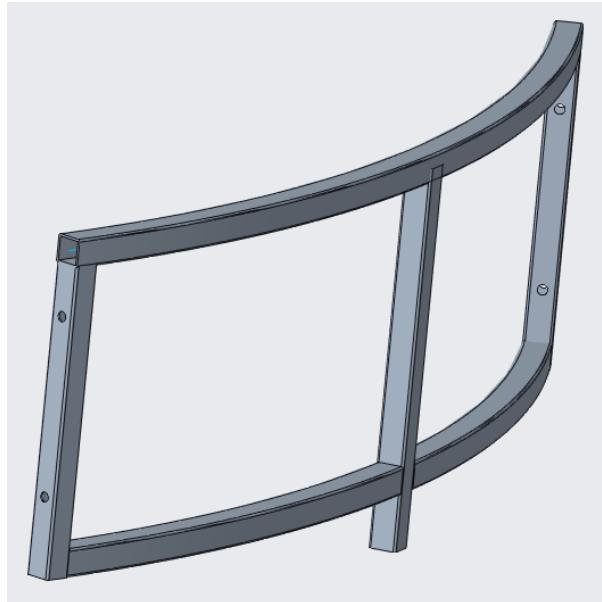


Figure 11 - Assembled frame structure for Short front panel in Creo.

6.3.7 Back Panel - Tall:

Back panels are the curved vertically assembled panels which are at the back of each module and connected between back ends two side panels. The Tall back panel is of the same height as Tall side panel. It is 575mm in height and curved on 732mm over 39.25°. The thickness of this panel is almost same as width of box section with ±2mm tolerances due to polyrattan.

The structure, joining and assembly of the back panel is same as front panel, just the parts used are of different dimensions. Instead of the horizontal top curved bar (fp_h_top_1086) of front panel, shorter top curved bar (b kp_h_top_732) is used. Similarly, short two bottom bars (b kp_h_bottom_330) are butt welded between side and middle bar at the end of side bar. The same side and middle bars from front panel can be used as they have the same height and serve similar function. Leg assembly is same as front panel.

6.3.8 Back Panel - Short:

The short front panel assembly is similar to the tall back panel. Even the structure and hole features are same only the height of the panel is short. Here, short side bar (fp_v_side_273) is used instead of tall bar (fp_v_side_500) and short vertical middle bar (fp_v_middle_323) instead of tall middle bar (fp_v_middle_550). The structural design remains the same and leg is inserted into open bottom end of the middle bar.

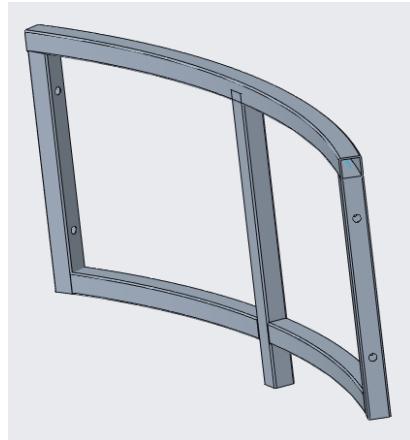


Figure 12 - Assembled frame structure for Short Back panel in Creo.

6.3.9 Door Panel:

This is the panel used as door exclusively for closed storage module. The door is curved and has in built handle to it. The curved length of the door is 490mm and it is 420mm in height. One part of detachable hinge is attached to the door. There are 2 door panels required for one closed storage module and they are mirror image of each other. The thickness of this panel is almost same as width of box section with $\pm 2\text{mm}$ tolerances due to polyrattan.

The frame is welded together with the components and alignment shown in Appendix Pack 3 Panel Assembly Fig 6. All the weld joints are butt weld joints. The top curved bar (cd_h_both_490) is rested on the end box section surfaces of the side vertical bars (cd_v_side_420) are welded. The bottom curved bar (cd_h_both_490) is welded on the remaining ends of side vertical bar. The handle is welded on the internal surface of right-side vertical bar for left door and on the left side for the right door. The rattan is weaved around the complete door, leaving the handle part open, so that user can put hand through it and open the door. At the end, two detachable hinges are to be screwed on the side bars of the door with M6 countersunk screw. Right-handed hinges are to be assembled on left bar of the left side door and left handed hinges are to be assembled on right bar of the right side door.

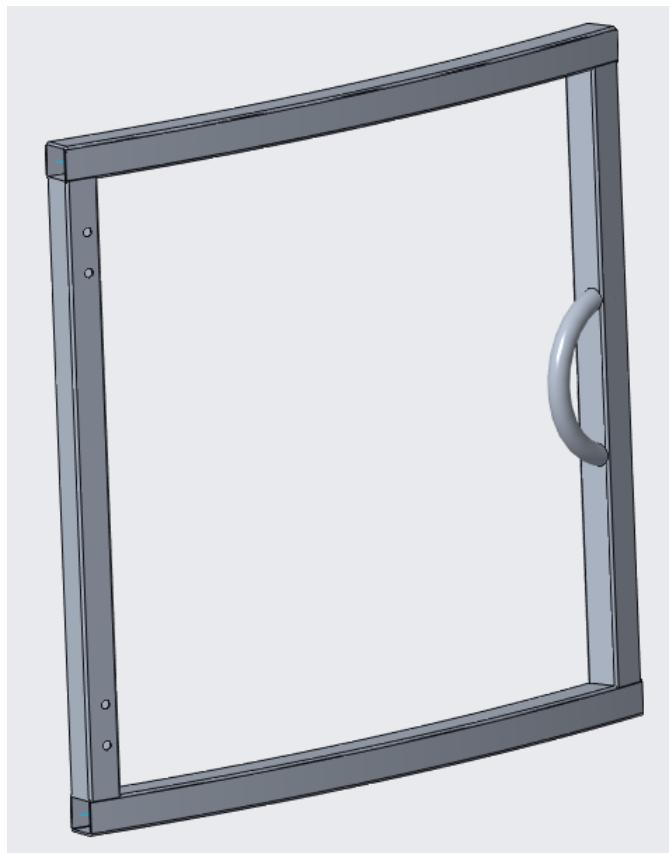


Figure 13 - Assembled frame structure for door panel in Creo.



Figure 14 - Completely assembled door panel in Creo.

6.4 Miscellaneous Parts

These include extras or accessories that are not completely modular and are built of various materials. These are primarily attached to or assembled with certain basic modules. These components play an equal role in a surround system because they include additional functionality to basic modules. However, leaving them out of a final surround system won't affect how well the surround modules work. Their detailed design is discussed in following,

6.4.1 Chiller Stool:

It is similar to a regular plastic stool but made to fit within the chiller module and be used on the ground outside. The stool's shape is slightly curved since it must fit inside the curved arc-shaped module. Two stools can be used as a platform to keep the ice bucket on so that drinks can be kept cold and accessible while sitting in the hot tub. Two stools fit easily inside the chiller module. The stool is made of HDPE plastic, which resists deteriorating from sunlight and is resilient in outdoor use. This tool's colour can be changed to match the surround system.

The stool is designed to work on ground as well. It has flat edges at the bottom to avoid from sinking into the ground. The centre opening on the top surface of the stool enables for easy holding and picking up, and as it is constructed of plastic, it is lightweight and portable. The wall thickness is 10mm which is sufficient for standard load bearings. For better cooling and stress relief during the moulding process, corner rounds are provided. Additionally, the rounded edges make it easier for the material to flow through the mould. Ribs are provided beneath the stool's top surface to prevent the plain top surface from shrinking and warping. Additionally, two-degree draft angle is provided to make it simple to remove the stool from the injection mould. The stool's bottom feet serve as the parting line, and a 2 mm thick flange is included to ensure that molten plastic reaches every component inside the chamber of the mould. The mould flow analysis is showed in the Appendix Pack 4.

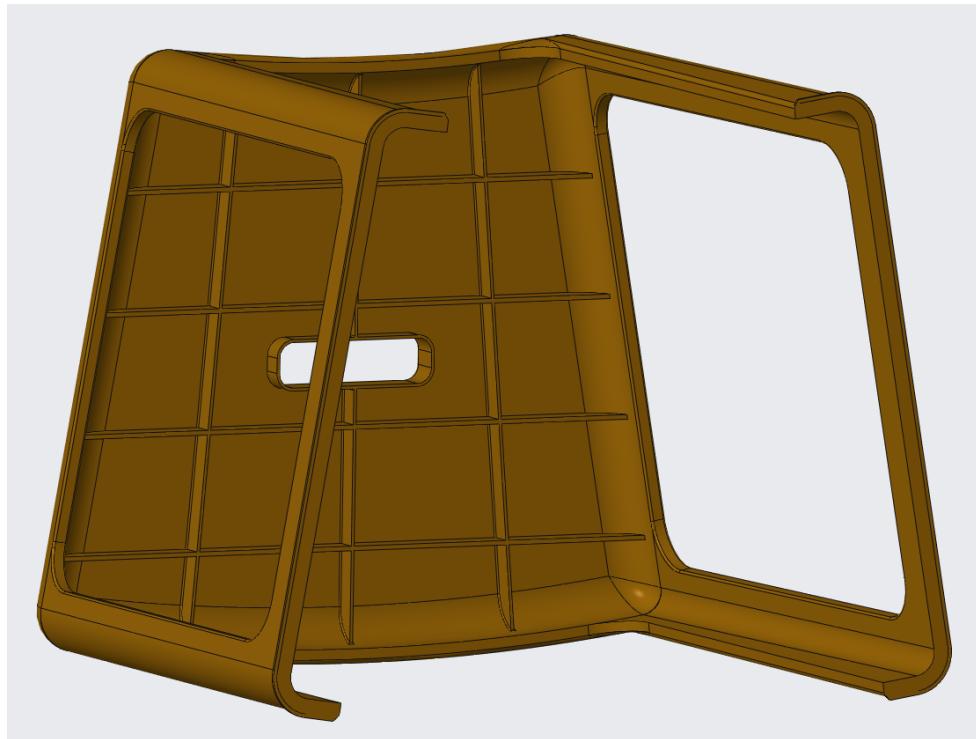


Figure 15 - Curved shape of stool and ribs below the top surface.

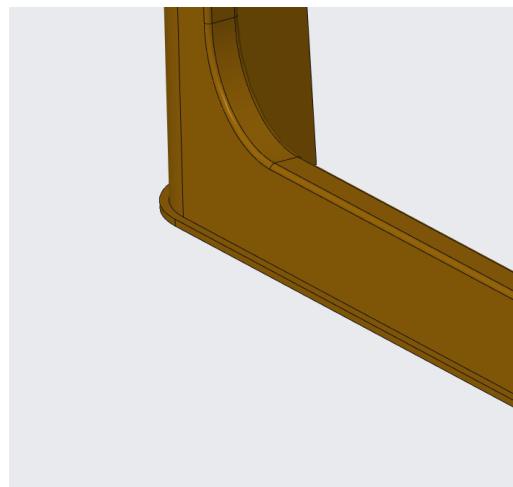


Figure 16 - Flange provided at parting line.

6.4.2 Splashproof Cover:

The splashproof cover is an attachable accessory which can be assembled with the open top panel if the module to protect the valuables from water. This acts as cover which can be closed and opened easily. The material used is transparent HDPE. This allows user to see the things that are kept inside it without forgetting to take them after spending time in hot tub. HDPE is good for outdoor use and does not deteriorate in UV rays. It is also lightweight so user can easily lift up and shut down the cover from inside the pool.

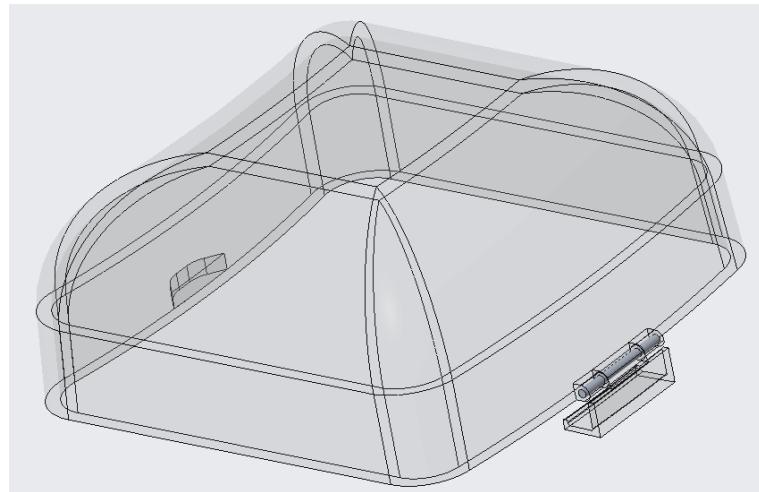


Figure 17 - Complete assembled Splashproof Cover

Shape of splashproof cover specifically designed to fit on the top panel. The cover is made of two parts, one is actual cover and other is supporting hinge. The cover is shaped like square box with one of the parallel edges curved and with rounds for corner. The rounds are provided for better material flow and to avoid high stress concentration at the edges. The thickness of the wall is 12mm which is sufficient to withstand normal handling forces. This thickness also helps HDPE to reach all the parts in mould cavity without providing ribs inside. Food trays are made in similar ways. The 3° draft angle is provided to make sure that the cover comes out of the mould easily. The handle is provided on the parting line, and it can act as flange, so no extra flange provided. The attached hinge is provided at the outer back curved face of the cover. It is also on parting line, so can be made sure that it fills that part completely. A small core of 8mm diameter can be inserted to get the space for hinge pin in cover structure.

The supporting hinge is remaining part of the hinge and act as clipping part to hold on to the outer bar of the top panel. It is shaped like C clip with support holding round at the end. The average thickness of the supporting hinge is 5mm. This can snugly fit to the 25x25 bar easily, also countering the handling forces acting on the part. The hinge pin rests on the top surface of the top panel. So, the main forces are transferred to the top panel and hinge needs to counter minimal horizontal and rotary forces. This part is also injection moulded and parting line is on the C shaped surface for easy removal of the material. Both parts to be assembled to make complete splashproof cover using a locking pin and sold as single unit.

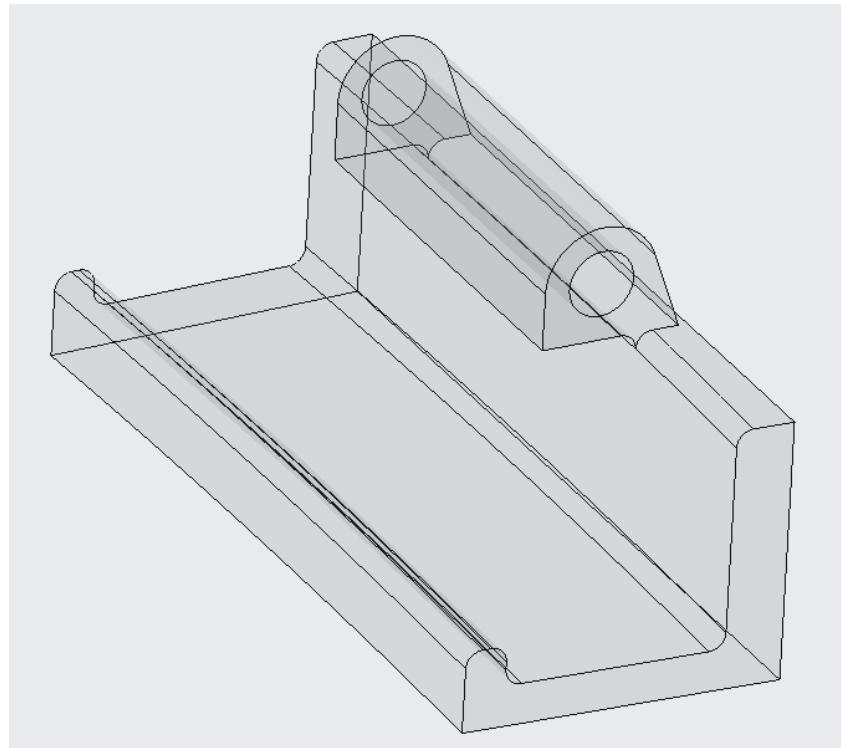


Figure 18 - Hinge clip part of the Splashproof Cover

6.4.3 Tabletop Glass:

The Tabletop glass is resting on the top of the top panel of the tabletop module. It serves as a table or a platform for eating and drinking. The glass will make cleaning up an easy task. The glass is frosted so that it masks what is underneath. The glass is supported by the rubber pads, which will keep it firmly in place on the top surface and prevent it from slipping and splitting. To keep the glass in place, the pads must be adhered to the top of the aluminium frame. The glass is 9mm thick, making it sturdy enough to withstand typical tabletop forces. The top panel will gain weight as a result, making the module sturdier. The corners of the glass slab are rounded, and chamfers are provided for safety and protection.

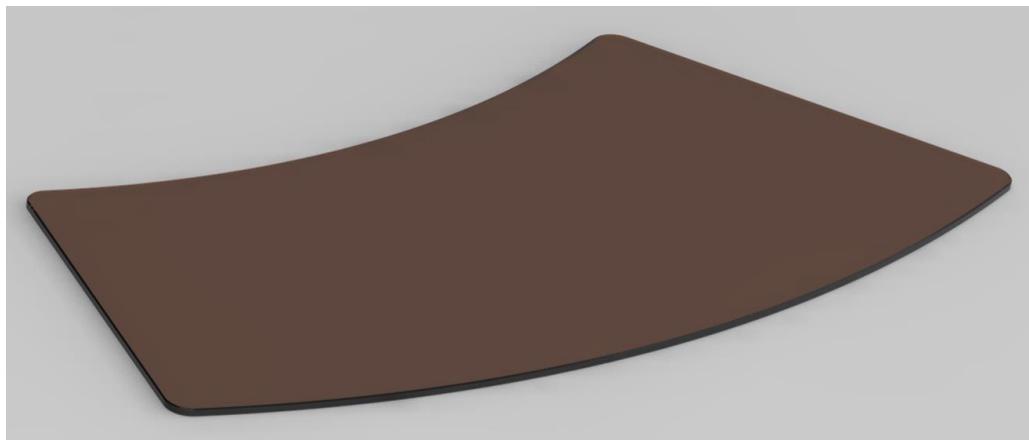


Figure 19 - Frosted glass tabletop

6.5 Outsourced Parts

The parts which are standard in sizes and readily available in market are used to complete the surround system. Utilizing these components will enable product uniformity and enable part replacement. The parts that are outsourced are purchased from reputable suppliers and used in products as needed. These parts need to be bought in vast numbers and easily accessible to customers. Additionally, the use of these components is intended to allow customers to simply swap or replace them if they get damaged or broken.

6.5.1 M6x40 Button Head Flanged Hex Bolt:

These bolts are used as fasteners for assembly of the different panels. They are steel bolts with a zinc plating that can be tightened with an Allen wrench. Hex type is used so that Allen key with recommended length can be provided to restrain the torque applied on the bolt. There will be more strain used on these bolts because they are essential components for keeping panels together. Because of their excellent torsional strength and shear resistance, M6 bolts are chosen. They have a 200 kgf maximum capacity. Each bolt is easily capable of supporting 60 kg of weight. Thus, 120 kg of weight can be carried easily utilising 2 bolts on one side.

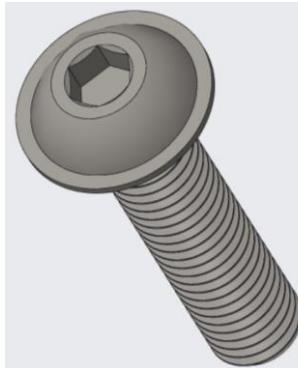


Figure 20 - Model of M6x40 Button Head Flanged Hex Bolt in Creo

As these bolts are fixed above the 2mm surface and can need to be accessed during maintenance or repair, button head is selected as they provide nice look and easy access with rounded edges. In one module assembly there are at least 6 bolts of these kind are required. To make assembly easy, flanged bolts are chosen instead of providing and assembling washer separately. These flanges also reduce and evenly distribute the liner force applied on the surface on which the bolt is fixed. This prevents distortion of the surfaces. These bolts are used to screw two 25mm wide sections, the length is selected to be 40mm, so it can securely fasten the parts together.

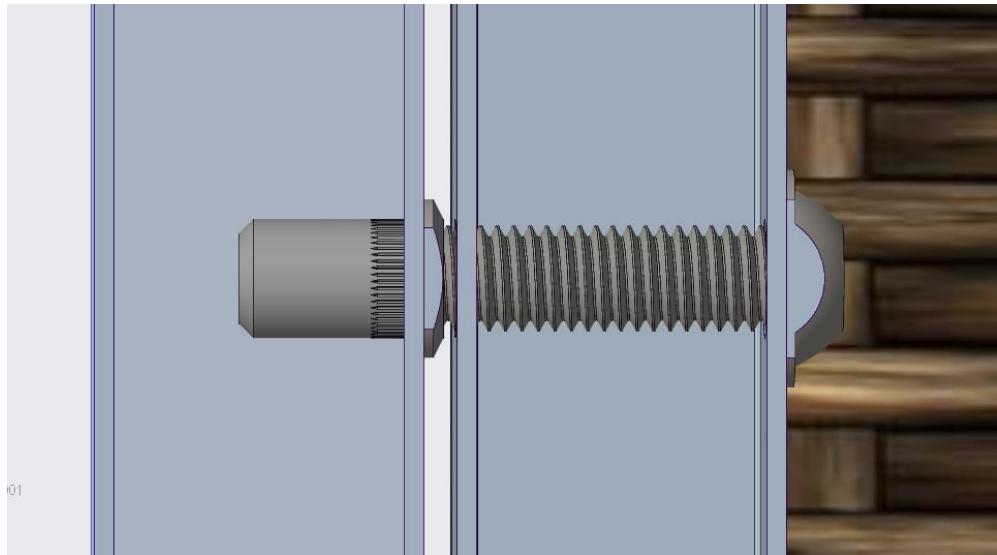


Figure 21 - Cross section view of fastening of two bars of panel

6.5.2 M6 Rivet Nut Inserts:

These are the inserts which can be used to provide fixed nut to assemble the bolt into thin sections. The rivet nuts used are made from zinc plated steel and have threads for M6 bolt. These rivets can be fixed into thin section like the wall of box section to provide more thread area to fasten the bolt securely. The hole diameter required to fix these holes is 9mm. Special fixing tool is required to insert the rivet into the hole. It secures the rivet around the hole by deforming the outer wall of the fixture and this can be used as normal nut to assemble.

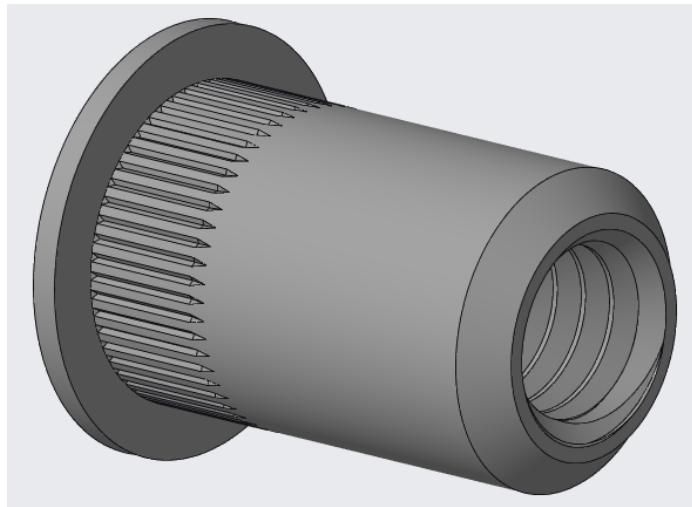


Figure 22 - Model of M6 Rivet Nut Insert in Creo

6.5.3 Adjustable Leg Insert:

Leg insert is simple product installed in the bottom of the frame leg to adjust the height of the structure as per the requirement. Multiple adjustable leg insets can be used in structure to make structure flat and stable on uneven surfaces. This part has two parts, one is leg insert and other is adjustable leg bolt. The bolt screws into the leg inset and can be rotated to adjust the height. The leg insert is simply to be inserted into the box section and fits securely due to interference fit. Here, leg insert of suitable size for 25x25x2mm box section is

selected. It has M10 screw, and it can carry up to 150kg load. The bottom face of the leg is hexagonal and is 25mm wide. The area of the face is large enough that it will prevent sinking of the feet for 120kg.

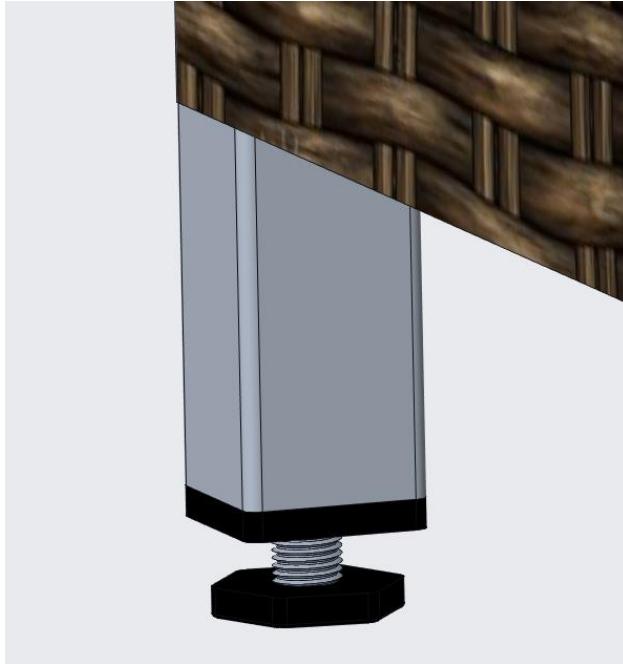


Figure 23 - Adjustable leg inserted at the bottom of the leg

6.5.4 Left-handed and Right-Handed Detachable Hinge:

The hinges are used for closed door to provide closing and opening action. They are attached by screws to side bars of front panel and door panel. The detachable hinges are selected for easy assembly and removal of the doors. Whenever customer wants to use the space frequently in season, they can remove the door for that period and then again attach the door easily to use as closed storage unit. So, detachable hinges provide freedom to the user. Left-handed and Right-Handed hinges are used for left and right door.



6.5.5 M6x15 Countersunk Hex Screws:

These are used for fastening the hinge to the door securely. Countersunk Hex screw is used as hinge has provision for countersunk M6 screw. The Hex type is selected so that it can be assembled with same Allen wrench.

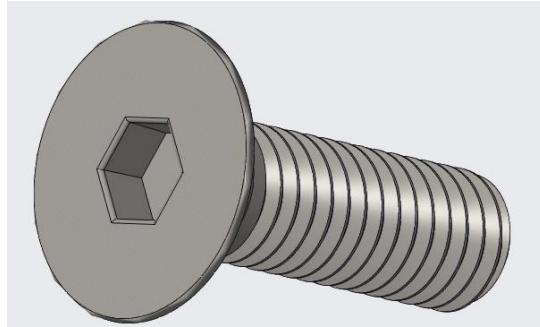


Figure 24 - Model of M6x15 Countersunk Hex Screw

6.5.6 Cushions:

The cushions are used for comfortable sitting on the deck module. The shape of the cushion is customized into arc shaped to fit on the top panel of the module. It can be attached to rattan of the top surface using cushion ties. They also provide elevated platform for sitting which is ergonomically suitable. The cushion cover is made up from polyurethane laminate, which is water resistant, breathable and can statin in sunlight without fading.

6.5 Recommended Module Assemblies

Open Storage



Deck



Close Storage



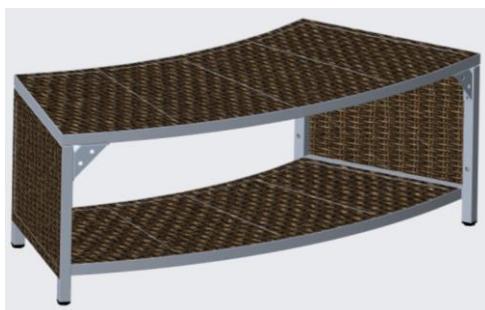
Planter



Tabletop



Showcase Platform



Chiller

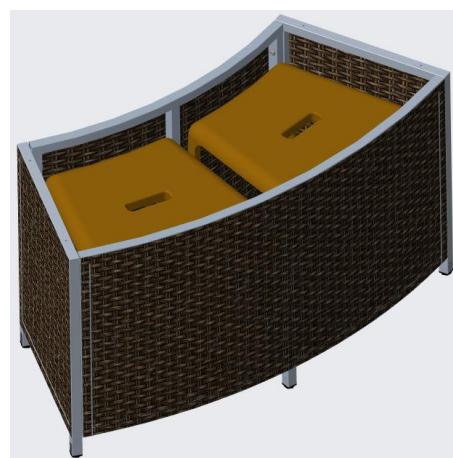




Figure 25 – Visualization of Surround system with recommended Modules

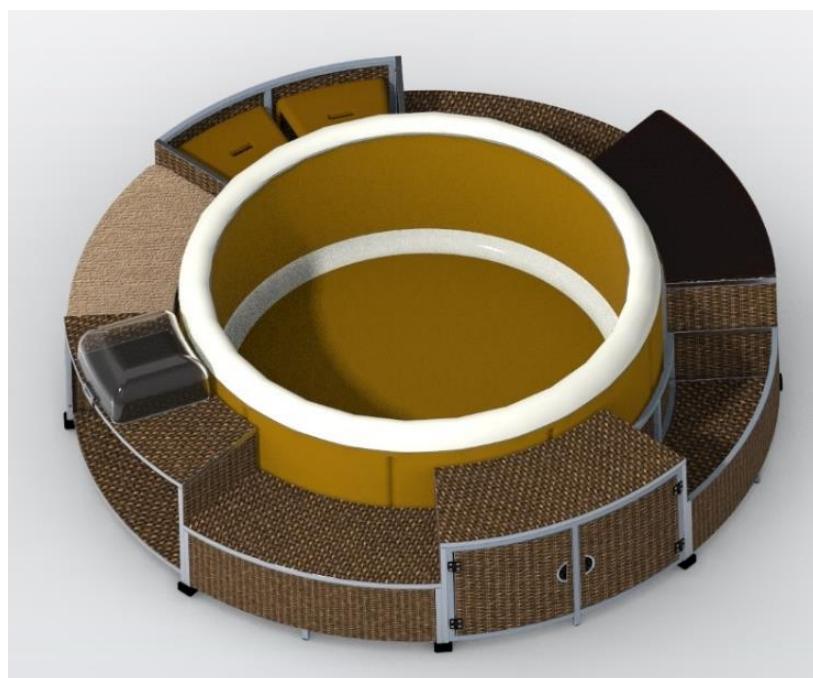


Figure 26 - Surround system assembled with recommended Modules

7.0 Conclusions

The project is aimed to design and develop a modular surround for an affordable inflatable hot tub. The inflatable hot tub surround design that is being offered is made with an emphasis on modularity to the fundamentals and creating the desired surround by connecting building blocks. The general design is feasible and can be manufactured with some modifications and additional refinements. The inflatable hot tub's surround system is flexible and enables customers to buy the various module sections at various times. It becomes more challenging to develop features freely as the design's modularity increases. For the customer to use the product to its full potential, there should be a clear understanding of its modular design. The existing design can serve as a base for it.

The design process for this project starts with understanding the market and the customer, moves on to generating concepts based on analysis to meet requirements, and ends with delivering manufacturing data for a complete design. Understanding the product's design and development process helps to achieve the project's objectives. Everywhere feasible, engineering science knowledge is used. To strengthen the design, many tools are used, including analytical software and DfMA. To make the product model in CAD software more detailed, new techniques and abilities are explored. Learning visualisation software and graphics tools helps to see how adaptable the design process, as it is used to display the model. To clearly communicate and analyse the product at the conceptual phase, a lot of sketches and exploration of the concepts for the product should be done. In general, the specifics of the design process are understood.

The designed product is not perfect. There is certainly room for development and improvement. Before putting it on sale, the product needs to be quality and safety verified. Additionally, outside criticism or professional opinion should be taken into account for refining the design. Before manufacturing, the product must also be prototyped and tested. The design is constantly subject to revision to enhance the usability of the finished product. For a product to succeed, marketing, supply chains, and services are all equally crucial. Report offers design details that check the fundamental goals and is open to improvement.

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10.0 Appendix

The supporting documents are grouped into following packs for easy access as follows,

- Pack 1: Ethics and sustainability statement
- Pack 2: Product Design Specifications
- Pack 3: Manufacturing Data
- Pack 4: Analysis
- Pack 5: Miscellaneous

SCHOOL OF ENGINEERING
ENGG660: MSc (Eng) INDIVIDUAL PROJECT 2021-22

ETHICS AND SUSTAINABILITY STATEMENT

The hot tub surround system product is designed to provide desired hot tub experience with accessible additional features to the inflatable hot tub while being cost conscious. The product is designed to demonstrate the highest levels of modularity and user convenience to purchase and assemble the product. The product inspires to create the surround for the inflatable hot tub as per the need and assemble into a reliable and user-friendly system which can be used in a variety of weather conditions across the year in the United Kingdom. The design is focused on providing additional features to the round inflatable hot tub while considering the user involvement and function of each module of the system to provide a satisfying experience. This is incorporated while considering the current market of the round inflatable hot tub, accessibility, and usability for a better user experience. The surround system product is committed to providing a safe and reliable interface to the customer for the usability of the product while providing clear transparency about the build, purchasing and assembly of parts. The design also takes extra steps to follow the regulations of the hot tub and spa community in the United Kingdom to ensure that basic guidelines are followed and uncomfortable or violating features are eliminated. The design decisions are made considering the environmental impacts and minimising adverse effects on the community, and natural resources within their manufacturing operations while safeguarding the health and safety of the public.

The hot tub surround product will seek to comply with all international, national, and local legislation affecting its operations. It will strive to follow the best practice in corporate governance. The further development of the product will also rely on a corrective action process, identified by internal or external assessments, inspections, investigations, and reviews. Intellectual property rights are to be respected, transfer of technology and know-how is to be done in a manner that protects intellectual property rights, and customer and supplier information is to be safeguarded. The product is designed while assuring that no regulations and intellectual property rights are violated. All of the materials and parts used in the product are to be disclosed in accordance with applicable regulations and prevailing industry practices. The variety of parts, features and module assembly with the purchases involved should be made transparent and clear to the buyer without hiding any ambiguities and short costs. The company will take all reasonable care to avoid misleading statements, concealment, and overstatements. Suppliers will be chosen on the basis of factors such as price, quality, delivery, service, and integrity. The choice of suppliers will be made objectively. Honesty and openness will be paramount in the company's dealings with its affiliated suppliers.

To design a sustainable product, it is assured that sustainable practices across the entire product lifecycle are to be integrated. The materials incorporated in the product are environmentally friendly. Use of any harmful, toxic, impure, or altered material is avoided. The use of energy-efficient and recyclable materials like Aluminium, Polyethylene (PE) and High-Density Polyethylene (HDPE) is promoted. Also, correctly recycled material (from above) can be incorporated to produce the product. It is preferred to implement energy-efficient processes for recycling of the material used in

the surround system for hot tub. The design focuses on the 'Cradle to Cradle' lifecycle of the product, favouring the reuse of the material and parts instead of the 'Cradle to Grave' lifecycle which can lead to landfill. The design is centred around the assembly of the simple module parts which ensures the easy maintenance, repair, replacement, and recycling of the overall product. This allows replacing just the damaged or faulty part instead of the complete module or system, saving energy and making the product sustainable and cost-efficient. The modular nature will allow easy recycling and maintenance while cutting down on the resources used.

The sustainability of the product is also embraced in the manufacturing phase of the product by selecting identical core parts as building blocks of the product. Standard parts, sizes and attachments are used wherever possible to save the material and lower the variety and supply management. The energy is saved by producing repeated modular parts, rather than creating special parts for different features. The design allows manufacturing to be simple and sustainable without any special or additional tools. The excessive use of the materials is avoided, if possible. Emissions and discharges of pollutants and generation of waste are to be minimized or eliminated at the source or by practices such as adding pollution control equipment; modifying production, maintenance, and facility processes; or by other means. The efficient supply chain and inventory at outlets should be managed to be sustainable and cost-effective. The parts are to be sold as per the requirements and in a flatpack manner only to cut down on packaging and transmission energy consumption. Further measurements and developments are to be welcomed to make the product eco-friendlier and more sustainable.



UNIVERSITY OF
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Product Design Specification - PDS

ENGG660

Conceptualisation Design and Development of an Innovative Hot Tub Surround

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Date of Submission: Aug 2022

Academic Guide: Prof. Dan Hibbert

1.0 Summary

This project entails the conceptualization, design and development of a modular hot tub surround system that will allow users to create bespoke environments of their own at a reasonable price. The surround will help users to improve the functionality of the hot tub by providing additional features to enhance the time in the hot tub. The product is designed in a modular way so that changes can be achieved desired surround system for the hot tub, providing freedom to customers to buy a part of the surround at a time.

The project necessitates the identification and evaluation of the products marketplace, consumer, user, and place of use. Through studying this information, a positive differentiation can set Hot Tub Surround System away from the current market, creating unique selling points that appeal to a wide variety of customers.

The creation of a product design specification ensures effective identification and evaluation of the market, customer, and competitors. A product design specification requires the production of a performance specification detailing characteristics and key elements of the Hot Tub Surround System. The performance specification must remain an active document serving as a set of guidelines against which all designs can be evaluated.

Looking into the legal aspects of the project is the next milestone in a product design specification. It helps in understanding the different standards that comply with our design and prevents avoiding any ideas and concepts used before. Patents of products having similar functions must be closely checked so that it does not hinder the future developments and success of the Hot Tub Surround System.

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4.0 Introduction

This innovative design project focuses on the conceptualisation, design and development of the surround system for an inflatable hot tub. The proposed product should have modularity in order to create the desired environment around the hot tub. In turn, the surround system must be interchangeable and compatible with existing inflatable hot tub models in the UK market. The project aims towards enhancing the hot tub experience by providing supplementary features for the inflatable hot tub while giving personalization freedom to the customer for creating the bespoke surround of their own choosing.

The surround system fundamentally is an additional unit around the hot tub which improves the functionality of the hot tub by providing additional features. The objective of the project is to design a modular surround system which can easily go along with the spa theme, maintaining or refining the hot tub aesthetics. The system should be simple and safe to use in diverse surroundings. The design is aimed to be easy to assemble and utilize while keeping painless to move, if necessary. The product is developed with intention of allowing the customer to buy the piece of the surround system at a time for cost-conscious.



Figure 1. Inflatable Hot Tub in Use.

Inflatable hot tubs have started to become popular purchases for UK consumers. Due to their traditional features at low cost and easy set-up process and low maintenance, inflatable hot tubs are trending in the UK market for leisure activity. Many families and groups of youngsters prefer to spend their time in the hot tub for relaxation or enjoyment purposes. They are, however, provided 'as is' meaning that there is an opportunity to develop products that surround the hot tub and provide enhanced functionality. The available inflatable hot tubs are marked as an economical and portable option for indoor spas, so they are just inflatable tubs with heating and air-jet functionality. This gives rise to supply surround systems for these hot tubs to provide an enhanced experience of the hot tub.

Although there are a few surround options available, there are limitations on the flexibility of features and space. Almost all of the surround system options are costly and must be bought as one piece. The bulky and complex installation characterisation of the available surround system creates the need for the

modular system. The modular nature of this surround will allow the consumer to create a bespoke surround of their own choosing whilst also allowing for the surround to be bought a piece at a time without being a toll on the wallet.

For the project to be a success, a variety of resources are required. The project necessitates the creation of a product design specification, a variety of online and library resources like Mintel reports are utilised for this to be carried out successfully. Following the project proposal concepts shall be developed through a repetitive design process, CAD software is then required to further develop these conceptual designs. The final materials and processes used for the product are vital to its success, thus the requirement of materials and processes selection software to aid in their choice. Finally, visualisation software shall be used for the presentation, marketing and sale of the completed project.



Figure 2. Inflatable Hot Tub with Wooden Surround.

5.0 Product Design Specification

5.1 General Product Description

The product is a modular surround system for an inflatable hot tub. It is a collective combination and arrangement of modular parts which can be assembled around the tub to create the bespoke surround for the hot tub. Different modular parts have unique features and functions. These parts can be assembled in relation to each other and can be exchanged in the position around the hot tub. The modular nature allows them to fit and function in a variety of arrangements or individually.

5.2 Commercial Considerations

5.2.1 Customer

The key customer of the hot tub surround system would be the owners of the Inflatable hot tub or the hot tub which are already installed in the house or backyard across the UK. The product is targeted toward people who want to elevate their hot tub pool experience with the help of additional surround products or accessories. The surround system would provide a better hot tub experience to the user throughout all seasons. The hot tub users who want to improve the surroundings of their hot tub with additional tools or accessories which are effortless to use at a reasonable price can be the main customer domain for the product. Potential consumers of this surround system differ greatly from families with kids, and old couples to youth that have space to accommodate a hot tub and few attachments are potential customers. The owners of the inflatable hot tub can take advantage of the modular feature of the product and construct the desired surround for their hot tub usage in diverse weather. Then potentially customers with inflatable hot tubs across Europe, America and Canada can be targeted.

To reach the desired target customers the modular surround system should have the required popular features, compatibility, easy installation and low cost. The excessive and difficult installation and setting up process can defeat the purpose of having additional features for mobile inflatable hot tubs. Availability of a variety of features in the surround system will appeal to customers and modular design will allow users to make the surround for the hot tub according to their needs. Giving freedom to the customer to buy the modular parts individually will enable more hot tub owners to buy the product as they can buy just the essential features of the surround system. The customer can later purchase more features of the surround and add to the existing surround system to achieve the bespoke environment. Marketing the product and creating a recognised brand name are essential to the success of the product. The product must be conveyed properly to the concerned buyer to increase the customer number. A variety of advertisement methods like flair, magazines and online display can be implemented to reach the customer. As the number of inflatable hot tub owners

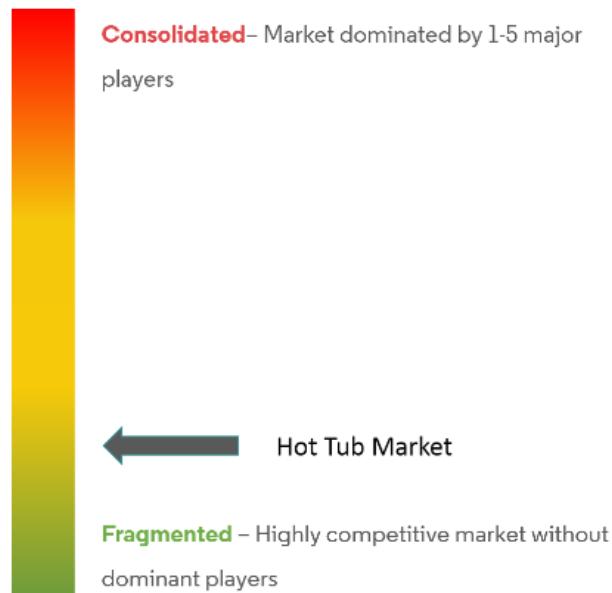
is in low percentage, targeted marketing in hot tub stores, catalogues and sites would make the reach to the customer most efficient.

Currently, the customers have to buy the complete surround system for their hot tub which cannot be customised according to the requirement. The modular surround system will enable customers to purchase the variety and number of parts of the surround as per need and put them around the hot tub as per desired arrangement. The customer can take advantage of the simple installation of the surround system around their inflatable hot tub and remove and move the parts easily whenever needed. The surround system must provide stability and strength as expected by the buyer. The surround systems in the current market cost around £1000. This cost is not necessarily the amount a potential customer is willing to pay hence the modular surround system facilitates modular parts with unique features, providing choice and freedom to the customer as a cheaper option. The customer wants a warranty and a greater lifespan of the product, but it is not provided by any of the models available in the market. Providing a warranty creates a perception of quality within the customer thus a decent warranty period should be provided for the product to attract more customers. Having a particular aesthetic theme to the modular parts of the surround system levitates the hot tub experience, appealing to different customers.

5.2.2 Market

The demand for hot tub surrounds is increasing in the UK. Especially in summer, people use inflatable hot tubs frequently to enjoy the weather. The summer of 2021, Britons showed significant interest in hot tubs as using their garden space to create outdoor living experiences. The number of hot tubs in the UK estimated at around 100,000 and Britain ranking within the top ten in the "World hot tub market". Almost every family with children owning a house with a comfortable garden owns an inflatable hot tub or similar product. In current times, hot tubs are also popular among the young generation for both relation and celebration purposes. Due to COVID impacts, people are preferring to spend leisure time outside in their garden and water leisure spa is one of the top activities. These customers want to enhance their experience with the help of hot tub surrounds.

The UK home water leisure market is now worth billions and it's a sector that is projected to grow as more and more people look spend more time outdoors, providing greater scope for inflatable hot tubs and surround products. According to data sources, 227,000 total new hot tubs were sold in year 2020, marking about 10% increase from previous year. This can lead to good market opportunity for surround systems about £56.75 million turnover, assuming that at least half percentage of the hot tub owners are willing to buy complete surround system. The market can be further expanded outside the UK as The Global Hot Tub Market is growing at a CAGR of 9.63% over the next 5 years. This will also help to reach more customers across the globe.



Source: Mordor Intelligence



Figure 3. Global Market Concentration of Hot Tub in last 5 years.

The current hot tub market is considerably competitive while only few names are providing the surround systems for the inflatable hot hubs. There is only handful variety of surround system options available in the market. Also, there is small amount of market (around 9%) which has custom build surround, either they are commissioned or crafted as DIY. All of the surround systems mostly revolve around the basic two model designs of the inflatable hot tubs mainly circular and square. The following research is done to get a brief of products available in market to develop the surround system considering them as the owners of these hot tubs will be the future customers.

Circular models:

					
Product Name	CleverSpa Onyx Round	Lay-Z-Spa Circular Miami	MSpa Round Lite	MSpa Silver Cloud Delight	Intex PureSpa
Sitting	4 Person	4 Person	4-6 Person	4 Person	4 Person
Air Jets	110	120	138	118	120
Rating	220-240V~50Hz, 1,800W	220-240V~50Hz, 2,050W	220-240V~50Hz, 1,500W	220-240V~50Hz, 1,500W	220-240V~50Hz
Water capacity (litre)	800	669 (at 80%)	930	700	795
Outer Diameter (mm)	1800	1800	2040	1800	1960
Height from the base (mm)	650	660	700	700	700
Weight (kg)	25	27.47	22.5	23	38.6

Table 1. Comparison of Popular Circular Inflatable Hot Tubs.

Square Models:

			
Product Name	CleverSpa Onyx Square	Lay-Z-Spa Square Hawaii	MSpa Blue Square Lite
Sitting	4 Person	4-6 Person	4-6 Person
Air Jets	110	140	132
Rating	220-240V~50Hz, 1,800W	220-240V~50Hz, 2,050W	220-240V~50Hz, 2,100W
Water capacity (litre)	800	840	930
Width (mm)	1800	1800	1850
Height from the base (mm)	650	710	680
Weight (kg)	26	36.28	23

Table 2. Comparison of Popular Square Inflatable Hot Tubs.

Small circular hot tubs are prominent- due to their shape, easy and uniform inflation. The design of a round inflatable hot tub offers a more traditional hot tub feel. Hot tubs were generally made to be round so a round inflatable hot tub will give a more classic spa experience. The walls of the round inflatable hot tub feel more comfortable since the walls are curved in a way that encircles the person while sitting, implying less stress for long periods of sitting. The shape of the round hot tubs allows equal airflow in the tub. The round inflatable hot tubs generally give gentler hydrotherapy than square hot tubs. The jets of the round inflatable hot tub blow air and push water gently into the hot tub. This causes the water to give a whirlpool effect because of the round shape of the hot tub. The round hot tubs are easy to store and simple to accommodate things around them. Although the circular hot tubs consume little more electricity in comparison, it is popular among the masses for their looks, feel and symmetric use.

Market Share by Type 2021

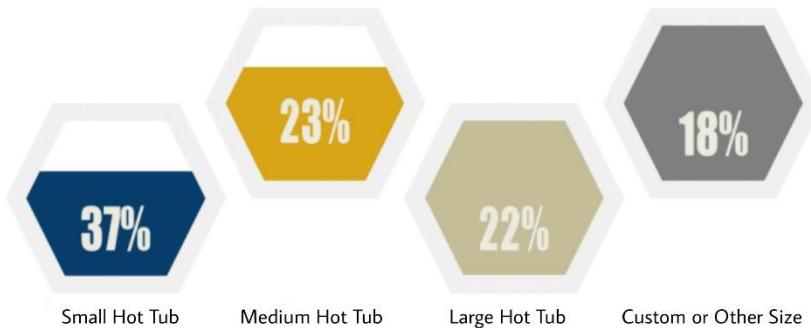


Figure 4. Hot Tub Market Share by Size 2021.

5.3.3 Competitors

5.3.3.1 Companies and Products

There are plenty of companies in the market which offer quality inflatable hot tubs at low prices with a variety of options and designs. Some of the popular brands available in the UK are-

1. Lay-Z-Spa
2. VidalXL
3. Festnight
4. A&B Accessories
5. Intex PureSpa

There are many other variations available in the market but most of them are from the companies mentioned above.

Based on the two main types of models mentioned above, attachable or connective surround options are available. As the sizes of the inflatable hot tubs are quite standard, these surround solutions are also standardised in a way. But some companies have developed the surround systems for a particular model or company products that cannot be used effortlessly with other models. Following are the few types of surrounding solutions found in the current market –

A. Rattan Spa Surround:

This is poly rattan hot tub surround is a versatile accessory for a hot tub. It gives the hot tub an obsolete and modern look while creating a more functional and user-friendly spa area. It has a built-in storage area and a cut-out section for a power pack, the spa surround keeps all the essentials organised and within arm's reach. Requires specific assembly process and proper installation before using.

Material: PE rattan

Frame: Powder-coated steel + eucalyptus tropical hardwood

Outer diameter: 2830 mm and Inner diameter: 2030 mm

Size: W2680, H550 mm

Weight: 56 kg

Price: £500-1000



Figure 5. Complete Circular Rattan Spa Surround for Inflatable Hot Tub.



Figure 6. Complete Square Rattan Spa Surround for Inflatable Hot Tub.

B. Wood Spa Surround:

This wooden surround is simple and durable with plenty of open space. It is also hard-wearing, weather-resistant and provides additional seating as well as a useful surface for different purposes and those essential creature comforts to keep close whilst being in a hot tub. Requires installation and assembly before use. No adjustment can be done for fitting with different hot tubs.

Material: Acacia wood with a natural oil finish

Frame: Powder-coated aluminium

Outer diameter: 2730 mm and Inner diameter: 2030 mm

Size: W700, H570 mm

Weight: 60.8 kg

Price: £450-500



Figure 7. Complete Circular Wooden Spa Surround for Inflatable Hot Tub.

C. Inflatable Surround Deck and Step:

This Lay-Z-Spa surround is constructed from a fibre forced layer between PVC layers material with an I-beam structure and can be easily inflated by using the spa or air pump. This surround is suitable for the Lay-Z-Spa round shape range. It can conveniently be connected by a fastener which is located on each end. Such 3 surrounds can be used to form a circle and assemble around the spa to sit or lie on. Needs minimum assembly before placement in hot tub surrounding.

Size: H400, W2000, L400 mm.

Weight: 5.86 kg.

Price: £72-80



Figure 8. Inflatable Deck for Inflatable Hot Tub.



Figure 9. Inflatable Deck and Step in Use.

D. Tub Canopy:

This surround is suitable for all Lay-z-spa inflatable tubs, protecting from direct sun with a comfortable and compact factor. It is 190T Polyester PU1000mm coated, UV index UPF 30+ protection. It contains one tent, three poles for structural strength and two guy lines to attach the canopy to the hot tub. It is made from polyethylene which is easy to store and can deal with the sun effectively. It also has high-density, ventilated mesh windows. Needs a few assemblies and attachments before use.

Size: H1830, W940, D1090 mm.

Weight: 1.36kg.

Price: £40-60



Figure 10. Tub Canopy in Use.



Figure 11. Tub Canopy for Inflatable Hot Tub.

E. Bar Table:

Rattan Bar Table features a nice utility for the hot tub. It is constructed of durable, weather-resistant, synthetic rattan. It includes a tempered glass top for aesthetics and convenience to putting a drink by side. An aluminium frame is provided inside for support. Needs to be assembled before usage.

Size: H500 x W1140 x D740 mm.

Weight: 9 kg.

Price: £250-500



Figure 12. Rattan Table with Glass top.

F. Steps

This is a small surround accessory for an inflatable hot tub. The steps are simple to store and use in any surrounding, improving the accessibility to the hot tub and avoiding accidents and damage. The surround steps are usually included in other big surround packages, but some of them are sold separately. The steps are either made from PP plastic or rattan supported by an aluminium frame. Usually, no assembly or installation is required.

General size: H250 x W920 x D500 mm (rattan) / H350 x W750 x D550 mm.

General weight: 4-6 kg.

Price: £110-200



Figure 13. Different Steps for Circular Inflatable Hot Tub.



Figure 14. Application of Rattan Step with Inflatable Hot Tub.

G. Bluetooth Entertainment Station

This is a surround accessory hot tub with Air jet pump machines. It is compatible with all AirJet pumps and can be attached to it easily. It has a water-resistant speaker system which is supported by Bluetooth 4.0 for music and phone calls.

This station is rechargeable and has a built-in LiPo battery. It also includes two drink holders. As most of the companies provide Air jets which have different designs, this surround is out of commission now. But some of the old surrounds support this station.

Re-sell Price: £50



Figure 15. Bestway Bluetooth Entertainment Station.

H. Multicolour LED lights:

This is a unique but small surround feature available as an accessory with an IP68 Waterproof rating for underwater use. It has 7 bright alternating colours – red, pink, orange, yellow, green, blue, and light blue which can be switched by simply pressing a button on the remote. It requires 3 x AAA batteries (not included) and has an auto-shutoff feature to help preserve battery life. It requires simple installation before use. It comes in a variety of options and designs, but popular ones being- LED disk (H15, D30 mm) and LED strip (4 to 5 m long).
Price: £16-80



Figure 16. Types of LED light System for Inflatable Hot Tub.



Figure 17. LED Light System in Use.

5.3.3.2 Unique Selling Points

One of the unique selling points of this product is its design and features considering the modularity. The product is custom and adaptable compared to all competitors in the market while providing a variety of features which improve the functionality of the overall hot tub surround. The modular design allows flexibility to create the desired surround at a time. If the customer wishes to have only a few features of the surround for current use, then this product allows them to accommodate those features effortlessly. In addition, if the customer wants to add more functions in future, they can adapt it easily to the current surround. This helps customers to create bespoke environments of their own.

The cost of the product while considering the flexibility and availability of features is within the budget, compared to other competitors. The product allows the customer to buy the surround only with the functions they need, saving the cost while providing the desired experience. The product is compatible with the main

standard models of inflatable hot tubs available in the UK market and can be used without any extra equipment.

5.3 Performance Specification

The Performance specification creates information to be later referred to as a testing method to whether a design is meeting the given criteria. A coding system and importance rating have been created to make referencing individual statements simpler at a later date.

5.3.1 Function

Table 3. Function section of Performance Specifications.

Nº	Description	Importance Low (1-5) High	Notes
1.	Utilisation	3	Once installed the modular part must remain in its position and not move or misplace as a result of external force. Each modular part must fit in a concise space. The system must be adjustable to be arranged around the hot tub.
2.	Storage	2	Must not acquire more than necessary space in storage. Should be stored so that parts are not damaged. Must be easy to put in and bring out of storage.
3.	Modularity	5	Must fit together effortlessly. Must provide the required feature without the need for other parts. Should combine together to form a unique system. Parts must be separated and recombined while maintaining flexibility.
4.	Shape	4	The system should maintain its shape during use. Must resemble to the outer shape of the hot tub. Must surround the whole hot tub.
5.	Total Size	4	Must be comparable to the hot tub. Should not be bigger than the requirement of function. Standard sizes should be applied whenever possible.
6.	Accessibility	3	Must be accessible to the user from the hot tub. Must be simple to operate and function. Interacting parts must be suitable for comfortable use.
7.	Weight	3	Each modular part should be kept as light as possible for easy assembly, disassembly and portability. The mass of the supporting structure must be minimised. Must not imply weight on the hot tub while in function.
8.	Personalisation	4	Must connect easily in a sequence that creates desired surround. Should provide different choices of sequence to customer. Should fit in different environments.
9.	Strength	4	Must withstand impacts and forces from the operation. Must be able to hold the average weight of the person. Should not deform or break while

			functioning. Must be able to support forces from the hot tub.
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5.3.2 Material

Table 4. Material section of Performance Specifications.

No	Description	Importance <i>Low (1-5) High</i>	Notes
1.	Appearance	4	Must fit in with the general appearance of an inflatable hot tub. Must look safe and functional. Must look attractive whilst remaining subtle. Features of the parts should be visible.
2.	Density	3	The structure must have as low a density as possible to decrease the overall weight of each module.
3.	Hardness	3	The system must be hard enough to avoid deformation or bending when in use. The system must be hard enough to avoid deformation when being installed, removed or stored.
4.	Strength	4	Must be strong enough to retain its shape and rigidity when in use. Parts must not break or fall apart when force is applied. Structure and coverings must support forces that are exerted on them as a result of impacts and general usage.
5.	Texture	3	Surfaces to be interacted with by the user must have a comfortable and identifiable texture. Must have a rugged surface to avoid slipping and sliding. Should not be uncomfortable or unsafe for human interaction.
6.	Colour	2	No bold colours should be used. Natural and calming colours that fit in with the spa theme should be used. Structures' colour must reflect their functionality and strength.
7.	Mass	3	Must be as light as possible for operation, assembly, disassembly and storage. The mass of the supporting structure must be minimised.
8.	Phase	3	All materials used must be in a solid-state at a temperature range of -20°C to 35°C. The functionality and performance of materials at this temperature range should not be compromised. Interaction with water must not change material properties.
9.	Recycling content and potential	2	With an increasing green theme influencing politics across the world, increased recycling potential shall increase the product's sellability. Must be simple to disassemble for recycling. Should not be fused with other toxic materials. All materials of parts must aim to be recyclable or reusable.

5.3.3 Dependability

Table 5. Dependability section of Performance Specifications.

Nº	Description	Importance Low (1-5) High	Notes
1.	Availability	4	Must be available to the customer when they demand. Each modular part must be available in multiple quantities. Standard components should be available off the shelf.
2.	Disposal	2	The majority of the product must be recyclable. Components susceptible to damage should be replaceable.
3.	Level of service	2	The maintenance schedule must be eliminated as far as possible. Any damage must be evident to eliminate accidents when in use, brittle fractures cannot occur. Modular parts must be interchangeable to maintain both their level of aesthetic pleasure and functionality.
4.	Life cycle Costs	4	Costs involved with regular use of the product should be minimised. Costs of replacement parts after damage should be minimised as far as possible.
5.	Maintainability	3	The maintenance schedule must be eliminated. Servicing must be minimised or eliminated. Working joints should be accessible for easy maintenance when necessary.
6.	Modification	5	Must be easy for the customer to modify and update their modular parts. Must be easily modified to create a variety of surround options.
7.	Refurbishment	2	Replacement panels and structures must be available as separate entities for refurbishment. Refurbishment must be offered to the customer as an additional service.
8.	Redundancy	3	Parts must fit together with respect to the tub and each other. Must connect such that no gaps are evident when in use.

5.3.4 Environment

Table 6. Environment section of Performance Specifications.

Nº	Description	Importance Low (1-5) High	Notes
1.	Access	3	Working components and joints must be easily accessible for required maintenance.
2.	Air and water flow	2	Parts shall predominantly function near the water body and thus must not collect water when in use or being moved from and to storage. The product may be subject to rain and water; this must not collect as it may induce corrosion. Must withstand a minor gust of wind.

3.	Altitude and depth	1	Surround parts are to be used at ground level, a level in which the hot tub is kept thus no special considerations need to be made for depth.
4.	Corrosion	4	The joints, components and structure of each module must have high corrosion resistance. The base of the structure must not corrode as a result of being in contact with the wet ground for long periods due to regular use.
5.	Erosion	3	If any erosion occurs the product will fail. The product cannot erode as a result of water being in contact with the base. The product cannot damage extensively as a result of general usage.
6.	Force	4	The product shall be functioning under a variety of forces and impacts. Must support the average weight of humans easily without deforming.
7.	Noise, vibration and shock	3	Must withstand heavy shocks and vibrations as a result of impacts during use and being moved to and from storage.
8.	Precipitation	3	Surround parts can be in an environment with excessive precipitation over night and high humidity. This must not affect the performance of the barrier in any negative way. Joints, components and main structure must remain functional.
9.	Pressure	3	Must withstand the pressure applied from the top, usually from the person standing or sitting. Must not deform under pressure.
10.	Radiation	2	Should not produce or emit any radiation as it is to be used in public places and have regular interaction with a variety of users. Product may be used outdoors thus sunlight must not discolour the external surfaces.
11.	Temperature	3	All parts and components must function between a temperature range of -20°C to 35°C without any effects of phase transition, degradation or corrosion.
12.	Relative humidity	2	The product will be subject to relatively high levels of humidity in an outdoor environment. This must not affect the aesthetics, functionality or effectiveness of the barrier in any way.
13.	Pollution	2	Production of the panels must produce as little waste as possible. No pollution should be created through the use of the product.

5.3.5 Ergonomics and Aesthetics

Table 7. Ergonomics and Aesthetics section of Performance Specifications.

Nº	Description	Importance Low (1-5) High	Notes
1.	Accessibility	4	The components to be interacted with by the user must be comfortable for use by the average person. Moving components and joints susceptible to damage must be easily accessible. Must be accessible to the user from the hot tub.
2.	Colour	3	Must be in keeping with its surroundings. Cool and calm colours in the spa theme must be used. The structure must portray rigidity and strength to both the customer
3.	Controls and display	2	Controls should be easily identifiable for the user and simple to function both correctly and comfortably. Any function feature or instruction should be displayed clearly.
4.	Mass	3	The mass of the product must be minimised to increase ease of use.
5.	Operating force	2	Must withstand forces when in use and when being moved. Should not fail under excess operating force or force in the wrong direction.
6.	Size and shape	4	The system must surround the whole hot tub. The shape must resemble to the outer shape of the hot tub. The size of the system must be comparable to the hot tub. Standard sizes should be applied whenever possible.
7.	Transportability	2	It is important to make transportability of the product as easy and low-cost as possible thus the size and weight of the product must be minimised, also making it easy for assembly and installation.
8.	Visual impact	4	Must portray quality and functionality increasing the general aesthetic of the facility it is within whilst remaining subtle and in keeping. Should fit in the theme of a hot tub spa.
9.	Texture	3	Surfaces to be interacted with by the user must have a comfortable and identifiable texture. Must prevent from slipping and sliding while in use, avoiding accidents.
10.	Signs and instructions	3	Semantics and semiotics must be used where appropriate to aid the user. Simple effective instructions must be supplied with the product signifying its purpose and how to use it appropriately.
11.	Temperature	3	It is essential that components to be regularly interacted with must remain comfortable to touch and hold between temperatures of -20°C and 35°C.

5.3.6 Interface

Table 8. Interface section of Performance Specifications.

Nº	Description	Importance <i>Low (1-5) High</i>	Notes
1.	Accessibility	3	Joints, components and panels must remain easily accessible for easy maintenance and repair. Components to be interacted with by the user to move the product to and from storage must be easily identifiable and accessible for increased ease of use.
2.	Configuration	2	Components should not only be easy to access but also easy to operate and manipulate to the customer's desired requirements.
3.	Compatibility	3	The product must be compatible with a standard inflatable hot tub. Must be adaptable to be used and stored on a variety of flat surfaces.
4.	Interchangeability	4	Components must be interchangeable so that the product can be altered to suit use on a variety of functions without significant increases in cost. Must remain easily interchangeable in case of damage occurs.
5.	Use and abuse tolerance	2	Must withstand heavy use and misuse. Parts must not function below standard following misuse, forces acting downwards on the surfaces, forces acting diversely on components and forces exerted directly onto the structure must all be withstood without compromising performance.
6.	Visibility	1	Individual parts and their functions must be easily visible.
7.	Security	3	The product is to be used by members of the general public and so may be misused on a regular basis. Components and joints must not be easily accessible for arson.
8.	Custom and culture	2	Components to be interacted with must not be shaped in such manners that may offend people i.e. should not be shaped like a crucifix or knife.
9.	Emissions	2	Emissions during both manufacturing and transit must be minimised as far as possible. Recycling potential must be increased to reduce emissions through the disposal of the product. The product must not emit any pollution whilst in use.
10.	Local utilities	2	No power or water supply is required for the functioning of this product and so need not be considered.

5.3.7 Cost and Timing

Table 9. Cost and Timing section of Performance Specifications.

Nº	Description	Importance <i>Low (1-5) High</i>	Notes
1.	Availability	4	Must be available to the customer on the day of their order, special features should also be available but in limited amounts. Full working systems and individual modules must be readily available.
2.	Installation and commissioning	4	Installation of modular parts around the hot tub should be simple for the customer and take a few minutes. Clear instructions should be supplied with surround parts.
3.	Life cycle costs	4	Must be minimised for increased success, cost and availability of replacement components must be minimised. Repair and replacement costs of components must be minimised.
4.	Transportation and storage	3	The size and weight of the product must be minimised to decrease the cost of transportation and make storage simpler. Shipping time to customers from the shop or factory must be minimised.
5.	Range and scope	2	Time to market should be minimised to increase the potential market. More Features can be added. Standard packs or surround combinations can be sold.
6.	Unit Cost	4	The cost of the individual module must be as low as possible and should be similar to other parts. Materials and processes should reflect quality whilst remain as cheap as possible.
7.	Marketing and sales factors	2	Marketing must draw on the unique selling points of the product. The easy incorporation of special features such as modularity. The availability of the product. The increased functionality, compatibility and decreased price of the product.
8.	Customer support	2	Product advice and information must be readily available. Would be in the form of a physical brochure and a website which offer information free of charge. Regular services and maintenance of the mobile dasher boards must be an option that the customer can select if necessary.

5.3.8 Safety

Table 10. Safety section of Performance Specifications.

Nº	Description	Importance <i>Low (1-5) High</i>	Notes
1.	Accessibility	3	Working components and joints must be easily accessible for required maintenance.
2.	Custom and culture	2	No provocative or offensive material should be within the product or company.
3.	Emissions	2	Emissions during manufacturing, transportation and disposal must be minimised. The product must not emit any pollution whilst in use, and noises created through impacts when in use.
4.	Ergonomics	4	Must be safe to transport, carry and install. Should not require other tools for protection.
5.	Protective coating	3	As the product can come in contact with water frequently, a protective layer should be painted wherever necessary and a rough coating can be applied to avoid slipping accidents on wet surfaces.
6.	Security	3	The product is to be used by members of the general public and so may be misused on a regular basis. Components and joints must not be easily accessible for arson.
7.	Signs and Instructions	3	Simple clear signs should be incorporated where necessary on the product to improve safety during the use of the product. Instructions on use should also be visualised within the documentation provided.
8.	Tools and Equipment	2	Minimal additional tools should be required for safe assembly and disassembly of a complete surround system.
9.	Testing and auditing	4	Tests should be carried out according to both BS EN 750-2004 and ORFA regulations

5.4 Regulatory Requirements

5.4.1 Legislation

Government rules and regulations must be followed at each step of the project. Abiding the government and international standards for the project is something to be taken care of. The recent change in UK and EU have resulted in changes in the supply chain and selling of products across Europe. These changes have to be noted and a proper working solution for a global approach has to be considered.

5.4.2 Patents

Throughout the design and development of the hot tub surround system, it is crucial to know and understand the patents that surround the product and others similar to it. Knowing these patents ensures that they are not infringed, and all designs can potentially develop legally. The following patents are related to general hot tub systems, they require little understanding for the development of an outdoor surround system for the hot tub but would bear greater significance if the project were to expand in more directions. The following listed patents may require closer consideration and understanding with the project expansion. Although the patents are in the same domain as hot tub, they are not entirely relevant and so can be avoided easily.

	Patent Number	Title	Author
A	US5745932A	Hot tub cover and enclosure	David L. Barovetto
B	US20060218716A1	Hot tub assembly	James Prescott and Paul Van Stone
C	US20050235406A1	Convection loop hot tub system	Stephen August

Table 11. Patents that may need closer consideration with project expansion.

The patent 'US5745932A Hot tub cover and enclosure' has the design of the cover product for the hot tub kept outside. The design of the product is aimed to be foldable and protect the complete hot tub in all weather. The slanted top cover and side wall enclosure are the main parts of the product which occupy additional space outside the tub.

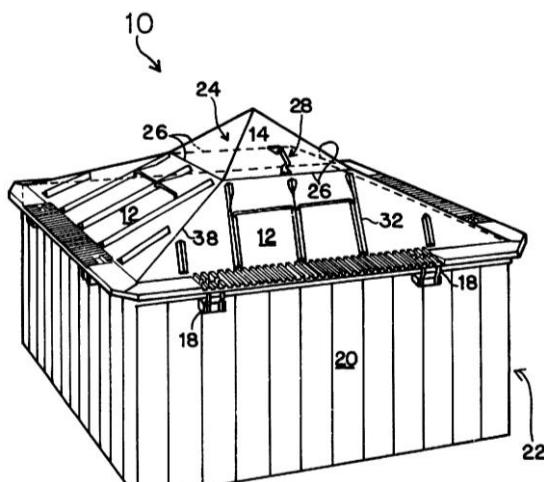


FIG. 1

Figure 18. Patent US5745932A Cover Drawing.

The patent 'US20060218716A1 Hot tub assembly' include associated methods for adding desirable features to portable hot tub systems. It focuses on a base pedestal and flexible liner which can provide additional features like sitting,

protection and stairs to the portable hot tubs. The patent describes the assembly and its features to achieve the extra function for the hot tub.

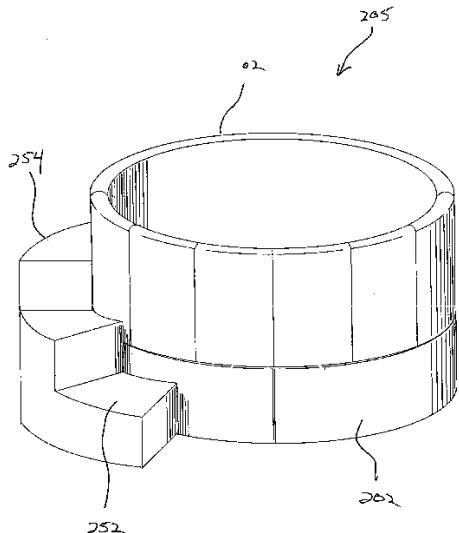


Figure 19. Patent US20060218716A1 Image

The patent 'US20050235406A1 Convection loop hot tub system' provides the solution for portable spa feature for normal tubs or pools. This can be accommodated by hot tubs to enhance functionality. The portable water heating and air-jet unit with the purifying system must be placed outside near the tub. This should be taken into account as compensating feature and making space in the surround system.

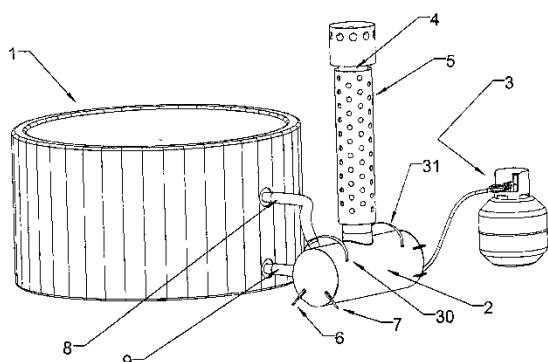


Figure 20. Patent US20050235406A1 Installation Image.

6.0 References

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Lay-Z-Spa® UK. (2022). Detachable Canopy for Inflatable Hot Tub [online] Available from: <https://www.lay-z-spa.co.uk/lay-z-spa-canopy.html> [Accessed: July 2022].

6.1 Images

Figure 1: [Intex Pure Spa Plus Bubble Hot Tub - 28405E for sale online | eBay](#)

Figure 2: [Hot tub awesome | Hot tub garden, Soft tub hot tub, Hot tub backyard \(pinterest.fr\)](#)

Figure 3: [Hot Tub Market | 2022 - 27 | Industry Share, Size, Growth - Mordor Intelligence](#)

Figure 4: [Global Hot Tub Market \(2020 to 2024\) - Featuring Jacuzzi Brands, Marquis & Masco Among Others - ResearchAndMarkets.com | Business Wire](#)

Figure 5: [UK's best hot tub surrounds: circular and square surround kits reviewed on price and build quality » Shetland's Garden Tool Box](#)

Figure 6: [Festnight Square Spa Surround Garden Hot Tub Wicker Furniture Outdoor Conservatory Patio Black 268 x 268 x 55 cm Poly Rattan : Amazon.co.uk: Garden & Outdoors](#)

Figure 7: [vidaXL Spa Surround 273x53 cm Solid Acacia Wood \(manomano.co.uk\)](#)

Figure 8: [Bestway Lay-Z-Spa Inflatable Hot Tub Surround, Square : Amazon.co.uk: Garden & Outdoors](#)

Figure 9: [Bestway Lay-Z-Spa Inflatable Hot Tub Surround, Square : Amazon.co.uk: Garden & Outdoors](#)

Figure 10: [Bestway Lay-Z-Spa Spa Canopy Hot Tub Sunshield Canopy Protector Mesh Window on OnBuy](#)

Figure 11: [Bestway Lay-Z-Spa Spa Canopy Hot Tub Sunshield Canopy Protector Mesh Window on OnBuy](#)

Figure 12: <https://www.wayfair.co.uk/garden/pdp/canadian-spa-co-bar-table-round-spa-surround-furniture-cspc1024.html>

Figure 13: [vidaXL Spa Step Poly Rattan 92x45x25 cm Black | vidaXL.co.uk](#)

Figure 14: <https://www.wayfair.com/outdoor/pdp/usa-spas-29-spa-step-qca10022.html>

Figure 15: <https://www.onbuy.com/gb/bestway-bluetooth-entertainment-station-lay-z-spa-hot-tube-music-rechargeable-c8151-p60913937/?exta=qshp&stat=eyJpcCI6IjQ2LjkyMDAiLCJkcCI6bnVsbCwibGIkljo4NzcyNjU2MCwicyI6bnVsbCwidCI6MTY1NDY3ODQxMSwiYm1jljowfQ==>

Figure 16: <https://www.lay-z-spa.co.uk/underwater-led-light.html>

Figure 17: https://clevercompany.com/shop/cleverspa-led-light-strip/?srsltid=AQP2TeOu_PMRM_zeP6441dwN0IMJakmZ0abZhTPr8QMUIkLK_n_R0RVbpSHo

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[Global Hot Tub Market Professional Survey Report 2019– WiseGuyReports](#)

[UK Bathroom and Bathroom Accessories Market Report 2021 | Mintel.com](#)

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[Home - BISHTA](#)

[Ergonomics and anthropometrics - Considering usability when designing - OCR - GCSE Design and Technology Revision - OCR - BBC Bitesize](#)

[PeopleSize Anthropometry Data \(openerg.com\)](#)

8.0 Appendix

8.1 Anthropometrics and Ergonomics

The width and length of surround system have effect on ergonomics. The size and dimensions of the individual surround part are to be considered using anthropometrics and the standard size of the inflatable hot tub.

The sitting arrangement in surround system should be at height between 350mm to 450mm, width between 380mm to 420mm for 50th percentile female to 95th percentile male in UK.

The Length of arm should be considered for ease of access to the surround top area for usage. The width of these accessible surfaces of surround parts should be within 422mm to 506mm for 50th percentile female to 95th percentile male in UK.

The single step height should be considered with the standard step size and should be consistent. Width of step should be standard for better foot placement. Also, total height of steps should provide user comfortable platform to get in or get out of the hot tub without losing the balance.

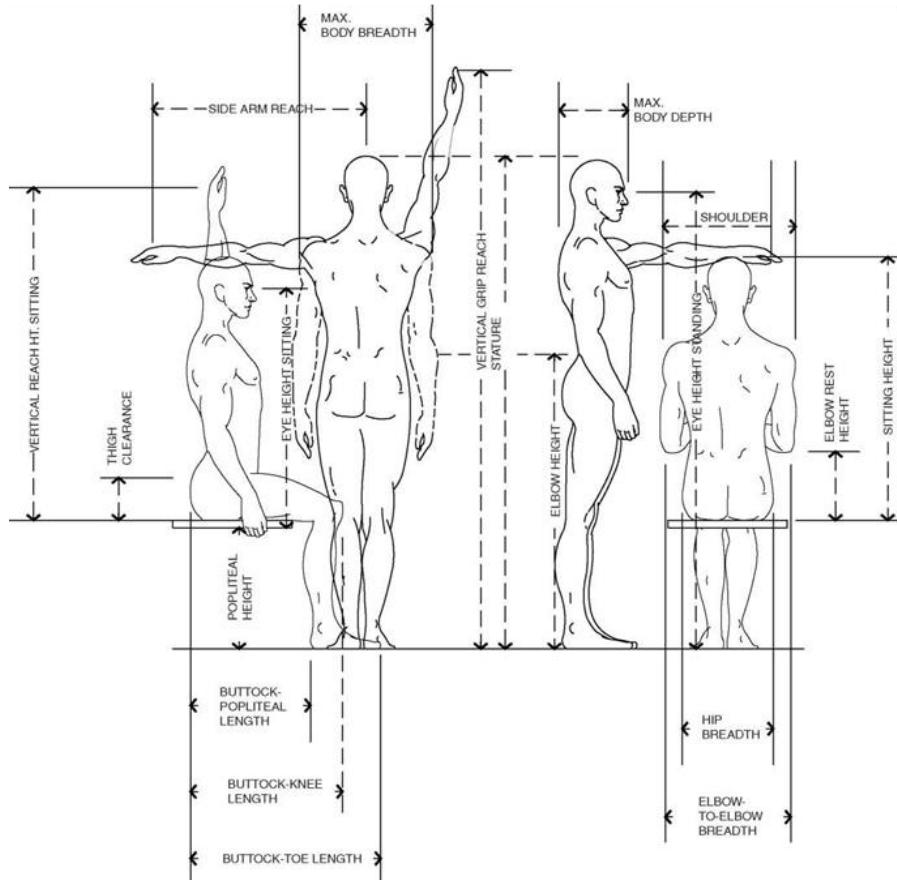


Figure. Anthropometric Representation with Naming of Standard Lengths.

8.2 Patents

[US5745932A - Hot tub cover and enclosure - Google Patents](#)

[US20060218716A1 - Hot tub assembly - Google Patents](#)

[US20050235406A1 - Convection loop hot tub system - Google Patents](#)

SCHOOL OF ENGINEERING
ENGG660: MSc (Eng) INDIVIDUAL PROJECT 2021-22

MANUFACTURING DATA

Nomenclature

To identify and manage the parts conveniently, name codes are used for this product. This will help to manage inventory and make easy to refer to parts while building the parts. As there are so many box section bars in the product with different holes, it would be convenient to name them using their all unique features. The nomenclature system is based on the dimension, assembly position, alignment, and parent panel of the bar. For e.g.

tp_h_side_450

The first part of the name has two letters which represent the parent panel of the box section bar. Here, it is 'tp', meaning this bar belongs to top panel.

The second part of the name is for the alignment of the bar. Now, 'h' is for horizontal alignment and 'v' is for vertical alignment.

The third part indicates the assembly position of that bar in its parent panel. From example, 'side' means that the bar will be welded on the extreme sides of the panel, or it will be used as side bar.

The last part of the name is number, and it represents the prominent or defining dimension of the bar. In this case, '450' indicates that the bar is 450mm long.

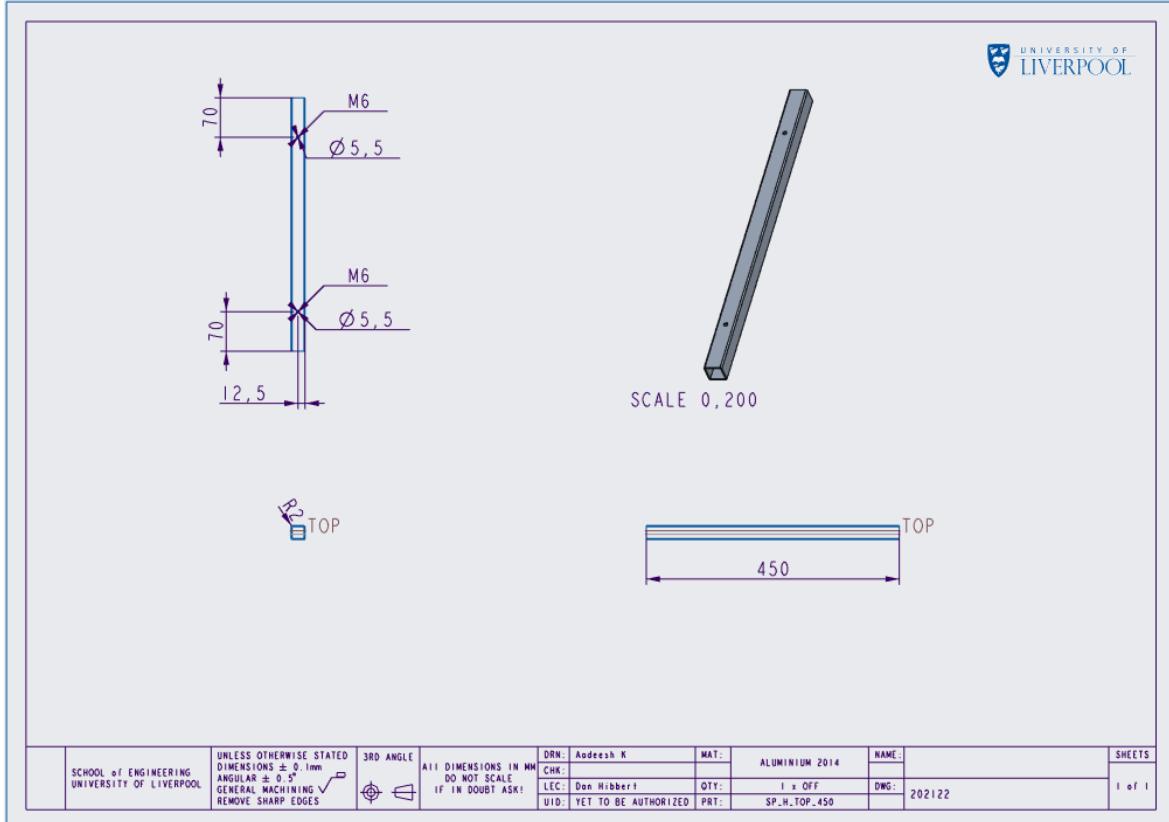
Bill Of Materials

Nº	Name of the Part	Quantity	Material	Manufacturing Process
1	sp_h_top_450	16	Aluminium 6082T	Extrusion
2	sp_v_side_550	16	Aluminium 6082T	Extrusion
3	sp_h_bottom_400	26	Aluminium 6082T	Extrusion
4	sp_v_side_325	16	Aluminium 6082T	Extrusion
5	tp_h_outer_1090	6	Aluminium 6082T	Extrusion and cold rolling
6	tp_h_side_450	12	Aluminium 6082T	Extrusion
7	tp_h_inner_735	6	Aluminium 6082T	Extrusion and cold rolling
8	tp_h_middle_400	18	Aluminium 6082T	Extrusion
9	bp_h_outer_1015	5	Aluminium 6082T	Extrusion and cold rolling
10	bp_h_inner_702	5	Aluminium 6082T	Extrusion and cold rolling
11	bp_h_middle_350	15	Aluminium 6082T	Extrusion

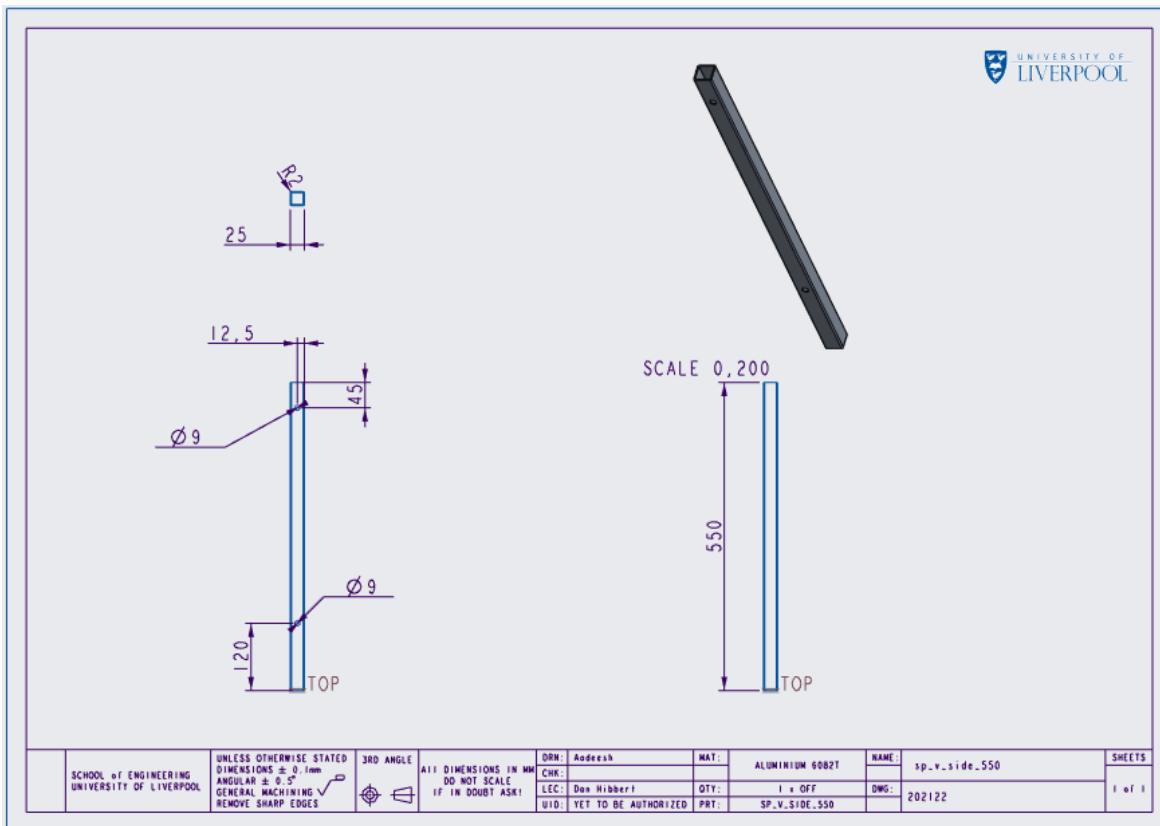
12	fp_h_top_1086	5	Aluminium 6082T	Extrusion and cold rolling
13	fp_v_side_500	6	Aluminium 6082T	Extrusion
14	fp_h_bottom_505	10	Aluminium 6082T	Extrusion and cold rolling
15	fp_v_middle_550	5	Aluminium 6082T	Extrusion
16	fp_v_side_273	11	Aluminium 6082T	Extrusion
17	fp_v_middle_323	6	Aluminium 6082T	Extrusion
18	bkp_h_top_732	5	Aluminium 6082T	Extrusion and cold rolling
19	bkp_h_bottom_330	10	Aluminium 6082T	Extrusion and cold rolling
20	cd_h_both_490	4	Aluminium 6082T	Extrusion and cold rolling
21	cd_v_side_420	4	Aluminium 6082T	Extrusion
22	cd_v_handle_110	2	Aluminium 6082T	Extrusion and bending
23	fp_v_side_500_clsd_stre	2	Aluminium 6082T	Extrusion
24	Adjustable Leg	42	Plastic (from vendor)	Injection Moulding and threading
25	Rivet Nut Insert	140	Zinc plated steel	Extrusion and threading
26	M6x40 Button Head Flanged Fine	90	Zinc plated steel	Forging and upsetting
27	Left-Handed Hinge	2	Glass fibre enforced plastic	Injection Moulding and threading
28	Right-Handed Hinge	2	Glass fibre enforced plastic	Injection Moulding and threading
29	M6x16 Countersunk Hex Fine	16	Zinc plated steel	Forging and upsetting
30	Clipper Fixture	8	Plastic (from vendor)	Injection Moulding
31	90_triangle bracket	4	Aluminium 6082T	Blanking, Punching, Bending and Threading
32	Splashproof cover	1	Transparent HDPE	Injection Moulding
33	Stool	2	HDPE	Injection Moulding
34	Tabletop Glass	1	Glass	Float Glass
35	Cushion	1	Polyurethane laminate cover and foam	N/A

2D Technical Drawings

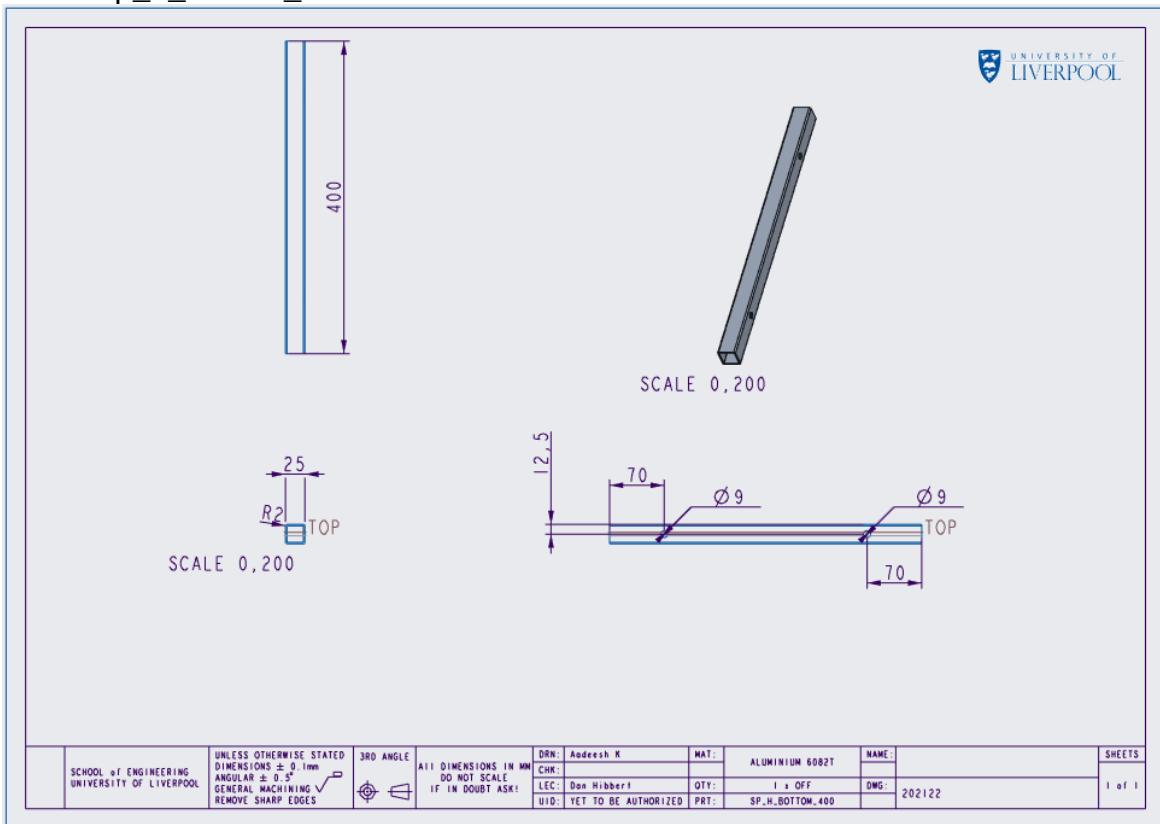
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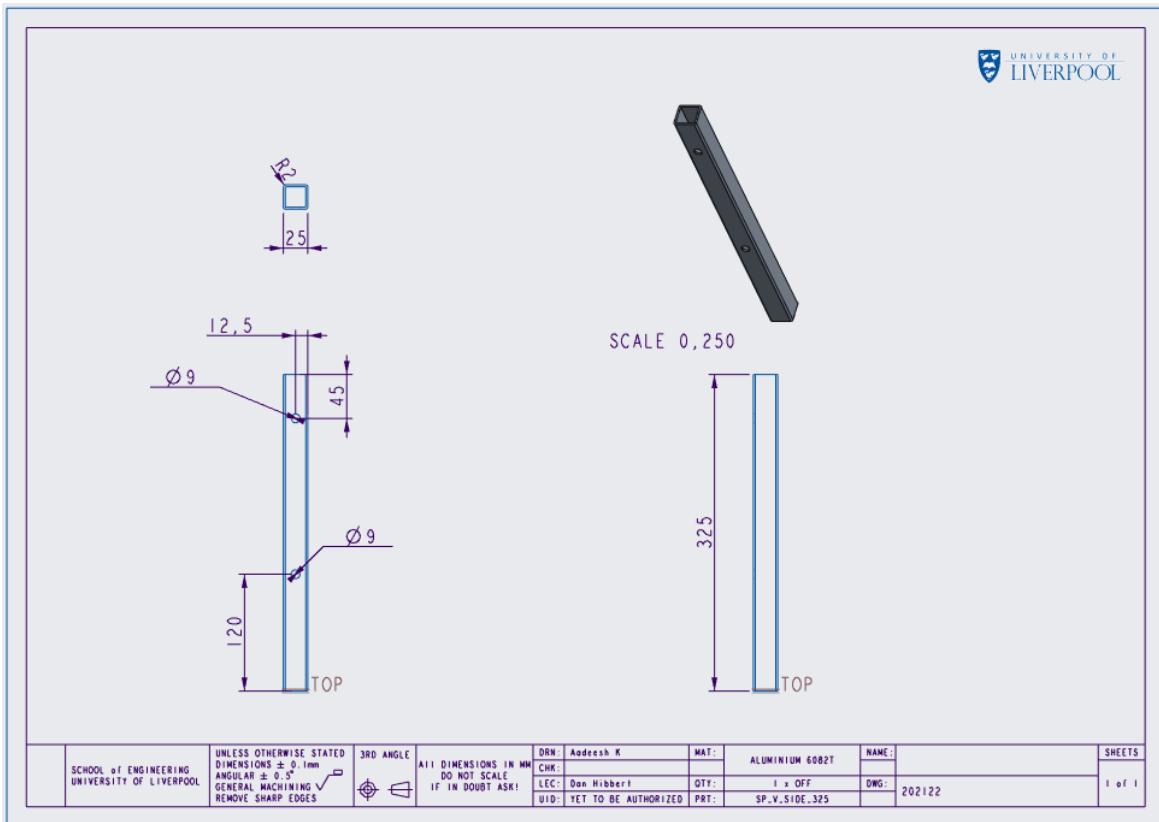
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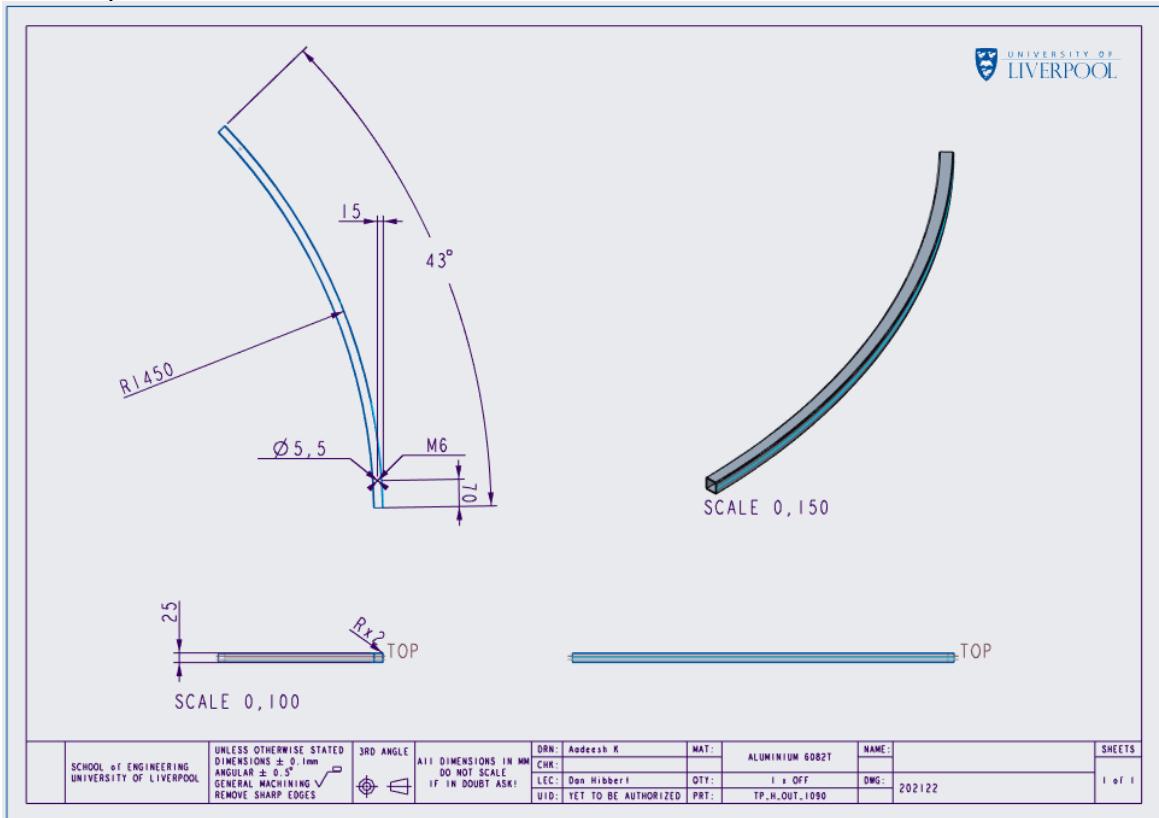
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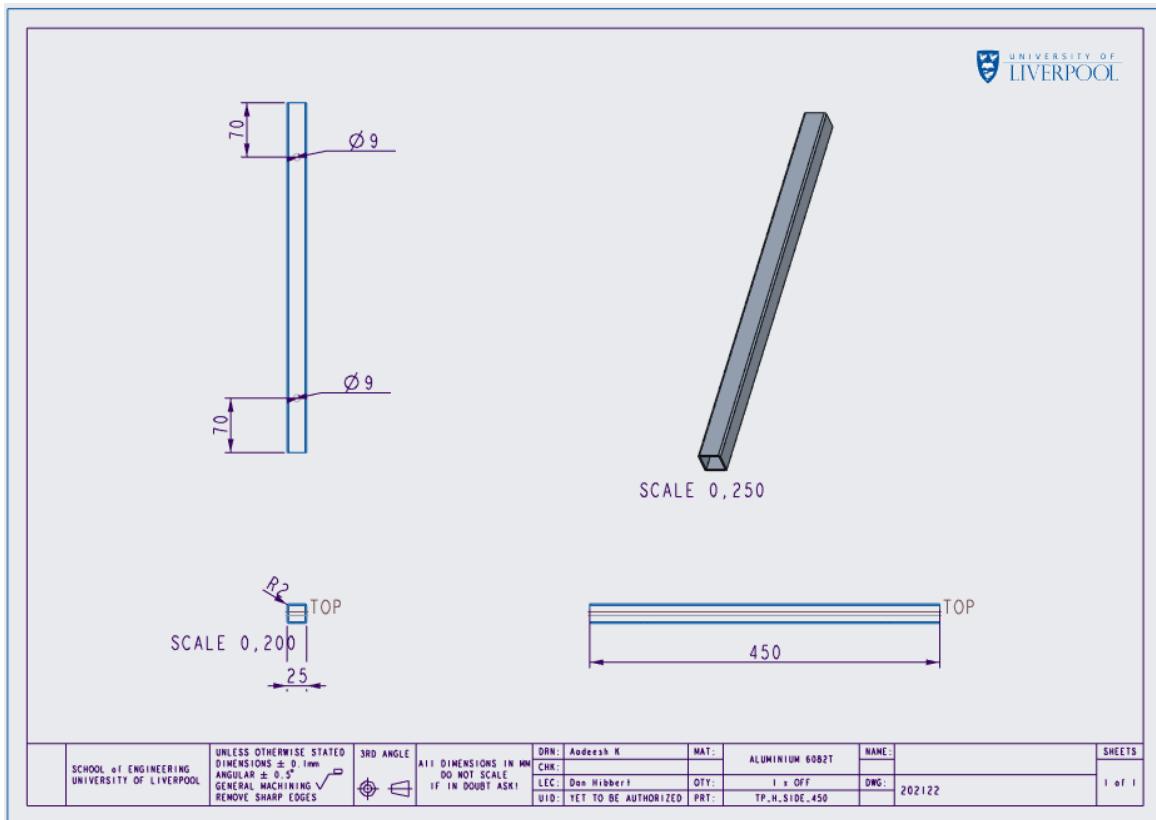
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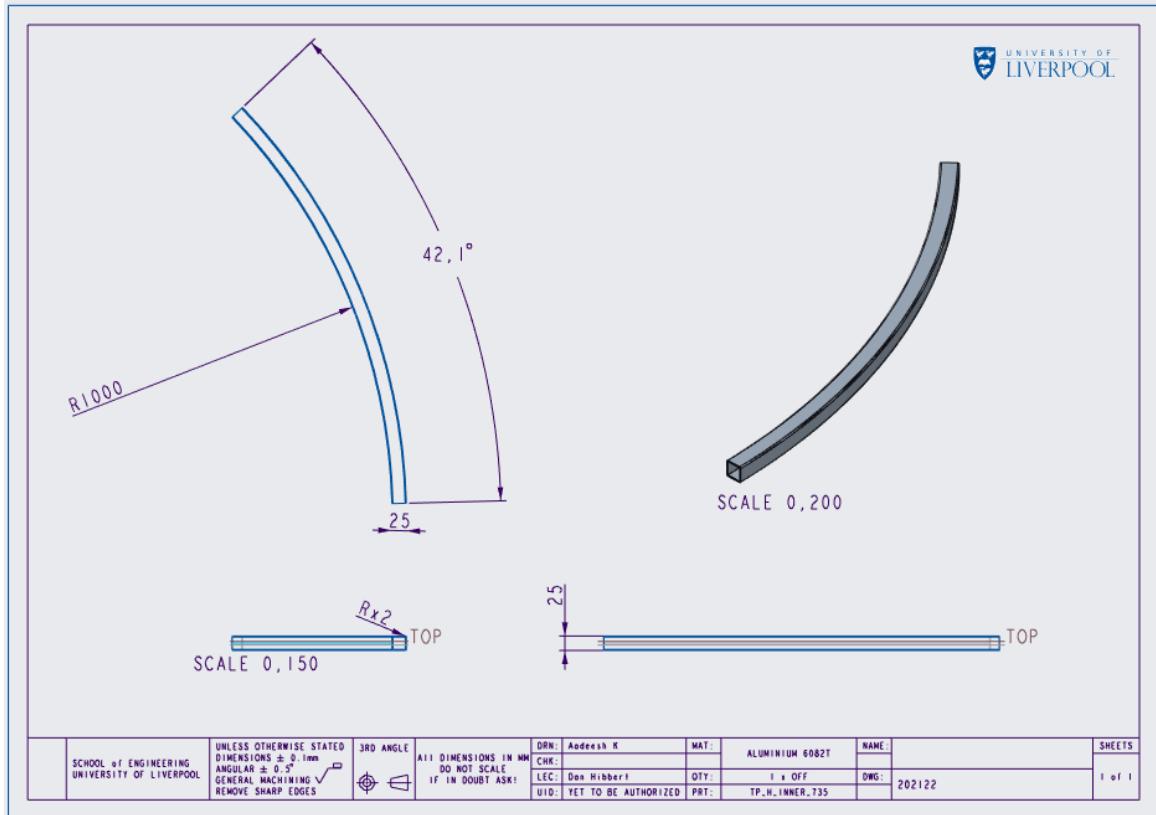
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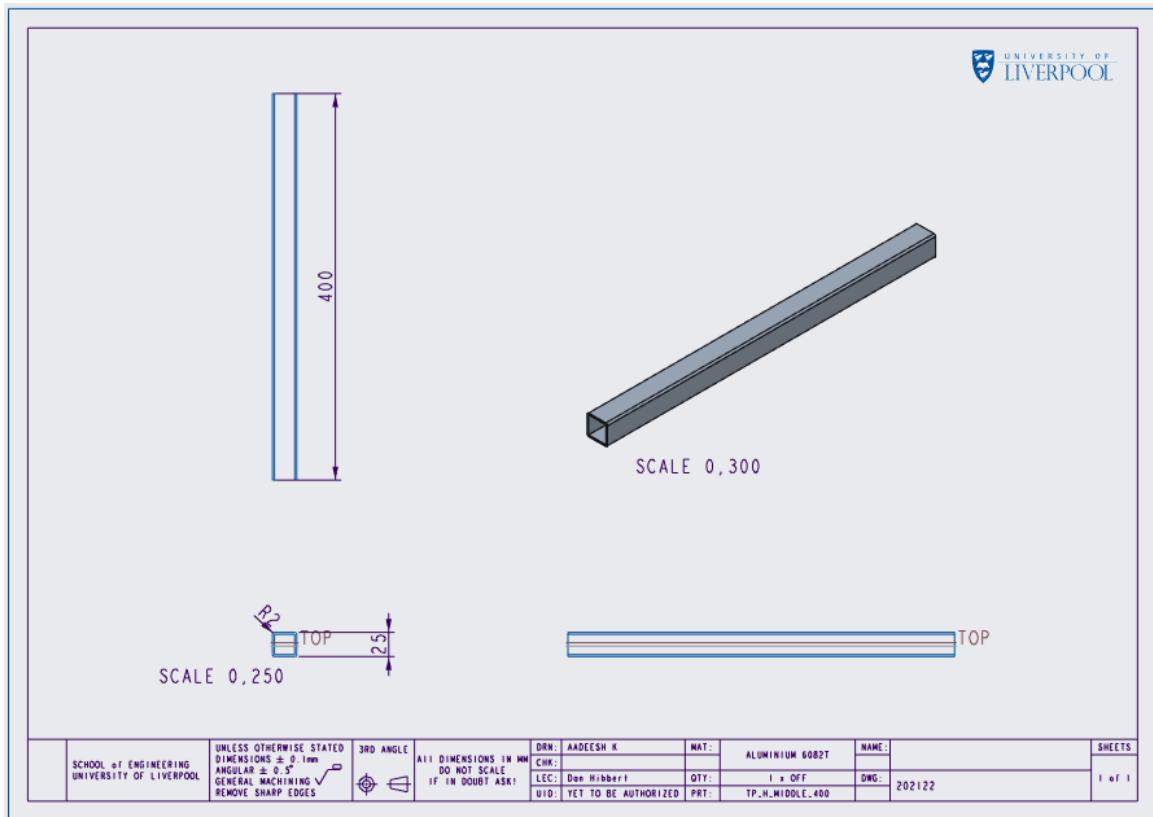
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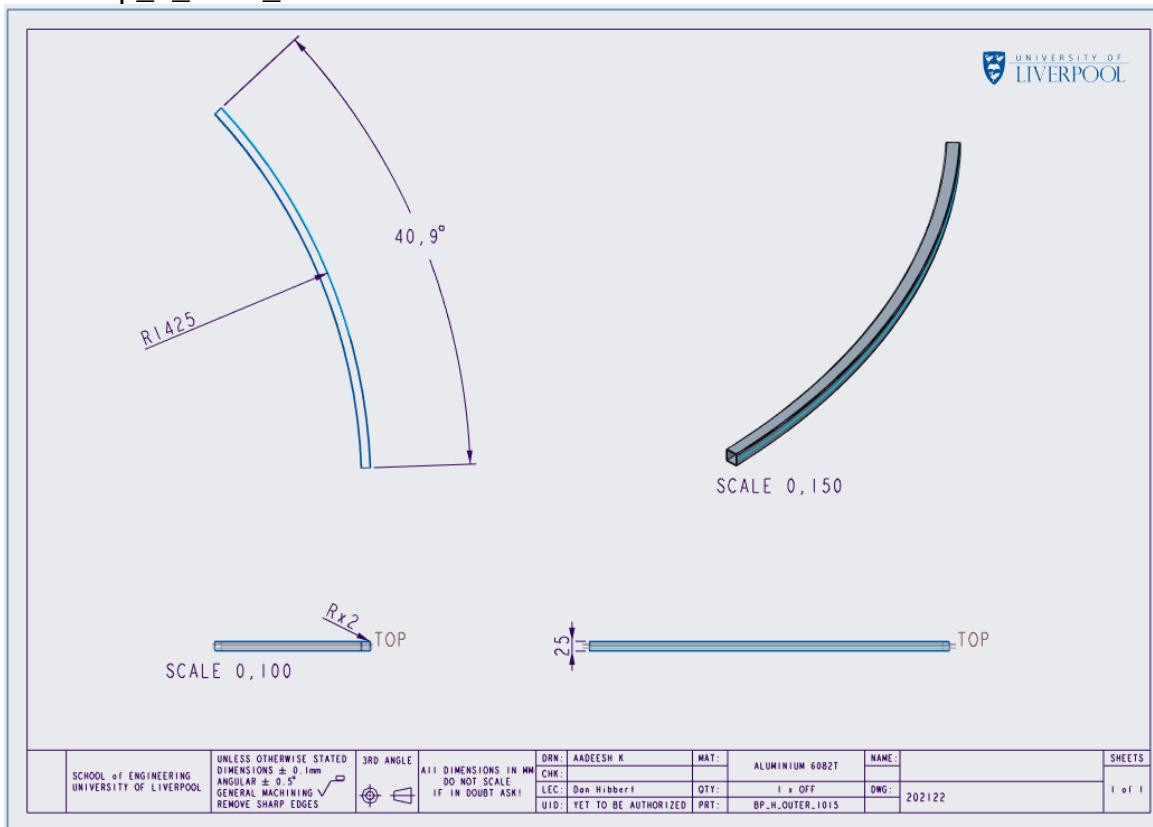
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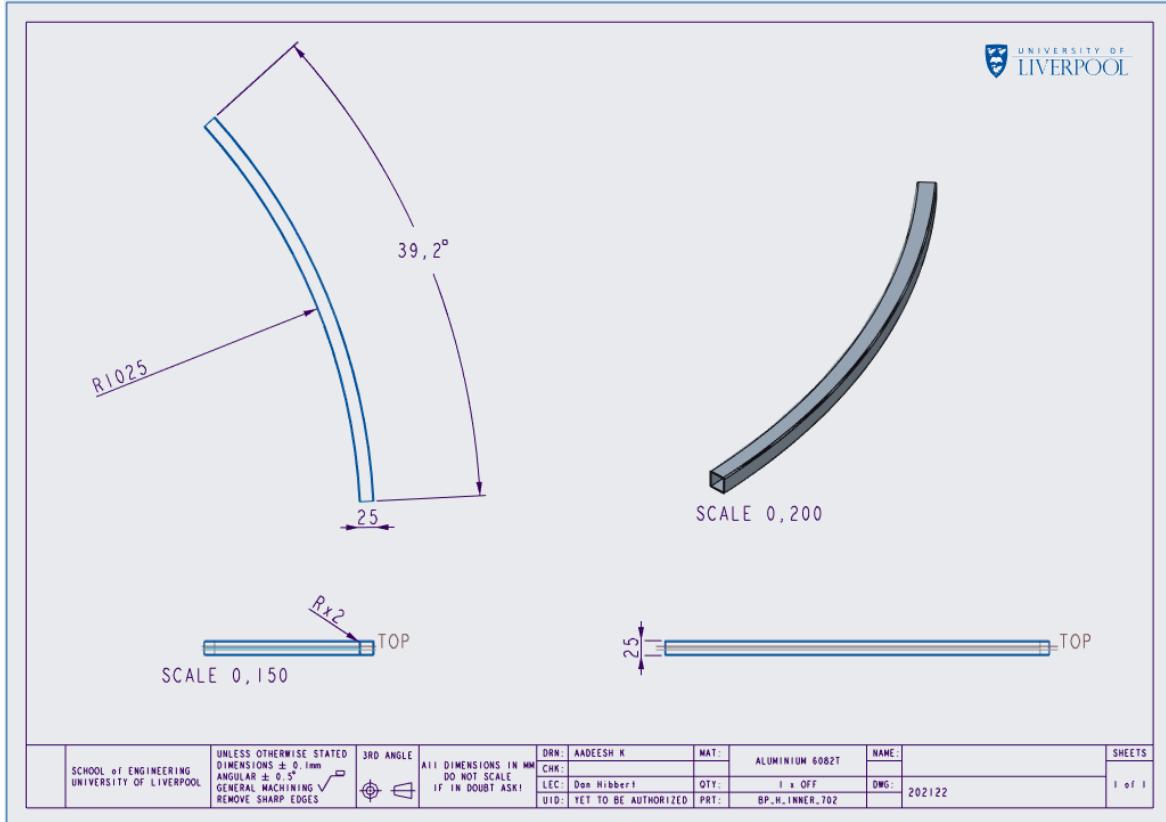
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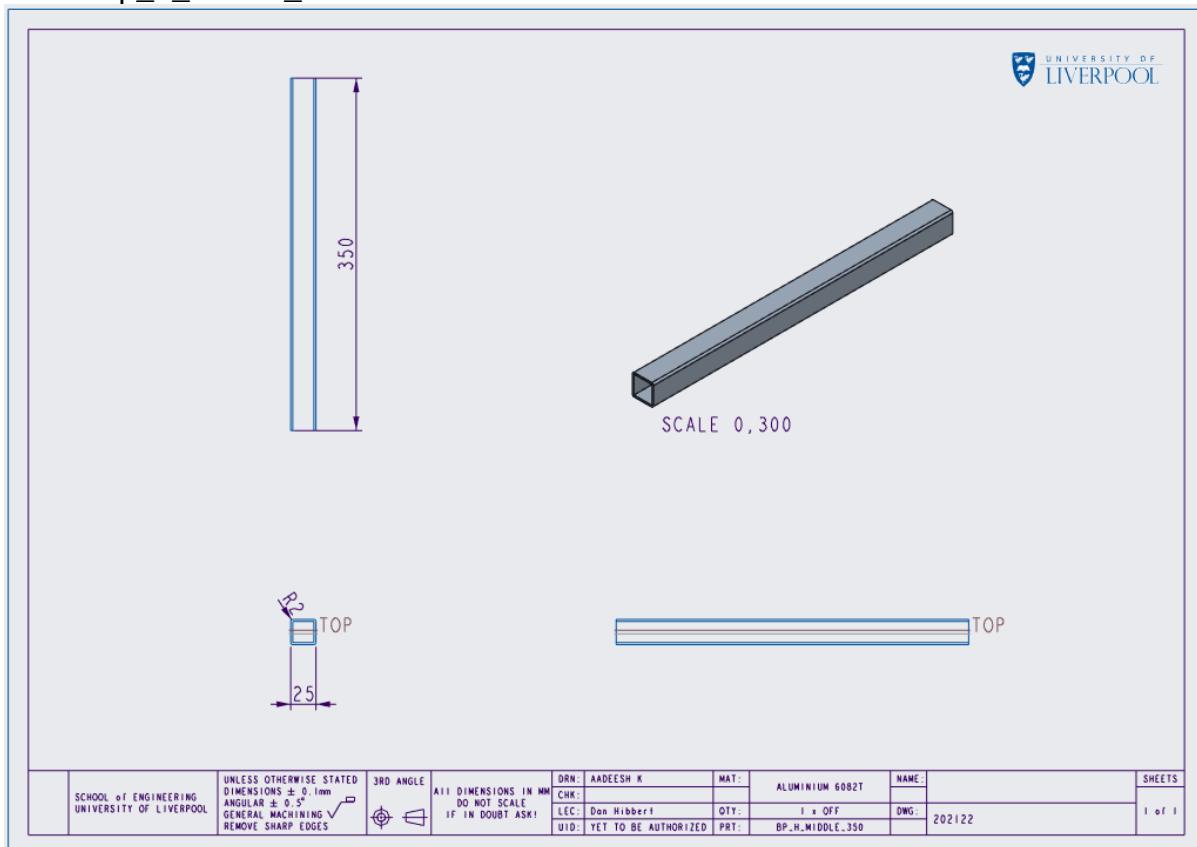
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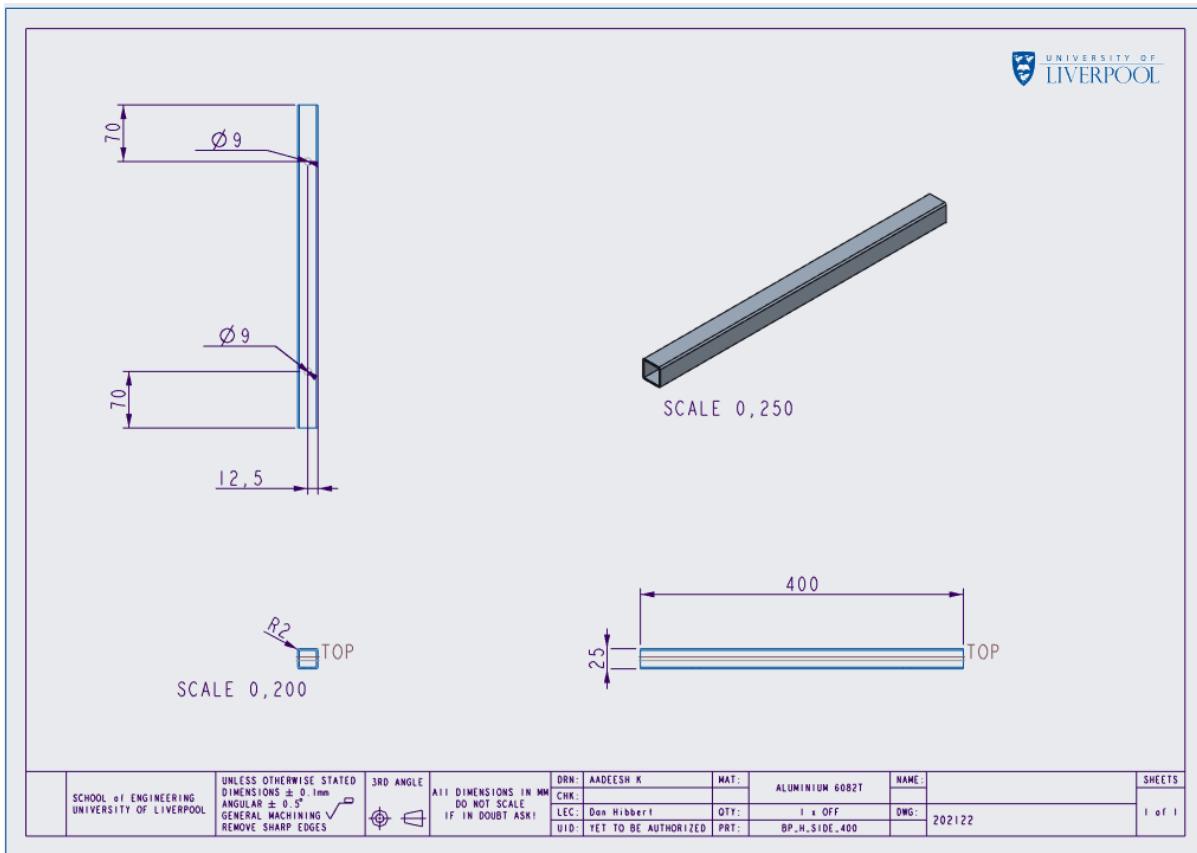


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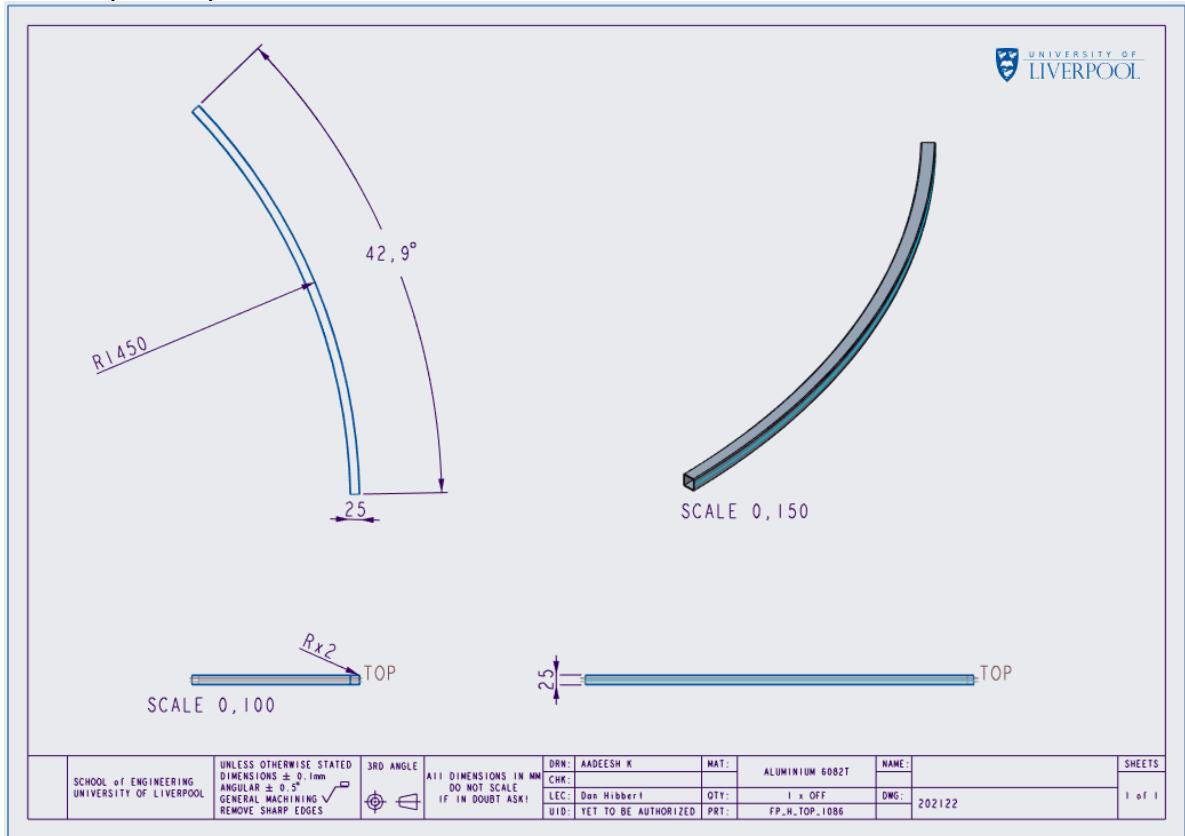


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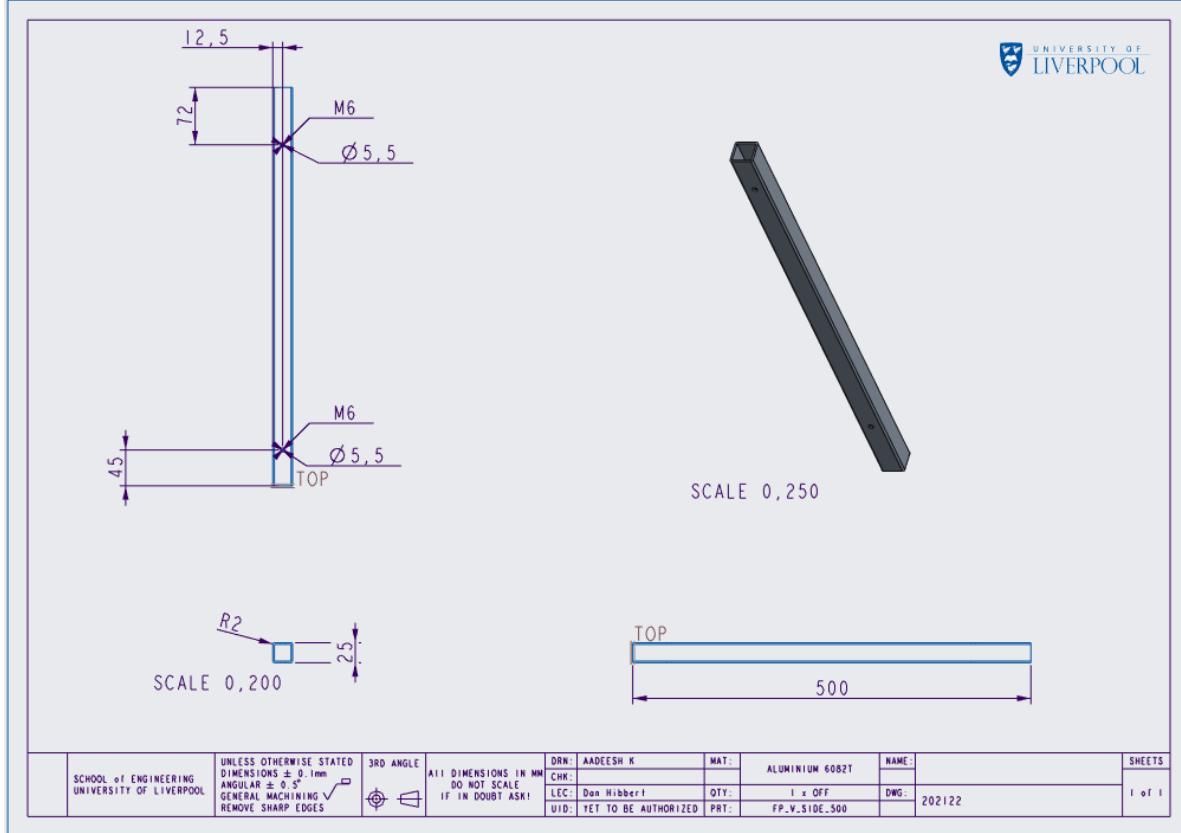




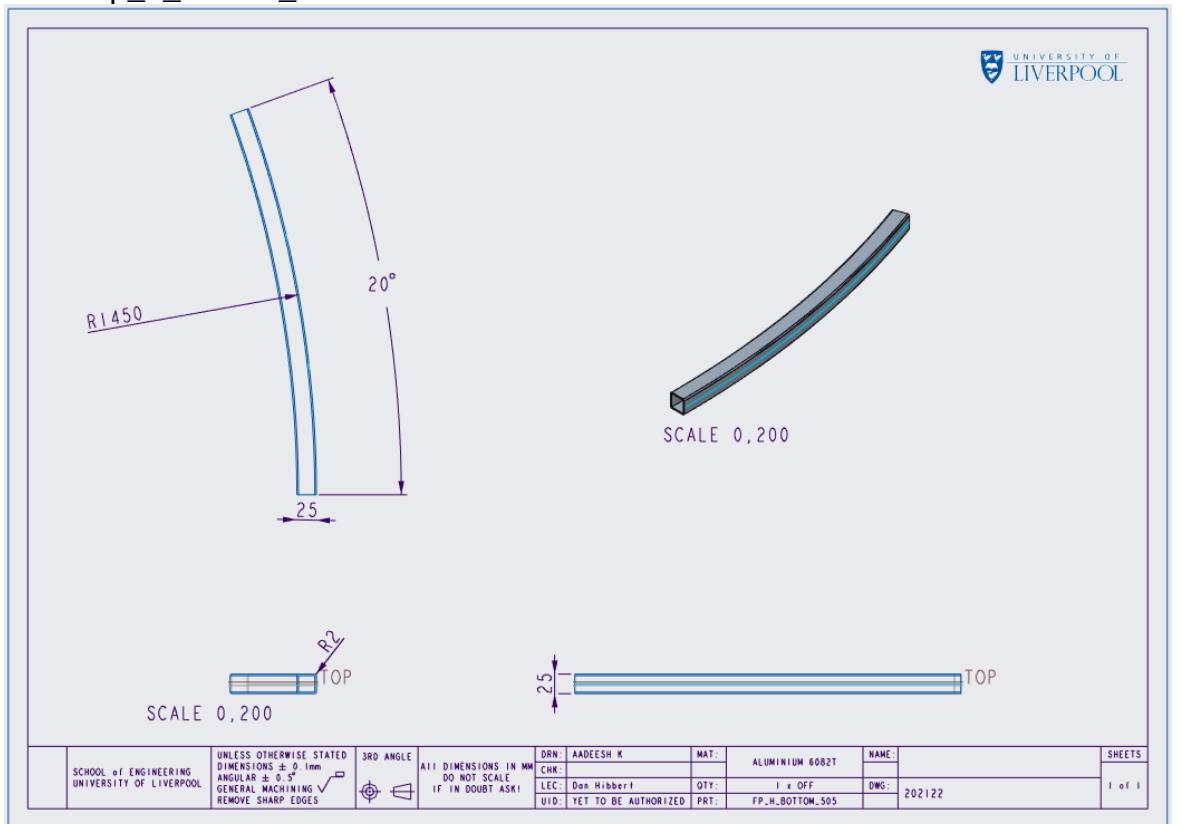
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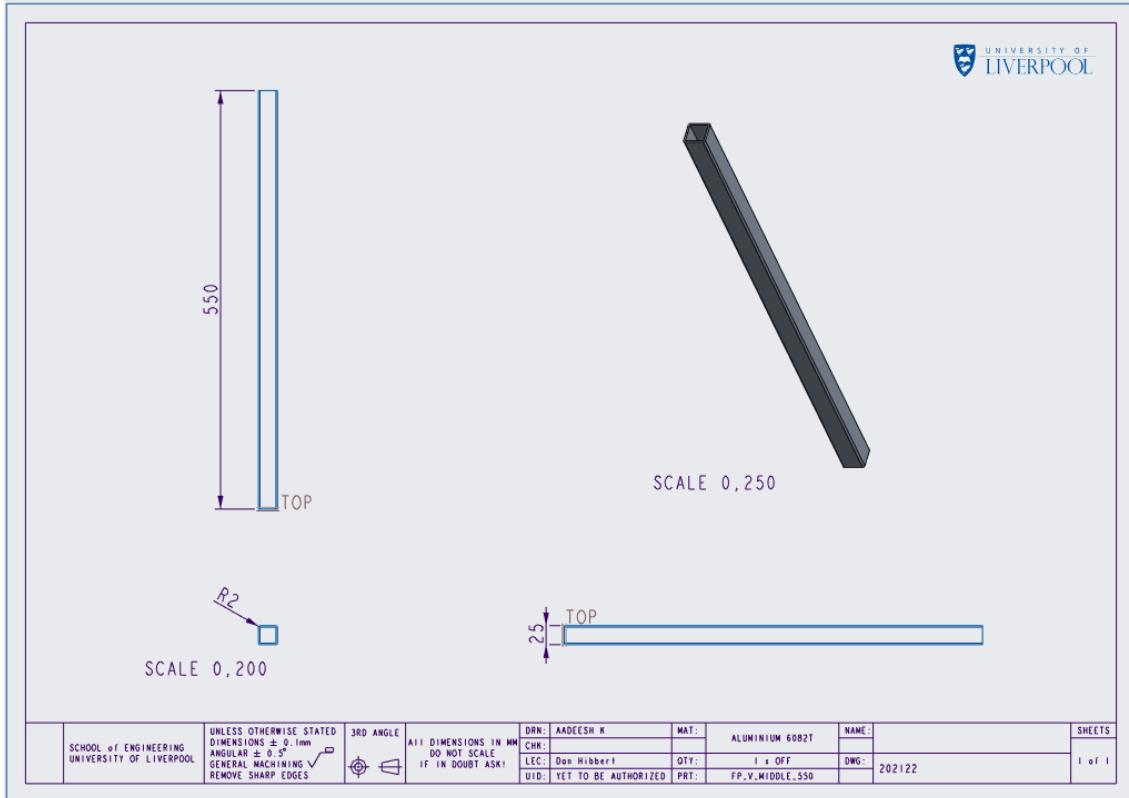
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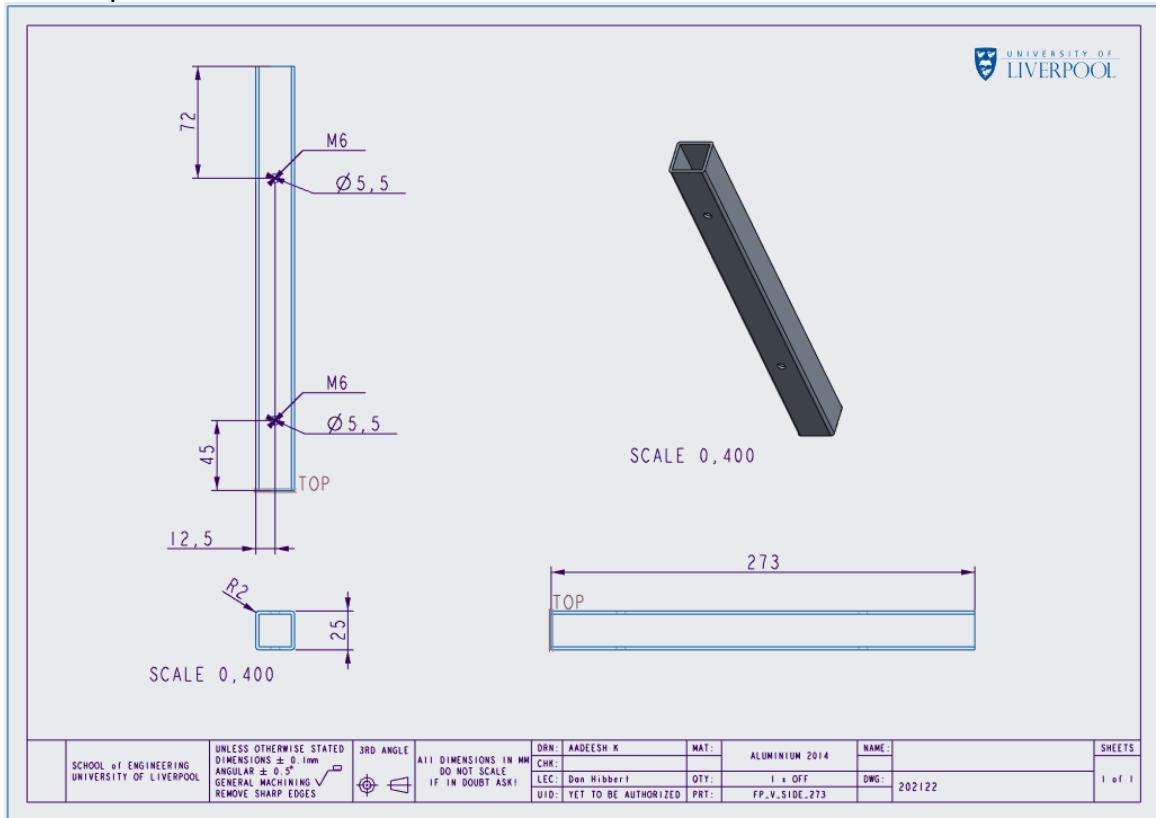
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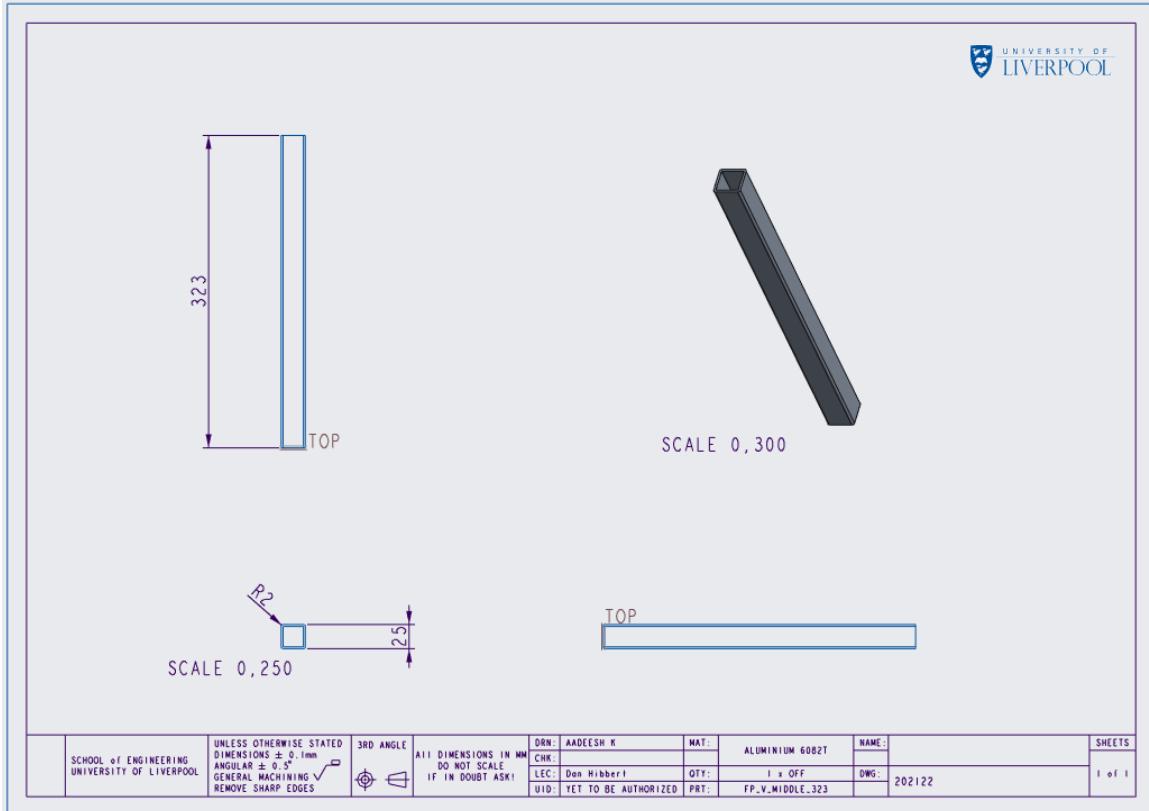
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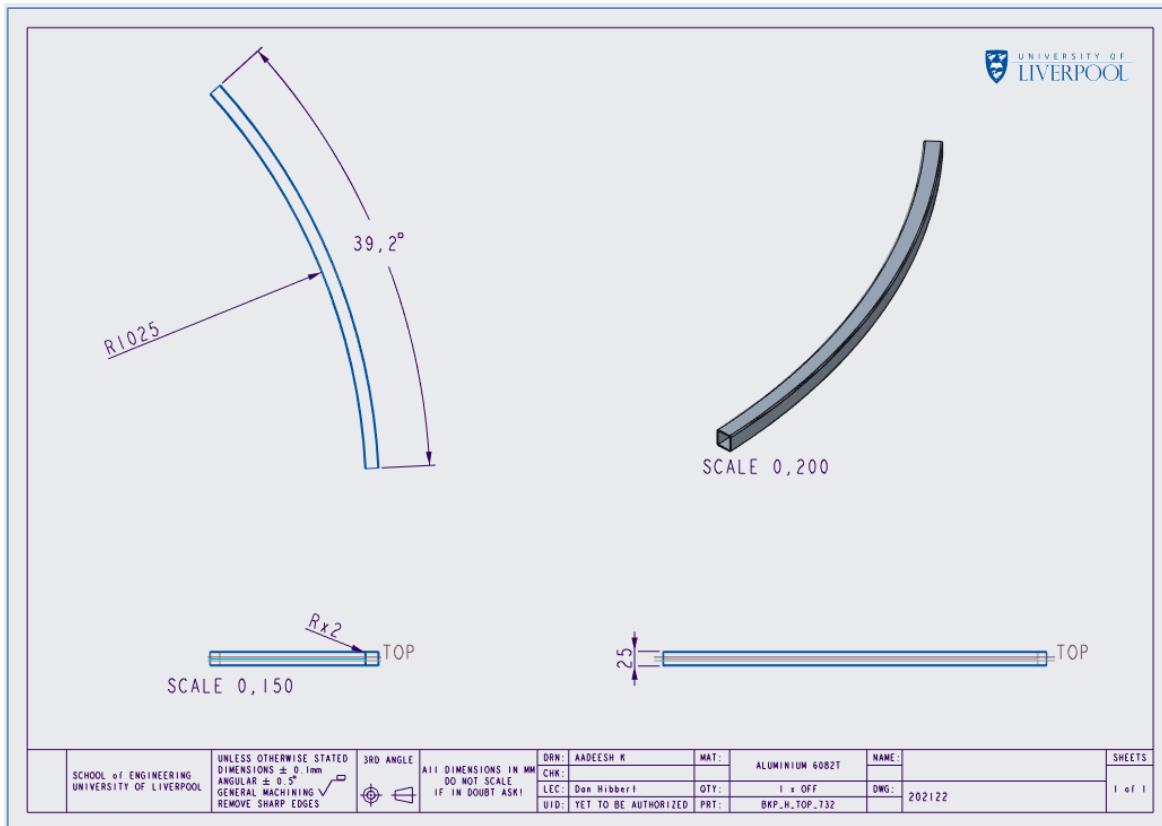
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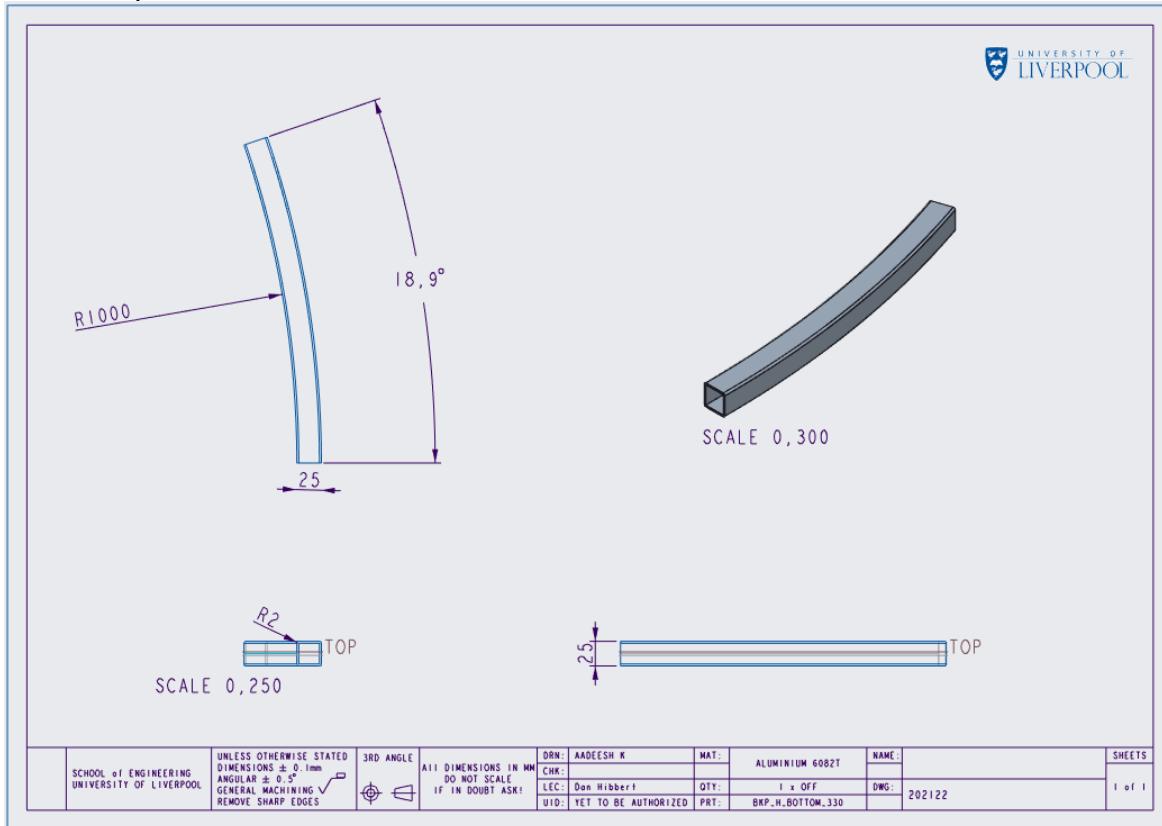
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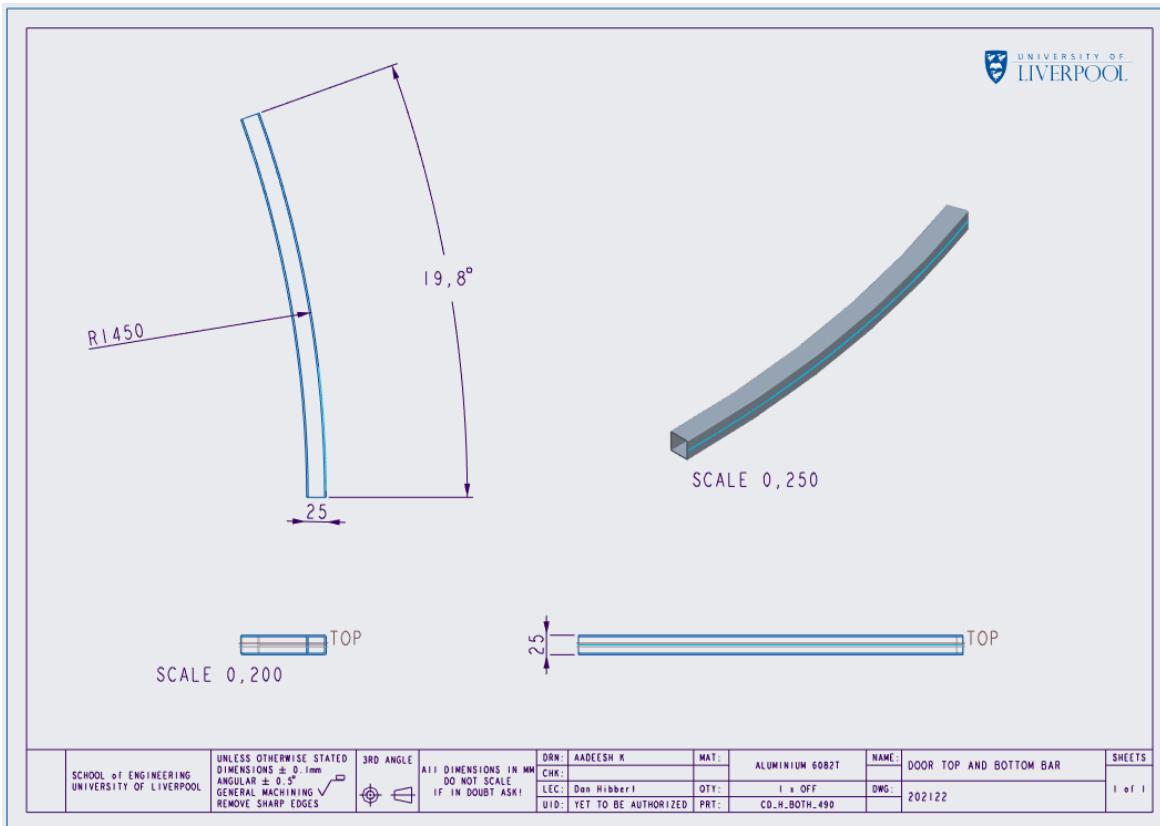
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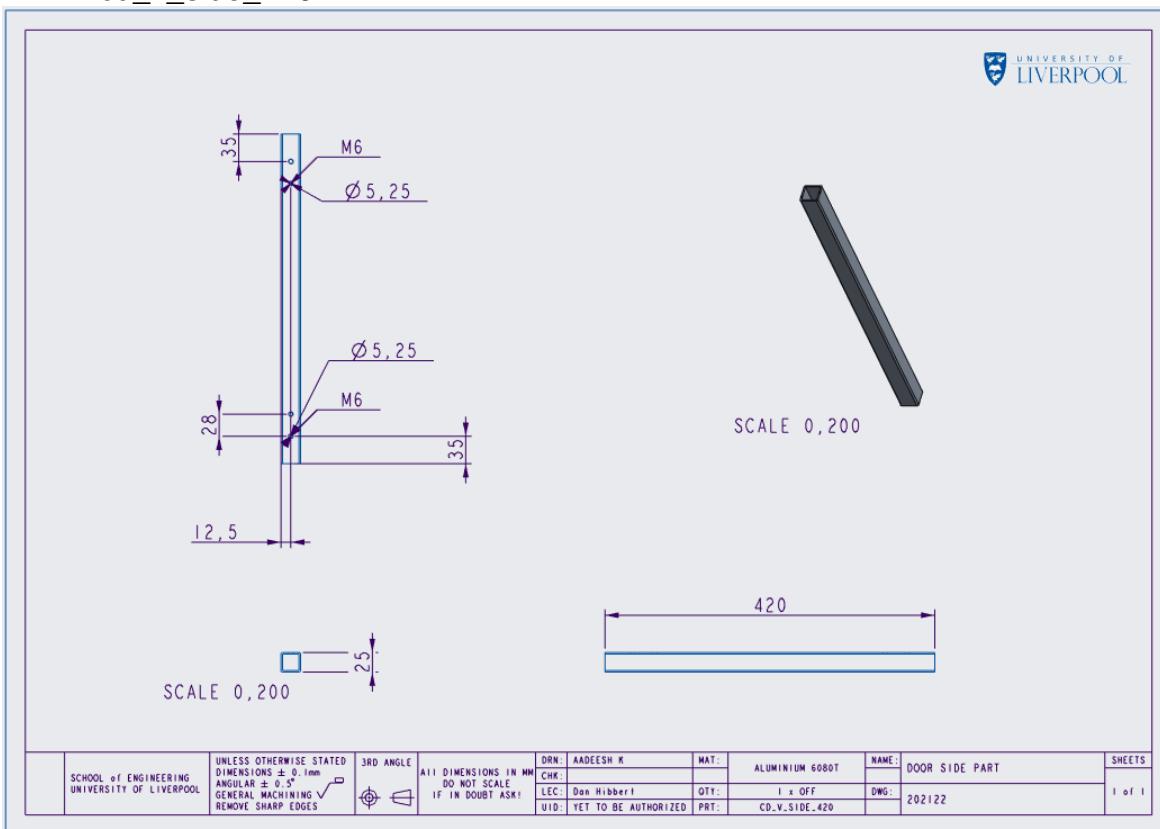
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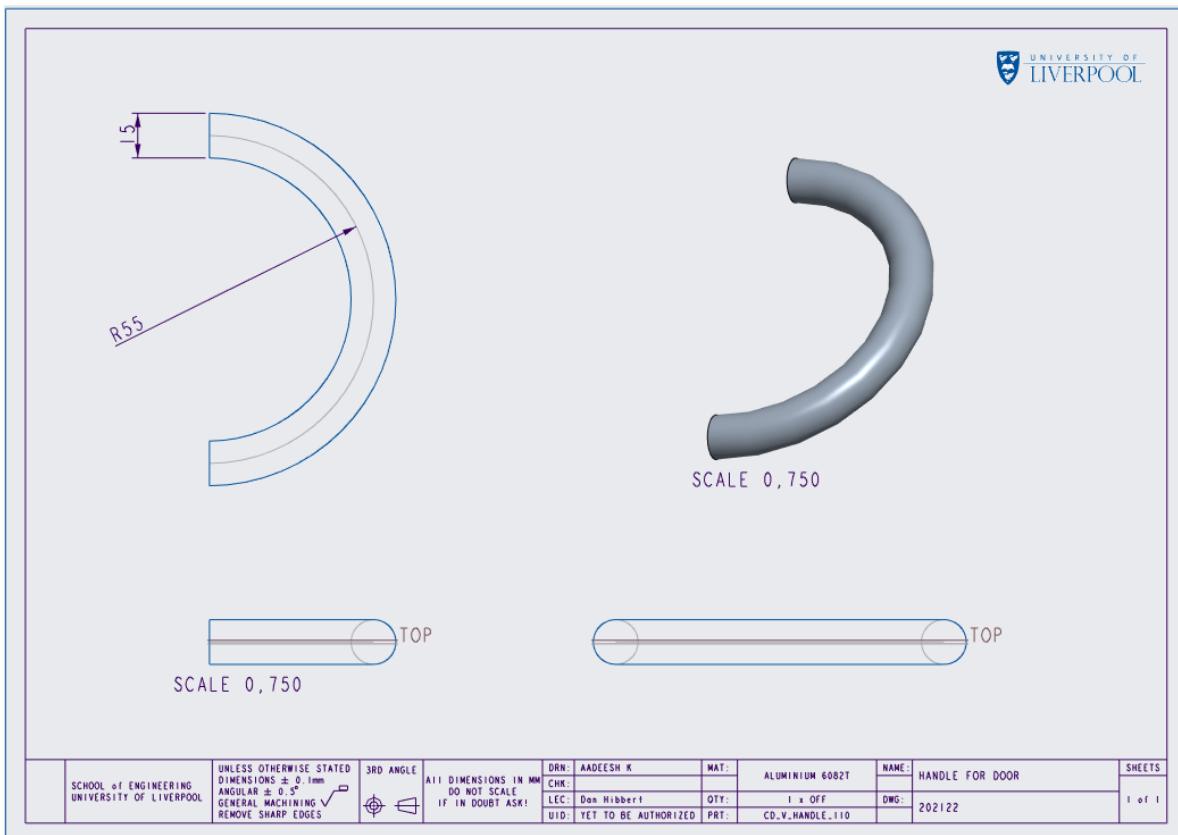
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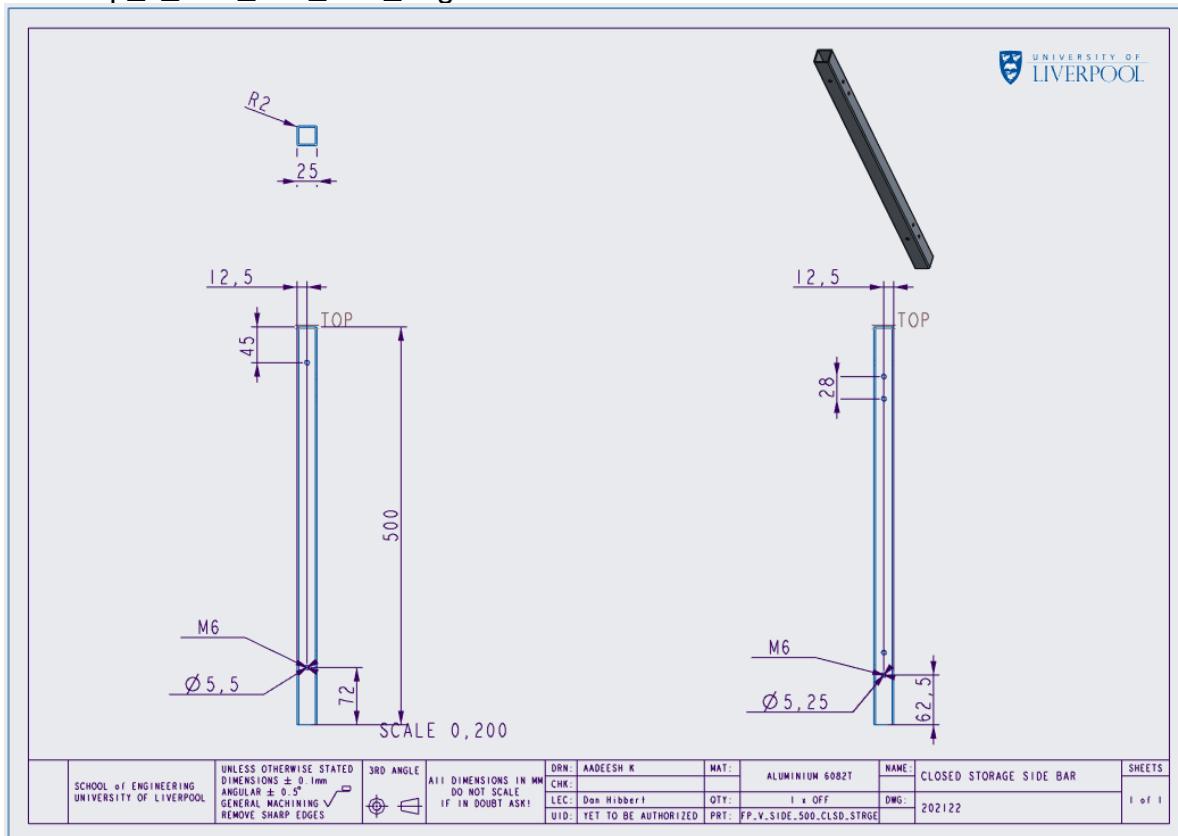
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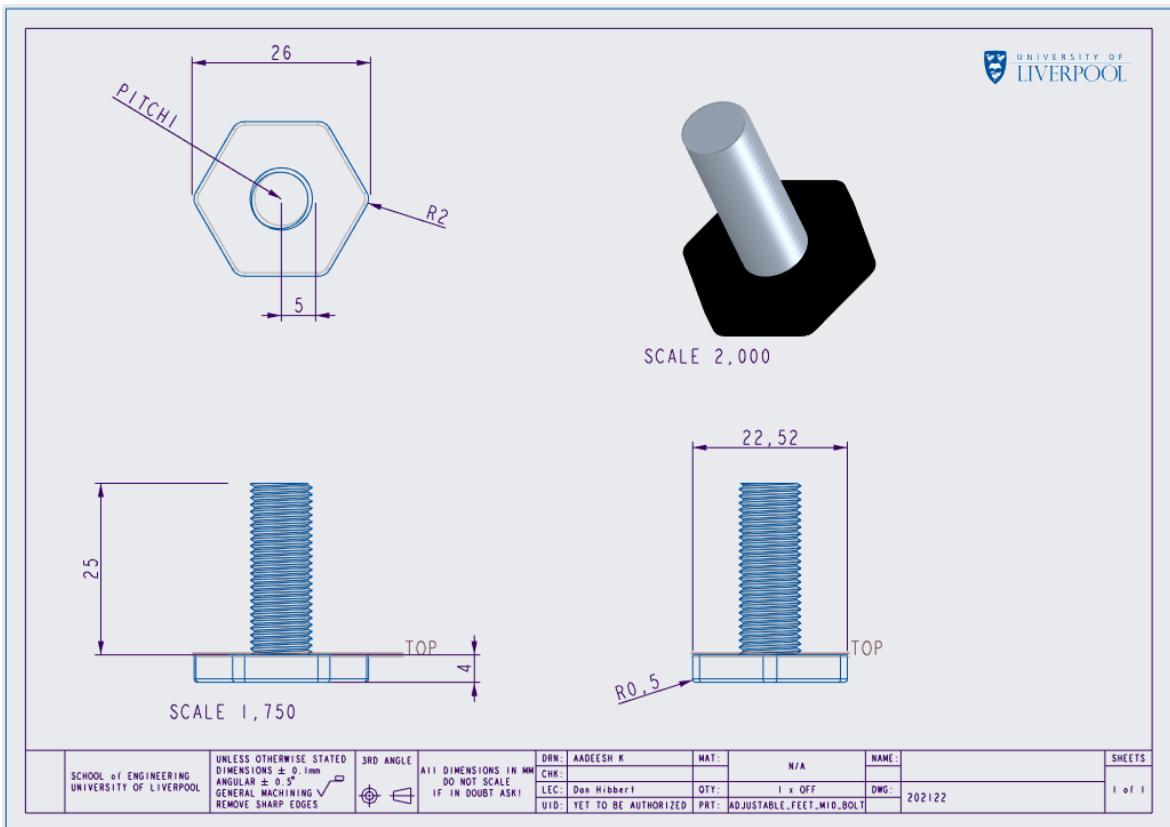
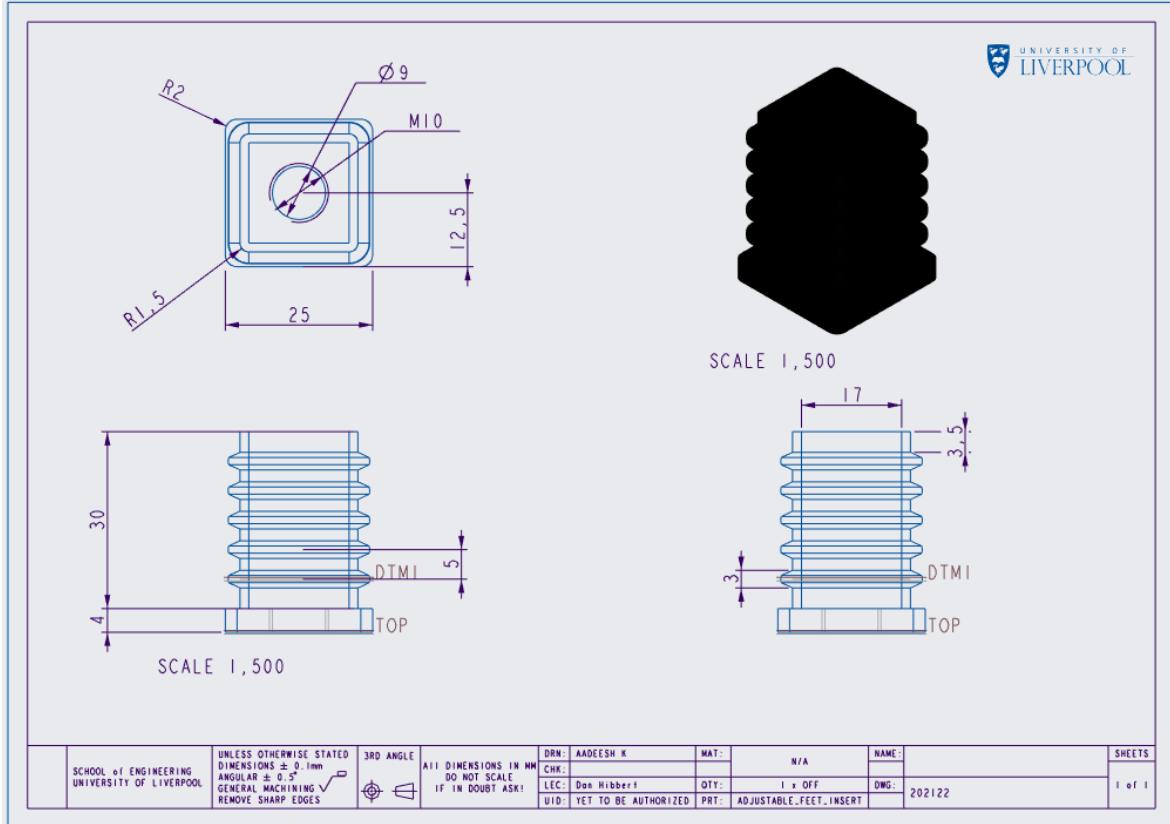
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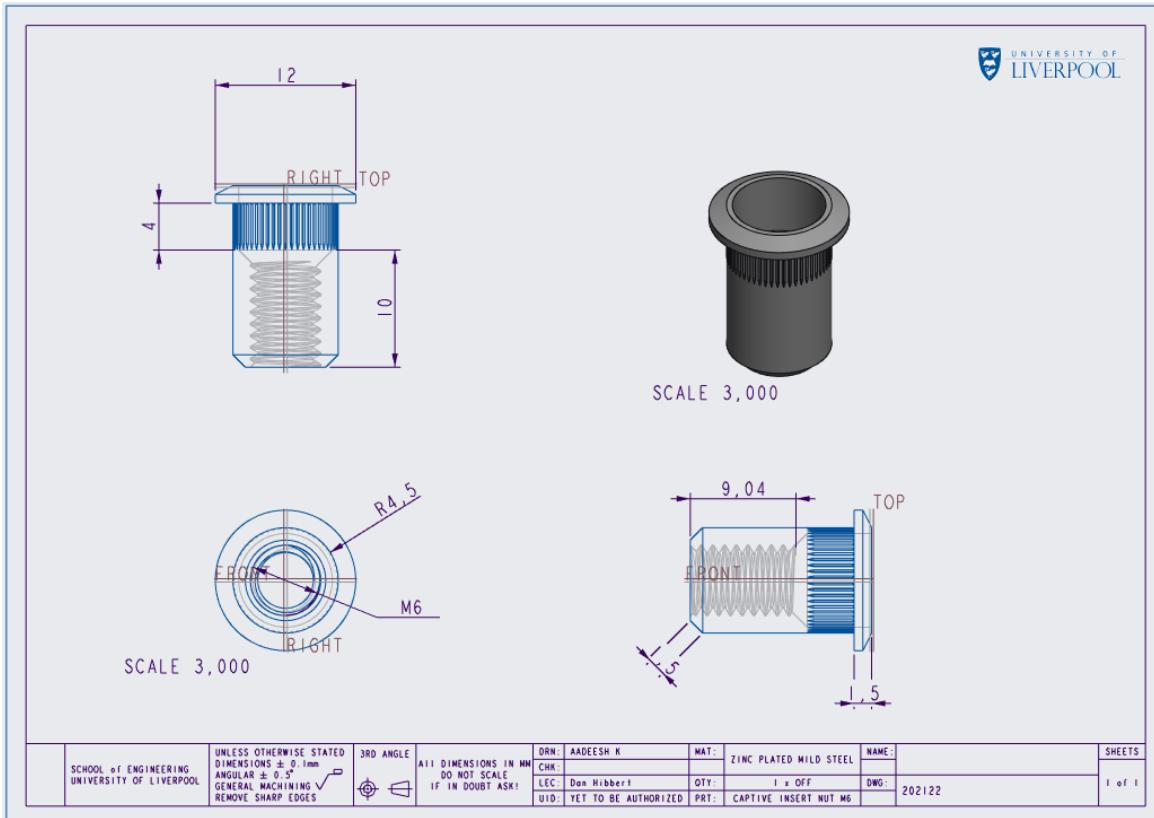
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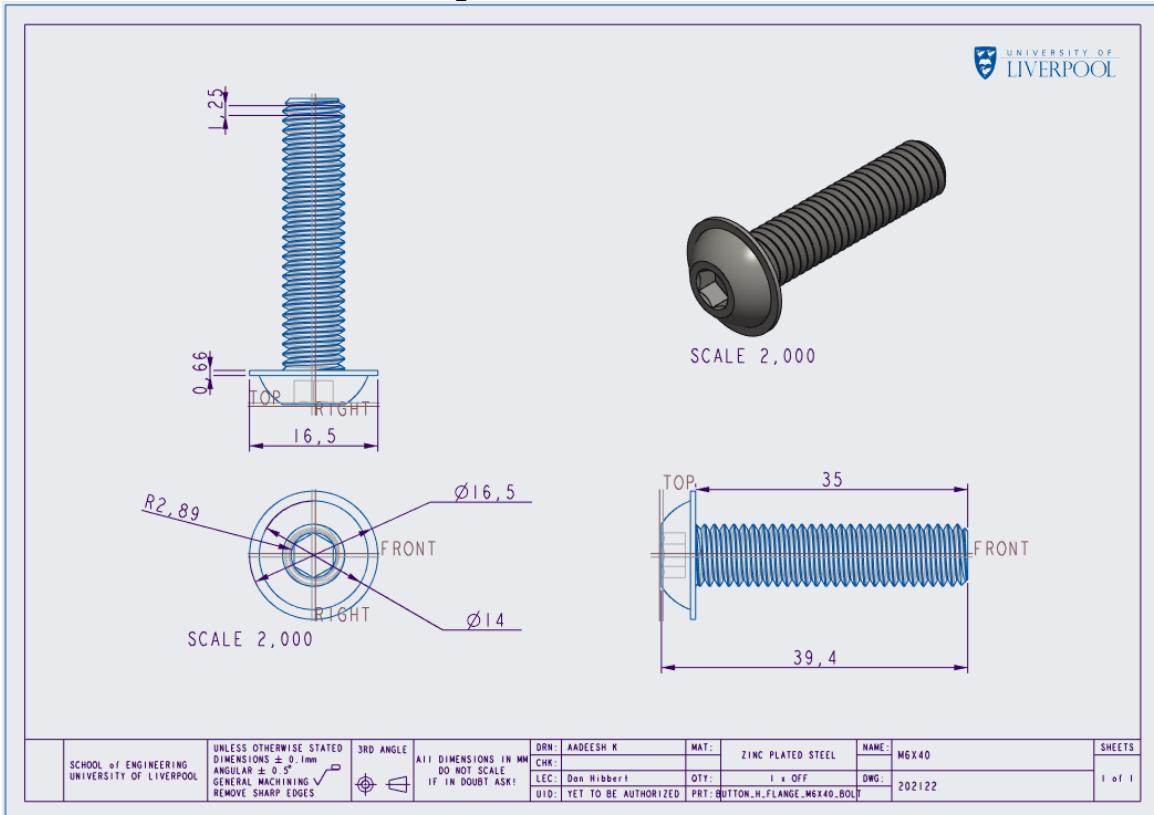
24. Adjustable Leg



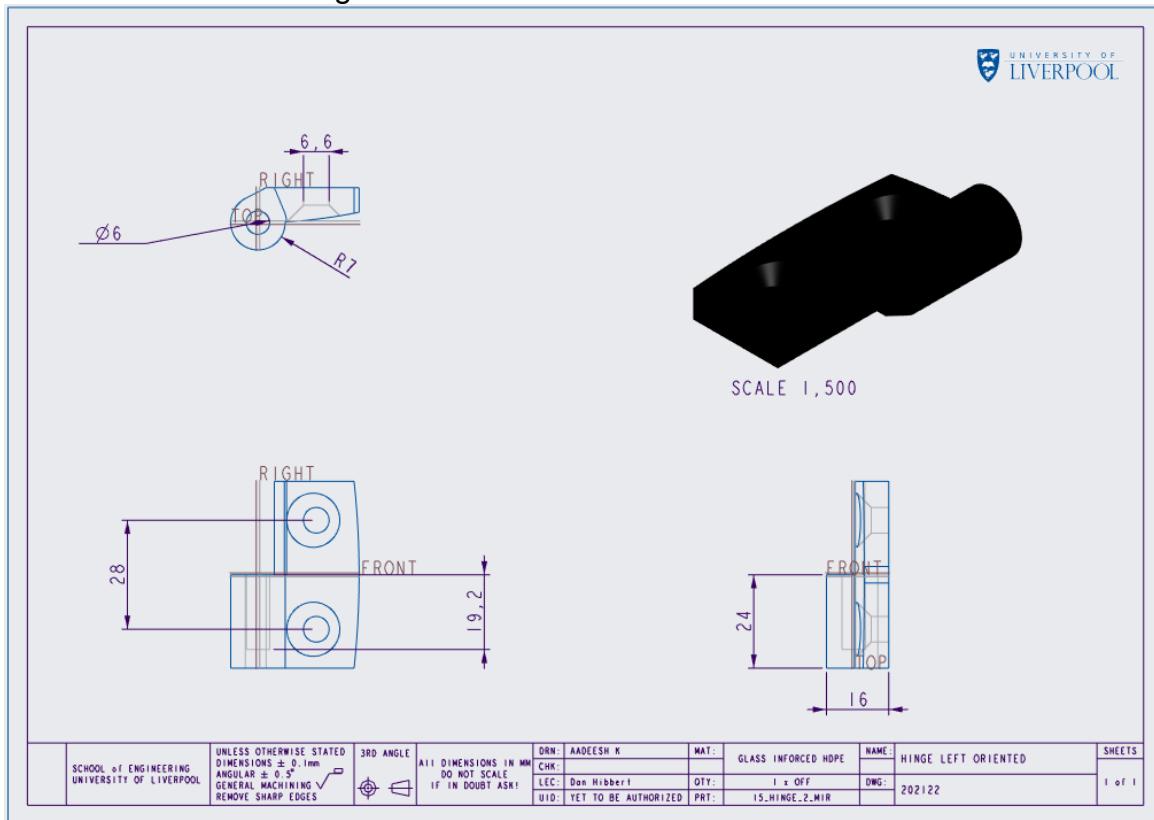
25. Rivet Nut Insert



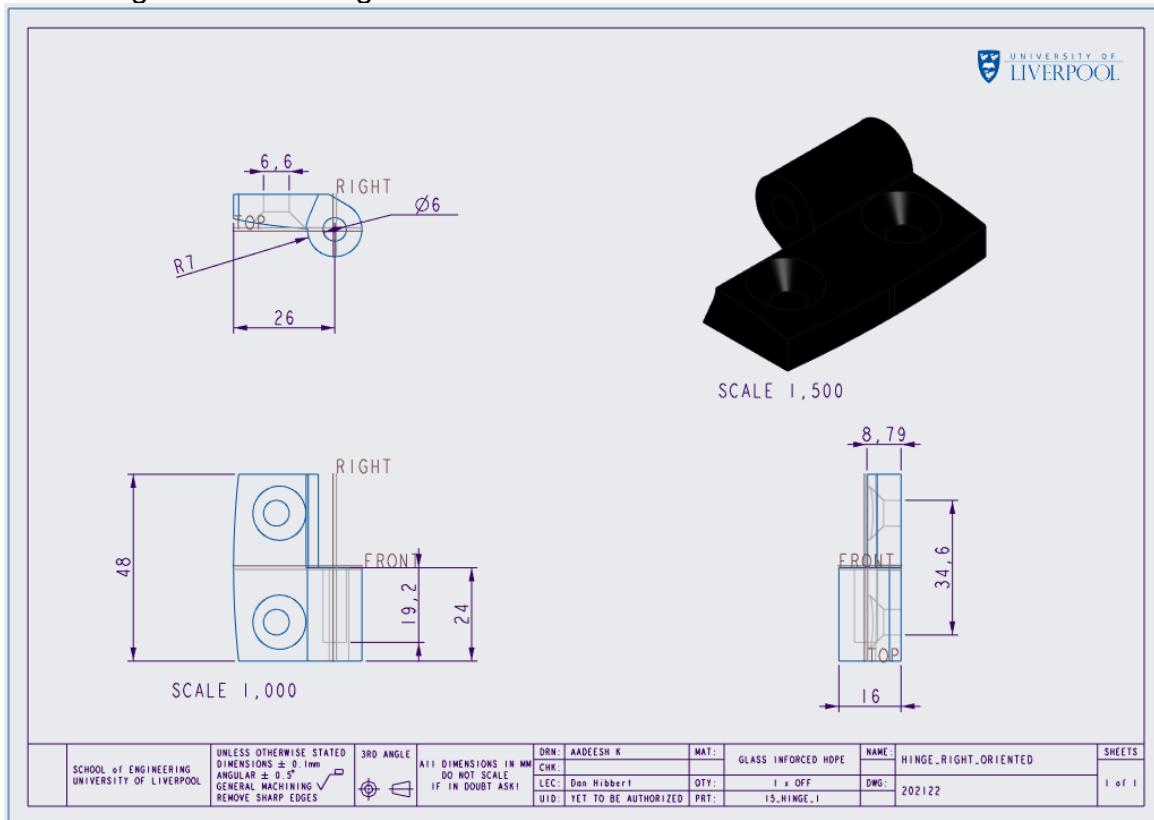
26. M6x40 Button Head Flanged Hex Screw



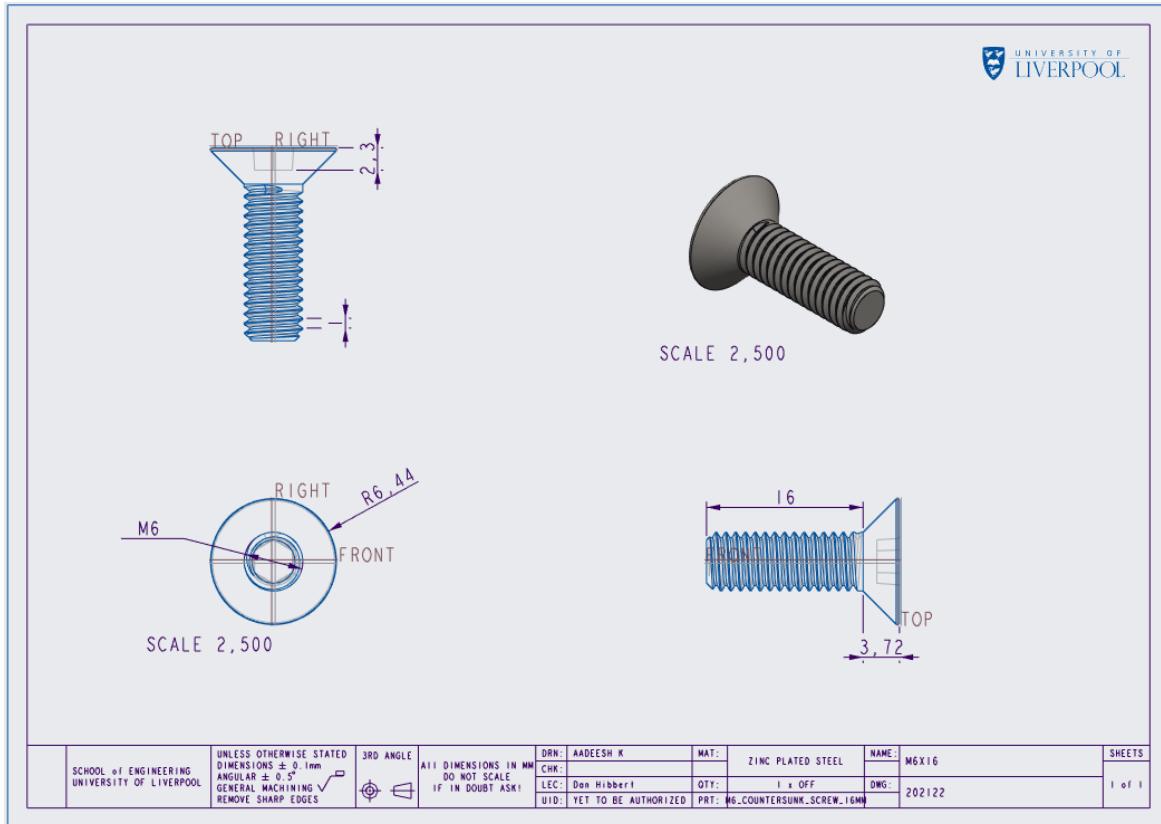
27. Left-Handed Hinge



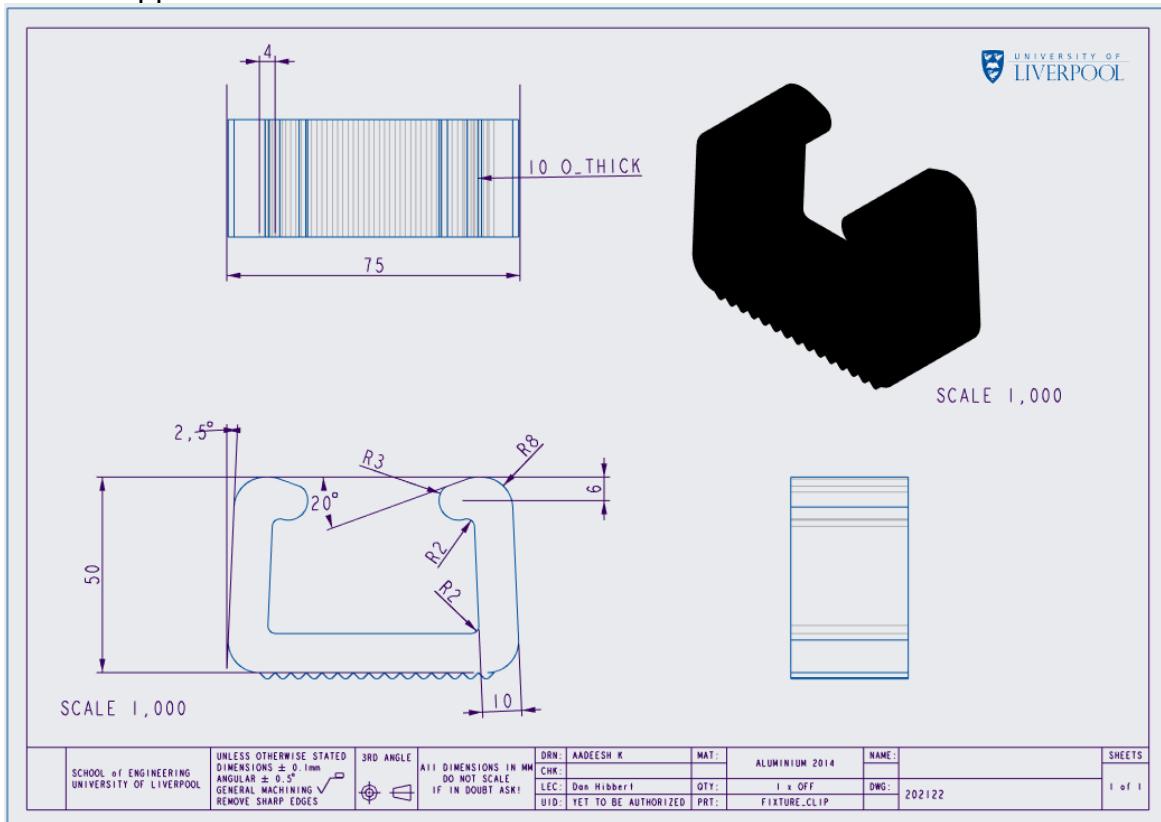
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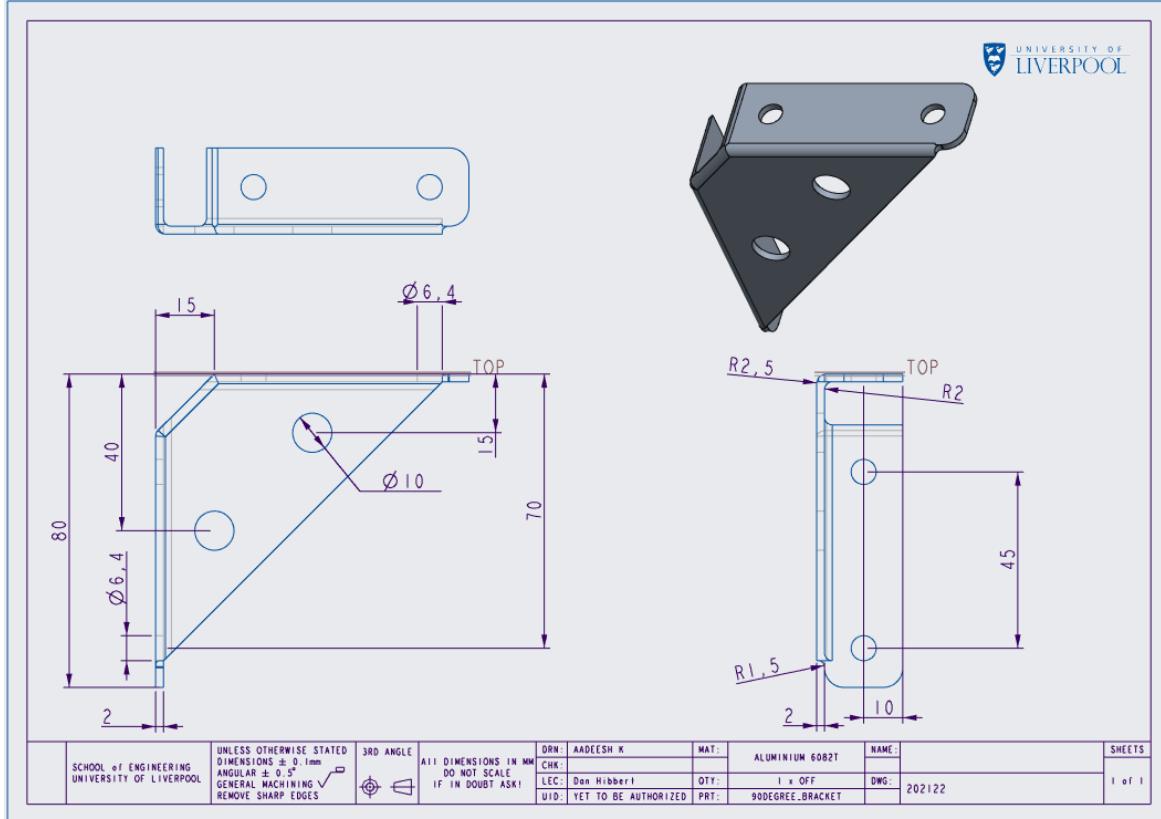
29. M6x16 Countersunk Hex Fine Screw



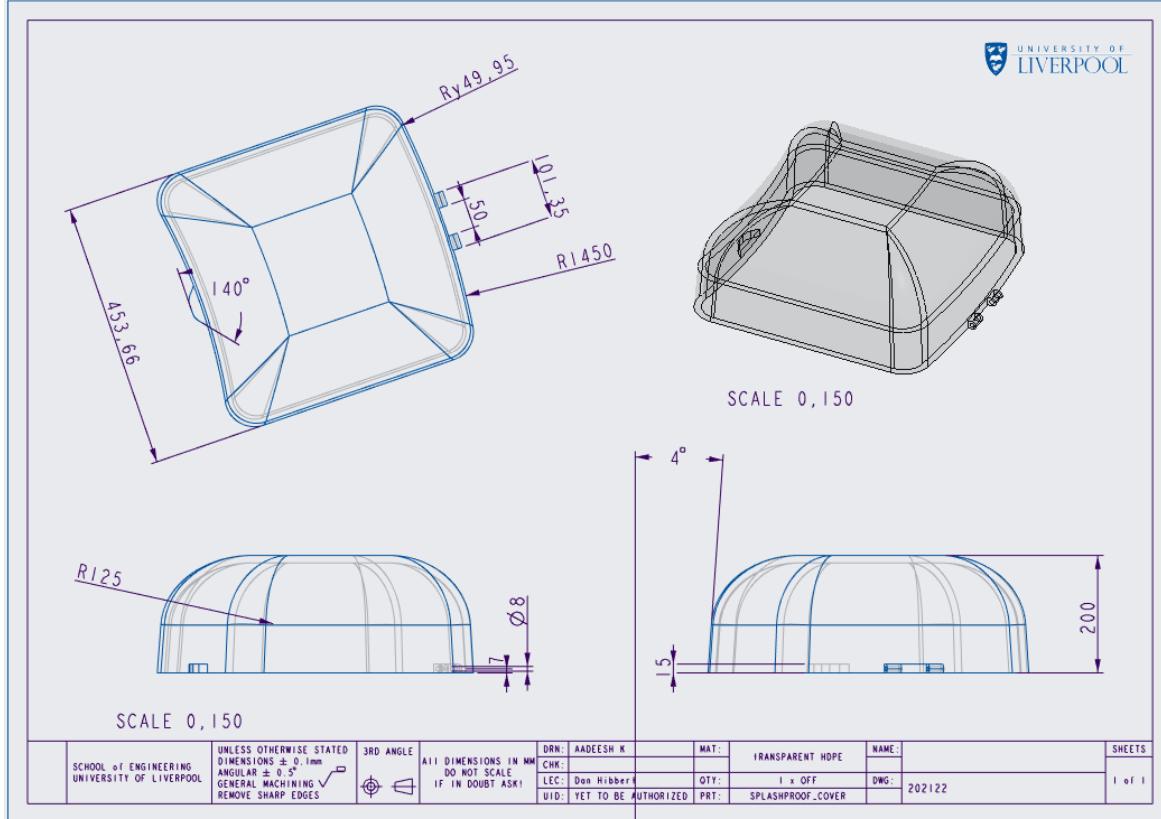
30. Clipper Fixture



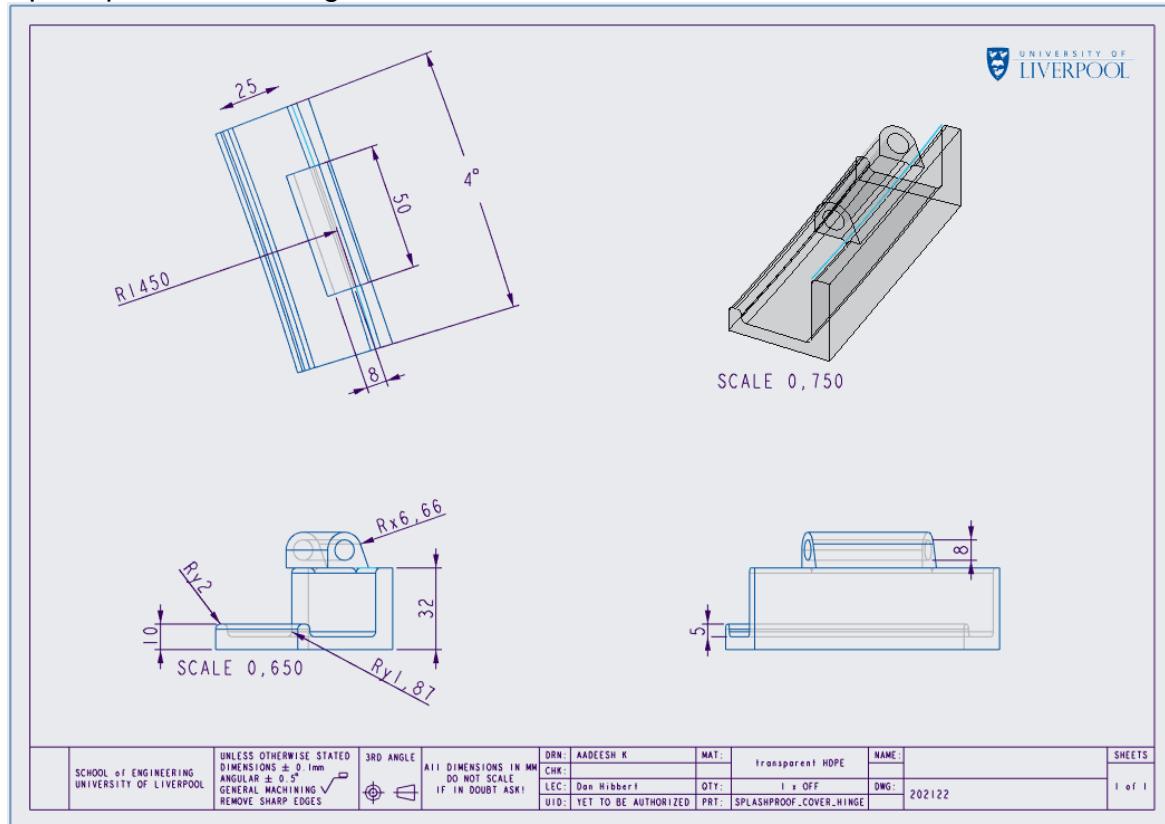
31.90_triangle bracket



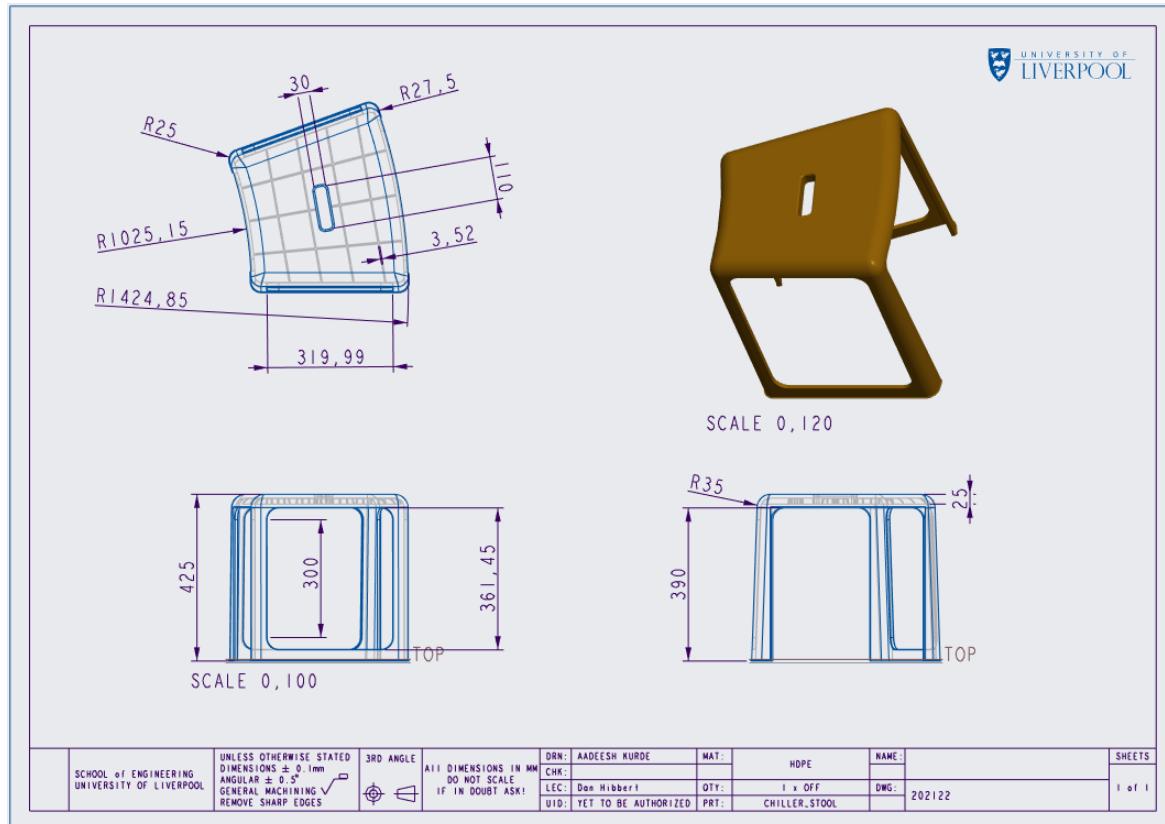
32. Splashproof cover



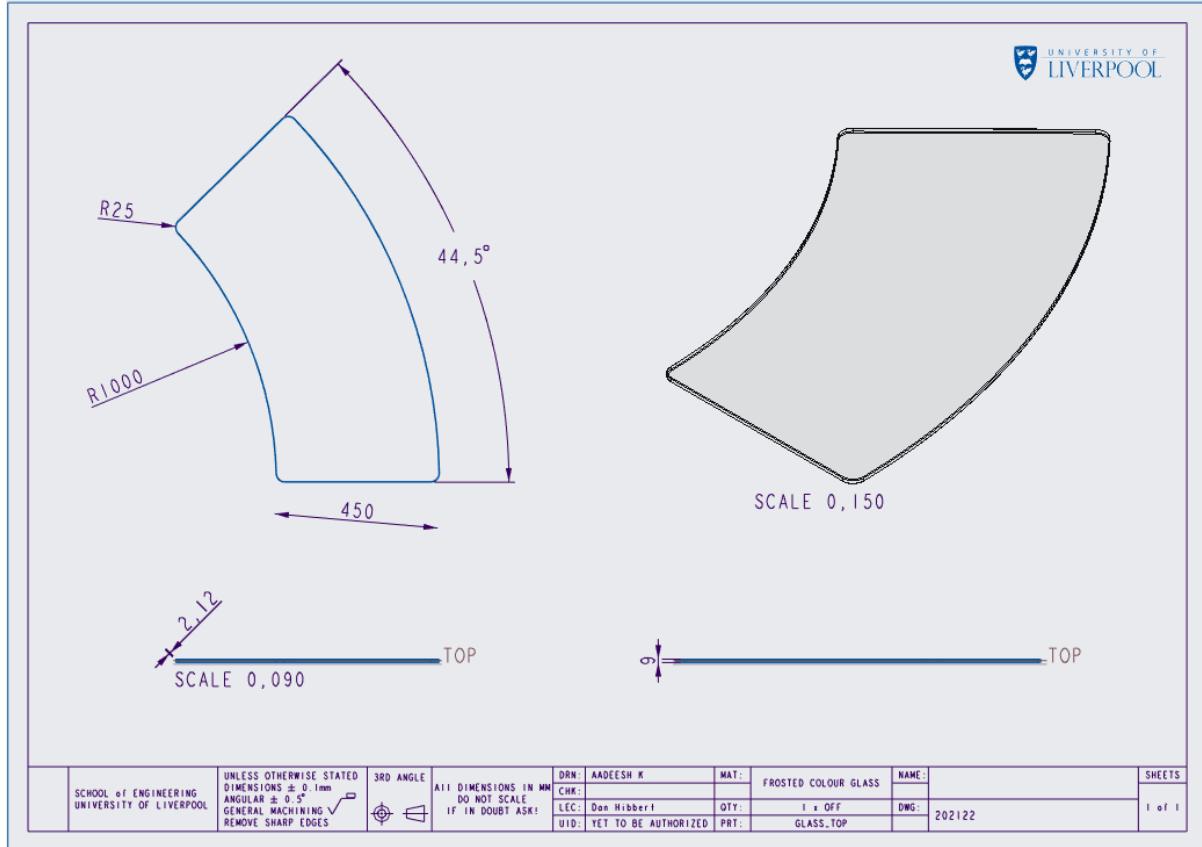
Splashproof cover Hinge



33. Stool



34. Tabletop Glass



Panel Assemblies

The following table shows the Quantity of each panel required to make the showcased surround system,

Nº	Panel Type	Quantity
1	Tall side panel	8
2	Short side panel	8
3	Top panel	6
4	Bottom panel	5
5	Tall front panel	1
6	Short front panel	3
7	Tall back panel	2
8	Short back panel	3
9	Door panel	2
10	Closed front panel	1

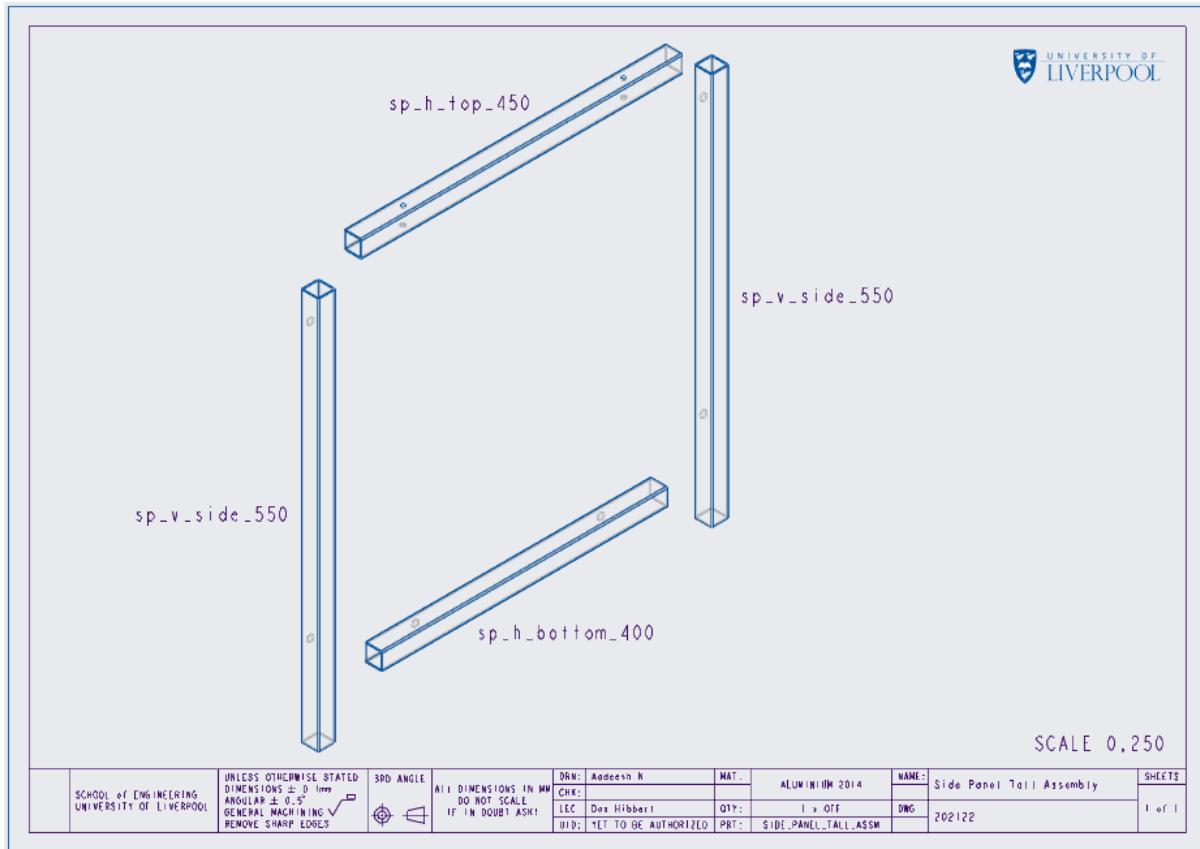
The following table shows the type and number of parts required to build the required panel type,

Nº	Panel Type	Parts Included	Quantity
1	Tall side panel	sp_h_top_450	1
		sp_v_side_550	2
		sp_h_bottom_400	1
		Rivet nut insert	6
		Adjustable Leg	2
2	Short side panel	sp_h_top_450	1
		sp_v_side_325	2
		sp_h_bottom_400	1
		Rivet nut insert	6
		Adjustable Leg	2
3	Top panel	tp_h_outer_1090	1
		tp_h_side_450	2
		tp_h_inner_735	1
		tp_h_middle_400	3
		Rivet nut insert	4
4	Bottom panel	bp_h_outer_1015	1
		sp_h_side_400	2
		bp_h_inner_702	1
		bp_h_middle_350	3
		Rivet nut insert	4
5	Tall front panel	fp_h_top_1086	1
		fp_v_side_500	2
		fp_h_bottom_505	2
		fp_v_middle_550	1
		Adjustable Leg	1
6	Short front panel	fp_h_top_1086	1

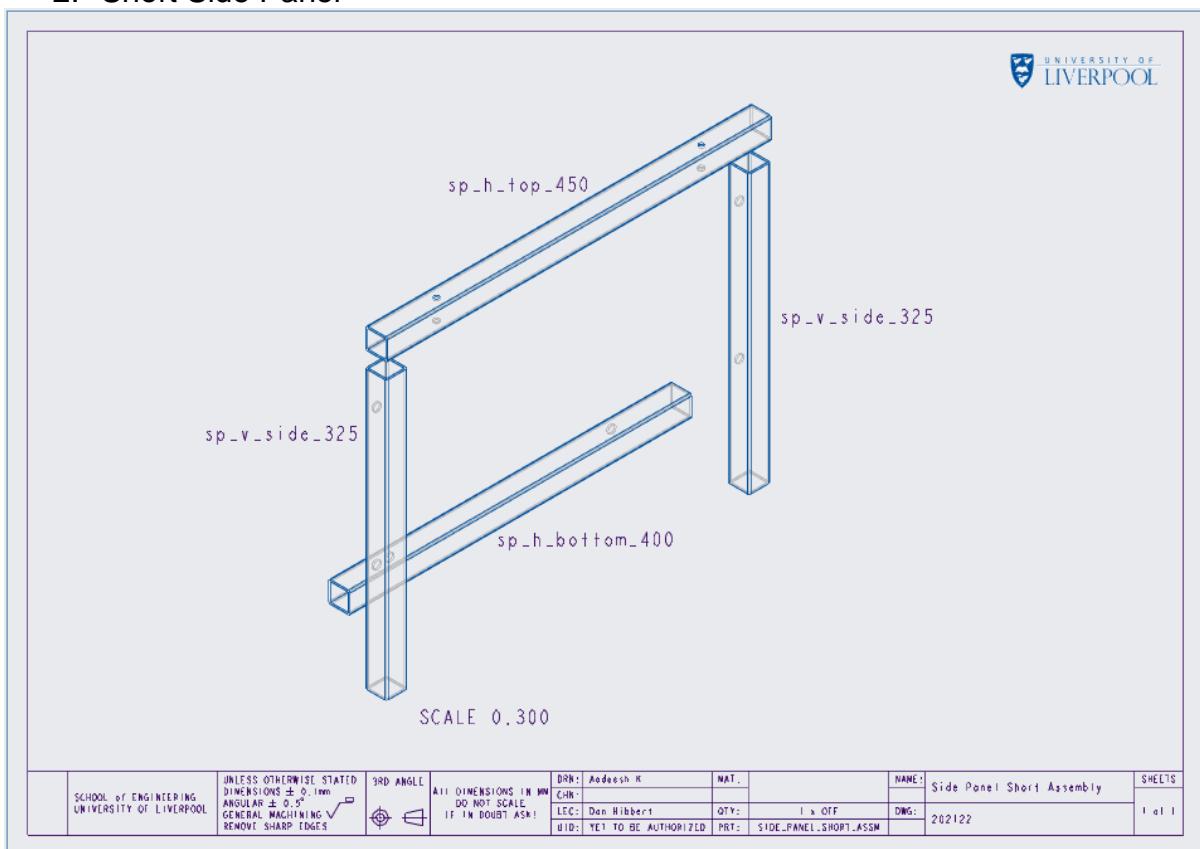
		fp_v_side_273	2
		fp_h_bottom_505	2
		fp_v_middle_323	1
		Adjustable Leg	1
7	Tall back panel	bkp_h_top_732	1
		fp_v_side_500	2
		bkp_h_bottom_330	2
		fp_v_middle_550	1
		Adjustable Leg	1
8	Short back panel	bkp_h_top_732	1
		fp_v_side_273	2
		bkp_h_bottom_330	2
		fp_v_middle_323	1
		Adjustable Leg	1
9	Door panel	cd_h_both_490	2
		cd_v_side_420	2
		cd_v_handle_110	1
10	Closed front panel	fp_h_top_1086	1
		fp_v_side_500_clsd_strge	2
		fp_h_bottom_505	2
		fp_v_middle_550	1
		Adjustable Leg	1

Following figures show type of parts required and how the bars are welded together to get the required frame for the panel-

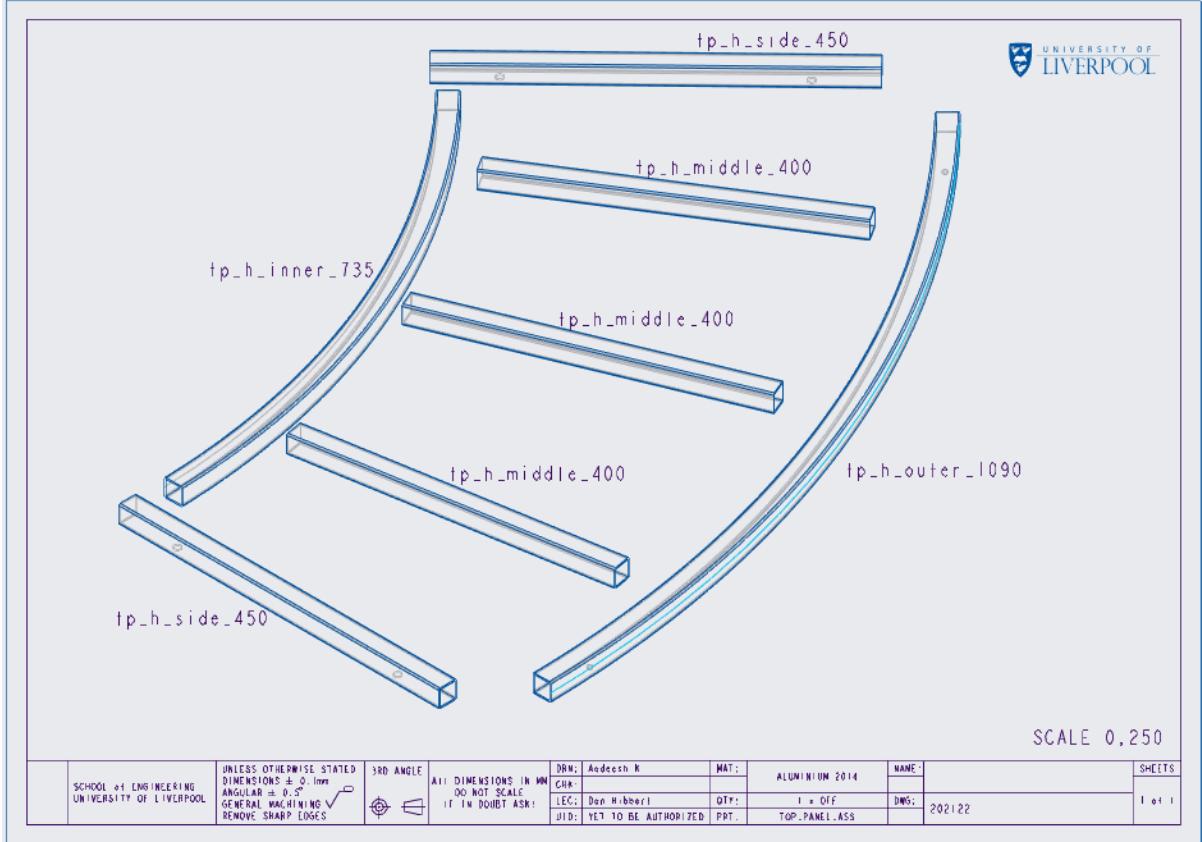
1. Tall Side Panel



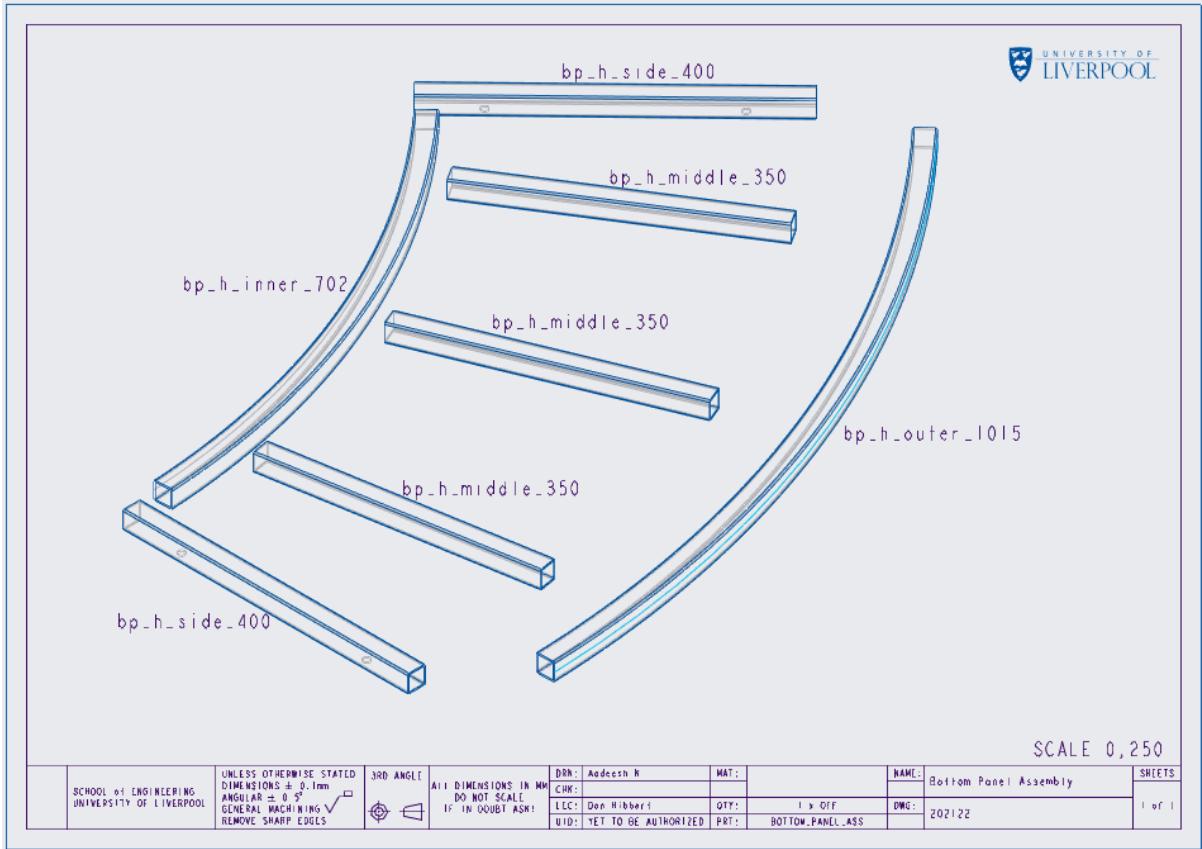
2. Short Side Panel



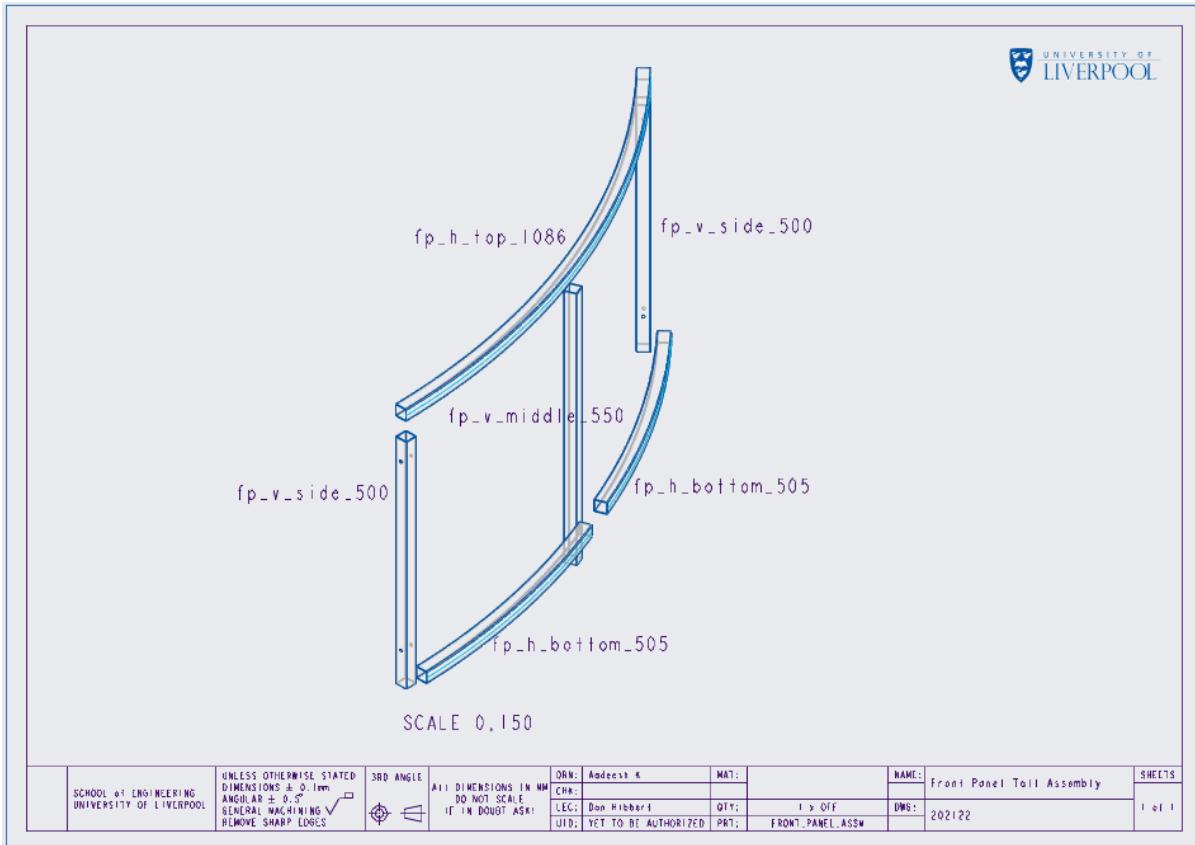
3. Top Panel



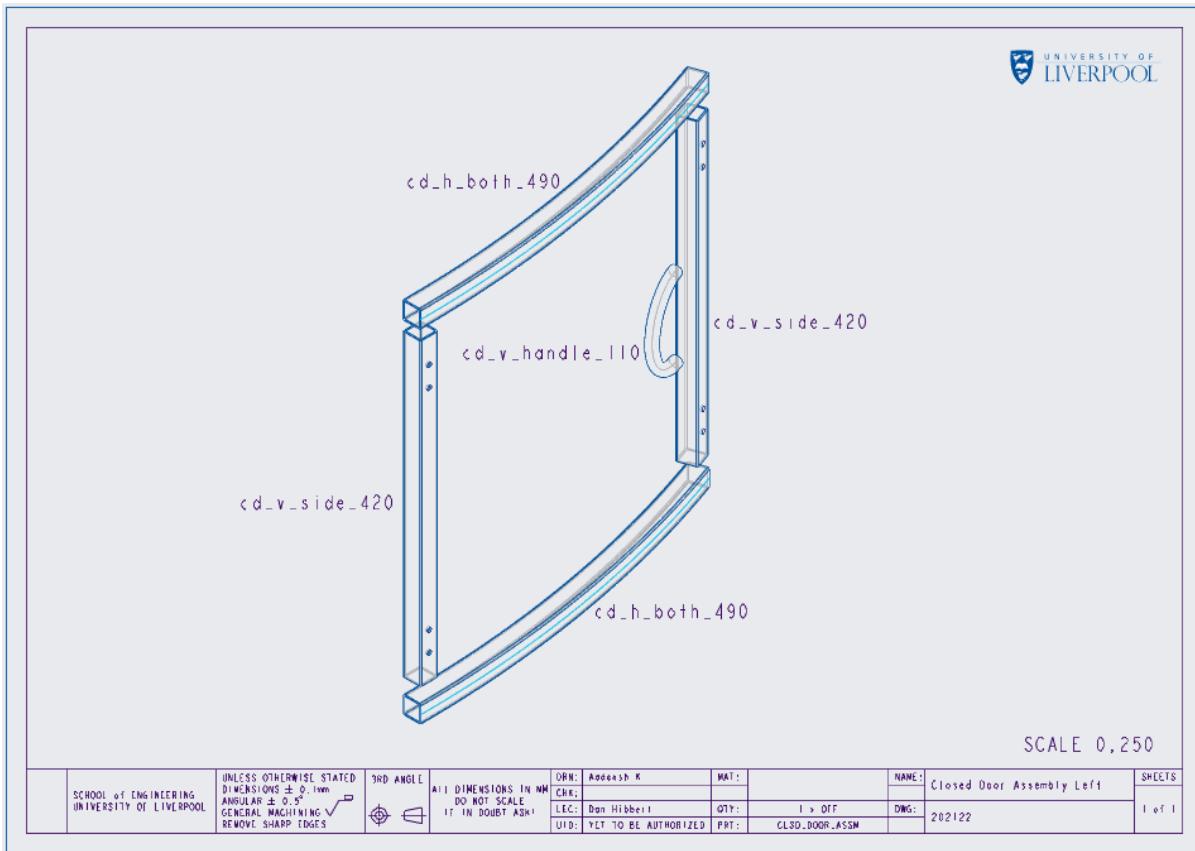
4. Bottom Panel



5. Tall Front Panel



6. Door Panel



Assembly of Modules

1. Open Storage Module



Parts required to make this module-

Top panel	1
Tall side panel	2
Bottom panel	1
Splashproof cover	1
M6x40 Button Head Flanged Hex Bolt	4



2. Deck Module

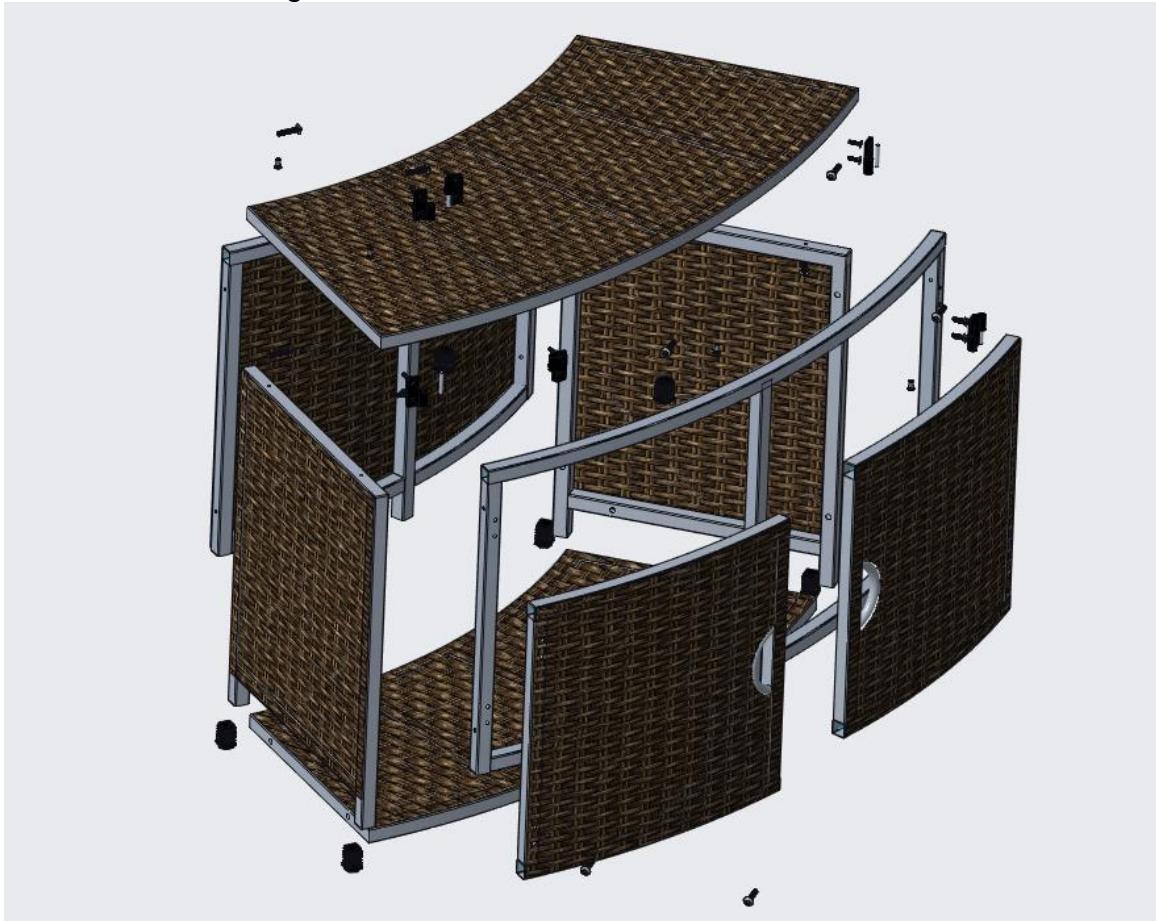


Parts required to make this module-

Top panel	1
Short side panel	2
Short front panel	1
Short back panel	1
M6x40 Button Head Flanged Hex Bolt	12



3. Closed Storage Module

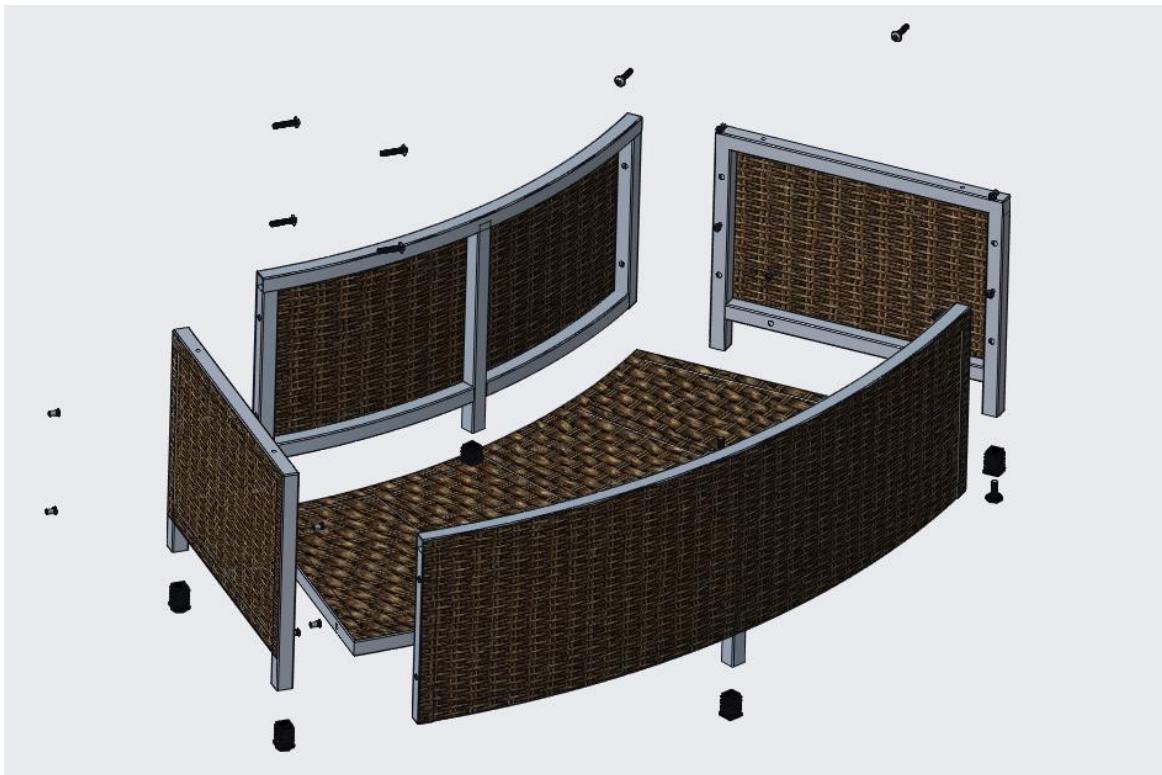


Parts required to make this module-

Top panel	1
Tall side panel	2
Tall back panel	1
Closed front panel	1
Bottom panel	1
Door panel	2
M6x40 Button Head Flanged Hex Bolt	16

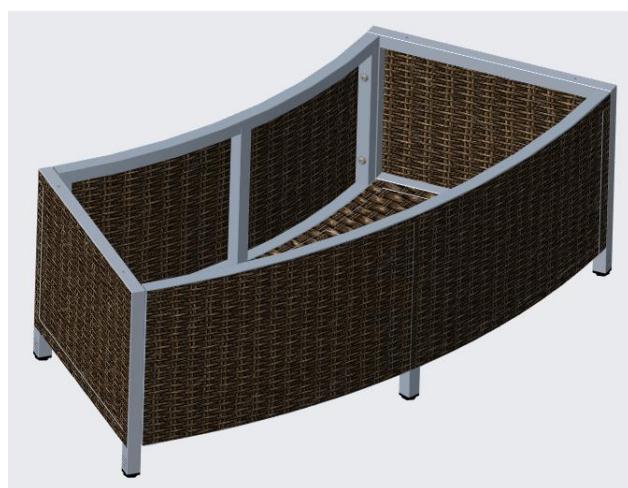


4. Planter Module



Parts required to make this module-

Short side panel	2
Short front panel	1
Short back panel	1
Bottom panel	1
M6x40 Button Head Flanged Hex Bolt	10



5. Tabletop Module

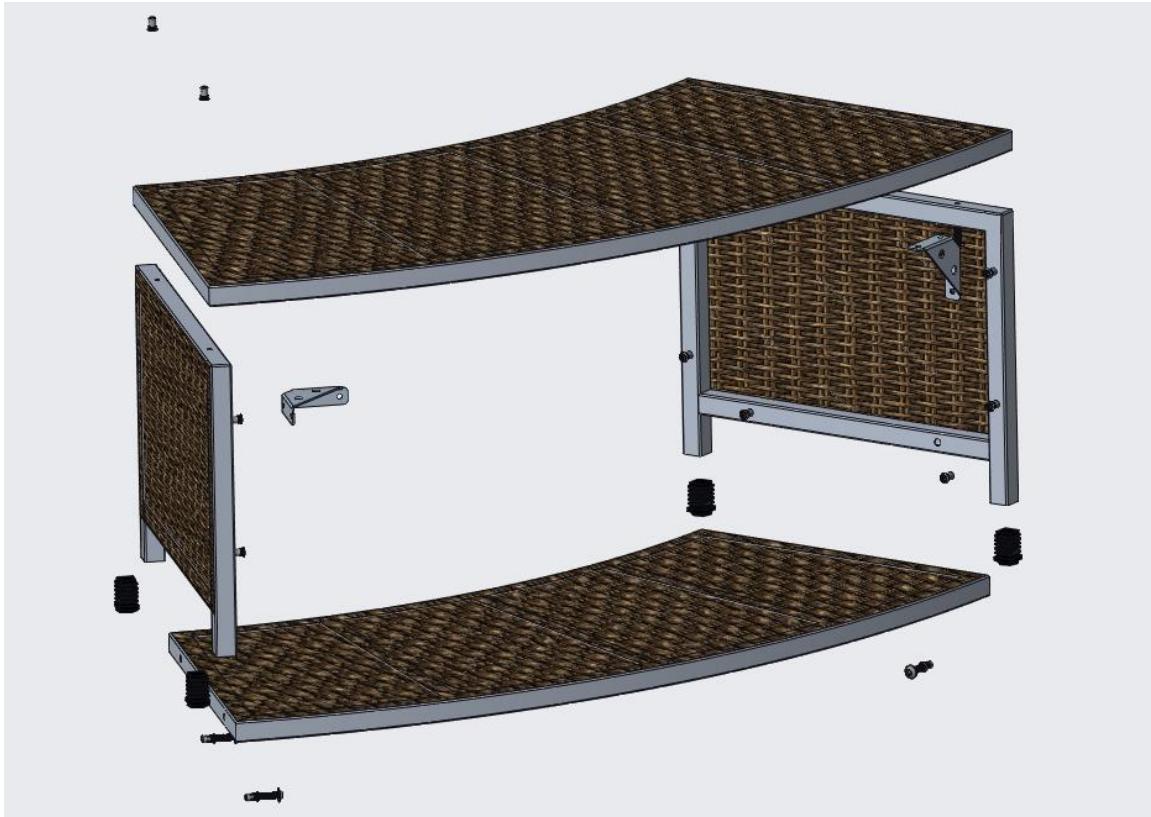


Parts required to make this module-

Top panel	1
Tall side panel	2
Glass	1
M6x40 Button Head Flanged Hex Bolt	4
90° triangle bracket	2

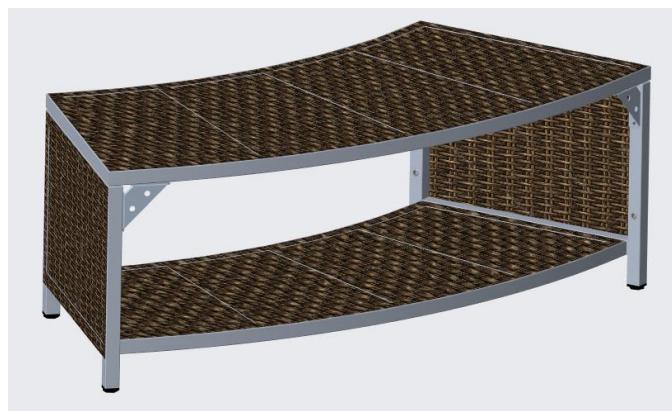


6. Showcase Platform Module

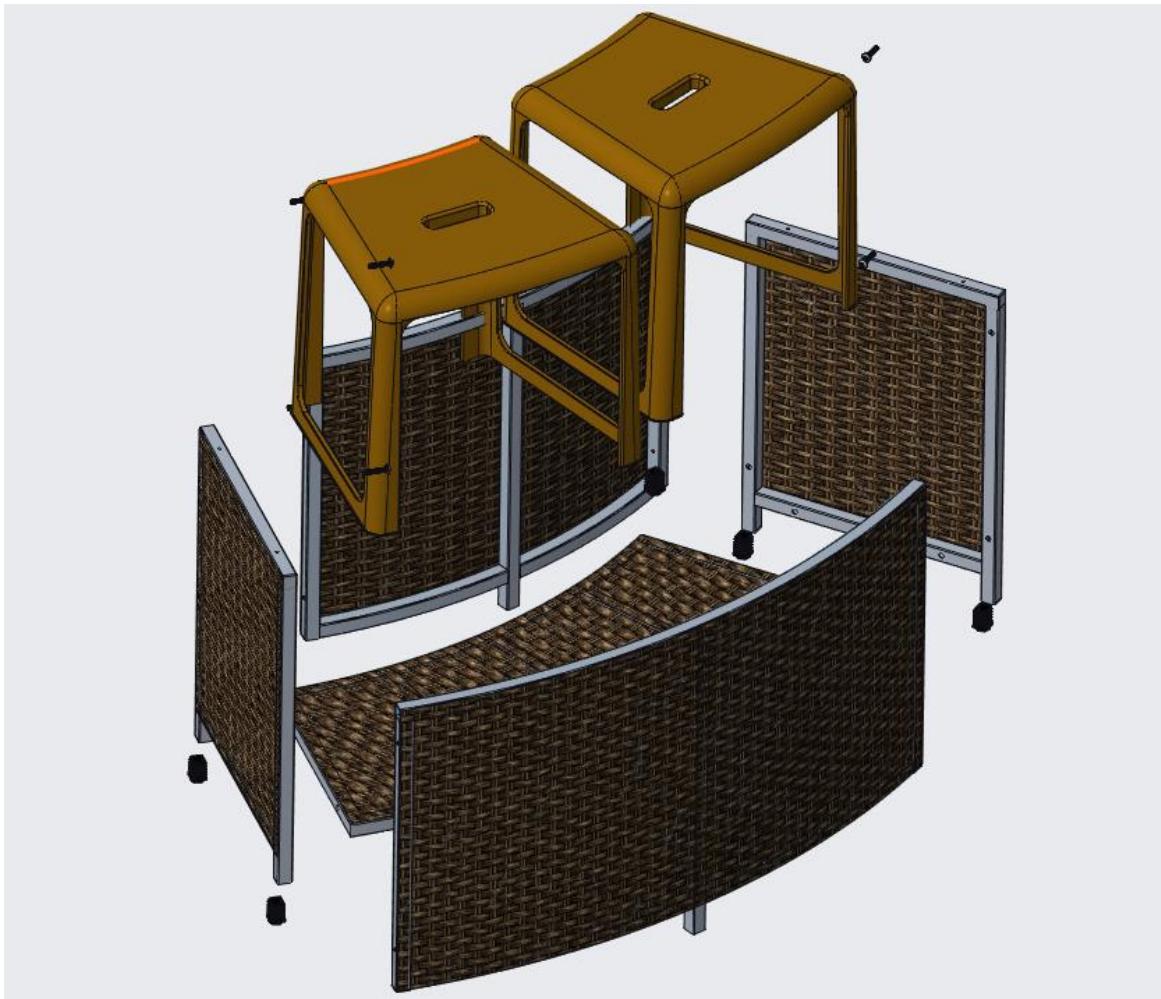


Parts required to make this module-

Top panel	1
Short side panel	2
Bottom panel	1
M6x40 Button Head Flanged Hex Bolt	8
90° triangle bracket	2



7. Chiller Module



Parts required to make this module-

Tall side panel	2
Tall front panel	1
Tall back panel	1
Bottom panel	1
Stool	2
M6x40 Button Head Flanged Hex Bolt	12



Pack 4

SCHOOL OF ENGINEERING
ENGG660: MSc (Eng) INDIVIDUAL PROJECT 2021-22

ANALYSIS AND CALCULATIONS

Mould flow Analysis

The mould flow analysis is done in Creo Parametric software to assure that the designed part can be injection moulded. By selecting the material from directories, injection moulding process is simulated, and results are obtained. One of the results show the mouldability of model considering the features and suggests area for improvement. The material used is standard HDPE. The physical properties are shown below,

Description	
Polymer type	HDPE
Grade name	ALTECH PE HD A 2020/506 GF20
Producer	ALBIS PLASTIC
Melt flow index	Unavailable
Process condition	
Melt temperature (Minimum)	200.0 °C
Melt temperature (Normal)	250.0 °C
Melt temperature (Maximum)	300.0 °C
Mold temperature (Minimum)	10.0 °C
Mold temperature (Normal)	50.0 °C
Mold temperature (Maximum)	85.0 °C
Ejection temperature	87.00 °C
Freeze temperature	107 °C

The parameters selected for moulding process are as follows,

Material information

Material type: HDPE
Producer: ALBIS PLASTIC
Grade name: ALTECH PE HD A 2020/506 GF20
Characteristics: Fiber-reinforced polymer

Process condition

Filling time: 8 sec
Melt temperature: 250.00 °C
Mold temperature: 47.50 °C
Maximum injection pressure: 144.00 MPa

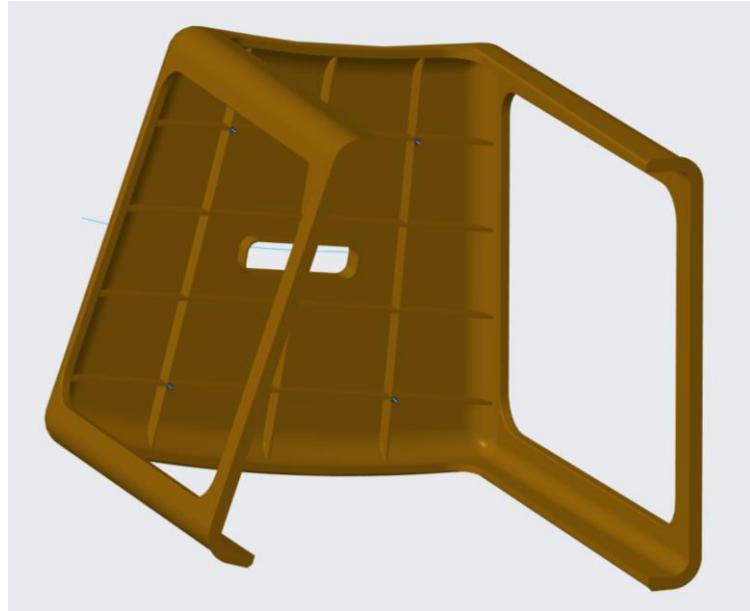
Optional simulations

Calculate maximum cooling time
 Calculate sink mark
 Calculate fiber orientation

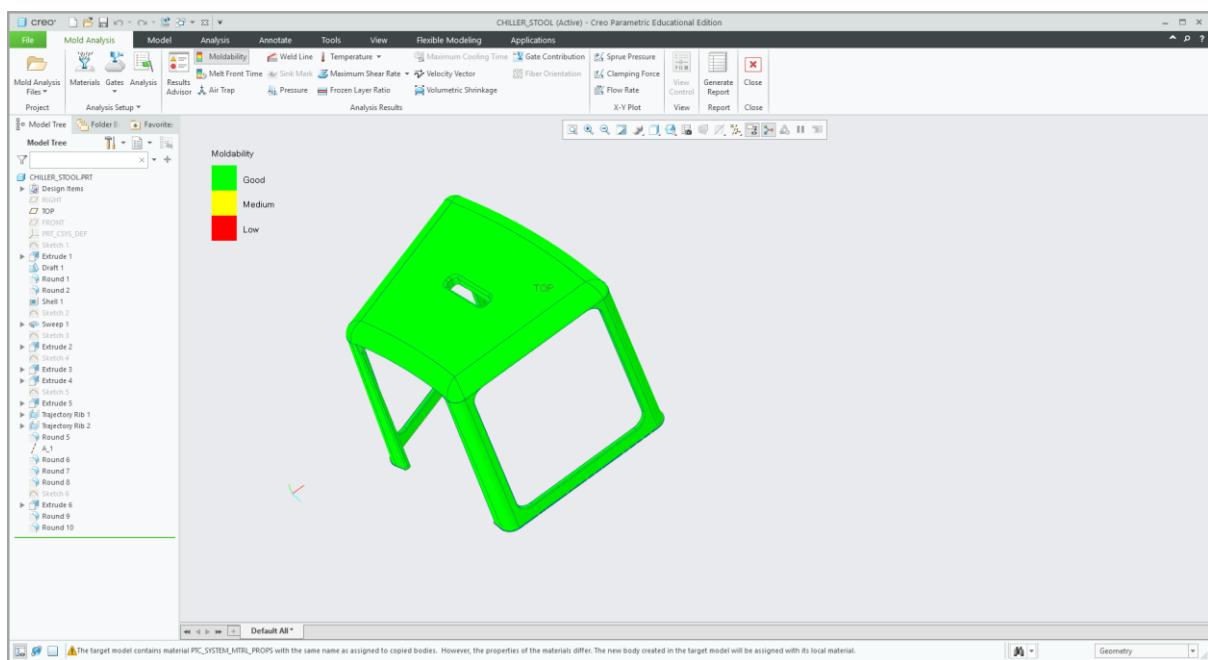
Mesh element size

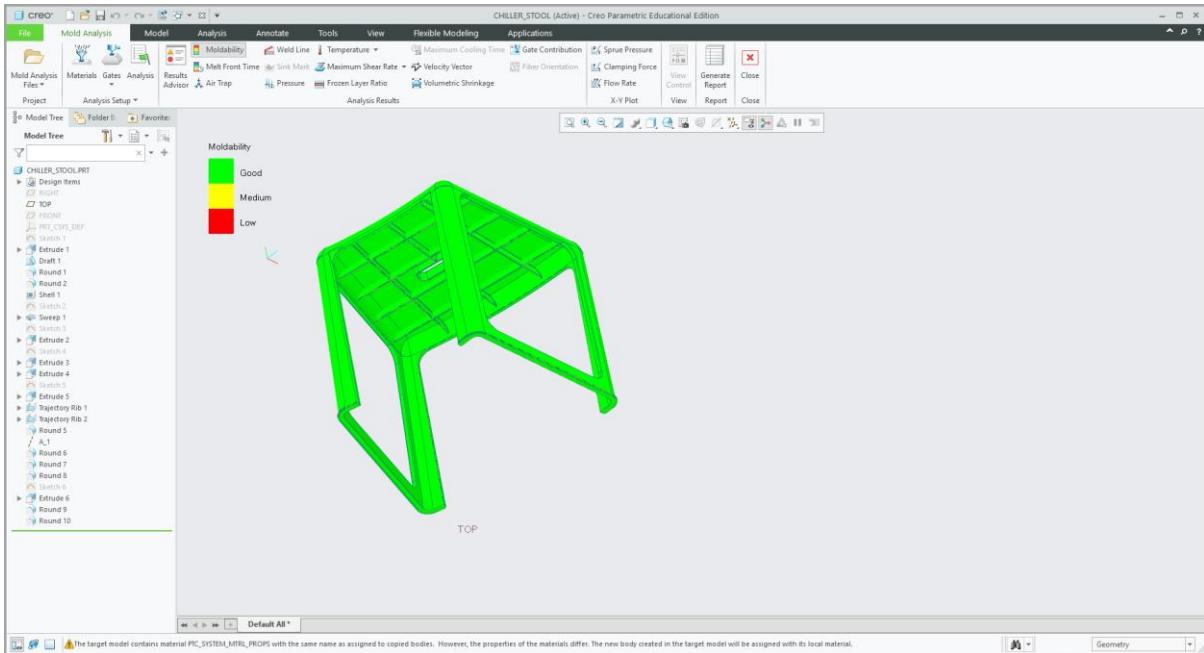
Coarse Medium Accuracy

For Chiller Stool, the gate size selected was 3mm and they were placed on surface below the top of the stool.

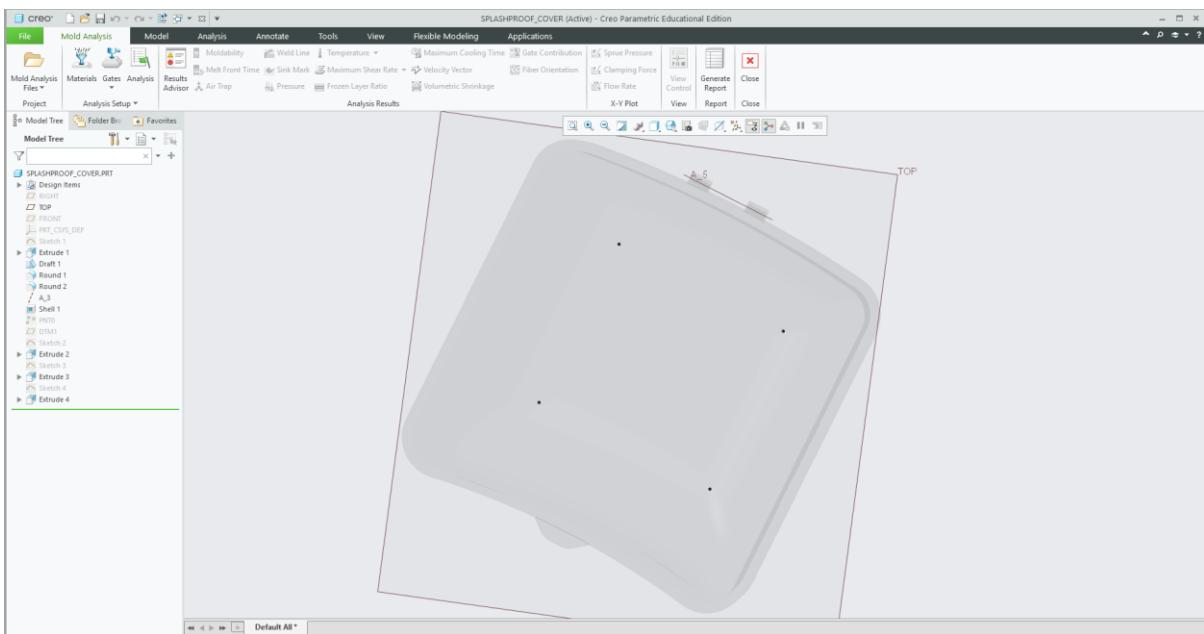


The following result show that the stool can be accurately injection moulded with selected design features.

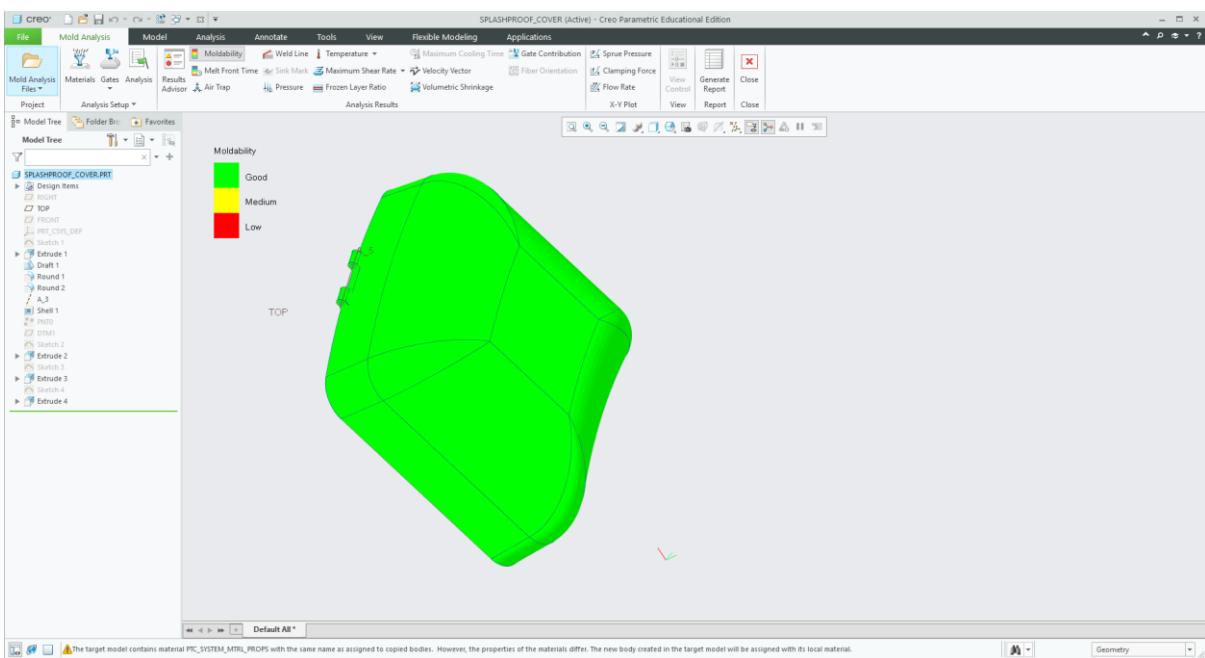
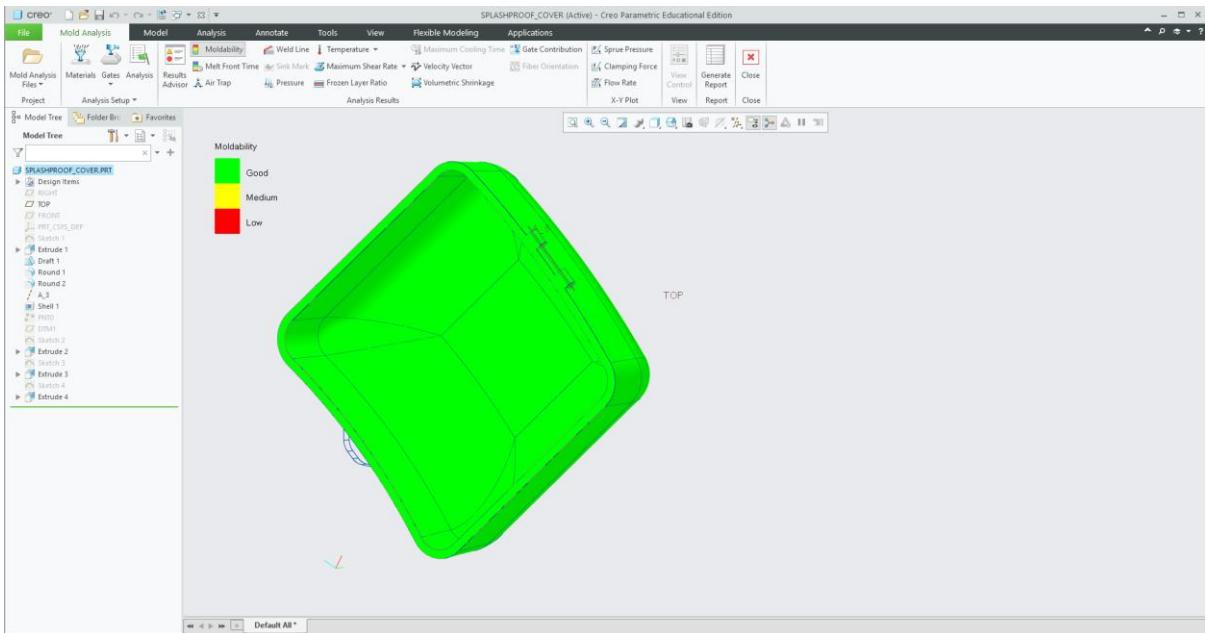




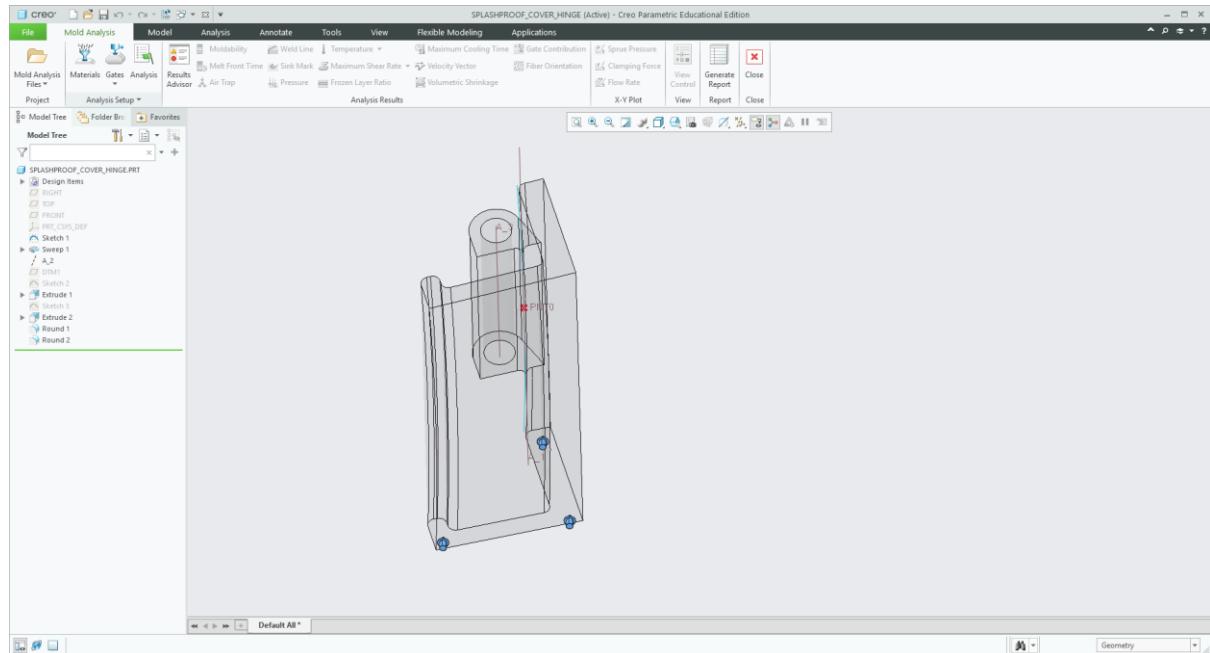
For Splashproof Cover, the gate size selected was 3mm and they were placed on inner top surface of the cover.



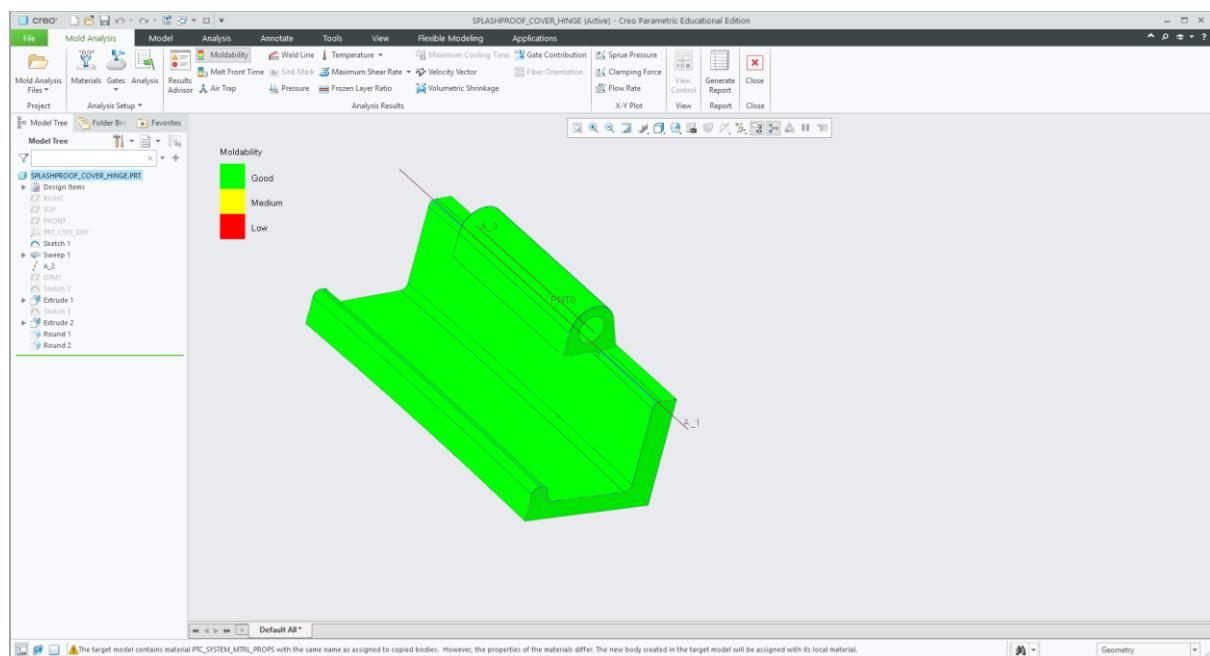
The following result show that the splashproof cover can be accurately injection moulded with selected design features.



For Splashproof Hinge, the gate size selected was 3mm and they were placed on the c-shaped end face of the hinge.



The following result show that the splashproof cover can be accurately injection moulded with selected design features.



Beam Calculations:

Aluminium Box section dimensions = 25x25x2 mm

Thickness of the box section is 2mm

So, the dimension of the inner wall box is 21x21mm

Deflection,

$$\delta = [5 * W * L^4] / 384 * E * I$$

Where, E = Young's Modulus (N / mm²)

L = Length of Beam (mm)

I = Second Moment of Inertia (mm⁴)

W = Force per Length (N/mm)

2nd Moment of Inertia,

$$I = [(b^3 * h) / 12] - [(b * h^3) / 12]$$

So, for square it becomes,

$$I = [a^4 - (a_1^4)] / 12$$

Where, a = 25 mm and $a_1 = 21$ mm.

Putting the values in,

$$I = [(25^4) - (21^4)] / 12$$

$$I = 16,345 \text{ mm}^4$$

For Aluminium 6082 T6,

$$E = 71 \text{ GPa} = 71 * 10^3 \text{ N / mm}^2$$

Let's assume extreme case scenario where 220 kg uniform load is applied on the beam of length 450 mm.

So, Load of 220 kg = 2.15 kN distributed over 450 mm,

$$W = 2.15 / 450 \text{ (kN/mm)}$$

Substituting values in initial relation,

$$\delta = [5 * (2.15/450 * 10^3) * 450^4] / [384 * 71 * 10^3 * 16345]$$

$$\underline{\delta = 0.2 \text{ mm}}$$

But,

$$\text{span} / 360 = 450 / 360 = 1.25 \text{ mm}$$

Now as, $\delta < \text{span}/360$

This implies that the design is safe.

For beam of 550 mm,

Distributed load becomes, $W = 2.15 * 10^3 / 550$

Putting the values in,

$$\delta = [5 * (2.15/550 * 10^3) * 550^4] / [384 * 71 * 10^3 * 16345]$$

$$\underline{\delta = 0.9 \text{ mm}}$$

But,

$$\text{span} / 360 = 550 / 360 = 1.53 \text{ mm}$$

Again, as $\delta < \text{span} / 360$, The design is safe.

Allen Key Forces

Normal force applied by human hand = 120N

According to manufacturing data,
length of 5 mm Allen key is 70-80mm

So the torque Acting is,

$$T = F \times d$$

$$T = 120 \times 0.08$$

$$T = 9.8 \text{ Nm}$$

Which is less than safe torque for steel M6 bolt (16Nm)

PACK 5

Task	Task Name	Duration	Start	Finish	Pre	June 2022	July 2022	August 2022
Mo		▼	▼	▼	▼	30	01	02
▲	• Dissertation Project	63 days?	Wed 01/06/22	Fri 26/08/22				
▲	Summary for PDS	3 days	Wed 29/06/22	Fri 01/07/22				
▲	Introduction in PDS	29 days	Wed 01/06/22	Sun 10/07/22				
▲	General Product Description	9 days	Wed 01/06/22	Sat 11/06/22				
▲	Customer Information	10 days	Mon 13/06/22	Fri 01/07/22				
▲	Market Research for PDS	15 days	Mon 13/06/22	Fri 01/07/22				
▲	Competitors	23 days	Wed 01/06/22	Fri 01/07/22				
■	• Performance Specifications	10 days	Mon 13/06/22	Sat 25/06/22				
▲	Function	5 days	Mon 13/06/22	Fri 17/06/22				
▲	Material	5 days	Mon 13/06/22	Fri 17/06/22				
▲	Dependability	5 days	Thu 16/06/22	Wed 22/06/22				
▲	Environment	5 days	Thu 16/06/22	Wed 22/06/22				
▲	Ergonomics	6 days	Mon 20/06/22	Sat 25/06/22				
▲	Interface	6 days	Mon 20/06/22	Sat 25/06/22				
▲	Cost and Timing	6 days	Mon 20/06/22	Sat 25/06/22				
▲	Safety	6 days	Mon 20/06/22	Sat 25/06/22				
■	• Regulatory Requirements	15 days	Mon 13/06/22	Fri 01/07/22				
▲	Legislations	4 days	Wed 22/06/22	Sat 25/06/22				
▲	Patents	15 days	Mon 13/06/22	Fri 01/07/22				
▲	References and Bibliography	5 days	Mon 27/06/22	Fri 01/07/22				
▲	Sketching	29 days	Mon 06/06/22	Thu 14/07/22				
▲	Development of Concepts	8 days	Thu 30/06/22	Mon 11/07/22				
▲	Concept Sketching	6 days	Mon 04/07/22	Mon 11/07/22				
▲	Concept Variation Analysis and Research	4 days	Fri 08/07/22	Wed 13/07/22				
▲	Presentation Boards	4 days	Mon 11/07/22	Thu 14/07/22				
▲	Handout	4 days	Mon 11/07/22	Thu 14/07/22				
■	• 3D assembly	25 days?	Mon 18/07/22	Fri 19/08/22				
▲	Hot Tub	5 days	Mon 18/07/22	Fri 22/07/22				
▲	Frames	15 days	Mon 18/07/22	Fri 05/08/22				
▲	Modules	20 days	Mon 25/07/22	Fri 19/08/22				
▲	Assembly	10 days	Mon 08/08/22	Fri 19/08/22				
■	• Final Report	25 days?	Mon 18/07/22	Fri 19/08/22				
▲	Detailed Design	21 days	Mon 18/07/22	Sat 13/08/22				
▲	Conclusions	5 days	Mon 15/08/22	Fri 19/08/22				
▲	References and Bibliography	5 days	Mon 15/08/22	Fri 19/08/22				
▲	Powerpoint Presentation	5 days	Mon 22/08/22	Fri 26/08/22				
■	• Manufacturing Data	7 days	Fri 12/08/22	Mon 22/08/22				
▲	BOM	6 days	Fri 12/08/22	Fri 19/08/22				
▲	2D Tech Drawings	6 days	Mon 15/08/22	Mon 22/08/22				
▲	Ethics and Sustainability Statement	10 days	Mon 01/08/22	Fri 12/08/22				
▲	Analysis and Calculations	25 days	Mon 18/07/22	Fri 19/08/22				