ARCADA

3D Printed Computer Case

Transforming a broken laptop into a desktop PC

Zofia Swierczynska

Degree Thesis

Materials Processing Technology

2019

DEGREE THESIS	
Arcada	
Degree Programme:	Materials Processing Technology
Identification number:	6781
Author:	Zofia Swierczynska
Title:	3D Printed Computer Case
Supervisor (Arcada):	Mathew Vihtonen
Commissioned by:	

Abstract:
The objectives of this thesis included designing, manufacturing and assembling of a PC case, optimizing the design and parameters of manufacturing, and using computer components disassembled from Lenovo Yoga 510 laptop. The aim of this thesis study was to produce a fully functional desktop PC. The design was inspired by an igloo shape and was done using SolidWorks software. The PC case consists of: igloo dome, support structure for computer components, and a readymade metal bottom plate. The manufacturing method was additive manufacturing performed on two MakerBot Replicator 5th Generation 3D printers in Arcada University of Applied Sciences. The igloo PC case was printed in 10 pieces, the support structure for the computer components was printed in 2 parts. In total approximately 0,9 kg of white PLA filament was used, with a total printing time of 88 h. Assembling process involved sanding off all the surface imperfections, gluing and screwing. First the igloo dome was glued, then the computer components were screwed and attached to the support structure. The support structure was then screwed to the metal bottom plate. Lastly, the igloo cover was placed on top of the assembly. The result is a working PC, which is fully functional, it was tested by plugging it to a computer screen and turning it on. Several design aspects could had been designed better, especially small geometry parts, as due to the limitations of 3D printing, they did not have desired quality, although the imperfections were fixable and they did not affect the overall product.

Keywords:	3D printing, PC case, desktop PC, design, SolidWorks, PLA, optimization, assembling
Number of pages:	67
Language:	English
Date of acceptance:	

Table of Content

ABBREVIATIONS

2D   two dimensional

2PP two-photon polymerization

3D   three dimensional

CAD computer-aided design

CPU central processing unit

DLP digital light processing

FDM fused deposition modelling

GPU graphics processing unit

HDD hard disk drive

LAN local area network

LED light-emitting diode

PC   personal computer

PLA polylactic acid

PSU power supply unit

RAM random access memory

SDD solid-state drive

SLA stereolithography

UV   ultra violet

VPU Visual Processing Unit

1 INTRODUCTION

As part of this study, a laptop with a broken screen will be reused and transformed into a desktop PC. The product of this thesis will be a fully functional computer. The main focus will be kept on designing, optimizing, 3D printing, and assembling of a PC case for the electrical components of the laptop. It is easy to go to buy a new computer and throw away a broken laptop, but it is a challenge and a learning curve to re-use its components in a totally new casing.

1.1 Objectives

The objectives of this thesis:

1. Creating a viable design of the desktop PC case and implementing of the design to a fully functional desktop PC using 3D printing technology.
2. Reusing the components from a laptop with a broken screen in the desktop PC.
3. Comparing of parameters and printing times.
4. Determining optimal 3D printing method, material, and cost.

1.2 Relevance of the problem to working life

Reusing and recycling of already existing resources is an important aspect. If possible each item should have be given as many lives as possible, in order to reduce Earth pollution. Landfields are full with trash, ecological aspect is important while dealing with dangerous to environment, hazardous, and non-biodegradable components such as computer parts, which are most often made from different metals, alloys, and plastics. Transforming a not fully functional laptop into a desktop PC, gives a second chance to the electrical components to be still useful to the user.

1.3 Relationship to existing knowledge

In this thesis the main focus is on producing a creative and personalised PC case for electrical components from a laptop with broken screen, to demonstrate the ways

of reusing functional elements of partly broken machine, and giving them a new life. The result of this study is a one of a kind desktop PC.

The design and simulation of the PC case is performed using SolidWorks. All features are designed, the stress analysis of the elements is run. This software was studied in depth during several courses in Bachelor's degree of Materials Processing Technology in Arcada University of Applied Sciences.

3D printing files are prepared for MakerBot 5th Generation 3D printers, using MakerBot Print software, which was also studied during the Materials Processing Technology's Bachelor's degree. Also the printing procedure was explained and presented step by step during the studies in Arcada University of Applied Sciences.

2 LITERATURE REVIEW

2.1 3D Printing

The process of 3D printing is based on digital technology. First, a detailed design is created using CAD software. The design can be also generated by scanning an already existing object that will be later 3D printed. The file is then sent to the printer. The time of printing and the amount of material needed is directly related to the size of the object. (Smither, 2013)

A 3D printer is somehow similar to a document printer, as the carriage that applies the material moves in a series of repetitive passes across the surface. In the 3D printer, when the layers are built, the platform lowers less than 1 mm at a time, so that on top of the object next layers can be added. The material is stacked up successively and in different shapes. A solid part of any shape is built in three dimensions, based on a digital model. The difference between 3D printing and traditional machining technologies is the process itself. Traditional technologies are based on subtractive processes. The solid piece of material is shaped into desired shape, by removing the excess material by drilling, cutting, or sanding. 3D printing

is based on the additive processes, the opposite of subtractive technologies. The product is created by successively adding the material to an empty space. The object is created layer by layer, one on top of another. The layers are of different shapes, and they are stacked together, creating a three dimensional product of desired shape. (Smither, 2013)

2.1.1 Sources of 3D Models

Prior to 3D printing, the 3D printer needs to receive the instructions how to print. The options to obtain the input file with instructions for the machine include: modelling, image-based modelling, and scanning. (Smither, 2013)

Modelling

For creating the input for the 3D printer virtual blueprints can be used. The plan of the object is produced by the user with the use of CAD software or animation modelling software. (Smither, 2013)

A finished CAD file is then saved by the user in the STL format. The STL format is a standard data interface between the CAD software and the 3D printer. STL files are readable by the 3D printer, CAD files are not. The design in STL format is represented as a composition of a series of horizontal slices of the model (Figure 1). Those slices are read by the 3D printer as layers of material to be printed from the filament materials inside of the 3D printer. A precisely identical duplicate of the virtual model is printed layer by layer by the 3D printer. (Lipson & Kurman, 2013)

Figure 1: A 3D model presented as a set of slices (Shropshire 3D Printers)

Image-based Modelling

Another method for obtaining the input instructions for the 3D printer is combining a serious of pictures. In this user-assisted approach the specifications for the 3D printing are created by a series of pictures of the product to be reproduced. Photographs from numerous different angles are used to create a virtual image - with the use of photogrammetry, photos of the object are assembled into a series of instructions that the 3D printer follows to build a model of the product. (Smither, 2013)

Scanning

A 3D scanner is used to record the dimensions of the object to be replicated (Smither, 2013). It analyses an object to collect information about its shape and, if possible, also its appearance. The obtained data is then used to create a digital, three dimensional model of the object. (Roebuck, 2011)

3D scanning creates a point cloud of geometric samples on the surface of the object. Those points are then meshed together, to reconstruct the shape of the subject (Figure 2). If the colour information was collected at each point, then it is possible to determine the colours on the surface of the object. (Roebuck, 2011) The colour specifications are stored in WRL or VRML format (Smither, 2013).
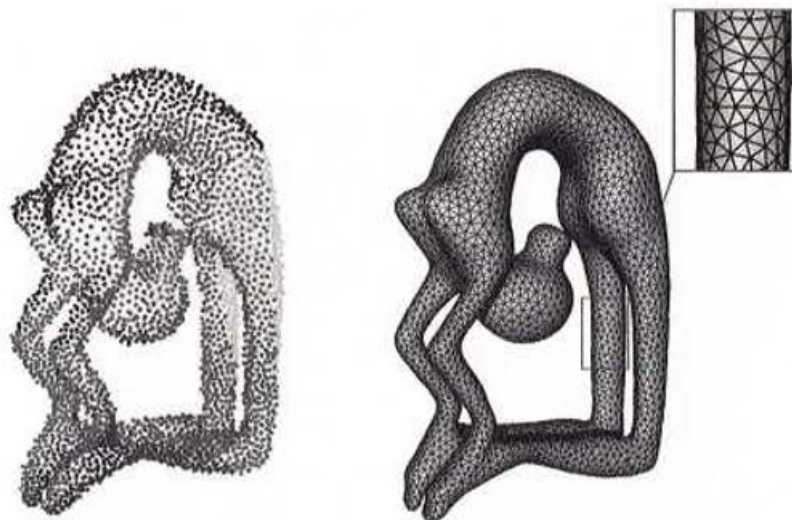

Figure 2: Point cloud data and surface mesh of the model (Lipson & Kurman 2013 p. 97)

3D scanners are very similar to cameras. They can collect information only about surfaces that are unobstructed in their cone-like field of view. The difference is that the camera collects the colour information about the surfaces, but 3D scanners collect information about the distance of the surfaces from the scanner. The image created by 3D scanner presents the distance to a surface at each point in the image. In order to achieve that, a spherical coordinate system is defined in a way, that the 3D scanner is located in its origin. The vector out of the front of the 3D scanner is $\varphi=0$ and $\theta=0$. In this manner, every point in the image is associated with φ and θ. The spherical coordinates are supplemented by the distance, the r component. With this set up, in a local coordinate system relative to the 3D scanner, the three dimensional position of every point in the image can be fully described. (Roebuck, 2011)

3D scanning devices can be built using different technologies, with its advantages, limitations, and costs. There remains many limitations due to type of the object that can be scanned and digitalized. (Roebuck, 2011) Shiny or transparent objects present difficulties to the 3D scanner, as the light from the scanner does not follow the outline of the product (Smither, 2013).

As the 3D scanner can scan only unabstracted surfaces, multiple scans from different directions are often necessary to create a full three dimensional model of an object. Those multiple scans have to be then processed and brought to a common reference system, and then merged together to create a complete model. 3D scanning pipeline is the name of this process. (Roebuck, 2011)

3D scanners are widely used by the entertainment industries, in the production of video games and movies. Other applications include prototyping, reverse engineering, orthotics and prosthetics, industrial design, inspection, quality control, and documentation of cultural antiques. (Roebuck, 2011)

2.1.2 Product Design for Plastics

There are numerous joining techniques available, depending on the material and the requirements of the final product. Some plastics are suitable only for several techniques, while some others can be joined by a wide range of methods. (Mastro, 2016)

Threads and threading requires a minimum lead-in relief of 0,76 mm (0,030'') at both parts, to protect from high stresses and the end of the thread (Figure 3). (Mastro, 2016)
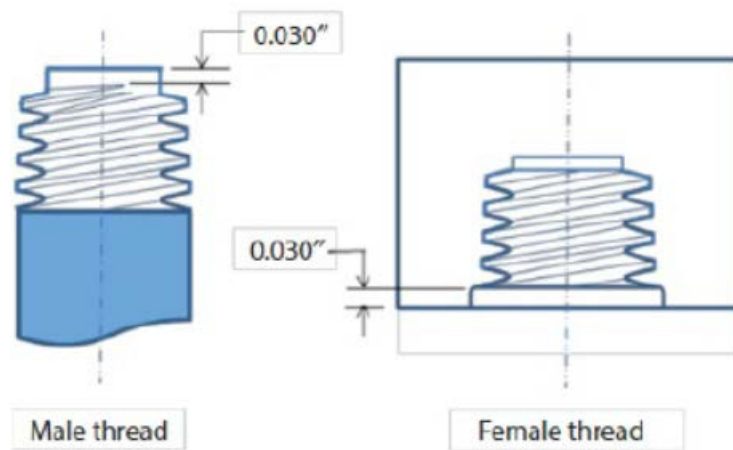

Figure 3: Thread relief (Mastro 2016 p. 221)

Bolt and Screw Assembly

A convenient way of assembling parts together is a use of standard metal fasteners. Multiple assembling and disassembling of the product are possible. However, it needs to be ensured that there is no excessive forces (for example compressive force due to assembly torque) acting on the plastic parts. Reduction of compressive forces is important and simple. The key is to distribute the forces over greater area. Examples of good and poor designs for reducing compressive forces are presented on Figure 4. With the use of a small washer the tightening force is distributed over a small area of the plastic part it is tighten against. Using a larger washer with four times the contact surface area, distributes to forces over a larger area.
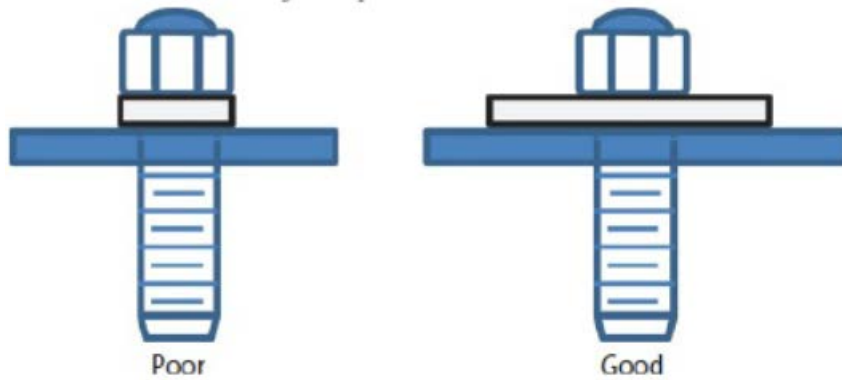
Figure 4: Distribution of assembly torque (Mastro 2016 p. 236)

2.1.3 Intellectual Property

In 3D printing technology intellectual property is a primary concern, as a CAD file can be shared with any number of people. Intellectual property is separated into 3 groups: patents, copyrights, and trademarks. (Smither, 2013)

Patents protect from duplication for up to 25 years. The time can be varied by jurisdiction. Copyrights protect artistic works for the time of artist's life plus 70 years. Trademarks identifies a service or a product from unique source. The trademark itself is a recognizable sign, design, or expression, which is owned by business, legal entity, or a person. (Smither, 2013)

The supporters of 3D printing technology offer open source CAD designs to encourage others in creating and building a device. Opponents claim that property laws must be respected when manufacturing products with patents, trademarks, and copyrights. The freedom to 3D print any object from CAD design file must be balanced with regard to the commerce laws. (Smither, 2013)

2.1.4 Controversies

``The responsibility for proper use of any technology rests with the user.``

~A.H Smither (2013)

Any technology originally created for solving a certain problem, can as well be used for potentially controversial purposes, for instance guns or health related products. (Smither, 2013)

In the USA, the gun control was improved after a series of events, where innocent people were killed with the use of guns and high capacity magazines. Shortly after that, CAD design files for magazines and guns (Figure 5) were available on numerous webpages for anyone to access and use. The State Department of the government reacted rapidly, however the response was ineffective and unsuccessful. Regarding the legislation, the use of CAD designed gun is as difficult as trying to confiscate 300 million guns existing in the USA. (Smither, 2013)

Figure 5: A 0,22 caliber gun, partly manufactured with 3D printed plastics (Lipson & Kurman 2013 p. 128)

Regarding the health products, 3D printing of human cells, tissues, and skin could be perceived by some people as questionable. Whereas, 3D printing is revolutionizing the medical sector, where precision is essential for medical application. Artificial heart valves had been already 3D printed (Figure 6). Ethics are questioned, if the source

of the materials used crosses the moral boundaries. Every decision of medical professional and researches must consider the value of human life. (Smither, 2013)

Figure 6: A 3D printed heart valve (Lipson & Kurman 2013 p. 128)

2.1.5 History of 3D Printing

3D printing developed rapidly during last 30 years. The first working 3D printer was created in 1984 by Chuck Hall at 3D Systems Corporation. Nowadays objects are printed from various materials, with thousands of thin layers. (Smither, 2013)

Prototypes always have been one of the most expensive elements of the manufacturing process. With the invention of 3D printing, this is no longer an issue. The prototype of a unique object can be designed using computer-aided design (CAD) software, and then forwarded to the 3D printing software. The most important priorities are accuracy, speed, usability, colour, and affordability. The 3D printing innovation revolutionized the world in a similar manner that the document printers did in 20th century. Both of those machines changed the way of presenting information. (Smither, 2013)

The innovation of 3D printers can be divided into 3 generations. 1st Generation 3D printers were printing basic materials in layers to reproduce the concept objects into 3D objects. In the 2nd Generation the printing speed was improved, which attracted

more people and the interest grew. Rapid prototyping with more materials and in more colours became possible. The prices of the printers decreased to the affordable range. The 3rd Generation introduced self-contained printers. The ease of use improved the process of printing. Large printers became cheaper and thus more accessible for people to create larger products. (Smither, 2013)

Manufacturing innovation is a cautious and slow process. Nowadays mass production industry is the core of the economy. Logistics and complexity make the innovation risky. The experiments must be performed carefully. The gold proportion of manufacturing is to reduce overall costs, obey workplace and environmental regulations, and keep the logistics efficient. 3D printing technology reduces the risks and costs by introducing peculiar products to the market. As upfront investments are lower, small companies are able to answer market's demands and manufacture few products at the time. Then, depending on the selling rates of each product, the production can be optimized scaling up the manufacturing of the products that sell well. A small company assumes fewer financial risks and it creates and sells products in small volumes to see how the market reacts. There is no need to purchase a traditional injecting moulding mould, which costs at minimum 10 000 USD. Using 3D printing, small inventions can be tested, without waiting for overhead costs to be covered. Trying numerous of small ideas becomes possible with 3D printing technology. (Lipson & Kurman, 2013)

In the 21st century the interest in 3D printers increased exponentially. The price of 3D printers has dropped and allowed many industries to incorporate 3D printing technology into their companies and factories. The design and materials can be transformed for tolerable price into the desired shape. Creating peculiar and unique products is no longer cost restricted. (Smither, 2013)

2.1.6 Thermoplastic Extrusion

The majority of 3D printers create parts by extruding semi-liquid material through the print head nozzle, which is controlled by a computer. The process is called thermoplastic extrusion or material extrusion. The spool of build material,

called filament, is slowly fed to the print head and heated to 200-250°C. The filament melts and is then extruded through a fine head nozzle and deposited onto flat, smooth, horizontal surface named build platform. Due to temperature differences the filament rapidly cools down and sticks to the build platform. The print head moves in 2D space and creates the outline of the first layer. The build platform is then lowered, second layer is imprinted in the same manner. Layers are successively added one on top of another, until the desired object is complete. It might take up to several hours to manufacture one object, depending from its size and complexity. The setup for thermoplastic extrusion is presented in Figure 7. Most of the customer thermoplastic extrusion 3D printers have a build volume starting at 125 mm × 125 mm × 125 mm. (Barnatt, 2013)
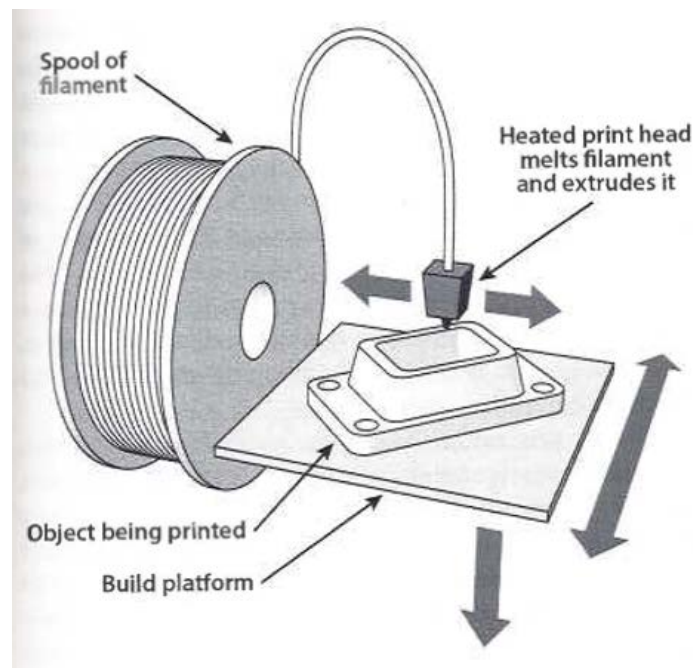
Figure 7: Thermoplastic extrusion 3D printing (Barnatt 2013 p. 29)

Wide range of materials can be used: thermoplastics, metals, ceramics, concrete, and even chocolate. Currently the most common materials for thermoplastic extrusion are melted thermoplastic, including acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), polycarbonate (PC), and ABS-polycarbonate composites. (Barnatt, 2013)

2.1.6.1 Advantages and Disadvantages

Objects created with thermoplastic extrusion 3D printing, have a visible stepping. Human eye can distinguish that the object has been built up layer by layer (Figure 8). (Barnatt, 2013)
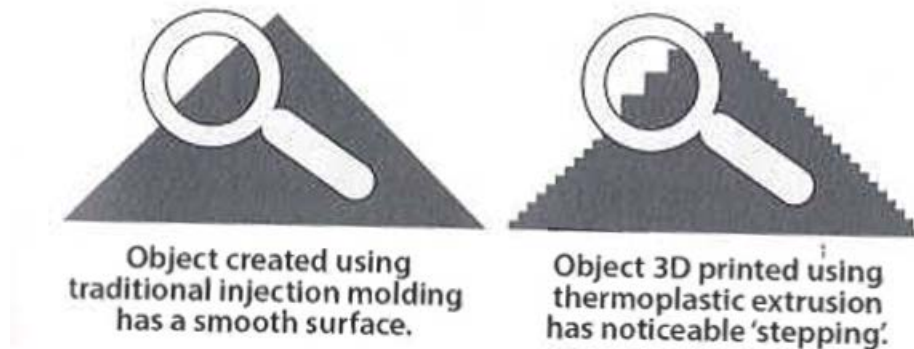
Figure 8: Injection moulding vs thermoplastic extrusion (Barnatt 2013 p. 33)

The stepping can be minimalized by increasing the resolution and accuracy of the 3D printer. The best industrial 3D printers can extrude objects in layers of about 0,1 mm, with similar accuracy on the other axes. More affordable machines have the accuracy of 0,2 mm, and minimum layer thickness of 0,2-0,5 mm. A thermoplastic extrusion 3D printed product never feels entirely smooth, unless it was slightly sanded after printing. (Barnatt, 2013)

2.1.6.2 History

Thermoplastic extrusion was invented by a company called Stratasys. The innovation was labelled 'fused deposition modelling' (FDM). This term is widely used and misused, while referring to material extrusion in general. FDM is a trademark owned by the Stratasys company, thus it is the only manufacturer that can use those labels. Due to that, other corporations when referring to thermoplastic extrusion use terms of 'plastic jet printing '(PJP), 'fused element fabrication' (FFF), 'fused filament modelling' (FFM), or 'fused deposition method'. (Barnatt, 2013)

2.1.7 Stereolithography (SLA)

Stereolithography (SLA or SL) is a technology in additive manufacturing used for creating prototypes, models, patterns, and even production parts. Stereolithography has many common names: 3D printing, photo-solidification, solid imaging, optical fabrication, and solid free-form fabrication. (Roebuck, 2011)

SLA uses a tub of UV-curable liquid photopolymer resin and a UV-laser to manufacture parts. A layer at a time is created: on the surface of liquid resin the beam of laser traces a part cross section pattern. The resin cures and solidifies due to exposure to UV-laser light, and so a new layer is created. Once the pattern has been imprinted, the SLA's elevator platform lowers by a single layer thickness, usually 0,05-0,15 mm. On the new liquid surface, the consecutive layer of pattern is traced. It adheres to the previous layer. The steps are repeated until the complete three-dimensional part is produced. The setup for stereolithographic 3D printing is presented on Figure 9. (Roebuck, 2011)
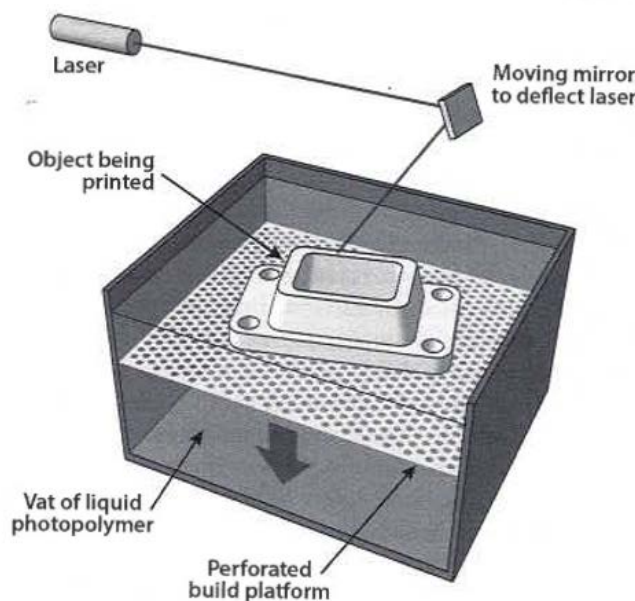
Figure 9: Set up for stereolithographic 3D printing (Barnatt 2013 p. 46)

Using support structures enables attaching the part to the elevator platform. It also prevents certain types of geometries from deflecting because of gravity (Figure 10).

The supports precisely hold the 2D cross section in place, in a way that the part withstands the side pressure from the re-coating blade. The support structures are created automatically during the preparation of 3D CAD models for stereolithography machine. The supports can also be modified manually. (Roebuck, 2011)
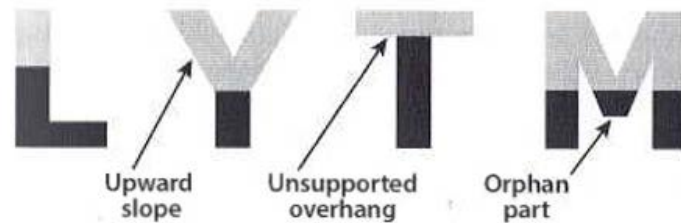

Figure 10: Different types of geometries (Barnatt 2013 p. 35)

After printing, the supports must be broken away or removed with tools. Next, the 3D printout has to be cleaned with a solvent and a water rinse, to ensure the cleanliness of the end product. Then, the part needs to be cured in UV oven. The accuracy on X and Y axis is about 0,025 mm. (Barnatt, 2013)

2.1.7.1 Advantages and Disadvantages

With the use of SLA a functional part can be produced within one day. The printing time depends on complexity and size of the part, overall it can take few hours to over one day to complete the project. SLA machines usually can manufacture parts within the maximum size of approx. 50 cm × 50 cm × 60 cm (20¨ × 20¨ × 24¨). (Roebuck, 2011)

Stereolithography is a very high-quality 3D printing method with good: surface quality, resolution, and ability to create complex shapes with high repeatability (Barnatt, 2013). Regarding the shapes, there is almost no limitations (Roebuck, 2011).

The prototypes created by SLA are strong enough to be machined and they can be used as master patterns for blow moulding, thermoforming, injection moulding,

and in various metal casting processes (Roebuck, 2011). Parts produced with SLA have a smooth surface and are very accurate (Barnatt, 2013).

SLA is a relatively expensive method, the UV-curable resin can cost 300 - 800 USD per gallon (approx. 3,8 l). The SLA machine cost from 100 000 USD to even more than 500 000 USD. (Roebuck, 2011) The prices just start to change. In November 2011, a desktop SLA printer was launched by Asiga and it costed under 7 000 USD. In May 2013 a desktop SLA printer Form1 was launched by Formlabs, the price was 3 299 USD. (Barnatt, 2013)

2.1.7.2 History

Stereolithography was characterized as apparatus and a method for creating solid objects by consecutively 'printing' thin layers of the UV-curable material one on top of another. The term 'stereolithography' itself was invented by Charles W. Hull in 1986. First company focusing on commercialization of the procedure was established immediately alongside the invention. (Roebuck, 2011)

2.1.8 Digital Light Processing (DLP)

In DLP projectors, the image is created with the use of microscopically small mirrors placed in a matrix on a semiconductor chip, called Digital Micromirror Device (DMD). Each of the mirrors represents one or more pixels in the projected image. The resolution of projected image is strictly dependent on the number of mirrors. The mirrors can be rearranged quickly to reflect light either onto a heat sink or through the lens. The main light source in DLP technology is based on replaceable high-pressure mercury-vapor metal halide arc lamp. The lamp consists of a quartz arc tube, electrical connections, reflector, and sometimes a quartz or a glass shield. In newer DLP projectors lasers or high-power LEDs are the source of illumination. (Roebuck, 2011)

In DLP projection 3D printers, the mirrors can be rapidly rotated, reflecting light onto a heat sink. The high-quality image for projection is created by controlling

the orientation of the mirrors. DLP projector is used to solidify a photopolymer liquid in the heat sink. The set up for DLP projection 3D printing is presented on Figure 11. (Barnatt, 2013)
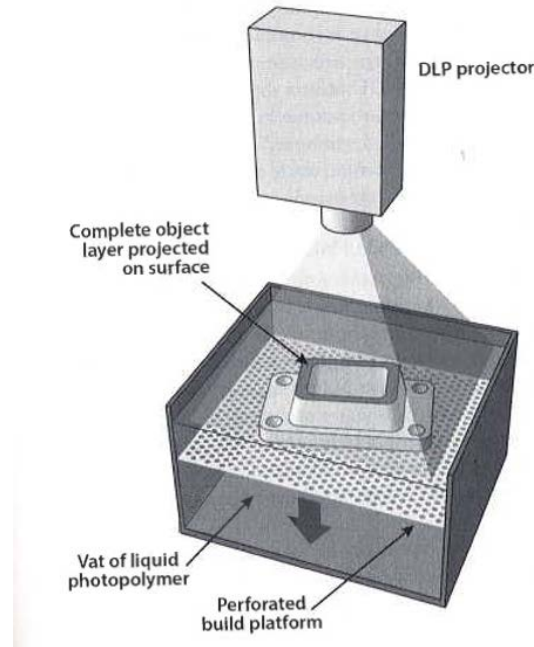

Figure 11: DLP projection 3D printing (Barnatt 2013 p. 49)

The largest DLP projection 3D printers can build a volume of 267 mm × 165 mm × 203 mm, a minimum layer thickness is 0,025 mm. The is numerous different photopolymers available as build materials, including opaque and transparent substitutes of traditional plastics, wax-based polymers, and several dental and medical plastics. (Barnatt, 2013)

DLP technology is used in TVs and in video projectors in cinemas, schools, lecture theatres, and 3D printers. (Roebuck, 2011)

2.1.8.1 Advantages and Disadvantages

DLP projectors can process even 7 separate colours, which enables strong colour performance. The light source is easily replaceable, and it can be done by the user not a professional. (Roebuck, 2011)

DLP projection 3D printers can achieve a high level of accuracy. Furthermore, the accuracy in smaller printers can be greater than in larger printers, because the projector needs to focus on smaller area. (Barnatt, 2013)

Enthusiasts are using DLP projectors to make their own DLP projection 3D printers. The price of operating is quite high due to expensive liquid photopolymers, but the print quality is excellent. A competent amateur can create own DLP projection 3D printer for a few thousand American dollars. Printing is possible at resolution of 0,1 mm or less, and the DLP projector can be removed from the 3D printer and used to watch movies. (Barnatt, 2013)

2.1.8.2 History

Digital Light Processing is a trademark owned by Texas Instruments. It was developed by Dr Larry Hornbeck of Texas Instruments in 1987. (Roebuck, 2011)

2.1.9 Two-photon Polymerization (2PP)

Two-photon polymerization (2PP) is based on selective solidification of a vat of a liquid. Layers of photopolymer resin are successively solidified by a femtosecond pulsed laser. It is a similar method to stereolithography (SLA), and in the future can be a mainstream 3D printing technology. The technique is constantly under development of numerous teams of researchers worldwide, including The Additive Manufacturing Technologies (ATM) group at the Technical University of Vienna, and the Nanoscribe GmbH in Germany. The researchers from Vienna 3D printed a model of Formula 1 car, that is only 0,25 mm long, which took about 4 minutes. Another extremely small model they imprinted is Vienna's St. Stephen's cathedral, the print out is 0,1 mm long (Figure 12). In the future 3D printing of microelectronic and optoelectronic circuits might be possible with 2PP technology. (Barnatt, 2013)
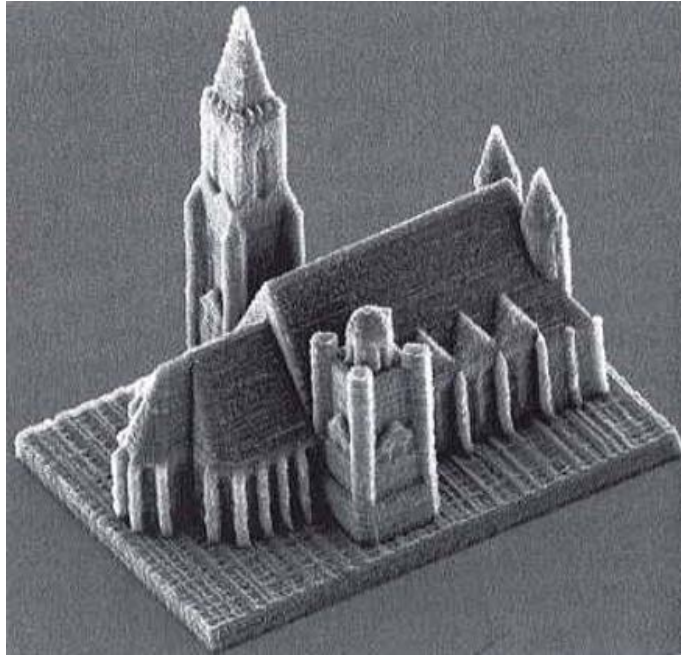
Figure 12: The printout of St. Stephen's cathedral in Vienna using two-photon polymerization technology (Barnatt 2013 p. 52)

2.1.9.1 Advantages and Disadvantages

2PP is capable of printing layers up to several meters per second. 2PP 3D printers are 250 times more accurate than stereolithography. 2PP 3D printers has a resolution of 0,0001 mm on all axes of printing (layer thickness Z axis, and X-Y axis). Objects smaller than a bacterium can be printed with 2PP technology. (Barnatt, 2013)

2.2 Desktop PC Case

On the market there is numerous different models of readymade desktop PC cases available. The most common PC cases consist of top panel cover, back of frame, front of frame, bottom of frame, feet, external 5.25'' drive bays, external/internal 3.5'' drive bays, LED and speaker wires, auxiliary cooling fan, drive power connectors, power cord plug, I/O plate with I/O connector ports, power supply, power supply fan vent, expansion slot inserts, and vent holes. The parts of the PC case are presented on Figure 13. (Parts of the System Case)
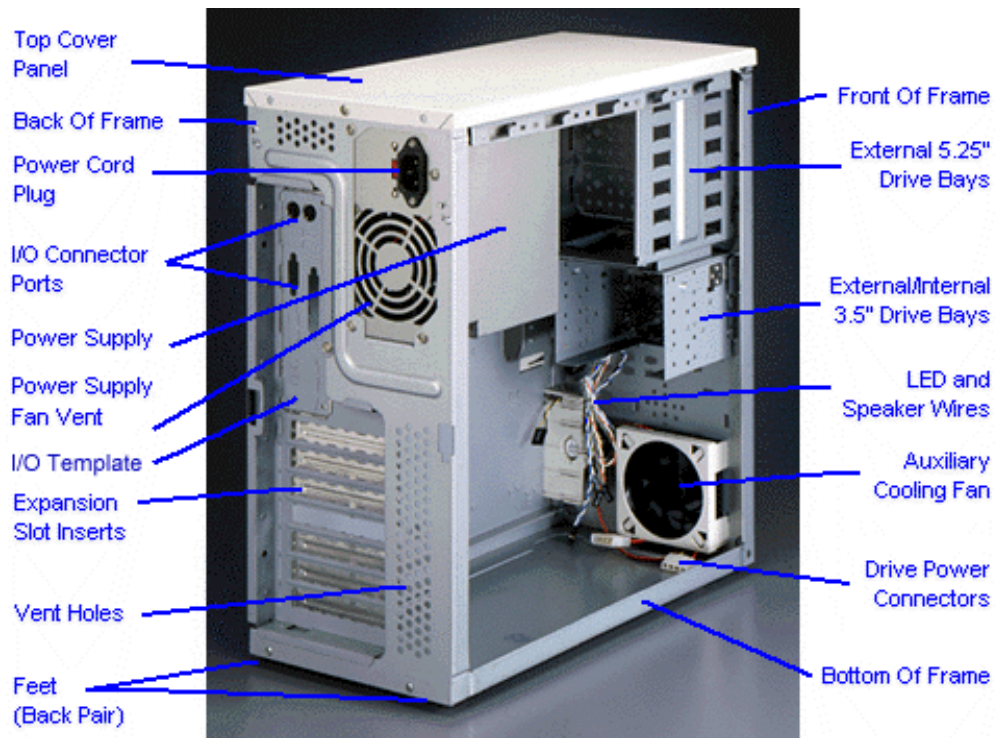
Figure 13: Parts of PC case (PC Guide)

2.2.1 Cost

For many users cost is an important factor while choosing the PC case. In the market there are numerous options, within different price ranges. The price of the PC case is dependent on the features, design, materials used, and even the manufacturer. Usually the more advanced PC case, the higher its price. The desktop PC cases available on the market can cost between 39,90 EUR and 970,90 EUR.

2.2.2 Requirements

2.2.2.1 Motherboard

Each PC case needs to have free space and mounting points designed for the motherboard. There are several standards for the motherboard's sizes and attachment points. The most common one is ATX, Advanced Technology eXtended, a configuration for motherboards developed in 1995 by Intel. The official ATX specifications were revised and upgraded many times since then. ATX brought a major change in motherboard and power supply design, and in desktop

computer enclosure. The development of ATX standards improved standardization and interchangeability of parts. ATX specification describes the key mechanical dimensions, attachment points, Input-to-Output (I/O) panel, power and connector interfaces between the motherboard, the power supply and the computer case. (Intel)

The dimensions of a full size ATX board are 305 mm × 244 mm (12 in × 9,6 in). Other standards for smaller boards (microATX, Flex-ATX, nano-ITX, and mini-ITX) most often keep the basic rear layout but decrease the size of the board the number of expansion slots. Thus, numerous ATX chassis also accept microATX boards. The most common standards for motherboards are presented on Figure 14. Common attachment points positions are presented on Figure 15. The most common ATX motherboards are: FlexATX (229 mm × 191 mm), microATX (244 × 244 mm), Mini ATX (284 mm × 208 mm), Standard ATX (305 mm × 244 mm), Extended ATX (EATX) (305 mm × 330 mm), and WTX (356 mm × 425 mm). (Intel)
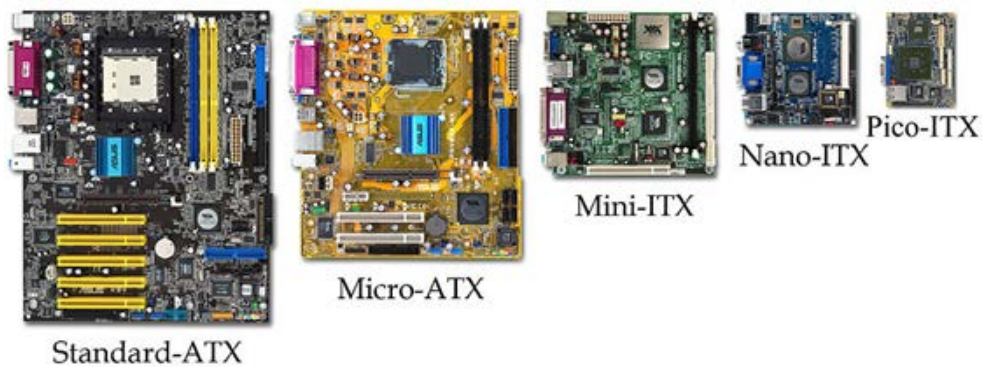
Figure 14: Common motherboard standards (Intel)
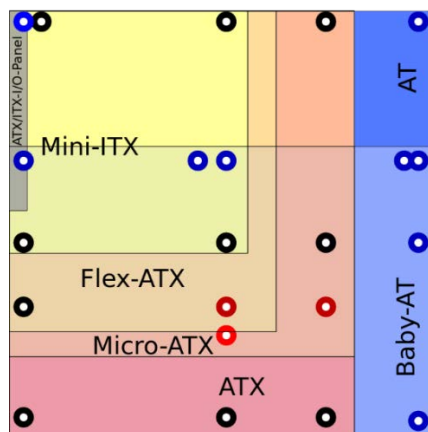
Figure 15: Mounting points positions of most common standards (Intel)

The back of the computer case usually has a snap-out panel, also known as Input-to-Output plate (also named I/O plate or I/O shield). ATX simplified the ports layout by locating the ports in a rectangular area. Couple of general patterns were created, but motherboard manufacturers could decide and modify the arrangement themselves, depending from the needs. In the end, most manufacturers followed the common general patterns introduced by Intel. The I/O plates are most often incorporated with a motherboard, not designed separately for each computer case. Several ATX motherboards are integrated with an I/O plate. (Intel)

2.2.2.2 Graphics Processing Unit (GPU)

Graphics Processing Unit, commonly named graphics card, also known as Visual Processing Unit (VPU), is one of the expansion cards. GPU is used for controlling and boosting the performance of graphics and video. It is designed to create faster graphics and video, reducing the work of the CPU. Most often the GPU is a separate card connected to the motherboard, but modern CPUs today can have integrated graphics within the CPU chip itself (called APUs). GPUs are widely used in computers, phones, game consoles, and display adapters. (Technopedia)

2.2.2.3 Central Processing Unit (CPU)

Central Processing Unit is responsible for most of the processing in the computer. It is thought that the CPU is the brain and the heart of a computer. It controls the instructions and data flow between different components, relaying strongly on a motherboard. (Technopedia)

2.2.2.4 Fans

Processors, graphic card, and other electrical components produce heat as a side effect of normal operation. Sufficient cooling is required in order to ensure continuous efficient and safe work of the computer. Each component needs to be kept within strictly specified range of temperatures to prevent overheating, malfunctioning

or damage of the component. Sometimes passive cooling of the computer is enough, but modern components might require more efficient active cooling. Fans are widely used for cooling graphics card, hard drive, CPU, and other components depending from the needs. (ExplainingComputers)

A computer fan is used for active cooling, it is usually attached to the computer case. Depending from the model, fans let the cooler air from outside into the case, take the warm air out from inside of the case, or they move the air across a heatsink to cool a particular component. Fans can be successively added, depending from the needs. Their speed can be controlled by computer's BIOS, or by the user. (ExplainingComputers)

The fans are of different sizes, the standard most common ones are squares of: 80 mm × 80 mm, 92 mm × 92 mm, 120 mm × 120 mm, 140 mm × 140 mm, 200 mm × 200 mm, and 230 mm × 230 mm. The heights typically are: 10 mm, 25 mm, and 38 mm. (ExplainingComputers)

The dimensions and mounting points need to suit the component that the fan is cooling. Screw hole spacings are usually smaller than fan sizes, for example 60 mm fan has 50 mm space between screw holes (Figure 16). (ExplainingComputers)
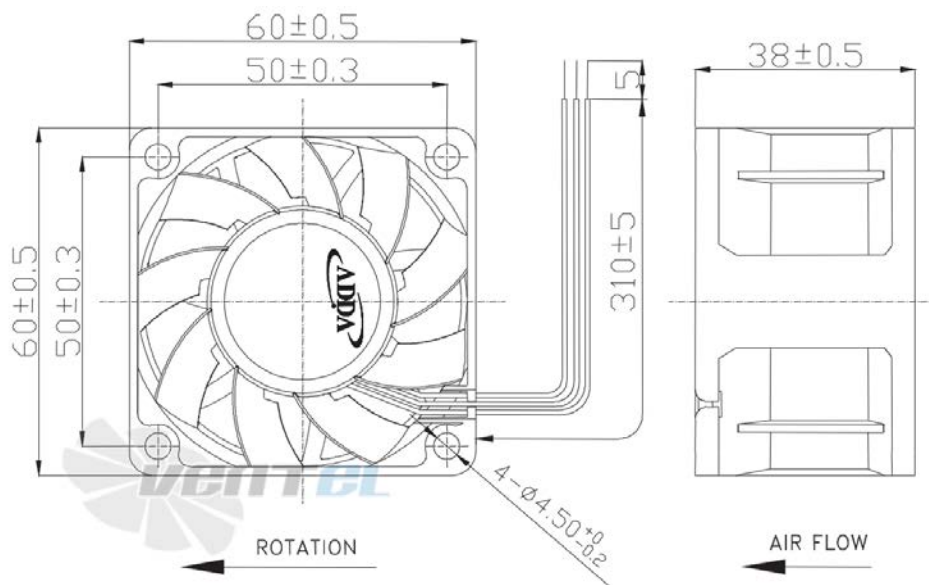
Figure 16: Dimensions of the fan (Ventel)

2.2.2.5 Disk Drives

Disk drives are used for long term storage of data, operating system, programs, etc. They are most commonly divided into SDDs (solid-state drives) and HDDs (hard disk drives). (Webopedia)

2.2.2.6 Power Supply Unit (PSU)

Power Supply Unit, known also as Power Supply, Power Brick, or Power Adapter, is a device responsible for providing electric power to other components. Generally, it converts one type of energy (electrical, chemical, solar, or mechanical) into electrical energy. Most often it is located on the rear part of the computer case. (Technopedia)

2.2.2.7 Random Access Memory (RAM)

Random Access Memory is used for short term data storage, used by computer applications. RAM can hold data only when the power is on. (Techtarget)

2.3 Homemade Desktop PC Cases

Besides of ready-made desktop PC cases available in shops, there is numerous homemade desktop PC cases. There are even several tutorials in the internet how one can manufacture them.

The designs of those homemade PC cases are usually different from the ones available in shops. They have more personal look and peculiar appearance, which makes them one of a kind products. The ideas include combining several of manufacturing methods and different materials. The end product can incorporate LED technology, plywood, plexiglass, metal, plastic, and 3D prints. One of such projects was held by a student, and is described on www.boredpanda.com. The author created a PC case out of wood. Step by step instructions are presented together with pictures. The readymade PC case (Figure 17) consists of wooden frame, plexiglass, aluminium sheets, and LED lights. (Bored Panda)

Figure 17: A homemade wood PC case (Bored Panda)

3 METHOD

In this chapter the external and internal design, shape, structure, features, 3D printing, tools used, and assembling process of the PC case are described.

3.1 SolidWorks Design

The design was created using SolidWorks software.

3.1.2.1 Shape

The shape of the PC case is inspired by an igloo. The PC case consists of the bottom plate and a hemisphere cover, imitating the structure and appearance of the igloo.

3.1.2.2 Structure

The structure of the PC case consists of: the bottom plate, the igloo, the entrance of the igloo, and the support structure for the electrical components.

The igloo is designed to have LEDs inside of the dome, in order for the PC case to be illuminated from inside whenever the desktop PC is turned on. On Figure 18 the first design and the final design of the igloo are presented. The concept of the first design was to maximize the airflow and to allow the light from the LEDs to be as visible as possible. However, the visual properties of this design were not satisfying, and also the structure of the 2 mm diameter bars seemed to be too serious of a weak-point. In the end the final design added more material to the gaps between the bricks, yet kept the LEDs being visible through 2,4 mm × 16 mm gaps, the airflow is still ensured. Other aspects like shape or dimensions were not changed. The overall visual properties became more satisfying, the structure appeared to be sturdier.
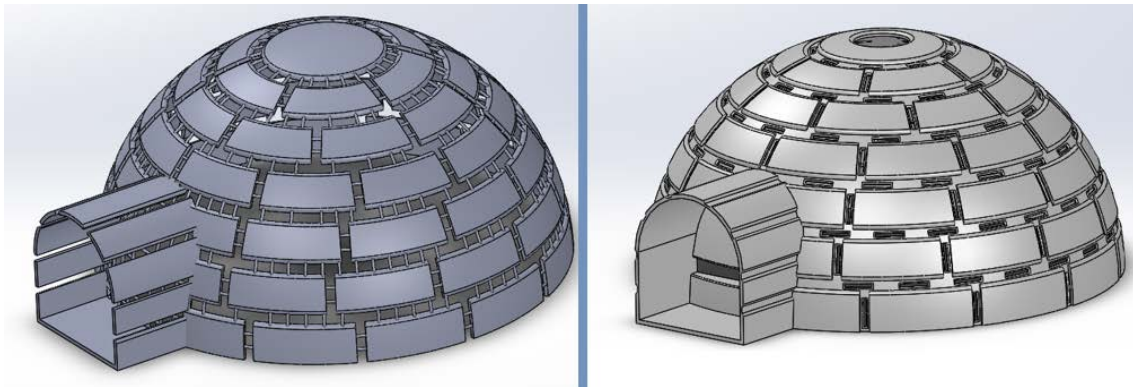
Figure 18: The igloo: first design (left), final design (right)

The support structure is shown on Figure 19. Both igloo and support structure are designed to be 3D printed. The bottom plate is a ready-made metal part (Figure 20).
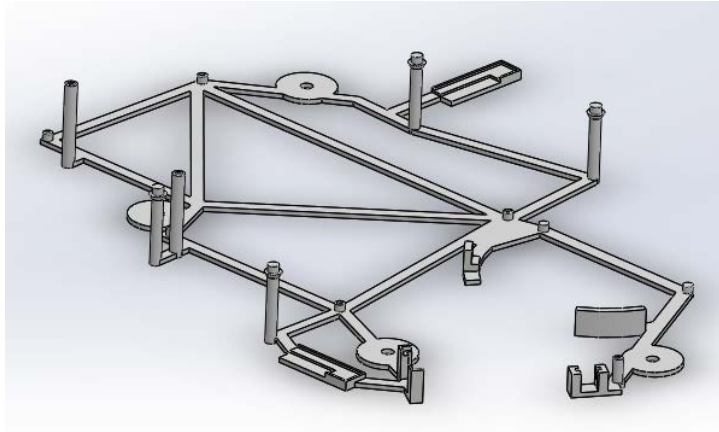
Figure 19: The supporting structure
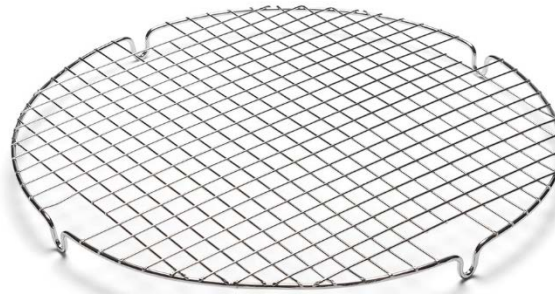
Figure 20: Readymade metal bottom plate (MITIS s.c.)

3.1.2.3 Features

The PC case is designed for the electrical components of a Lenovo Yoga 510 laptop. The laptop has a broken screen, but otherwise it is functional, and it works as intended.

Motherboard

The motherboard has an integrated I/O plate. SDD disk, LAN card, and RAM are connected directly to the motherboard by connectors. The cooling for GPU is rigidly attached. The motherboard and its components are presented on Figure 21.

Figure 21: Motherboard with components: heat sink (blue), GPU cooling plate (green), RAM (orange), LAN card (red), I/O plate (pink), SATA 7+15 pin connector for the SDD disk (violet)

Random Access Memory (RAM)

The Random Access Memory is directly connected to the motherboard, it is shielded with a metal casing.

SDD Disk

The SDD Disk is directly connected to the motherboard by SATA 7+15 pin extension cable. The SDD Disk and its SATA 7+15 pin connector are presented on Figure 22.

Figure 22: SDD Disk (top), and SATA 7+15 pin connector (bottom)

I/O Plate

The I/O plate is an integrated part of motherboard. The I/O plate has the following slots: 2 USBs, HDMI, and Internet cable. In the Figure 23 the I/O plate on the motherboard is highlighted in pink.

Figure 23: I/O plate on the motherboard, from left: internet connector, HDMI, and 2 USBs

As an addition to the I/O plate, there is also a I/O module (Figure 24) with slots for: headphones, SD card, and USB. It is connected directly to the motherboard by a flat ribbon cable.
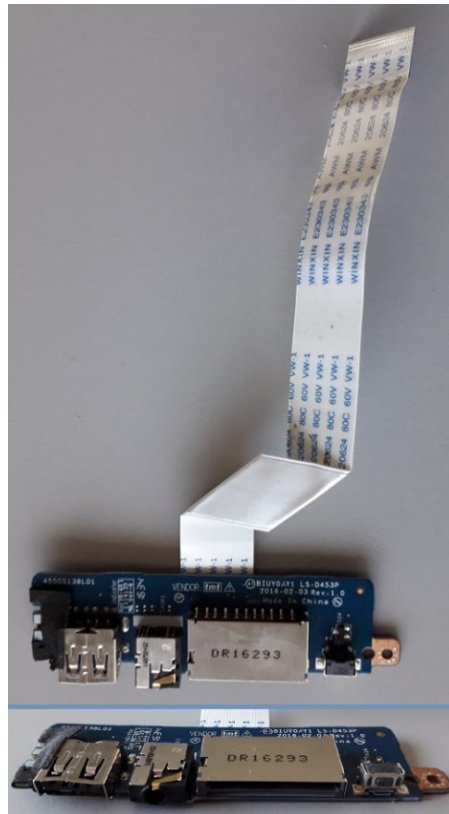
Figure 24: I/O module with its flat ribbon cable (top), and slots- from left: USB, headphones, and SD card (bottom)

Power Cord Plug

The Power cord plug connector is attached directly to the motherboard. The computer is powered through a charger plugged in a standard wall socket. The charger and power cord plug are presented in picture Figure 25 and Figure 26 respectively.

Figure 25: Laptop charger

Figure 26: Power cord plug: connector for the charger (blue), connector for the motherboard (red)

Power Button

The power button was firstly disassembled form an old desktop PC. It consists of a mechanical switch, and decorative plastic button structure with one blue LED (Figure 27). Both the switch and the LED are directly connected to the motherboard.

Figure 27: The parts of the power button: switch (left), plastic button (middle), and LED (right)

LAN Antennas

There is two LAN antennas directly connected to the LAN card through two separate snap in connectors (Figure 28).
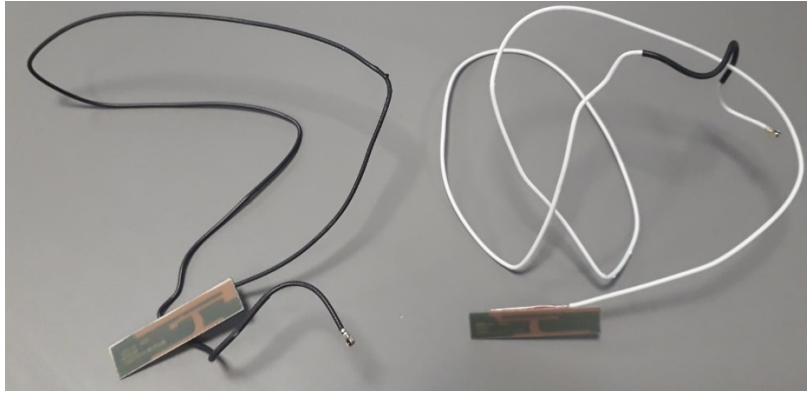
Figure 28: LAN antennas and their snap in connectors

Cooling System

The cooling system consists of: a fan, a heat sink, and a GPU cooling plate with connection to the heat sink. The fan is in close proximity of the GPU cooling plate, and the heat sink. It is connected through a connector directly to the motherboard. The set up of the cooling system is presented on Figure 29.
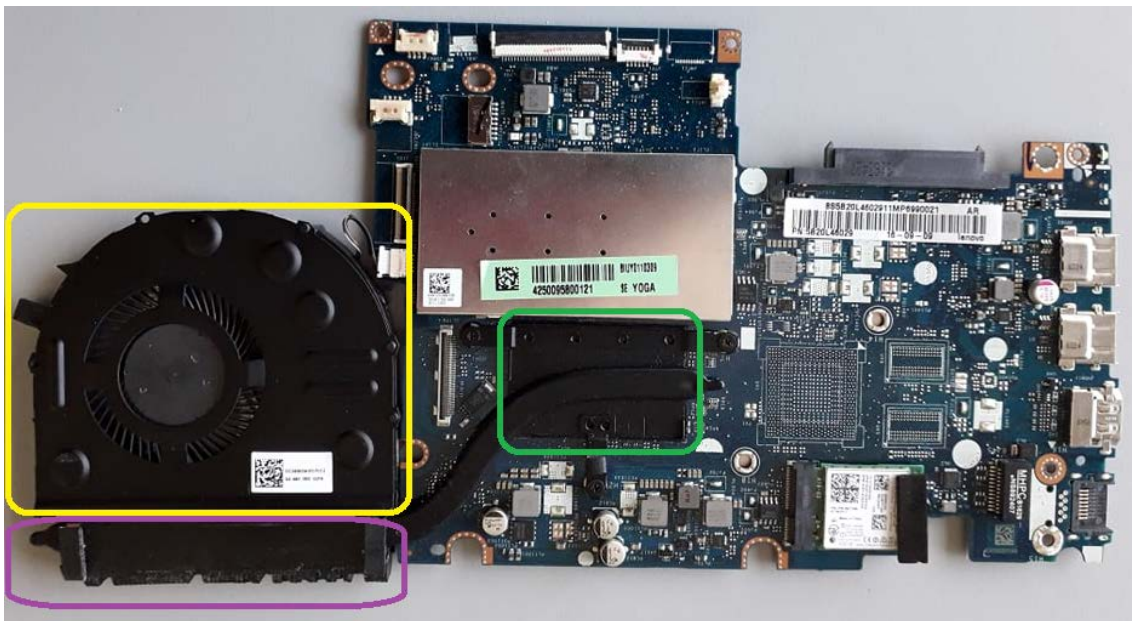
Figure 29: A cooling set up, from left: fan (yellow), heat sink (violet), GPU cooling plate (green)

Speakers

The speakers have 1 shared connector, which is directly connected to the motherboard. Both speakers and their connector are presented on Figure 30.

Figure 30: Speakers and their shared connector

LEDs

Two stripes of colourful LEDs with shared power connector are used for visual purposes (Figure 31). LEDs are powered through the USB connector attached to the motherboard.

Figure 31: Two stripes of LEDs and their power USB connector

3.1.1 Internal Design

The internal design of the PC case refers to positioning the electrical components inside the PC case. Attachments and locations, of all the components inside of the igloo dome. For the purpose of designing the PC case in SolidWorks, all the components were measured using callipers and based on the key dimensions they were drawn in the software.

All the electrical components: motherboard, SDD disk, fan, I/O module, speakers, power cord plug, LAN antennas, are rigidly attached to the 3D printed supporting structure. The set up is presented on Figure 32.
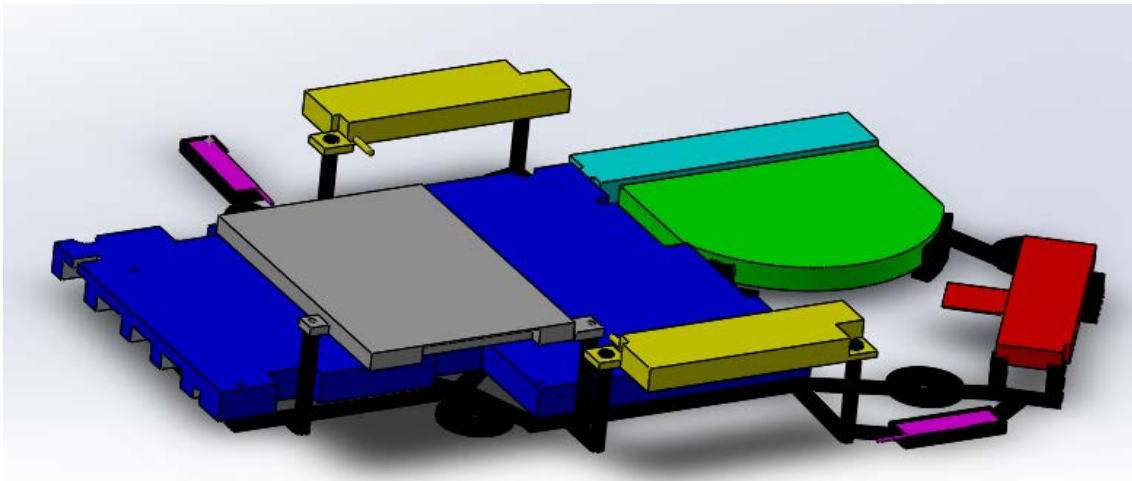
Figure 32: The setup of all electrical components: support structure (black), motherboard (dark blue), SDD disk (grey), speakers (yellow), fan (green), heat sink (light blue), I/O module (red), LAN antennas (pink)

The motherboard is located on the bottom of the PC case, with the I/O plate pointing to the igloo entrance. The motherboard is attached to the supporting structure with 5 M0 size bolts.

The I/O module is located above the motherboard, on the opposite side to the I/O plate. The I/O module is connected to the motherboard by flat ribbon cable. The I/O module is attached from its corner to the supporting structure with 1 M0 size bolt. The other side of the I/O module is placed on a corner support structure.

The fan is placed right next to the motherboard, it is directly connected to the motherboard. The fan is attached to the supporting structure by a tight fitting structure.

The SDD disk is placed above the motherboard, it is connected to the motherboard by a SATA extension cable. The SDD disk is attached to the supporting structure with 3 M0 size bolts. The power cord plug is placed next to the fan. It is attached to the supporting structure by a tight fitting structure for the connector. The speakers are placed on opposite sides of the PC case, they are connected directly to the motherboard by 1 shared connector. The speakers are attached to the supporting structure with a total of 4 mounting holes, 2 for each speaker.

3.1.2 External Design

The external design of the PC case refers to positioning of the features on the outer side of the PC case including locations and attachments of all the components of the igloo dome.

To lower the risk of braking away a plugged USB, the I/O plate of the motherboard was positioned pointing to the entrance of the igloo, so that any plugged in cable or device is protected from 4 sides from being destroyed due to lack of attention. A special shielding structure was design on the dome: a rectangular cut out for the I/O plate with walls extending into the PC case, to prevent dropping of small objects inside of the PC. Same shielding solution was applied to the I/O module on the back of the igloo: the hole for accessibility is secured with walls protecting from dropping of objects into the PC case. The cut outs are marked in red in Figure 33.
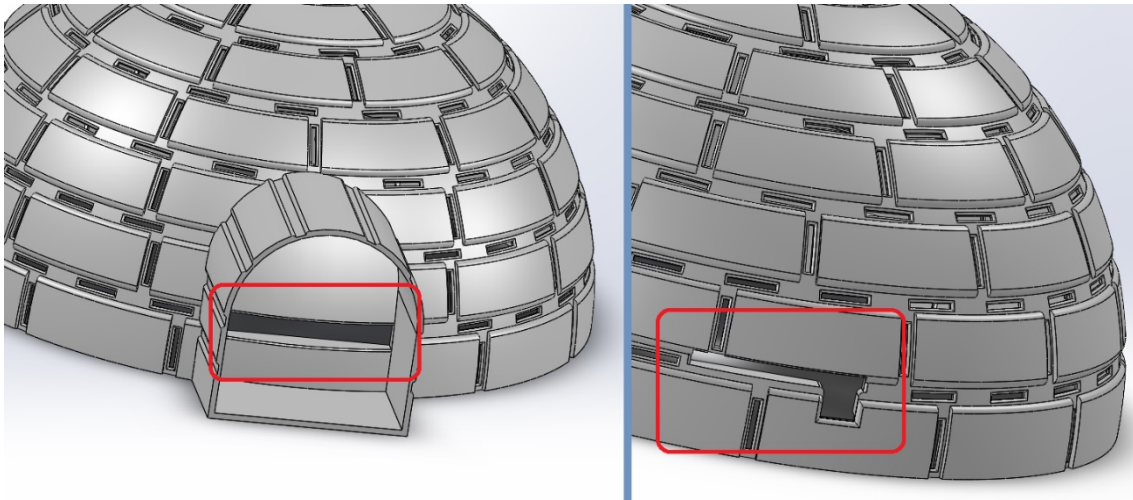
Figure 33: Front cut out (left), and rear cut out (right)

3.2 3D Printing

The parts will be manufactured using two MakerBot Replicator 5th Generation 3D printers, which are available in Arcada University of Applied Sciences. The printing material is PLA, the maximum printing volume is 25 cm L × 20 cm W × 13 cm H.

The igloo's dimensions are 34,4 cm diameter and 17,5 cm height. The greatest dimension of 39,2 cm is between the back wall and the entrance of the igloo. The PC case is too big to be printed in one piece. The igloo model is divided into 10 CAD parts (Figure 34). Each part will be printed separately, and the igloo will be assembled afterwards.
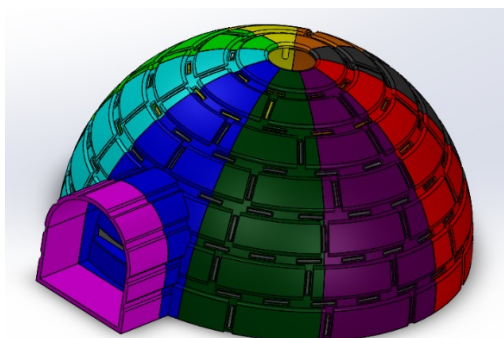
Figure 34: the assembly of the igloo, consisting of 10 pieces: 9 dome pieces and 1 entrance piece (pink)

In order for easier assembly process afterwards, each of 10 parts was modified. A set of poles and holes was created on each piece (Figure 35).
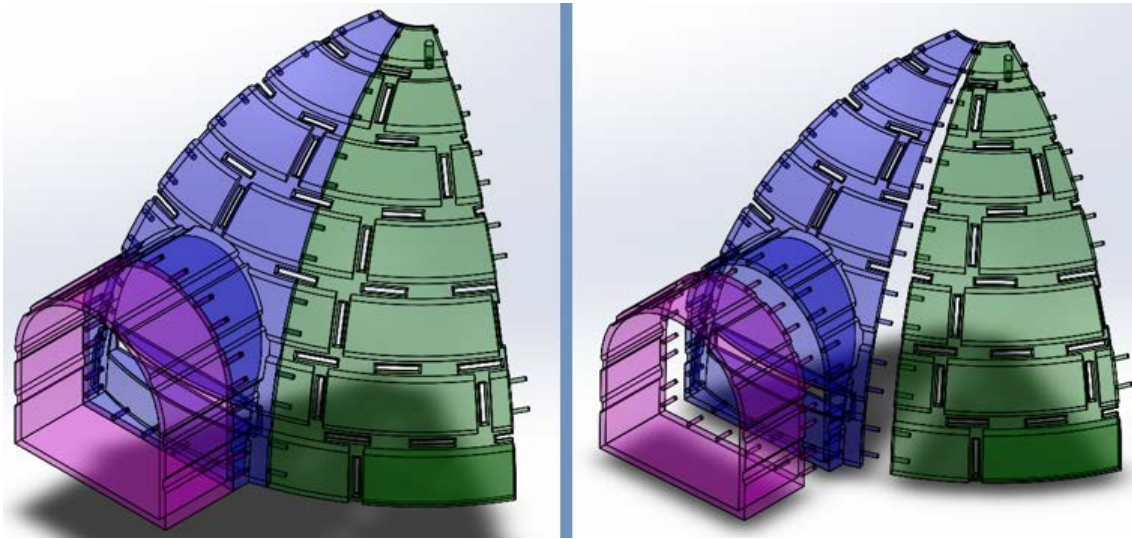
Figure 35: A sample connection between the pieces of the igloo

The support structure is 25,3 cm wide, 30,3 cm long, and 3,5 cm tall, it is too big to be printed in one piece. The model of the support structure is divided into 2 parts (Figure 36), which will be printed separately and assembled afterwards.
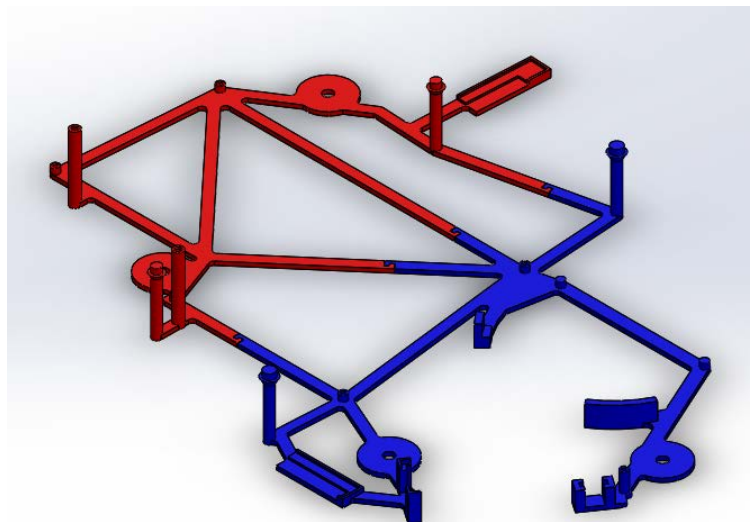
Figure 36: The assembly of 2 pieces of the support structure, part SDD (red) and part FAN (blue)

3.2.1 Materials

The material used for 3D printing the PC case is white PLA, 1,75 mm diameter. It is compatible with the MakerBot Replicator 5th Generation 3D printer. PLA material for 3D printing is rolled on a spool (Figure 37). Compared to ABS, PLA can be printed without heated build plate, as there is less curling and wrapping of the part. With the use of PLA sharp corners and small details can be printed without problems, the surface of the printout will in general have a glossier feel and look. (MakerBot)
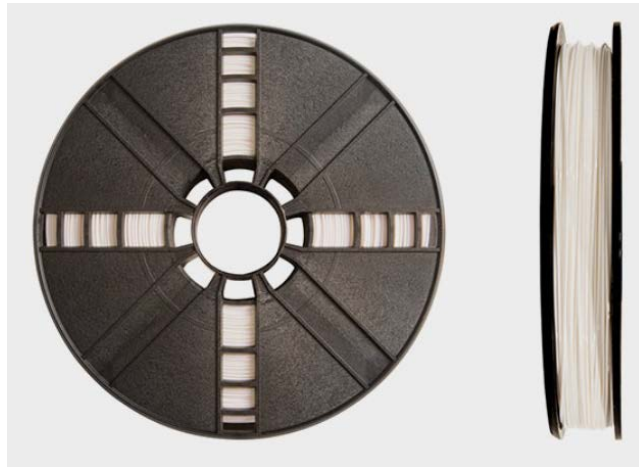
Figure 37: A roll of white PLA filament for 3D printing (MakerBot)

3.2.2 Time Analysis and Quality

Time of the printing can vary, depending from preferred properties of the end product. Usually, the faster the printing the poorer the quality. In this case quality is an important factor, although it should be balanced with printing time. The parts requiring the most precision are LED attachment, switch support, and the support structure. Those designs include small attachment points, where even a slightest offset created during 3D printing might result in unfunctional structures.

3.2.3 Parameters of Printing

Igloo

The igloo was printed in 10 pieces: 9 dome parts (Figure 38) and 1 entrance part (Figure 39). The parameters of printing are set same for all 10 elements: Infill 20%,

material PLA, support infill 20%. The times varied slightly between the 9 pieces, but were oscillating around 8h, predicted material use per part is 70 g. The 10th part, the igloo entrance, takes 5h 16min and 55 g of filament to 3D print.
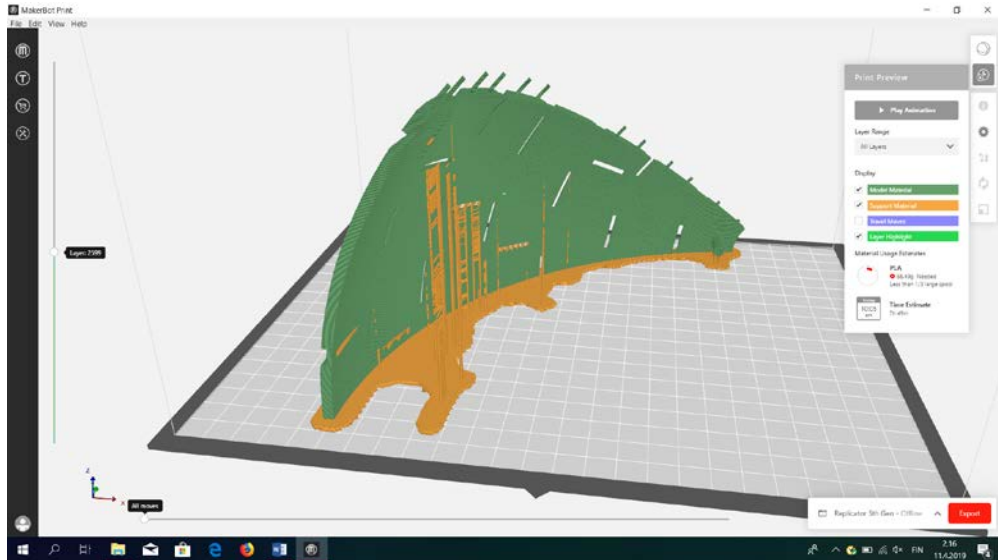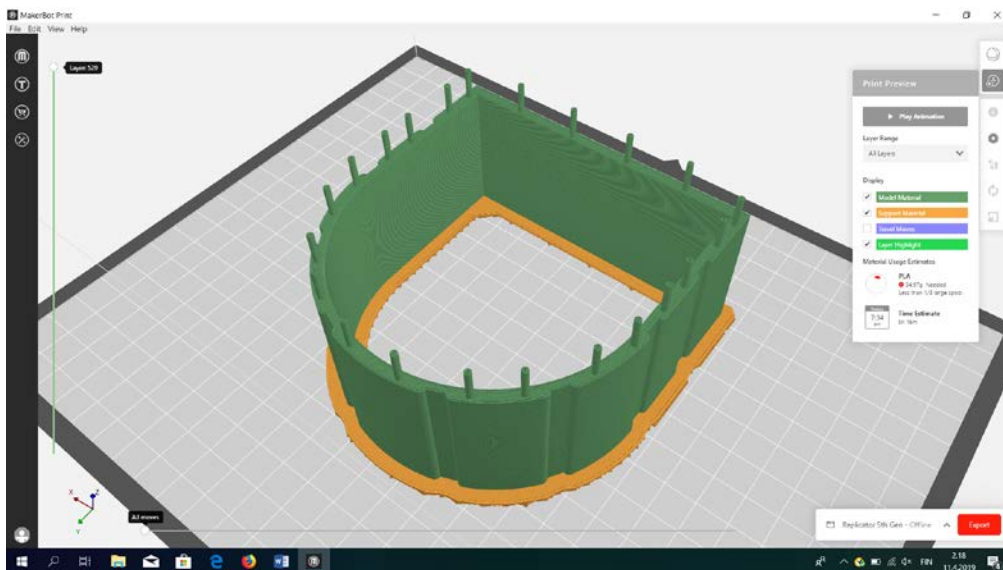

Figure 38: 1 out of 9 dome parts

Figure 39: The entrance part

Support Structure

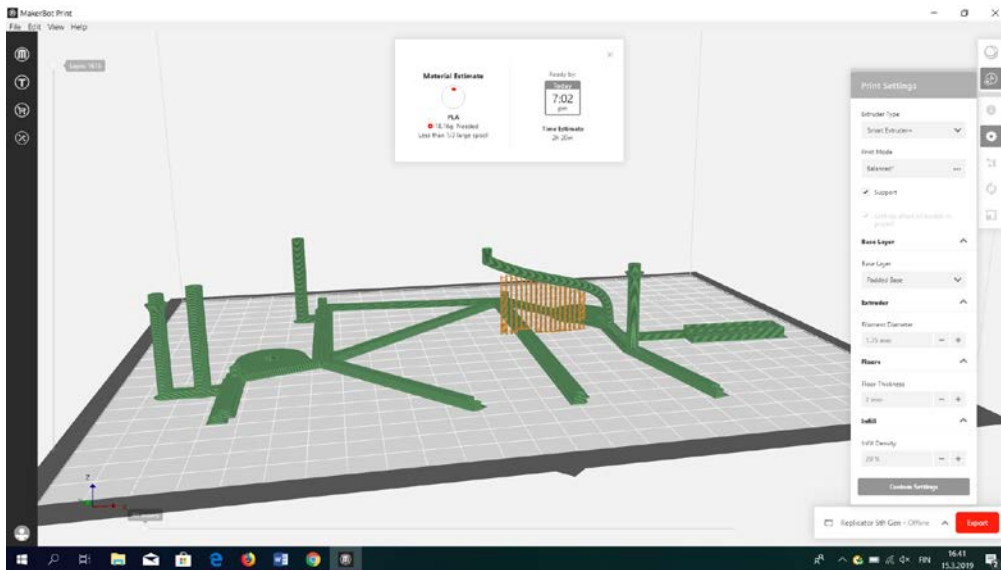The support structure was printed in 2 pieces: Part FAN and Part SDD (Figure 40).

Figure 40: Part SDD of the support structure (green), support for overhangs (orange)

The parameters of printing are set same for both elements: default print mode- balanced, base layer- padded base, infill 20%, floor thickness 2 mm, roof thickness 0,8 mm, support angle 68 deg, support density 20%, support to model spacing 0,4 mm. Printing time for each part is 2h 30min, predicted filament use is approx. 20 g. Both parts were printed on MakerBot Replicator 5th Generation 3D printer (Figure 41).

Figure 41: Part FAN and Part SDD during 3D printing

Power Button Structure

The power button structure, both the LED support and the switch attachment have good quality, they are fully functional, no optimization is necessary (Figure 42).
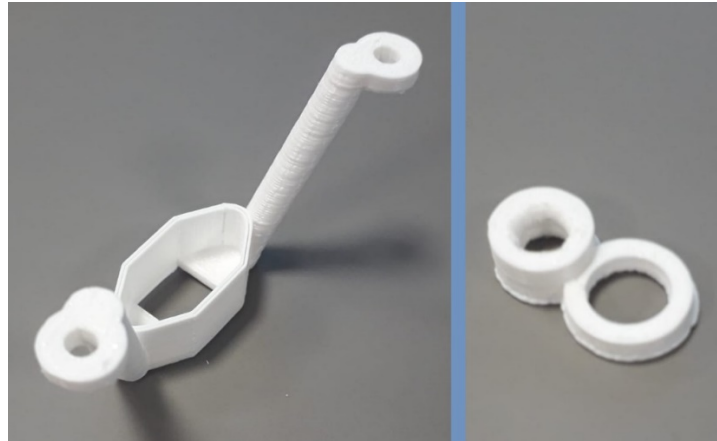
Figure 42: 3D printed switch attachment (left), and LED support (right)

3.2.4 Optimization

Igloo

All the igloo parts have good or acceptable quality, there were no problems during 3D printing. Optimization is not needed, the pieces are fully functional and esthetical. All 10 parts are presented on Figure 43.

Figure 43: All 10 parts of the igloo casing

Supporting Structure

The quality of the Part FAN is satisfactory, the 3D print is fully functional. Slight wrapping of the material occurred but it does not affect the final geometry of the structure at its most important parts, the tight fitting corner gap for the I/O module keeps its desired shape and properties, no displacement nor misalignment of the material occurred on the top of the structure, the wrapping is present only on the first layers of the 3D print (Figure 44).
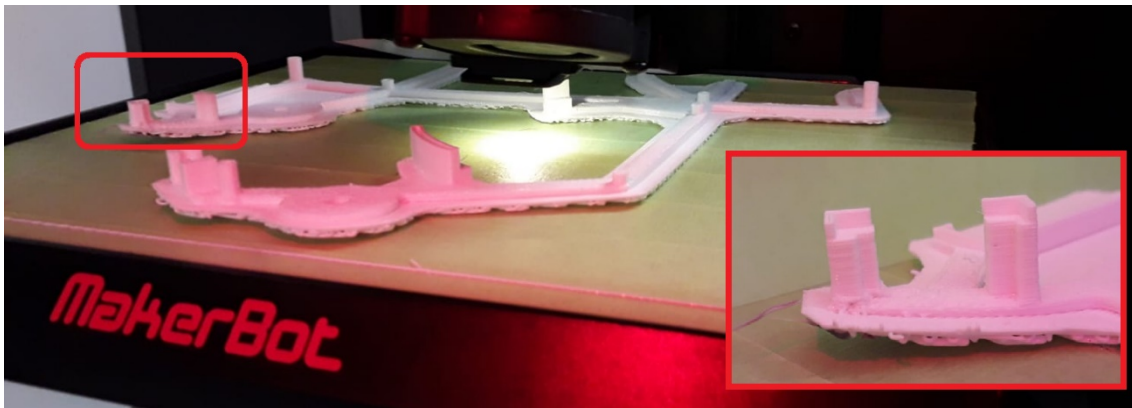
Figure 44: Slight wrapping of the Part FAN of the supporting structure (highlighted in red)

Part SDD has slightly different geometry, it has 3 long and thin elements, which were wrapping more than it is acceptable (Figure 45). Due to that, the base layer was changed from Padded Base to Raft, which should provide more support for the 3D print. The rest of the parameters remains unchanged. The new printing time for the Part SDD is 3 h 22 min, predicted filament use is 33,91 g.

Figure 45: Wrapping of the Part SDD of the supporting structure (highlighted in red)

With changed settings, the 3D print of Part SDD has grater quality, slight wrapping still occurred, probably due to part's geometry (Figure 46). This time the wrapping does not affect the functionality of the 3D print.
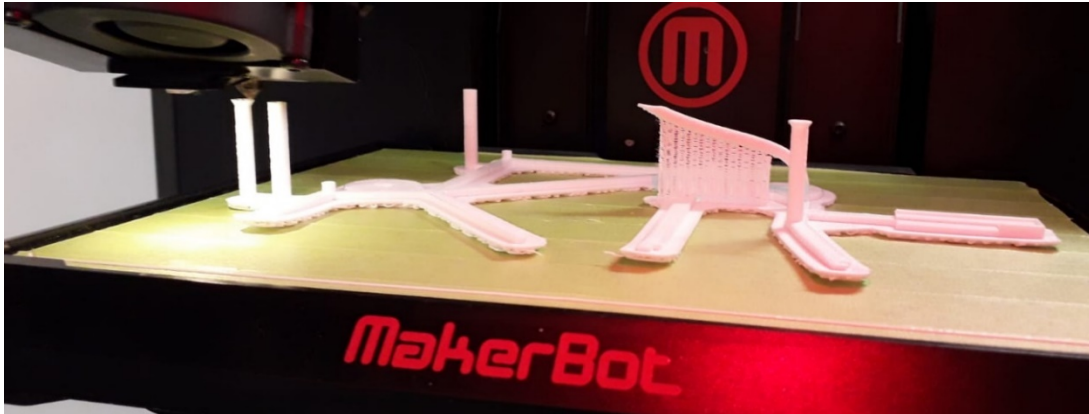

Figure 46: 3D printed part of the supporting structure, the Part SDD

3.3 Assembling

3.3.1 Igloo

The raft base and the supports were first removed from all the 10 parts of the igloo. Then, any surface imperfections were smoothened with sandpaper: first with P100 and then for finish P240 (Figure 47).

Figure 47: An example of improvement of the surface quality: before sanding (left), after sanding (right)

Some of holes turned out clogged with the support material or they had imperfect circular shape. The reason for that can be the geometry of the parts, as in the SolidWorks design the holes are only 2,3 mm in diameter. Moreover, the diagonal positioning of the holes was not the most optimal for the 3D printer. Additive manufacturing has its limitations, thus some small details might not always look perfect and might not be fully functional, post processing is needed in this case. To improve and ease the assembling process, the imperfect holes were drilled with 2 mm drill (Figure 48).
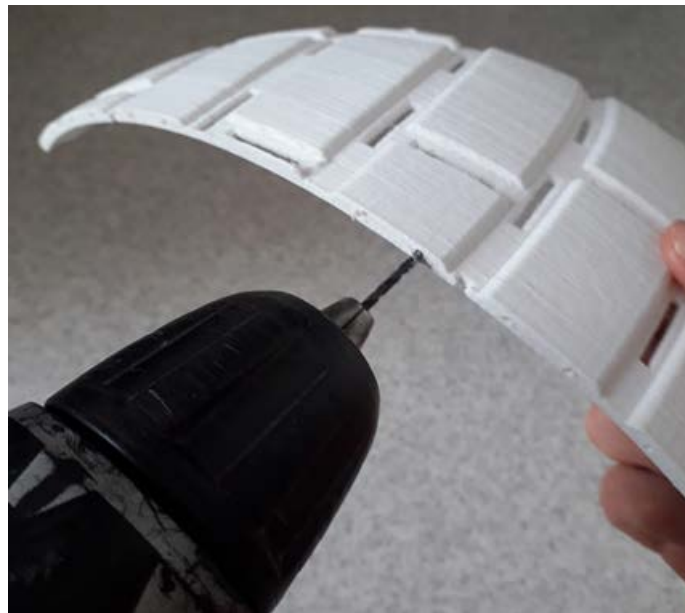
Figure 48: The holes in the parts of the igloo drilled with 2mm drill

Some of the poles turned out to have imperfect circular shape and/or have a bulky head, thus they were not fitting to the holes of the system. This might be caused by the geometry of the part, as in SolidWorks design the poles have 2 mm diameter and diagonal positioning. 3D printing has its limitations and some small details might sometimes not be fully functional and might not look perfect, post processing is required in this case. To ease and improve the assembling process, the mis-shaped poles were cut shorter with the cutting pliers, so that the imperfections are removed from the part, several of the poles accidentally broke during post processing (Figure 49).
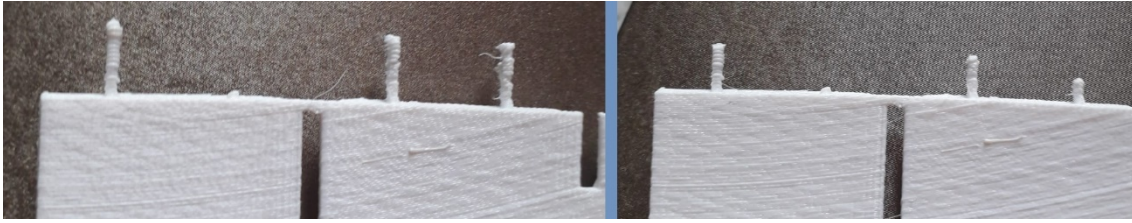
Figure 49: An example of shortening of the imperfect poles in the igloo part: poles with imperfections before cutting (left), shortened poles with better overall geometry (right); a broken pole is visible on both sides

The igloo is firstly assembled without glue, to ensure that all the parts are fitting together and everything is as it is supposed to be. The entrance is attached to the front part, and then parts are added until the dome is complete. After ensuring that all the elements fit well, the whole structure is glued with Loctite SuperGlue, according to the instructions given by the manufacturer. To ensure ease of possible maintenance the entrance of the igloo is not glued to the dome, it is attached only with the poles and holes system, so that it can be easily dismantled if needed. The ready glued igloo is presented on Figure 50.
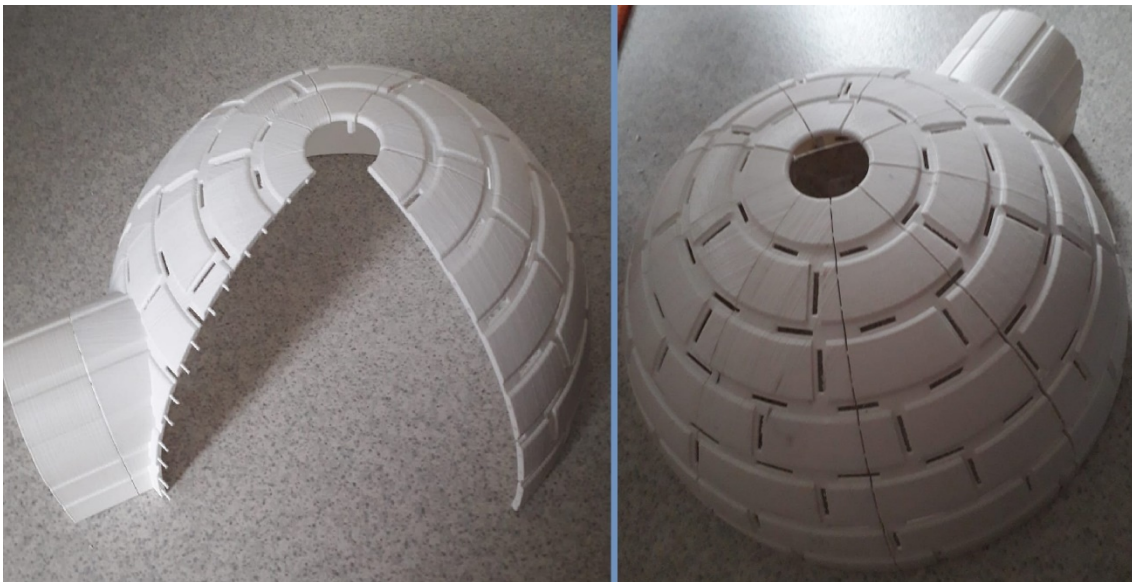
Figure 50: The process of assembling the igloo from 10 parts (left), and the ready glued igloo (right)

3.3.2 Supporting Structure

First, the supporting structure is assembled, and all electrical components are rigidly attached to the 3D printed supporting structure with bolts, tight fitting corners, or poles for holes with rubber. The motherboard is attached to the supporting structure with 5 M0 size bolts. The fan is placed right next to the motherboard, it is attached to the supporting structure by a tight fitting structure. The SDD disk is attached to the supporting structure with 3 M0 size bolts. The I/O Module is attached to the supporting structure with 1 M0 size bolt and a tight fitting corner structure. The speakers are attached to the supporting structure with a total of 4 mounting holes, 2 for each speaker. LAN cards are attached by tight fitting structures. The power button is attached on the top of the igloo, it is connected to the original power button on the motherboard. The ready setup of all electrical components is presented on Figure 51.
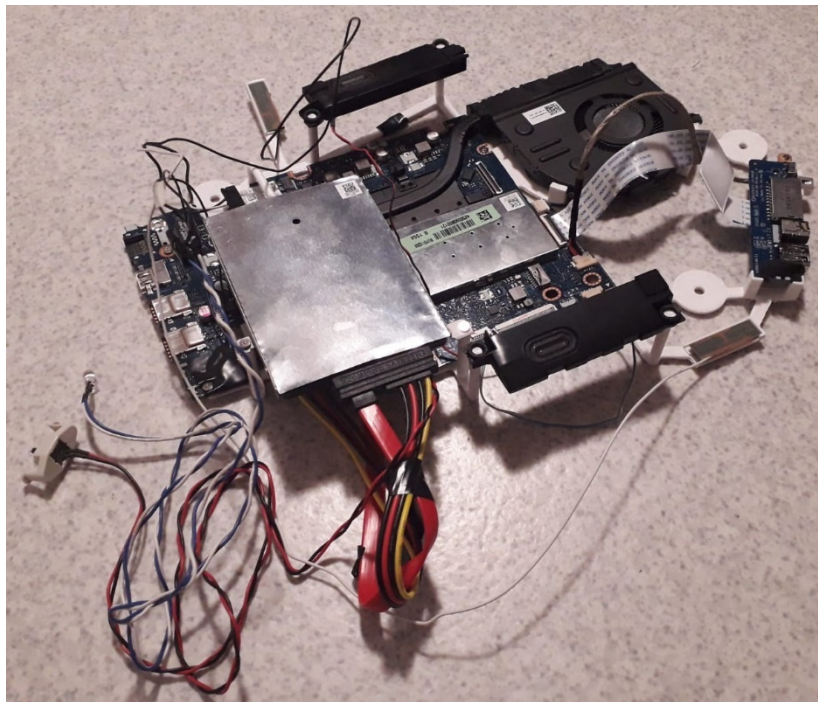
Figure 51: The assembly of all electrical components on the 3D printed
supporting structure

3.3.3 Power Button

Firstly, the LED support was mounted on the plastic button, then the LED was attached to the structure. The switch was placed inside the mounting structure and it was screwed to the 2 poles on the inner side of the igloo with 2 bolts. The springs release the button to its original position, making it possible to push it again. The ready assembly of power button is presented on Figure 52.

Figure 52: Ready assembly of the power button

3.3.4 Final Assembly

The ready set up of the electrical components is attached to the bottom plate with 4 M4 size bolts, 4 M4 size nuts, 8 washers sized 5×15, and 8 washers sized 8×24. Ready assembly of the bottom plate and the support structure is presented on Figure 53.
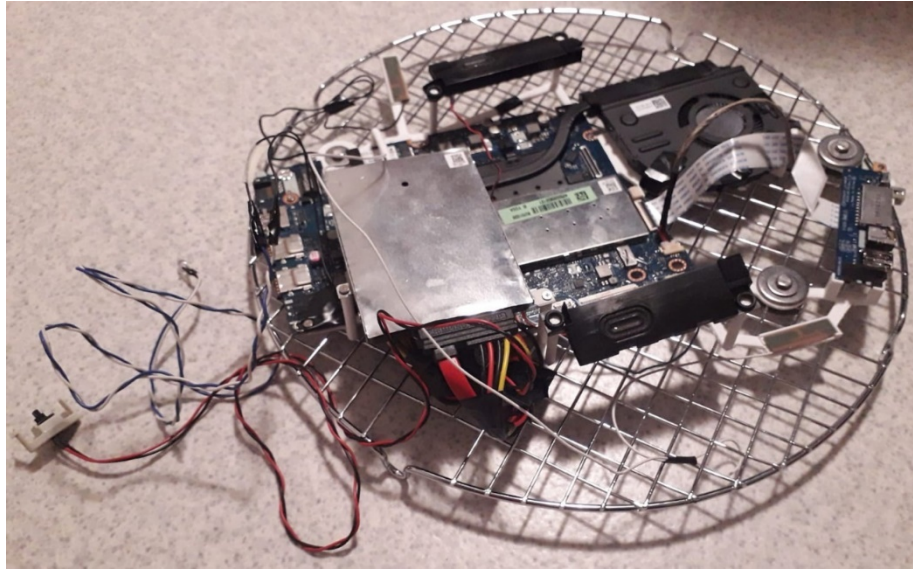
Figure 53: Ready assembly of the electrical components on the support structure attached to the bottom plate

The bottom plate with electrical components is then covered with the igloo casing. Special attention needs to be paid while placing the I/O plate in the entrance of the igloo, and the I/O module in the cut-out in the back of the igloo casing (Figure 54).

Figure 54: Positioning of the I/O plate (top) and I/O module (bottom) in the cut outs of the igloo casing

Then 2 stripes of LED lights are installed inside the dome of the igloo. They are attached to the walls with double sided mounting tape. The USB cable, which is the power of the LED lights, is connected to the USB slot in the entrance of the igloo (Figure 55).

Figure 55: The USB power plugged to the USB slot in I/O plate

Lastly, the charger is connected. The ready-made PC case with all the components assembled is presented on Figure 56.

Figure 56: A ready assembly of the desktop PC

4 RESULTS

4.1 Stress Analysis

All the simulations of the 3D printed parts are described in details in this chapter. The summary of stress analysis is presented in Table 1.

Table 1: Summary of stress analysis of the 3D printed components of the PC case

	strain (no unit)		stress (Pa)		displacement (mm)		factor of safety	
	min	max	min	max	min	max	min	max
igloo dome	$5{,}512*10^{-11}$	$3{,}981*10^{-5}$	$2{,}665*10^{-1}$	$2{,}181*10^{5}$	$1{,}000*10^{-30}$	$5{,}710*10^{-3}$	$3{,}210*10^{2}$	$2{,}627*10^{8}$
support structure: top	$3{,}083*10^{-14}$	$4{,}680*10^{-4}$	$1{,}002*10^{-4}$	$2{,}382*10^{6}$	$1{,}000*10^{-30}$	$6{,}483*10^{-3}$	$2{,}938*10^{1}$	$6{,}989*10^{11}$
support structure: cable	0	$1{,}445*10^{-4}$	0	$7{,}519*10^{5}$	$1{,}000*10^{-30}$	$3.495*10^{-3}$	$9{,}310*10^{1}$	$1{,}000*10^{16}$

Stress is the pressure in the material in response to applied load. If the Von Mises Stress is greater than the yield strength, then the material will yield. Strain is a change in length under applied force over the original length. Factor of safety (FOS) refers to strength of the product. If FOS is equal to 1, it means that the object is at breaking point. If factor of safety is equal to 2, it means that the object would break if the force would be doubled.

The yield strength for PLA is $7*10^{10}$ N/m^2. All the maximum stresses are smaller than the yield strength of the material, and the minimum factors of safety are higher than 1, meaning that both the products are strong enough and they will not break or yield under the load of 10 N.

4.1.1 Igloo

The SolidWorks simulation was run with 10 N (equivalent of 1 kg) applied on the top of the igloo, the fixture was set on the bottom of the igloo (Figure 57). The yield strength for PLA is $7*10^{10}$ N/m^2 and the maximum stress is $2,181*10^5$ N/m^2. The maximum stress in the igloo is smaller than the yield strength, meaning that the igloo can withstand the load of 10 N without breaking. The maximum strain is $3,981*10^{-5}$, and the maximum displacement is $5,710*10^{-3}$ mm. In this particular design the displacement of 0,006 mm is negligible, as there is nothing touching the igloo walls that could break under the dome. The results of Von Mises Stresses and equivalent strain (ESTRN) are presented on Figure 58 and Figure 59 respectively. The displacements in the assembly are presented on Figure 60.
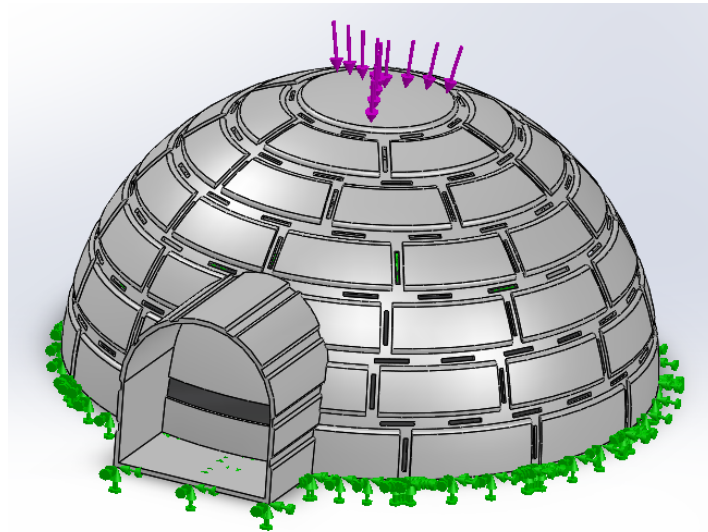
Figure 57: The force of 10 N is applied on top of the igloo
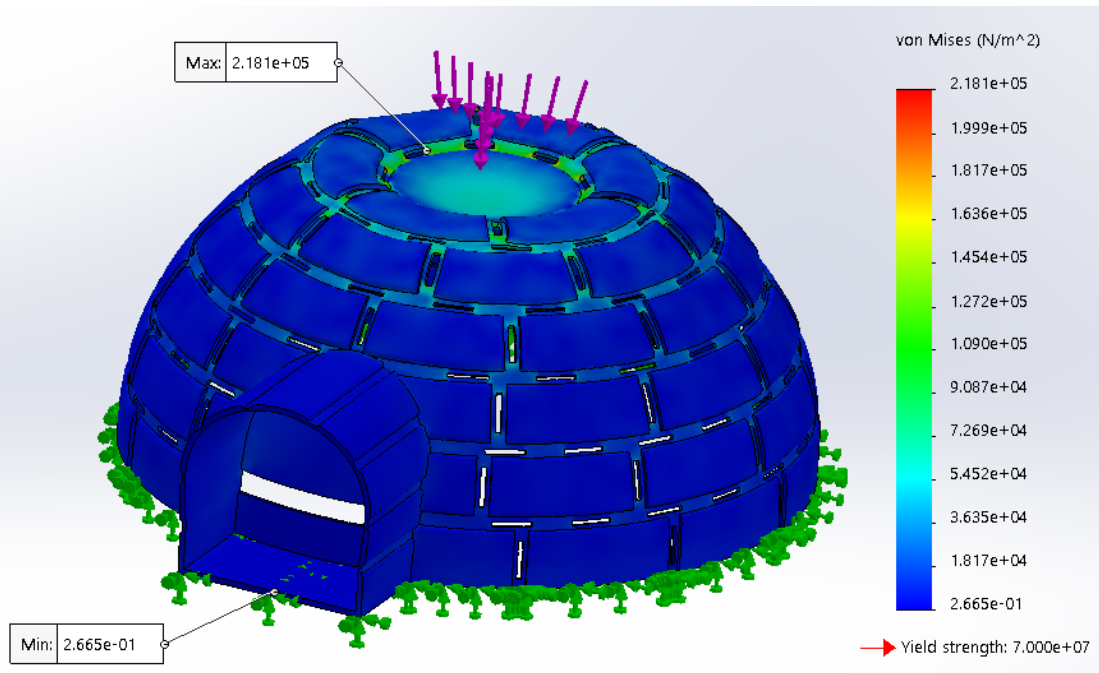
Figure 58: Von Mises Stresses in the PC case under 10 N
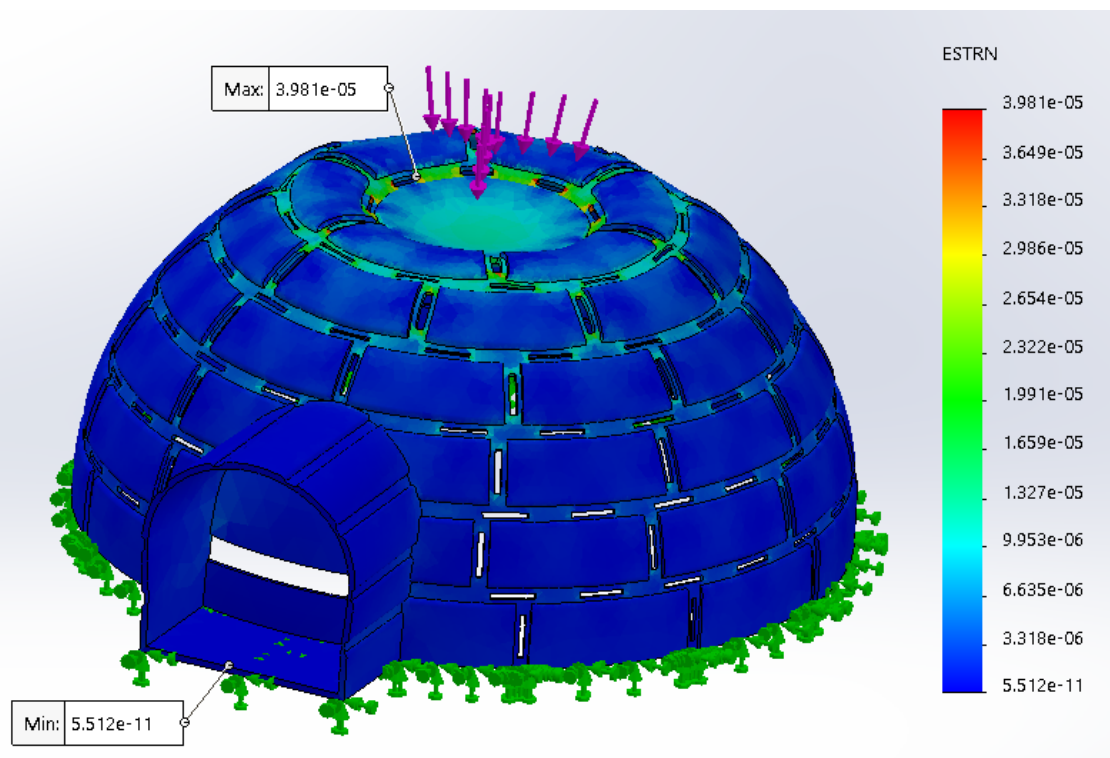
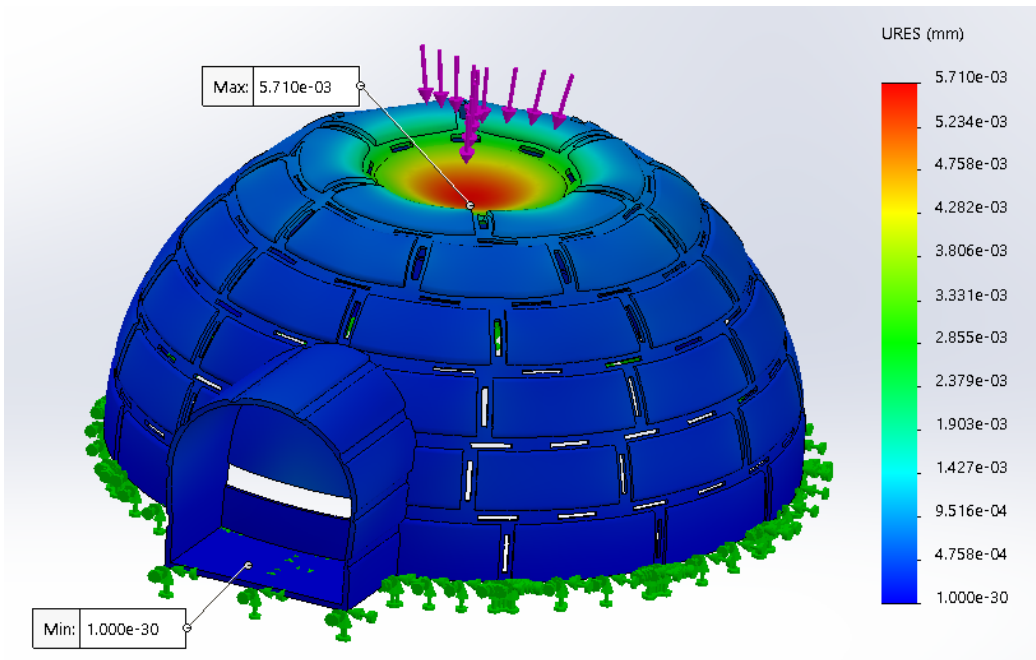Figure 59: Equivalent strains (ESTRN) in the PC case under 10 N

Figure 60: Displacements in the PC case under 10 N

In the igloo design the minimum value of factor of safety under 10 N load is 321, and the maximum value is $2,627*10^8$, both those numbers are greatly larger than 1, meaning that the PC case can stand at least 10 N, and theoretically up to even 3210 N. Distribution of factor of safety in the PC case is presented on Figure 61.
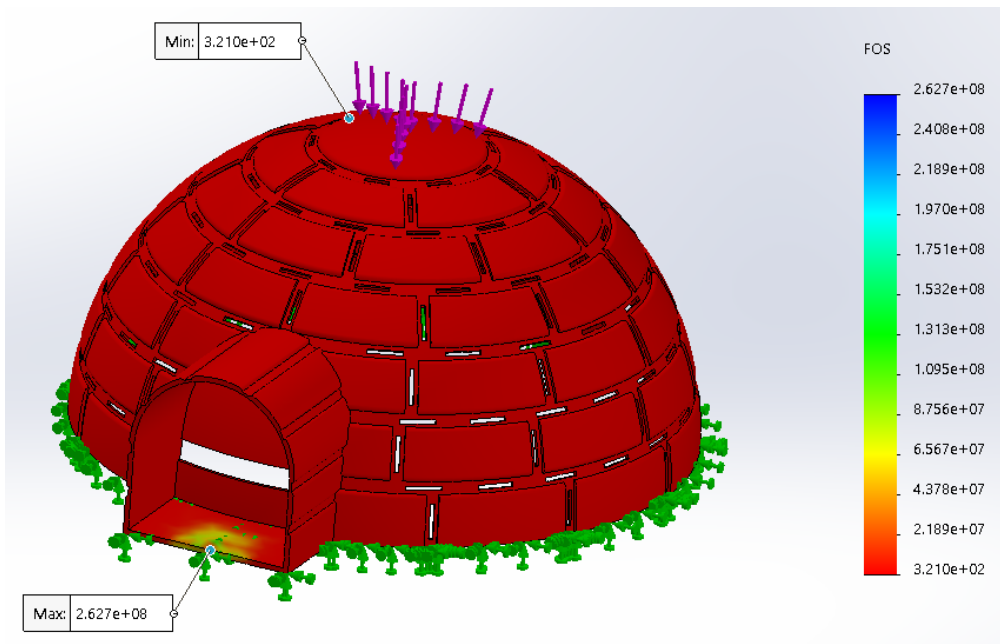

Figure 61: Distribution of factor of safety (FOS) in the PC case under 10 N

4.1.2 Support Structure

The SolidWorks simulation was performed on the support structure. There were 2 simulations: imitating the weight of the electrical components connected to the support structure, and imitating plugging the charger in and out. For both simulations the fixture was set on the bottom of the supporting structure.

The simulation imitating the total weight of all the electrical components was run with 10 N applied on the top of the structure (Figure 62). Maximum stress is $2,382*10^6$ N/m^2. The maximum stress is smaller than the yield strength ($70*10^{10}$ N/m^2), which means that the support structure can withstand the load of 10 N without breaking. The maximum strain is $4,680*10^{-4}$, and the maximum displacement is $6,483*10^{-3}$ mm. The displacement can be neglected in this design, as it is relatively small and does not affect the functionality of the PC case. The results of Von Mises Stresses and equivalent strain (ESTRN) are presented on Figure 63 and Figure 64 respectively. The displacements in the assembly are presented on Figure 65.
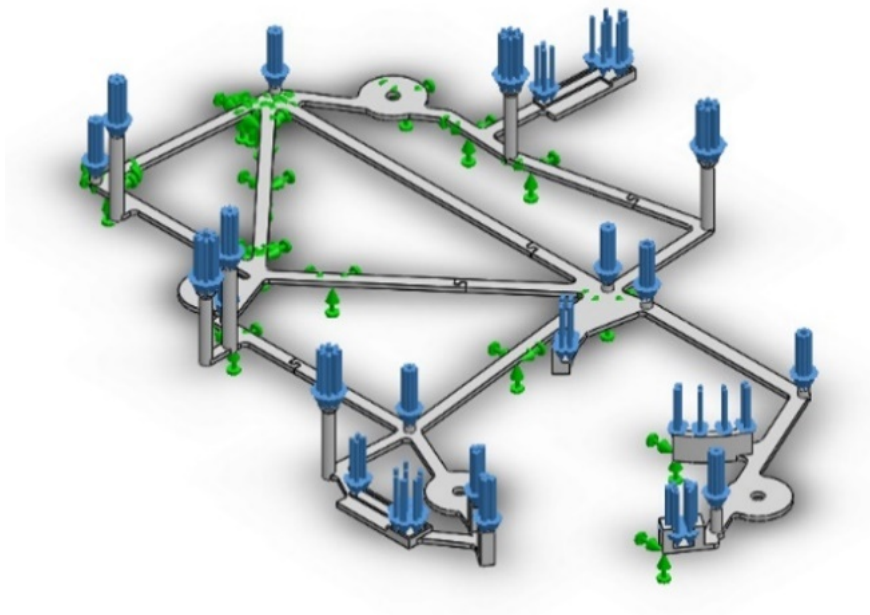

Figure 62: The force of 10 N was applied on top of the support structure
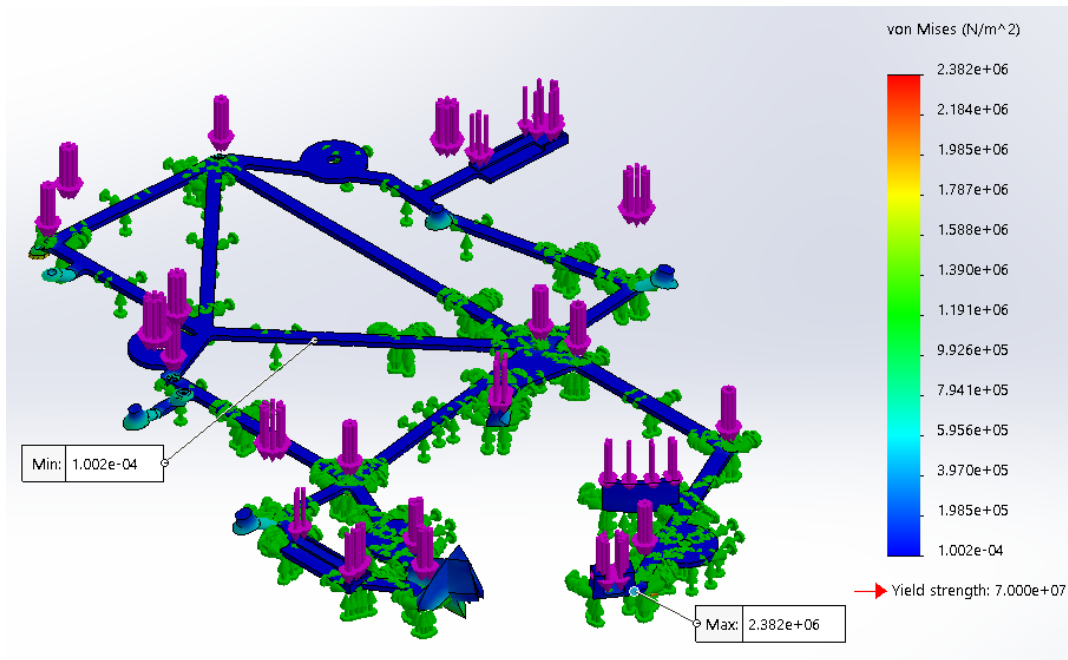
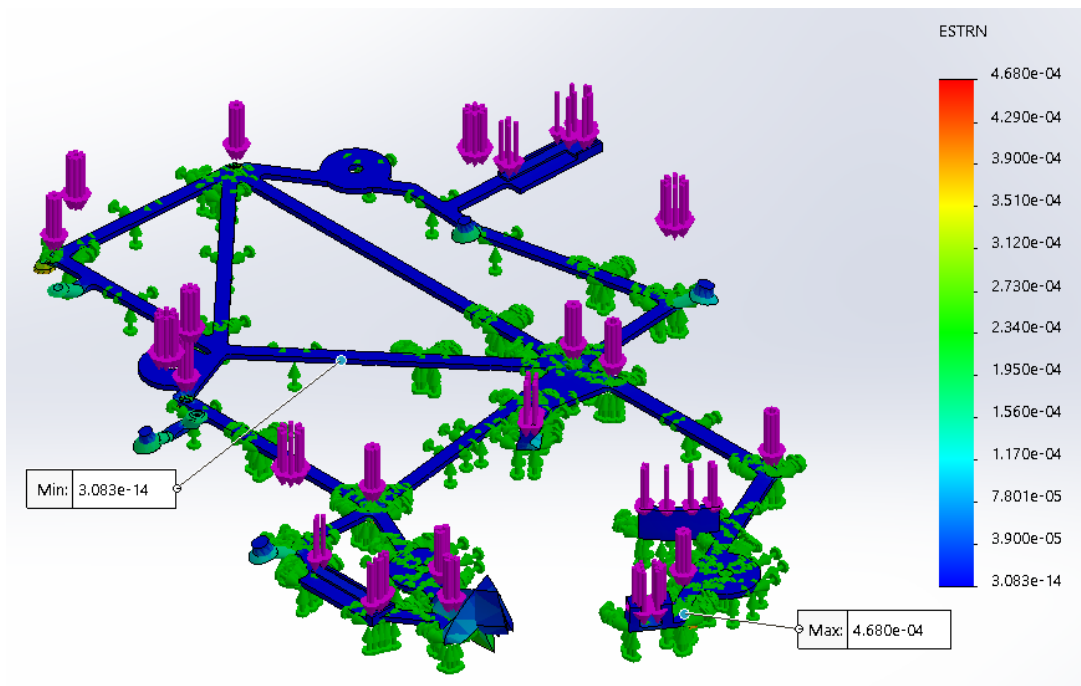Figure 63: Von Mises Stresses in the support structure under 10 N

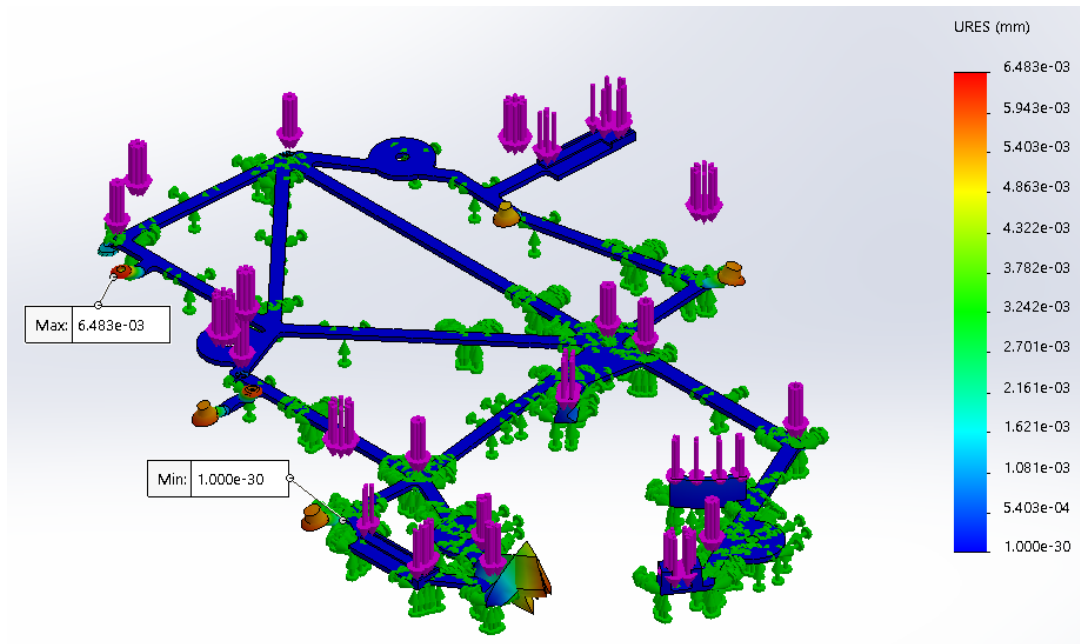Figure 64: Equivalent strains (ESTRN) in the support structure under 10 N

Figure 65: Displacements in the support structure under 10 N

Under the load of 10 N the factor of safety oscillates between 29,38 and $6,989*10^{11}$ (Figure 66), meaning that the support structure could theoretically stand up to 29,38 times more load.
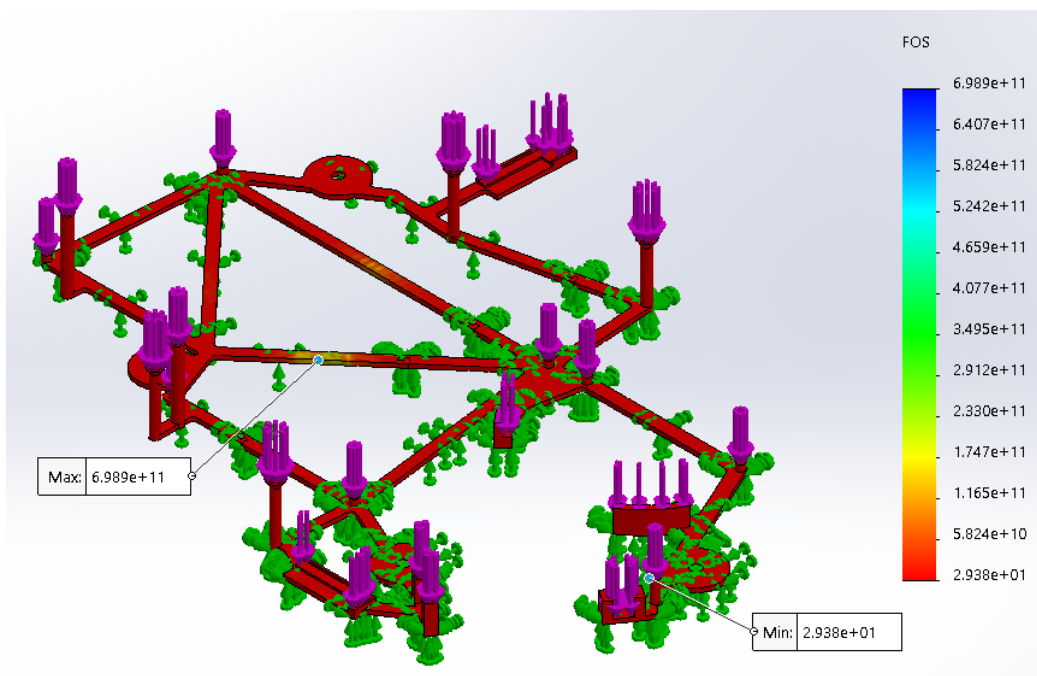

Figure 66: Distribution of factor of safety (FOS) in the support structure

The simulation imitating plugging the cables in and out was run with 10 N applied to the power plug mounting (Figure 67). Maximum stress is $7,519*10^5$ N/m^2. The maximum stress is again much smaller than the yield strength ($70*10^{10}$ N/m^2), meaning that the support structure can withstand the load of 10 N without breaking. The maximum strain is $1,445*10^{-4}$, and the maximum displacement is $3.495*10^{-3}$ mm. Once again, the maximum displacement is so small that it can be neglected in this design. The results of Von Mises Stresses and equivalent strain (ESTRN) are presented on Figure 68 and Figure 69 respectively. The displacements in the support structure are presented on Figure 70.
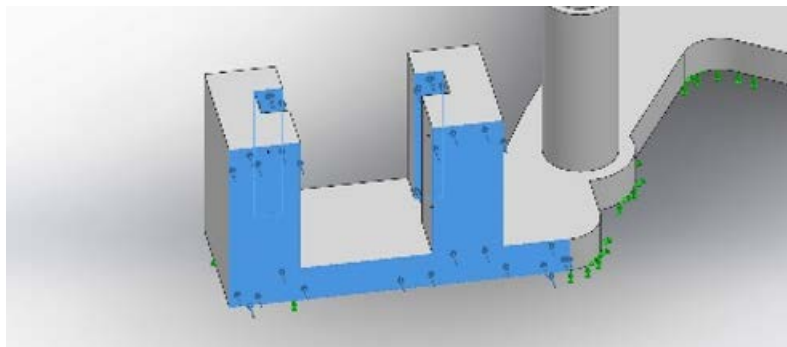

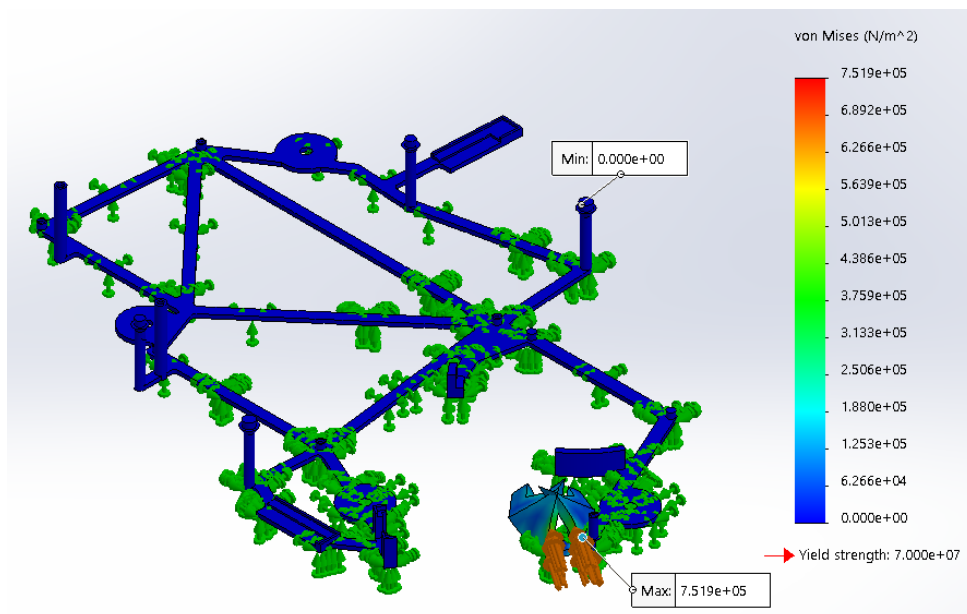Figure 67: The force of 10 N was applied to the power cord plug mounting structure

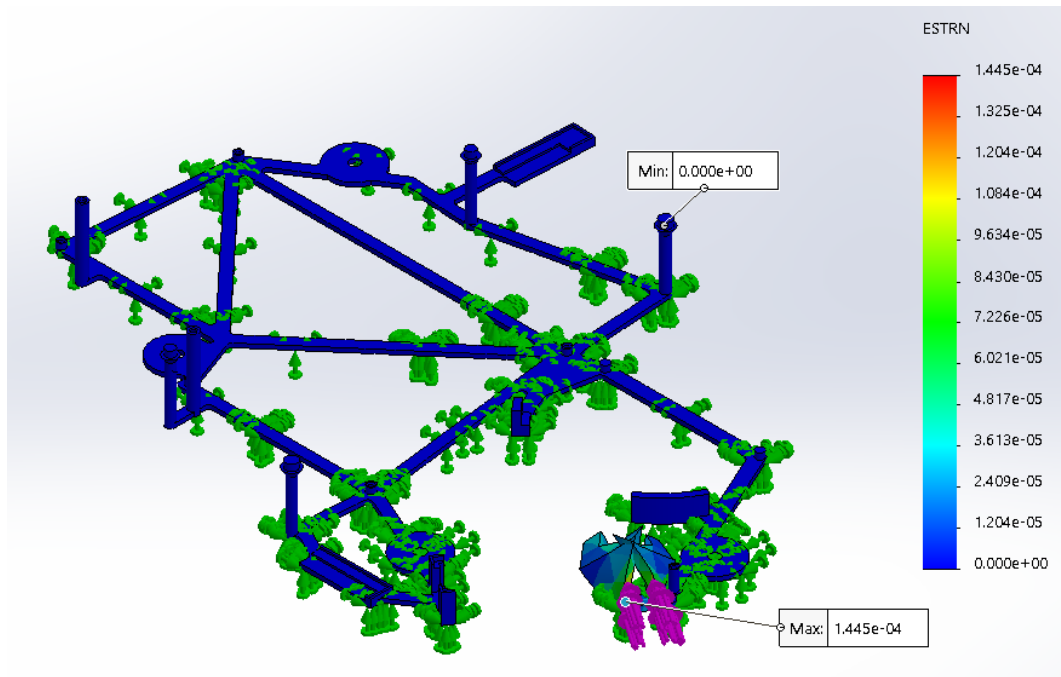Figure 68: Von Mises Stresses in the support structure under 10 N

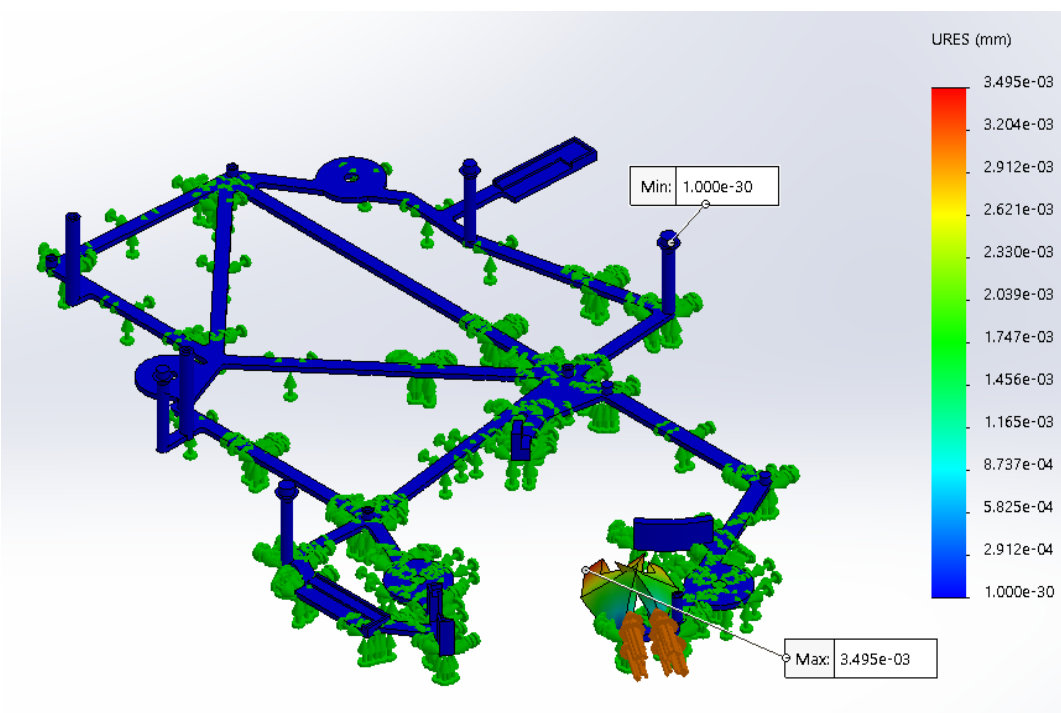Figure 69: Equivalent strains (ESTRN) in the support structure under 10 N

Figure 70: Displacements in the support structure under 10 N

The factor of safety in the support structure under 10 N load varies between 93,10 and $1,000*10^{16}$ (Figure 71), which means that the part could theoretically take up to 93,10 times more force before breaking.
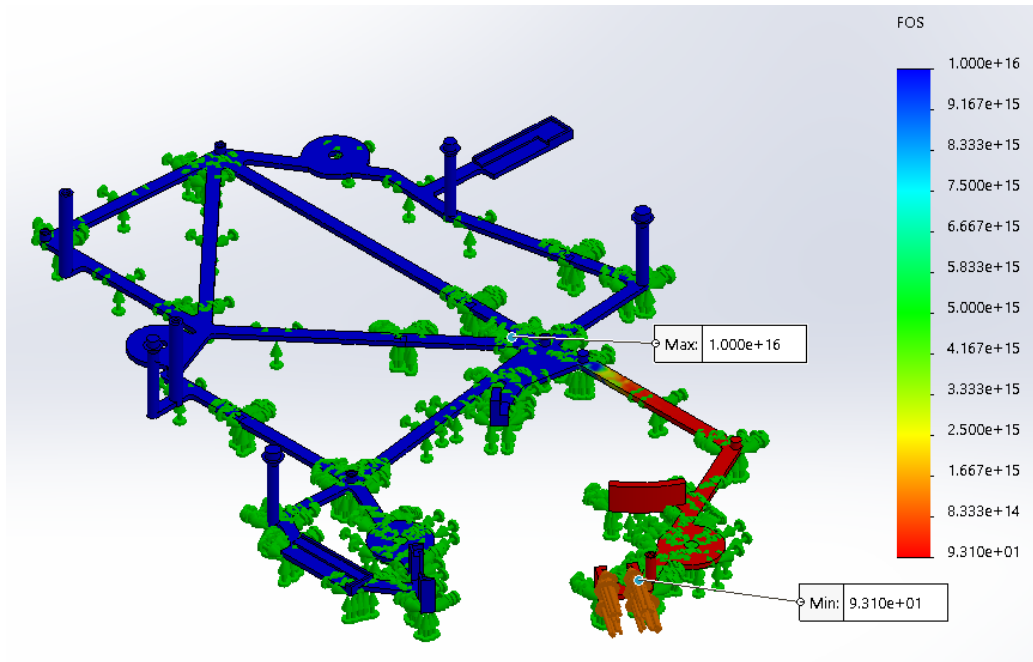
62

Figure 71: Distribution of factor of safety (FOS) in the support structure

4.2 Functionality

To check the functionality of the desktop PC, it is connected by a HDMI cable to a screen. The PC is then turned on by pressing the power button (Figure 72).

Figure 72: Checking the functionality of the desktop PC

5 DISCUSSION

As a result of this thesis study, a PC case was designed, manufactured, and assembled, for the purpose of reusing a not fully functional laptop as a desktop computer. Several design aspects could have been done better, but the overall outcome has good mechanical and visual properties.

The stress analysis of the PC case showed that the igloo dome as one solid object could theoretically withstand up to 321 kg. Although due to its size and limitations of 3D printing, the igloo was assembled from 10 pieces, which could affect the real strength of it.

Both cut outs in the igloo casing are bit offset from the electrical components. Although, they still shield the inner components form dust and small object dropping into the PC case, and make the I/O plate and I/O template accessible for plugging in external devices (like USB or headphones). One option would be to drill the cut outs last, after physically positioning the computer parts in the PC case and converting the dimensions to the igloo walls, and based on that drilling the cut outs.

The small geometry parts, especially the poles and the holes had some imperfections. This system was very helpful while gluing the igloo parts together, as it was guiding the gluing surfaces and keeping the structure of the igloo in shape. Although, the system could be implemented with greater dimensions or with redesigned geometry, so that the 3D printing limitations do not affect the functionality of the readymade part, and the whole assembly.

The supporting structure turned out to be quite flexible part, although it is still fully functional. From one hand the flexibility eased the assembling process, but from the other hand the 3D print is not as strong as it could be, some rapid shock or impact could perhaps destroy it and as a result possibly also harm other computer components. As a stable and not portable desktop PC it is a strong enough structure, which is the most important concern in this case.

6 CONCLUSIONS

During this project a desktop PC case was designed, manufactured, and assembled. All the electrical components were successfully positioned and mounted. The objectives of this thesis were met, the learning curve was great, knowledge and skills were put into practice and tested. The outcome is a fully functional desktop PC, although there is still some space for further improvements, but overall it is a successful project.

REFERENCES

ATX, Wikipedia. Available from: https://en.wikipedia.org/wiki/ATX Accessed 29.04.2019

ATX Specification- Version 2.2, Intel. Available from: https://web.archive.org/web/20120725150314/http://www.formfactors.org/developer/specs/atx2_2.pdf Accessed 29.04.2019

Barnatt, Christopher. 2013, *3D Printing: The Next Industrial Revolution*, ExplainingTheFuture.com., 262 pages.

Central Processing Unit (CPU), Technopedia. Available from: https://www.techopedia.com/definition/2851/central-processing-unit-cpu Accessed 14.01.2019

Disk Drive, Webopedia. Available from: https://www.webopedia.com/TERM/D/disk_drive.html Accessed 14.01.2019

Graphics Processing Unit (GPU), Technopedia. Available from: https://www.techopedia.com/definition/24862/graphics-processing-unit-gpu Accessed 14.01.2019

Hardware, ExplainingComputers.com. Available from: https://www.explainingcomputers.com/hardware.html Accessed 29.04.2019

I Made a Computer Out Of Wood, Bored Panda. Available from: https://www.boredpanda.com/diy-wood-computer-louis-vanwalleghem/?utm_source=bing&utm_medium=organic&utm_campaign=organic Accessed 14.01.2019

Kratka do studzenia ciasta. MITIS s.c.. Available from: https://ciastojady.pl/Kratka-do-studzenia-ciasta-32-cm-Patisse-01321 Accessed 09.04.2019

Lipson, Hod & Kurman, Melba. 2013, *Fabricated: The New World of 3D Printing*, Indianapolis: John Wiley & Sons, Inc., 302 pages.

Mastro, P. 2016, *Plastics Product Design*, John Wiley & Sons, Inc., Available from: https://ebookcentral-proquest-com.ezproxy.arcada.fi:2443/lib/arcada-ebooks/detail.action?docID=4427243&query=Product+Design+for+Plastics+# Accessed 15.03.2019

Parts of the System Case, Pc Guide. Available from: http://www.pcguide.com/ref/case/parts.htm Accessed 02.01.2019

PLA Material Large Spool, MakerBot. Available from: https://store.makerbot.com/3d-printers/replicator-materials/pla-large/#truewhite Accessed 11.04.2019

Power Supply, Technopedia. Available from: https://www.techopedia.com/definition/1756/power-supply Accessed 14.01.2019

RAM (Random Access Memory), Techtarget. Available from: https://searchstorage.techtarget.com/definition/RAM-random-access-memory Accessed 16.01.2019

Roebuck, Kevin. 2011, *3D Printing*, Tebbo, 264 pages.

Smither, A.H. 2013, *The 3D Printing Revolution: Licence to Print Money?,* CreateSpace Independent Publishing Platform, 54 pages.

Ventel. Available from: http://www.lufter.ru/product/adda-ad0612mb-f73ds/ Accessed 14.01.2019

3D Printers & 3D Scanners. 2014, Shropshire 3D Printers. Available from: https://www.shropshire3dprinters.co.uk/media/wysiwyg/i.png Accessed 16.01.2019