Project Agreement - Cover Sheet

Student Name: Ben Pearson

Course: Sustainable Product Design

Module: SPD320

Title of Project: Exploring a Sustainable Future for Consumer Additive Manufacturing

Area of Study

The additive manufacturing sector has experienced sustained rapid growth for the last decade and is set to surpass sales of over 15 million 3D printers by 2028[1]. Most of this market is made up of consumer sales, with printers being valued under the £400 mark. In the wake of this growth, a huge quantity of e-waste is being generated from broken, out-of-date and discarded machines. Most of these printers only require minor software updates or replacement parts to bring them up to current consumer standards. My goal is to create a product or ecosystem that is accessible for both enthusiasts and beginners alike. The focus of this system will be to increase the service life of budget and mid-tier 3D printers through the application of modular and emotional design. I aim to achieve this by enabling users to expand and improve upon their original machine, tailoring their experience as their interest and skills develop. I want to explore the attachment that develops with the objects we build, in the hopes of using this relationship to make the 3D printer more than a tool. The target audience will be individuals who are new to additive manufacturing, so the use of human-centred design and research probes will be key.

[1]Grandviewresearch.com. 2021. *3D Printing Market Size, Share | Industry Report, 2021-2028*. [online] Available at: <https://www.grandviewresearch.com/industry-analysis/3d-printing-industry-analysis/segmentation> [Accessed 19 November 2021].

Design Phases

Discover

- Project direction overview
- Primary Research
    - LCA
    - Survey the VORON community (build difficulty, previous experience)
    - Survey the 3D printing Discord (printers owned, how long they use a printer for, key features, thoughts on building a printer etc.)
- Secondary Research
    - Modular Design
    - Emotional Design
    - 3D printer construction
    - Biomaterials
    - OEM / ODM vs COTS / MOTS
- Design criteria evaluation
- Project Partners and advisors

Define

- Research analysis
    - Type of 3D printer to design
    - Target Audience
    - How to apply emotional and modular design
- Biomaterial testing and evaluation
- User-printer interaction
- Confirmation of project direction

Develop

- Ideation
    - Sketching
    - Rough models
    - Simple CAD
- Iterative development of designs
- System prototypes (isolate aspects of concepts)
- Refined concepts
- Detailed CAD model
- Renders, animations and simulations
- Project Partner and community feedback
- Feedback analysis
- CAD feedback implementation
- Prototype using chosen materials

Deliver

- Final CAD
- Renders, animations and simulations
- Technical drawings
- BOM and product cost analysis
- LCA
- Final prototype
- Project Partner feedback
- Design report

Design Brief

I will be designing a solution to the large volumes of e-waste currently being generated by consumer 3D printing. By focussing on the community, I hope to apply emotional and modular design strategies effectively. I will be assessing the impact and feasibility of using biomaterials in 3D printer construction; however, the primary focus will be creating a platform that can support an increase in printer service life. Creating a sustainable and accessible ecosystem that encourages upgrading and repair will be key to this goal. It will also be imperative for the cost of adopting an upgradeable machine to be competitive with existing products on the market.

Objectives

- What functionality is critical in a 3D printer for first time buyers? How does this differ from existing and experienced users?
- How can potential users and community members offer feedback throughout the project? How will this be analysed and implemented?
- What are the pros and cons of utilising an OEM / ODM vs COTS / MOTS for 3D printer construction?
- Can modular design be effectively applied to a 3D printer without support from an OEM / ODM?
- Once the characteristics of an intuitive and accessible design are defined, how should it be evaluated? By whom?
- How can emotional design strategies be effectively applied to a tool that prioritises function over form?
- How can the formation of an emotional attachment be measured or proved?
- Are biomaterials suitable? Can they be used without detrimentally affecting longevity?
- For products that rely on longevity to be sustainable, how long should support and updates be provided for?

Critical and Contemporary Context

I will be focussing on the sustainability issues at the core of the 3D printing industry, specifically in relation to the additive manufacturing solutions available to consumers. I will be exploring how the successful application of both emotional and modular design can be used to effect a change in consumer behaviour. With the industry experiencing year on year growth, continued operation at the status quo will cause a once promising technology to become a sustainability crisis. Consumer electronics are one of the primary sources of e-waste, with over 30Mt being produced annually by devices ranging from smartphones to refrigerators[2].

Emotional design, applied through methods such as the IKEA effect, could be one potential method of evolving the consumer printer market. I will be conducting research into companies such as VORON Design, who design self-build 3D printers based on the RepRap movement. Analysis of user engagement with this style of printer will need to be conducted to identify potential limitations for future development. Modular design will be explored through the research of companies such as Framework, who use modules extensively in the construction of their laptops. Furthermore, I will be investigating how modular design can be used to prevent a negative experience with a product, and the consequences if this fails.

[2]Forti, V., Balde, C., Kuehr, R. and Bel, G., 2022. *GEM 2020 - E-Waste Monitor*. [online] E-Waste Monitor. Available at: <https://ewastemonitor.info/gem-2020/> [Accessed 14 November 2021].

Methodology

Qualitative and Quantitative Research

During the early stages of the project, I will be conducting significant amounts of secondary research. Initially, I will focus on identifying as many additional sources as possible of information that were not considered while creating my project brief. This research will be conducted informally, with the goal of consuming as much information from as many different avenues as possible, including using platforms like Reddit, Youtube, Discord and Forums. My hope is that this will aid me in identifying and working with a diverse range of 3D printing communities, which will be critical for my user-focussed design process to be successful.

The key topics I will be researching are modular and emotional design, 3D printer construction, biomaterials and, lastly, the differences between OEM/ODM and COTS/MOTS. For instances where technical data is required, such as researching biomaterials, I will be primarily using academic papers and data sets from accredited third-party institutions. Where possible, I will avoid data provided solely from the manufacturer; however, with many biomaterials being so new this may be unavoidable in some cases.

My primary research can begin once I have a better understanding of the data I need to collect, as informed by my secondary research. I will be connecting with several 3D printing communities, including but not limited to the VORON and 3DP communities on Discord, Facebook and Reddit. These will act as a way of collecting large sets of data, primarily in the form of surveys. During the project I will be asking volunteers to participate in more focussed feedback sessions, where they will be able to more directly influence the project. Additionally, I have partnered with the founder of 3DTomorrow, Callum Coles. Callum has offered to supply a variety of biomaterials that have been developed and produced within the UK. During the later stages of the project, he will also offer feedback and development opportunities. Daniel Johnson from Open Imagination, a web development company based in Oxford, will be acting as an advisor when I create a website to host all the relevant materials and software for my project. He will not give feedback on the contents of the site, only assist with its creation and management. Contact with all supporting parties has been and will continue to be conducted remotely. This will be subject to change later in the project, upon the completion of a revised risk assessment.

Prototyping will be conducted using two primary methods. Rough and ready prototyping will be used for rapid testing of concepts generated in my ideation phase, with 3D printed prototypes being used on more established and vetted concepts. All printed prototypes will be manufactured from 3DTomorrow’s bio filament, which Callum has provided for this project. For tests of prototypes where user interaction is required, a revised and up-to-date risk assessment will be created that reflects any changes in government guidelines. If this proves not to be feasible, feedback will have to be postponed or generated in another manner.

Project Risks

Before conducting any primary research, I will need to carry out a risk assessment. As Covid-19 is still a major factor for me, being high risk, I will be conducting all (if any) in person activities socially distanced. For activities where user interaction is required, I will create additional risk assessments for those specific events, as additional measures, such as cleaning equipment for prototypes, will need to be taken. Participant consent forms will be distributed at least one week prior to any organised sessions, allowing sufficient time for any queries or concerns to be raised. For instances where personal information is collected, individuals will have the opportunity to contact me at any point in the project to have this information destroyed.

External Partners

I have reached out to several companies to assist me throughout my project.

VORON Design will be acting as project advisors, specifically regarding printer construction and design. Adam is founder of the PIF (Print It Forward) program at VORON, which aims to provide quality printed parts with which to build one of their printers. The service is non-profit and community run, and only supplies parts to individuals unable to print their own. Adam has an excellent technical understanding of the printed parts for the VORON and will be able to offer valuable insights into the dos and don’ts when designing my own.

3D Tomorrow is a UK based manufacturer and distributor of sustainable filaments. They also offer a parts printing service. Callum founded the company to combat the growing sustainability issue of filament manufacturing. They have created several products, including their fully cardboard filament spools. Callum will be advising me on the use of their recently developed BioPro filament, which aims to be a suitable substitute for ABS.

Open Imagination is an Oxford based website design and development service. Daniel works primarily as a backend developer; however, he also works extensively with server configuration. Daniel will be assisting me in the latter stages of my project, guiding me on setting up a website that can support all the software and guides that my project will require. This will be essential in ensuring the success of my design, as I wish to avoid potential users from having to search for relevant information.

Resources

Software

- Fusion 360
- SuperSlicer
- Adobe InDesign
- Adobe Photoshop
- Concepts for iOS
- Klipper
- Fluidd
- PuTTY
- WinSCP
- Visual Studio Code

Technologies

- 3D Printing
- Laser Cutting
- Soldering
- CNC Milling / Routing

Health and Safety

- Respirator
- Particulate Filtration / Ventilation (for materials identified by COSHH)
- PPE
- Electrical Safety Certification
- Risk Assessment

310 Deliverables

- Primary research and analysis
- Secondary research report
- LCA
- Sketches
- CAD models / renders
- Initial prototypes

Final Project Deliverables

- Project Portfolio
- Design process documentation (development of ideas through sketches, CAD and prototypes)
- Final CAD Model
- Final Renders
- Final Prototype
- Website (hosting all the software required for the prototype)
- Final Product Report

This will be subject to additions and changes, which will be reflected in my Gantt chart as the project progresses.

Contacts Database

Project Partner
Adam - Team Member at VORON Design
Discord: VORON Design#1378
Email: vorondesignteam@gmail.com
Website: https://vorondesign.com/

Project Partner
Daniel Johnson - Web Developer at Open Imagination
Discord: Dandeky#2998
Email: dajohnson321@gmail.com
Mobile: 07393226866
Website: https://www.openimagination.co.uk/
Business Address:
Open Imagination Ltd
3 Kings Meadow
Osney Mead
Oxford
OX2 0DP

Project Partner
Callum Coles - Founder of 3D Tomorrow
Email: mail@3dtomorrow.com
Mobile: 07495825317
Website: https://3dtomorrow.com/
Instagram: @3DTomorrow

Participant Information

Title of Research Project

A Sustainable Future for Consumer Additive Manufacturing

I would like to invite you to take part in my research. Before you decide whether to participate, I would like you to understand why the research is being carried out and what it would involve for you. I will go through the information sheet with you and answer any questions you have.

What is the purpose of the study?

This is a practice-based research project, evaluating several design prototypes of modular 3D printers. The research will be used to support the development of a modular ecosystem that aims to solve the growing issue of e-waste from cheap consumer printers. It is expected that your participation will provide useful insight into improvements to existing designs and provide a forum for evaluating the subsequent prototypes that are developed.

Why have I been invited?

Your existing experience with additive manufacturing and/or your experience in building a 3D printer, will provide useful insight and feedback in developing a modular printing ecosystem.

Do I have to take part?

It is up to you to decide to join the research. We will describe the study and go through this information sheet. If you agree to take part, we will then ask you to sign a consent form. You are free to withdraw at any time, without giving a reason.

What will happen to me if I take part, and what will I have to do?

Your participation could involve physically testing a modular 3D printer prototype and providing feedback on your experience. The research period is expected to run for the first two quarters of 2022, and you may be invited to contribute to the project at any time during this period. Sessions will run for approximately one hour. The tests could include (though are not limited to): the partial or total assembly of modular electronic modules, assembly of modular print bed and frame, printer software interaction. During this process you may be photographed by the researcher, as well as observational notes being collected. You will be required to disclose how long you have been using additive manufacturing, as well as any other relevant experience you have. You will not be required to disclose any other personal information, such as your name, age etc.

What are the possible disadvantages and risks of taking part?

The risks to participants are low. All the prototypes being tested will be non-functional, meaning they will have no connection to a power source. This negates any of the potential risks of testing prototype electronics. For activities where some assembly is required, there may be difficulties if your dexterity and/or grip are affected in some way. In these instances, if you feel comfortable, inform the researcher so that accommodations can be made; you will not be excluded from participation, as data from individuals of all abilities is desired. You will be able to stop the testing at any time if you feel uncomfortable for any reason.

What are the possible benefits of taking part?

The feedback and insight you provide will be a highly valuable contribution to the development of a new design of a modular 3D printer. All concepts and designs generated in the project will be published as an open-source project to GitHub, allowing anyone to download, modify and re-upload the designs. This will allow the project to continue to evolve and develop beyond the final prototype. Your participation will ensure that the designs generated are of the highest quality, allowing a solid foundation for others to build off of.

What happens when the research ends?

You are invited to keep in touch with the development of the modular 3D printer. Please indicate on this consent form if you wish for your email address to be retained to receive updates on the project progress.

What will happen if I don't want to carry on with the study?

You can withdraw from the study, for any reason, at any time by contacting the Researcher. If you do withdraw from the study, data previously provided will still be retained and used for the purposes outlined above, unless otherwise requested.

What if there is a problem?

For further information about the research, please contact:
Ben Pearson, Falmouth University Student
Sustainable Product Design, Falmouth University, Penryn Campus, Treliever Road, Penryn Cornwall TR10 9FE
Tel - 07903812908
Email – bp214707@falmouth.ac.uk

Will my taking part in this study be kept confidential?

The data gathered in the study will be stored digitally on an encrypted online repository and backed-up on a password protected drive, stored in a safe in my personal residence. Paper copies of notes or feedback will be scanned and stored electronically in the same way, and the originals will be destroyed. Your personal opinions and the researcher's observation of you will be central to the research and as such could be published as part of a research output. You will remain anonymous and your name, images in which you can be identified, and audio of your voice will not be published without prior written consent. The data will be retained for future use but only for the further development of the modular 3D printer concept. Your data will only be shared with the research team directly involved with the study, which includes personnel from Falmouth University and the VORON Design Team. The data gathered will not be used other than for the purposes described above and third parties will not be allowed access to it (except as may be required by the law). Your data will be held in accordance with the Data Protection Act.

What will happen to the results of the research study?

Primarily, the research results will directly inform the design development of a new modular 3D printer. The project will be written and presented as a design project, as part of my final year at Falmouth University.

Who is organising and funding the research and who has reviewed the study?

The sole funding source for the research is Ben Pearson, the primary researcher. The University is committed to advancing and safeguarding high quality academic and ethics standards in all its activities. When undertaking research, researchers are expected to consider and observe ethics principles and the University's mission and values. The Falmouth University Research Ethics Policy sets out the principles and conditions the ethics review requirements of a research project. Detailed operational requirements are set out in the Procedures for Research Ethics Reviews. The Policy has been developed in consultation with university stakeholders and builds on and codifies existing practice, relevant legislation and guidance from professional and funding bodies.

Consent Form

Title of Research Project: A Sustainable Future for Consumer Additive Manufacturing

	Please Circle
1. I confirm that I have read and understand the participant information provided dated..... for the research study. I have had the opportunity to consider the information, ask questions and I have had these answered satisfactorily.	Yes / No
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected.	Yes / No
3. I agree to take part in the above study.	Yes / No
4. I agree to my participation being photographed and filmed.	Yes / No
5. I agree to photographs and film taken during my participation to be used for research publication and other information dissemination, via a web site for example, to inform others about the project.	Yes / No
6. I would like my email address to be retained to receive updates on the project progress and new product availability.	Yes / No

Name of participant……..Date:.....

Signature……..

Preferred contact method……..

Name of researcher: Ben Pearson Date:.....

Signature……..

Two copies to be signed by both the participant and researcher, one kept by each.

Risk Assessment

Risk ID	Flag	Risk	Assigned To	Description	Severity	Risk Likelihood	RISK SCORE	Risk Management	Risk Severity PM	Risk Likelihood PM	Calculation
	-	SPD 310	Location								
		Printer Build	Falmouth								
		Wiring	Flat								

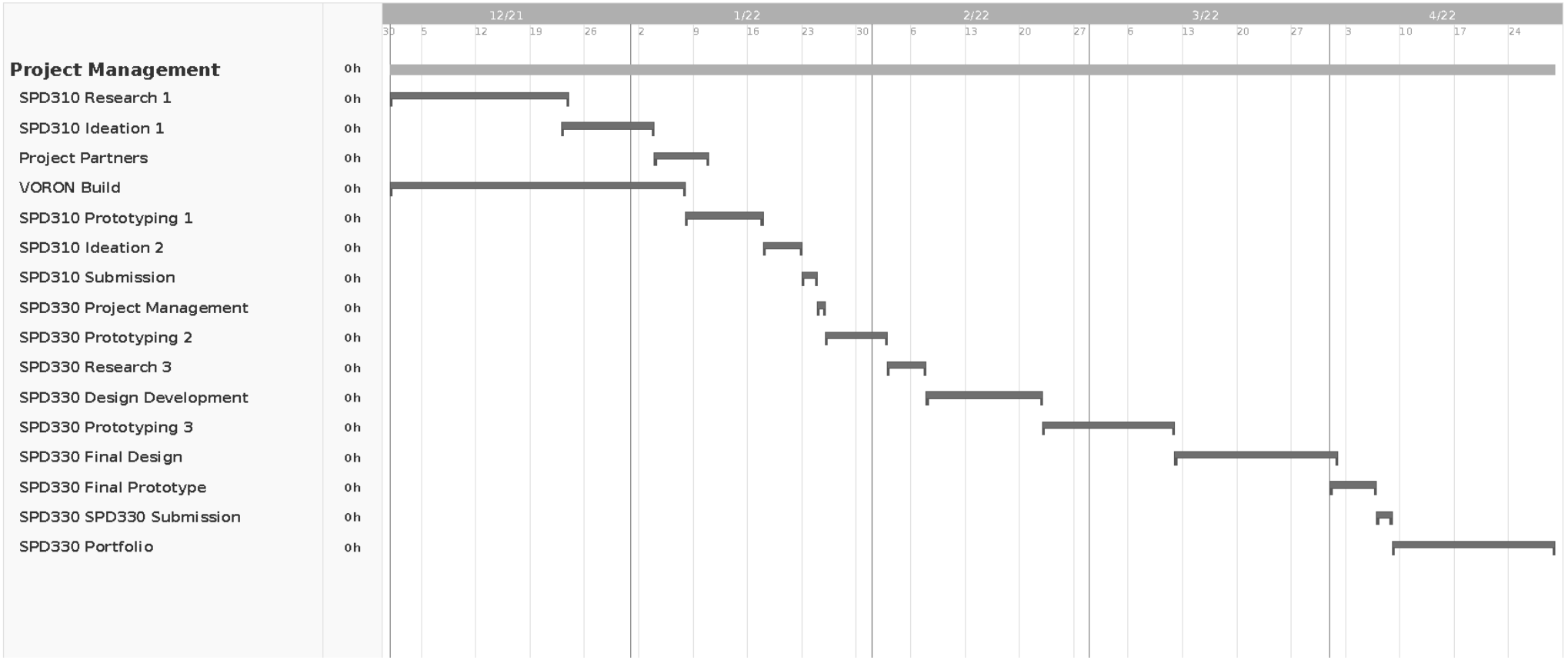
	FLAG	IDENTIFIED RISK		BRIEF DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	RISK RATING	RISK MANAGEMENT	RISK SEVERITY (post management)	RISK LIKELIHOOD (post management)	FINAL RISK RATING
RISK-1001		Electrocution	Ben Pearson	Wiring the printer involves the use of mains power, which can kill.	Unacceptable	Improbable	4	Course on how to safely wire for mains power. Printer powered on remotely when testing circuits.	Tolerable	Improbable	2
RISK-1002		Fire	Ben Pearson	Wiring the printer incorrectly can cause electronics to catch fire.	Unacceptable	Improbable	4	Printer powered on outside for initial tests. Fire extinguisher kept by printer. All circuits continuity tested with a multimeter	Acceptable	Improbable	1
RISK-1003		Incised Wound	Ben Pearson	Wiring involves the cutting and stripping of cables. The tools used could cause cuts.	Tolerable	Probable	6	Wear protective gloves when using sharps. For instances where fine motor control is paramount, removal of the gloves may be necessary	Acceptable	Possible	2
RISK-1004		Puncture Wound	Ben Pearson	Crimping connectors uses a tool that compresses the connector around the wire. The tool has sharp teeth that could pinch or puncture tissue.	Tolerable	Improbable	2	Normal gloves can't be worn due to the size of the connectors and wires, however fingerless alternatives can be worn to protect the palms and majority of the finger.	Tolerable	Improbable	2
RISK-1005		First Degree Burns	Ben Pearson	Wiring involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 355C, a first degree burn would be almost instant.	Tolerable	Possible	4	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Acceptable	Improbable	1
RISK-1006		Second Degree Burns	Ben Pearson	Wiring involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 355C, a second degree burn would form within seconds.	Tolerable	Improbable	2	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Acceptable	Improbable	1
RISK-1007		Third Degree Burns	Ben Pearson	Wiring involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 355C, a third degree burn is unlikely to form on the fingers, due to the skin thickness giving the user time to react. However other exposed skin can burn much faster	Undesirable	Improbable	3	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Tolerable	Improbable	2
		Mechanical Assembly	Flat								
	FLAG	IDENTIFIED RISK		BRIEF DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	RISK RATING	RISK MANAGEMENT	RISK SEVERITY (post management)	RISK LIKELIHOOD (post management)	FINAL RISK RATING
RISK-2001		Laceration or Amputation	Ben Pearson	The frame for the printer will be cut on a mitre saw, operating at approximately 5000rpm. The saw blade would pull an appendage inside if it made contact with the blade.	Unacceptable	Improbable	4	Gloves should not be worn as it increases the chance of the saw blade catching. Extrusion should be clamped instead of held by hand. Emergency stop should be within reach of the machine. Automatic saw stop should be functioning.	Tolerable	Improbable	2
RISK-2002		Particulate Inhalation	Ben Pearson	Cutting the frame will cause micro-particulates of aluminium and carbide to become suspended in the air.	Unacceptable	Certain	16	Respirator half mask with a protection level of at least A2P2 should be worn. The room should be well ventilated.	Acceptable	Improbable	1
RISK-2003		Incised Wound	Ben Pearson	Cutting the frame on the mitre saw will leave sharp burs that could cause cuts.	Tolerable	Possible	4	Gloves should be worn when deburring the extrusions.	Acceptable	Improbable	1
RISK-2004		Crush / back Injury	Ben Pearson	The printer is built on a granite slab, used to ensure assemblies are square. The slab is 600mm x 600mm x 30mm, weighing 30kg. The slab will have to be moved multiple times during the build, which could lead to appendages being crushed or broken.	Tolerable	Improbable	2	The granite slab should be moved by 2 persons, as it is above the 25kg load that is advised for a single person to move.	Acceptable	Improbable	1
RISK-2005		Carcinogenic and Toxic Fume Inhalation	Ben Pearson	There are multiple instances where fumes will be present in the build, such as from aerosols and ABS fumes from installing heat set inserts	Unacceptable	Certain	16	Respirator half mask with a protection level of at least A2P2 should be worn.	Acceptable	Improbable	1
RISK-2006		First Degree Burns	Ben Pearson	Installing heat set inserts involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 225C, a first degree burn would be almost instant.	Tolerable	Possible	4	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Acceptable	Improbable	1
RISK-2007		Second Degree Burns	Ben Pearson	Installing heat set inserts involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 225C, a second degree burn would form in seconds.	Tolerable	Improbable	2	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Acceptable	Improbable	1
RISK-2008		Third Degree Burns	Ben Pearson	Installing heat set inserts involves the use of a soldering iron, which can operate from 100C to 500C. Used predominately at 225C, a third degree burn is very unlikely to form on the fingers, due to the skin thickness giving the user time to react. However other exposed skin can burn much faster.	Undesirable	Improbable	3	Normal gloves can't be worn due to the dexterity required to solder, however insulative fingerless alternatives can be worn to protect the palms and majority of the finger. Long sleeves and trouser should be worn to prevent accidental contact with the iron.	Tolerable	Improbable	2

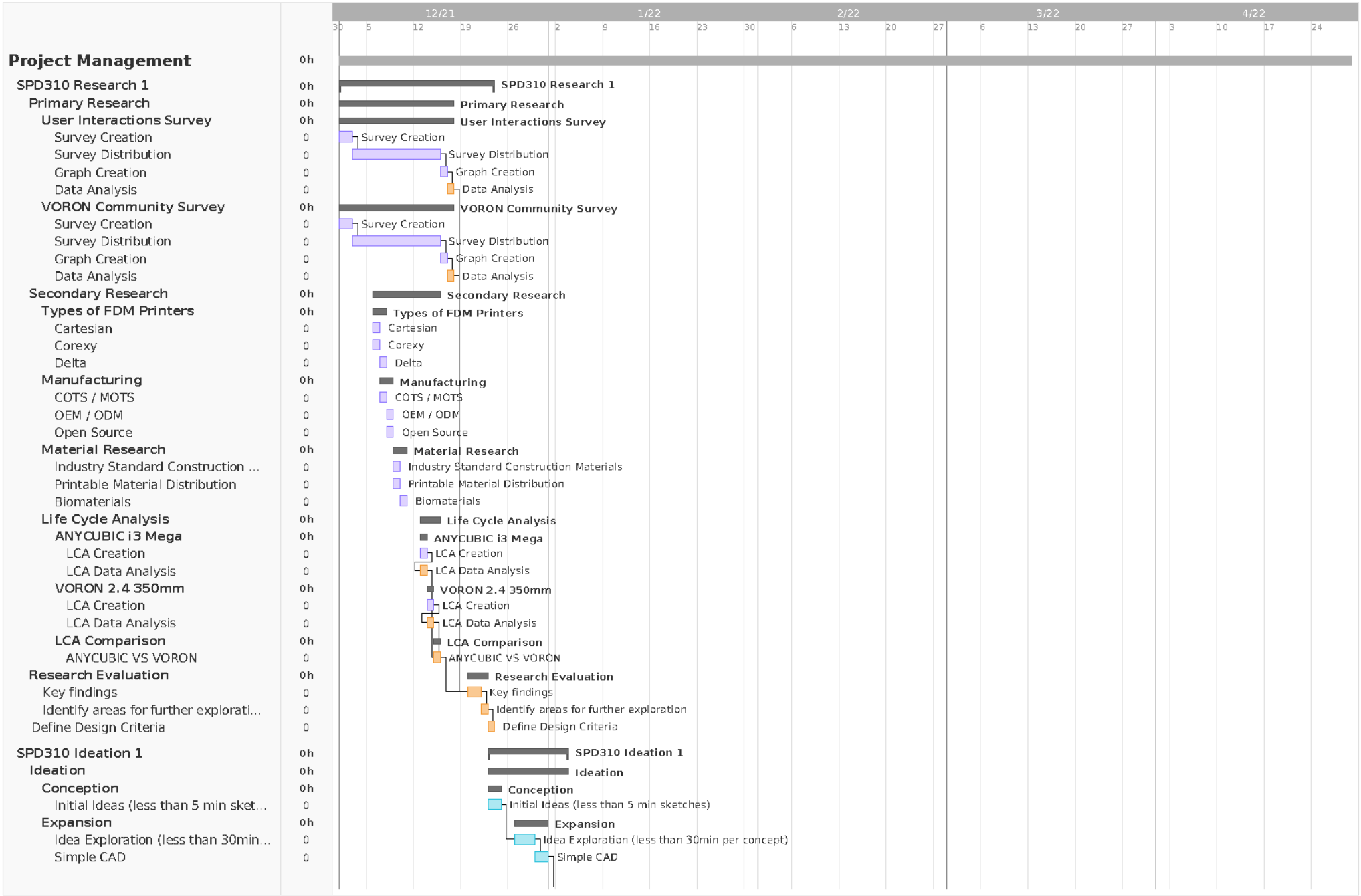
Risk Assessment Key

RISK SEVERITY	RISK LIKELIHOOD
Acceptable - 1	**Improbable - 1**
(Little to no effect on event)	(Risk is unlikely to occur)
Tolerable - 2	**Possible - 2**
(Effects are felt, but not critical to outcome)	(Risk will likely occur)
Undesirable - 3	**Probable - 3**
(Serious impact to the course of action and outcome)	(Risk is very likely to occur)
Unacceptable - 4	**Certain - 4**
(Could result in disaster)	(Risk will occur)

Gantt Chart

teamgantt
Created with Free Edition





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