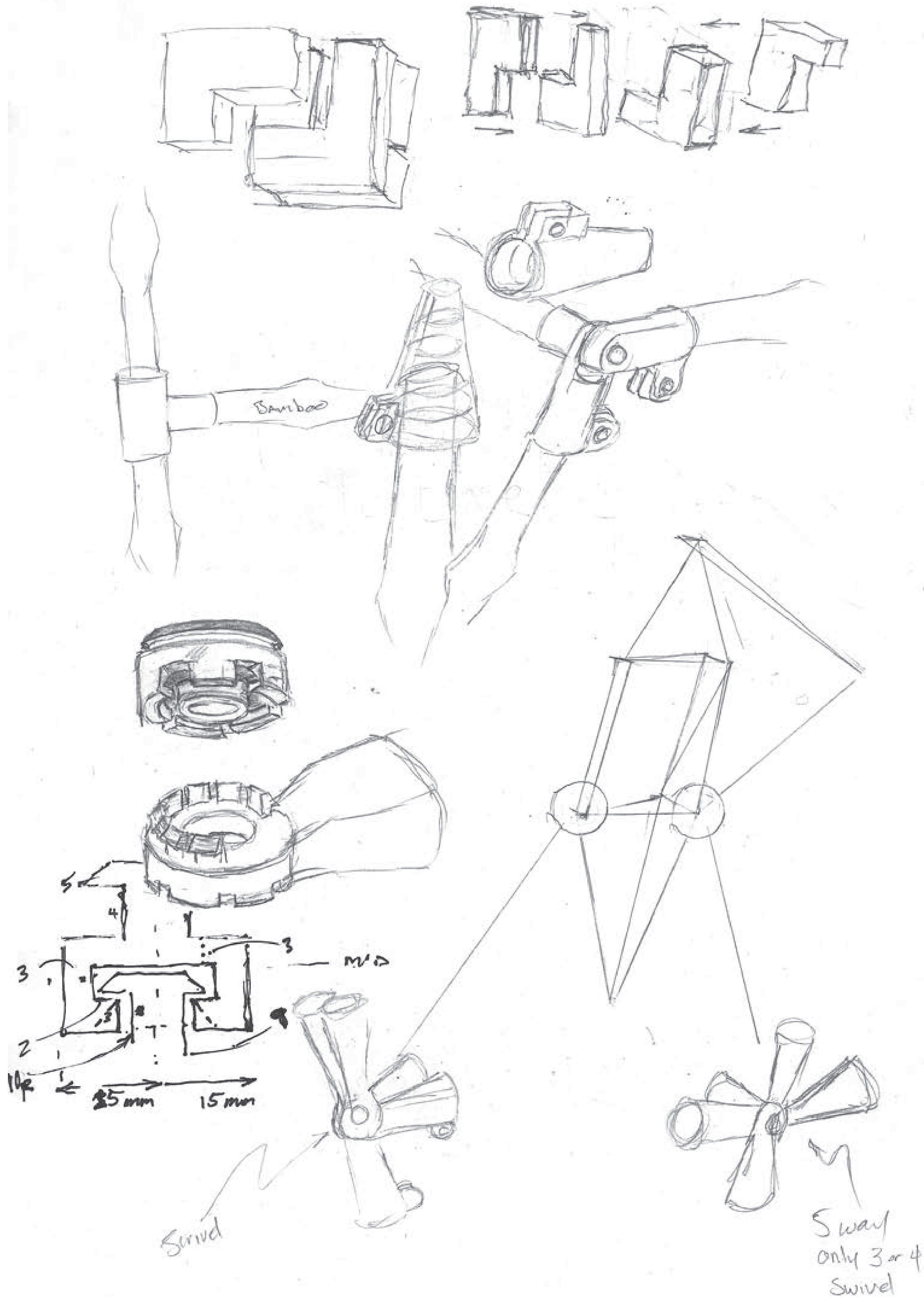
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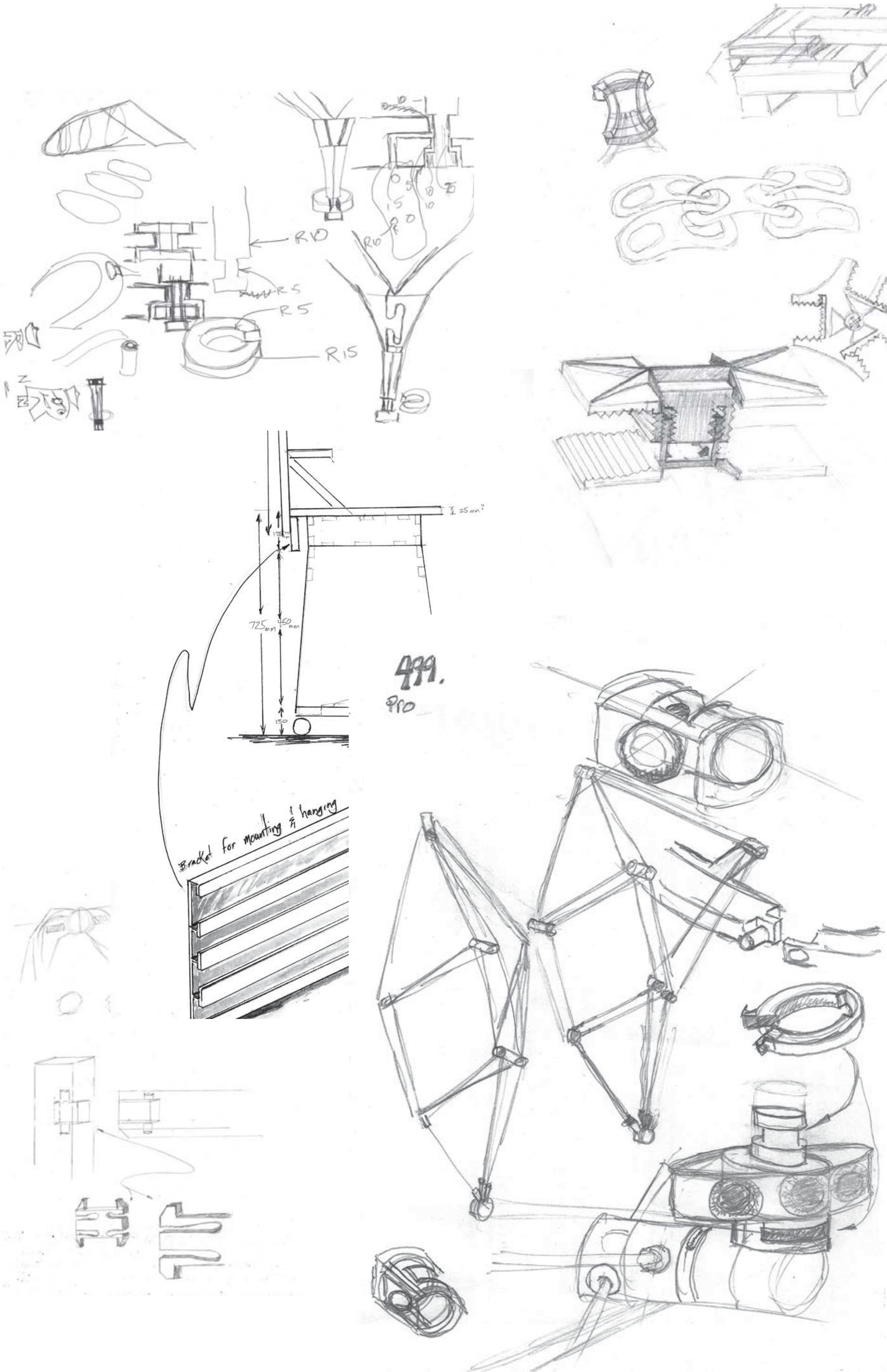
The Art of Potential

A Design-Led Exploration of Developing Sustainable Modular Furniture Joints
with a Desktop 3D Printer

By The Raque Kunz

An exegesis presented in partial fulfillment
of the requirements for the degree of
Masters of Design
at Massey University, Wellington,
New Zealand, 2014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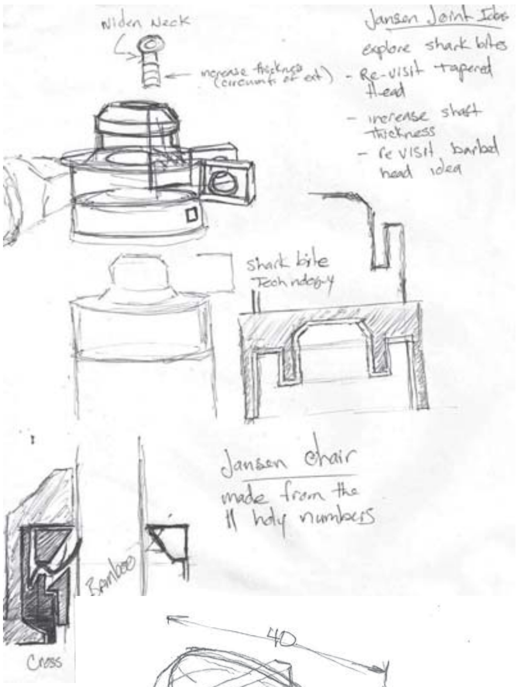
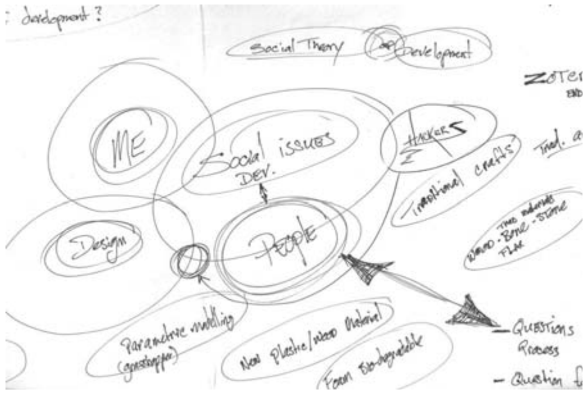
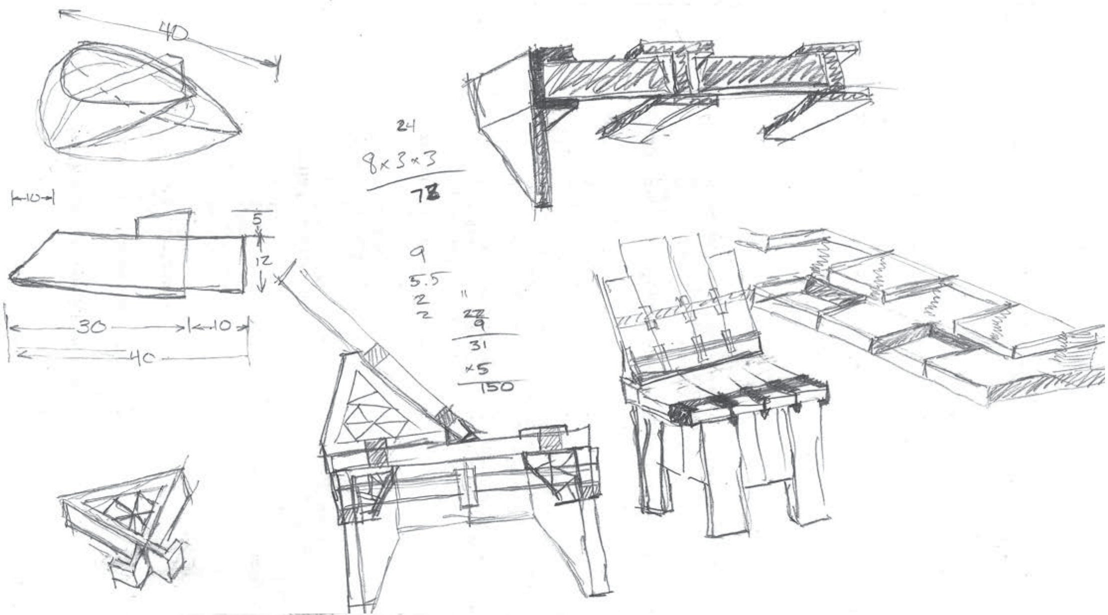
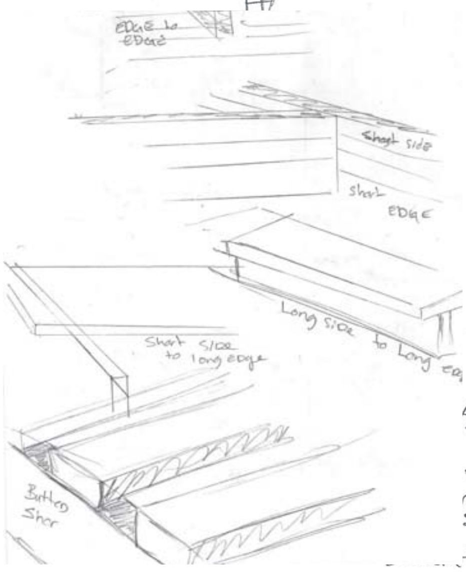
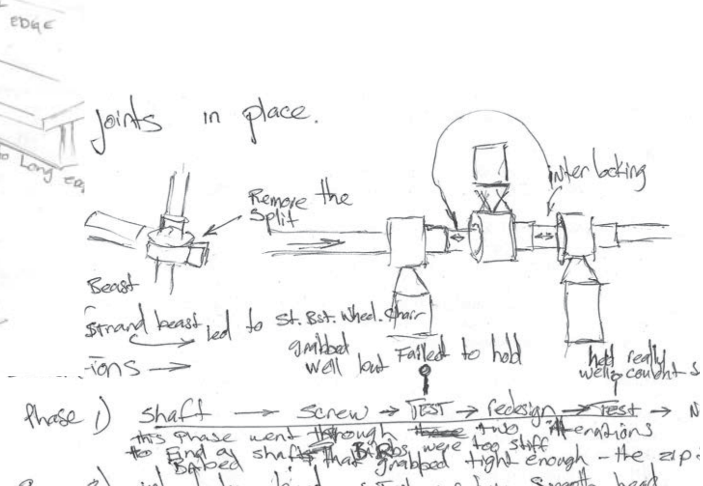




Sketches and ideation for the Potential *project*







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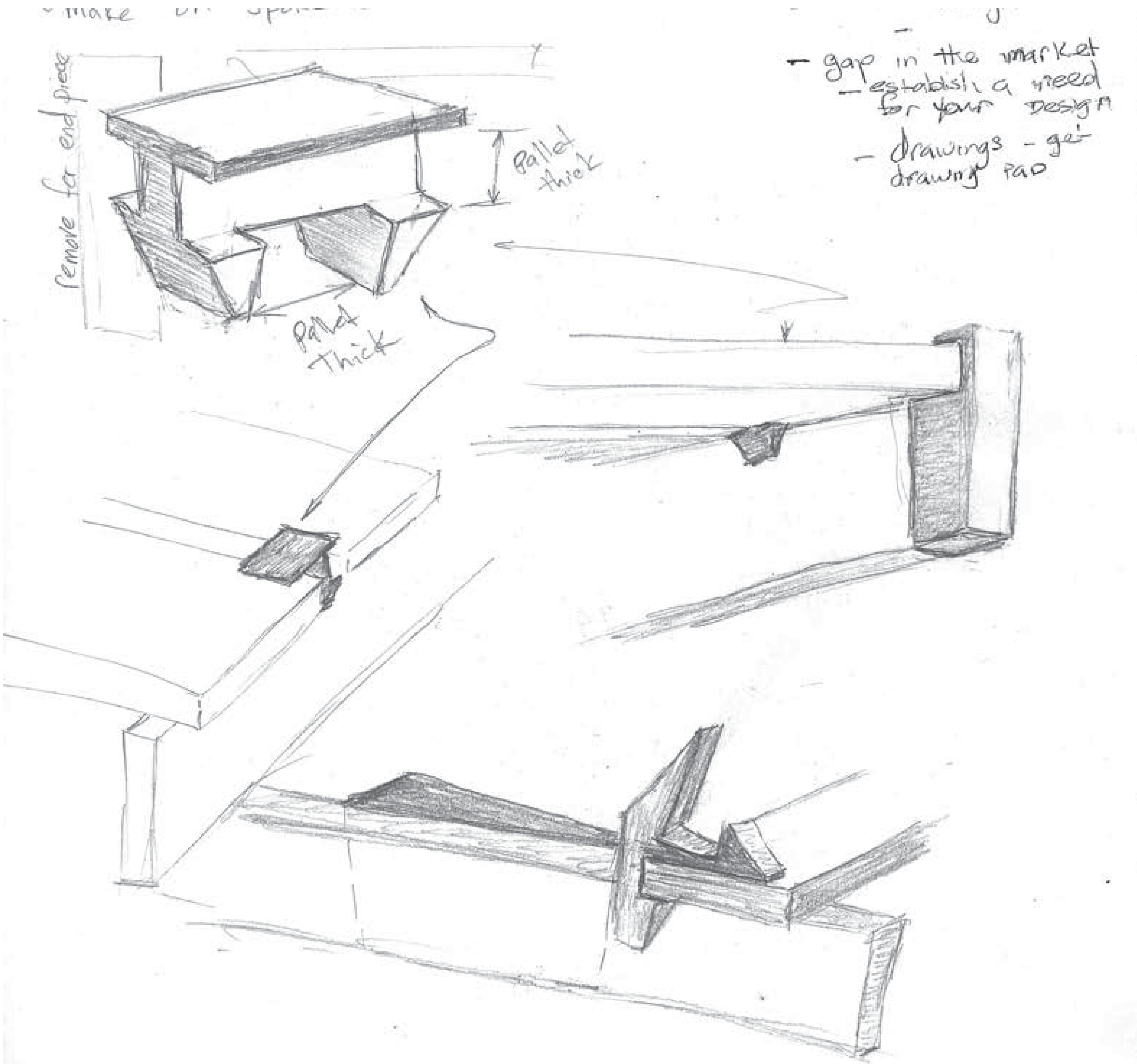
And to Patricia Ford, for helping me get into my helicopter so I could get a better view.



'Pallet Joint' sketches

Introduction

This is a story about joins.

The join is the place where two or more things come together.
A place where the properties of one thing must find agreement with the properties of another in order to achieve a union –
to become one...
to become whole.

More specifically, this is a story about joining by and with design. At its most simplistic level, this is a story about using design to join the parts of a piece of furniture together. At its most ambitious level, it is a story about joining people living in poverty who are neglected by the designers of manufacturing with technology that can empower them to design AND manufacture for themselves (Papanek 1971; Melles, de Vere, and Misic 2011; Gershenfeld 2005; Anderson 2012). At its most abstract, it is a story about joining our industrial past with the future at this present moment in time. At its most personal, it is a story about joining two cultures and two careers. At its most academic, it is about joining design with art and engineering. And at its most pragmatic, it is about joining technology and manufacturing with sustainability.

"Earth… It's a pretty small spaceship and 50 to 60 percent of the population cannot help run it, or even help themselves stay alive, through no fault of their own.

– Papanek 1971, 59

This project explores the question: Can a desktop 3D printer (D3DP) be used to fabricate a sustainable, modular, press-fit joint, which could be used to make furniture?

On the surface this question indicates that the *Art of Potential* project is about making furniture parts with a fancy new technology. However, a stronger question drives this research: How can 3D printing (3DP) become a more relevant and accessible technology that can empower the people who need the benefits of on-demand manufacturing the most – people living in poverty?

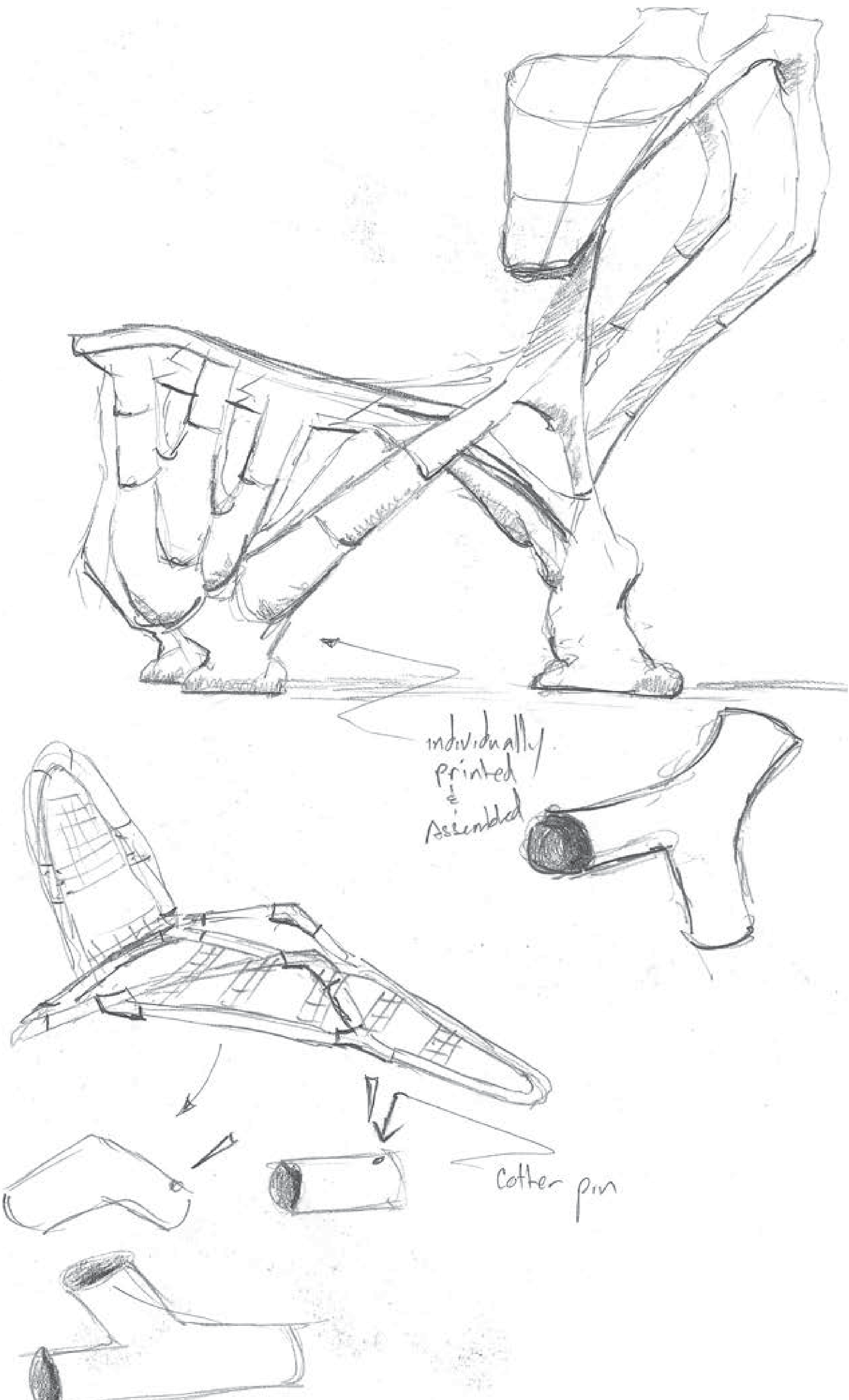
Accessible technology: a technology or product that can be easily and/or intuitively used or adopted by individuals with a minimum of education or preparation.

Join: a place where two or more things are connected or fastened together.

Joint: a point at which parts of an artificial structure are joined.

Relevant technology: a technology that is affordable, accessible, and functions according to an individual's needs

In 1971 Victor Papanek wrote his critique of the industrial design profession, *Design for the Real World*. In it, he identifies the environmental and social injustices that industrial design and the manufacturing industry are responsible for by catering to the needs and whims of the smallest and wealthiest segment of society while neglecting the needs of the poorest 75%. He cites numerous examples of how design can change the lives of people living in poverty and challenges industrial designers to give their attention to the needs of this majority. Today, with 1.2



Early development of the "Jansen Joint"

The intent of The Art of Potential project, is to use design to positively affect, in some small way, a social and environmental change in the current trajectory of the field of 3DP.

billion people living in extreme poverty on less than $1.25 USD a day Papanek's challenge to industrial designers is just as relevant as it was in 1971 ("UNESCO Global Profile of Extreme Poverty" 2012).

I have seen this change take place. I saw it when I worked for two years in the West African country of Cape Verde to design better educational resources and sanitation facilities in rural communities. I saw it when I worked in the San Francisco bay area as an environmental activist in low-income neighbourhoods to pressure industries to use better processing equipment to minimise pollution. And, I saw it growing up. As half Kiwi and half Yank I have witnessed in the past four decades the transition that the remote, mostly rural island nation of New Zealand has gone through as it has embraced technology and design to rival and surpass the USA in services, systems and sailing (Matheson 2009; Woo 2013).

"The only important thing about design is how it relates to people.

– Papanek 1971, 1

The intent of *The Art of Potential* project, or more simply, the *Potential* project, is to use design to positively affect, in some small way, a social and environmental change in the current trajectory of the field of 3DP. To accomplish this goal, two design-research paths were simultaneously explored. One focused on material design and one on product design. In turn, these paths were guided by two investigative questions: Can a more sustainable material be developed that improves on the properties of the current, dominant D3DP materials? And can a functional, easy-to-use, modular furniture joint be made using a D3DP?

3DP is currently a toy of the wealthiest members of our society.

While the social and environmental relevance of developing more sustainable materials might be obvious, the reader may find it difficult to see how a modular furniture joint relates to helping the world's poor. The *Potential* project recognises that 3DP is currently a toy of the wealthiest members of our society. I will argue that to change this paradigm, 3DP must begin to make 'functional' objects that can be integrated into our daily lives. As an industrial designer I see furniture as an ideal focus for this project because furniture is socially relevant (it is ubiquitous in almost every society) and it is manufactured from environmentally relevant resources. It is 3DP relevant because of the current limitations of 3D printers. I will discuss these topics in more detail in the following sections of this exegesis.

Kiwi: a national of New Zealand;

Yank: a national of the United States of America

Throughout this design-led research project, I have joined elements from different methodologies to address design challenges. In fact the title, *The Art of Potential*, evolved from an explanation of creative methodology in Theo Jansen's book, *The Great Pretender*. Jansen writes:

Photos I took while working in Africa

> What you need is the capacity of being able. This is the art of escaping, of breaking out of the cramped conditions of being unable. Suppose I can't find my glasses because without my glasses I can't find anything. Or you want to get into your house but the key's indoors. This puts you, so to speak, in the cramped condition of being unable. The art of being able consists of escaping from this restricted state. Irrational optimism is a way out. Obviously it's possible to find your glasses without glasses. And get into your home without the key. Being able is something you have to master, and then all doors will open for you (Jansen 2007, 34–35).

> *"You'll probably never arrive at a destination in the accepted sense of the word, but you are very likely to call in at places where no-one has ever been before.*
>
> *– Jansen 2007, 37*

I approach this project as an industrial designer, but I am also an artist. I have a Bachelors of Fine Arts degree and worked as an artist for many years. When I use the word "art" in the context of this project, I mean the art of something – the process. I felt that Jansen's "irrational optimism" was an apt description of the intent and aspirations that have guided this project. But in this project the irrational optimism is focused on the potential of a new technology: desktop 3DP.

My education in fine arts taught me many skills but it also fundamentally changed the way that I approach problem solving. I don't just look for solutions; I look for opportunities to discover and learn so that my solutions are creative and dynamic. This often means I will forgo an obvious solution or the usual approach in lieu of an alternate approach that offers the potential of discovery in solving a problem in a different way. This approach engenders an experimental and wandering methodology. Jansen calls this approach the "artists' method".

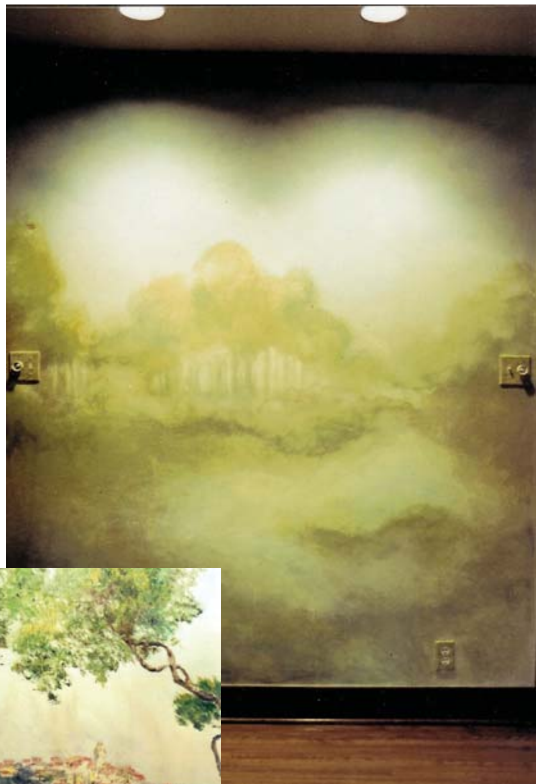
> *"The objects that I work on are real and the relationship formed between myself and the object is informed through this heuristic approach.*
>
> *– Neale 2010, 2*

> In (this) approach, which I shall call the artists' method, your destination has yet to be decided. You park your car along the hard shoulder and scramble down the bank, machete in hand, hacking a path through the undergrowth. You'll probably never arrive at a destination in the accepted sense of the word, but you are very likely to call in at places where no-one has ever been before (Jansen 2007, 37).

I design, prototype, test, reflect, and repeat until I resolve design challenges to my satisfaction. I sketch out an idea by hand or on a computer. Then, I make the object and test it to see if it functions the way I want. I evaluate: what is working, what isn't working? If needed, I adjust my design and repeat the process.

This heuristic process is a hands-on approach that draws on empirical techniques developed from working and living as an

Paintings and photography I completed while working as a freelance artist



Heuristic: *A methodology or process that enables a person to discover or learn something for themselves. A "hands-on" or interactive approach to learning. Exploration proceeding to a solution by trial and error or by rules that are only loosely defined.*

artist, designer, welder, painter, home-renovator, electrician, teacher, development worker, activist, Kiwi, and American. This methodology respects the "interdependence and interaction" (Snodgrass and Coyne 1992, 72) of each phase of this design process.

> Design methodologies are based on problem solving, analysis, synthesis, evaluation, and other models which represent the design process as a mathematical problem to be solved by way of prescribed logical steps" (Snodgrass and Coyne 1992, 56).

When I design for others, I join this heuristic, artistic method with elements of what Tim Brown, author and CEO of the global design firm IDEO, calls "design thinking". Design thinking is a user-centred approach that gauges any design solution with its relevance to the people it is intended to serve. It employs a similar process to more traditional industrial design methodologies (i.e., Double Diamond) in conjunction with a focus on divergent and convergent exploration. However, design thinking emphasises the repetition of this process based on feedback from five stages of the design process (Brown 2009):

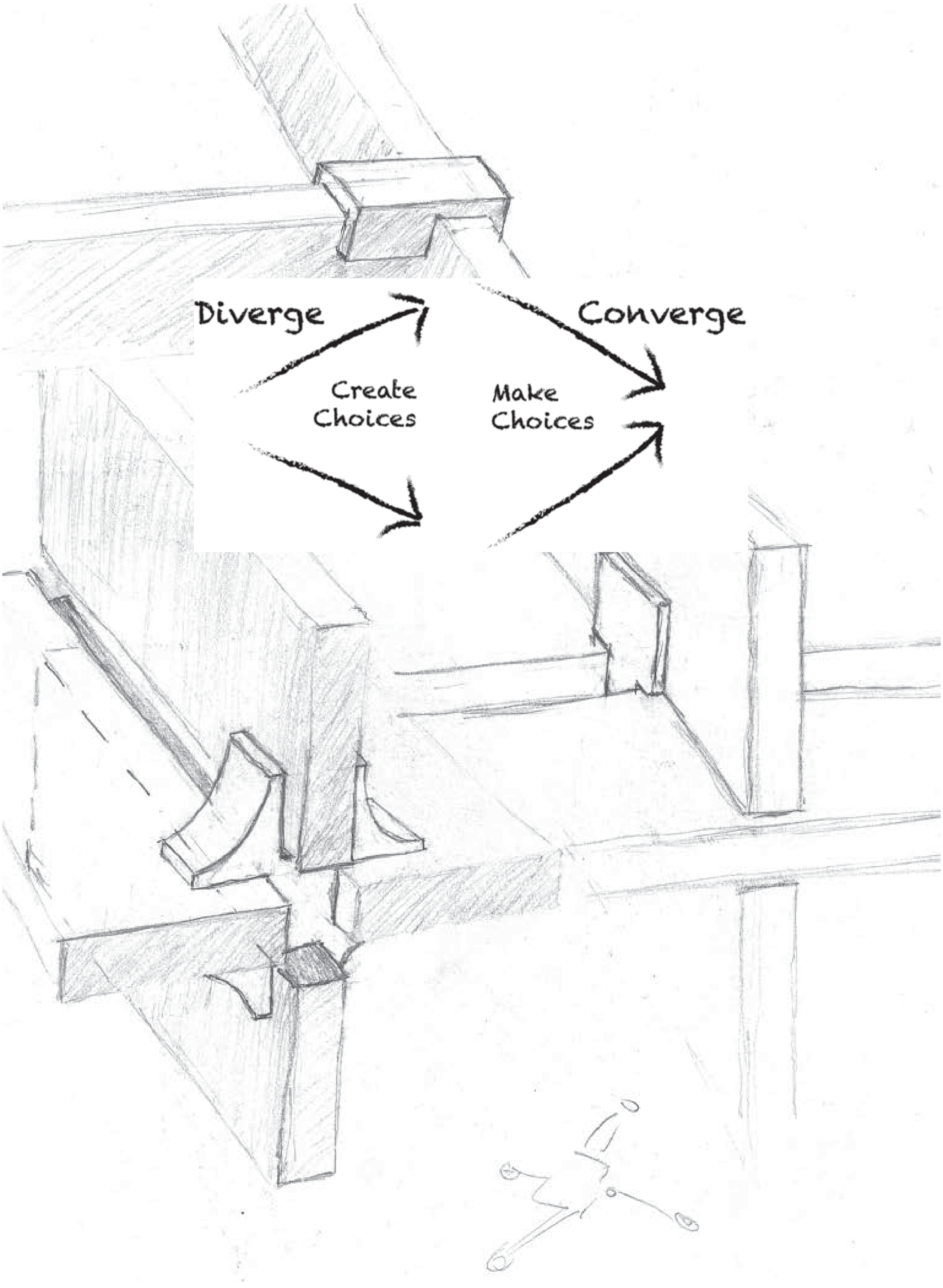
1. Understand (Empathy)
2. Define
3. Ideate (Point of View)
4. Prototype
5. Test

This is not always a linear process as the stages are carried out and repeated according to the evaluation of each stage.

"Instead of accepting a given constraint, ask whether this is even the right problem to be solving. ... A willingness to ask 'Why?' ... will improve the chances of spending energy on the right problems.

– Brown 2009, 67

Throughout the *Potential* project I have selectively employed elements of design thinking to address design challenges. I employed understanding and empathy by always focusing on how easy, functional, and adaptable the furniture joint and the plastics I designed were to use. I worked hard to define and redefine the design challenges by conducting an extensive literature review on 3DP and the associated subjects and exploring which designers and artists are already working within these fields, as well as by journaling my progress and recording data from all of my 3DP. Moreover, I frequently returned to this data to determine not just what went wrong but also to identify trends and patterns that emerged from sets of problems. I actively ideated with my industry partners, colleagues at Massey University, and peers to address the design challenges and brainstorm alternative solutions. And, I iteratively prototyped and tested my material designs and product designs for their ease of use and functionality (Stanford Institute of Design 2011).



'Pallet Joint' sketches

This exegesis is divided into three sections: Social Change, Sustainability, and Design. In each of these sections I will explore and critique the current landscape of D3DP as it relates to these subjects and join my findings together to argue that 3DP must become more sustainable, more relevant (i.e. affordable, accessible, functional), and more accessible (i.e. user friendly, intuitive, simplified) for it to achieve the assertions of its advocates.

The right side is filled with images, quotes and profiles, like the intuitive, symbolic and creative right brain.

It has been helpful for me to visualise these three areas of focus as three intersecting circles that join around the materials and products of 3DP. I see my background as the frames or boarders of these circles. My experience as an artist, designer and a DIY home renovator frames the focus on the design of a functional, modular furniture joint. My experience as an environmental activist and my exposure to the environmental degradation in both the “developed” and the “developing” world has expanded the boarders of my interest in sustainability. And my experience as a community development worker, teacher, and a political activist has helped to define my interest in social change. The area where these circles join and overlap is what this document seeks to address.

“

They are there to add a lighter touch, a moment of respite from the rigours of the narrative.

– Jansen 2007, 5

This theme of joining runs throughout this project and is evident in the way that I simultaneously pursued material and product design research and joined them together to make a final, modular furniture joint; in the way that I iteratively joined plastics, rubber and wood together to make a composite material for 3DP. It is evident in the way that I join artistic, heuristic, and elements of design thinking into a single guiding methodology to navigate the design challenges of this project. And it is evident in the way that I have organised this document. The two halves of it are split but joined in the concluding chapter. The main body of text is on the left pages, like the logical, literal, and analytical left brain. The right side is filled with images, quotes and profiles, like the intuitive, symbolic, and creative right brain. These sides join together in the final chapter to form a combined and cohesive set of conclusions and images (Jansen 2007; Neale 2010).

Social change: change that has relevant impact on the majority of a population or a social group.

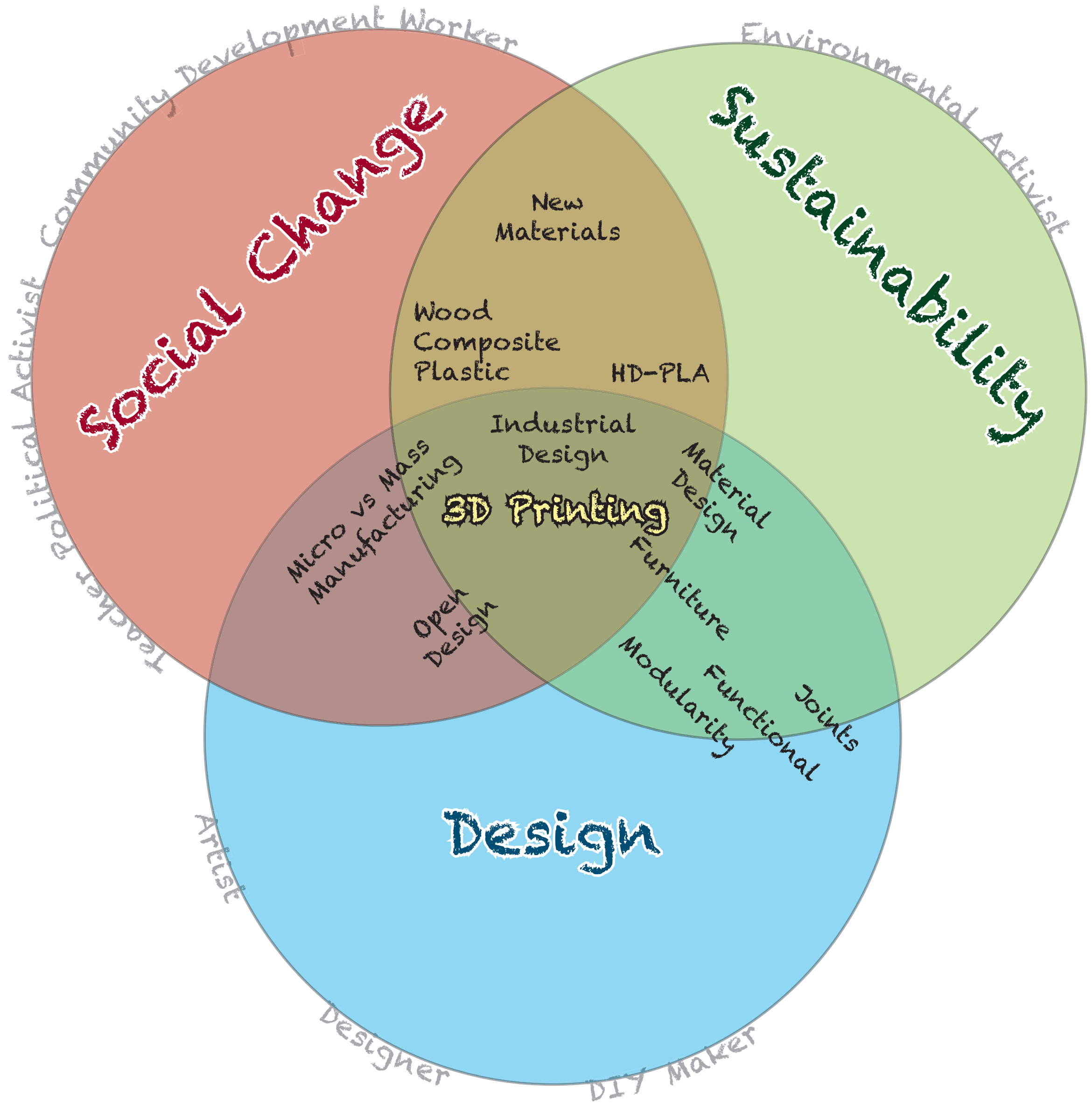


Diagram I used for visualising the relationship
between 3D printing and focus areas

Social Change

In this section I will discuss the functionality, potential, and current landscape of D3DP. I am very excited and hopeful that this transformative technology will lead to the kind of social change that its advocates predict. Because of this hope, I have pursued this research in order to determine for myself the validity of their claims. I will argue in this section that in order to achieve these predictions, several key areas of D3DP must change for it to become relevant and accessible to the general public.

> ***"The new industrial revolution.***
>
> ***– Anderson 2012***

In the 1990s, the Internet, MP3s, and peer-to-peer music file-sharing forced the newspaper and record industries to reinvent themselves in order to survive. Today, the popularity of digital fabrication is a harbinger of mass manufacturing's bleak future. Neil Gershenfeld, director of MIT's Centre for Bits and Atoms, points to the old paradigm of manufacturing as the sociological, political, and economic driver behind this development.

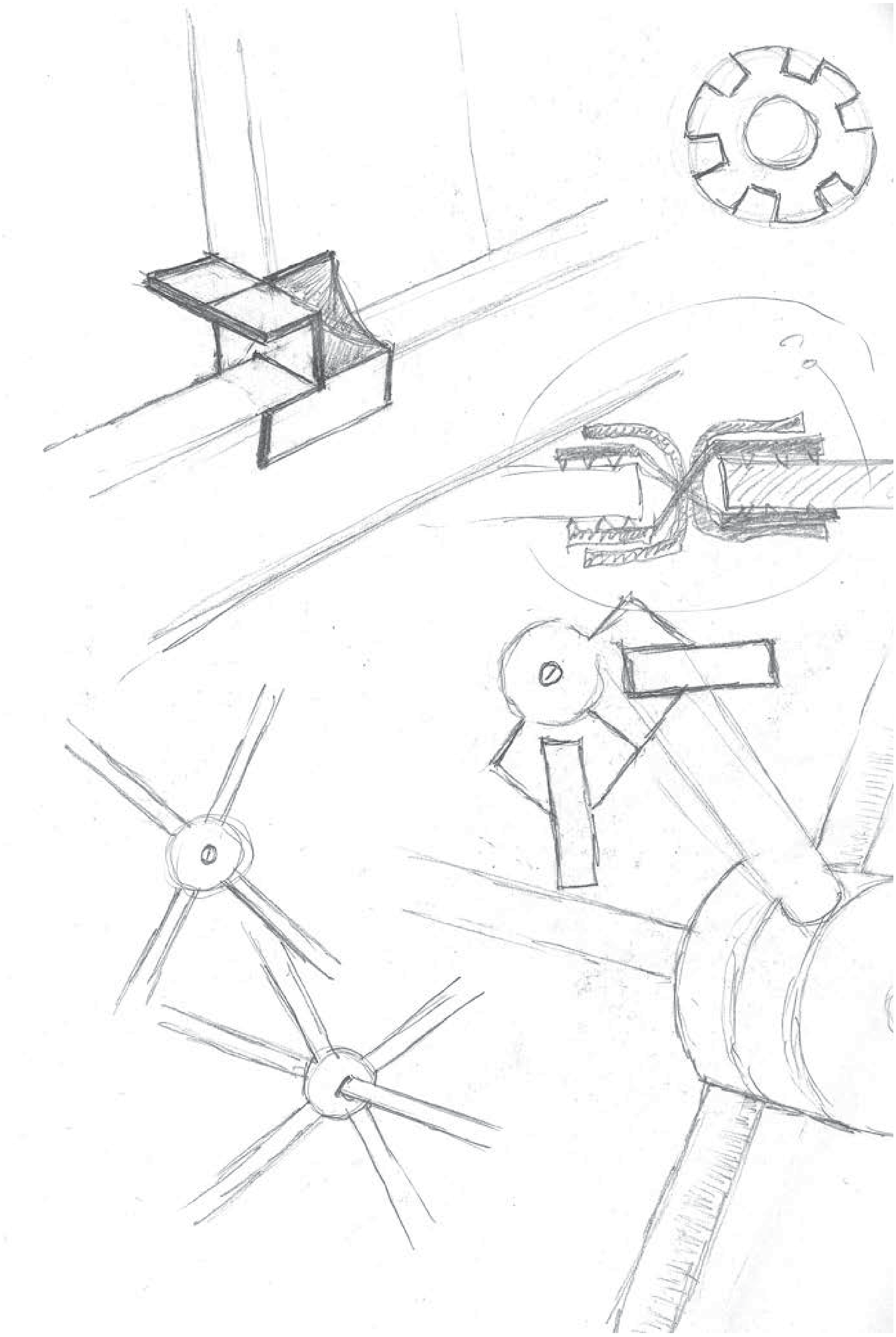
> The means for industrial production has long been the dividing line between the workers and the owners (Gershenfeld 2005, 15).

Chris Anderson, former CEO of *Wired* magazine and author, says that we are at the beginning of a "new industrial revolution" which he titles the "maker movement". Anderson believes that high-tech digital fabrication can let regular people harness big factories at will to make what they want.

> Today, the popularity of digital fabrication is a harbinger of mass manufacturing's bleak future.

> It's the perfect combination of inventing locally and producing globally, serving niche markets defined by taste, not by geography. And what's clear about these new producers is that they're not going to be making the same one-size-fits-all products that defined the mass-production era. Instead, they're going to be starting with one-size-fits-one and building from there, finding out how many other consumers share their interests, passions, and unique needs (Anderson 2012, 69–70).

Anderson explains that, "Today the maker movement is where the personal computer revolution was in 1985 – a garage phenomenon bringing a bottom-up challenge to the ruling



"Pallet Joint" sketches

order of the time" (Anderson 2012, 21–22). He argues that the transformative characteristics of the maker movement are:

> • Use of digital tools to design, prototype, and fabricate ("digital DIY")
> • A culture of collaboration to share these designs in online communities
> • A unified vehicle (common file type) that allows them to engage with commercial manufacturers to get these designs produced in larger numbers (Anderson 2012, 21).

"What is so important about the word desktop? Just consider the history of the computer itself. Until the late 1970's, computing connoted room-sized mainframes and refrigerator-sized minicomputers, which were the sole domain of governments, big companies and universities...Then in 1985, Apple released the LaserWriter, the first real desktop laser printer, which, along with the Mac, started the desktop publishing phenomenon. It was a jaw dropping moment, combining in the public imagination words that had never gone together before: 'desktop' and 'publishing'!

– Anderson 2012, 56-57

For me it is difficult not to get caught up in the excitement and possibilities of these arguments. After seeing how people living in poverty struggle to get what they need, this technology promises to join them with the ability to make what they need for themselves. The above authors point out that digital fabrication has reduced a factory down to a desktop and the 3DP synthesises these production capabilities into one machine. The publisher of *Forbes* magazine, Rich Karlgaard, writes:

> The transformative technology of the 2015–2025 period could be 3DP. This has the potential to remake the economics of manufacturing from a large-scale industry back to an artisan model of small design shops with access to 3D printers (2011).

Anderson lists three economic principals that 3DP gives users for free, compared to mass manufacturing:

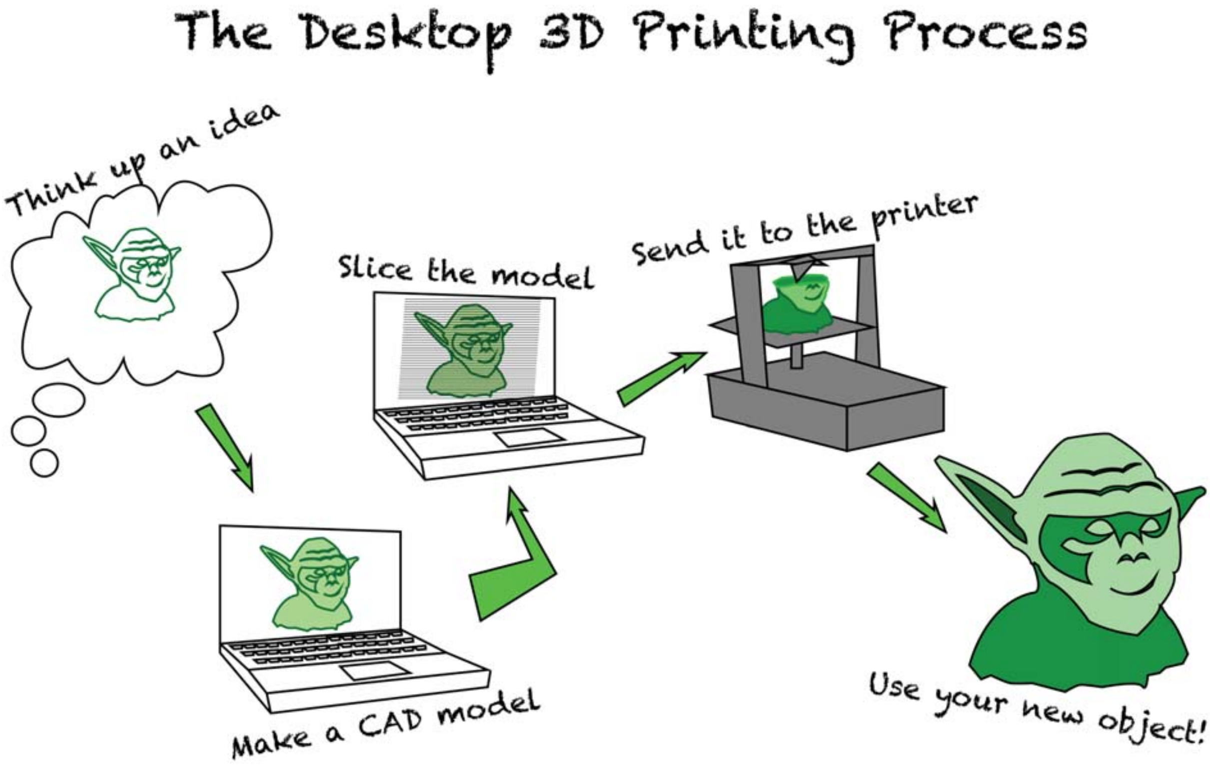
> • Complexity (the printer doesn't care how fiddly or simple the object is)
> • Variety (a different product every time)
> • Flexibility (intervening in the process and customisation after production begins) (Anderson 2012, 88–89).

"If Karl Marx were here today, his jaw would be on the floor. Talk about 'controlling the tools of production': you (you!) can now set factories into motion with a mouse click.

– Anderson 2012, 26

But it isn't just Anderson and Gershenfeld singing the praises of this new technology. The media is drunk with stories about 3DP, how easy it is to use, and how it will change the world.

In my attempts to use and learn about this technology I was amazed at what it could produce at the hands of an experienced user but frustrated with the difficulty of using it to make things for myself. I learned that the talk about 3DP is very different than the reality of using this technology. I felt I had been misled and that the technology was so difficult to use that it may never achieve my or its advocates' aspirations for it. In my research, I came across other users who had come to similar realisations. Lee Hutchinson, writer for the online technology review website, *Ars Technica*, writes:



...A 3D Printer In Every School.
(Biggs 2013)

...A 3D printer as easy to use as a toaster.

(Hall 2012)

A 3D Printer in Every Home.
(Tsoi-A-Sue 2013)

3D Printing Will Change the World!
(D'Aveni 2013)

> What I found as I dug in was a pit without a bottom—an absolute yawning Stygian abyss of options and tweaking and modifications and endless re-printing. To own and use a 3D printer is to become enmeshed in a constant stream of tinkering, tweaking, and upgrades. It feels a lot like owning a project car that you must continually wrench on to keep it running right (2013).

In fact the problem of people coming to 3DP with unrealistic expectations and misconceptions about what it can and can't do is so common that the 3DP service *3DPRINTUK* have a page on their website dedicated to debunking the hype, titled "Is It All True?"(Nick 2013) What is interesting is that many of the misconceptions are centred around the principals that Anderson identified as economic benefits of 3DP. In their book *Fabricated: The New World of 3D Printing* (2013), Hod Lipson and Melba Kurman build on Anderson's economic principals and list what they title the "10 Principals of 3D Printing". For me, when these principals are indiscriminately used and not clearly defined it is akin to false advertising, engendering misconceptions and misunderstanding.

> ***"** After a full week of very few successful prints, my enthusiasm for 3D printing waned. It didn't seem like something particularly fun or useful, just a way to creatively and very slowly deform PLA filament before throwing it into the trash.*
>
> ***– Hutchinson 2013***

1. Manufacturing complexity is free

In Brian Proffitt's article titled "Surprise: 3D Printing Won't Be Closing Any Factories Down", he challenges the idea that complexity is free and refutes that 3DP objects "can be intricate but they are not complex" (Proffitt 2013). Whether you call it "complex" or "intricate" it isn't cheap! When I got started with 3DP I was hypnotised by photos of incredibly complex looking 3DP objects, like Voronoi vases and chain-mail iPhone cases. But in trying to produce items like this for myself I discovered that the tolerances and precision required were beyond the capabilities of most of the D3DP I tried to use. I spent hours preparing, modifying, calibrating, and attempting to print these items only to have the printers consistently fail half way through the print. These prints would take up to 16 hours to complete and I would often return to find a tangle of plastic that was as complicated and intricate as a pile of spaghetti. In terms of time spent and materials wasted, attempting complex or intricate items is, at the very least, a costly endeavour.

2. Variety is free

To address this principal I refer the reader to my print log (see Appendix 7), which documents my attempts to vary and alter the joints that I designed. It shows that almost every variation in my designs required a recalibration or exploration of new print settings. Again, this costly process wasted both time and materials.

3. No assembly required

This principal carries with it the promise of printing everything

A Voronoi vase and chain-mail I attempted to print.

Print # 283:
Perimeters were set to 4 and the temp to 210ºC. This setting didn't seem different than the 5-perimeter setting. However, the PLA was lumpy again. I guess the higher temp is affecting the PLA print quality.

Print # 158:
There are no words left to express my exasperation... The entire day has been spent fighting with this machine. It never does the same thing twice, or rather it always does the opposite of what I would like it to do. I have tried so many different versions of these prints and so many different settings and nothing works.

Print # 258:
This print was very different from the last. Even though I only changed the number of perimeters the extruded filament came out differently… it was very rolly…it would roll up easily off the nozzle and not lay down in a line... I stopped it at the beginning of the third print because the first layer rolled up too much and there wasn't enough of this layer to properly build upon.

in one go with already assembled movable parts. Proffitt's point about complexity versus intricacy bears mentioning again because, as he explains, "If you want moving parts, you can create them, but you will nearly always have to remove any rafts or supports that will turn the single-piece printed object into something with movable components. That's a big deal, because it places limitations on what can be made" (Proffitt 2013). My experience of trying to add a hinge joint to the Jansen Joint illustrates the trouble with this assertion. Printing the joint so that it could move and rotate required an enormous amount of fiddly post-printing work with miniature screwdrivers, razors, and pliers to remove the support structure and try to separate the parts that had fused together during the printing process. Many times it was impossible or the printed object would break. This experience was as fun as it sounds and it pushed me to alter my design so that I could avoid this frustrating experience.

> ***"***
> ***The process is not like using an inkjet printer, it is far more time consuming, remember that there are other factors like data preparation, machine warming and cooling, model cleaning, etc! Some things can be printed in a number of hours, but these are only tiny items, this makes it unlikely for you to be able to call up and collect a print a few hours later.***
>
> *– 3DPRINTUK 2013*

4. Zero lead-time

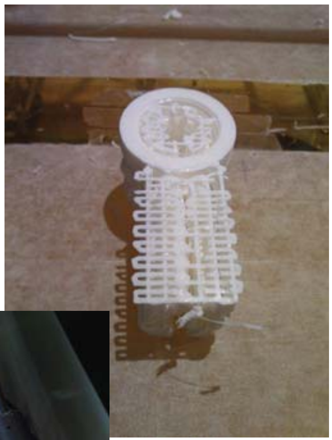
"A 3D printer can print on demand when an object is needed" (Lipson and Kurman 2013). I have one word for this claim – poppycock! Gershenfeld even says, "They should be called not-so-rapid-prototyping. Build times for a complex part can range from hours to days" (2005). While it is true that you do not have to wait for items to be shipped to you from a distant manufacturer, you do have to allocate the time to process and print the item yourself. On the surface this sounds simple enough but the fact is that just because you can design something on a computer does not mean that the printer will be able to print it. I found that I frequently had to revise and edit my designs just to get things to print. To get the results I wanted required a large time investment. In fact, even with a month to prepare for my fourth critique I was not able to produce adequate prototypes in time to meet my deadline. The proponents of 3DP are emphasising the advantages of this technology over traditional big-business mass manufacturing and in many respects their point is well made. However, saying that there is "zero lead time" engenders the notion that you will be able to print what you want when you want it and this is simply not consistent with my experience.

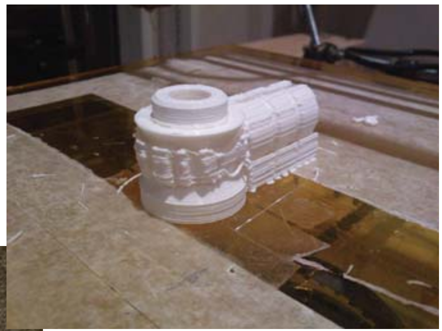
CAD (Computer Aided Drafting): a method of drawing that utilises a computer software programme to simulate a 3D space based on an XYZ coordinate grid.

5. Zero skill manufacturing

This is one that really gets me! This claim is made in various forms in headlines and articles that promise that 3DP will be easy. It is not. As Hutchinson (2013) puts it, "It wasn't just frustrating—it was actually enraging!" This from the writer and reviewer of a technology review website; a person with the skills and experience necessary to operate many complicated and technical devices. The fact is that the learning curve for using CAD modelling software is steep. The learning curve for making consistently good-quality objects with a 3DP is steep. And the ability to foresee problems that will affect the printing process and

Star Trek: A popular science fiction television show created by Gene Roddenberry. The original series only aired from 1966-1969 but has become an international phenomenon inspiring several movies and four spin-off television shows: Star Trek – The Next Generation, Star Trek – Deep Space Nine, Star Trek – Voyager, and Star Trek – Enterprise.





Required

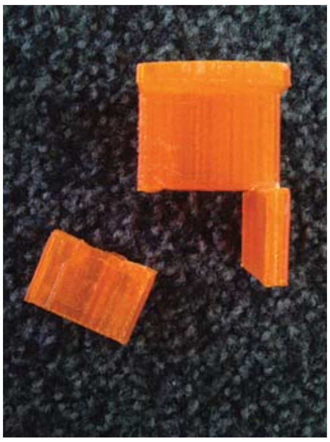
No

Assembly

Intra-strand

Poor

Cohesion



its success is a SKILL acquired through many, many hours of hard work.

> *“One of the hugely overlooked parts of 3D printing is the fact that you need a CAD model to print from. This is generally a very time consuming and specialist job. If you don’t have any CAD skills, you can either try learning with numerous free CAD programs that are out there, but it’s not the easiest thing in the world, so you could get one of our trusted CAD companies to do it for you.*
>
> *– 3DPRINTUK 2013*

6. Unlimited design space

The gist of this principal is “If you can imagine it, you can make it. A 3-D printer is the ultimate prototyping tool, the fastest way to turn something from bits on the screen to atoms in your hand” (Anderson 2012, 234). This principal engenders the popular misconception that a 3DP is like the Star Trek replicator – a machine that can create anything. While it is true that you can create shapes that were at one time only possible in nature, my experience with 3DP is that many designs are impossible or produce non-functional objects due to the limitations and variables of the printing process. Aaron Pratt, writer for the website *3D Printing Industry*, explains why this is “The fusion between the layers of the model is a weak point. In two dimensions the product is reasonably strong, but in the vertical or z-axis of a printed model, you can generally break it with your hand” (2013). But, this is just one of many current limitations to D3DP. Some others that I encountered that prevented successful printing were objects that had unsupported/unsupportable overhangs, very small bases, miniature or delicate parts, many small repetitive parts, and parts that were oriented askew to the printing axis.

7. Compact, portable manufacturing

I agree with Lipson and Kurman on this point. “Per volume of production space, a 3D printer has more manufacturing capacity than a traditional manufacturing machine” (2013). For me this is one reason why a 3DP is so much more interesting than other digital fabrication tools such as the CNC router and the laser cutter.

> *“Many things I tried to print failed to stick correctly to the print bed, and I wasted a tremendous amount of filament on aborted prints.*
>
> *– Hutchinson 2013*

CNC (Computer Numeric Control): a means of precisely controlling a device (e.g. router) where the device is calibrated to function within an established area that correlates to an XYZ coordinate grid.

8. Less waste by-product

My excitement about 3DP is heavily grounded in the hope that 3DP will be more environmentally friendly than traditional manufacturing. However, it is too early to tell if this really is true. “Manufacturing experts say it’s hard to determine whether 3D printing is economically and environmentally desirable because this sort of research hasn’t been done yet. It very well may be the greatest thing for the environment since beer in a can or sliced bread,” says David Dornfeld, professor of mechanical engineering at the University of California, Berkeley. “But you have to think about the energy that comes in the door with every kilogram of metal or material that you’re using. We don’t yet have the numbers for that o[r] the powders and extruded [plastics] used in additive manufacturing” (Dornfeld as quoted in Nowak 2013). From my experience of working on the *Potential* project, I was surprised by how much waste I created. I generated bags and bags of waste through excessive extrusion during filament

Less waste manufacturing?

processing, miss-prints and errors that led to wasted prototypes and purging the nozzle to unclog it. Recycling may eventually be an option for this waste but currently very few facilities will process this type of plastic (Boyd 2011).

9. Infinite shades of material

I go into much greater detail about this point in the section on sustainability, because much of this research wouldn't have been necessary if this statement were true. Pratt explains,

> The materials are limited to a few plastics. ABS plastic, by far the most popular, is relatively safe but not food safe (and the domestic kitchen is one place that seems to see the most constant customization and design... PLA plastic, which is somewhat more food safe and bio [sourced] (it's made from plant starches) is more finicky to work with... Every day I have someone ask about other materials. Nylon. Wax. Metal. The answer is, unfortunately, no. Nylon may be close, but it's not likely you'll see metal or wax in a desktop printer for a while yet (2013).

"...if you want to combine materials you need to have multiple print heads or switch from one to another, like the different color cartridges in your desktop inkjet printer.

– Anderson 2012, 81

But it isn't like the colour cartridges in your desktop printer! At least not yet. A standard desktop printer can handle only one material at a time and switching requires stopping the machine – which can ruin a print that took hours to build. Multiple nozzle printers are moving in this direction but they are in their infancy.

10. Precise physical replication

Again, this one comes down to the skill of the user and the precision of the printer. My experience has been that variations in extrusion flow of the plastic during the printing process, room temperature, ventilation, and the colour of the plastic used can affect the precision of the final object. While these issues are not so important if you are printing a bust of Yoda they will prevent a 3D-printed LEGO from connecting with another LEGO.

Refuting Lipson and Kurman's "10 Principals of 3D Printing" (2013) is not done contentiously, but to demonstrate what I feel are some of the key issues that lead to the sort of enraged frustration experienced by users of this new technology when they discover the reality is much different to the hype. My concern here is not that the media has it wrong or that people should be more specific in what they say but that these issues make 3DP inaccessible to a wider general public who do not have the skills, time, or patience to learn this new technology.

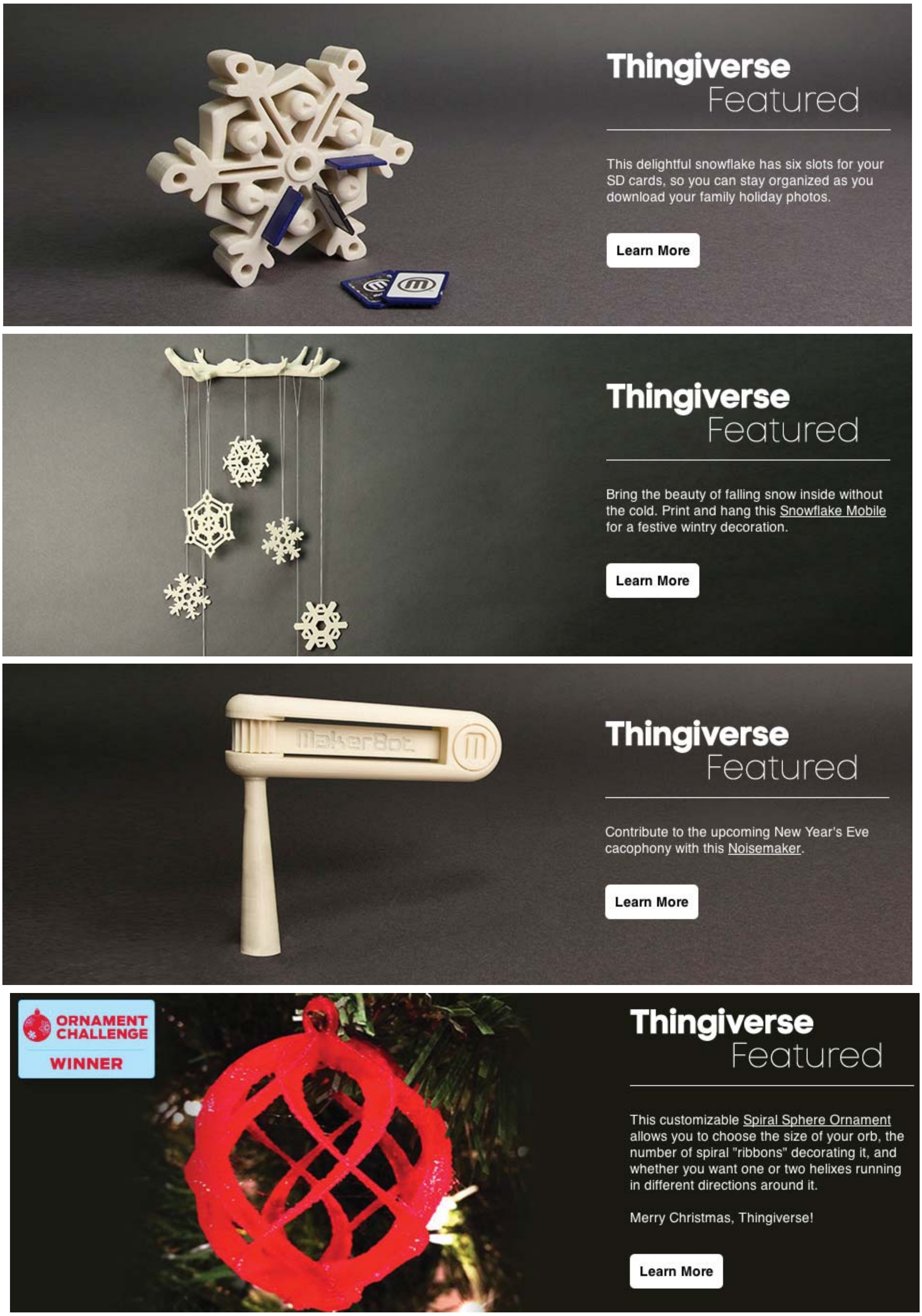
ABS (acrylonitrile butadiene styrene): a common petroleum-based thermoplastic, the most common type of fused filament fabrication 3D printing material.

PLA (Polylactic Acid): a common thermoplastic derived from starch (often vegetable), the second most common D3DP material.

There is one more limitation of 3DP that needs to be addressed. In fact, I feel that resolving this limitation may be the key, or "killer app" (Gershenfeld, 2005), that ensures 3DP's relevance to society at large. The limitation is that "You can't print much that's genuinely useful". Or at least that is how Dave Johnson of CBS news puts it. Johnson goes on to say,

> Here's a little exercise you can do to test the 3D printing waters: Browse the Thingiverse (www.

MakerBot Thingiverse



Featured 3DP Items on the Makerbot Thingiverse Website,
December 30, 2013

thingiverse.com), the open-source library of printable objects you can download and print with your 3D printer. What you'll probably find is that it's mostly a lot of toys and tchotchkes that have little practical use (2013).

Johnson's example highlights the lack of functionality of most 3DP objects; a point that has been raised by many other writers and users of this new technology (Pratt 2013; Nowak 2013; Hagerty 2013; Whitwam 2012). In my research using the 3DP to design functional furniture joints, I have deduced that the two factors responsible for this lack of functionality are the printing process and the materials used in 3DP.

The printing process, as Pratt pointed out earlier, causes weak intra-layer adhesion of 3DP objects. I found that this problem can be caused by the temperature of the nozzle, the room temperature, humidity, size, and flow of the extruded plastic, and the direction that the layers are printed in. Many of these variables are carefully monitored by expert users of this technology. Vik Oliver, who worked on the development of the first RepRap 3DP and owns Diamond Age, a plastic filament supplier in Auckland, New Zealand, explained to me that he keeps a small heater in the room where he uses his 3DP so he can combat these variables. To a novice, however, there can be a lot of frustration in troubleshooting why his/her printed objects are excessively weak in certain directions.

If the slicing programmes permitted users to dynamically control the direction of specific layers or groups of layers, then objects designed and made with 3DP could be reinforced according to their intended use.

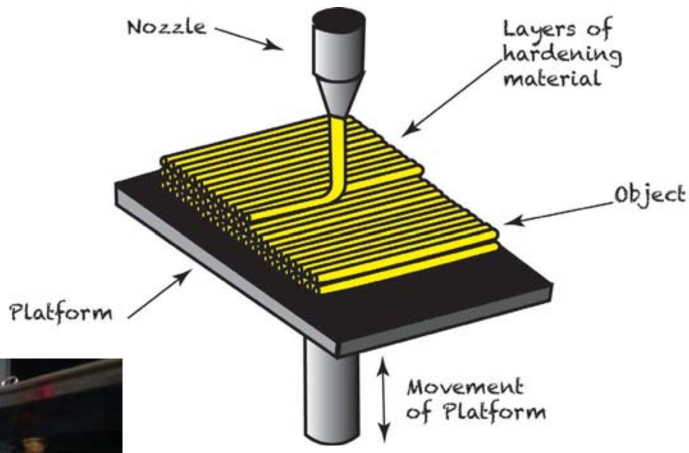
To explore this issue further I tensile strength-tested the materials that I developed to make the Jansen Joint. I found that, when stressed along the print direction, unidirectionally printed objects (all layers printed in the same direction) were stronger than multi-directionally printed objects. These same samples however, are weaker than multi-directionally printed objects when they are stressed horizontally to the print direction.

This finding is significant because it is one way that the functionality of 3DP objects could be dramatically improved. If the slicing programmes permitted users to dynamically control the direction of specific layers or groups of layers, then objects designed and made with 3DP could be reinforced according to their intended use.

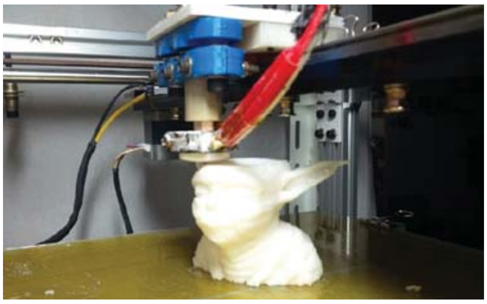
FFF (Fused Filament Fabrication): (AKA: FDM or Fused Deposition Modelling) A 3DP technology that employs a heated nozzle to plasticise thermoplastic filament to build objects according to the instructions of a digital .stl file.

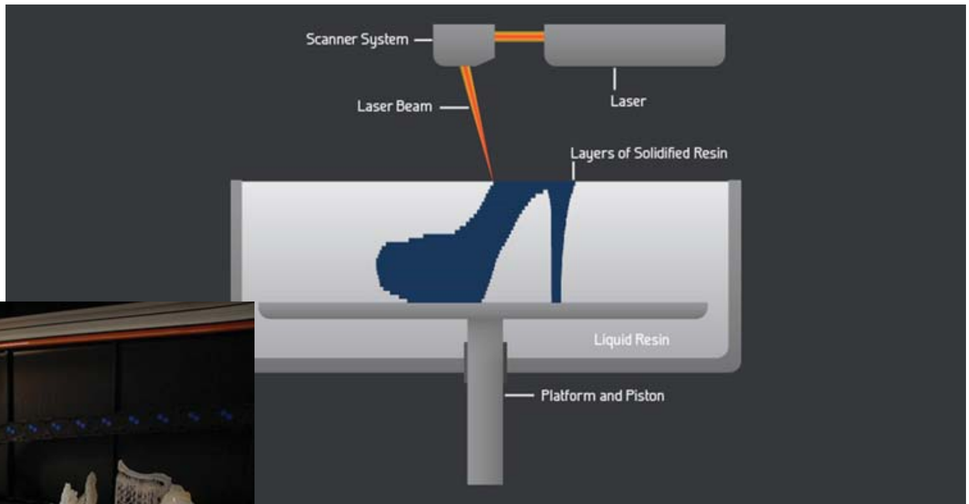
Stereolithography (SLA): a 3D printer that uses a laser beam to build up the required structure, layer by layer, from a liquid polymer that hardens on contact with laser light.

But this solution is rooted in fused filament fabrication (FFF), the currently dominant D3DP technology. Using design thinking and Tim Brown's tactic to "ask whether this is even the right problem to be solving" (2009) leads me to question whether the better solution may actually be in the development of other existing or currently undiscovered technologies to address this problem. Perhaps stereo-lithography (SLA) or selective laser



FFF Printing Method





(Proto 3000, 2013)

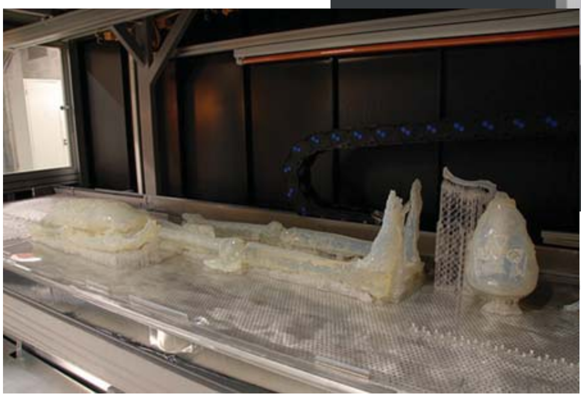
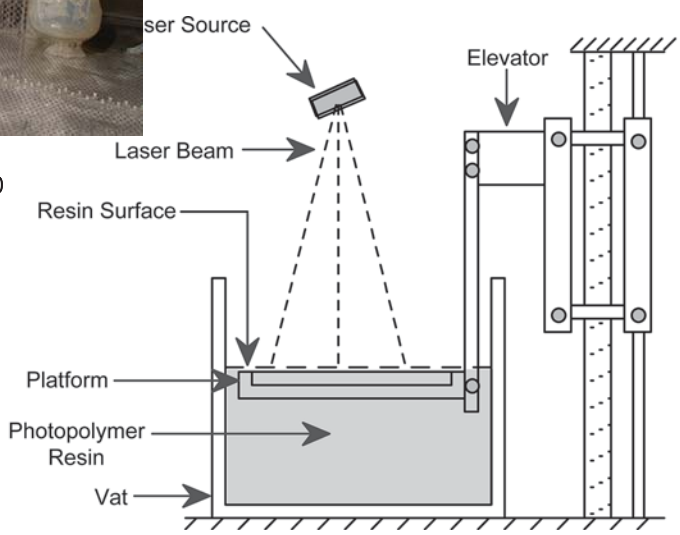


Photo from *Bones* TV show
as referenced by Peel, 2010



SLA Printing Method
(Zhang, Tsou and Rosenberger, 2000)

sintering (SLS), which uses lasers to heat the surface of a resin or powder bath to build models, would be better than FFF as a D3DP technology? Currently, several companies are working to develop less expensive desktop SLA 3DP (e.g., the Form 1 3DP). Or perhaps a hybrid form of SLA or SLS where layers are not necessary because lasers or ultra sound forms a model below the bath's surface? These suggestions hinge upon the results of further research. In the meantime, however, it is worthwhile to deal with the technology we have and explore how it can be refined.

The other major factor limiting the functionality of 3DP objects is the materials used by 3DP (Gershenfeld 2005; Anderson 2012; Pratt 2013; Hagerty 2013). Currently, materials are both limiting the development of 3DP *and* pose the greatest possibility for solving the problems of functionality and relevance to the greater population.

> The final frontier in rapid prototyping is to introduce functional as well as structural materials, in order to print complete working systems (Gershenfeld 2005, 101).

The development of 3DP materials that have a wider range of properties like flexibility, electrical conductivity, and structural strength will mean that the objects printed can be put into use in people's daily lives. When people can print a replacement leg for their dining table, replacement desk lamp for their office, or replacement glass for their cell phone, then this technology will become relevant to everyone.

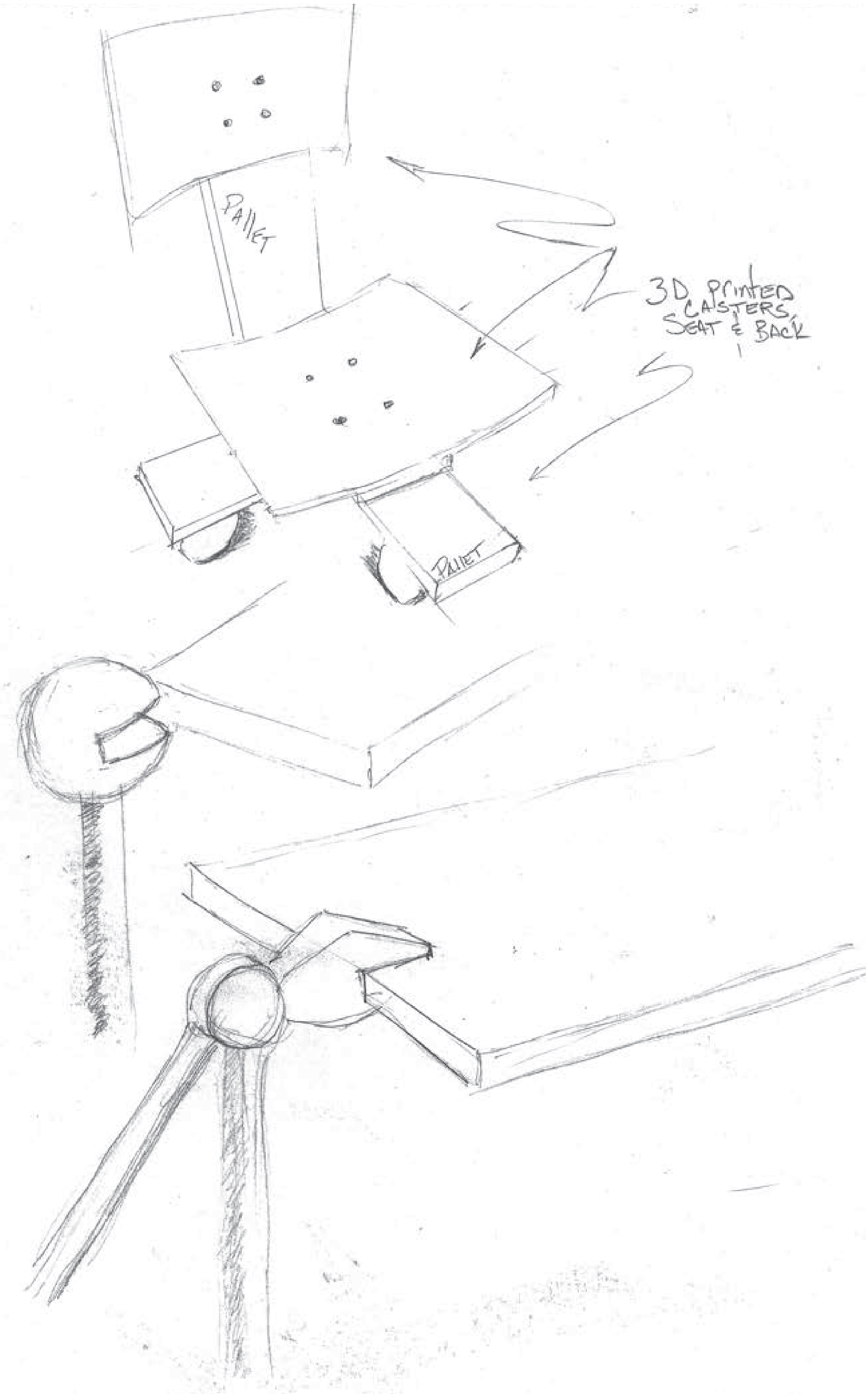
"We are all designers now. It's time to get good at it.

– Anderson 2012, 59

When this happens we will all be designers of our own products. We will have a vested interest in modifying, adapting, and making our objects to fit our specific needs. However, as designers we must choose these new materials carefully. In the next section I will explore the role design has to play in minimising the impact these new materials will have on our environment.

Selective Laser Sintering (SLS): a 3D printer that uses a moving laser beam to build up the required structure, layer by layer, from powdered polymer that melts on contact with laser light and then hardens as it cools to form each layer.

In this section I have explored the functionality, potential, and current landscape of 3DP. I have argued that key principals, as outlined by Lipson and Kurman, must change for 3DP to become more accessible to the general public. Also, I argued that the functionality of 3DP objects must improve for 3DP to become relevant to people's lives and that this depends on two factors: improving the process and user control of how the technology builds objects, and developing a wider range of materials. This was done to emphasise the potential for social change and to identify limitations that must be overcome if this change is to happen. However, the adoption of this technology by a greater portion of the population will have significant environmental implications, which I will address in the next section.



Early sketches of the Pallet Joint

Sustainability

> There are professions more harmful than industrial design but, only a very few of them (Papanek 1971, 1).

What happens when we have a mini factory in every garage? Won't the disperse duplication and reproduction of products be more wasteful than the centralised industries we have now? Most of the materials of 3DP are petroleum based. What impact will this increased dependence on oil have on our environment and its ecosystems? "In 2010 alone, 265 million tonnes of plastics were produced [in the world], 15 million more than the previous year. This means that on the one hand more resources are being used to meet demand but also more plastic waste is being generated" (UNEP 2011).

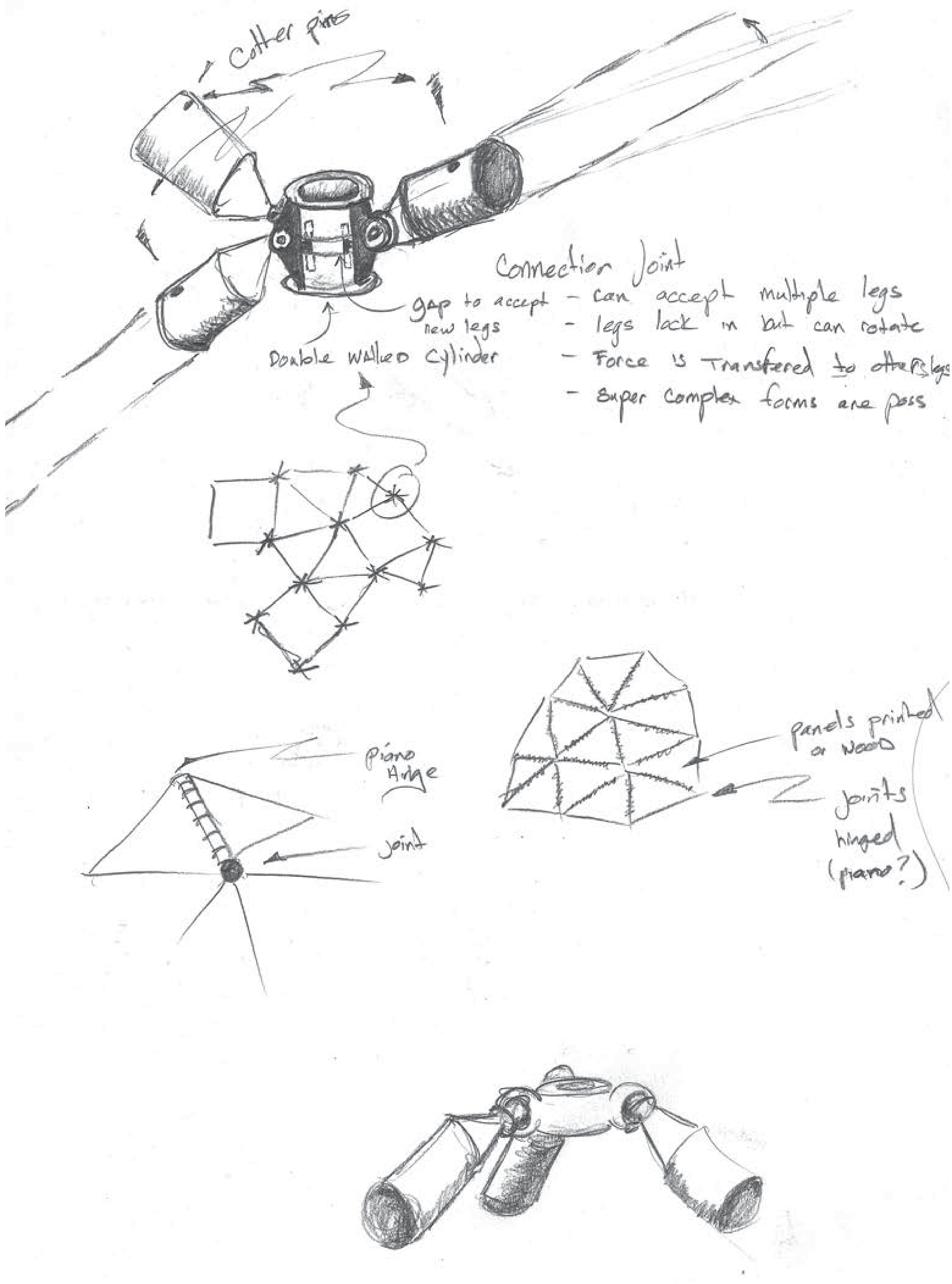
> ***"The collective potential of a million garage tinkerers is about to be unleashed on the global markets as ideas go straight into production, no financing or tooling required.***
>
> ***– Anderson 2012, 78***

In my experience as an environmental activist and my travels throughout the United States of America, Mexico, West Africa, and South East Asia, I have seen the effects of this build-up of plastic. I struggle as an industrial designer and an artist to reconcile my profession of making things with my desire to reduce our excessive waste. However, packing up my tools and refusing to make things is not a sustainable solution, as others will continue to make things despite my actions. Therefore, I hope to help change this situation and am motivated to use my skills as a designer to explore the materials of industry and production to see if there are better, more sustainable alternatives to what we currently use to make our products.

In this section I will discuss my design-led research into alternative 3DP materials and argue that a greater range of functional and sustainable materials need to be developed in order for 3DP to become relevant to the widest possible audience without creating additional environmental damage. Moreover, I will argue that this process of material development is not solely the realm of material engineers but, in fact, is where design and designers may provide the greatest hope of achieving this goal.

Thermoplastic: denoting substances (especially synthetic resins) that become plastic on heating and harden on cooling, and are able to repeat these processes.

Currently there are two dominant materials available for use with a 3DP, Acrylonitrile butadiene styrene (ABS) and Polylactic Acid (PLA). While there are other types of thermoplastics available for use with a 3DP, they were deemed to be outside the scope of



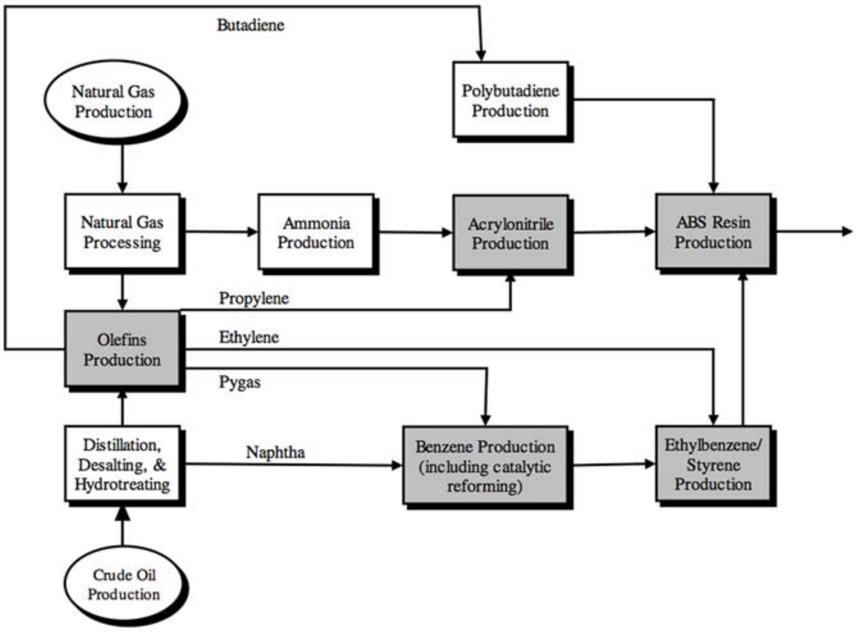
Jansen Joint development sketches

this research because they are not used often enough to have a substantial global impact.

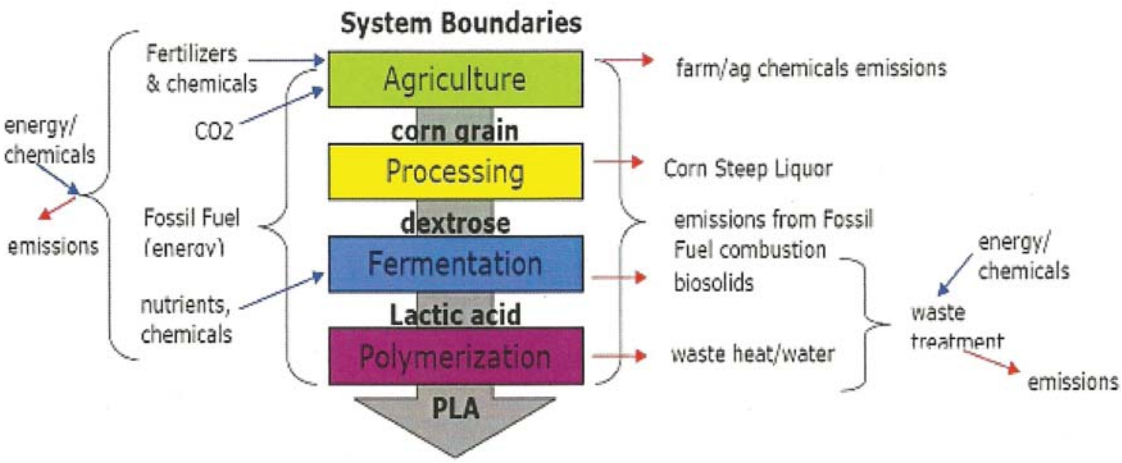
ABS, the most popular material for 3DP, is a common petroleum-based plastic used to make boats, mobile homes, pipelines, and LEGO blocks. It is the go-to material for many types of manufacturing because of its low melting point and mechanical properties like impact resistance, strength, good electrical insulation, and dimensional stability (Dynacorp 2013). However, the environmental and health considerations of this material are a key consideration. “1.37 billion pounds of ABS were produced in the U.S., Mexico and Canada in 2004” (Tullo 2005 as cited in Franklin Associates 2011). Manufacture of ABS produces high levels of toxic hydrogen cyanide (HCN) and acrylonitrile, which are normally sent to deep well disposal, a disposal method where hazardous waste is injected into the earth below the water table. Global plastic production in general has been increasing by about 5% a year. While ABS can be recycled, it usually isn’t. Studies in the U.S. in 2011 show only an estimated 8% of produced plastic was actually recycled (UNEP 2011; EPA.gov 2013). This low recycling rate reflects the problems that many developed countries have with plastic recycling. Moreover, when ABS is burned, which is a common solid waste disposal technique, toxic HCN and carbon monoxide (CO) are released into the atmosphere. It is unclear how long it takes ABS to decompose, but estimates range from 700 years to never (Harrris 2013; Recycling-facts.com 2013; Luz 2013). These statistics are focused on North America because it is better developed than many other parts of the world and it has established recycling networks. Less developed parts of the world are just as dependent on the plastics manufacturing produces but their recycling systems are not as robust.

> ***“ Modern industries still operate according to paradigms that developed when humans had a very different sense of the world. Neither the health of natural systems, nor an awareness of their delicacy, complexity, and interconnectedness, have been part of the industrial design agenda.***
>
> ***– McDonough and Braungart 2008, 26***

The second most common material for 3DP is biosourced PLA plastic. Made from milk or plant starch (i.e., corn, cassava, kiwifruit, etc) PLA is not as strong or durable as ABS but it resists warping, a common problem when printing with ABS. PLA is highly politicised because of its corn-based origins and is often cited as the green alternative to using petroleum-based plastics. However, the high energy consumption and release of CO_2 during production is greater than similar petroleum-based plastics, like high density polyethylene (HDPE)(Chiarakorn, Permpoonwiwat, and Nanthachatchavankul 2010). Current manufacturing is estimated to be about 180,000 tonnes per year and most of this is done by the U.S.-based Nature Works (Astley 2012). Dr Sarah Boyd of The Sustainability Consortium at the University of California, Berkley turned a critical eye on these claims. Boyd explains that while PLA is biosourced the time-frame for biodegradation may ranged anywhere from 10 to 10,000 years. Currently, widespread recycling facilities for PLA do not



ABS Production (Franklin Associates, 2011)



Processing of PLA (Landis, 2012)

exist, and because manufacturers often mix it with other colorants and chemicals when PLA is incinerated it can produce carbon monoxide or other toxic emissions like other plastics (Boyd 2011). Moreover, recycling “still requires a lot of energy and the use of other chemical solvents” (Huyhua 2013). This energy-intense process requires shipping, sorting, cleaning, processing, shipping again and re-manufacturing.

My investigation into alternate sustainable materials for D3DP identified several bio-plastics and plastic composites that might be worth testing. I reviewed studies that had used natural materials like flax fibre, palm fibre, or rice straw and mixed them with bio plastics like thermoplastic starch, poly-3-hydroxybutyrate (PHB), polyamide 11 (PA 11), polyhydroxybutyrate-co-valerate (PHBV) and biopolyethylene (BPE) (Bledzki and Jaszkiewicz 2010; Admin 2010; Siyamak et al. 2012; John and Thomas 2008). However, due to variables like availability, mechanical properties, and cost, wood plastic composites were more appropriate than the rest (Maine 2013; Plastics Technology 2004; Ashori 2008; Lu, Wu, and McNabb 2000)

“

Some Designers, equally adept at representation as they are with putting things together, are grabbing this opportunity to redefine their role as hybrid disciplinarians.

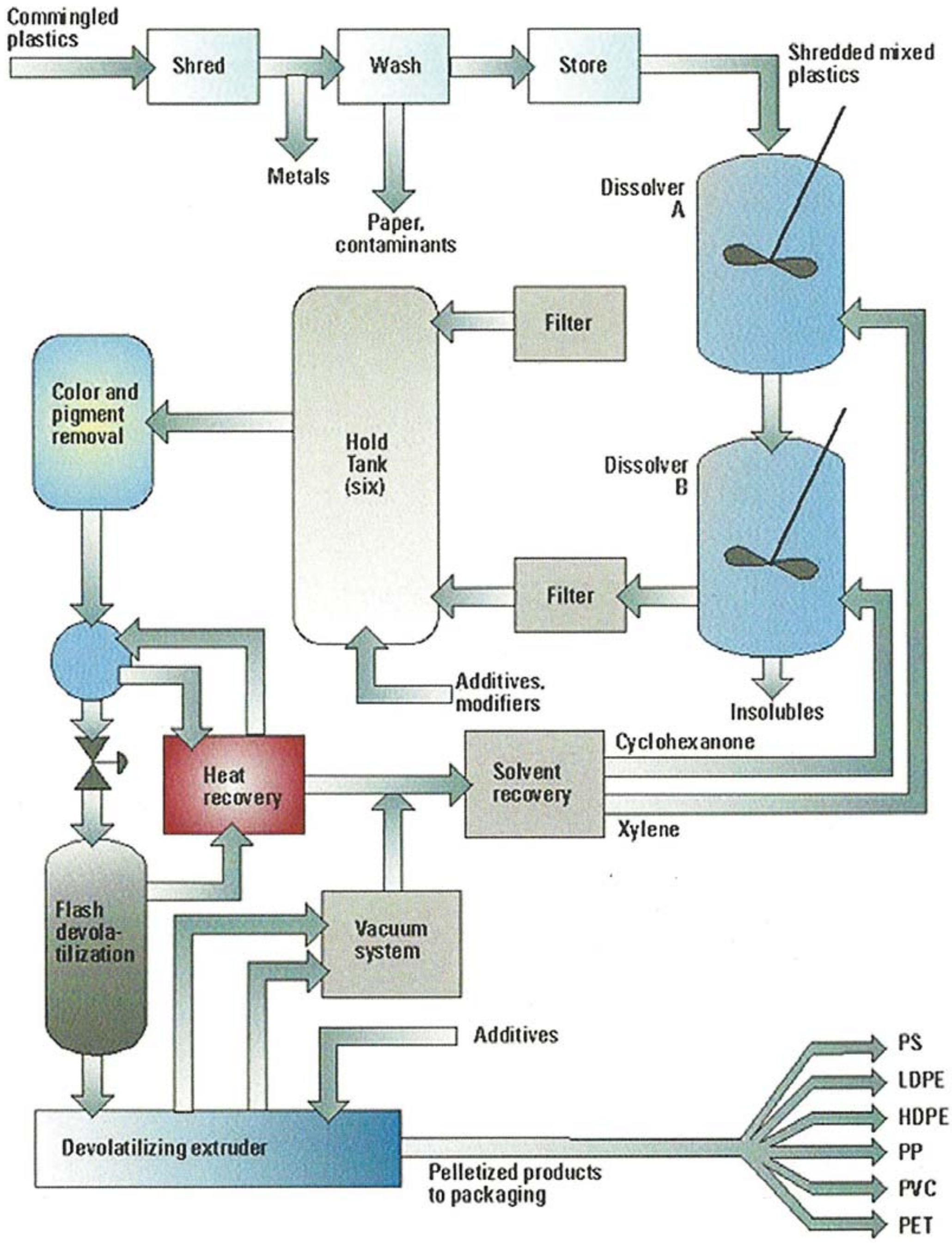
– Sheil 2012, 156

In a wood plastic composite (WPC), wood flour or fibres lend their mechanical properties of lower density, high strength, modulus (stiffness), and biodegradability to the elastic properties of plastic when they are combined. WPCs are often stiffer and biodegrade faster than the original plastic (Ashori 2008). This fact has led to greater consumer interest in WPC and in recent years WPC timbers have out-performed competing plastic products in decking applications (Migneault et al. 2008).

Locally, the New Zealand based SCION (a Crown research institute) has been working with wood fibres to develop a quality Wood Fibre Plastic Composites (WRPC) for the New Zealand construction market. In injection moulding, WRPC have been shown to increase the strength of some plastics and increase the plastic’s bio-degradability (Le Guen 2013). In February of 2012 I met with several representatives from SCION and learned of their interest in finding practical applications for their WRPC. I arranged to begin working with them in a sort of client-designer relationship and develop design applications for their WRPCs.

Modulus (Young’s modulus): a measure of elasticity, equal to the ratio of the stress acting on a substance to the strain produced.

At the onset of this project, the major question to answer was whether it was even possible to use a WRPC in a D3DP. Due to the D3DP’s small nozzle opening, it seemed likely that a WRPC would clog the machine and make printing impossible. If I was able to get the WRPC to print then it was also necessary to experiment and test different recipes or formulations of plastic and wood to see which combination offered the best mechanical properties for 3DP.



One common plastic recycling process. PLA is not one of the recycled plastics (Huyhua, 2013)

I saw this process of getting the material to work in the printer and testing it simply as a stepping-stone toward being able to design and make objects using this material. However, I discovered that this step was, in itself, a design process. I designed materials through the iterative process of making different formulations, testing them (both in a 3DP and with the tensile strength-testing machine at SCION), evaluating their properties, and then using a heuristic process to guide me in reformulating the next plastic so I could, in turn, design the best furniture joint possible.

> ***"In their symbolic work of making products 'meaningful', designers are a key link in our cultural circuit; for amongst many other things, they articulate production and the world of engineers with the market and consumers.***
>
> ***– Melles 2012***

Charles Owen, professor at the Illinois Institute of Technology, explains how design and materials science are related. In his diagram he places design on a scale opposite science, where science deals with subjects analytic and symbolic and design deals with subjects synthetic and real:

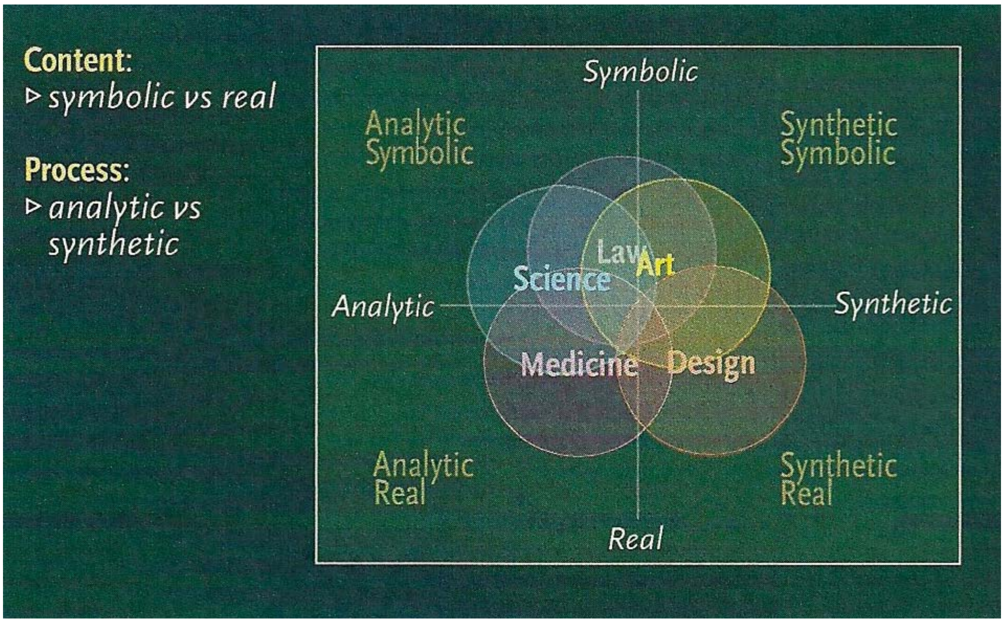
> Design in this mapping is highly synthetic and strongly concerned with real world subject matter. Because disciplines of design deal with communications and symbolism, design has a symbolic component, and because design requires analysis to perform synthesis, there is an analytic component—but design is a field relatively specialized, and specialized nearly oppositely to science...There are elements of science, however, that are synthetic in process (as, for example, in materials science or organic chemistry) (Owen 2007).

> ***"There is a connection between what that specific material wants to be and the intention imposed on the material.***
>
> ***– Oxman as quoted in Shiel 2012, 145***

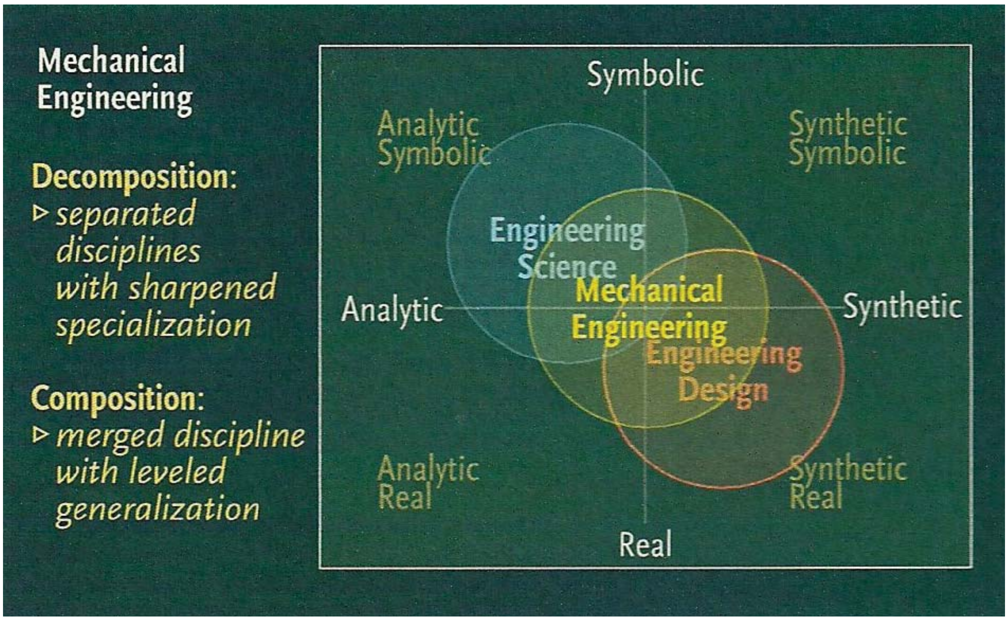
He argues that there is much to benefit from joining design thinking with science thinking because "...a combination of science thinking and design thinking is better than either alone as a source of advice" (Owen 2007).

Neri Oxman is an architect and designer who uses this approach and focuses much of her work on materials design, often allowing the materials to dictate the form and function of what she designs. Oxman, who holds a PhD in Design Computation, founded and directs the MIT Mediated Matter research group. "Her group explores how digital design and fabrication technologies mediate between matter and environment to radically transform the design and construction of objects, buildings, and systems" (Oxman 2011). In an interview with Sean Hanna, Oxman explains the design concept behind her digitally fabricated chaise lounge, "Beast".

> Beast was a design for a chaise lounge with the aim of integrating material structure and geometry in one process, but also integrating between those various phases in design which we've discussed; modelling, analysis and fabrication. Typically in the Modernist chaise lounge there's a separation between materials



Specialisation of Design vs Science
(Owen, 2007)



Relationship of Engineering Science and Design (Owen, 2007)

> and performances, but here the idea was to work with one material system and allow that system to differentiate itself locally so that it could work both as a structural supporting system, but also provide for comfort, so you are integrating between structural performance and corporeal performance (taken from Sheil 2011).

Another person who designs the materials and the processes that he uses to create his furniture is Belgian designer Peter Donders. Donders has created C-Stone and C-Bench in collaboration with composite technology facilitators Seifert and Skinner & Associates (SSA), who specialise in developing equipment and software for bespoke automated processes.

"Technologies that actually make a difference – that actually generate a paradigm shift – they don't come that often. And, I believe that 3D printing is one of those technologies.

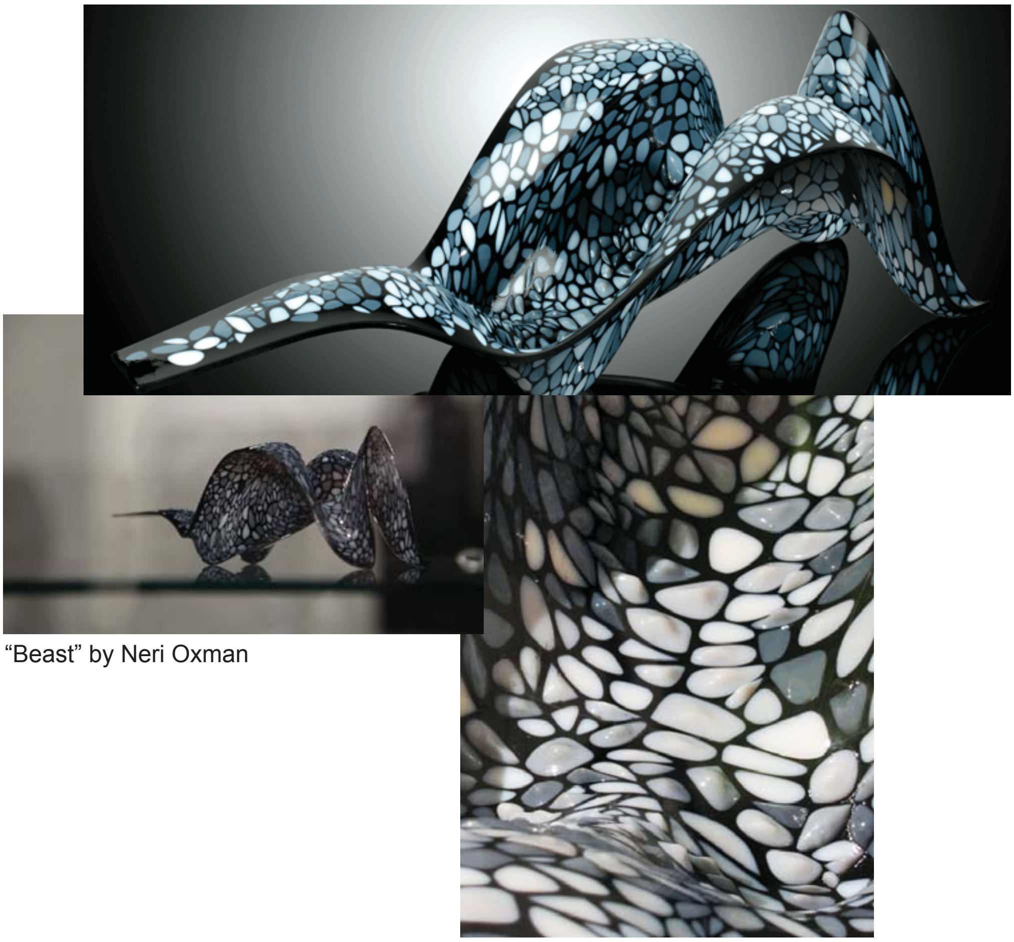
– Oxman as quoted in Stratasys 2012

Using advanced industrial materials from, amongst others, the aerospace sector, SSA have fabricated a variety of artefacts in carbon fibre and epoxy resin, using a process called filament winding where a band of fibres, impregnated with resin, is wound around a mould or mandrel in a specific pattern to produce the desired part's geometry. The resin is heat-cured and the part solidifies. The mandrel is then removed from the skeletal woven structure. The process is typically used in the manufacture of pressure vessels and pipes for industrial use, where fibres are wound in a regular and dense geometric pattern.

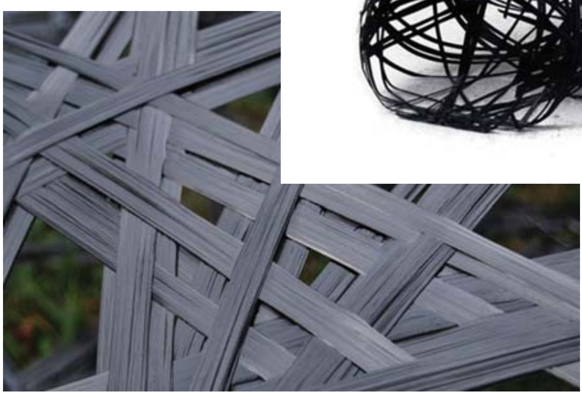
For me, the *Potential* project's focus on the design of WFPC for use in a 3DP is firmly situated in this join or intersection, of material design and digital fabrication design. This area of design is different from other industrial design practices in that it seeks to design materials and processes that generate design, allowing the materials to dictate the form or function as opposed to the designer dictating the form or function for the material and "the design process becomes the product, or the subject of desire" (Oxman as quoted in Sheil 2011).

I was eventually able to print with the WFPC recipes I formulated at SCION, but only after modifying and enlarging the printer's nozzle to a 1mm opening. With that hurdle behind me, I began the iterative process of testing each formulation in the printer to identify the optimal print setting for that recipe. My first printed samples used recipes that SCION had prepared using only PLA and wood fibre in very small quantities. However, due to the natural stiffness of PLA these proved to be too brittle for use in furniture construction; the samples would snap under light stress.

During this phase of the project I also did a comparative case study of Laywood, the first commercially available WPC filament for D3DP. This flexible and lightweight material appears to be made using wood flour and polymers, however I found it difficult to print with as the nozzle of the printer would frequently



“Beast” by Neri Oxman



C-Bench and C-Stone
by Peter Donders

clog. Moreover, objects made using this material were so lightweight and fragile they would not be appropriate for furniture construction.

Based on my feedback about the brittleness of the PLA my liaisons at SCION sent me three new formulations that were composed of PLA, Polypropylene (PP), Wood Fibre (WR) and Wood Flour (WL). Polypropylene is a non-biodegradable petroleum-based thermoplastic and I was surprised that they had chosen to include this in their formulation as this type of material goes against the intent of this research. At SCION's request I did test this formulation in the printer, and found them impossible to print with due to nozzle clogs caused by the WR and WL, problems with the PP composite adhering to the print bed, and a tendency for these composites to 'roll' or ball up instead of extrude in a continuous line of plastic.

In late July I visited the SCION facility in Rotorua to use their plastic extruder to make additional filament formulations. This visit proved to be pivotal in this research.

> ***"The exchange of information between design and fabrication is no longer a slow chain of vulnerable links, but a rapid flow of data, where design and making can be a simultaneous process.***
>
> ***– Sheil 2011, 149***

In discussions with my liaison, Marie Le Guen, I shared my concerns with using PP in the formulations. She explained that PP is a more flexible plastic than PLA and would help to resolve issues of brittleness. I asked that we explore other options that pose less environmental risk. In our discussion of biosourced and biodegradable alternatives we eventually settled upon an elastomer which I will call ELST. We determined that this elastomer would offer some interesting mechanical properties. Like PP, ELST is petroleum-based but it is also a biodegradable elastomer. In its pure state it is rubbery and flexible. While I was unhappy about the petroleum origins of ELST, I chose to work with it because it would increase the biodegradability of the PLA. Moreover, my intention was to use its flexibility to counter the stiffness of the PLA.

ELST: a petroleum-based elastomer that is more flexible than PLA, melts at a lower temperature and is also biodegradable.

Neat: pure; not diluted or mixed with anything else; non-composite.

Polypropylene (PP): usually refers to a common petroleum-based plastic, however recent research has developed a way of producing PP from bio-sources. This experimental technology is currently far too expensive to be relevant to commercial manufacturing.

In my recipes, I combined different quantities of WL, WR, PLA, and ELST, and extruded them using a large twin screw extruder. During a two-month period, I printed two sets of five samples to test each formulation. The results of these tests revealed several surprising mechanical characteristics of the WPC, and one of them stood out above all the rest. To explain this I will need to provide some context.

When using WRPC and WLPC in an injection moulding process these WPC's are generally stronger than non-composite (neat) PLA (Ashori 2008; Maine 2013). I anticipated that my WPC D3DP objects would be similarly strong. It turned out that almost all of them were weaker. My liaisons at SCION suggested this might be because of poor intra-strand and intra-layer cohesion that results

Making filament and using the extruder at SCION

Trying to print with the filament and some of the failed prints

from the D3DP process. These results were disheartening but there was a silver lining.

ELST is naturally much weaker and melts at a much lower temperature than PLA. Combining the two typically makes a weaker composite than just plain PLA by itself. However, my tests showed that D3DP samples made from a composite of PLA and a small amount of ELST were more dense, durable, flexible, and almost as strong as neat PLA-printed samples. The flexibility of this high density PLA composite (HD-PLA) is significant because other D3DP materials do not have this attribute!

Another significant finding was that in most circumstances, the WR and WL significantly decreased the strength of the composite plastics. Again, my liaisons at SCION suggested that the wood decreases the bonding strength between the 3DP layers of an object. But it appears that when small amount of wood fibre and wood flour are mixed with HD-PLA the composite sample is more flexible and still almost as strong as a neat-PLA-printed object. Further testing is needed to verify the degrees and nuances of these findings but, from a heuristic design perspective, it appears that a refined version of these composite plastic recipes would be well suited to the intention of this part of my design research – to identify more sustainable alternatives to the current dominant 3DP materials.

...these products will offer mechanical properties that currently do not exist with the dominant 3DP materials.

I returned to Rotorua and made several refined variations of this composite recipe. Further testing showed that the wood fibre also helped the composite to resist warping (a common problem with 3DP objects). In addition, printing got easier because the ELST has a lower melting point, liquefying sooner in the printing process than the PLA and increasing the viscosity of the composite plastic. Discovering these benefits allowed me to use refined versions of the WR, WL, PLA, and ELST to print prototypes of the modular joints that I was designing for furniture construction. These initial prototypes still needed to be tested and developed but this success offered the opportunity to join this path, my material design exploration, with the other path, my product design exploration, to develop a sustainable modular furniture joint.

For me, the significant result of designing this plastic for use in 3DP is not the material itself but the proof of concept that the material represents. It is possible to develop more sustainable materials for 3DP and these products will offer mechanical properties that currently do not exist with the dominant 3DP materials. In turn, the increased range of mechanical properties will mean that more things can be made with 3DP, enabling this technology to become more relevant to a wider population. Greater relevance of this technology, in turn, may lead to

Final material samples sent to SCION for testing significant social change by enabling the “have-nots” of the world to make for themselves what they do not have.

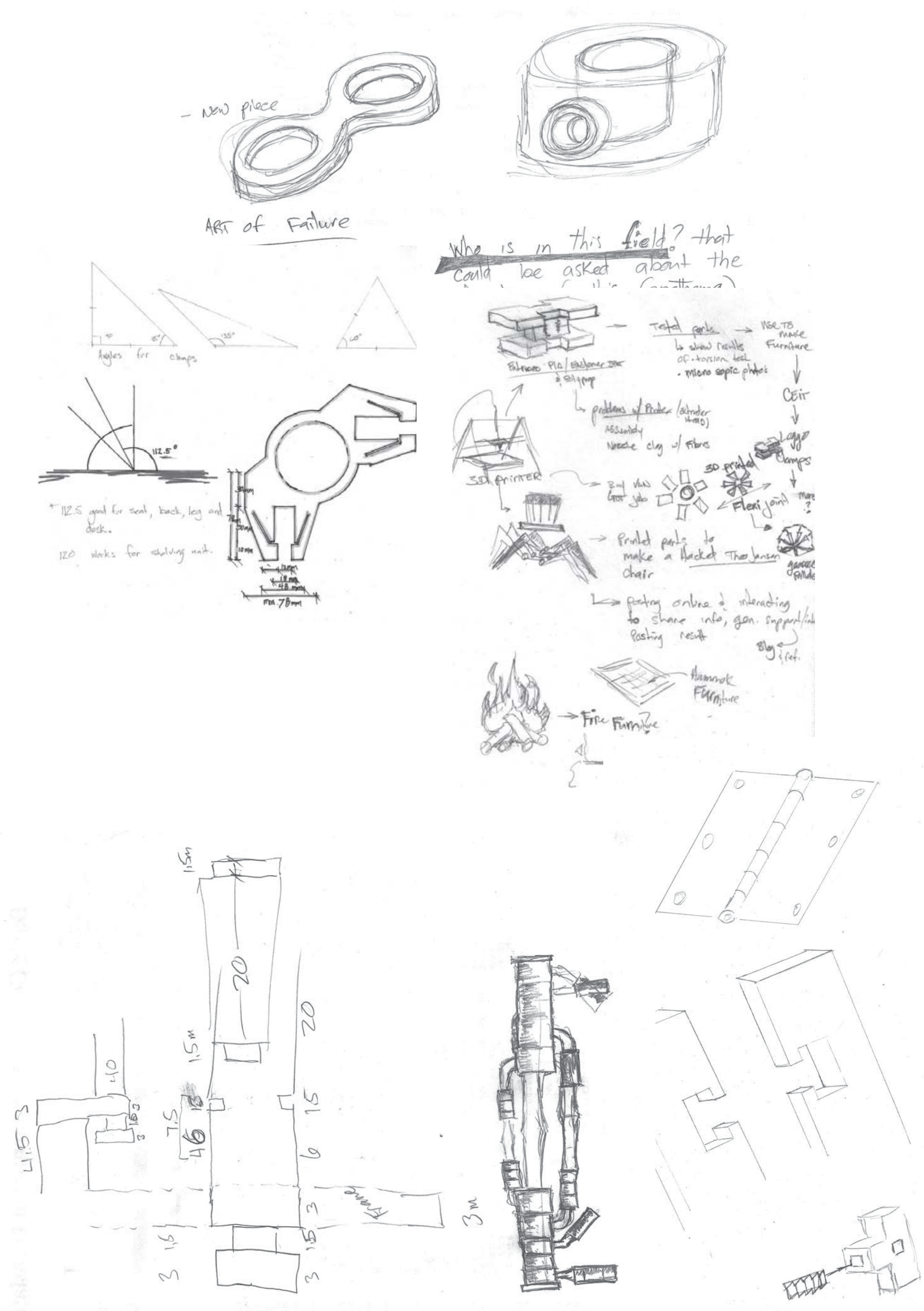
Even as I have tried to find alternative and more sustainable materials for D3DP, I have been conscious of the resources I have consumed and the waste I created. During the *Potential* project I have saved the wasted bits of filament and plastic from the extrusion process and the failed objects that resulted from clogs and other printing errors. This was done as much to see what the result would be as it was to explore the commonly asserted principal that 3DP is essentially a no-waste manufacturing process (Lipson and Kurman 2013; Anderson 2012). I certainly agree that the quantity of waste produced by additive manufacturing is substantially less than other manufacturing techniques. However, I was surprised by the quantity of rubbish I produced in the process of developing these relatively small furniture joints. This disproportionate quantity of waste is even more startling when it is multiplied by the potential waste to be created by the millions of new users of this developing technology.

In this section I have discussed my design-led research into alternative 3DP materials and argued that a greater range of functional and sustainable materials need to be developed in order for 3DP to become relevant to the widest possible audience without creating additional environmental damage. Moreover, I have argued that this process of material development is not solely the realm of material scientists and engineers but, in fact, is of distinct interest to design and designers. Material design is an integral part of digital fabrication as we develop and explore these new technologies and ways to functionally and sustainably apply them to our design needs.

“

All things appear and disappear because of the concurrence of causes and conditions. Nothing ever exists entirely alone, everything is in relation to everything else.

– Attributed to the Buddha, 563–483 BC



Joint development sketches

Design

> *“*
> ***Technology cannot be understood solely in terms of its conditions of possibility, But should also be analysed in terms of concrete artifacts that play a role in the relation between human beings and their world.***
>
> ***– Verbeek 2005, 47***

At the core of the *Potential* project is the understanding that D3DP isn’t going to be able to make everything we need. How then do we join what the printer makes with other materials to easily and sustainably create objects or structures that have function and can provide a benefit? Moreover, how does a DIY maker manage this when a D3DP is their primary tool? This section examines the creative exploration and development of the *Potential* project. The intention of this exploration was to initiate concepts using hand sketching and CAD software and develop their design through an iterative prototyping-redesign-prototype-again process in order to fully engage the D3DP as a design tool. The prototypes developed build on the data obtained in case studies on joints (see Appendix 3) and material testing conducted in the previous section of this exegesis. Using an experimental approach to design means exploring a range of options when solving design challenges. During the *Potential* project I experimented and designed many different joint types. This section focuses primarily on one design exploration, the Jansen Joint.

This project followed two paths of design-led research. The Double Diamond diagram, a common visualisation tool for design thinking and other industrial design methodologies, is a good model for the trajectory of this research. It emphasises the expansive nature of this design process and underscores the theme of joining employed in this exegesis. Two paths split from an apex and diverge at angles, getting wider and wider until they reach a point of maximum separation, at which they begin their journey back to each other and eventually join again at a final point to make a final product – a diamond. In my design exploration of the *Potential* project I began with an idea to make a furniture joint on a D3DP. I expanded this exploration to look at an adjustable joint, a pallet joint, a flexi-joint, and the Jansen Joint, as well as to investigate alternative materials for use in 3DP. Like a diamond, from this widest point of my exploration, I began to narrow things down, focusing on what was working and leaving off what wasn’t. Finally, I arrived at a design solution that joined my design exploration of 3DP materials with my joint design exploration. This spotlight focus on just one joint has been chosen because the design development and exploration of this joint sufficiently encapsulates the design process used in my design exploration of other joints.

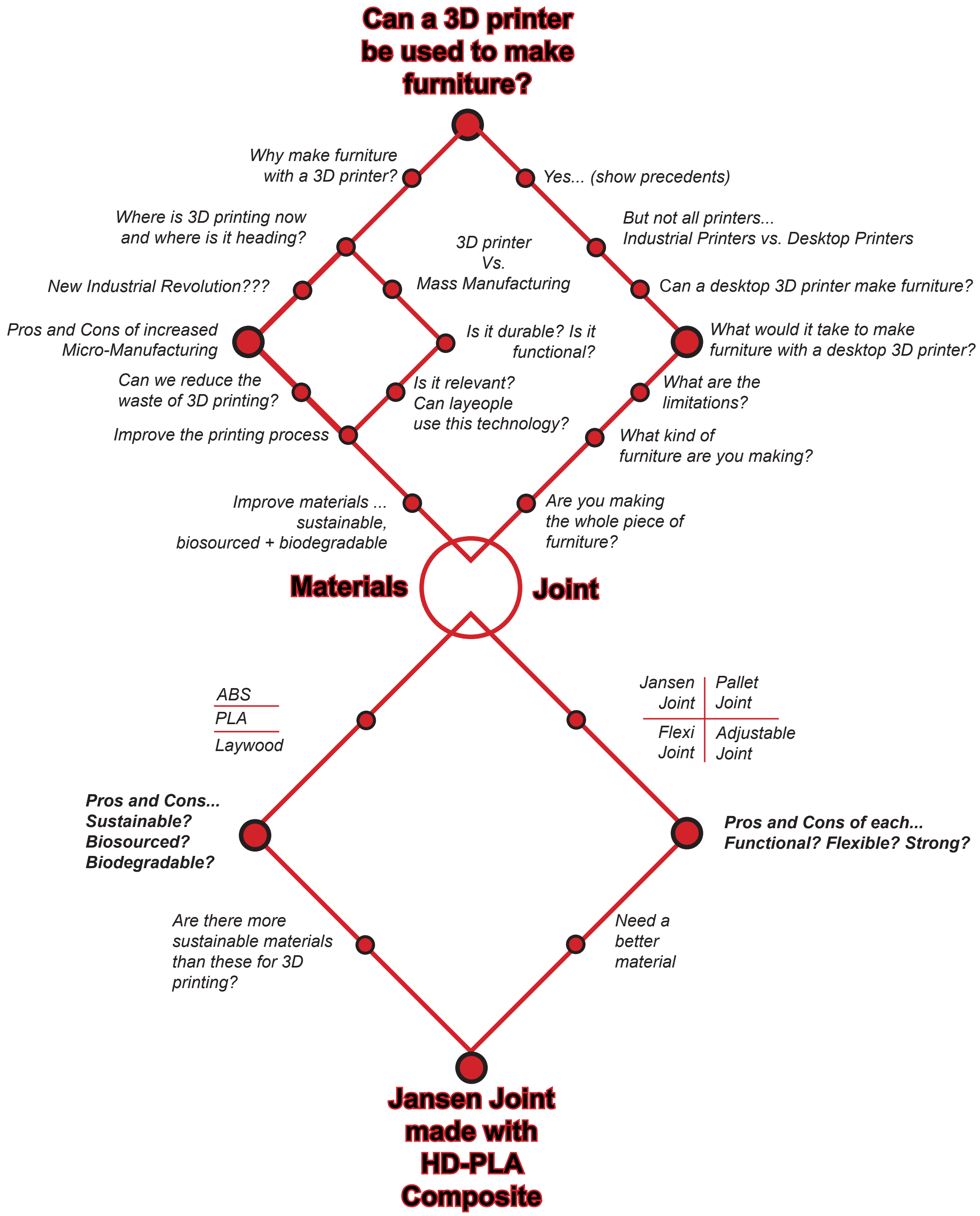


Diagram I used to visualise the research paths
that I pursued during the *Potential* project

Jansen started making his sculptures long before the rapid prototyping revolution. What if he had used a D3DP instead of cable ties to join the rods of his sculptures?

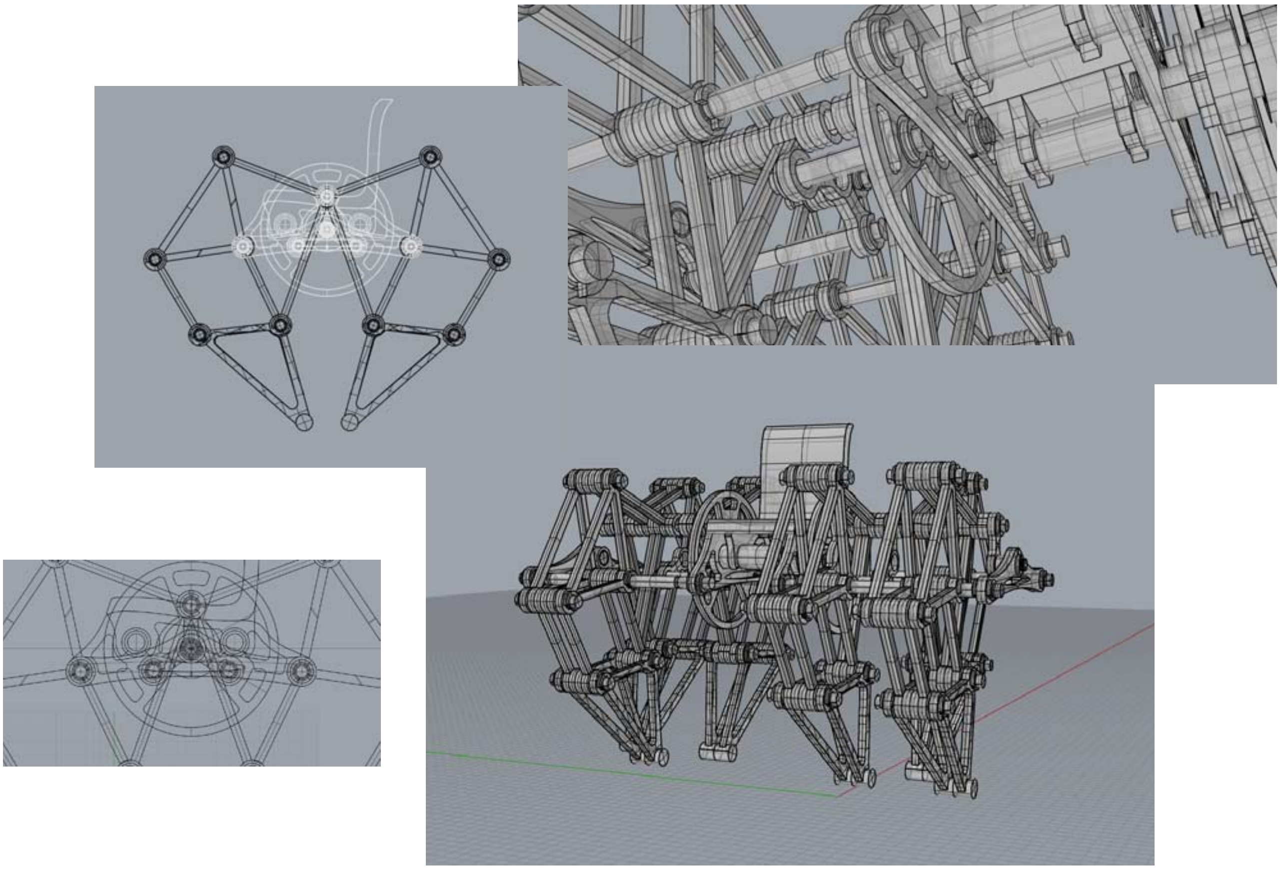
Kinetic: an object, sculpture or work of art dependent on movement for its effect

My design concept for the Jansen Joint developed from Theo Jansen's book *The Great Pretender*. In it, I discovered his impressive creatures, the "Strandbeests" (Dutch for "beach animal"), and his method of working. Jansen has spent nearly 30 years developing this group of kinetic sculptures to the point where they can now "live" on the beaches of Holland with very little assistance or maintenance from him.

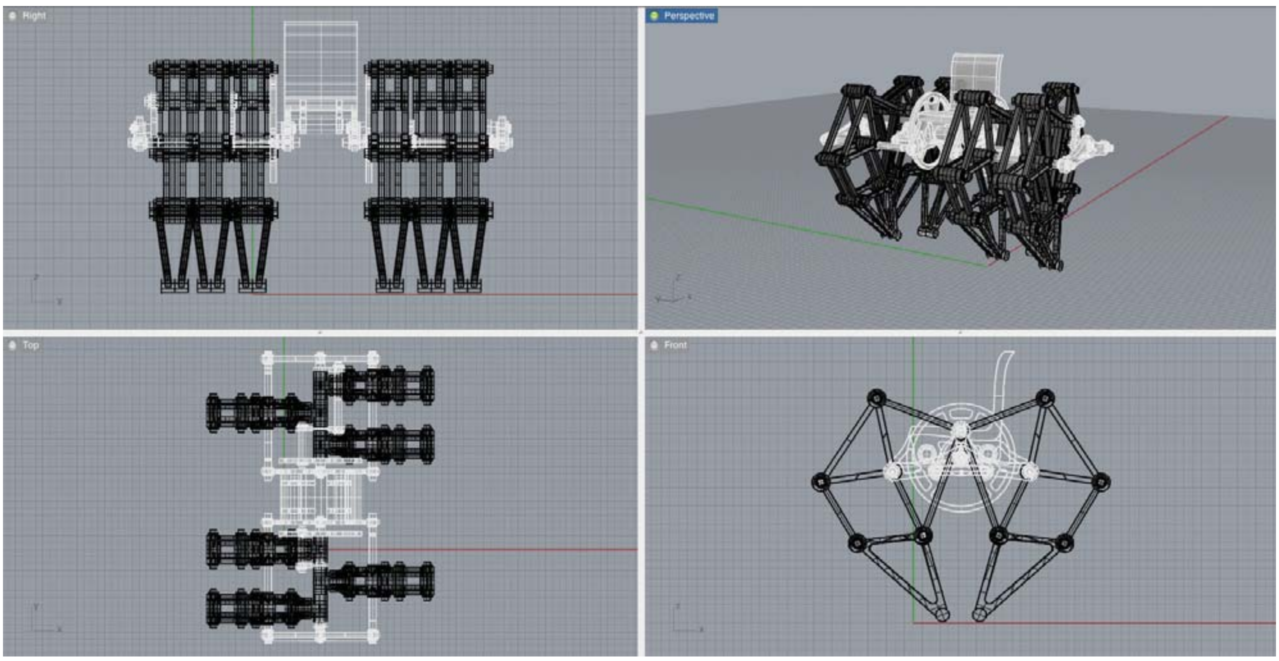
These walking sculptures were, at their most basic level, structures built from common plumbing pipes (rods) joined together with cable ties. They were the artistic equivalent of a rapidly prototyped, DIY answer to building a structure that could perform a variety of functions. What Jansen had done with pipes and cable ties I was trying to do using a D3DP. Jansen is building animal sculptures and I am building furniture, but structures can serve many purposes. In fact, the purpose of any structure is a subjective matter that is relative to each individual's perspective. What is a chair when it isn't used for sitting in? It is a ladder, a sculpture, a doorstop, or whatever use it is applied to. Jansen started making his sculptures long before the rapid prototyping revolution. What if he had used a D3DP instead of cable ties to join the rods of his sculptures?

I envisioned a walking chair as a design destination that would challenge the D3DP's ability to make what I could imagine and, in doing so, show the potential of the technology in a way that was socially relevant. However, as an artist I am prone to letting ideas fly away with my imagination. As a designer I am capable of grounding these ideas to practical and relevant design solutions. Building a Jansen walking chair was clearly outside the scope of this project, which is about designing something functional, socially relevant, sustainable, and 3DP. As an industrial designer I see furniture as an ideal focus for this project for three distinct reasons:

- Social relevance: furniture is ubiquitous in society. Every culture of the world uses it. Therefore, the development of 3DP furniture has the potential to impact a wide segment of the population.
- Sustainable relevance: Mass manufacturing is responsible for much of the environmental degradation of our planet. Furniture is mass manufactured all over the world. Developing 3DP furniture has the potential of providing a more sustainable alternative manufacturing option to consumers.
- 3DP relevance: D3DP are limited by many factors but three that are commonly referred to as hindering the development and widespread adoption of this technology are the ease of use, the size of their print area, and the functionality of the objects they make (Gershenfeld 2005; Anderson 2012; Johnson 2013; Hagerty 2013; Hart 2012; Pratt 2013; Proffitt



Screen-shots of my 3D-printable CAD model of the walking Jansen chair



2013; Hutchinson 2013). Exploring the design of D3DP furniture has the potential to identify ways in which this technology might improve and develop.

Despite furniture being well suited to the intentions of this research, it seemed unrealistic to hope to make a whole piece of furniture using a D3DP for the very reasons just mentioned. Modular furniture or, more specifically, modularity was an obvious solution to this challenge. I reasoned that if the furniture could be printed in sections and assembled then it might be possible to make the whole piece of furniture using a D3DP. But even this idea seemed flawed. Another limitation of D3DP is their speed (Gershenfeld 2005; Pratt 2013). Making a whole piece of furniture, even one divided into parts, would be so time-consuming and involved it is doubtful that anyone would bother. Again, modularity was the answer. Taking from the examples of IKEA furniture, scaffolding systems, and many tent manufacturers, I determined that making a modular joint could be the solution. By designing a modular joint to fit with other commonly available building materials (i.e., tubes or pipes like Jansen used) I could use the D3DP as an indispensable tool in the design and fabrication of a modular furniture joining system. I envisioned a DIY maker who just moved into a new apartment, maybe a student at university or a migrant labourer in a new town, printing off a batch of joints to connect inexpensive building supplies from a local hardware store to make a chair to sit on. This idea really came to roost when I realised that a modular joining system like this could permit the DIY maker to then convert his chair into a table or other furniture object as needed, re-using the same parts. For me, this idea was ticking all the boxes: socially relevant (enabling people to provide for themselves and save money), sustainably relevant (convertible furniture, the need to make less furniture, reduced waste) and functionally relevant (designing a modular furniture joint would showcase how a 3DP could be used to make functional objects).

> ***“Consumers tend to value more highly products in which they feel that they have had a hand in their creation, whether assembling a kit or just encouraging the creators themselves online. Researchers call this ‘the IKEA Effect’....***
>
> ***– Anderson 2012, 78***

This manner of designing furniture around a modular joint or joining system is the same idea behind German designer Christof Schmidt’s two chairs DaR and KaB. With these chairs, Schmidt used rapidly expanding polyurethane foam to form joints which hold standardised wooden rods. With the DaR chair, “The solid wooden elements of the chair are broken to measure and placed into a silicone-mould. Due to its expansion, the poured in polyurethane foam infiltrates every single wooden fibre at the breaking point and connects the pieces soundly. The foam hardens within minutes” (Schmidt 2010). With the KaB chair, Schmidt cuts the wooden rods instead of breaking them and exaggerates the size of the joints making them much larger than the wooden rods they hold. This works to create a blocky “LEGO” aesthetic and emphasises the joint’s importance. Schmidt’s

KaB Chair by Christof Schmidt

DaR Chair by Christof Schmidt

DaR Joint
by Christof Schmidt

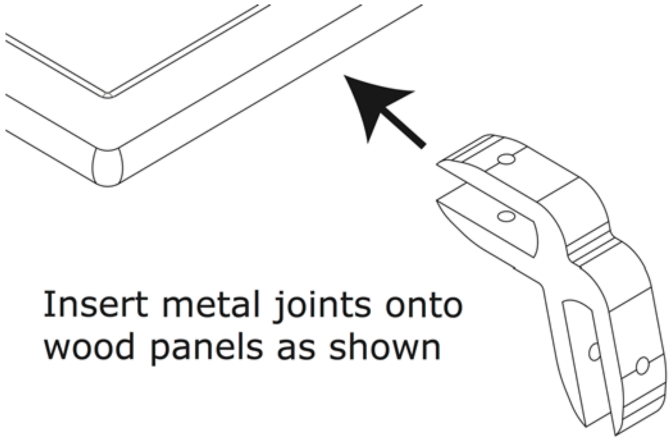
KaB Chair by Christof Schmidt

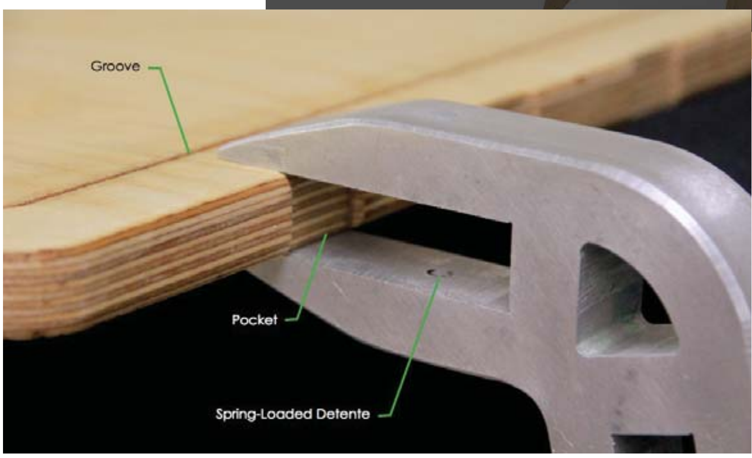
This works to create a blocky 'LEGO' aesthetic and emphasises the joint's importance.

modular joint fabrication technique is an excellent example of a system that is designed to work with a standardised building material (square wood rods). The system permits Schmidt to alter the length of the rods to make different sized chairs or change the configuration to re-use the same joint mould to make different types of furniture. The oversized joint in the KaB chair is especially relevant to 3DP because its simple shape is essentially an extruded outline; an easy shape for a D3DP. I appreciate Schmidt's system and the playful-blocky aesthetic of the KaB chair, but its bulkiness isn't for everyone. This chair would be problematic in a small living space and would clash with the more simplistic design styles that are dominant in contemporary furniture. For the *Potential* project, I am keen to avoid using polyurethane foam or other toxic non-biodegradable materials. Moreover, once Schmidt makes a joint using the foam, the pieces permanently are fixed into the joint and cannot be removed. This lack of adjustability is problematic as it isn't user friendly. The *Potential* project seeks to design a system that gives the user LEGO-like control to assemble and disassemble furniture structures easily.

Another example of a modular joining system is the "Snap" joint that was made by MIT students Lindy Liggett, Lisette Lopez, Morris Taylor, Josh Ramos, and My Vu. The system consists of slotted wooden panels held in place by metal joints that clamp the panels and hold them using a spring-loaded ball-pin which seats in the groove. As I observed with Schmidt's joint, extruded shapes of this type are well suited to the slicing and layering process inherent in the 3DP process. The Snap joint system is ideal because it is easily assembled and disassembled by the user. This reconfigurability gives the system a dynamic element that the Schmidt joint lacks. However, the system lacks the strength and rigidity that Schmidt was able to achieve using a material that tightly formed and bonded around the materials the joints hold in place. The spring-loaded ball is not completely captured in the groove and cannot resist horizontal stress very well, which leads to instability. This effect can be minimised by adding extra supports but requires a fair bit of additional room. The spring-loaded ball-pin can't be achieved using D3DP unless the joint is re-designed to allow these parts to be assembled after printing. Aesthetically, this joint and the modular furniture system are geometrically simple and bulky. The slight angle of the legs of the chair and tables is reflected in the trapezoidal shape of the panels. This simple shape gives the system a clean, well-designed feel in spite of its bulkiness.

During the *Potential* project, I designed two modular joint systems that worked with the same principal of joining panels that the Snap joint is based on. With the first joint, the Adjustable Joint, I explored making a joint that was re-positionable to give the user/





Snap Modular Joining System
The Paper Clique©

Maker more control and a greater variety of structural options. With the second joint system, the Pallet Joint, I worked with pallet planks instead of plywood in order to explore a less expensive and recycled building material. In both of these explorations the joints went through many iterations and prototypes to identify the benefits and limitations of each system.

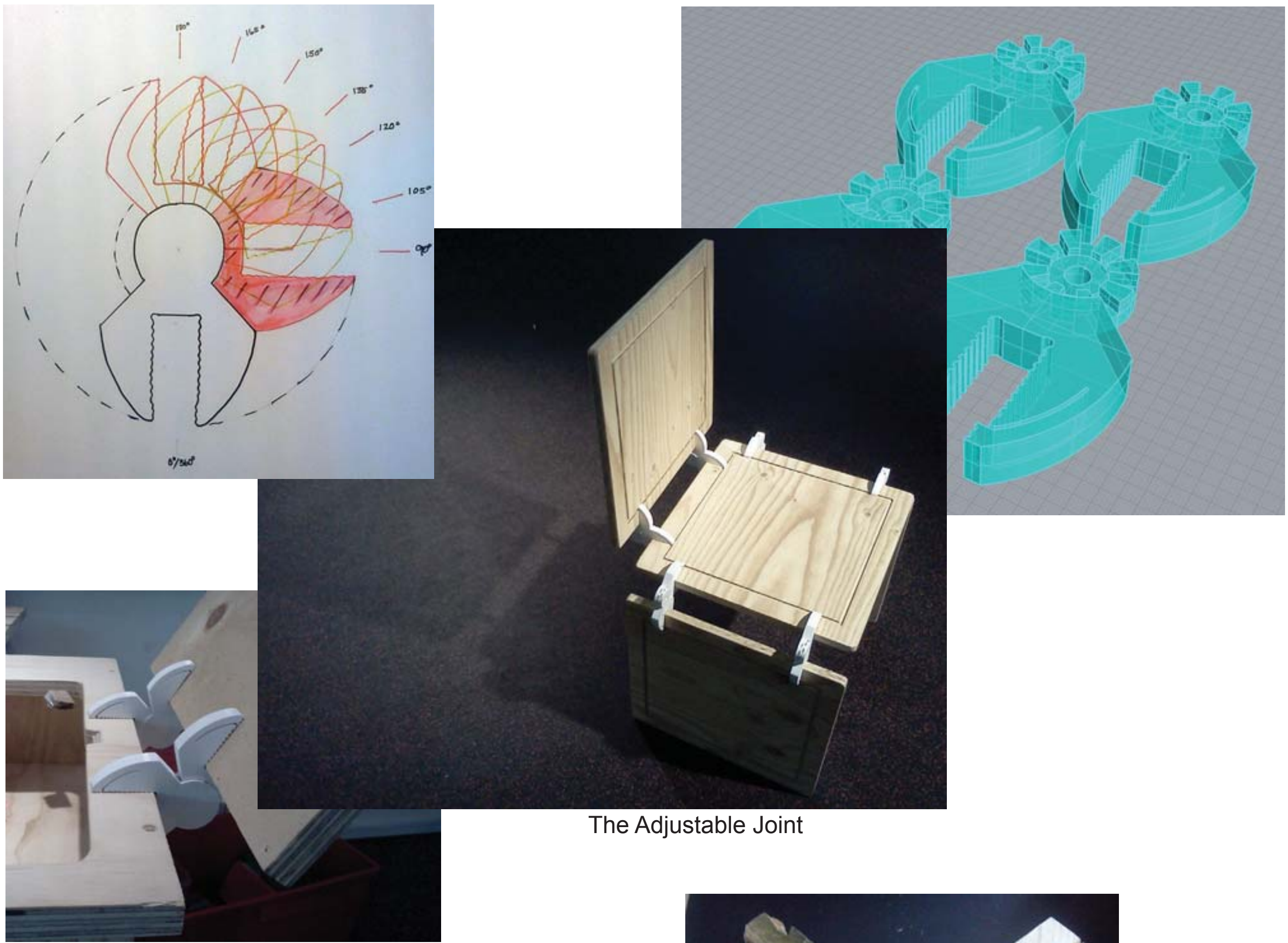
The Adjustable Joint is a multi-positional clamping joint that is designed to seat into a grove in pre-cut standardised plywood panels. The clamp can be angled to 90º, 120º, or 180º, depending on the furniture structure needed. Then the clamps are attached to the panels and seat their flexible "tooth" into a groove cut inset from the panel's edge. The clamps must be locked into place using a wing-nut and bolt which can also be 3DP. This joint system was one of my first explorations into using a 3DP as a design and prototyping tool. I used an Ultimaker 3D print, one of the better open-source D3DP, and had a relative amount of success at first getting the printer to make the objects that I designed. However, after a short time things started to break down. The printer would clog, the print nozzle would knock objects off the print bed and a number of other issues developed. I struggled to get the printer to function and complete tasks. Moreover, the functionality of the joint was a major stumbling block. While I was quite pleased with my design of this system, which allowed the user to quickly assemble a variety of structures, I struggled to make rigid shapes with the clamp. There was too much flex in the plastic, the adjusting mechanism, and the way the tooth seated in the inset groove. My attempts to address these issues by adjusting the design were hindered by the fundamental weakness in the 3DP construction process. This led me to explore other opportunities.

Ultimaker: A Dutch based 3D printer manufacturer that produces printers that run on open-sourced software. They embrace a philosophy of community over profit for the benefit of the industry as a whole.

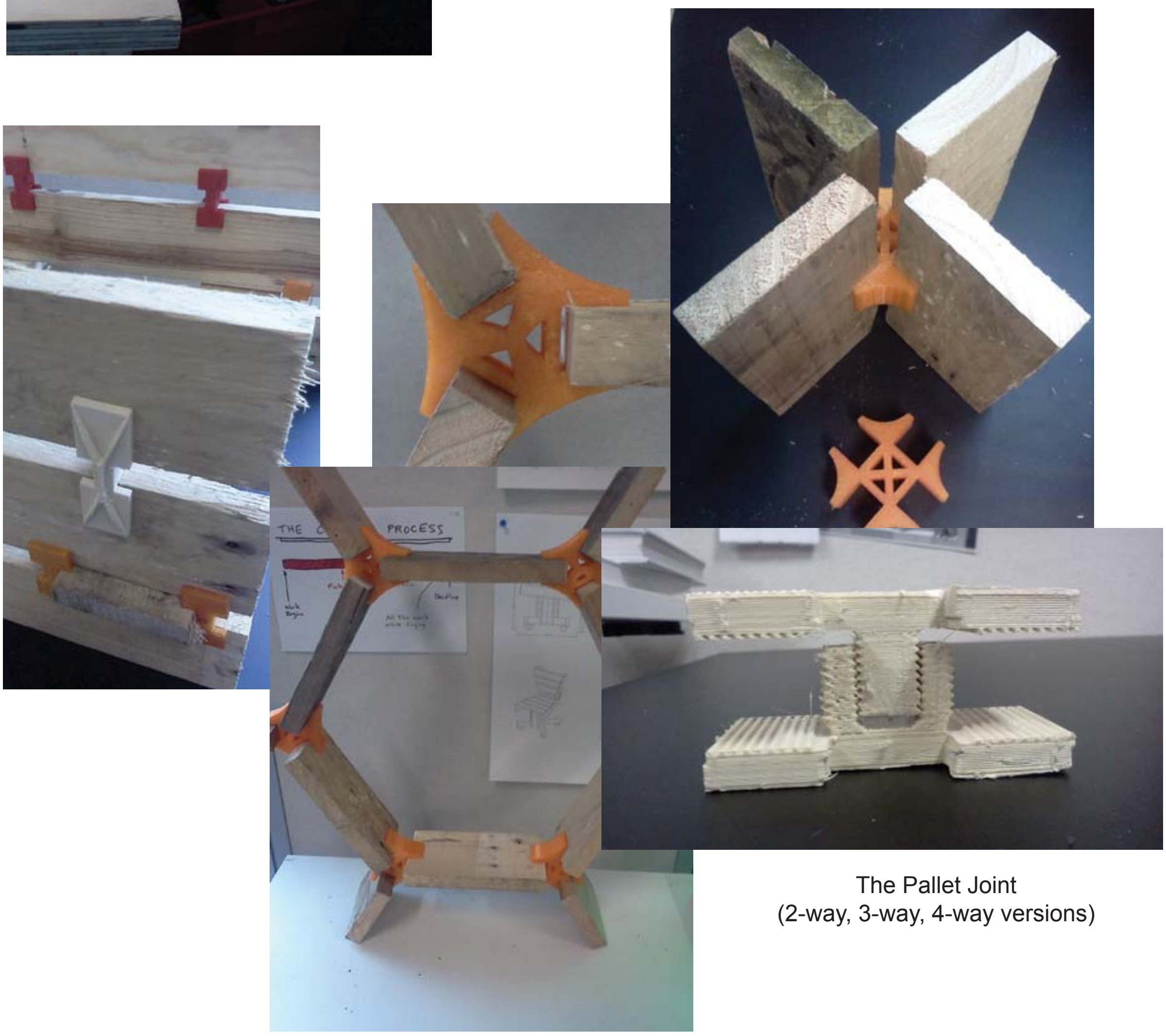
The Pallet Joint is a rigid or fixed position joint that is designed to join the planks from a recovered commercial pallet. There are several variations on this joint that allow the user to connect pallet planks in a variety of directions and combinations. The Pallet Joint design also went through several iterations and, in its most developed state, it also became adjustable to accommodate a variety of standardised pallet plank thicknesses. This system is designed to be a quick-connect system that easily slides onto pallet planks, allowing the user to quickly "sketch" a structure and then cinch the structure together using standardised tie-down straps. My challenge with the Pallet Joint was to achieve rigidity and strength sufficient to hold the various structures the joint could build. My success in achieving this goal was again limited by the structural weakness caused by the printing process as the joints often are required to hold planks that apply stress along the z axis of the joint; the weakest of the three axes. While I searched for better ways of making joints I was also in the process of defining the aesthetic for the *Potential* project.

"We dare to share our knowledge because we believe we can achieve even more when working together.

– Ultimaker 2013



The Adjustable Joint



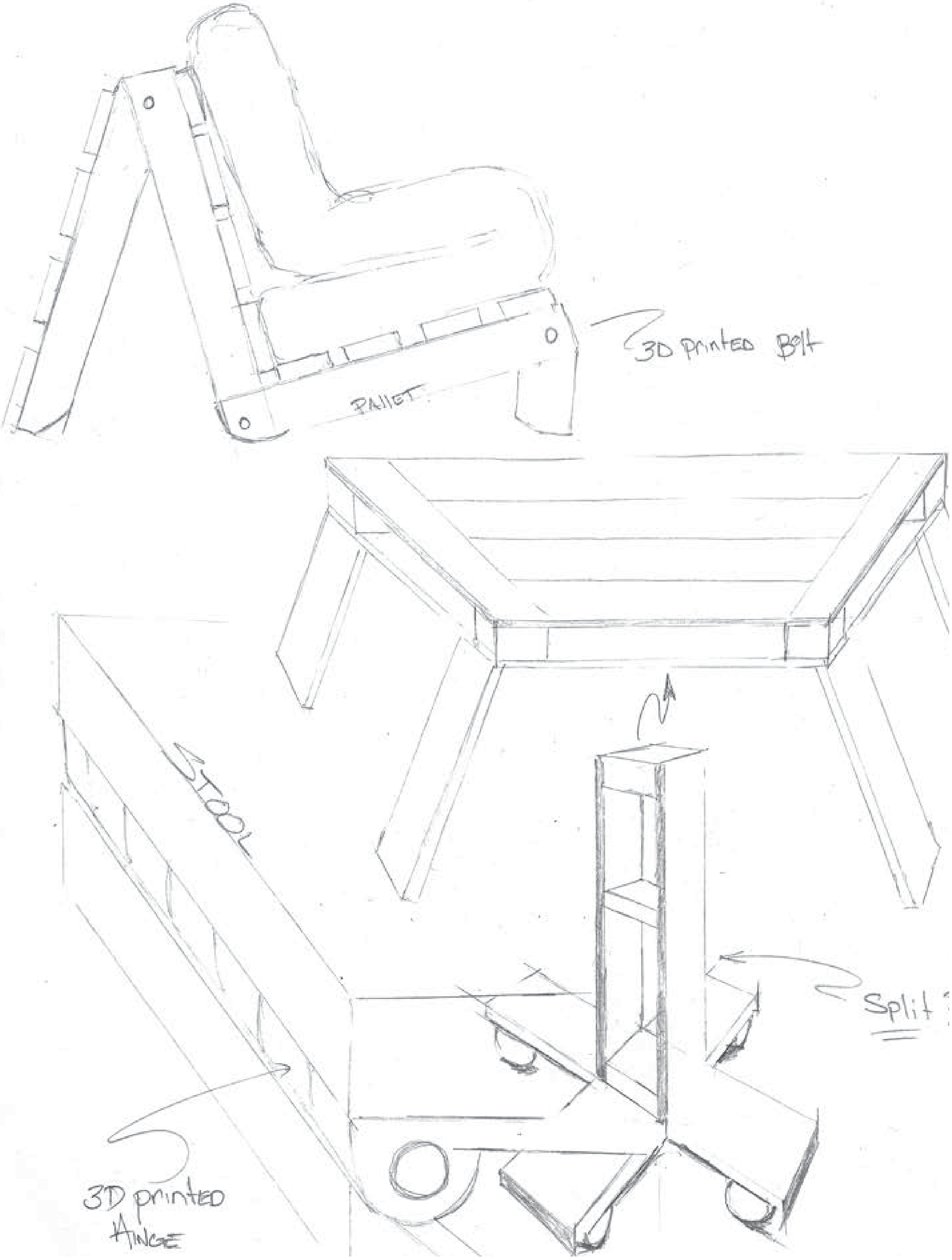
The Pallet Joint
(2-way, 3-way, 4-way versions)

Philosopher Peter-Paul Verbeek argues in his book *What Things Do* that: "Industrial design is occupied with the aesthetics of objects" (2005, 211). Verbeek establishes that, "industrial design generally treats products from one of two perspectives: their functionality and their sign-value. A product must first of all be functional; it must do what it was designed and manufactured to do. Besides this, it has meaning or sign-value: human beings are drawn to particular product styles and not to others, and use a product to express the lifestyle to which they (want to) belong" (2005, 204). In the design of the joints I developed for the *Potential* project, I maintained a modernist "form follows function" (Verbeek 2005, 204) approach. The aesthetic choices I made were based on the underlying geometry of the surfaces I was connecting and objects I was joining. These aesthetic choices were made as much for the simplicity of working with these shapes as it was to maintain the integrity of the object I was creating.

> ***"Reality cannot be adequately understood if humans and non-humans are treated 'asymmetrically'. The two cannot be had separately, but are always bound up with each other in a network of relations. Only by virtue of this network are they what they are, and can they do what they do.***
>
> ***– Bruno Latour quoted by Verbeek 2005, 149***

From a functional design perspective, it makes sense to avoid the embellishment of an object until its fundamental form and function have been achieved. Objects dripping with embellishment and decoration risk betraying their intended function and conceal their natural form. The aesthetic challenge for many designers is, once the form and function have been established, to imbue the object with the "sign-value" that Verbeek describes through sleek lines and/or flashy colours. However, the *Potential* project's intention is to appeal to the broadest audience and, hopefully, engage the designers and users of 3DP technology through the open-design development of whatever products this project produces. I envision placing the design files for the joints that I make in this project on Thingiverse or some other DIY digital design repository for others to use and develop further. While the pursuit of this goal is beyond the scope and time frame of this phase of the *Potential* project, this intention has helped to guide aesthetic choices. By keeping the look of the joints geometric and simple I hope to encourage others to improve on what I have started. By designing a wood/plastic composite without dyes or colouring, I have kept its natural wood-like appearance. In line with Verbeek's point, by using this material to make my modular furniture joints I am imbuing them with the lifestyle choice of "eco-friendly". Aesthetically, like Jansen with the Strandbeests and Schmidt with the KaB chair, I am designing skeletal geometric joints that are more about function than form.

My impression of other industrial designers' processes is that early in their process they often work toward or have a clearly defined and well-resolved design destination. My process, in comparison, may seem more like what Jansen calls "hacking a path through the undergrowth" (Jansen 2007, 37). To me, it often feels as though I am turning left three times to go to the



Pallet furniture development ideas

> “
> *I want to make my own life forms from a single material.*
>
> *– Jansen 2007, 35*

> “
> *It was the beach animals themselves that let me make them. And the plastic tubing showed me how.*
>
> *– Jansen 2007, 37*

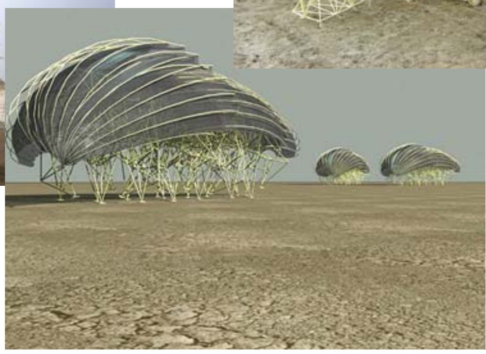
right. However, I know that when I am in this uncertain design landscape I often find the keys to overcoming my design challenge. With the development of the Jansen Joint, a more conventional design strategy might have been to design a chair or a table or a desk, define its form through sketches and modelling, and then design a joint to work with that form or furniture piece. My approach, on the contrary, focused on exploring Jansen’s sculptures, studying his building practices and identifying his techniques. It was a process of imitation where I studied his “dance moves” and, in doing so, I explored his design style. By putting myself through this process of replicating Jansen’s building practices, I began to more fully comprehend the variables that I should seek to address with the joining system I wanted to make.

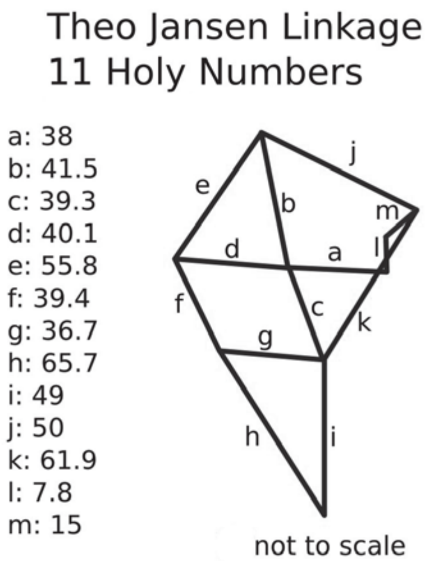
Jansen says that his entire system is based on “eleven holy numbers” (Jansen 2007). With the aid of a computer simulation programme, he identified 11 measurements as ideal for constructing the leg armature that enables his sculptures to walk. The armature is based around connecting two fixed or rigid triangles to four hinged rods. Each of these armatures is, in turn, connected to a central crank that is propelled by wind energy. The whole system works smoothly when constructed using Jansen’s exact measurements. However, when one of the measurements is off by even a bit it puts a ‘hitch-in-its-giddy-up’ and the Strandbeest begins to limp instead of walking smoothly. This limp occurred to several of the scale models that I built but I also learned that a limp is not necessarily a bad thing; it doesn’t prevent the mechanism from working.

I downloaded the instructions for my first two scale Strandbeest models from the Thingiverse web site. The Paper Strandbeest (Dombeef 2013), a paper cut-out assembly, took me two days to make and assemble. Pieced together with card stock and grommets and connected to a wire crank, this model lacked the strength and stability to walk easily by itself. It needed a helping hand to steady it as it moved. Still it was a great exercise to help me grasp the dynamics of the Jansen mechanism. The Brabeest (Wood 2013) is a 3DP set of parts that can be assembled to make a Strandbeest armature. I had difficulty getting the D3DP to make this model. I spent the better part of a day printing and re-printing this assembly before I was able to salvage enough of the parts from all the attempts to make one armature. This exercise was helpful because I was able to explore the functionality of the 3DP with a file that I knew had already worked for someone else. It also encouraged me to design my own 3DP assembly using CAD software.

I designed two scale models using Rhinoceros (Rhino), a CAD modelling programme. The first was a similar assembly to the

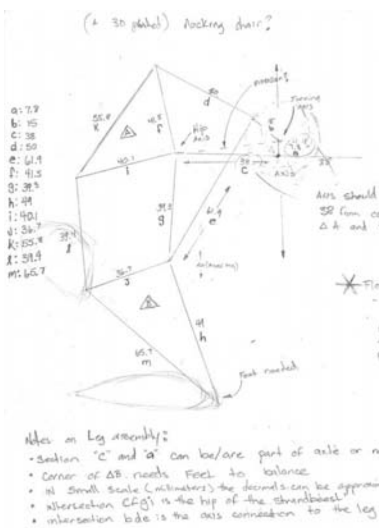
Strandbeests by Theo Jansen (Sandhana, 2013)





(Alley, 2010)

Notes on the Jansen linkage prototype I made



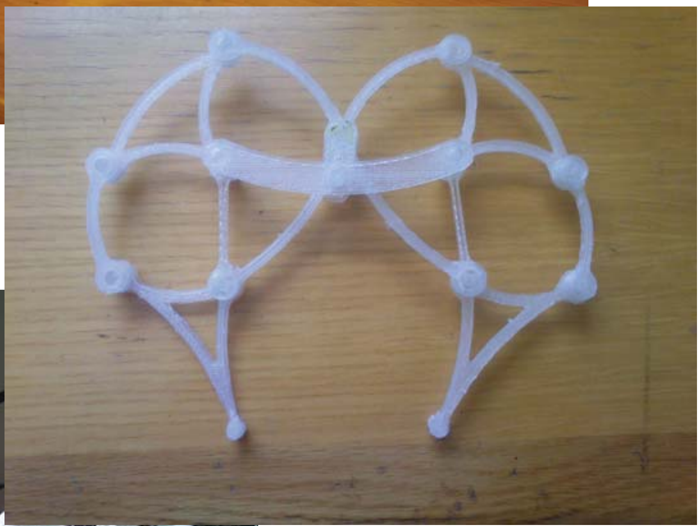
Brabeest. I spent the better part of a week working out the details of how the pieces needed to fit together and resolving issues that cropped up with the software. Rhino is a powerful modelling programme that can also be highly temperamental. Models must be constructed in ways that can be counter-intuitive to the way one would construct a physical 3D object due to the way that Rhino "thinks" of an object. Rhino is a Non-uniform Rational Basis Spline (NURBS)-based modelling programme, which is a computer programmer way of saying that Rhino "thinks" of objects as many little points in space, as opposed to intersecting planes that are represented on the screen. Users (in this case, me) often get stuck when they try to make changes to a surface or group of surfaces instead of addressing the points that Rhino uses to define the parameters of a surface. When this happens, Rhino doesn't tell you what you have done wrong, it just tells you that it can't complete the action you have requested. Subsequently, creating complex models can take an enormous amount of time, as each step of the process can turn into a scavenger hunt to decipher why the programme isn't doing what you want it to do. My point in discussing this is not to air my frustrations with the computer programmers of the world but to emphasise the time, patience and skills that are required to develop a standard level of proficiency with these types of programmes. The programmes make up a significant part of the 3DP landscape.

> "
> ***I spent nearly an hour trying to adjust the print head to juuuust the right height so that the extruded plastic would stick to the bed. It was a matter of carefully adjusting, starting a print, watching it screw up, aborting the print, cleaning the dried plastic off the bed and extruder, repositioning the head by some fraction of a millimeter, and trying again.***
>
> ***– Hutchinson 2013***

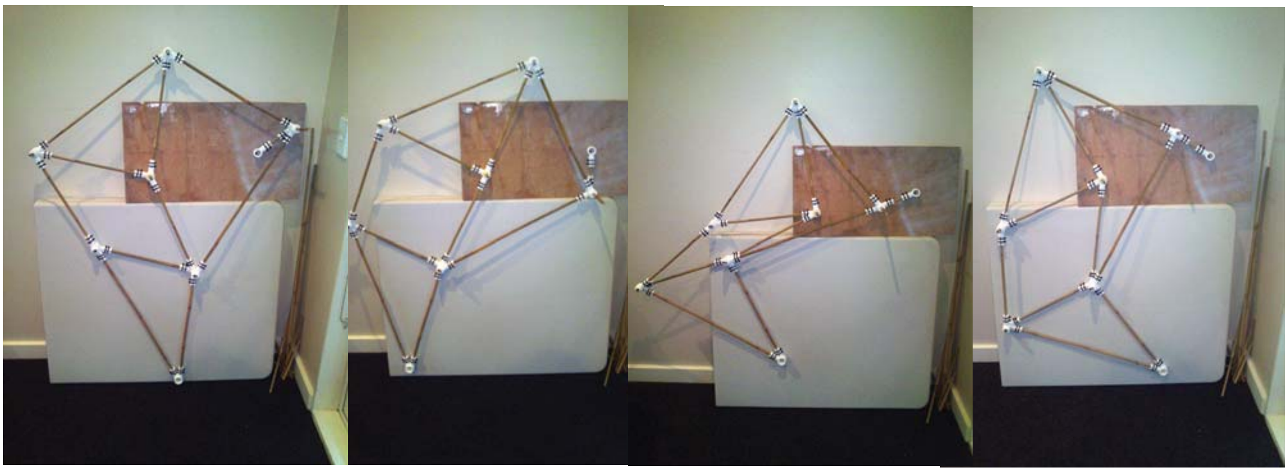
Making these models enabled me to explore and develop the ways that the Jansen mechanism could be manipulated. I was able to focus on how the parts joined together as a system and how they might be joined in other ways. I made the second full-scale model much later in the overall design process of the Jansen Joint, after I had developed some of the joint prototypes and tested them to ensure that they were functional. The largest of the models I constructed was designed to join these prototypes and bamboo to make a moving or "walking" armature. This model gave me the opportunity to challenge the prototypes I was working with in dynamic ways so that I could observe how they dealt with stress and strain and how they held up over time. Moreover, I was able to explore techniques in joining the prototypes to a common building material – bamboo.

NURBS (Non-uniform Rational Basis Spline): a computer programme that uses points located in an XYZ coordinate grid to define an object's parameters.

Jansen used PVC because it is inexpensive and easy to get (Jansen 2007). However, PVC is a controversial and potentially toxic petroleum product, not a sustainable choice. In my search for alternatives I decided on bamboo, a staple of the sustainability movement, which has a wide range of industrial and agricultural applications. Moreover, it is often used in furniture construction because it is both strong and flexible. Finally, bamboo's tubular profile matches the profile of common plumbing piping, curtain and closet rods, rebar, and many other common building materials. This meant that others could easily adapt the system



Scale models of the Jansen linkage
I made using cardboard,
the 3D printer, and bamboo



“

...you have to leave (in engineering terms a massive gap between these moving parts. This gap is to prevent the parts fusing together when you print them. This gap has to be around 0.5mm between moving parts. This may sound [like] a little, but if you’re talking about efficiency on a gearbox, it’s terrible! You can get a little closer on higher detail machines, but these machines generally work with brittle resins, basically giving you another problem whilst not really solving the first one.

– 3DPRINTUK 2013

“

It is thus possible to conclude that the majority of the sample population will prefer products that are simple and easy to use, as it has become a central tenet to that which consumers perceive as good design.

– Porter 2008, 26

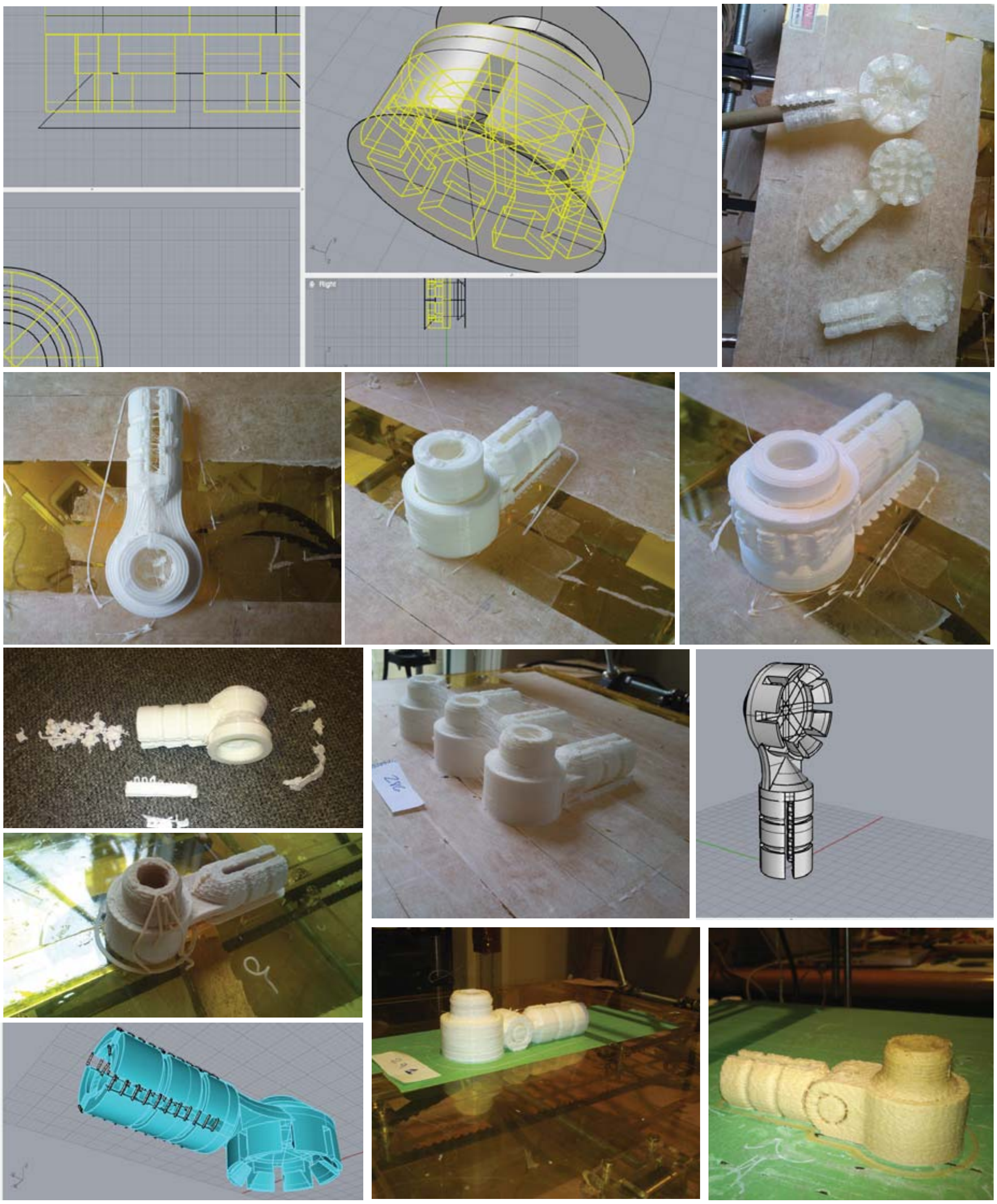
to work with their preferred building material. In my exploration of this material I sampled the bamboo sold at some of the local hardware and garden DIY stores in Wellington (Bunnings, Mitre 10, and Placemakers) and determined that the average range of diameters for the bamboo garden stakes ranged from 7 to 12 mm.

My development of the Jansen Joint can be imagined as a staircase where the flights progressively build on the successes and failures of each step. The landings between the flights are littered with the sketches and images of Rhino models, revisions, and occasionally were points of departure where I left one staircase to explore a completely different but related joint system. The first flight contains the steps I went through to develop the threaded cylinder that holds onto the bamboo rods. The next flight covers the development of the joint’s head and exploring modular connections. The final flights cover the most difficult part of the Jansen joint – the neck, where the parts of the joint are joined together. These last few flights had more steps than previous flights as I explored ways of hinging and bending the joint to give users a wider range of assembly options.

In the sixth design phase I printed the hinged joint, which required extremely tight tolerances. The previous iterations could only achieve right-angle connections – the hinge overcame this limitation. However, printing two components that were not joined but still encased the other pushed my developing 3D printing skills to the limit and it always required a good deal of post-printing finishing work to separate the pieces so they could move. Often the pieces would fuse together and I just couldn’t separate them. I was concerned. This version was not user friendly and I feared it would frustrate other users. I needed a different way to achieve the same sort of flexibility.

The theme of joining that runs throughout this exegesis culminates in the resolution of this design challenge. How could I get the joint to achieve non-right-angle connections if the hinge was too difficult to print and standard 3DP materials were too brittle to flex? I was able to solve this design challenge by joining this product-oriented design path with my material-oriented design path. I realised that by using the flexible HD-PLA that I had developed I could print joints that would bend without needing a hinge.

The flexible neck has several advantages over the hinged neck. It is simpler and smaller than the hinged neck, which means that the printing process is faster – almost 20 minutes faster. The flexible material actually give the user a greater range of motion because the neck can twist slightly from side to side, which the hinged neck couldn’t do. Also, the flexible neck builds a more rigid structure than the hinged neck because the gap that must be



CAD models and iterations of the Jansen Joint

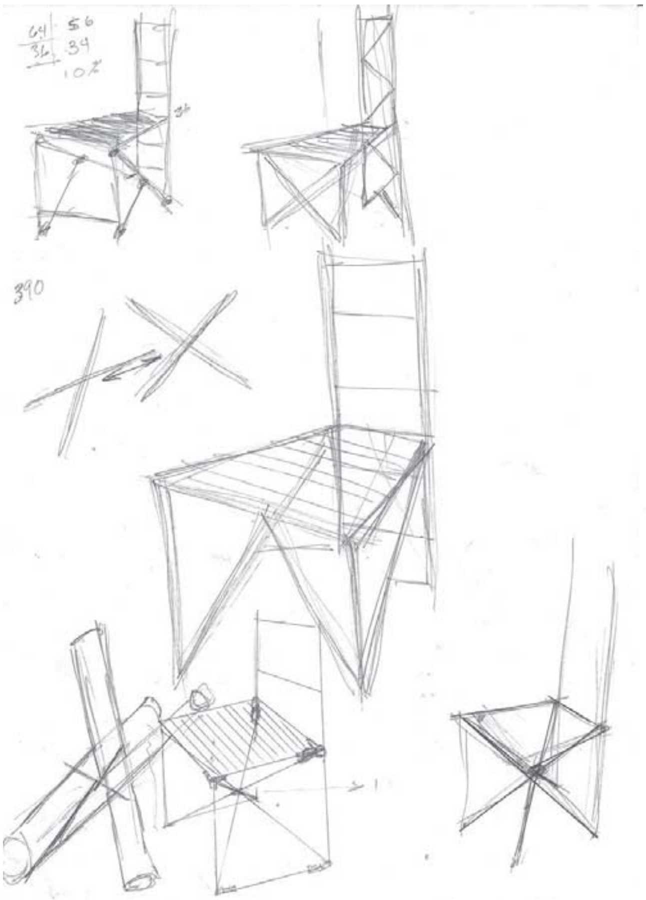
present for the hinge to function leaves the structure less stable than if the neck were made without gaps.

HD-PLA can be used with or without wood fibres to make a durable flexible 3DP material. The wood fibres decrease the strength slightly but they reduce the tendency of the printed objects to warp during the printing process. Moreover, the wood makes the D3DP object lighter and gives it a more natural wood-like appearance.

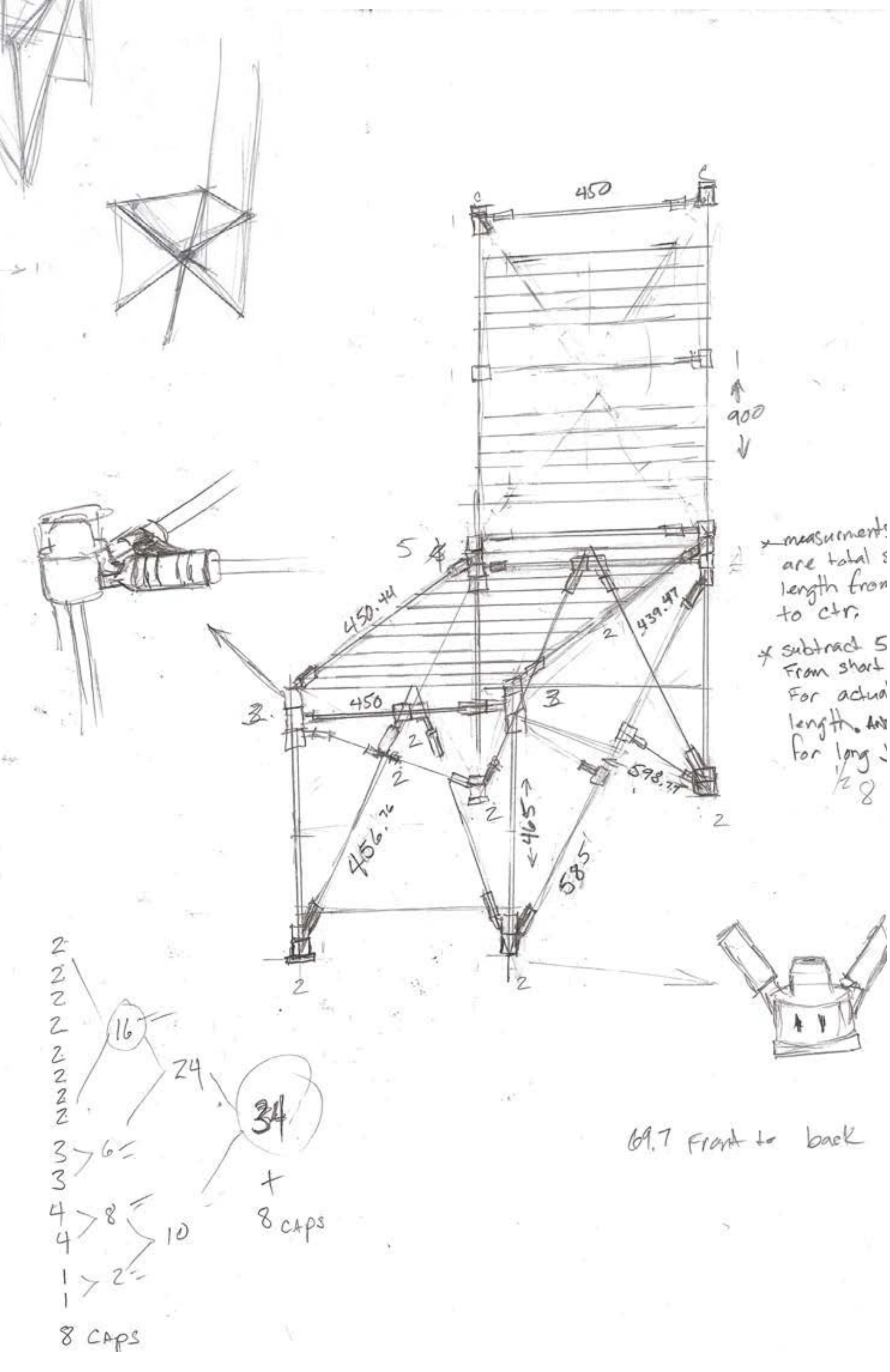
The significance of this development directly relates to design. The current commercially available printing materials limit industrial designers in the types of objects that they can produce. ABS and PLA make rigid objects. With the modular joint system I was designing before this discovery I had to plan out any angles or transitions in advance and my designs were limited to whichever angle I chose. But, designing HD-PLA meant that I could, in turn, design the modular system in a new way. The HD-PLA enabled me to simplify my joint and provide the user with an increased number of construction configurations.

In its final version the Jansen Joint is a sustainable modular D3DP furniture joint that can be used to make a wide variety of furniture structures. The joint has been designed to be easily 3DP and it exploits the benefits of a designed sustainable material, HD-PLA, which, gives it mechanical properties that are distinct from the dominant 3DP materials. This aesthetically simple joint is intended to act as a blank canvas and encourage other designers and D3DP users to develop and personalise the joint for their own needs. The achievement of this material and this joining system is an initial proof-of-concept that, with further research and development, 3DP can become more functional and relevant than it is now.

This section has examined the creative exploration of the *Potential* project by focusing on the design and development of the Jansen Joint. The intention of this exploration was to initiate concepts using hand sketching and CAD software and develop their design through an iterative prototyping-redesign-prototype-again process in order to fully engage the D3DP as a design tool. This section also explored the aesthetic approach of the Jansen Joint, the work of other design precedents, and analysed the pros and cons of adapting these systems for use in a D3DP.



Sketches of the Jansen Joint chair



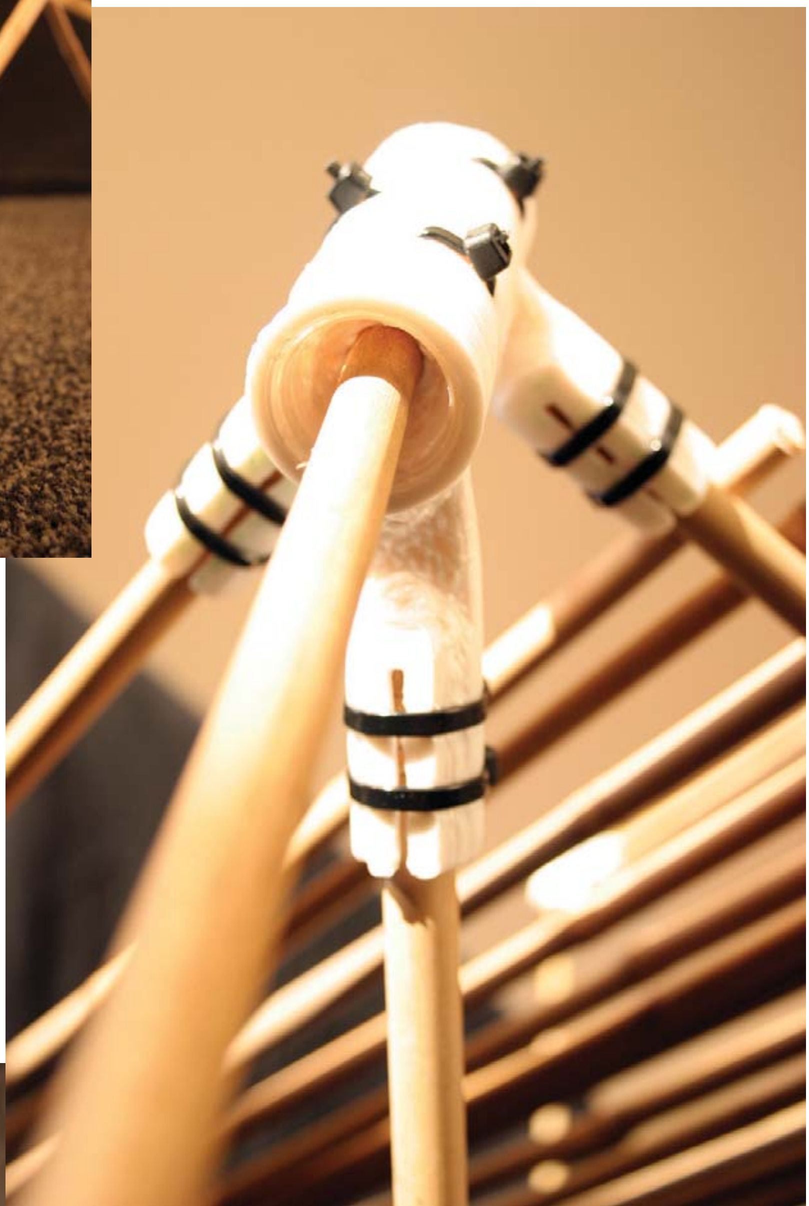
Conclusion

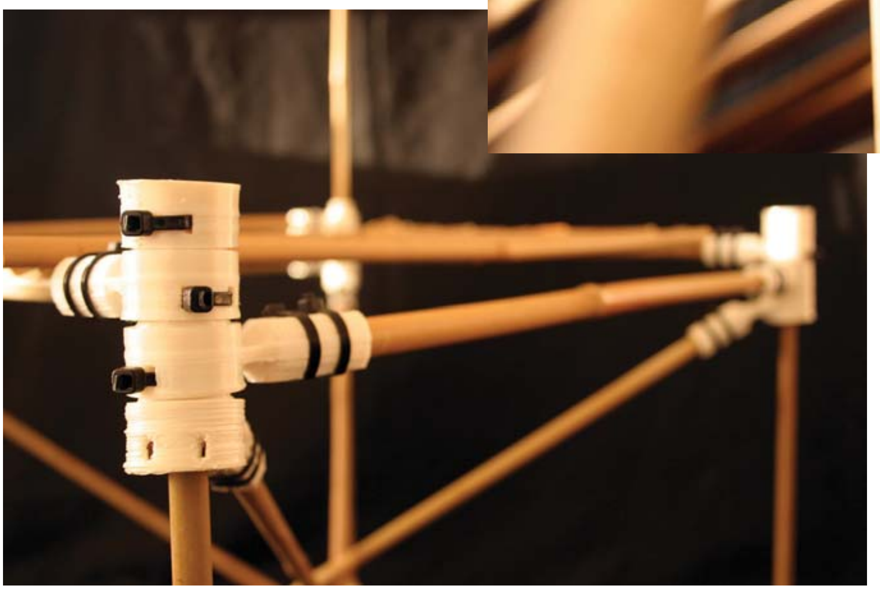
The theme and the goal of the *Potential* project was to join *by design* and *with design*. By design, I brought together my training and skill and interests with a social problem to determine if I could make a difference. That was my starting point. I narrowed it down to determine if 3DP, which has been celebrated by many as a technology and tool that will revolutionise and democratise manufacturing, is actually capable of being used by the average person to create something useful. I wanted to join my training as a designer and artist with what I know of engineering and construction/manufacturing. I wanted to join my concern for the environment and for public health with an investigation of sustainable materials that could be used in a 3DP. The research joined academia with the private sector to facilitate the project. It joined existing designs and concepts with new designs to build upon others' success while also innovating. It relied on two separate design-led research paths which eventually joined together to produce, quite literally, a joint. This joint was created from newly developed materials that were designed to be more sustainable and less harmful to the environment than most other commercially-available materials. It was designed to join recycled materials together to create something functional and aesthetically pleasing. Joining was the theme. Design and elements of design thinking were the means by which the joining was made possible.

The Jansen Joint system is a 3DP modular furniture joining system developed from and designed to apply essential elements of Theo Jansen's kinetic sculptures, The Strandebeests. The joint enables a DIY furniture builder to connect a wide variety of rod- or tube-shaped building materials (e.g., bamboo, plumbing pipe, wood dowels, and threaded steel rods) to construct a variety of furniture pieces. The Jansen Joint was designed to be manufactured using a HD-PLA composite. This was done to increase the sustainability of the modular joining system by increasing the biodegradability of these objects. And this resulted in bringing a new material to the landscape of 3DP which offers additional properties to the currently limited selection of 3DP materials.

This research experimented with making HD-PLA in two ways: rigid and flexible. In its rigid state, HD-PLA offers nearly equal

Working prototype of the Jansen Joint chair
using bendable and rigid HD-PLA





strength and produces a less brittle object than one made from neat PLA. When made to be flexible, HD-PLA offers a rigid flexibility that gives objects more adjustability and variability than ones made from neat PLA or ABS. These rigid yet flexible joints can be linked in a wider range of configurations than are possible when making objects with the dominant 3DP materials, ABS and PLA.

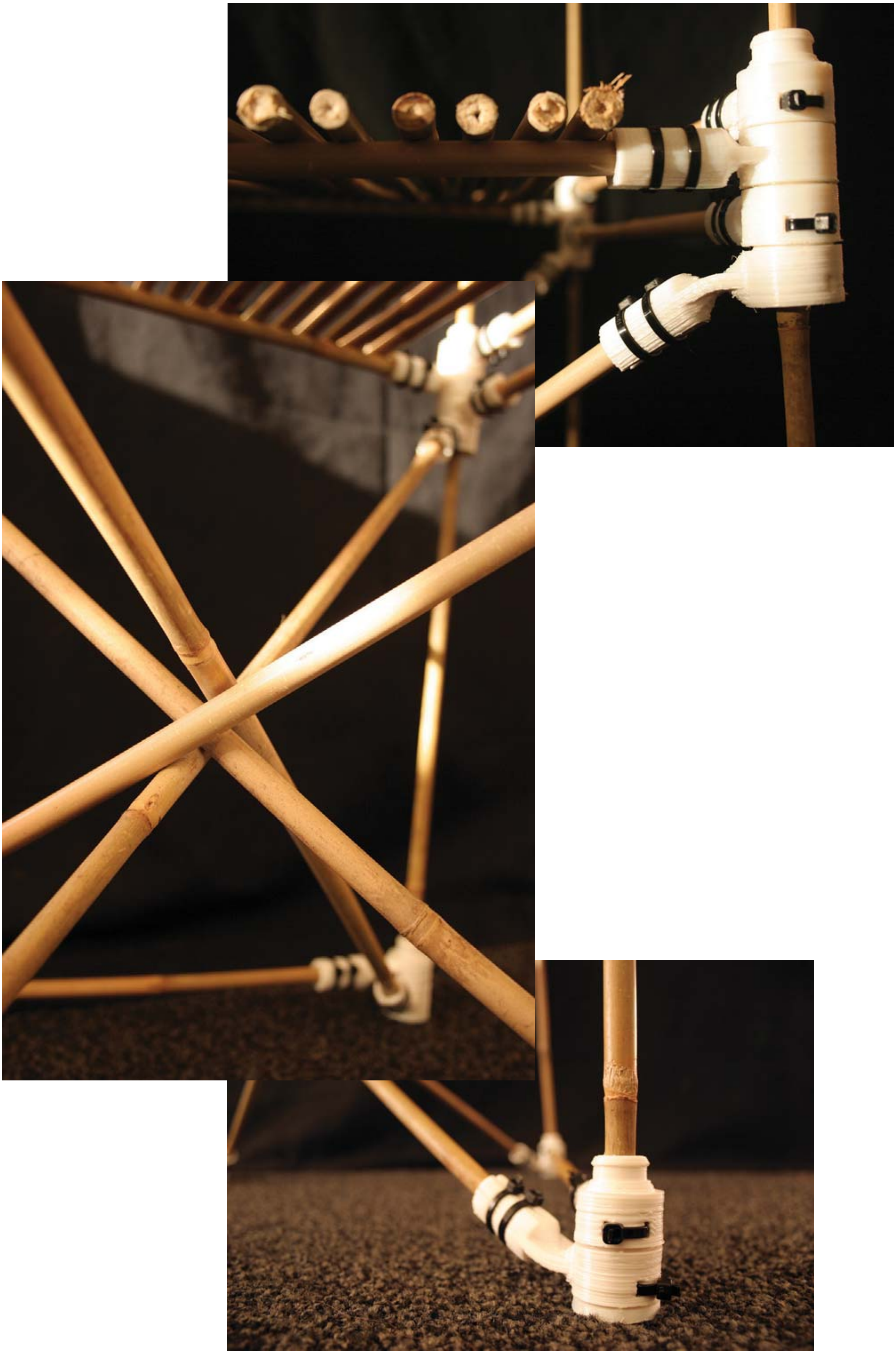
A key motivation in conducting this design-led research and critique of 3DP was to identify what areas of the 3DP landscape need further research. Some areas that should receive further investigation include:

- Resolving the difficulties of using this technology by:
    - Integrating systems that monitor the quality of the objects being made.
    - Developing a single user interface for the multiple software applications used.
- Increasing the user's control over the printing process by developing:
    - Manual control over print operations that enable:
    - Returning to a previous point in the build process
    - Repeating steps to fortify parts of a model
- Dynamic model adjustments to address printing issues that result from:
    - Excess or insufficient extrusion
    - Poor intra-layer bonding and delamination
    - Curling or warping
- The availability and range of materials to include a wider range of:
    - Biosourced and biodegradable options.
    - Materials with significantly different mechanical properties, including:
- Determining the optimal formulation of the HD-PLA to achieve the strongest 3DP object.
    - Determining the complete range of mechanical properties for different formulations of WFR, WFL, PLA and ELST.
    - Identifying biosourced and biodegradable additives that would improve the bonding between WFR, WFL, PLA and ELST.

> ***"***
> ***To the absolutist in every craftsman, each imperfection is a failure; to the practitioner, obsession with perfection seems a perception for failure.***
>
> ***– Sennett 2008, 52***

Additionally, the Jansen joint system needs further research into:

- Additional product testing in a wider range of applications and conditions.
- Observation of end user application and experience.



- Expansion of the modularity, adjustability and adaptability of the system to new construction materials and configurations.

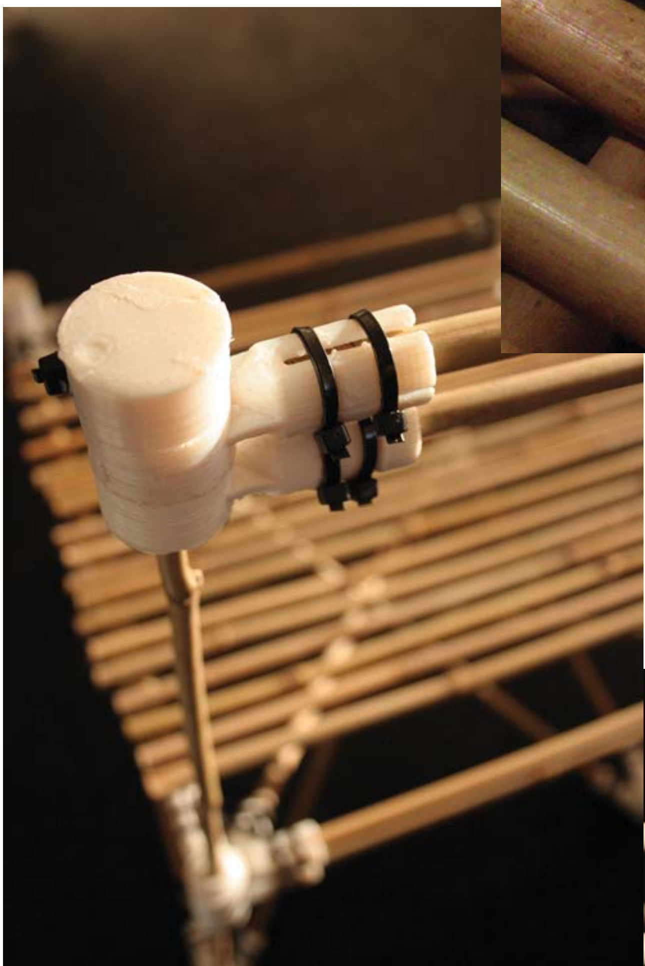
While further research is key to developing FFF D3DP to make it more accessible and relevant, it may be even more important to ask “whether this is even the right problem to be solving” (Brown 2009, 67). Over and over again during the course of this project, progress was halted by the FFF technology itself. The extruder motor on the printer would slip and strip the filament, causing a print to fail. The nozzle would stick to an adjacent part and drag it along, knocking other pieces over as it went, causing the print to fail. Temperature, vibration and even minor changes in air current all have led to prints failing. As I mentioned in the section on social change, the better solution to these problems may actually be in the development of other existing or currently undiscovered technologies. For example:

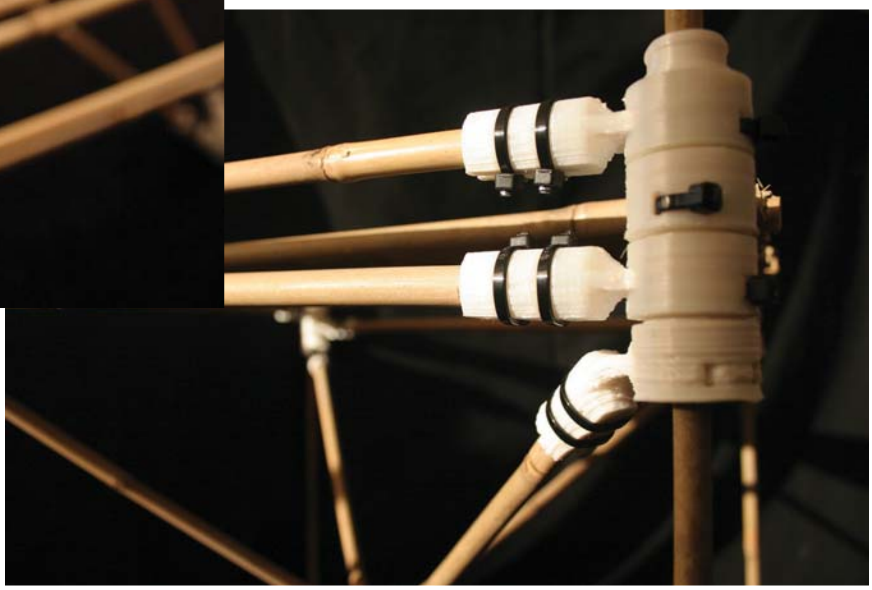
I see the key to resolving these obstacles on the path to social change and greater sustainability as greater social engagement, specifically – ‘Open Design’.

- SLA and SLS, which use lasers to heat the surface of a resin or powder bath to build models, may be more effective and efficient than FFF as D3DP technology.
- The Form 1 3DP is a SLA D3DP that avoids the problems of extruder motors and nozzles by use of its lasers.
- Pellet feeders, which store and feed into the printer pellets of plastic, in place of filament and extruder motors. The pellet feeders use a screw to force the pellets through the heated nozzle, which avoids the problem of filament striping.
- These developments suggest that the landscape of 3DP is still forming and a reliable technology has yet to be established.

This exegesis marks the conclusion of this phase of The *Potential* project but this is not the end. In this exegesis I have spoken at length regarding the potential of 3DP technology to influence social change and be more relevant to the world’s poor. But, I have also noted that this technology is currently a play thing of the privileged, and have identified many of the ways in which it is decidedly not user-friendly. I see the key to resolving these obstacles on the path to social change and greater sustainability as greater social engagement – specifically “open design”.

> Rooted in information and communication technology, [open design] gives us all the instruments to become the one-man factory, the world player operating from a small back room (Strikker as quoted from Troxler 2012, 4–5).





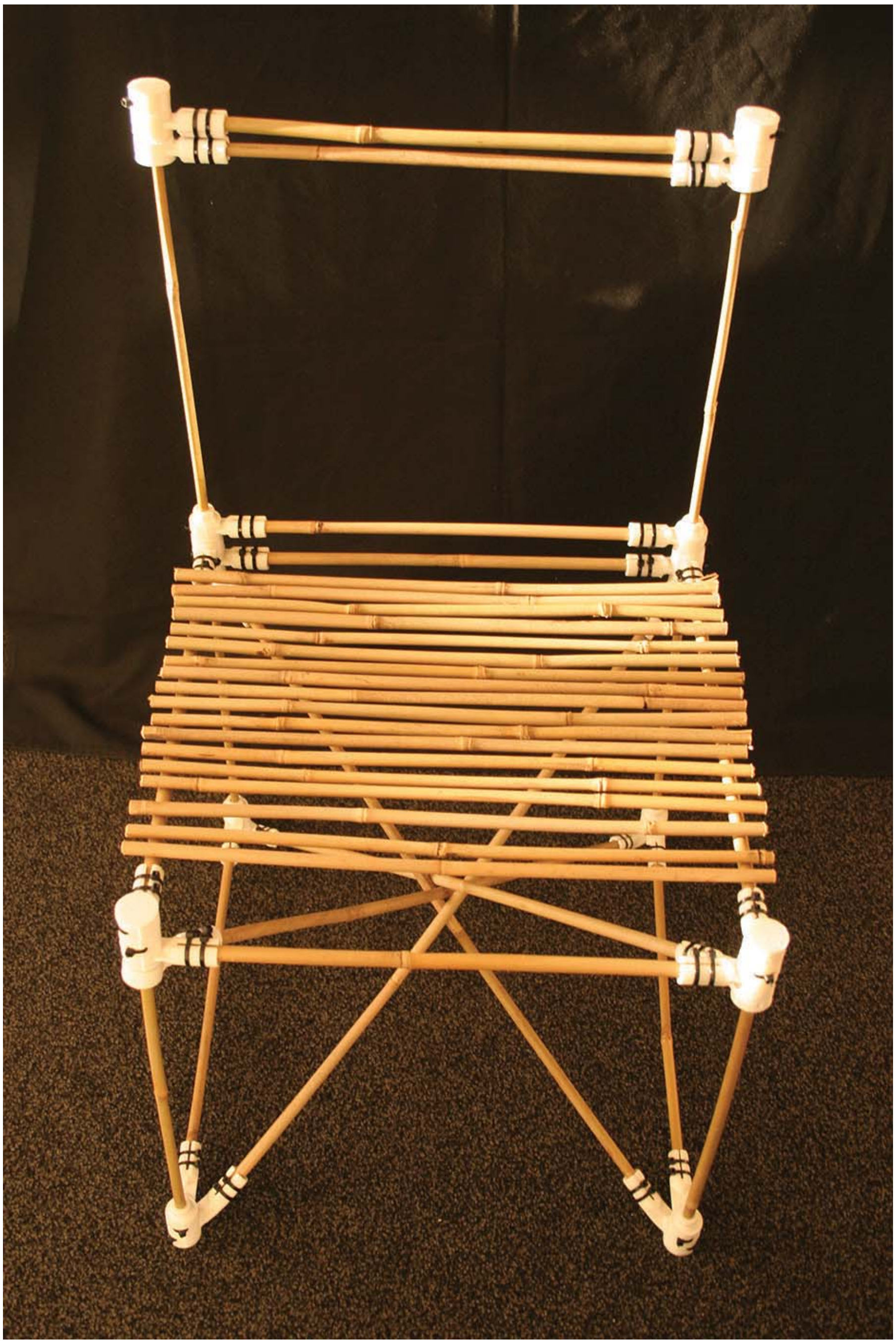
and

> The open design model diminishes the traditional vertical value chain that is formed by designer-manufacturer-distributor-consumer relationships and offers an alternative, open web of direct links between designers and consumers (Avital as quoted from Troxler 2012, 4–5).

In fact, a fundamental element of this project that I have alluded to but not yet fully explored is engaging with the community of digital designers that are currently learning and developing 3DP technology. The next phase of this project is to develop this modular system through open design collaboration by publicising the digital files and the findings of this research for others to use and experiment with. This will be done by utilising the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (Creative Commons 2013), which designates that the designs I have created are available for use by anyone so long as they share what they make and they do not seek to use it for commercial profit without my express consent. In this way, I hope to encourage others to post their successes and failures for the D3DP community to see, use, and benefit from. Therefore, open development of this design and further exploration of user experience and material development will be the focus of the next phase in the *Potential* project, a phase that aims to further leverage design to join 3DP with sustainability and social change to achieve the potential of this exciting new technology.

"Newton did not really act alone in creating the theory of gravitation: he needed observational data from the Astronomer Royal, John Flamsteed, he needed publication support from the Royal Society and its members (most especially Edmund Halley), he needed the geometry of Euclid, the astronomy of Kepler, the mechanics of Galileo, the rooms, lab, food, etc. at Trinity College, an assistant to work in the lab, the mystical idea of action at a distance, and more, much more (see the book by Michael White). The same can be said of any scientific or technological project.

– Goguen 1998



Working prototype of the Jansen Joint chair
using bendable and rigid HD-PLA

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Glossary

(The New Oxford American Dictionary 3rd Edition 2010)

3DP: 3D Printer/ers/ed/ing/able.

ABS (acrylonitrile butadiene styrene): a common petroleum-based thermoplastic, the most common type of FFF 3DP material.

Accessible technology: a technology or product that can be easily and/or intuitively used or adopted by individuals with a minimum of education or preparation.

The Artists' method: this methodological process is loosely defined as a process by which problems are solved through an intuitive, experimental, iterative, and heuristic exploration of possible solutions.

CAD (Computer Aided Drafting): a method of drawing that utilises a computer software programme to simulate a 3D space based on an XYZ coordinate grid.

CNC (Computer Numeric Control): a means of precisely controlling a device (e.g. router) where the device is calibrated to function within an established area that correlates to an XYZ coordinate grid.

D3DP: desktop 3D Printer/ers/ed/ing/able.

Design thinking: for the purposes of this project, design thinking is a methodological process that focuses on empathy with the participants within the context of a problem in order to define what the exact problem is. Then a process of ideation is employed to explore possible solutions to the problem and, from this, prototypes are developed and tested to explore the relevance of these ideas.

FFF (Fused Filament Fabrication): (AKA: FDM or Fused Deposition Modelling) A 3DP technology that employs a heated nozzle to plasticise thermoplastic filament to build objects according to the instructions of a digital .stl file.

Join: a place where two or more things are connected or fastened together.

Joint: a point at which parts of an artificial structure are joined.

ELST: a petroleum-based elastomer that is more flexible than PLA, melts at a lower temperature and is also biodegradable.

PLA (Polylactic Acid): a common thermoplastic derived from starch (often vegetable), the second most common D3DP material.

Heuristic: a methodology or process that enables a person to discover or learn something for themselves. A "hands-on" or interactive approach to learning. Exploration proceeding to a solution by trial and error or by rules that are only loosely defined.

Kinetic: 1) of, relating to, or resulting from motion. 2) (of a work of art) depending on movement for its effect.

Modulus (Young's modulus): a measure of elasticity, equal to the ratio of the stress acting on a substance to the strain produced.

Neat: pure; not diluted or mixed with anything else; non-composite.

NURBS (Non-uniform Rational Basis Spline): a computer programme that uses points located in an XYZ coordinate grid to define an object's parameters.

Polypropylene (PP): usually refers to a common petroleum-based plastic, however recent research has developed a way of producing PP from bio-sources. This experimental technology is currently far too expensive to be relevant to commercial manufacturing.

Relevant technology: a technology that is affordable, accessible, and functions according to an individual's needs.

RP: rapid prototyping

Rhino (Rhinocerous®): a NURBS-based CAD modelling programme.

Social change: change that has relevant impact on the majority of a population or a social group.

Selective Laser Sintering (SLS): a 3D printer that uses a moving laser beam to build up the required structure, layer by layer, from powdered polymer that melts on contact with laser light and then hardens as it cools to form each layer.

Stereolithography (SLA): a 3D printer that uses a laser beam to build up the required structure, layer by layer, from a liquid polymer that hardens on contact with laser light.

Thermoplastic: denoting substances (especially synthetic resins) that become plastic on heating and harden on cooling, and are able to repeat these processes.

WL: wood flour

WLPC: wood flour plastic composite

WPC: wood plastic composite

WR: wood fibre

WRPC: wood fibre plastic composite

Appendix 1: 3D printing Primer

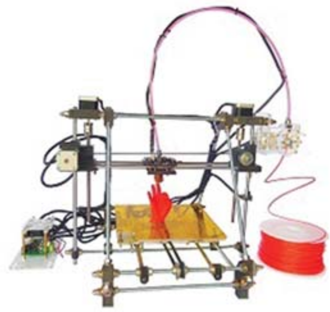
The 3DP – a really brief history

3DP, also called rapid prototyping (RP) or additive manufacturing (AD), began in 1983 when Charles (Chuck) W. Hull invented the first “Stereolithography” machine (Wagner 2013; “30 Years of Innovation” 2013). Three years later, Hull went on to found 3D Systems Corp. (aka Z Corp), which today is one of the largest 3DP manufacturers (Barnatt 2013; Wagner 2013). Hull defined the term “Stereolithography” as the process of making solid objects by “printing” successive layers of a curable ultraviolet material. Hull’s machine uses a laser aimed at a bath of light-sensitive resin. The laser light “cures” or hardens the resin’s top layer according to whatever pattern it is programmed to follow. When the laser finishes a layer of the pattern the hardened material is lifted out of the bath so that it is just touching the surface of the resin. Then the laser begins to cure the next layer of resin which simultaneously attaches it to the previous one. In this way, layer by layer the laser “builds” an object. Since 1983 RP has further evolved and currently there are four major types of rapid prototyping technologies:

- Stereolithography (SLA), which uses liquid resin and laser.
- Selective laser sintering (SLS), which uses plastic powder and laser.
- Fused filament fabrication (FFF), also known as Fused Deposition Modelling or FDM, which uses plastic filament and a heated nozzle.
- Laminated object manufacturing (LOM), which uses layered material that is bonded and then cut with a laser.

In 2005, researchers from the University of Bath in England, led by Dr. Adrian Bowyer, began a project to build an open-source 3DP called the RepRap that would be able to make most of its own parts. This initiative was based on the idea that the printer would democratise manufacturing by cheaply distributing RepRaps so that individuals everywhere could make their own products. In 2008 the RepRap “Darwin” was released; the first desktop 3D FFF printer (T. Rowe Price 2011). Since then the public interest in 3DP has skyrocketed, with industry sales and services figures reaching $2.204 billion in 2012 (Park 2013). In 2013, FFF-style printers are the most common type of D3DP on the market, due to the low cost of parts and materials, and the simplicity of their processes (Taylor 2013; Palermo 2013).

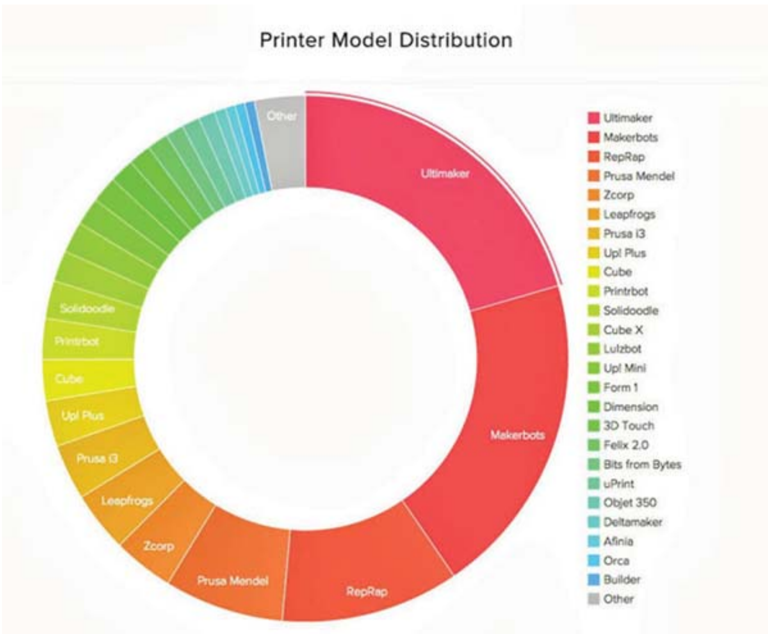
3d Systems Pro 230 (2013)



RepRap Prussa
(3D Stufmaker.com 2013)

Industrial versus desktop 3D print

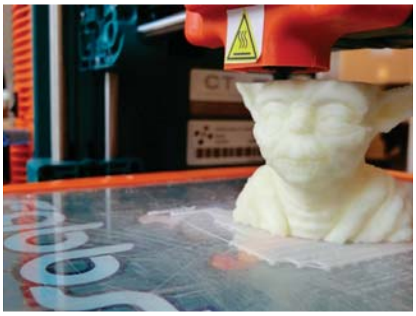
There are many companies that make commercial or industrial 3DP but two companies dominate the market: Stratasys and 3D Systems/Z Corp (Zhang 2013). These companies make industrial 3DPs that are focused on quality and can cost anywhere from US$10,000 to hundreds of thousands of dollars (Hagerty 2013). These printers are often very large, however the largest object size that the biggest of them can produce is approximately 3 feet wide or tall (Anderson 2012; Hagerty 2013). These complex printers require a trained technician to operate and maintain them. Moreover, the resins and powders these machines use are normally patented and can only be purchased from the manufacturer, which means there is no option to shop around for the best deal on printer supplies. Because of their large size, cost and complexity these are not the kind of 3DP that you will find in the average DIY maker or hobbyist's workshop (Hardy 2013).



Print Model Distribution chart showing the top four printers sold are FFF technology.(Taylor 2013)

Since 2008, the cost of desktop 3D printers has dropped from several thousand dollars to about $400 (Johnson 2013). An interesting fact is that the largest manufacturer of desktop 3DP, Ultimaker, offers their printers and software under an open source licence freely sharing information about how the printers and software are made. Individual users are free to modify and build on the basic components and software programmes that come with the printer. “We dare to share our knowledge because we believe we can achieve even more when working together" (Ultimaker BV 2013). Moreover, the third and fourth most widely sold printers are also open source models that are made and resold by a number of small companies who are capitalising on this open source model for business. This research focused on FFF D3DP because, as one writer put it, these kinds of printers "are more commonly found in homes (Anderson 2012, 90)", implying that the adoption and social relevance of this technology is more widespread.

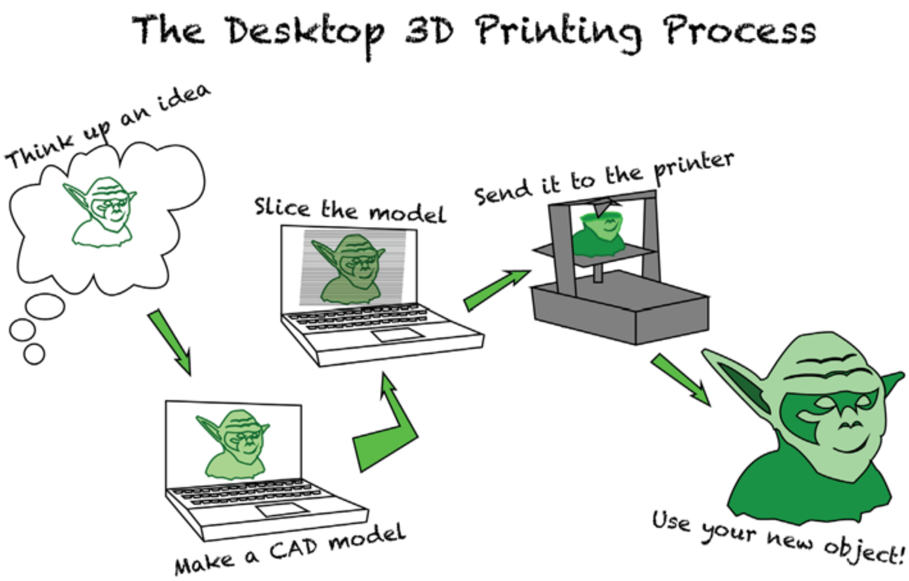
The D3DP ...How does it work?



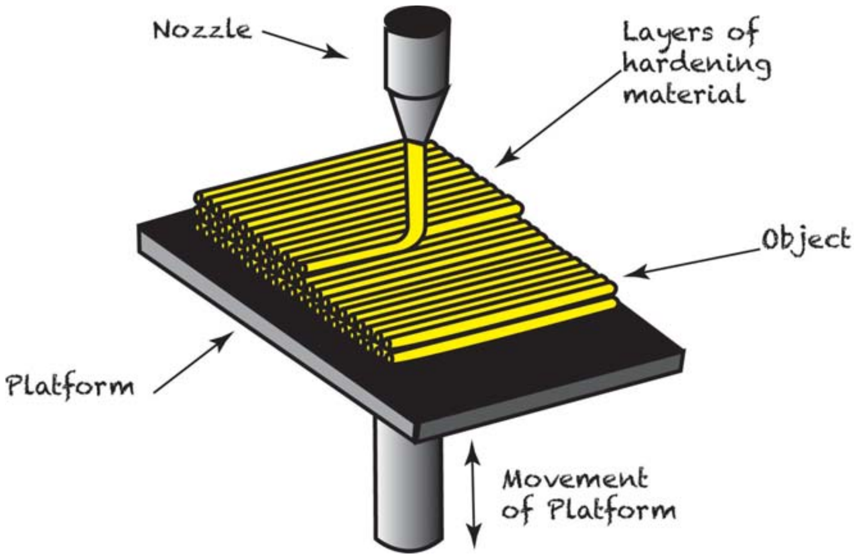
(Ashley, 2013)

(Agence France-Presse, 2013)

It all starts with a digital model of an object, lets say a bust of Yoda's head. This digital model is made on a computer using CAD software. The model of Yoda must be prepared for printing in a "slicing" programme like Slic3r® or Cura®. In this programme, the model is divided into many layers according to how finely the printer can lay down an individual layer of plastic. After the first layer solidifies, the 3D "print head" returns and forms another thin layer on top of the first one. When the second layer solidifies, the print head returns yet again and deposits another thin layer on top of that. Eventually, the thin layers build up and a three-dimensional object forms.



Much like squeezing a tube of toothpaste to draw a picture on a plate, a fused filament fabricaton (FFF) 3DP squeezes melted plastic out of a tiny nozzle to “draw” or “print” each layer of a CAD design. Guided by instructions in the design file the printer lays down the molten or liquid material to make lines of plastic side by side across the print bed until the first layer of the design is complete. Many of these 3DP can print layers that are less than .2 mm thick. Then it raises the print head (or lowers the bed, depending on the printer) and begins to draw the next layer of the model on top of the first. It continues in this fashion, building the object layer by layer, one on top of the other, until the object is complete.

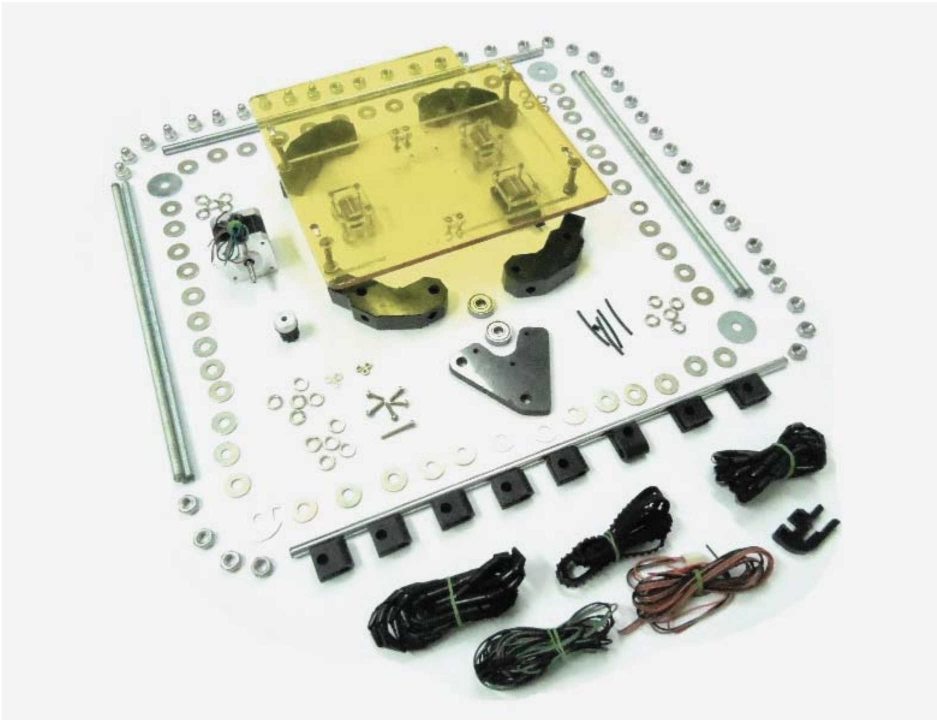


The FFF building process

An FFF printer in its most basic form is composed of several essential components:

- A print bed
- A print head (where the extrusion nozzle is located)
- An extrusion mechanism (often mounted on the side of the printer or on top of the print head)
- Four stepper motors
- An X,Y, and Z axis belt or shaft

- A mother board
- An electrical plug with power reducer
- A frame or housing
- Connecting wires from the motherboard to the motors



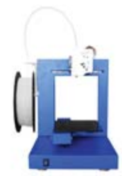
Parts to an unassembled RepRap Mendel 3D printer
(3D Stufmaker.com 2013)

When all of these parts are assembled the printer must be formatted to work with a computer and then carefully calibrated.

Appendix 2: 3D Printer comparison

A comparison of three common FFF D3DP based on a user approach to D3DP:





	RepRap “Prusa”	**uPrint SE Plus**	**Up Mini**
Style	Hobbyist	Professional	Technophile
Assembled	DIY Kit	Service Agent	Yes
Pre-programmed	No	Service Agent	Yes
Software	Open Source (flexible)	Proprietary	Proprietary
Modifications/ adaptable	Yes	No	No
Ease of use	Difficult	Easy to Moderate	Easy to Moderate
Resolution (layer height in mm)	.35	.254	.2
Materials	Any ABS or PLA filament	Manufacturer filament only	Any ABS or PLA filament
Build envelope (in mm)	200x200x100	203x203x152	140x140x135
Cost (prices in USD)	$595.00	$18,769.00	$1,499.00

Discussion:
In order to develop a better understanding of D3DP technology, I evaluated a wide range of 3DP and their features. There seem to be three dominant classifications or types of this technology which I have labelled hobbyist, professional, and technophile. These names are intended to serve as identifiers and are not rigid categorisations. The table above summarises my findings and is presented here to round out the reader’s understanding of

the current landscape of D3DP and how I arrived at my decision to purchase a RepRap.

The “hobbyist” style of printer is aimed at the DIY maker who is comfortable with wiring, software, and building things themselves. This project kit is an educational experience with a very steep learning curve, but it will pay off in competence about how the process works and how to best manipulate it to get what you want. The build area for these printers is usually medium to large and the components are modifiable and adaptable to new types of software and hardware, so the machine you buy can be upgraded piece by piece.

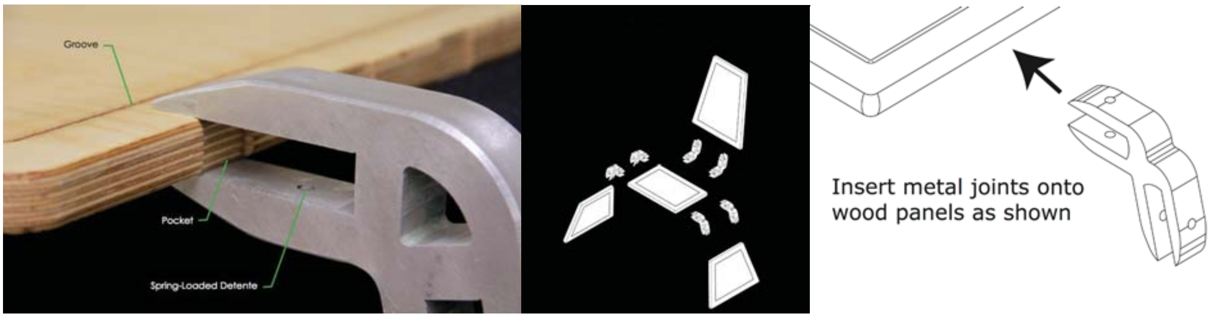
The “professional” style printer is geared to small businesses and quality-oriented enthusiasts. Stratasys was a pioneer of 3DP and their machines have an excellent track record of being low maintenance and making great prints. These machines print using two materials, ABS and PLA at the same time, but the PLA is only used for support materials. The printer comes with a special bath that dissolves the PLA and leaves the ABS. However, if something does go wrong this machine requires a service agent to attend to it. Additionally the printing composite material used in this printer can only be purchased from Stratasys.

The “technophile” style of printer is geared at the no-fuss DIY maker. These printers come pre-assembled and are designed to be easy to operate (i.e., simplified). They tend to have small to average build areas and there are often no options for changing out parts or using alternate materials. They are an entry-level printer that can handle most projects.

Analysis:
While there aren’t extreme differences in the size of the build areas or the resolution of these FFF D3DPs there is a considerable difference in the quality of the objects they produce and their ease of use. Currently this is reflected in the wide gap in price, but this gap is expected to close as it did in the 1990s with digital cameras.

The hobbyist appeared to be the best choice of this group for the experimental and iterative nature of this research project. High-quality printing was not as important as the ability to modify and adapt the printing process to fit the design variables.

Appendix 3: Joint Case Studies



(Liggett et al. 2012)

Case Study: SNAP Joint
Designers: Lindy Liggett, Lisette Lopez, Morris Taylor, Josh Ramos, My Vu
Type: Joint for Reconfigurable Furniture

Description:
In this MIT project, theses students designed a joint for use in a system of modular furniture that could be used in an office to quickly adapt the office to different needs. The system consists of slotted wooden panels held in place by metal joints that clamp the panels and hold them using a spring-loaded ball-pin which seats in the groove. The design of this joint is ideal for D3DP because its shape is a simple extrusion of the joint's outline. Extrusion shapes of this type are well suited to the slicing and layering process inherent in D3DP. This metal joint is, in concept, an example of what I am trying to achieve with a D3DP using sustainable plastic. The spring-loaded ball is not completely captured in the groove and cannot resist horizontal stress very well. It would indicate that these furniture pieces are susceptible to a wobbly effect. This effect could be minimised by adding extra supports but requires a fair bit of additional room. The spring-loaded ball-pin can't be achieved using D3DP unless the joint is re-designed to allow the parts to be assembled after printing. Aesthetically, this joint and the modular furniture system are geometrically simple and bulky. The slight angle that the legs of the chair and tables have is reflected in the trapezoidal shape of the panels. These simple shapes give the system a clean, well designed feel in spite of its bulkiness.

Design Relevance: Use of modular joint to make furniture. Ideally suited for D3DP. Joint allows many different positions and configurations.

(Otter Ganter GmbH & Co. 2013)

(Te-Co Inc 2013)

Case Study: Generic Swivel Clamp Joint
Designers: Unknown
Type: Repositionable joint for Scaffolding

Description:
This joint is used for scaffolding and construction purposes. It's designed to fit with standardised tubular steel poles from various manufacturers. The joint housing is designed with two flanges that are split and slightly separated. A bolt and nut are used to compress these flanges to provide the friction necessary to clamp the housing onto a steel pole. The swivel hinge affords rotational adjustability after the joint has been fixed into place. The shape of this joint is also well suited to D3DP because it is also a simple extrusion. However, the design relies on nuts and bolts to compress the joint, which poses several problems for a D3DP, most notable of which are the threads of the bolt or screw that are too fine for the print resolution of many D3DPs and requires a very strong material. Currently only nylon can achieve this level of strength. The sustainable plastic that this project seeks to use requires a wide 1mm nozzle, which makes this level of printing resolution impossible. Moreover the strength of bolts and nuts that I have made with 3DP has been very poor due to the weakness of the plastic or issues with the print direction. Overall there are some worthy concepts at work with the generic swivel clamp, especially compression and adjustability. However, the design of this clamp depends too much on a strong material like metal and won't translate easily into D3DP plastic.

Design Relevance: Modular and designed to connect with standardised materials from various manufacturers. Compression fitting allows it to be repositioned if necessary. Swivel hinge gives rotational adaptability to construction variables.

(LEGO, 2013)

(Chia 2003)

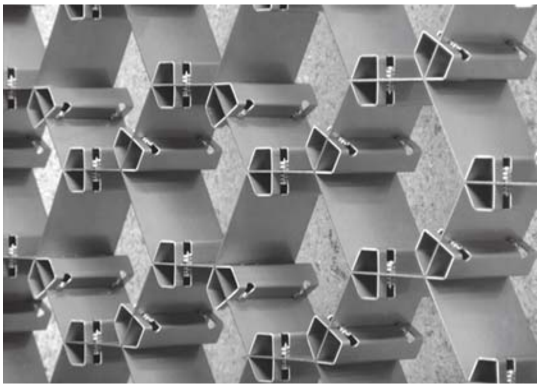
Case Study: LEGO Modular “Automatic Building Blocks”
Designer: Ole Kirk Christiansen, Denmark, 1949
Type: Repositionable Modular Press-Fit Joint

Description:
The now iconic children’s toy LEGO was originally called the Automatic Building Block. This building system is remarkably simple and originally came in two sizes of four and eight studs. The stud and tube system was patented in 1958. This system works because of its tight manufacturing tolerances. Each block has a .2mm offset in the dimensions of the studs compared to the base of the block that they join with. This makes joining them easier for the user but still maintains a haptically satisfying click when they are joined (Dimensions Info 2013; OrionRobots 2013). This offset is useful as a rule-of-thumb for printing two-piece modular systems that must fit together. The capped extrusion-based system is more difficult for a D3DP because it would require the printer to make a support structure so the cap could be placed on the extrusion.

Since LEGOs are printable using a D3DP, it would be possible to make furniture by printing oversized versions of LEGOs. However, there are several reasons why this would not be appropriate for the *Potential* project:

- The LEGO company owns the patent to this system and there would be ethical issues in working with this design.
- The stubs on the blocks are not conducive to furniture and would have to be removed or covered.
- Disassembly of large blocks would be difficult for some users.
- The length of time to print enough large blocks would be immense and a substantial amount of material would be needed to achieve this.

Design Relevance: Single module design, .02mm offset for easy fit.

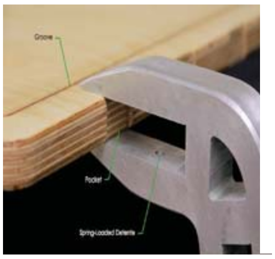
 

(Zieta Prozessdesign 2013)

Case Study: Paravent
Designer: Zieta Prozessdesign, 2012
Type: Modular Bolt-Fastened and Press Fit Joint

Description:
The Paravent (“screen” in French) wall is a digitally crafted wall that is made from CNC bent sheet metal. The wall was designed “to explore the possibilities of a multi-purpose machine, combining the mechanical 3D-deformation utensils with laser cutting equipment, for creation of complex forms. (Zieta Prozessdesign 2013)” The design is based on an interlocking system of modular triangular joints that are fastened with two bolts at every join. The extruded nature of this form is well suited to D3DP and the way that the pieces interlock creatively addresses the load requirements of the system by placing the interlocking grooves parallel to the direction of the load. Because of this, the bolts used are not under a separating tension and instead use their material strength to prevent lateral shift. While making bolts is problematic with a D3DP, the concept of using a pin retaining device is relevant. This creative modular construction system is too dependent on the strength of metal to be easily adapted to D3DP. Moreover, the shape and modular nature does not lend itself to joining with other materials. This would mean that the D3DP would have to make all of the structure which would be slow and expensive (Gershenfeld, 2005).

Design Relevance: Digitally designed join made using digitally controlled machinery; modular system based digital fabrication; extruded shape suited to D3DP; retaining pin concept.

Complexity	Easy	Moderate (tools required)	Easy	Moderate (tools required)
Modular System	yes	Yes	Yes	Yes
Desktop 3D printable	No	No	Yes	No
Sturdy Construction	No	Yes	Yes	Yes
Sustainable Materials	Yes	Yes	No	Yes
No Additional tools required	Yes	No	Yes	No
Dynamic? (Works with Common material	Yes (Plywood)	Yes (Steel Poles)	No (Works with itself)	No (Works with itself)

Discussion
The modular systems studied rely on two principals to retain the parts they join:

Friction joints, like those used in the Snap joint and LEGOs, hold parts together through the use of tight fitting tolerances.
Friction is increased by suction, texture or a similar mechanism.
The loads that these joints carry compress the joint more or are perpendicular to the direction of the friction.
Capture joints, like the swivel clamp and the Paravent joint, are formed to fit like puzzle pieces and lock or encircle each other.
These joints rely on the material strength of the encircling part to prevent separation.
Encircling capture joints offer a rotational element that can be used to address other variables.
When split, encircling capture joints can double as friction joints for forces perpendicular to the capture direction.
Retaining pin, or similar device, can be used to oppose lateral shift of interlocking pieces.

Industry Observations
These findings were applied to a larger industry-wide analysis that focused on DIY retailers and department stores like Bunnings, Mitre 10, IKEA and the Warehouse. Of the modular systems retailed at these stores, the following additional observations were made:

Most modular systems rely on mechanical fasteners (bolts and screws).
Many capture joints use opposing tapered or jigsaw shapes to prevent separation.

The most common shapes in modular furniture systems are panels and rods.
The shape of many processed or manufactured building materials are also panels and rods:

Panels: plywood, foam insulating sheets, cardboard, glass, tile, bricks, etc.
Rods: plumbing pipe, closet rods, framing timber, rebar, wire, etc.

Summary
The designs of modular joining systems exploit several basic principals that rely on standardisation of materials. This same principal of modularity is present in common building and merchandising systems. By exploiting these principals, digital models can be fashioned that match common profiles and then scaled to fit an enormous range of materials.

Appendix 4: Design Research

This section examines the creative steps taken in the development of the Jansen Joint. The process began with identifying the key features or objectives that the final product should have. These were broken up into three groups according to feasibility, viability, and desirability. This hierarchy is based on what Tim Brown establishes as the key concepts of Design Thinking (2009) and Patrick Jordan's hierarchy of product experience: Functional, Usable, and Pleasurable (Jordan 2000). Accordingly, my objectives were to make a chair that featured:

Feasibility: Functional

- Strong (i.e., withstand general use)
- Secure (i.e., user comfort and confidence)

Viability: Usable

- Modular system integrating common commercial products
- Adaptable to multiple configurations
- Easily assembled without additional tools

Desirability: Pleasurable

- Sustainable
- Quickly printable (i.e., within 1 hour)
- Smallest possible (i.e., easy to print, store, and use less material)
- Simple construction (fewest number of parts)
- Support-less printing (less post-printing hassle)
- Unify into an attractive product

Selection of Construction Materials
Jansen used PVC because it is inexpensive and easy to obtain (Jansen 2007). However, PVC is a petroleum product and not a sustainable choice.

In my search for alternatives I decided to use bamboo. A symbol of the sustainability movement, bamboo has a wide range of industrial and agricultural applications and is often used in furniture construction. Its tubular profile matches the profile of common plumbing piping, curtain, and closet rods, rebar, and many other common building materials. This research determined that the average range of diameter for the bamboo garden stakes sold at national DIY stores ranged from 7 to 12 mm.

Ideation & Concept Sketching

The ideation phase was instrumental in initially exploring the viability of design concepts. In these drawings, I searched for joints that would solve the most variables possible.

Graphically I tested construction connections that were appropriate for common commercially sold materials or products. However, these visual iterations could not answer all of my questions.

CAD Modelling

Goal:

> To digitally develop the models, resolve design issues, and prepare for prototyping.

Technique:

> All CAD models were executed using Rhinoceros (Rhino) 5 Beta for Mac, a NURBS-based modelling programme. Digital models were developed from sketches to begin the prototyping process.

Design:

> The aim in this phase was not to completely resolve the model's detail but to focus instead on structural relationships. This quick-and-dirty approach to design is central to the design thinking methodology.

In this way, the final CAD designs have developed in a generational progression from basic, blockish geometric forms to complex system of parts that address the many variables of the printing, assembly, and functionality of the joint.

Evaluation:

Making changes and altering CAD models can take significant time in Rhino. Additionally, this software is prone to "bugs". To avoid these factors I have developed several techniques for working with the software. For example, I will copy a model and make the changes to the copy in order to preserve a bug free model. If my new copy develops a bug that I can't fix, I can return to the original model. On large projects, my work area can begin to resemble a junkyard but this landscape tells a visual story that links a project's beginning and end.

Scale Model Development

Goal:

> My aim is to understand the dynamics of the Jansen walking mechanism and identify key variables that the Jansen joint needs to address.

Technique:

> Four scale models were constructed at different scales and levels of complexity based on the Jansen walking mechanism. Paper modelling, 3D prototyping, and DIY assembly were used.

Design:

> The first two, the Paper Strandbeest (Dombeef 2013) and the Brabeest (Wood 2013), were built following instructions and using files that were found on the

internet. The second two were developed in Rhino from prototypes using the D3DPs based on the principals learned form the previous models.

Evaluation:
The models were useful in identifying that a modular system based on this mechanism would:

- Have joints that interlock to form stacked “nodes” or clusters instead of one joint with many attachments.
- Allow the joints and the system to work in adjacent planes to each other
- Gain strength through the repetition of the joint instead of each joint being independently strong.
- Use fixed and flexible triangular shapes for strength.
- Feature mainly three-way intersections (there is only one four-way and one two-way intersection).

Product Testing
Testing of the joints was done concurrently with the design prototyping phase. Models that achieved the initial goals of printing intact and fitting the material they were printed to join with were then put through a series of tests that included:

1. Withstanding full weight.
2. Withstanding repeated load tests.
3. Withstanding twisting and racking of joined materials.
4. Integration into a scale model and load test.

In most cases, models did not make it to the end.

Design by Prototyping
Goal:

Challenge the D3DP to test its limitations, evaluate it compared to the claims of advocates and detractors, and iteratively design a sustainable modular furniture joint system.

Technique:

Prototyping was done using a RepRap Prusa Mega printer that was purchased from 3Dstuffmaker, an Australia-based company (a New Zealand supplier could not be located). Digital models were pre-processed using either Slic3r v0.9.10b (early phase) or Cura v.13.10 (late phase) and printed using the print driver, Pronterface v1.2.

Design Challenges
The Jansen joint had to:

- Grab the slick bamboo surface and hold it securely.
- Be repositionable at many angles.
- Accommodate various bamboo diameters.
- Capture/encircle intersecting bamboo rods and hold a position.
- Interlock in a way that permits more than two connections at a given join.

Design Solutions

Phase 1: Shaft Design
Design:

- The internal cavity is threaded like a nut or bolt to hold the bamboo.
- First iteration used a conical shape.
- Second iteration used a split shaft.

Testing:

- The first iteration failed due to the shape.
- The second iteration grabbed and withstood two people trying to pull apart the joined bamboo using full force.

Analysis:

The threads are a challenge for the D3DP to make. In building the model the small short movements to make the threads caused the machine to shake quite a bit and the next area the nozzle went to build did not receive an even flow of material. This design may be problematic.

Phase 2: Barbed Head
Design:

- Cylinder head with barbs on each side (male/female) to grab and retain joints when snapped together.

Testing:

- Four progressively larger iterations, each failing because the material (PLA) was too brittle to connect with another joint.
- Last iteration was too thick to flex and broke from being too brittle.

Analysis:

Nylon clips for bags use a similar principal but are longer and are usually made from injection-moulded nylon. A more flexible material that is just as strong as PLA is needed to accomplish this kind of design.

Phase 3: Tubular Head
Design:

Tubular cavity in head to encircle bamboo for rotational stability and variable positioning.

Testing:

Shafts collide when rotated; heads need to be enlarged to correct this.

Analysis:

I miscalculated with this one by trying to keep the profile small. Lesson learned: overbuild first and then scale back.

Phase 4: Tapered head

Design:

- Inverted bamboo aesthetic applied to head.
- Lengthened lower rim of head to compensate for removed material in head design.

Testing:

Heads do not seat well because protrusion on head is too small.

Analysis:

I really like the tapered design but it is problematic at this stage because too much material must be removed for it to work. The elongated base of the head made printing very difficult and required support materials. Using support material caused the printer to make very short, light strokes and the slow extrusion led to a clog.

Phase 5: Extended neck

Design:

- Returned to Euclidean cylinder head.
- Added neck between the shaft and the head to reduce rotational interference from cable ties. Lengthened and tapered protrusion and increased depth of cavity on head to create tighter-fitting parts.

Testing:

- The heads fit pretty snugly and still rotate.
- When mounted on a bamboo rod and retained with cable ties, they hold fast and rotate freely.
- A large full-scale model of the Jansen leg mechanism was built with this model to show proof of concept.
- Model performed moderately well, however cable tie retainers tend to slip. Single plane construction seems too weak for making furniture.
- More strength testing is needed, but fully functional prints were not possible at this time due to software issues.
- Users who tried the joint were able to understand its function and manipulate it without much guidance.

Analysis:

This is the first really functional joint after so many prototypes. The joint does most everything being asked of it, however the tolerances for the printer are not tight enough to produce a snug enough fit for the heads to snap together. More experimentation with printer settings and tolerances is needed. Problems with the software are fouling up prints and:

- Not printing top layers on models, which compromises their strength.
- Blobbing the extruded plastic and building models that were extremely rough.
- Vibrating so violently that the Y-axis was skipping steps, causing models to be slanted and ruined.
- Infill of prints was incomplete and did not overlap the perimeter of the models, leading to exterior shell separation and delamination.

Scale model of mechanism received mixed critique. Many reviewers were impressed at the functionality and system but unimpressed at the look of the joints.

Phase 6: Hinge Neck

Design:

Developed a hinge neck that would print in place based on the concept of a ball joint.

Altered surrounding parts to increase strength in this area.

Testing:

- Early iterations broke because of weak neck parts
- Final version of this hinge is sturdy at .5mm tolerance with minimal amount of flex or torsion when attached to a rod.
- Construction of a bamboo chair prototype failed due to tubular head slipping from position on shaft.

Analysis:

Printing this hinged joint requires very tight tolerances. This may mean that inexperienced makers would find this too difficult to print. However, the joint tests well using PLA. Was able to print one of these using WPC, and it rotates but does not feel strong. With light use, the WPC is delaminating around the shaft. Shaft size may need to be increased. Construction of a prototype chair needs a retaining device or something stronger than the zip tie around the shaft to hold the joint in place. Some success with using a hand drill to make a hole in the bamboo to thread the zip tie through but I feel that this method goes against the ethos of this project because it makes a system dependent on power or other tools beside the D3DP. SCION has returned the results from the materials testing which shows that the PLA and ELST composite, a high density PLA (HD-PLA) is potentially better suited to the design of this joint. It may enable the neck to bend and thus not require a hinge.

Phase 7: Cap, Plug, and Cable Ties

Design:

- Developed a cap and plug that fit either end of the joint head.
- Created a channel between the male/female surfaces of the head connection that allows a cable tie to be threaded through the channel and lock the two heads together.

Testing:

- Initial tests of these modifications show that the cable tie creates a good hold of the two joints. In one case, the joint slipped and separated, however it did not completely fail because the cable tie prevented it.
- The plug fits very snugly on the bamboo ends and looks like a proper foot to a chair.
- The cap may need some modification to fit as snugly.

Analysis:

The cap and plug are a nice addition to the system. They give a stack of connected Jansen joints a nice beginning and end and will help keep them together for storage and transport. Further investigation into quick-fit plumbing technology may prove beneficial to improving this system.

Phase 8: *Neck extension*

Design:

- Reverted the design back from hinge to the extended neck.
- Lengthened the neck even more to enhance material properties.

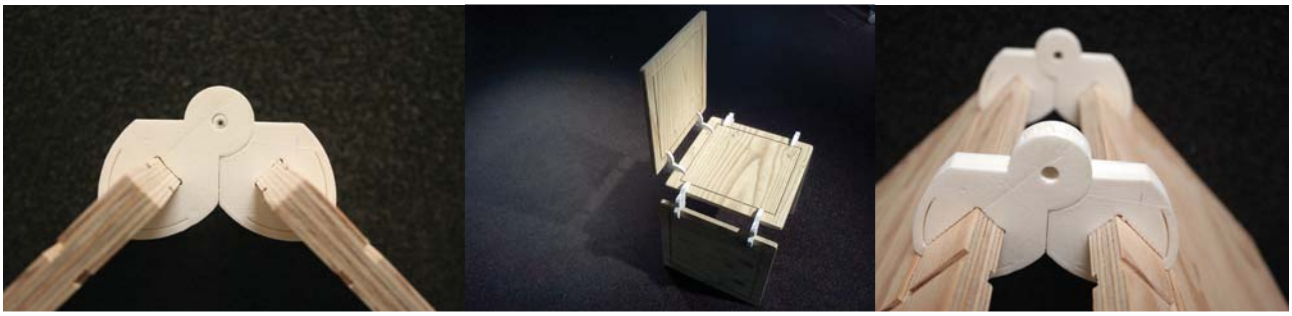
Testing:

- Comparison tests between this version done in PLA only and the PLA/ELST composite blend show that the composite is more flexible.
- The composite Jansen joint is able to achieve a greater range of configurations than the PLA-only version because of the angles.
- The composite is functionally about as strong as the PLA-only version.
- The composite Jansen joint cracks and then progressively breaks, whereas the PLA-only version snaps suddenly.

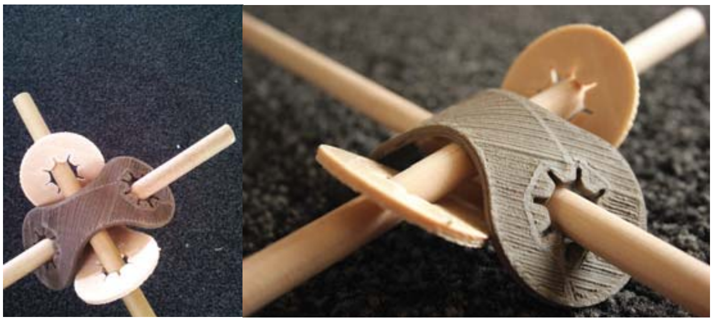
Analysis:

The use of the HD-PLA in place of the neat PLA means that the hinged neck is not necessary to achieve many angled configurations. Using this material gives the Jansen joint a stronger, denser structure than a neat PLA version when printed on a desktop FDM D3DP, because the ELST in the HD-PLA fills the voids left between intra-layer extrusions. This is a significant design change because the materials were designed to fit the tool and subsequently the object that the tool makes can be designed to perform a function that would not be possible with a standard material. A major benefit of this design change is that inexperienced makers will find this faster (only 45 minutes at a speed of 20 mm/second) and easier to print.

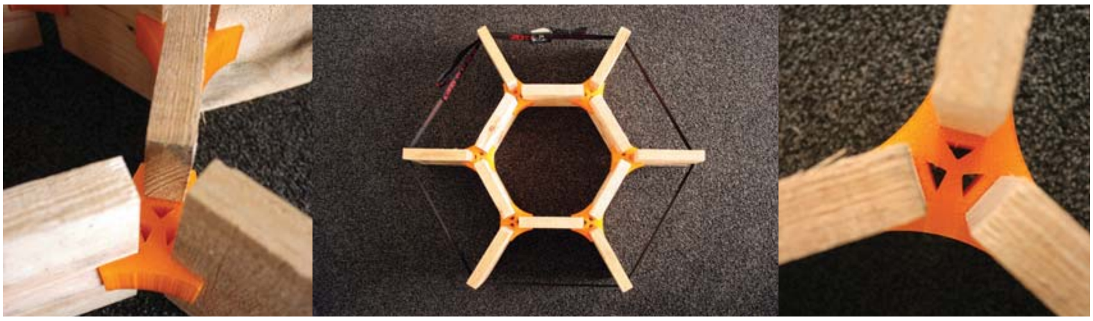
Appendix 5: Joint Profiles



The ‘Adjustable Joint’
A multi-positional clamping joint inspired by the “Snap” joint by MIT students Lindy Liggett, Lisette Lopez, Taylor Morris, Josh Ramos, and My Vu that is designed to work with pre-cut standardised plywood panels (“Snap-Reconfigurable Furniture” http://web.mit.edu/2.744/www/Results/studentSubmissions/conceptRefinement/tpc2744/system/). The Adjustable Joint improves on the “Snap” joint because it can be 3D printed and positioned at 90º, 120º, or 180º angles depending on the furniture structure needed. When printed solid with the hardest version of the plastic made with SCION this joint can be used to make chairs, desks, and shelving units.



The ‘Flexi Joint’
Modelled after silicone ‘Stick-lets’ by Christina Kazakia (http://www.dezeen.com/2013/10/20/stick-lets-by-christina-kazakia/). This 3D-printable joint allows users to quickly build structures using sticks and bits of wood to sketch structures. It can be very useful for prototyping or for use in making temporary structures or tents. This 3D version is only possible because the material developed with SCION is flexible enough to allow these joints to bend without breaking, whereas the same joint made with PLA or ABS would fracture, due to the brittle nature of these materials.



The “Pallet Joint”
Joins the planks of a dismantled commercial pallet. The joints slide onto pallet planks, allowing the user to quickly “sketch” a structure and then cinch the structure together using standardised tie-down straps. Using pallets or other common commercially available plank or board timber a user can print off the pallet joint and build furnishings for a studio or casual living space for much less than retail furniture.

The “Jansen Joint”
A desktop 3D-printable modular furniture joining system modelled after Theo Jansen’s kinetic sculptures The Strandebeests (http://www.strandbeest.com). Designed to emphasise the flexible mechanical qualities of the composite plastic developed with SCION. The joint can accomplish positions that would be challenging or impossible if it was made with standard 3D printing materials. The Jansen Joint is displayed here in a variety of materials. The top left photo shows how the short neck version when printed with a durable material can be used for rigid structures and at the same time the long neck version can be used to achieve acute angles. Alternately the joint can be printed with a hinge using wood composite plastic. This light-duty version is useful for structural components that need to adapt to uneven building conditions.

Appendix 6: Limitations of D3DP

Limitations of Desktop FFF 3DP based on heuristic and iterative product development and testing during this project.

This list is intended to give an idea of the major factors responsible for a print not being successful or functional. It is by no means a complete list.

- The print bed size.
- The bearings can cause wobble in print.
- The stepper motor. A better motor can mean better smoother print and finer resolution; the difference between being able to print an object that moves and having to print pieces that are later assembled.
- The firmware; different firmware interprets G-code in different ways.
- The belts, which can slip or lose tension. When making intricate models where the printer must move in many short exact strokes this can cause vibrations that actually shift the printer off the axis.
- The print surface is heated, which is good for some prints but can be detrimental to others. Kapton tape can be great for easy removal but can cause the initial layers of a print to come undone and lead to curling or warping. Masking tape can be better for the initial layers but can imprint the surface of the print with unwanted texture.
- Side Mount Extruder motor is too far from print head to apply sufficient force to push filament through nozzle, resulting in more clogs.
- Top Mount Extruder Motor adds extra weight to print head and can slow down print process so that certain types of prints are difficult or impossible.
- Ventilation can cause the extruder nozzle to clog. Can reduce or prevent the layers of plastic from bonding, which leads to delamination of layers and a broken/non functional object.
- Old/dry/damp/UV exposed/fractured filament can lead to the filament breaking in the extruder mechanism or the extruded plastic not bonding well between layers.
- Variations in the size/thickness of the filament used can cause the filament to get stuck in the extruder mechanism or cause a weakness in the printed object due to uneven extrusion.

Appendix 7: Printing Log

Printing Log

Print Number	Type of Print?	Date of print	Internal support pattern	Raft/No Raft	Dbl sided tape/ Tape type	Extruder nozzle size	Extruder temp	Extruder multiplier	Print speed	Filament Size/ setting	Layer Height	Extrusion multiplier / Flow Percentage	Fill Amount(.1 - 1) / Print Quality (Fine/Normal/Fast)	Est weight of finished print	Length of print time	Outside Temp (Cº) (inside Temp was between 16º and 19º C)	Outside Weather	Outside Humidity	Time Started	Setting (ABS or PLA)	Printer	Slicing Software	Firmware	Printer interface	Success?	Notes
1	Wedge for chair	11/05/13	2/Tight criss cross	Raft									Fast	82.4 grams	4 hours	12º	Overcast/Drizzle	72%	5:30 PM	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged - partial print)	
2	Wedge for chair	12/05/13	3/Medium criss cross	Raft									Fast	82.4 grams	4 hours	16º	Clear	63 -68 %	12noon	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged - partial print	
3	Wedge for chair	12/05/13	4/Loose criss cross	Raft									Fast	82.4 grams	4 hours	16º	Clear	63-68%	5pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged - partial print	
4	Wedge for chair	13/05/13	3/Mediumcriss cross	Raft									Fast	82.4 grams	4 hours	15º	Clear	88%	8pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged - partial print	
5	Black joints for Pallet	18/05/13	4/Loose criss cross	Raft									Fast	84.7 grams	4 hours	12º				ABS	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
6	Orange joints	22/05/13	4/loose	Raft									Fast	76.8 grams	5 hours 33 min	14º	Passing clouds	82%	6pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
7	Chain Mail	29/05/13	3/Medium criss cross	No Raft									Fast	7.1 grams	6hours	8º	Clear	65%	7:36pm	ABS	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged)	
8	Chain Mail	29/05/13	3/Medium criss cross	Raft									Fast	7.1 grams	6hours	8º	Clear	65%	8:30pm	ABS	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	no(nozzle clogged - birds nest)	
9	Chain Mail	29/05/13	zig-zag	Raft									.25mm	7.1 grams	6hours	8º	Clear	65%	8:50pm	PLA	BFB	BFB Software	BFB Software	BFB Software	yes/no	Base layer too thin from uneven platform. Print broke trying to remove it from platform. Chainmail stuck together.
10	Pallet Joints	4/06/13	2/Tight criss cross	No Raft									Normal	71.9 grams	5 hours 33 min	14º	partly cloudy	70%	12:25pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	PLA didn't stick to tray. Birdsnest	
11	Pallet Joints	4/06/13	2/Tight criss cross	Raft									Normal	79.5 grams	5 hours 53 min	14º	partly cloudy	70%	12:35pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
12	Pallet Joints (4 way)	4/06/13	2/Tight criss cross	Raft									Normal	73.6 grams	5 hours 35 min	10º	Raining	94%	9pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
13	Pallet Joints (3 Way)	5/06/13	2/Tight criss cross	Raft									Normal	71.5 grams	5hours 7min	9º	partly cloudy	81%	4:25pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
14	Chain Mail	5/06/13	zig-zag	No Raft									.25mm	14.2 grams	3 hours	9º	partly cloudy	81%	5:45pm	PLA	BFB	BFB Software	BFB Software	BFB Software	yes	(base layer too thin from uneven platform. Chain mail size was increased by 100% from 1.5mm high to 3mm high
15	Chain Mail	6/06/13	zig-zag	No Raft									.125mm	35.3. grams	3 hours	9º	partly cloudy	79%	6:45pm	PLA	BFB	BFB Software	BFB Software	BFB Software	yes	(base layer too thin from uneven platform. Chain mail size was increased by 100% from 3mm high to 4.5mm high
16	Pallet Joints (H joint)	6/06/13	1/Near Solid Fill	Raft									Normal	37.5 grams	3hours 41 min	9º	partly cloudy	79%	6:45pm	PLA	3up	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	
17	Pallet Joints (H2 joint)	11/06/13	1/Near Solid Fill	Raft									Fine	15.6 grams	1hour 33min	14º	partly cloudy	68%	4:30pm	PLA	3up	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	Min opening= 13.31mm / Max opening (3 teeth) = 21.69
18	Pallet Joints (H2 joint)	11/06/13	1/Near Solid Fill	Raft									Fine	15.6 grams	1hour 33min	15º	partly cloudy	94%	4:15pm	PLA	3up	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	Min opening= 13.31mm / Max opening (3 teeth) = 21.69
19	Chain Mail	11/06/13	zig-zag	No Raft									.125mm	30.24 grams	11hours 1 min	15º	partly cloudy	94%	3:45pm	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Used tape on bed to improve removal of print. Nozzel dragged print off bed… didn't stick to tape
20	Chain Mail	11/06/13	zig-zag	No Raft									.125mm	30.24 grams	11hours 1 min	15º	partly cloudy	94%	4:00pm	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Used tape on bed to improve removal of print. Nozzel dragged print off bed… didn't stick to tape
21	Chain Mail	11/06/13	zig-zag	No Raft									.125mm	30.24 grams	11hours 1 min	15º	partly cloudy	94%	4:15pm	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Removed tape from bed. Found problem with print file/printer. Was not putting down layers evenly… was starting base layer for some links after the 4th layer had been set for most other links.
22	Pallet Joints (H2 joint)	12/06/13	1/Near Solid Fill	Raft									Fine	42.1 grams	4hours 4 min	13º	partly cloudy	94%	11:30am	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	Altered the H2 file to increase Min opening to 15mm.
23	Pallet Joints (H2 joint)	12/06/13	1/Near Solid Fill	Raft									Fine	44.7grams	5hours 19min	13º	partly cloudy	82%	2:15pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	yes	First print of Laywood. Using brand new nozzle on 3Up printer. Final print is very light… like it is made of cardboard. Material feels a little spongey. Threads on model are not useable… material slumped between threads. Lots of extra hairs from etruder nozzle. can dent material with finger nail. Color is consistent indicateing relatively even heating throughout print.
24	Chain Mail Coke Tab	12/06/13	zig-zag	Raft									.125mm	45.67 grams	11hours 47 min	12º	partly cloudy	82%	8:33pm	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Reprint of Coke Tab after fixing corrupted file. BFB file took 7 hours to build! Accidentally built file with Raft - oops! Watched print for nearly 2 hours with no issues present. Left and returned to find back half of print in a tangle. Not sure what caused the problem except that the nozzle obviously dragged through the other bits of the print. Some of the print was in tact enough to identify that the new coke-tab design is more robust than the square chain mail. Suprisingly the PLA raft removed quite easilly from the print...however this is consistent with the BFB printer... I will try the same print on the UP! which consistently is difficult to remove.
25	Chain Mail Coke Tab	13/06/13	1/Near Solid Fill	Raft									Fine	54.8 grams	7hours 50 min	14º	partly cloudy	82%	11:45am	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Nozzle clogged and stripped out PLA filament. I suspect that the tension on the filament is to blame because as soon as I withdrew the filament and then reinserted it into the nozzle it began to flow out again. I will attempt again on another printer that has a new nozzle.
26	Pallet Joints	13/06/13	1/Near Solid Fill	No Raft									Fine	88.6 grams	10 hours 26min	14º	partly cloudy	88%	12:00pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	print didn't stick to bed without raft.
27	Pallet Joints	13/06/13	1/Near Solid Fill	Raft									Fine	96.2 grams	11 hours 00min	14º	partly cloudy	88%	12:20pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Nozzle clogged 3/4 of the way through.
28	Chain Mail Coke Tab	13/06/13	1/Near Solid Fill	Raft									Fine	55.4 grams	14 hours 01 min	14º	partly cloudy	88%	5:30pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Nozzle clogged within first layer.
29	Pallet Joints (3 Way)	13/06/13	1/Near Solid Fill	No Raft									Fine	88.7 grams	8hours 41 min	14º	partly cloudy	94%	6pm	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Nozzle clogged.

30	Chain Mail Coke Tab	13/06/13	zig-zag	Raft							.125mm		45.67 grams	**11hours 47 min**	14º	partly cloudy	94%	**6pm**	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Returned to find a perfect raft and a rats nest of filament. Not sure where to go from here...Prints don't work on either machine. File looks like it is ok but I suspect the shape of the links is messing with the print heads.
31	Pallet Joints (3 Way)	14/06/13	1/Near Solid Fill	No Raft							Fine		94.3 grams	**10 hours 25 min**	14º	partly cloudy	82%	**11:30am**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Base layer didn't stick. Nozzle moved model out of position.
32	Pallet Joints (3 Way)	14/06/13	1/Near Solid Fill	Raft							Fine		94.3 grams	**10 hours 25 min**	14º	partly cloudy	82%	**12:00pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	Yes	Finally a succesful print with the orange PLA. It is interesting how some designs are consistently successful and others are not.
33	Pallet Joints (H joint)	14/06/13	1/Near Solid Fill	Raft							Fine		36.3 grams	**6hours 19min**	14º	partly cloudy	88%	**12:30pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Nozzle clogged 1/2 way through
34	Pallet Joints (H2 joint)	14/06/13	1/Near Solid Fill	Raft							Fine		41.8 grams	**4hours 2min**	14º	partly cloudy	82%	**3:25pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	Yes	Used khaki/off white PLA from FabLab. Worked a treat!
35	Pallet Joints (3 Way)	14/06/13	1/Near Solid Fill	Raft							Fine		95.4 grams	**10 hours 25 min**	14º	partly cloudy	88%	**7:45pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Khaki PLA broke again...it is incredibly brittle. Even moderate bending causes it to break in some spots
36	Pallet Joints (H2 joint)	14/06/13	1/Near Solid Fill	Raft							0.25mm		127.34 grams	**14hours 3 min**	14º	partly cloudy	88%	**7:30pm**	PLA	BFB	BFB Software	BFB Software	BFB Software	Yes	Perhaps the best print of this design yet. Very clean print.
37	Pallet Joints (3 Way)	15/06/13	1/Near Solid Fill	Raft							Fine		94.3 grams	**10 hours 25 min**	10º	partly cloudy	82%	**1:30pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	Yes	
38	Chain Mail Coke Tab	15/06/13	zig-zag	Raft							.125mm		45.67 grams	**11hours 47 min**	14º	partly cloudy	94%	**6pm**	PLA	BFB	BFB Software	BFB Software	BFB Software	No	Fought with machine as it knocked the base layers off erratically moving through the print. Tried to pause the machine and tape down the disloged bits but gave up. 3d file needs to be redone so the bottom of the link is flat.
39	Pallet Joints (H2 joint)	15/06/13	1/Near Solid Fill	Raft							0.25mm		127.34 grams	**14hours 3 min**	12º	partly cloudy	67%	**7:45pm**	PLA	BFB	BFB Software	BFB Software	BFB Software	No	PLA spool was pulled off spool holder and jammed in machine. Why???!!!!
40	Pallet Joints (3 Way)	15/06/13	1/Near Solid Fill	Raft							Fine		94.3 grams	**10 hours 25 min**	12º	partly cloudy	82%	**7:00pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	No	Filament was broken on spool. Why???!!!
41	Pallet Joints (R4mm)	16/06/13	1/Near Solid Fill	Raft							Fine		75.7 grams	**8 hours 00 min**	12º	partly cloudy	100%	**2:30pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	Yes	Watched print all day..at 8pm was about to leave when I noticed that the filament was broken on the spool about 5 meeters in from current printing position. Removed 5 meeter, trimmed current filament and fed in new end after current filament was taken. No issue with this print. Yay!
42	Pallet Joints (H2 joint)	17/06/13	1/Near Solid Fill	Raft							Fine		42.1 grams	**4 hours 04 min**	15º	partly cloudy	88%	**2:45pm**	PLA	UP!	Smart Visual Print Driver	Smart Visual Print Driver	Smart Visual Print Driver	Yes	
43	*****																								Purchased and set up new Mendel Printer.
44	Dog bone	21/07/13	Rectilinear	No Raft	Yes	.07mm	210º C	1	150	1.75mm		1	N/A	**23min**	13º	partly cloudy	82%	**8pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	trouble with extruder motor and filament kinking.
45	Dog bone	21/07/13	Rectilinear	No Raft	Yes	.07mm	230º C	1	75	1.75mm		1	N/A	**23min**	13º	partly cloudy	82%	**8pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Rough print. Last few layers the extruder was clogged but first few layers were great.
46	Dog bone	21/07/13	Rectilinear	No Raft	Yes	.07mm	230º C	1	35	1.75mm		1	N/A	**23min**	12º	partly cloudy	88%	**11pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Kink in line in extruder... perhaps extruder should be above nozzle to prevent loss of force
47	Dog bone	21/07/13	Rectilinear	No Raft	Yes	.07mm	230º C	1	35	1.75mm		1	N/A	**23min**	12º	partly cloudy	88%	**11:45pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Shitty print but relative success because I hand fed the filament into the nozzle during the entire print. More force is required to push through the clogs with the wood fibre and occasional cleaning of head by forcing a think wire up the nozzle opening.
48	Dog bone	22/07/13	Rectilinear	No Raft	Yes	.07mm	230º C	1	35	1.75mm		1	N/A	**23min**	13º	partly cloudy	88%	**9am**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Had to hand feed filament through. Extruder could not maintain pressure because polypropylene kinked
49	Dog bone	22/07/13	Rectilinear	No Raft	Yes	.07mm	230º C	1	35	1.75mm		1	N/A	**23min**	13º	partly cloudy	88%	**9:30am**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Had to hand feed filament through. Extruder could not maintain pressure because polypropylene kinked
50	Dog bone	22/07/13	Rectilinear	No Raft	Yes	.07mm	240º C	1	15	1.75mm		1	N/A	**23min**	13º	partly cloudy	88%	**10am**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	As plastic comes out of nozzle it rolls...perhaps due to flour. Higher heat? Adding a lubricant to the plastic to increase liquidity? As print progressed nozzle clogged. Removing tube and pushing on filament improved print quality although plastic still wanted to ball up. Plastic was too flexible and increased pressure cause it to easily kink. Much easier to kink than lower flour/plastic ratio.
60	*******																				Slic3r	Marlin	Pronterface		Rotorua Trip... Started new school semester.
61	Dog Bone	20/08/13	Rectilinear	No Raft	Yes	1.0 mm	210º C	1	150	3.0mm (2.8mm)		1	N/A	**23min**	15ºC	Clear	59%	**3:52pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Lots of trouble setting up printer. Bed was out of alignment. Nozzle is acting funny... at home position it is a cards thickness (approx .35 mm away from the print bed but when printing starts the nozzle lifts to more than a millimeter above the bed. Filament wasn't sticking. Had to set home position lower (flush with bed) so it would print at an approprate height from the bed. Final print ok... resolution poor. Probably due to increased nozzle opening size. Lots of false starts... probably ten or so.
62	Dog Bone	20/08/13	Rectilinear	No Raft	Yes	1.0 mm	210º C	15 perimiter/20 1 interior		3.0mm (2.8mm)		1	N/A	**23min**	15ºC	Clear	59%	**7:30pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Nozzle clogged...Then printer took a nose dive...Z home over shot and pushe end stop out of range and z axis came off spools. Had to recalibrate z axis, print plate, and devise way to level table. Extruder started acting weird. Was extruding at crazy fast speed. Shut everything down. Disconnected Z stop, extruder, and Z stepper motors from PCB board and shut down software and rebooted. Still didn't fix it. Leveled everything. It took 3 hours. Then the extruder started working ok again?!!!!? Print of 35/35/30 went really well when I got things situated. Had to set Z home low again because it is still printing higher than Z home level. Print had some splotchy areas where it didn't extrude filament... it could be cloggs or insufficient extrusion speed vs print speed. Changing print speed to check.
63	Dog Bone	20/08/13	Rectilinear	No Raft	Yes	1.0 mm	210º C	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**20:20 min:sec**	15ºC	Clear	59%	**8:20pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print came out very consistent. Tried a different speed (10) for all settings but too slow and the material was backing up into the nozzle and clogging. At 15 the print came out quite good but would clog occasionally. Will try a different material to see if it does the same thing. WIll try a different speed (faster) to see what the difference is.
64	Dog Bone	20/08/13	Rectilinear	No Raft	Yes	1.0 mm	210º C	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**20:20 min:sec**	15ºC	Clear	59%	**9:07pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print had some trouble during the last three layers. Nozzle seemed to clog and then unclog itself repeatedly. Already printing at higher temp which seems to have increased flow... not sure what else to do other than improve filament with some sort of lubricant or improve material distribution in filament (thinking that perhaps the distribution of fibres is uneven which may be causing the blockage. Thinking that mounting extruder on nozzle bracket may help.
65	Brabeest (leg brace)	22/08/13	Rectilinear	No Raft	No (Masking)	1.0 mm	210º C	15 perimiter/20 1 interior		3.0mm (2.8mm)		1	N/A	**12 min**	13ºC	Rain	82%	**1pm**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Extruder is putting out too much plastic. Print resolution is so bad that items will not fit together. Tall thin items on print bed are being globbed on by nozzle because too much plastic is coming out once a line is completed and nozzle moves to next line (Slow down extruder, slow down nozzle speed). Plastic is taking too long to harden (210º may be too high). Was having trouble with PLA sticking to yellow kapton tape. Switched to masking tape.
66	Brabeest (leg assembly)	22/08/13	Rectilinear	No Raft	No (Masking)	1.0 mm	210º C	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**2hrs 20min**	13ºC	Rain	82%	**2:30 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Items didn't stick well and 1/2 way through nozzle knocked the pieces about and print was ruined.
67	Brabeest (leg assembly)	22/08/13	Rectilinear	No Raft	No (Masking)	1.0 mm	190ºC	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**2hrs 20min**	13ºC	Rain	82%	**4:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	2nd attempt... I slowed down print speed. better success but tall bits were still wobbly.
68	Brabeest (leg assembly)	22/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	210º C	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**2hrs 20min**	13ºC	Rain	82%	**6:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	3rd attempt... I changed nozzle back to .7mm. Better print resolution but still problem with globbing from nozzle. Researched Slic3r settings and learned about "Lift". Lift affects the nozzle retraction of filament between executed tasks. Will attempt to reprint with 1mm of retraction.
69	Brabeest (leg brace)	23/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	15 perimiter/15 1 interior		3.0mm (2.8mm)		1	N/A	**12 min**	13ºC	overcast	82%	**8:00 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed lift to 1mm but too much plastic was coming out. Will switch to 2mm

70	Brabeest (leg brace)	23/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	**12 min**	13ºC	overcast	82%	**8:15 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Switched to 2mm but still too much plastic was coming out...however perimiter lines were great. Problem is with overlap of interior lines on fill layers. Will switch seeting to read that there is a 1mm nozzle even though there is a .7mm nozzle to see if this solves or improves problem.
71	Brabeest (leg brace)	23/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	**12 min**	13ºC	overcast	82%	**8:30 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Problem seems mostly solved. Overlap is better on infill layers.
72	Brabeest (mixed parts)	23/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	**15:05 min**	13ºC	partly cloudy	82%	**1:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the print layer thickness to .6 and turned down the extrusion to 10 mm/ min. Much better resolution but some areas are weak and there are gaps in construction. Going to increase to 20 mm/ sec
73	Brabeest (mixed parts)	23/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	**15:05 min**	13ºC	partly cloudy	82%	**3:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Still rough. Going to increase size of design. Scaling up to double area of print. - this proved to be quite involved as I was not clear on the proper formula to do this and there is no simple setting in Rhino to double the size of an object. I had to research trigonometry formulas and learn how to use a scientific calculator to compute the cosine and inverse cosine of an angle.
74	Brabeest (mixed parts)	26/08/13	Rectilinear	No Raft	No (Masking)	.7 mm	190ºC	1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	**24 min**	16ºC	partly cloudy	77%	**2:20 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Larger print was much better quality but had lots of globbing issues. Need to adjust feed rate of extruder to fix this. Going to switch back to printing dogbones for a while to get them done.
75	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	185º	1	30perimiter/60 interior	3.0mm	1	N/A	**10:26 min:sec**	9ºC	Clear	94%	**6:40 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Downloaded new software for 3D printer. This version works with an Apple computer. This version of Slic3r provides greater optimization and control of the printer during the print process. Original software had been modified by 3Dstuffmaker (the company that sold the printer). Will have to play a bit with new settings to see how and what adjusments are necessary for an optimal print. This print was set too fast for the interior infill. Perimiter layers were good but interior layers were awful...globbs with gaps between them. Extruder nozzle was moving too fast for extruder.
76	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	185º	1	30perimiter/30 interior	3.0mm	1	N/A	**14:41 min:sec**	9ºC	Clear	94%	**7:07 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Decreased the speed of interior infill. Better print... more or less solid infill layers. Adjusted to concentric infill to try to get unidirectional infill but printer still did infill at 90º to previous layer. Adjusting the settings so the first layer is printed at the same speed as all other layers (before it was at 30% of other layers) and slowing speed for all layers to 10 (both perimiter and infill). Adjusting the degree angle of infill to 0º to see if this fixes the problem of infill layers printed at 90º to previous layer.
77	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	10 perimiter/10 interior	3.0mm	1	N/A	**26:35 min:sec**	10ºC	Clear	94%	**7:31 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print is darker slightly than previous print (temp). Infill layers were still at 90º. Not sure how to adjust this setting. Will write to Marie and see if they have any idea. Re-reading Slic3r manual. No info in it on how to correct this. Print was really consistent. Every other layer was concentric and then a 90º zig-zag. This filament at these settings was fine for printing. Could be used for most print uses.
78	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**18:58 min:sec**	11ºC	Clear	88%	**8:45 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed settings so that base layer and top layer are printed at 200% width. This causes gaps between lines of filament to be filled in better. Produced the nicest print yet. Changed speed to 15 on all settings.
79	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200ºfirst layer and 185º on all others	1	20 perimiter/20 interior	3.0mm	1	N/A	**14:31 min:sec**	12ºC	Clear	82%	**9:26 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed speed to 20 on all settings. Changed temp to 200º on first layer and 185º for each one after. Printing with new filament. All was good till final layer and then it clogged and got splotchy. Speed and temp are likely causes. Setting temp to constant 200º C. Decreasing speed back to 15.
80	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**19:40 min:sec**	12ºC	Clear	82%	**10:05 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Excellent print! Filament mixture produces a very flexible dog bone. Interesting properties that differ significantly to plain PLA or ABS.
81	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**19:40 min:sec**	12ºC	Clear	82%	**10:45 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Not nearly as good of a print. It got very rough on the last layer and the interior layers were sparse...as though the nozzle was clogging. Perhaps increasing the width of each layer will fix this problem and make it so that each layer is completely filled in.
82	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**25 min:sec**	13ºC	Clear	77%	**11:15 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed settings so each layer printed at 200% width and the result was a much more dense print but the quality was progressively more and more rough. Restoring previous settings of top and bottom layer at 200% and all others at standard width.
83	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**19:11 min:sec**	13ºC	Clear	72%	**11:58 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Same problem as two prints ago...final layer is rough. Printer progressively put down less material and in second to last layer the cross section didn't reach the perimeter so the top layer was laid without proper support and this caused the globbing.
84	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	210º	1	15 perimiter/12 interior	3.0mm	1	N/A	**39:15 min:sec**	15ºC	Clear	51%	**1:17 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	changed settings too 250% for first layer and 100% for infill layer. Result was a print that had few gaps between print lines but the print was rough and the filament would roll off the nozzle now and then causing a break in the line. Final piece is darker(temp is higher at @210º) and heavier than the previous three prints.
85	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**12 min:sec**	13ºC	Clear	63%	**2:20 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Nozzle clogged.
86	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**7 min:sec**	13ºC	Clear	63%	**2:35 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Nozzle clogged
87	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	**12 min:sec**	13ºC	Clear	63%	**2:54 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed filament size setting from 3mm to 2.7 to see if this change affects the amount of material that the printer puts down with each layer.
88	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	**18:29 min:sec**	14ºC	Clear	63%	**3:37 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Best print yet with this filament. Lines overlapped and extrusion was consistent. Determined that filament was getting stuck in the extruder mechanism. Thick part of filament is hanging up in the channel and the extruder mechanism is stripping the filament that it is trying to push through. Used digital calipers to scrape the filament down to 3mm for several meters. Marked on filament where largest bulge is and will monitor it as it feeds through. Researched other people who are having similar problems with prints. Suggestion was to check extruder and certify the extruder was accurately calibrated. Determined that extruder is only feeding 90mm of filament for every 100mm it is asked to feed. Adjusting the extruder multiplier by .1 and result was better overlap of lines.
89	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:20 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed setting back to 3mm filament. ..... Printer wasn't putting out enough material and then clogged - perhaps because it is the filament size that improved the last print
90	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:24 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed setting back to 1 extruder multiplier and 2.7mm filament.... Printer wasn't putting out enough material and then clogged. Ok... something is wrong with the extruder nozzle
91	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:28 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Cleaned out nozzle and got it running. Print was looking good but the clogg means that I am not sure which setting improved print number 88. Starting over.
92	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:33 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed setting back to 3mm filament. ..... Printer wasn't putting out enough material and then clogged - It looks like it does have to do with the filament size.
93	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.9 mm)	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:39 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed setting back to 1 extruder multiplier and 2.7mm filament.... Printer wasn't putting out enough material and then clogged. Ok... so maybe it is the combination of the two settings.
94	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.9mm)	1	N/A	**18:29 min:sec**	13ºC	Clear	63%	**4:53 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed setting back to 1.1 extruder multiplier and 2.9mm filament.... Print turned out really good... slight gap in between lines on top and bottom layer. Perhaps 2.8 filament size is the magic number.

95	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:29 min:sec	13ºC	Clear	63%	5:45 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Changed filament back to the 30% wood flour and set filament at 2.8mm. Wood flour filament has a tendancy to roll with the extruder nozzle. It does not stick to the print bed as well as the wood fibre does. This quality causes lines to break as the extruded plastic rolls with the nozzle. Print wasn't any better than previous ones... there was still a gap in the center of the print. Decreasing the filament size again to see if that improves things.
96	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	18:29 min:sec	13ºC	Clear	63%	5:52 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Decreased the size to 2.7mm and it Still had a gap in the first layer.
97	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	210º	1.2	15 perimiter/15 interior	3.0mm (2.5mm)	1	N/A	18:21 min:sec	13ºC	Clear	63%	5:57 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Decreased the filament size to 2.5. Increased the multiplier to 1.2. increased the temp to 210. No gap! Lines are overlaping quite a bit. It is over extruding.
98	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.5mm)	1	N/A	5 min:sec	12ºC	Clear	72%	6:17 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Try again. Decreased temp to 200ºC. increased filament to 2.6mm. Decreased extruder multiplier to 1.1. The gap is back...hmm...maybe 2.5mm.
99	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.5mm)	1	N/A	18:27 min:sec	12ºC	Clear	72%	6:22 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	2.5 is the magic number! Gap is gone. Extrusion is pretty good and overlaps are not excessive.
100	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:16 min:sec	12ºC	Clear	72%	6:50 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Nice print the first time. Reset settings to match last wood fibre print. Very small gap on bottom and top layer but all layers were good.
101	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:16 min:sec	12ºC	Clear	72%	7:13 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Same as before. No change in settings. Good print.
102	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:19 min:sec	12ºC	Clear	72%	7:40 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Switched to new filament. This filament is darker than the 20% wood fibre filament that has an even mix of PLA and ELST. Filament is also much more stiff and more glossy/plasticy. Printer is handling the material well. Good flow through extruder.
103	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:20 min:sec	12ºC	Clear	72%	8:05 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Same as print 102.
104	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.6mm)	1	N/A	18:20 min:sec	12ºC	Clear	72%	8:40 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This filament is very white. It prints really smoothly without many disruptions and doesn't roll the way that the higher concentrations of wood flour roll off the nozzle. There is quite a bit of flexibility to the final print. But it is stiff enough to indicate that it would still be functionally strong in many applications. Switched filament size to 2.6 to match last flour setting.
105	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.6mm)	1	N/A	18:20 min:sec	12ºC	Clear	72%	9:10 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Same as above
106	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.6mm)	1	N/A	18:21 min:sec	12ºC	Clear	72%	9:35 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print was very white due to the filament and low temperature setting. The extruded plastic was a little much as the layers were heavilly overlapped and there was excess plastic globbing on the top of layers.
107	Dog Bone	27/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	18:14 min:sec	12ºC	Clear	72%	10:04 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Adjusting the filament size to 2.7 to reduce the amount of plastic extruded.
108	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.8mm)	1	N/A	18:21 min:sec	11ºC	Clear	82%	6:58 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted filament size to 2.8 to match previous fiber setting. Print is good but too much is coming out. Overlaps are excessive. Retraction between moves needs to increase to reduce extrusion globs at beginning of new line. Printer clogged on last layer and didn't finish print.
109	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm (2.9mm)	1	N/A	18:27 min:sec	11ºC	Clear	82%	7:30 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Adjusted filament size to 2.9. Still globbing. But print was successful and acceptable.
110	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	18:21 min:sec	14ºC	Clear	67%	11:14 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted size of filament to 3mm and multiplier to 1 to reduce globbing. Nozzle dragged pre-print extruded plastic into print area and it got stuck in print and ruined it... started print over.
111	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	18:21 min:sec	14ºC	Clear	67%	11:16 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Same thing again! However print looks better. Lines are overlapping but not globbing
112	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	18:22 min:sec	14ºC	Clear	68%	11:22 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print.
113	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm	1	N/A	18:22 min:sec	15ºC	Clear	68%	12:30 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	print started good but extrusion was not enough and lines inside didn't touch.
114	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1	15 perimiter/15 interior	3.0mm 2.9mm)	1	N/A	18:22 min:sec	15ºC	Clear	68%	12:52 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Decreased filament size to 2.9. Same as above.
115	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	210º	1	15 perimiter/15 interior	3.0mm (2.7mm)	1	N/A	18:27 min:sec	15ºC	Clear	68%	1:16 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Decreased filament size to 2.7.Increased multiplier to 1.1. Increased temp to 210. Better print. Lines overlapped. But a bit too much extrusion.
116	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:17 min:sec	15ºC	Clear	68%	1:37 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Decreased temp to 200. Acceptable print. Still a bit much extrusion.
117	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:23 min:sec	15ºC	Clear	68%	2:05 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increased filament size to 2.8. Very nice print. Just a wee bit much extrusion.
118	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:26 min:sec	15ºC	Clear	68%	2:39 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Best print yet with these settings. Very little globbing. Very tiny area of gap between lines on top level at center of concentric circle pattern. Don't think it could be better without the lines not touching
119	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	20 perimiter/20 interior	3.0mm	1	N/A	13:56 min:sec	14ºC	Clear	72%	3:06 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increased speed to 20 on all speed settings. Print was very good but interior layers had small gaps at corners of each line.
120	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:21 min:sec	14ºC	Clear	72%	3:42 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Reset to same settings as print # 118
121	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:21 min:sec	14ºC	Clear	72%	4:45 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	printed at same settings as #118
122	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:21 min:sec	13ºC	Clear	72%	5:11 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	printed at same settings as #118
123	Dog Bone	28/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm	1	N/A	18:27 min:sec	13ºC	Clear	72%	5:34 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	good print. Infill was not as much as other prints but still acceptable...lines touching and only very small gaps at bridges.
124	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm(2.9mm)	1	N/A	18:27 min:sec	8ºC	Clear	93%	7:34 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Adjusted filament size to 2.9. Still had gaps at bridges but still acceptable.
125 A	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm(2.8mm)	1	N/A	53:24 min:sec	9ºC	Clear	87%	8:00 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increased number of dog bones per print to 3. Decreased filament size setting to 2.8. The dog bones on the outside lifted from the bed but the prints are acceptable.
125 B	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm(2.8mm)	1	N/A	53:24 min:sec	9ºC	Clear	87%	8:00 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
125 C	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	1.1	15 perimiter/15 interior	3.0mm(2.8mm)	1	N/A	53:24 min:sec	9ºC	Clear	87%	8:00 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	

126 A	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1 interior	3.0mm	1	N/A	53:25 min:sec	9ºC	Clear	87%	9:11 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Used triple print of dog bone. Matched settings to print 112 where filament was set to 3mm and extrusion multiplier was set to 1. Prints were slightly different than print 112. This time the lines were not overlapping and there is space at the center of the concentric circles. Prints are acceptable.
126 B	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1 interior	3.0mm	1	N/A	53:25 min:sec	9ºC	Clear	87%	9:11 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
126 C	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1 interior	3.0mm	1	N/A	53:25 min:sec	9ºC	Clear	87%	9:11 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
127 A	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.7mm)	1	N/A	53:29 min:sec	9ºC	Clear	82%	10:25 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Matched settings to print 107 where filament was set to 2.7 and multiplier was set to 1.1.
127 B	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.7mm)	1	N/A	53:29 min:sec	9ºC	Clear	82%	10:25 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
127 C	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.7mm)	1	N/A	53:29 min:sec	9ºC	Clear	82%	10:25 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
128	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.6mm)	1	N/A	20 min:sec	9ºC	Clear	82%	11:25 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Matched settings for print 105 where filament was set to 2.6mm and multiplier was set to 1.1. Nozzle clogged.
129	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.6mm)	1	N/A	18:20 min:sec	9ºC	Clear	82%	11:45 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Clogged again!
130	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.6mm)	1	N/A	18:20 min:sec	9ºC	Clear	82%	12:19 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	And again.
131	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.6mm)	1	N/A	18:20 min:sec	9ºC	Clear	82%	12:46 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	And again.
132	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.6mm)	1	N/A	18:06 min:sec	9ºC	Clear	82%	12:54 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This one worked. I had to watch it conastantly.
133	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.6mm)	1	N/A	18:06 min:sec	9ºC	Clear	82%	1:14 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	upped speeds to 20 on all settings and increased multplier to 1.3 Clogged again.
134	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.6mm)	1	N/A	18:06 min:sec	9ºC	Clear	82%	1:17 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Clogged again.
135	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.6mm)	1	N/A	18:06 min:sec	9ºC	Clear	82%	1:32 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Clogged again.
136	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.6mm)	1	N/A	18:06 min:sec	9ºC	Clear	82%	1:55 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	I give up.The problem that I have identified is that the filament that I extruded with Quentin in Rotorua is not 3mm wide but it varries too much and is flat and wide in places. It is getting stuck in the extruder mechanism and There is not a section long enough and uniform enough that isn't likely to clogg.Three samples will have to be enough.
137	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.5mm)	1	N/A	18:22 min:sec	9ºC	Clear	82%	2:02 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Using the faster settings because the unsuccessful prints were looking good each time I prineted with them.
138	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.1 interior	3.0mm (2.5mm)	1	N/A	18:17 min:sec (approx)	9ºC	Clear	82%	2:35 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	reverting back to slower settings that were used with print 99. Last layer clogged. Re-ran print so it printed on top of partial print and printed the first layer on the top. Acceptable result.
139	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.1 interior	3.0mm (2.5mm)	1	N/A	18:17 min:sec (approx)	9ºC	Clear	82%	3:14 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes ?	Print clogged on 6th layer?... I restarted printer and added three more layers but the organisation of this print is different than all the rest as the last layer is perpendicular to the base layer.
140	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.9mm)	1	N/A	4 min:sec	9ºC	Clear	82%	3:50 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Reset printer to match settings for print 94 where filament was set to 2.9 and multiplier was set to 1.1. print clogged.
141	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.8mm)	1	N/A	18:15 min:sec	9ºC	Clear	82%	3:54 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	switched to 2.8 filament setting per suggestion in notes on print 94.
142	Dog Bone	29/08/13	Concentric	No Raft	Masking	1.0 mm	200º	15 perimiter/15 1.1 interior	3.0mm (2.8mm)	1	N/A	18:15 min:sec	10ºC	Clear	62%	4:19 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	print finished very well. Good overlap without too much extra extruded plastic.
143	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.3 interior	3.0mm (2.5mm)	1	N/A	14:26 min:sec	11ºC	Clear	67%	11:49 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed lots of settings! So.... After discussing with Grant and Marie they impressed upon me the importance of getting all of the lines oriented in one direction. Not that I had any objection to this but the printer would not print in one direction. It would only print in alternating directions. Grant finally made the suggestion that worked. Switch the perimiters to 100 and viola! suddenly the printer is only printing in concentric circle so that all the central lines are paralell with the length of the dog bone. I have changed from concentric to rectilinear as it no longer makes a difference in the print direction and this setting is consistent with what SCION is using for their settings. From there it has been quite a struggle to get this particular filament to print. It would not flow consistently . I have had to increase the multiplier to 1.3 and reduce the filament size setting to 2.5mm and reduce the 1st layer height to .4mm. I was able to increase the speed to 20 on all settings but support material (60), Bridges(15) and gap fill (10). First layer speed is 75% of normal speed. The only problem with this print is that it is hollow in the center of the heads of the dog bone.
144	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.3 interior	3.0mm (2.5mm)	1	N/A	14:26 min:sec	12ºC	Clear	67%	12:21 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	I have increase the width of the infill and the solid infill to 150%. This change has filled in the hole... however it is a bit much and it exaggerates a funny zigzag pattern that it uses to make the center line so that this single short line is about 7 mm across.
145	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.2 interior	3.0mm (2.8mm)	1	N/A	14:26 min:sec	12ºC	Clear	67%	12:49 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	changed settings to 110% solid infill and 110% top infill and 1.2 multiplier and 2.8 filament. Much better print but center line is still a bit thick.
146	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	14:26 min:sec	12ºC	Clear	67%	1:55 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	good print but lines are not touching on top levels. Only one or two spots that were not perfect but overall it is acceptable.
147	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	14:26 min:sec	12ºC	Clear	67%	2:14 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print is actually worse! Changed settings back to match print 145 but something is off because lines are not touching like they did on print 145. Looks like one of my changes didn't save from Slic3r to pronterface. Still had the filament at 3mm.
148	Dog Bone	30/08/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	205º	20 perimiter/20 1.2 interior	3.0mm(2.8)	1	N/A	14:26 min:sec	12ºC	Clear	67%	2:42 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Pretty good print. Just like print 145.
149	Strandbeest leg	2/09/13	Rectilinear	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm(2.7)	1	N/A	13:45 min:sec	10ºC	Clear	71%	2:42 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Spent the last two days designing a new strandbeest leg system. Also designing a joint for bambooPrinting test versions of the parts for the strandbees leg that I made. Trying to get the balance right. Prints are too thin, are not fitting together and have too many globs to be used.
150	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm(2.9)	1	N/A	13:45 min:sec	13ºC	Scattered Clouds	67%	1:36 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	print has lots of globs. Center is not filling in. Adjusted the amount of filament extruding and changed the nozzle to the .7mm. Going to order a .4mm nozzle asap.

1	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm(2.9)	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**1:50 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Printed filament keeps rolling. After several attempts with different tape I have adjusted the settings to include support and raft material to see if it will help with the base layer. The resulting print was pretty bizzarre. The support material is excessive. Moreover the raft printed at the width of the pieces and then the actual pieces were printed at a single lines width instead of 3 mm wide. I have read online where others do not ever use raft or support material because it always bamboos up. I am inclined to agree with them.
2	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**2:24 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Made adjustments back to printing without support structure and without raft. Decreased filament to 3 and multiplier to. Turned on wipe feature to see what it does. Increased reverse filament to 3mm between layers and objects. Decreased extrusion speed on reversal to 10mm/s. Resulting print was much, much nicer. size of print is too small for print nozzle. parts are not able to fit into each other because the expansion of the heated filament causes swell between layers. and so tollerances are far from accurate. Globs still exist and have to be removed with a knife to get a usable print. doubling the print size to see if it improve prints.
3	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**3:06 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Increased size to double and tollerances are much better but not good enough.
4	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**3:22 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Increased size of file to quadruple and size was way too big but resolution looked good. Backing down to tripple size
5	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**3:33 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Size looks good. Print is good. Tollerances are good. Infill is non existant in heads of leg segments.
6	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	13ºC	Scattered Clouds	67%	**4:10 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Tried many different versions of prints to overcome the infill problem and nothing works. I attemtped to redraw an item to see if the problem was coming form Rhino as "bad geometry" but all of the items checked out and the redrawn item still didn't print with a center. I altered every possible combination of infill and filament setting adjustment without success. since this print is not a final print I am moving on for now.
7	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm	1	N/A	**13:45 min:sec**	12ºC	Scattered Clouds	77%	**4:10 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Printing whole leg assembly except base triangle. Must put double sided tape down to hold small pieces in place as they tend to pull up with the nozzle and it drags them into other pieces and ruins the whole print.
8	Strandbeest leg	3/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1.1 interior	3.0mm (2.7mm)	1	N/A	**3:11:49 hours min:sec**	12ºC	Scattered Clouds	77%	**10:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	There are no words left to express my exasperation. The entire day has been spent fighting with this machine. It never does the same thing twice or rather it always does what is the opposite of what I would like it to do. I hate it. I have tried so many different versions of these prints and so many different settings and nothing works. I really do not like doing this.
9	Strandbeest bamboo Joint	4/09/13	Rectilinear	No Raft	Masking	.7 mm	210º	20 perimiter/20 1 interior	3.0mm	1	N/A	**14:49 min:sec**	11ºC	Scattered Clouds	82%	**7:49 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	printing bamboo joint. Version 2. late for Dr. Appt. Ahhhhhhhhhh! Print failed just before it printed the top of the joint. Going to reiorient the joint so it prints laying flat on the bed.
0	Strandbeest bamboo Joint	5/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm	1	N/A	**28:51 min:sec**	9ºC	Scattered Clouds	76%	**3:48 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Failed print yesterday is very poorly printed. I have played quite a bit with the temperature settings and the flow rate of the extruder and my guess is that the problem is partially due to the fact that the PLA is clear and not colorured. Coloured PLA is more flexible than clear/pure PLA and I believe is flows better. I called Vic Oliver at Diamond Edge. Vic was involved in the making of the first Rep-Rap printer and he makes, extrudes and sells PLA filament through his company Diamond Edge. He told me about the differences between types of PLA and confirmed that clear/pure PLA is more brittle than other PLAs. He told me to turn down the heat on the extruder to avoid excessive brittleness and to print in a warmer room. A cold room can affect the print quality as well. He said it comes down to the chemicals used to colour the PLA. Red, Yellow and Purple all use the same chemicals and are more flexible than the rest. Black is made from the scraps of what is left from the extrusion of other colors and can be erratic in its qualities. Silver is similar to clear PLA and can be very brittle. I ordered white PLA which he said was a good "average" type of PLA that isn't too brittle and isn't too flexible. I also changed the orientation of this print and it printed better. To do this I had to create an armiture to hold the print in place while it printed. Unfortunately the armiture didn't print. I think I made the supports for it too small and the printer skipped printing those parts. I'll increase the size of it on the next print. Design needs fixing.... Prongs of handle are also too weak and need to be combined so there are only 2 prongs instead of 4. Orientation of prongs needs to change to the split is perpendicular to the print bed (so it follows the z axis)
1	Strandbeest bamboo Joint	5/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm	1	N/A	**49:13 min:sec**	8ºC	Scattered Clouds	82%	**4:55 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Having to take many separate measures to insure a good print as PLA wants to roll and not stick to surface. Since temp is lower (190ºC). Using double sided sticky tape to help 1st layer stick and it is working well - especially for small bits/parts with small footprints on print surface. Final print is good and bad... teeth are too weak and break easily. Need to fix design and increase teeth. Dimension of inner radius of teeth is off by 2mm (should be 20mm diameter) and the dimension of the prong head should connect to them is 2mm smaller (should be 22mm diameter). This difference means the head doesn't connect with another head. Must lengthen head and increase diameter by 2...or maybe the dimension difference is due to the print settings not being at 100% fill... First I'll change the settings to complete fill and see what happens.
2	Strandbeest bamboo Joint	6/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	10ºC	Clear	71%	**6:14 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed fill setting to 1 (ie - 100% fill) and increased perimiters to 100 and solid layers on top and bottom to 100 each. Print quality is still rough. I think the parts are just too detailed for this size print head. Increasing size of model and thickness of teeth wall.
3	Strandbeest bamboo Joint	6/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**72.31 min:sec**	10ºC	Clear	71%	**10:52 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
4	Strandbeest bamboo Joint	6/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**62.47 min:sec**	10ºC	Clear	71%	**12:39 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
5	Strandbeest bamboo Joint	6/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	10ºC	Clear	71%	**2:41 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
6	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	0.75	N/A	**16:19 min:sec**	13ºC	Passing clouds	72%	**9:29 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed Test extrusion tubes at with wall dimension ranging from 4mm to 3.5mm and 3mm to 2.5 mm. The test shows how the printeris forgetting to fill in layers within prints based on how it divides up the size of an object. It also determines an optimal print size for a solid print. Settings were adjusted to be .7 fill (as opposed to solid - or 1.0) and the number of perimiters was reduced to 2 from 100. the number of solid layers was reduced from 100 to 3. These changes were done because I was affraid they would give a false result. The print progressed well unitll it reached about the 3rd or 4th level and then it jiggled so violently while printing the 2.75mm extrusion that it actually shifted the y axis so that it tried to print the next layer about three millimeters off from where it had been.
7	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	0.75	N/A	**12:08 min:sec**	13ºC	Passing clouds	72%	**9:50 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Reprinted the extrusion test to get a good sample for display. Same problem happened at the 3rd layer. Stopped the print and documented the differences.
8	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	0.75	N/A	**11:17 min:sec**	14ºC	Passing clouds	72%	**10:22 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed a larger version of test tubes ranging from 5.5mm to 4.25 mm. Same problem happened with the y axis... this time at 4.5mm print. Both times it was during the infill on the center print. Holding my hand on the print bed while it shakes reduces the vibration quite a bit but this doesn't seem like a good fix as I don't want to sit watching every print the entire time it goes.

169	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	0.75	N/A	**11:20 min:sec**	15ºC	Passing clouds	72%	**10:45 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Switched perimiters to 100 and solid layers to 100 top an bottom. Same result in spite of changes. Switching infill to 1.mm or solid.
170	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**11:39 min:sec**	15ºC	Passing clouds	72%	**11:02 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Much better print in some cases. None were completely filled. But 4.75mm and 4.5mm were the best. However the jiggling of 4.5mm leves me leaning toward using the 4.75mm setting.
171	Test Tubes	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**9:32 min:sec**	15ºC	Passing clouds	71%	**1:02 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Had to go pick up new .4mm nozzle at the couriers across town. Excited to use it but will continue with current tests first. Redrew design to fix gap in printing. Printer leaves a gap in the middle where it should infill. Tried changing the geometry of the joint so it is sliced upand then rejoined to see if it interperets the design differently.
172	Strandbeest bamboo Joint	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**58:48 min:sec**	15ºC	Passing clouds	71%	**2:19 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	No improvement. Printer isn't doing infill when printing circular extrusions. Not sure why....infill is ok in other areas.. Actually, it isnt filling in the handle either, but the bamboo threads add strenght there. This print broke when trying to put it on the bamboo. Split vertically down the handle.
173	Strandbeest bamboo Joint	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	15ºC	Passing clouds	71%	**4:06 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increased the size of the handle from 8mm diameter from thread to thread to 10 mm diameter. Print was too big for almost all the bamboo. Measured all the bamboo again. Damn caliper is broken. Batteries are either dead or the caliper has shorted out.
174	Strandbeest bamboo Joint (tapered Head)	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	13ºC	Passing clouds	71%	**10:19 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed the design again. Previous print was too big around the bamboo (10 mm interior diameter from thread to thread) and even though the joints are supposed to fit together they don't. Decreased the size of the handle so the interior space is now 9 mm. Also the handles are still interfering with each other. Basically re designed the head from scratch. Created a mid body to the head that is effectively dead space but it matches in length the diameter of the handle (18mm). I tapered this area to give it some visual interest and to reduce the amount of plastic needed to make it. I also reduced the size of the male/female connectors to 6mm each as this means the overall height is 30 mm which matches the overall circumference of the head. I also tapered/chamfered the leading edges and interior edges of the male/female connectors to assist a bit in the connction process and to perhaps add strength too the extruded side. I also decreased the offset of the space between the male/female connection to .1mm so that they will fit together more snuggly... hopefully like legos. I am hoping the result is a lego like joint that snaps together before you attach the bamboo to it.
175	Strandbeest bamboo Joint (tapered Head)	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	13ºC	Passing clouds	71%	**10:35 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Huge problems with the shake of printer as it is infilling the layers. It vibrates so violently and quickly that it causes the Y axis to shift a few millimeters each layer. This causes the prints to be slanted toward the back of the Y palne. I scoured the internet looking for oprtions of what to do and eventually found that there is a setting for vibration limit in Slic3r. This allows you to supposedly reduce vibrations by reducing the hertz (Hz) of the stepper motors.
176	Strandbeest bamboo Joint (tapered Head)	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	13ºC	Passing clouds	71%	**10:39 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed setting to 9000 Hz from default of "0" which allows Slic3r to use full stepper hertz of 15000 Hz. No change... axis shifted 3mm with first layer shake.
177	Strandbeest bamboo Joint (tapered Head)	7/09/13	Rectilinear	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	13ºC	Passing clouds	72%	**10:56 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed setting to 4500 Hz. Small improvement... axis shifted 1mm with first layer shake.
178	Strandbeest bamboo Joint (tapered Head)	7/09/13	Concentric	No Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**14:49 min:sec**	12ºC	Passing clouds	77%	**11:03 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed setting to 2000 Hz. No improvement... axis shifted 1mm with first layer shake.
179	Strandbeest bamboo Joint (tapered Head)	7/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:04:17 min:sec**	12ºC	Passing clouds	77%	**11:44 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed to 500Hz, which is quite small, and still no change from the vibration.Seems as though the third layer is the worst and then the shake is less on successive layers. This time I held my hand on the print bed when the shake occurred and the Y axis held in place. I also changed the method of infill to concentric... hoping that this will aid in reducing the vibration problem. I also gave using the support material another try. I reasearched what problems and solutions there were available online and was suprised to se pictures of the support material being printed really well. I also reduced the number of interface layers to 0 from 3 - this was done to hopefully make it easier to remove the support structure and it did Left printer going while I slept for a few hours...this time the support material was nice and clean and the printer kept it's Y axis all the way to thend. The worst part of the vibration seems to be at the begining of the print. This print is actually very nice. It fits on the bamboo snuggly and feels heavy and sturdy in your hand (perhaps that is due to the fact that nearly 3 meeters of filament is used in the printing!). The male/female connection also fits relatively well. It allow the pieces to snap together and spin with just a bit of resistence. I think the resistence may be too much when duplicated with all the connnections but that's a problem best left to resolving when I have many of them printed.
180	Strandbeest bamboo Joint (tapered Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:04:17 min:sec**	13ºC	Passing clouds	72%	**9:26 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
181	Strandbeest bamboo Joint (tapered Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:04:17 min:sec**	16ºC	Passing clouds	59%	**11:44 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Made many false starts.
182	Strandbeest bamboo Joint (tapered Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:04:17 min:sec**	17ºC	Passing clouds	49%	**12:46 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
183	Strandbeest bamboo Joint (Cylinder Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**54:43 min:sec**	17ºC	Passing clouds	49%	**2:34 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed design. Tapered head would not allow the male end to enter female end deep enough to achieve lego type connection. Connection was slipping out. Adjustments made to shape of head so it is now more like a cylinder. This should allow for better connection even though I don't like the design because it is so simple.
184	Strandbeest bamboo Joint (Cylinder Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:22 min:sec**	16ºC	Passing clouds	55%	**4:10 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Cylinder head joint. Success. This one fits with the previous print quite well. It spins and holds well. It is accomplishing the lego sort of attachment to a degree.
185	Strandbeest bamboo ANGLE Joint (Cylinder Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:13:49 hr:min:sec**	13ºC	Passing clouds	72%	**6:36 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printing Angle Joint A. Increased speed to 30 mm / sec on all settings to see if it will print acceptably. Print was good with good resolution.
186	Strandbeest bamboo ANGLE Joint (Cylinder Head)	8/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:09:59 hr:min:sec**	10ºC	Passing clouds	76%	**10:16 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printing Angle Joint B. Incresed speed to 40 mm/sec on all settings.
187	Strandbeest bamboo ANGLE Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**4:49:00 hr:min:sec**	10ºC	Passing clouds	71%	**12:28 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printing four angle joints at the same time. Print was successful but bad because of shake from the y Axis. All of the joints are acceptable but they have a shift about 3/4 of the way up where they step 3 mm to the side of the ctr axis.
188	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**7:49 min:sec**	11ºC	Passing clouds	58%	**6:22 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Print failed because of vibration again. Apparently concentric infill isn't enough. This time I didn't put my hand on the print bed and the Y axis shifted. Arrrrrgh. (made several false starts after this print)

189	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**7:15 min:sec**	11ºC	Passing clouds	58%	**7:04 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Stroke of ... dare I say.... Genius???! Well, as they say, even a blind dawg eventually finds a bone. I cut up the polypropalene packaging foam that the nozzle came in and used it under the feet of the printer. Not only did this solve the vibration problem but it also cut down on the printer buzz that comes from the stepper motors. Now if I could just take care of the fan noise the process of printing would be more enjoyable. Maybe a box or a shroud around the fan? Quick note on the removal of support material: USE PLIERS! Needle nose pliers are pretty ideal for this task as they can reach into small cavities and remove the bits that fingers cant get to. Much safer than a box razor/safety knife.
190	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**9:23:40 hr:min:sec**	11ºC	Passing clouds	58%	**7:08 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Attempting to print nine joints at once. Had to wrestle with the printer to get it to start off all the first layer well on each joint Material was rolling in some parts of the print bed and adhereing well in other. Re-leveled the print bed. Speed set to 30 on all settings. Came home after teaching at uni all day to find that the prints failed. Nozzle apparently clogged about 3/4 of the way through the print process. What a sad waste of material! This is really frustrating as I have my presentation for the 3rd crit tomorrow and I intended to use these joints to make and display the Jansen leg armature. Going to go at it agin but on an individual basis and sit next to the printer while it prints each one till it finishes.
191	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	13ºC	Passing clouds	67%	**6:32 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good. Still not prining the center of the extruded cylinder of the head of the joint. Wish I could find out why.
192	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	12ºC	Passing clouds	63%	**7:30 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
193	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	12ºC	Passing clouds	67%	**8:27 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
194	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	11ºC	Passing clouds	67%	**9:25 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
195	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	11ºC	Passing clouds	67%	**10:24 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
196	Strandbeest bamboo Joint (Cylinder Head)	9/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:27 min:sec**	10ºC	Passing clouds	71%	**11:34 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Tried to print two joints at same time. Print failed several rows in due to shift in Y axis and jiggle. Had to recalibrate and level platform again. Going back to one at a time.
197	Strandbeest bamboo Joint (Cylinder Head)	10/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:15 min:sec**	10ºC	Passing clouds	67%	**12:26 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
198	Strandbeest bamboo ANGLE Joint (Cylinder Head)	10/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**56:04 min:sec**	10ºC	Passing clouds	67%	**1:24 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print was good.
199	Strandbeest bamboo Joint (tapered Head)	10/09/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**1:20:56 min:sec**	10ºC	Passing clouds	62%	**2:39 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Reprinting angle joint "D" as the original one was too weak and the head broke when I was attempting to assemble the Jansen leg armature. Head broke due to the fact that the printer isn't connecting the extruded cylinder of the head of the joint. Soooo frustrating! (NOTE: Software malfunction! I have had to reconstruct the last few days of printing because all the work I did in this document was lost when I restarted my computer. This refers to entries from 185 thru 192. I know that I have done more prints than I was able to remember and made many more observations. I was able to use the Pronterface log that I had saved in a word document to figure out what times the prints began and ended but my observations are only what I was able to remember about the major setbacks.)
200	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	190º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**6:16 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	good print but right side of print bed was out of alignment and was higher than the left. The first layer was so thin it was transparent on the right side. I adjusted the alignment but let the print finish..
201	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	190º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**6:44 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print.
202	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	190º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**7:07 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Attempting to print three dogbones at once. Print failed. Nozzle clogg on second dogbone on the first layer. Had to use a piece of thin wire to unclogg the nozzle.
203	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	190º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**7:14 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Returning to one print at a time. Print failed again. This time because filament was uneven and got stuck in the extruder
204	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**7:34 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Increaed temp to 200ºC. Failed again...Attempted to print again and made it to third layer before print failed. Extruder nozzle clogg.
205	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	77%	**7:41 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increasing temp to 210C. Extruded a couple hundred mm of filament to watch process. Seems that if the flow of filament stops for a moment then the wood fibres begin to clump together. On every restart of the extrusion motor after passing 20mm of filament and stopping I noticed in the first movement of the extruded material a darker lump of what appeared to be wood fibre. Further observation required to certify this theory. Prints are darker due to temperature. Print was successful until last layer and the lines are not touching.
206	Dog Bone	12/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:26 min:sec**	13ºC	Clear	82%	**8:01 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	print failed. Clogg
207	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**16:27 min:sec**	11ºC	Clear	72%	**6:49 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	print finished but top layers are not joined. Will reset filament to lower setting to try to fix
208	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**4:13 min:sec**	10ºC	Clear	63%	**7:11 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Failed clogg
209	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**5:53 min:sec**	10ºC	Clear	63%	**7:18 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Failed clogg. Adjusted flow to 250% on inflil and solid infill.
210	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**8:07 min:sec**	10ºC	Clear	63%	**7:31 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Failed clogg
211	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**8:06 min:sec**	10ºC	Clear	63%	**7:47 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Failed clogg. Cleaned out nozzle with pure pla. Extuded several hundred mm of pure pla. Examined filament closely. Filament seems to be just a tad too thick in spots. The extruded is tearing upp the filament as it passes through the extruder mechanism. Print has started off well. even wide rows of material.
212	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm	1	N/A	**8:00 min:sec**	12ºC	Clear	63%	**8:02 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Print is fine for first layer and then the individual lines are thinner and they don't touch. Can not seem to get printer to do the same thing for more than one layer. Decreasing the width setting on the filament for next print. Reset filament to 2.8mm setting to make printer extruding more material on upper layers. Print failed again. Clogg. Not sure why this is happening. Printer nozzle is 1mm. flow is not too high. speed is not too high. Perhaps it is due to the filament. measurments show that filament is varied from 2.5mm to 3.5mm. I have attempted to trim the filament down to 3.0mm using the sharp edge of the caliper set to this dimension.

213	Dog Bone	13/09/13	Rectilinear/Uni directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.8mm)	1	N/A	**15:39 min:sec**	14ºC	Clear	55%	**12:32 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes?	Print is mostly good. Ends of dogbones are not perfect. Lines are not touching on layer 7,8, and 9. I think that the tinsle strength testing machine will be designed so the center of the dog bone breaks. I think that this print might be acceptable.
214	Dog Bone	13/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.6mm)	1	N/A	**15:43 min:sec**	14ºC	Clear	51%	**1:05 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed the speed of the top infill to 10 from 20 mm/s. Changing the filament size to 2.6mm from 2.8mm. Changed infill to concentric. Print is very nice! All layers are touching each other and all lines as well. The new setting is perhaps a bit too much but certainly not excessive. Dialing it back to 2.7 mm / s for the next print. the concentric patter is identical to the rectilinear pattern while the perimter setting is at 100.
215	Dog Bone	13/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	14ºC	Clear	51%	**1:24 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Setting at 2.7 mm/s print is very nice. All lines touching on all layers. Print is a bit darker due to temp setting of 210º C.
216	Dog Bone	13/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	14ºC	Clear	51%	**1:40 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. All lines touching.
217	Dog Bone	14/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	4ºC	Clear	81%	**7:32 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Print failed due to clogg. Strange clogg… when I tried to declogg the nozzle with a wire there was nothing in the actual nozzle.
218	Dog Bone	14/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	4ºC	Clear	81%	**7:44 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Again the strange clogg.. Nothing in extruder nozzle when I attempted to clear it. Normallly there is backed up material and pressure and the liquid filament shoots out because of the pressure when the wire is inserted in the nozzle.
219	Dog Bone	14/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	9ºC	Clear	76%	**8:01 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Clogg again but this time it was a normall clogg where there was pressure built up.
220	Dog Bone	14/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	9ºC	Clear	76%	**8:12 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Clogg right away. Extruder nozzle was passing material beautifully but durning the beginning sequence where extruder was homing on all axises the nozzle clogged and stopped extruding.
221	Dog Bone	14/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	9ºC	Clear	76%	**8:15 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Nearly successful print. I stood by the printer during the entire print and pushed the filament that was entering the extruder and this prevented the extruder mechanism from stripping the filament. This forced the print to continue in spite of two occasions where the nozzle backed up but the additonal force unblocked the nozzle. The final print was not acceptable as the lines on the upper layers were not touching. Going to increase the multiplier to 1.3 on the next print to see if this improves the print quality.
222	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	8ºC	Scattered Clouds	76%	**7:40 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the multiplier to 1.3. Extrusion is very wide and smooth. Print continued till second layer before nozzle clogged and print was ruined.
223	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	8ºC	Scattered Clouds	71%	**8:00 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Trying to help extruder mechanism push filament through. By grabbing about 1 cm below the extruder mechanism and pushing the filament into the mechanism the filament does not strip on the extruder gear. This technique is fraught with problems as it is easy to break the filament by adding too much force and it does not insure that the nozzle wont get clogged. It also makes it hard to watch what is comming out of the extruder nozzle.
224	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:45 min:sec**	8ºC	Scattered Clouds	71%	**8:13 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print failed due to clogg. Filament snapped as I was pushing it into extruder. Known isues with this filament are: it is too brittle. (needs more ELST?); it is unevenly extruded (target extrusion diameter should be 2.75mm +/- .25mm); Nozzle cloggs to easilly (increase nozzle opening to 1.2mm?… Add lubricant to filament?)
225	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:45 min:sec**	8ºC	Scattered Clouds	71%	**8:23 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print failed due to clogg. Stopped and tried to fix the clogg and extrude plastic. But didn't get it sorted well enough and when I restarted the printer it wasn't extruding properly again. X axis keeps shifting on prints… not sure why. Belt seems tight enough
226	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:45 min:sec**	8ºC	Scattered Clouds	71%	**8:31 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes?	I sat and forced the filament into the extruder mechanism for the duration of this print. Hands were very tired and filament broke once but I was able to keep it moving through. This print completed the whole 9 layers although in some spots the filament stopped extruding for several lines as can be seen on the top layer. Dubious as to whether this is a worthy test sample as I assume the missed lines will impact the strength of the piece. X axis shifte on the middle layers. Not sure why.
227	Dog Bone	15/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	210º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:45 min:sec**	8ºC	Scattered Clouds	71%	**8:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes?	Same as before… but better print. This one only missed a couple of very short lines in the middle layers but the top and bottom are uniform with all lines touching X axis shifte again this time just on the second layer. All subsequent layers were directly above the second layer.
228	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:44 min:sec**	10ºC	Scattered Clouds	71%	**6:36 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	New day and a much better print. Adjusted the temp back down to 200º C to see if it affect the print… it didn't. Used a new strategy of only focussing on the extruder wheel/mechanism. I watched the filament closely and made sure it was constantly pushing through. I didn't really even look at the nozzle to see how it was going except occasional brief looks to make sure the print was continuing. There were several sketchy moments as thick bulges in the filament threatened to stop up the wheel but I was either able to push these through easilly or release the tensioning arm to allow them to pass the wheel and once it was through I re-set the arm. This print was really consistant and uniform with good overlapping of the lines on the inner layers and top and bottom layer. I noticed a fair bit of build up of extra plastic/composite material when the printer was finishing the innermost line of the infill but this amount of material was easilly absorbed in the subsequent layer. This print is just a shade lighter than 227 and 226 and 221. Probably due to the temp decrease.
229	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:44 min:sec**	10ºC	Scattered Clouds	76%	**7:05 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes?	This was a successful print in that it printed the entire time however the last two layers were not as good as the ones before. For some reason the lines stopped overlapping in spite of the fact that the filament was constantly moving through the extruder wheel. This indicates either a blockage in the nozzle or that the filament is actually smaller than 2.7 mm… which might actually be the case. I will clean out the nozzle with pur PLA just in case.
230	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:39 min:sec**	10ºC	Scattered Clouds	76%	**7:05 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes?	This print was similar to the last. Had trouble on the third layer and the filament broke in the extruder wheel mechanism (EWM). I stopped the print and was able to fix the problem and continue but there are a few gaps on that layer and on the last layer where is stopped extruding for a brief moment (about 1/2 the length of the dog bone and then started again. The problem that I have been having with this filament seems to be pretty well resolved as long as I dilligently watch the EWM. This fact is justification for modifying the EWM design. I see two problems with it. First it is so far from the nozzle that much of the force it applies to the filament is lost in the tube. Second the EWM grabs and pushes the filament by use of a toothed metal gear. I wonder if a textured rubber non-slip gear would be better? I also think that a filement stripper/sizer would help too. If the filament passed through a mechanism that stripped it down to exactly the diameter you wanted it to be… in this case 3 mm by shaving off any extra then the EWM might not get caught up so much.
231	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:58 min:sec**	10ºC	Overcast	76%	**8:06 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print had trouble from the start. Material wasn't flowing. Then at the end of the first layer it clogged again. I cleaned the nozzle with pure PLA.
232	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:48 min:sec**	10ºC	Overcast	76%	**8:14 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Fairly nice print. There were some spots where the extruder hung up briefly but I was able to push through the filament. Print is nicely uniform on top and bottom and centre layers didn't have any gaps.
233	Dog Bone	17/09/13	Concentric /Uni- directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:41 min:sec**	10ºC	Overcast	76%	**8:37 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Nice print. A little trouble on the sixth layer but the rest of the layers were uniform.

234	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:41 min:sec**	10ºC	Rain	76%	**9:19 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Another nice print. This one had a brief bit of trouble at first but then evened right out and finished up nicely.
235	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:41 min:sec**	10ºC	Rain	76%	**9:48 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print just like the last one. Moving on to new filament.
236	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:34 min:sec**	8ºC	Rain	87%	**11:00 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print started out wonderfully and didn't seem to need the same assistance with the EWM. But suddenly developed the same EWM problem.
237	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	8ºC	Rain	87%	**11:05 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Watched this one more carfully and helped it through several possible cloggs. Last layer was a bit skimpy and the lines didn't overlap but all others were good.
238	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	8ºC	Rain	87%	**11:48 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print went quite well. The EWM had to be helped the entire way but the result was a good quality print. The wheel seems as though it has lost it's ability to grag the filament but then again there are times when it works well. It seems at thoug there is additional pressure necessary to push the wood fibre filament through the EWM and eventually the nozzle.
239	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	10ºC	Rain	71%	**12:15 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Same as 237.
240	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:43 min:sec**	10ºC	Rain	71%	**12:41 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Same as 237.
241	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:41` min:sec**	9ºC	Rain	76%	**1:04 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Same as 237.
242	Dog Bone	17/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**15:41 min:sec**	9ºC	Rain	76%	**1:42 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Same as 237.
243	Dog Bone	17/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:18 min:sec**	10ºC	Rain	62%	**2:18 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. I switched the direction of the infill by adjusting the number of perimiters from 100 to 2 so that I can make some cross layered prints to test the strength against the unidirectional prints. Had to hand feed filament into extruder for duration of print. Only slight pressure is necessary in most cases to keep filament moving through EWM. However in some casess, especially when the printer shifts into a slower mode due to the direction of the print line (i.e. horizontal lines vs longitudinal lines) then there is a tendancy for the EWM to slip on the filament and then strip it out so that it doesn't move. A design improvement might be something that doesn't rely on digging into the filament but uses some other kind of traction.
244	Dog Bone	17/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:18 min:sec**	8ºC	Clear	71%	**8:40 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Had to hand feed filament into EWM for duration of print.
245	Dog Bone	17/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:18 min:sec**	9ºC	Clear	58%	**9:04 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Had to hand feed filament into EWM for duration of print
246	Dog Bone	17/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:35 min:sec**	10ºC	Clear	76%	**7:06 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. Had to hand feed filament into EWM for duration of print.
247	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:33 min:sec**	8ºC	Clear	62%	**7:36 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print was crap. I tried to leave the EWM to do it's job on its own and it went well for quite a while but then It clogged suddenly on the 7th layer and then again briefly on the 8th and then at the very end of the 9th. Each time I quickly set to pushing the filament through again. **What this printer needs is an optical feedback system that watches what the nozzle is putting down and follows the g-code as it is read. This system would enable the machine to identify where it did not successfully print on a given layer and then go back and re-print that line or lines of code. At the very least it should have a sensor on the nozzle and on the extruder to alert the user to when material is not going through either of them. Perhaps a light starts bliniking or it makes a noise or it the machine stops so that the extruder can be cleaned before begining the next slice.**
248	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**19:35 min:sec**	8ºC	Clear	62%	**8:03 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print like 243. Had to hand feed filament into EWM for duration of print.
249	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.1 interior	3.0mm (2.7mm)	1	N/A	**8:38 min:sec**	10ºC	Clear	62%	**9:02 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Switched to 10% Flour filament.Matching settings to print number 127 (i.e. - filament set to 2.7 and multiplier set to 1.1). However some changes. Increased speed to 40 on all settings in speed section except gap fill (60) and bridges (15). Left advanced settings at 250% on infill and top solid infill and solid infill (which I believe is diffierent from 127). ALso first layer speed is at 75% which is faster than I believe it was on 127. Attempting to print 5 at once. Print wasn't great. Printe did one complete dog bone first before moving on to the rest. It was great for the first layer and then it sped up and the lines no longer touched each other.
250	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.2 interior	3.0mm (2.7mm)	1	N/A	**7:11 min:sec**	10ºC	Clear	62%	**9:20 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	I have increased the first layer speed to be the same as the rest of the layers and also increased the multiplier to 1.2. Oops! Accidentally set speed to 100 mm/s and not 100 % for first layer. Print actually did really well on first layer. I think this is due to the fact that the first layer is a bit squished and the nozzle is closer to the bed than it thinks it is. The subsequent layers were slower but the lines didn't exactly touch.
251	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**8:07 min:sec**	10ºC	Clear	62%	**9:33 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Lines are still not touching. Really frustrating. Seems like everything is either the same as it was for print 127 or increased so that there would be more material but instead the lines are not touching. Increasing default line width under advanced settings to 200%
252 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**1:00:39 hr:min:sec**	10ºC	Clear	62%	**9:48 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Good print. First print (A) finished really well. Then the printer attempted to print three dog bones at once due to the way I loaded the file. Everything was fine till the sixth layer when a clog developed on one and the I didn't notice it till it had attempted a layer on each of the three dogbones. I fixed the clog but each one has either part of (B and D) or an entire missing layer (C). I watched carfully on print (E) and it finished really well. I'll have to reprint B,C, and D
252 E	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**1:00:39 hr:min:sec**	10ºC	Clear	62%	**9:48 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
253 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:47min:sec**	11ºC	Clear	54%	**10:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Loaded this file so that each one of the dog bones prints independently and completely in a series before moving on to the next print. Printer printed the middle dog bone firstbcause of the way I loaded the program. Overlap of lines looks good on all prints. It is frustrating to have to sit by and watch so carfully in case the EWM gets stuck. I guess the good thing is that I am not having to push the filament into the EWM like I did with the 30% wood Fibre however having to sit and watch so closely causes one to tense up in anticipation of an error and ultimately the person doing the printing is wound up like a top ready to spin off at the slightest provocation. One more reason to re-design the EWM and improve it.
253 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:47min:sec**	11ºC	Clear	54%	**10:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
253 C	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:47min:sec**	11ºC	Clear	54%	**10:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
254 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:52 min:sec**	12ºC	Clear	54%	**12:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print went really well. Used the same settings as the 10% flour from the prvious print. EWM needed quite a bit of help but otherwise it was a uniform print. Just printed three as the filament was running out. Had just enough to finish these three.

254 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:52 min:sec**	12ºC	Clear	54%	**12:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
254 C	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**36:52 min:sec**	12ºC	Clear	54%	**12:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
255	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:23 min:sec**	12ºC	Clear	54%	**12:58 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Used same settings again as previous two prints. This print was going fine when I realised that I should have changed the settings to be multi directional. Stopped print and started over.
256 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**32:02 min:sec**	12ºC	Clear	51%	**1:03 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printing only three again as there is very little filament. Good prints. Didn't have to help the EWM.
256 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**32:02 min:sec**	12ºC	Clear	51%	**1:03 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
256 C	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**32:02 min:sec**	12ºC	Clear	51%	**1:03 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
257 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**21:32 min:sec**	12ºC	Clear	51%	**1:38 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Looks like there is just enough for two more... gonna give it a try. Yay! Got two more. Good prints. Did not have to help the EWM.
257 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**21:32 min:sec**	12ºC	Clear	51%	**1:38 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
258 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**53:11 min:sec**	12ºC	Clear	51%	**6:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Amazing print. The EWM was able to grab this filament and push it through without any difficulty. I think the higher concentration of PLA makes it more rigid and less inclined to strip when pushed by the EWM. This filament is also quite irridescent... it kinda sparkles in the light. Again I think this is because of the PLA. All of the prints were good with nice overlap of lines. These dog bones are much more rigid than the others with higher concentrations of PLA. I would be interested to see if these charecteristics were consistant with a higher wood content. Also interested to see what a slight increase of ELST would do... maybe 5% more and 5% less PLA.
258 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**53:11 min:sec**	12ºC	Clear	51%	**6:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
					Masking														Slic3r	Marlin	Pronterface		
258 C	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**53:11 min:sec**	12ºC	Clear	51%	**6:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
258 D	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**53:11 min:sec**	12ºC	Clear	51%	**6:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
258 E	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**53:11 min:sec**	12ºC	Clear	51%	**6:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
259 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**25:45 min:sec**	12ºC	Clear	51%	**8:02 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print was very different from the last. Even though I only changed the number of perimiters form 2 to 100 the exturded filament came out differently... it was very rolly...it would roll up easilly off the nozzle and not lay down in a line. It was as though there was too much fiber in the filament and not enough plastic. I am affraid that the mixture of this filament was off and the fiber and plastic didn't get mixed evenly. At any rate the print continued well enough and the final piece is constent enough. I stopped it at the begining of the third print because the first layer rolled up too much and there wasn't enough of this layer to properly build upon.
259 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**25:45 min:sec**	12ºC	Clear	51%	**8:02 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
260 A	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**40:31 min:sec**	12ºC	Clear	51%	**9:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	This print happened after a false start that nearly took out the printer. Somehow the Z axis stop got moved and when the printer attempted to zero out all axises it kept cinching down the nozzle into the bed that the bed tilted straight up and the cross bar came completely off its threaded Y axis rods. It took about a half an hour to re-level the bed. This print finished up well and all the prints were good. None of the rolly problem from the last print. I also reduced the speed on the first layer so that the printer prints at 50% normal speed. **Important Note:** All the settings have remained the same on these last few filaments (since 251). The only change has been to switch the number of perimiters which affects the direction of the layers. This uniformity between different types of filament is uncharecteristic... and suprising. I am curious about the setting that I changed to acomplish this - the default line width setting. Since I increased that setting to 200% I haven't had any problems with prints being uniform and the lines connecting. This deserves further investigation.
260 B	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**40:31 min:sec**	12ºC	Clear	51%	**9:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
260 C	Dog Bone	18/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**40:31 min:sec**	12ºC	Clear	51%	**9:09 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
261	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**2:59 min:sec**	10ºC	Cloudy/ Overcast	71%	**7:15 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print is a test to see what affect the line width setting has on the overlapping of the lines. The material was not adhering to the print bed for the perimiter of this test but I was able to get it to stick by the third infill line. The print lines are distinct but they do touch. The line width setting was put at 0% which is the default setting. Important Note: When starting any print there is a very involved process that I go through to ensure a good print. The first layer is the most important layer as it is the foundation that all other layers rest upon. I start before I actually push print by having the printer extrude 20mm of material. This primes the extruder preparing it so that the material is moving through the nozzle and that there isn't a crispy clog at the mouth of the extruder blocing it. Then I push print and I must watch very closely to see that as the nozzle homes all axises it actually goes to the right place and stops. On several occasions the axis stops have moved slightly or slipped out of alingment and the nozzle passes the zero mark. On one occasion I wasn't watching closely and only when I heard a wierd noise did I look over to see that the nozzle had pushed the print bed all the way down to the table top and had come off of its bamboo bar causing the bed to sit at an extreme tilt and nearly breaking both the bed and bending the Y axis rod. Then I must watch closely as the printer goes through its first pass of the print. Normally it does one lap around where the print will be and while doing this extrudes a line of filament. Often though the nozzle drags a lump of filament from where it zeros the axises or from travelling across the print bed. this lump or the initial extrusoin of filament that comes out during the 1st lap (which is often a bit hard and rolly) can hang up on the nozzle causing all subsequent extruded material to latch onto it and ruining the print. I fight this probelm with a razor utility knife. As the printer does it's first lap I will chase it with the flat side of the extended blade of the knife and pinch down any dags that hang onto the nozzle. Then as the printer begins the perimiter of the print I watch to make sure that the material is coming out and adhering to the
262	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:00 min:sec**	10ºC	Cloudy/ Overcast	71%	**7:29 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the line width setting to 100%. As I expected this print is identical to the 0% setting. I did this just to certify that the two setings were identical.

263	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:10 min:sec**	10ºC	Cloudy/ Overcast	71%	**7:34 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the line width setting to 150%. The lines are still distinct here. There doesn't seem to be a change from the last setting.
264	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**3:08 min:sec**	10ºC	Cloudy/ Overcast	71%	**7:39 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the line width setting to 200%. The lines are still distinct and there doesn't seem to be a chinage from any of the previous prints. Confused! It seemed as though the 200% setting had had a noticable improvement from print 250 to 251 however here there is no apparent change. It seems that the only serious affect I have been able to influence is by increasing the multiplier and decreasing the filament width settings.
265	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**40:31 min:sec**	12ºC	Cloudy/ Overcast	72%	**8:55 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	This print was unsuccessful because the multiplier set at 1.3 caused the print to be bulge with too much material. This filament is actually quite thick. measurments with the caliper indicate that it is ranging between 3.6mm and 3mm. There were several false starts at the beginning. After the previous tests the filament was not sticking to the print bed. I had to go through ten or fifteen trial runs to determine that the right zero point for the z axis is not what the manufacturer recommends. The manufacturet recommends that the zero point for the z axis to be approx .2 mm above the print bed. They insturuct that one should use a business card to determine that the z axis is correct. If you can slide the business card between the print bed and the nozzle with only the slightest resistance then you are good to start printing. But whet I have had to do is set the zero point to be truly flush with the print bed. I raise and lower the z stop until when I home the z axis it just barely touches the print bed causing the slightest deflection of the print bed (the print bed is on flexible support struts that permit vertical movement). The problem that causes this discrepancy with the manufacturer instructions is that in the slic3r settings the first print layer is set to be (in my case) .4 thick. This would mean that if I followed the manufacturer instructions then my first layer would actually be .6 (.2 from the business card and .4 for my first layer setting in Slic3r). By setting the zero point for the z axis to true zero I get a true .4 mm layer for the first layer and the filament actually sticks.
266	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.0mm (2.7mm)	1	N/A	**7:39 min:sec**	11ºC	Cloudy/ Overcast	72%	**9:14 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the multiplier back to 1 and left the filament width at 2.7mm. This print was also unsuccessful because there was still too much material.
267	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	2.8mm	1	N/A	**3:37 min:sec**	11ºC	Cloudy/ Overcast	72%	**9:23 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the filament size to 2.8mm. Unsuccessful again.
268	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.0mm	1	N/A	**14:40 min:sec**	11ºC	Cloudy/ Overcast	72%	**9:32 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the filament size to 3mm. Unsuccessful again.
269	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.2mm	1	N/A	**2:26 min:sec**	11ºC	Cloudy/ Overcast	72%	**9:50 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted the filament to 3.2mm. Unsuccessful again.
270	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	4.0mm	1	N/A	**10:40 min:sec**	11ºC	Cloudy/ Overcast	72%	**9:53 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjisted the filament setting to 4mm. FINALLY!!!! The printer made a dog bone where the center was not lifted and over impregnated with filament. This print looked as if it was going to be good
271	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.75mm	1	N/A	**9:38 min:sec**	11ºC	Cloudy/ Overcast	72%	**10:12 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Adjusted filament size back to 3.75mm.
272 A	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**1:07:18 hr:min:sec**	11ºC	Cloudy/ Overcast	72%	**10:27 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Adjusted filament size back to 3.3mm. This print was pretty successful. The layers were overlaping and the center didn't bulge with too much material however the lines seemed to be filled with bubles or holes in them. It is as though the extruder is pulling the filament that is extrtuded and causing it to seperate slightly. However is seems strange that this would be happening because the filament that is extruded is coming out and spreading to the right and left of the nozzle as it goes. still these holes were even more present at the 4mm and 3.75mm setting and they were not present at the 2.7mm setting. I decided that as long as the material is extruding consistently, which it is, and both groups (unidirectional and multidirectional) are done at the same setting then we can establish a base line with this test as to the general strenght of the material.
272 B	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**1:07:18 hr:min:sec**	11ºC	Cloudy/ Overcast	72%	**10:27 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
272 C	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**1:07:18 hr:min:sec**	11ºC	Cloudy/ Overcast	72%	**10:27 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
272 D	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**1:07:18 hr:min:sec**	11ºC	Cloudy/ Overcast	72%	**10:27 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
272 D	Dog Bone	19/09/13	Concentric /Uni-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**1:07:18 hr:min:sec**	11ºC	Cloudy/ Overcast	72%	**10:27 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
273 A	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**59:17 min:sec**	12ºC	Cloudy/ Overcast	67%	**11:54 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Print looks acceptable. Some of the dog bones didn't start out very well but with a little help they made it through the printing process. The multi directional prints may end up being a good deal stronger because when the printer is doing the lines perpendicular to the length of the dog bone it travels a much shorter distance before turning. This fact means that the extruded filament backs up for a moment when the turn happens and then is stretched when the line is being drawn again. On the long longitudinal lines that run the length of the dog bone the extruded filament is pulled continuously and so the small pockets or holes develop in the material. But on the short cross longitudinal lines this isn't happening because the nozzle isn't travelling far enough before it turns and backs up with a little extra filament. This aspect of the filament stretching and pockets developing is troublesome as it means that all of these samples may varry in strength due to this mechanical element in the printing process.
273 B	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**59:17 min:sec**	12ºC	Cloudy/ Overcast	67%	**11:54 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
273 C	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**59:17 min:sec**	12ºC	Cloudy/ Overcast	67%	**11:54 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
273 D	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**59:17 min:sec**	12ºC	Cloudy/ Overcast	67%	**11:54 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
273 E	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.3mm	1	N/A	**59:17 min:sec**	12ºC	Cloudy/ Overcast	67%	**11:54 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
274 A	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.0mm	1	N/A	**49:23 min:sec**	13ºC	Cloudy/ Overcast	67%	**12:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed off 3 more of this filament at a different filament width setting to test this idea about the pockets or holes that form in the filament. This should show if there is a considerable difference between the strength of the multi directional dog bones that were pinted at 3.3mm filament setting vs. 3.0mm filament setting.
274 B	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.0mm	1	N/A	**49:23 min:sec**	13ºC	Cloudy/ Overcast	67%	**12:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
274 C	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1 interior	3.0mm	1	N/A	**49:23 min:sec**	13ºC	Cloudy/ Overcast	67%	**12:56 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	

275 A	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**59:15 min:sec**	13ºC	Cloudy/ Overcast	72%	**2:18 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed five of the 30% fibre. Print A was great. Brint B was a bit messed up on a couple of layers but only at the ends of the dog bone and not in the center where it will be tested.. Print C was ok. Print D was messed up on the first layers. Print E was messed up on the last layers. Prints A and C are probably usable.
275 B	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**59:15 min:sec**	13ºC	Cloudy/ Overcast	72%	**2:18 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
275 C	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.3 interior	3.0mm (2.7mm)	1	N/A	**59:15 min:sec**	13ºC	Cloudy/ Overcast	72%	**2:18 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
276 A	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.4 interior	3.0mm (2.7mm)	1	N/A	**32:41 min:sec**	13ºC	Cloudy/ Overcast	63%	**3:47 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Increased multiplier to 1.4 for this print because last print was having trouble with the filament. Pretty good prints. Ran out of filament on print C. Going to have to use Print B from 275. Had to feed filament into EWM for both 275 and 276. It seems that the nozzle starts to back up with fibre and the EWM is not strong enough and the filament isn't durable enough to withstand the pressure neccessary to push the material through. Need a stronger motor and need to increase PLA content in filament to make it more durable.
276 B	Dog Bone	19/09/13	Concentric /Multi-directional	No Raft	Masking	1.0 mm	200º	20 perimiter/20 1.4 interior	3.0mm (2.7mm)	1	N/A	**32:41 min:sec**	13ºC	Cloudy/ Overcast	63%	**3:47 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	
277	Strandbeest bamboo Joint (tapered Head)	1/10/13	Concentric	Raft	Masking	.7 mm	200º	20 perimiter/20 1 interior	3.0mm (2.8mm)	1	N/A	**54:38 min:sec**	12ºC	Clear	77%	**10:26 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Jason suggested revising the design in Rhino to address the issue with the head of the joint printing with a gap. He said the printer couldn't handle the small fillet and I needed to increase the size of it. I did so by changing it to a chamfered edge made from a trunckated cone that I booleaned to the rest of the design. This change worked very well. The resulting print is very solid and the layers were consistently alternating and overlapping. I am concerned about two remaining issues. The jiggle of the machine during printing infill and the top layer of the print did not fill in...however this may be because of the same issue that Jason pointed out. I will start by altering the shape of the top of the print to see how it affects the next print.
278	Strandbeest bamboo Joint (tapered Head)	1/10/13	Concentric	Raft	Masking	.7 mm	200º	30 perimiter/30 1 interior	3.0mm (2.8mm)	1	N/A	**54:37 min:sec**	13ºC	Clear	82%	**8:05 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	As I watched this print closely the printer is not infilling very well. It is moving faster than the material is coming out of the nozzle and so the infill is not complete. Also the print lines are touching but just barely. Each perimiter wall seems to be nearly independent of it's neighbour. Several things could be the reason. The filament diameter, the extrusion multiplier, the number of perimiter layers. I think that the infill problem is associated with the speeds of infil, top solid infil and solid infil.
279	Strandbeest bamboo Joint (tapered Head)	1/10/13	Concentric	Raft	Masking	.7 mm	200º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**1:06:59 min:sec**	13ºC	Clear	77%	**9:14 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed several settings. Changed speed of infill, solid infill and top solid infill to 15. Changed filament size to 2.7. Changed extrusion width in advanced settingst to 150% on infill and solid infill (first layer and top solid infill were already 250%). This print is much heavier than the previous print which I attribute to the extrusion width change. The slower speed made the layers fill in very nicely. There is still a problem where occasionally it zips through an infill and I think this might be the gap fill setting. I will change this to match 15 of the others. I actually don't think the extrusion width change is adding much to this piece...it simply makes it more dense. However I have noticed that the perimiters are not touching very well...perhaps increasing the perimiter extrusion width will change this.
280	Strandbeest bamboo Joint (tapered Head)	2/10/13	Concentric	Raft	Masking	.7 mm	200º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**1:17:31 min:sec**	13ºC	Clear	82%	**7:49 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed gap setting to 15mm/s. returned all extrusion width settings to 0 but increased perimiter width to 150%. Print is very clean even the top layer is pretty nice. However while watching it print the top tapered head on this print there were some gaps in the print. I will do some tests of the top portion to see what makes the best print.
281	Top Test 1	2/10/13	Concentric	Raft	Masking	.7 mm	200º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**4:12 min:sec**	13ºC	Clear	82%	**9:30 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Perimiters were set to 5. Print was more solid than the top of the previous print. However the PLA is almost lumpy. I wonder if this is caused by the temp? I saw one or two layers in this print where it didn't fill in well
282	Top Test 2	2/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**4:00 min:sec**	13ºC	Clear	82%	**9:38 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Perimiters were set to 3 and temp to 190. This one had a gap or two inside but was better than print 280. This time the PLA is much smoother.
283	Top Test 3	2/10/13	Concentric	Raft	Masking	.7 mm	210º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**4:03 min:sec**	14ºC	Clear	77%	**10:03 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Perimiters were set to 4 and the temp to 210ºC. This setting didn't seem different than the 5 perimiter setting. However the PLA was lumpy again. I guess the higher temp is affecting the PLA print quality.
284	Strandbeest bamboo Joint (tapered Head)	2/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.7mm)	1	N/A	**1:17:31min:sec**	14ºC	Clear	77%	**10:46 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	I did a false start with a 5 perimiter setting and it was not looking good as the center of the head was left empty. I increased the number of perimiters to 100. This has resolved some of the empty center problem but it comes back every few layers. reducing to 3 perimiters. The difference in print quality between this one and 280 is startling. The change in temp to 190ºC really cleaned up the print. The last stages of this print, as it printed the tapered head were not any better than the 2 perimiter setting.
285	Strandbeest bamboo Joint (tapered Head)	3/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.7mm)	0.6	N/A	**1:19:55 min:sec**	13ºC	Clear	82%	**7:58 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Switched the infill amount to .6 to try and save on the amount of material used and to see if it prints faster. Not totally happy with print method because there were some layers where it did not fill in the center of the model... however it then began filling it in again and so these pockets may not be terribly harmful to the strength.
286	Strandbeest bamboo Joint (tapered Head)	4/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.7mm)	0.6	N/A	**3:49:11 hr:min:sec**	14ºC	Clear	82%	**10:14 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed 3 joints at the same time. They turned out pretty nice. By printing 3 at the same time there were some issues with smoothing out the joining surfaces as the nozzle had left lots of hairs between the models. Have enough to assemble a new leg... just need to print angle joints.
287	Strandbeest bamboo Joint (hinged head)	5/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.7mm)	0.6	N/A	**1:43:47 hr:min:sec**	12ºC	Clear	82%	**11:18 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Re Designed head to include a hinge. Didn't work. Left 1 mm gap and it wasn't enough.
288	Strandbeest bamboo Joint (hinged head)	5/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)	0.6	N/A	**1:43:47 hr:min:sec**	14ºC	Clear	82%	**3:01 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Re-designed with a 1.5mm gap in hinge on head. This time it worked and I was able to turn the joint.
289	Strandbeest bamboo Joint (hinged head)	6/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)	0.6	N/A	**12:50:19 hr:min:sec**	12ºC	Clear	82%	**10:03 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Tried to print a group of eight and the print failed. The clear PLA clogged in the printer.
290	Strandbeest bamboo Joint (hinged head)	7/10/13	Concentric	Raft	Masking	.7 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)	0.6	N/A	**12:50:19 hr:min:sec**	10ºC	Clear	82%	**7:38 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed eight with white PLA. The final print was very rough and for some reason the printer did not print the top solid surface of the model. This means that the strenght is compromised and the joints look awful. The need to be re-printed but for now these may work enough to show prototype the joint.
291	Strandbeest bamboo Joint (hinged head)	14/10/13	Concentric	Raft	Green Painters	.4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)	0.6	N/A	**1:51:31 hr:min:sec**	14ºC	Clear	100%	**10:59 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Switched to the .4mm nozzle. Changed settings lots...lots of false starts. Experimented with changing line width for perimiters and infil, speed for all settings up to 60mm/s, printing infil first, removed retraction on extrudedr mechanism, increased multiplier to 1.3 and filament size to 2.7 diameter. Final print was done with: .4 mm nozzle, .2mm first layer height,3 perimiters, 100 solid layers top and bottom, .6 concentric infil density, .5mm2 , 20 mm/s on all speed settings except bridges (60) and gap fill (15), travel 100 mm/s and first layer speed 75% of normal speed, Support material was turned off, but it was "enforced for the first two layers, no raft, 250% on first layer width, 115% on perimiters, 250% on top solid infill, and bridge flow .5. This print was amazing! it didnt need any support removal and the print was moveable when I picked it off the print bed. The only issue is that the resolution is poor. Hmmm how to fix that?

292	Strandbeest bamboo Joint (hinged head)	14/10/13	Concentric	Raft	Green Painters .4 mm	200º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:40:36 hr:min:sec	10ºC	Clear	82%	3:44 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed the design so the joint has .5mm tolerance. The print was very nice but is stuck together. Have worked at it for some time but can't get it to move even though there are gaps in the joint and it seems only lightly joined. I had a hell of a time getting this print to print correctly. Eventually after many false starts I had success when I increased the temperature to 200ºC. I brought up my space heater and set it next to the printer to increase the ambient temperature in the room. Since it is colder today, apparently the filament is solidifying too quickly
293	Strandbeest bamboo Joint (hinged head)	14/10/13	Concentric	Raft	Green Painters .4 mm	200º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	6:12 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Changed the design so the print has .75mm clearance. This joint printed nicely and it was flexible right away when I removed it from the print bed! So easy!
294	Strandbeest Leg assembly	16/10/13	Concentric	Raft	Green Painters .4 mm	200º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	5:32 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Printed the leg assembly for a small model. Hoping to test it out and show how the chair could be used with the leg assembly. Many false starts. Finally had success by micromanaging the printer as it printed.
295	Strandbeest leg assembly	19/10/13	Concentric	Raft	Green Painters .4 mm	200º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	9:00 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Ordered a Rasperry Pi to help with printing. Trying to get it set up to run the printer so I can leave and use my computer at school or elsewhere. David has been helping me, teaching me Linux and showing me the command lines that I need to communicate with the Raspberry Pi. The process has been slow. First it was not possible to get the RP to read the sd card that had the software it needed to run. then it wouldn't connect with the router or my computer because it didn't have an IP address. It was neccessary to have David manipulate the RP with the terminal interface and use a special ethernet cable called a crossover cable to get the computer to see the RP and vice-versa. Then once the IP address was assigned and the two were communicating it was necessary to get the computer to act as a server so the RP could connnect to the internet through it. This required some special line commmands. Then once the proper software was installed on the RP it was necessary to get the RP to read information from a USB drive. This required many different trys and finally using the right command line structure it read the files that were on the USB drive. Then it was necesssary to determine how to start the printer and then be able to disconnect the computer from the RP and have it continue to run. This was very difficult as it required trying several different interfaces. Finally it was possible to do using the command line interface called "PrintCore" and not the GUI interface called "PronterFace" and its intermediate command line alternate called "Printrun" as well as several special lines of instructions. What a mess! Finally got it running but durning the print the print nozzle clogged.
296	Strandbeest leg assembly -foot	26/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	1:00 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Printed foot for Strandbeest model. It came out really poor. The support structure was really weak and the top layers were not sticking to each other. The piece holds together but just barely. Not acceptable.
297	Strandbeest leg assembly -foot	26/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	4:00 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Reprinted and chaned the orientation of the pices this time the piece and turned off the support structure. printed much better and stronger but unaceptable. As the new direction of the print led to the piece breaking as I was trying to remove the hairs from printing.
298	Strandbeest leg assembly -foot	26/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	5:00 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Success! I redesigned the foot so that it splits apart and can be printed in two pieces. I altered the printer settings so that each layer is printed at .2 mm and the resulting print is better than all the rest of the leg assembly. It still isn't printing the center of the objects. Not sure why. Some web sites suggest this is a slicing software issue but I feel it might be a combination of my settings for perimiters and slicer settings.
299	Strandbeest leg assembly - wasjers	26/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	8:00 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	My Go! It filled in the print! Ater three months of f$%*k-ups it finally filled in the the print. Oh my god! I don't believe it. Really. I followed a thread on the reprap forum to a posting that is only 1 month old but it was a similar problem and it advised doing the opposite of what I have been doing - which is to increase the settings to compensate for the machine not filling in. So, I decreased the perimiters to only 1 perimiter and reduced the infill and the solid infill settings in the advanced menu to 50% of normal. The printeer spent extra time making sure that each little washer was properly filled in. They are perfect - completely solid. Oh my god! I can't believe it was the opposite of what I have been doing. Exactly the same thing that happed with the Rhino/Bongo software. I couldn't get Bongo to animate the leg assembly for the strandebeest model and wrot to the developers to ask why and they fixed my file and sent it back to me with the parent-child chain organised from the middle as opposed to the ends. I had spend, at that point, five days and over 80 hours of labor fiddling with the parent-child chain to see what combination worked the best. Nothing worked. There is no way I would have thought to organise a chain of force distribution starting from the middle. It is sooo non-intuitive.
300	Strandbeest leg assembly - crank	26/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	20 perimiter/15 1 interior	3.0mm (2.9mm)		0.6	N/A	1:39::28 hr:min:sec	11ºC	Clear	72%	11:45 PM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Left crank assembly printing overnight. Found that the majority of the parts were printed without interior fill. Cannot seem to understand why this is still happening. It did fill in on the washers but not on the crank parts. Soooo Frustrating!
301	Strandbeest leg assembly - crank Test	27/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	1 20 mm/s	2.85 (default)		100%	11 grams	6 min	14ºC	Clear	72%	7:30 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Ran many test prints to see if I could fix the infill problem. No matter what setting I used I couldn't get it to print the infill. I even adjusted the design so the model was thicker and still it wouldn't print the infill on the narrowest parts of the crank assembly. Finally I followed another post on the forum and found that some people have had better luck with other slicing software programs. I downloadesd CURA and installed it. Sliced the model and it printed the crank assembly part beautifully. Actually better than any print so far. Almost injection molding quality. No hairs. Completely solid, smooth.
302	Strandbeest leg assembly - crank	27/10/13	Rectilinear	No Raft	Green Painters .4 mm	190º	1 50 mm/s	2.85 (default)		100%	11 grams	39 min	16ºC	Clear	59%	10:15 AM	N/A	Mendel	Slic3r	Marlin	Pronterface	No	Increased speed of printer to 50 mm/s exterior of model is a bit lumpy but acceptable for a model and still better than slic3r. Interior infill is sketchy. Perimiters are not touching each other and gaps can be seen for many layers...afraid this will lead to delamination. Still alternating layer pattern may compensate for this.
303	Strandbeest bamboo Joint (hinged head)	27/10/13	Multi Directional @ 45º to print bed	No Raft	Green Painters .4 mm	190º	1 60 mm/s	2.85 (default)	100%	100%	11 grams	1:33 min	13ºC	Clear	63%	8:45 PM	N/A	Mendel	Cura	Marlin	Pronterface	No	Printed a strandbeest hinge joint to see how it printed with the new software. I printed the version that I made with .5mm tollerance. I pulled it off the print bed and was able to move it with a little force at first and then it loosened right up! This new software has done what the other software couldn't do. Additionally the joint printed with solid infill and no holes in the layers. The only problem encountered is that the print is wavy. I was printing at 190ºC and have read that lower heat can cause bubbles in the filament as it extrudes. I increased the temp to 210ºC and the plastic went smooth! It also created an interesting effect. I think if I can repeat this effect on the wood composite plastic then I could increase the visual wood effect. I also increased the print speed to 60mm/second because this print threatened to take two hours and fortyfive minutes. At 60mm/s it printed in an hour and a half.
			Multi																				I printed the leg assembly again and it printed well. However the last few layers were shitty and

305	Strandbeest leg assembly	27/10/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	.4 mm	205ºC	1	60 mm/s	2.85 (default)	100%	100%	11 grams	**2:45 hr:min**	14ºC	Clear	63%	**8:30 AM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Several false starts. Had to re-calibrate the machine again. The Y axix sensor had fallen out of place and the machine would make a horrible grinding noise as the stepper motor tried to move the bed past the frame. All the nuts around the sensor had to be tightened. Had to fight to get the printer to print the first layer correctly. Finally it worked but after lots of adjustments. Seems like it is low in the center and central pieces are not sticking. Also, I added foam under the printer feet again. Printer was quite noisy and I am thinking the the trouble with vibration, noise, Y axis shift and sensor nuts coming undone can be helped by reducing the vibrations produced when the printer is filling in. Printer is much quiter with the foam under the feet. To address the low center of the print bed I cut a piece of wood and inserted it under the bed to prop up the center and see if this fixes things. Really had to fight to get the leveling bamboos to alingn the bed. They do not have a very large range of motion and often one of them will slip out of alignment because it is at the edge of its range. Had to remove green tape to get things leveled. Printed on just the Kapton tape and this time the print was beautiful as it started. Turned to look at the print several times during the process and things were progressing well. Turned to check toward the end and half of the print bed was spaghetti. One of the pieces had come loose and was stuck to the nozzle. It was knocking other pieces off their spot. Let the printer continue to the end as half of the parts were ok. In the end the final pieces were that hadn't been ruined were quite easy to remove but I am not sure that this fact merits the risk of the prints being ruined by the nozzle knocking them off the print bed. It seems like Kapton tape is only really useful if the object being printed has a large footprint.
306	Strandbeest leg assembly	28/10/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	.4 mm	205ºC	1	60 mm/s	2.85 (default)	100%	100%	11 grams	**1:15 min**	14ºC	Clear	63%	**11:00 AM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	Put new green tape back on the bed. Printed one leg assembly. Everything went well. Prints are a little rough... not sure why...well, I suppose it is because I am printing at 60 mm/second.
307	Strandbeest leg assembly	5/11/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	.4 mm	200ºC	1	30 mm/s	2.85 (default)	100%	100%	4 grams	**14 min**	21ºC	Clear	50%	**3:00 PM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	Printed extra parts to finish off the strandbeest leg assembly. Finally got all the pieces printed and assembled it. The design I have used for the center crank is not working. The crank is spinning too much because the segments allow each part to spin independently. I had thought that the individual cranks would spin more rigidly along the y axis but the combination of hinges allows too much movement. I could use a hex nut end for all the parts but feel that this might slip too easilly. A star shape might hold better but it could still slip out of its seating. Another direction is to embed the cranks in a wheel (like the final design of the wheel chair would have and then just use a bracket to hold them in place. I like this idea for its ease of printing and the unlikely chance of parts slipping.
308	Strandbeest bamboo Joint (hinged head - .5mm tolerance)	5/11/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	65%	100%	4 grams	**14 min**	21ºC	Clear	50%	**3:30 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Switched to 1mm head to print using 10%Flour 45/45. Had to fiddle quite a bit with the settings in Cura to get a good print. Started with 2.8mm at 100% flow and it was too much. Lines were thick and infill was bulging. Reduced the flow to 75%, then 50% then 25% and then back up to 37% 25% was too little as lines were breaking but 37% seemed to hold together great and infill a wee bit more than necessary but still acceptable. However after setting things up to go for a full print the second and third layer were crap. Lines began breaking and were not touching. It seems like there is extra extrusion on the first layer of build with Cura but I haven't yet found this setting . I increased to 50% and then to 65% and the print was heavy on the first layer and then evend out to an acceptable extrusion. As things progressed lines got thinner and some breakage occured. Lines toward the top of the print were not touching inside even though the setting is at 100%. Final print is really nice! It is lighter than the PLA and there are visible gaps between the infill lines on the top layers of the head but the shaft is solid and the interior threads look much better than I expected. I expectd there to be lots of blobbing and for the interior threads to cause the nozzle to begin blobbing. It didn't in spite of lots of litte jerky movements that cause blobbing with PLA. The .5mm tollerance is evident which is a real surprise! the print is not yet moveable but it looks like it would be with some minor work with a small bamboodriver to separate parts. I am going to redesign the joint so the hinge is gone and the neck is bendable to see if I can play up the flexibility of the material.
309	Flexijoint (3 way and 2 way (med))	6/11/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	65%	100%	7 grams	**14 min**	15ºC	Clear	77%	**10:30 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Printed the new flexi joint that is based on "Stick-lets" by Christina Kazakia. The prints that I made were 6mm high and I printed using the 65% flow and 2.8mm filament setting. This print was going well at first but again, like the last print, the lines got furhter and further apart. Final print was nice but the weave is like a basket with gaps in between the lines. I tried bending them and they do bend a little bit more than PLA but they are brittle and both prints snapped when over stressed.
310	Flexijoint 2 way (med)	6/11/13	Multi Directional @ 45º to print bed	No Raft	Green Painters	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	100%	100%	11 grams	**24 min**	13ºC	Clear	88%	**10:00 AM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	Reprinted the 2way version of the flexijoint with 100% infill. I also cut the print down to 3mm high. The print went smoothly. It printed in a criss cross pattenr for each layer at 45º to the print surface. I was afraid that this would make the resulting print more rigid and less tollerant to stress. The final print is very nice and evenly printed. It bends enough to let a stick pass through the holes and this allows another stick to be inserted at a cross ways. **This is an incredible success! This exploits the differences between this material and PLA and ABS and shows that there is a functional use for it. My hope is that I can do this same thing with Wood Fibre to show it is also possible with WF and that WF is stronger.**
311	Flexijoint 2 way (med)	6/11/13	Concentric /Uni-directional	No Raft	Green Painters	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	100%	100%	11 grams	**24 min**	13ºC	Clear	88%	**11:00 AM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Reprinted the flexi joint using Slic3r to see if I could get it to print unidirectionally. The print is really only partially unidirectional as the arear arojnd the openings the software prints the joint following the teeth and not the longitude of the model. **This again is evidence that the software needs a more dynamic interface that allows users to change the print direction for each layer of the print. In fact this aspect needs greater number of options that would allow objects like the 3 way flexi joint which doesn't lend itself to unidirectional printing to be printed with a radial pattern starting from a user controlled point (not necessarially the centre). Additionally with 3 dimensional objects this same organising ablility could allow a print to be build from a mid point along the z axis. To do this would be much more involved as the software would have to organise the build from the bottom to the center and then out in all directions. It is justification for a 5 axis 3D printer.**
312	Flexijoint 2 way (med)	6/11/13	Rectilinear/Uni directional	No Raft	Green Painters	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	100%	100%	11 grams	**24 min**	13ºC	Clear	88%	**12:00 PM**	N/A	Mendel	Slic3r	Marlin	Pronterface	Yes	Tried again to print this joint using Slic3r but used the rectilinear setting. There was no change between the two prints in terms of how the program orgnised the object and printed it. Perhaps this is because of the number of perimiters used (100) I may try to do this with only one (1) perimiter but if I recall correctly this setting didn't work for unidirectional prints.
313	Flexijoint 2 way (med)	6/11/13	Multi Directional @ 45º to print bed	No Raft	Kapton	1.0 mm	200ºC	1	15 mm/s	2.85 (default)	100%	100%	11 grams	**24 min**	13ºC	Clear	88%	**1:00 PM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	
314	Strandbeest bamboo Joint (Cylinder Head)(Strandbeest 14)	7/11/13	Multi Directional @ 45º to print bed	No Raft	Kapton	1.0 mm	200ºC	1	30 mm/s	2.85 (default)	100%	100%	30 grams	**44 min**	16ºC	Overcast/Drizzle	88%	**8:30 AM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	

315	Flexijoint 2 way (med)	8/11/13	Multi Directional @ 45º to print bed	No Raft	Kapton	1.0 mm	200ºC	1 30 mm/s	2.4	100%	100% 11 grams	**24 min**	16ºC	Foggy	88%	**3:00 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Printed formulation S1234 which is dark because of dark wood fibre that was used during formulation process at SCION. This print had trouble at first because the filament was breaking as it extruded. I decreased the size of the filament setting in the Cura menu to 2.4mm and the result was wide thick consistent extrusions. However the overlap of the extruded filament is too much and in some cases the filament goes past the perimiters. This print failed right on the last half of the last layer! Damn! I looked away to enter in data on the log and looked back to see it had finished but hadn't printed the last bit. Looks like the filament got stuck in the extruder mechanism. Gonna try something new... gonna loosen the tension bamboo on the extruder mechanism and see what happens.
316	Flexijoint 2 way (med)	8/11/13	Multi Directional @ 45º to print bed	No Raft	Kapton	1.0 mm	200ºC	1 20 mm/s	2.4 .4 mm	100%	100% 11 grams	**24 min**	16ºC	Foggy	88%	**3:30 PM**	N/A	Mendel	Cura	Marlin	Pronterface	Yes	Changed the overlap of lines in the Cura expert settings menu from 75% to 35%. All other settings remained the same. Loosened the tension bamboo on the extruder mechanism. Clog didn't happen! Final print is consistent and seems to be as bendy as print 310.This adjustment underscores how absolutely difficult it is to balance all the variables with 3D printing. The problems I had before, when I was printing dogbones with this same material, apparently could have been resolved by adjusting this bamboo. Such a simple mechanical adjustment! And yet, if I remember correctly, I did adjust it at that time but my adjustment didn't have such a drastic affect on the movement of the filament through the extruder mechanism. Perhaps I didn't adjust it enough or perhaps there was an additional factor like the filament size might have been thicker and unable to pass in spite of the adjustment. At any rate it is an important observation that these sort of factors need to be mitagated in some way for 3D printing to become more widely accessible. One idea would be to have a variable tension bamboo on the extruder mechanism that would allow unevenly extruded filament or filament that had thicker and thinner sections to pass the mechanism without getting stuck.
317	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**8:15 AM**	N/A	Mendel	Cura	Marlin	Pronterface	No	New batch of material from Rotorua. Trying to extrude new S82 and S64. Been trying for two days without success. Finally realized that my settings were wrong and I had the nozzle size set to .5mm instead of 1mm . Things started to work better after that. Print went better but still failed because of material balling and ruining the print
318	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**10:15 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Clogg ruined the print
319	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**12:15 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	This looks like hell. The exterior is awful but the print is better.
320	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**2:15 PM**	N/A	Mendel	Cura	Marlin	Pronterface	yes	Rough exterior but print is acceptable
321	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**4:15 PM**	N/A	Mendel	Cura	Marlin	Pronterface	No	Material balled. Printer was too fast. Slowed it down.
322	Jansent Joint Bendy-Neck	15/12/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20 mm/s	2.4 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**6:15 PM**	N/A	Mendel	Cura	Marlin	Pronterface	yes	Really rough print. This one will delaminate but is more or less intact.
323	Jansent Joint Bendy-Neck	1/01/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 30mm/s	2.15 .4 mm	100%	100% 28 grams	**60 min**		Overcast		**11:15 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	I printed this version of the bendy neck Jansen Joint when I came back from Rotorua last month around the Dec 10th. I had lots of trouble printing with the filament at that time. Many false starts and unsuccessful prints. Finally I was able to get two of the formulations to print S82 and S46. S82 was very strong when it cooled down. When it was warm it could be bent into a position and then it woud stay very rigid after it was cool. S46 is very rubberry. I makes a very pliable object.. I had to stop prining at that time to work on my exegesis. It appears I forgot to take notes on my printing at that time. This time I tried to reuse the Gcode file from the last session without success. I had to play with the setting to arrive at these and they finally worked but only because I monitiored teh printing process constantly. The major issue s the extruder motor. It keeps slipping and stops feeding the filament. This leads to bad or ruined prints. My only success thus far is a rough-as-guts joint that has really poor intrastrand cohesion and is trying to delaminate between the print layers. I am also having occasional issues with the filament feeding from the spool.
324	Jansent Joint Bendy-Neck	1/01/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 30mm/s	2 0.3mm	100%	100% 28 grams	**1hr 35 min**		Overcast		**8:19 AM**	N/A	Mendel	Cura	Marilin	Pronterface	NO	This is the most frustrating experience of my life!!! I cant leave the machine for a minute without the extruder motor slipping on the filament or something else causing the filament to get stuck and ruin the print. I have tried everything: adjusting the tension up and down on the extruder motor, ;unwinding the filament spool to release the tension on the filament; setting the filament spool up on a stand so it could roll easilly. taking it off the spool and unwinding enough filament for the remainder of the print. Each time some new thing prevents the friggin machine from doing what it is intended to do. This print failed after several false starts and the starting beautifully. It went more than half way before the first extruder motor error. I corrected it quickly but then it failed again in a much bigger way and then again later till the final print is useless. If there was just some way to back up with this dumb machine and redo a spot that isn't quite right! My next print will have finer layers to try to address the poor resolution and hopefullly increase the intra-layer bonding and I will use the remove-several-meters-of-filament-from-the-spool technique.
325	Jansent Joint Bendy-Neck	1/01/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20mm/s	2.25 0.2 mm	100%	100% 28 grams	**1hr 55 min**		Overcast		**2:21 PM**	N/A	Mendel	Cura	Marilin	Pronterface	NO	I HATE THIS!!!!!!! EVERY f$%*KING TIME I LOOK AWAY FOR A MOMENT THE f$%*KING PRINTER f$%*KS UP!!!! I am at my wits end. I have to get this f$%*King machine to print out enough joints to make a chair. I don't care if it looks nice or not but it has to make a final product so I can have something to display. As it is I have 12 days left and it is taking an entire day to print a single joint! I have attempted 2 today and each of them have failed. Each has taken 2 hours to make. Each has failed in the last half an hour. Ok, the things that worked: changing to 2.25mm/sec extrusion improved the quality and things seemed to be less impregnated. The slower speed really seemed to help things print better and overall the print looks better . Cleaning the extruder mechanism helped the extrusion process - there were less fails or at least they were less frequent.. What didn't work:The slow time frame is too slow. I can't focus constantly on it for that long.

326	Jansent Joint Bendy-Neck	1/02/14	Multi Directional	Yes Support	Green Tape	1.0mm	195º C	1 15mm/s	1.85 0.2 mm	100%	100% 28 grams	**2:22 min**	Overcast	**6:47 PM**	N/A	Mendel	Cura	Marilin	Pronterface	No	Afraid to look away long enough to write this. However, some small success it seems. Tried to print the 6335 formulation and it wouldn't go. I upped and downed the speed and the extrusion and the temp and the layer height without any big success. I did notice that slower speeds and higher extusion (higher than the actual thickness of the filament [filament was 2.75mm av and I set it at 2mm})improved the quality. however the material kept getting stuck/grinding out in the extruder motor and the extruded plastic was lumpy,lumpy, lumpy. I switche to formulation S144 and reduced the layer height to .1 mm the speed to 15mm/sec and the filament diameter setting to 2mm and the results were near perfect until I turned the fan on and somehow shorted the printer!!! Ahhhhhhh!!. Retry with an increase in layer height to .2mm and decrease in filament diameter setting to 1.85mm (there seems to be a ratio between the layer height and the diameter of the filament) I noticed that my first layers were consistently better than any others. It appears that my nozzle is actually set too low and the first layer is .1mm and not .2mm like the machine thinks it is ... so I realised that my extrusion was double for this layer according to what the printer is calculating.... so if I decrease the filament diameter setting this increases the extrusion per layer and ... viola! better print. Fingers crossed this continues as well as it has started. Also the S144 is stiffer than the S6335 and doesn't seem to be grinding out as much. This might mean that the S6335 needs less tension on the extruder motor but it may also mean that it is just too damn flexible for printing. However, I am going to retry with the new settings and see what happens. The final result from this was an almost good print. except that it screwed up on the last few layers and delamination in a middle layer caused it to break apart. The piece feels too light to be appropriate for furniture. Going to try again with a 50mm/s setting and a 200% flow to see if I can find the right ratio of speed vs flow so I can print faster and move through these itterations quicker. NOTE: I had so much trouble with the extruder mechanism on this print and have had the
327	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Green Tape	1.0mm	200º C	1 20mm/s	2.85 04 mm	200%	100% 28 grams	**2:22 min**	Overcast	**10:07 AM**	N/A	Mendel	Cura	Marilin	Pronterface	No	If I sit and force feed the filament to the extruder moter- constantly pushing the filament into the motor so it doesent slip on the filament and is simply modulating the rate that the filament passes - then the material extrudes wonderfully. This however, is not a sustainable solution. I can't do this and noone esle would. This leaves me with two choices: 1) reduce the speed and continue trying to get a good print with this material or 2) try a different material that won't strip so easilly. The second option seems more practical considering my time constratints. NOTE: the problem here is that the extruder mechanism is crap. A twin screw mechanism is most likely the better extruder mechanism. It seems worth it to experiment with these.
328	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Green Tape	1.0mm	195º C	1 50mm/s	2.85 0.4 mm	120%	100% 338 grams	**31 min**	Overcast	**11:08 AM**	N/A	Mendel	Cura	Marilin	Pronterface	Yes	Success! It printed the whole joint at 50mm/s without slipping!!! Ok... now, can it do the same thing with the other filaments? I guess the first thing is to try the S82 which is the closest thing to pure PLA and then progress to smthing else...S181? Or S46.
329	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Green Tape	1.0mm	195º C	1 50mm/s	2.85 0.4 mm	120%	100% 338 grams	**31 min**	Overcast	**12:00 PM**	N/A	Mendel	Cura	Marilin	Pronterface	Yes	Soooo close and yet still so far to go! With the S82 the extrusion is very similar to the pur PLA. However when It gets to the neck where it has to bridge the gap between the two sides the extruded filament breaks and it continues to break for many many layers. The friggin thing needs to slow down during these layers but how? How do you tell the damn thing to slow down for this? The slicing program needs to havea variable setting or you should be able to manually control the speed using pronterface the same way you can varry the temp.
330	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Green Tape	1.0mm	195º C	1 20mm/s	2.5 0.4 mm	120%	100% 338 grams	**53 min**	Overcast	**3:50 PM**	N/A	Mendel	Cura	Marilin	Pronterface	No	Several false starts where I slowly decreased the speed dow to 20/sec. I also played with the number of perimiters and increased it from one to two. I also increased the temp to 210 at first and the extrusion seemed to speed up or become easier. Then I eventually went to 220. However the final piece seems to be more brittle than the other samples so Im going back to 210. The final piece seemed like it was going to be perfect and then on the last twenty layers it messed up. The printer started and stopped in the same spot for each layer and because of this a gap appeared at the beginning/ending point because there wasn't complete extusion. In trying to do something about this I ended up bumping the build plate and knocked the whole thing off its axis. Sooooo frustrated. The only good news here was that there didn't seem to be any significant extrusion problems.
331	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	205-215 C	1 30mm/s	2.5 0.3 mm	110%	100% 30 grams	**58min**	Overcast	**6:18 PM**	N/A	Mendel	Cura	Marilin	Pronterface	No	Seems like the best one yet but there are several issues. The speed at 30 definitely helped. The 30 second min layer speed helped the top end of the build but the head just slowed down and didn’t rest between layers so there was still a crevass that tried to form. ONe layer in the middle was messed up somehow even though the extrusion was constant and so it will probably de-laminate.The double perimiter doesn't overlap enough with each other and a gap between them leads to problems. Taking the layers down to .25 and trying 45 sec between layers to fix the top end.
332	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**8:03 PM**	N/A	Mendel	Cura	Marilin	Pronterface	Yes	The best yet. Not the best ever but definitely an even and consistent print. Not sure what happened... maybe it is that I am listening to radio-lab and the printer likes the episode. However, the result is that all the layers are pretty well glued together and I think that this print will work for the final. Time to try again. 1 hour 10 min,,, 4.95 meters,,30 grams this might be the ratio I have been looking for. NOTE: with this filament I have to hand feed the filament into the extruder moter to get a complete print. I can't leave it for a minute to work on its own because inevitably the filament strips out because it is too soft or it kinks or the nozzle gets clogged. Usually it is because the filament is too soft and it strips out. This material needs more development to be stronger (maybe more additive?) and/or the extruder motor neds a re-design so it can process soft materials.
333	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**9:32 PM**	N/A	Mendel	Cura	Marilin	Pronterface	No	This was a tough one. Half way through the neck it clogged for no apparent reason. I decided that instead of scrapping it I would reverse the x axis. I gave it one full turn back and ended up taking approx 1.7mm off the neck. Not what I intended as I had measured the thread and it was.5mm wide. So... What this kinda tells me it that for every 1/3 of a turn I can add or subtract abot .5mm to an object. This may give me the edge I have been whishing for.. We'll see....
334	Jansent Joint Bendy-Neck	1/04/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**11:23 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good print... in many ways like two prints ago. However, these prints are rough on the exterior... like the printer isn't following the same path. The edges are wavy and rought. The finish is worse than the others.
335	Jansent Joint Bendy-Neck	1/05/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**9:17 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good print
336	Jansent Joint Bendy-Neck	1/05/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**4:12 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good Print
337	Jansent Joint Bendy-Neck	1/05/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**5:39 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good Print
338	Jansent Joint Bendy-Neck	1/05/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**7:22 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good Print
339	Jansent Joint Bendy-Neck	1/05/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:09min**	Overcast	**11:08 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good Print

Crazy problem with the printer. It suddenly stopped when nearly 3/4 of the way finished. I was able to save it by counting the layers down from the top and then finding that spot in the g-code. then deleting the g-code before that point and saving this new list of g-code. I then had to heat up the nozzle, extrude to get the filament flowing and then home all the axises and pushed print. I

341	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.2 mm	110%	100% 30 grams	**1:15min**	Clear	**12:39 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	So frustrating!!! On the last few layers the damn machine keeps failing. The filament gets clogged and it ruins the print. Again I tried to salvage this print by finding a suitible place in the G-code and erasing everything before it. Then I heated the nozzle; extruded a few times; homed all axes; and pushed print. This time it worked right off the bat. The final piece is rough due to excessive extrusion on the last bit of the head from doing severl lines twice. However, it is salvaged. I changed some of the settings for this pirnt. I increased the speed to 40 mm/s and decreased teh layer thickness to .2mm the print is not noticably different than the last print. This encrouages me to leave the speed and change the layer thickness back to .25mm.
342	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
342	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
343	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
344	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
345	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
346	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
347	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print.
348	Jansent Joint Bendy-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 40mm/s	2.5 0.25 mm	110%	100% 30 grams	**1:15min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Ok print. This is my 16th one. I should be ok to switch to the other material and make the rigid joints.
349	Jansen Joint Caps/Plugs	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**26min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	Switched to S82. Increased the speed to 50mm/sec and the layer size to .3mm and decreased the filament size to 2.25mm because the filament is noticably smaller and oval shaped. This filament is harder though and it doesn't strip out in the extruder motor as easilly. I can actually leave the printer to print on its own. Printing the caps and plugs for the joints.
350	Jansen Joint Caps/Plugs	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**26min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	good print
351	Jansen Joint Caps/Plugs	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**52min**	Clear		N/A	Mendel	Cura	Marilin	Pronterface	yes	good print
352	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**45min**	Clear	**5:14 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Printing the stiff neck joint. Good print
353	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**45min**	Clear	**5:40 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	good print
354	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 4min**	Clear	**11:57 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	I am printing these two at a time to see if it works. Good prints
355	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 4min**	Clear	**1:06 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	good prints
356	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 4min**	Clear	**2:35 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	good prints
357	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 1min**	Clear	**4:58 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	good prints
358	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 1min**	Clear	**6:32 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	good prints
359	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 50mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 1min**	Clear	**9:13 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	Good print
360	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 1min**	Clear	**9:13 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	
361	Jansent Joint Stiff-Neck	1/06/14	Multi Directional	Yes Support	Kapton Tape	1.0mm	215 C	1 30mm/s	2.25 0.3 mm	110%	100% 30 grams	**1 hour 1min**	Clear	**9:13 PM**	N/A	Mendel	Cura	Marilin	Pronterface	yes	

Appendix 8: Ethics Forms

NOTIFICATION OF LOW RISK RESEARCH/EVALUATION
INVOLVING HUMAN PARTICIPANTS

(All notifications are to be typed)
(Do not modify the content or formatting of this document in any way)

SECTION A:

1. **Project Title** Hacking the Hackers

Projected start date for data collection June 1, 2013 **Projected end date** January 31, 2013

(Low risk notifications will not be processed if recruitment and/or data collection has already begun)

2. **Applicant Details** *(Select the appropriate box and complete details)*

ACADEMIC STAFF NOTIFICATION

Full Name of Staff Applicant/s

School/Department/Institute

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** ☐

Telephone **Email Address**

STUDENT NOTIFICATION

Full Name of Student Applicant Raque Kunz

Postal Address 14 A Freeling Street, Island Bay, Wellington 6023

Telephone 0223144055 **Email Address** raquekunz@yahoo.com

Employer (if applicable) **Massey University College of Creative Arts, Fab Lab**

Full Name of Supervisor(s) Antony Pelosi and Stuart Foster

School/Department/Institute College of Creative Arts

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** ☐

Telephone 64 4 801 5799 **Email Address** creative@massey.ac.nz

GENERAL STAFF NOTIFICATION

Full Name of Applicant

Section

Region *(mark one only)* **Albany** ☐ **Palmerston North** ☐ **Wellington** ☐

Telephone **Email Address**

Full Name of Line Manager

Section

Telephone **Email Address**

Low Risk Notification 2013 Page

3 **Type of Project** *(provide detail as appropriate)*

Staff Research/Evaluation:		**Student Research:**		**If other, please specify:**
Academic Staff		Name of Qualification	MDes	
General Staff		Credit Value of Research	120	
Evaluation		(e.g. 30, 60, 90, 120, 240, 360)		

4. **Describe the process that has been used to discuss and analyse the ethical issues present in this project.** *(Please refer to the Low Risk Guidelines on the Massey University Human Ethics Committee website)*

Attended a class on the importance of Ethics in research and how to evaluate the ethical considerations of research at Massey. Discussed project parameters with supervisors and evaluated ethical implications from all conceivable perspectives

5. **Summary of Project**

Please outline the following (in no more than 200 words):

1. **The purpose of the research, and**
   The purpose of this research is to explore the materials and ways that digital fabrication can be used to improve the process of repurposing mass manufactured furniture on a micro manufacturing scale.

2. **The methods you will use.**
   The approach will include a literature review and a practical exploration of 3D printing processes. The products that I will print using a 3D printer will be integrated into furniture pieces that will be used to display the design possibilities when furniture construction incorporates 3D printed parts. Additional methods used may include expert interviews conducted with individuals working in this area of design or other relevant occupations and data collection using anonymous sources such as survey monkey or other online survey web sites.

(Note: ALL the information provided in the notification is potentially available if a request is made under the Official Information Act. In the event that a request is made, the University, in the first instance, would endeavour to satisfy that request by providing this summary. Please ensure that the language used is comprehensible to all)

Please submit this Low Risk Notification (<u>with the completed Screening Questionnaire</u>) to:

The Ethics Administrator
Research Ethics Office
Courtyard Complex, PN221
Massey University
Private Bag 11 222
Palmerston North

SECTION B: DECLARATION *(Complete appropriate box)*

ACADEMIC STAFF RESEARCH

Declaration for Academic Staff Applicant

I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. My Head of Department/School/Institute knows that I am undertaking this research. The information contained in this notification is to the very best of my knowledge accurate and not misleading.

Staff Applicant's Signature ______________________ Date: ____________

STUDENT RESEARCH

Declaration for Student Applicant

I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and discussed the ethical analysis with my Supervisor. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. The information contained in this notification is to the very best of my knowledge accurate and not misleading.

Student Applicant's Signature ______________________ Date: 7/5/2013

Declaration for Supervisor

I have assisted the student in the ethical analysis of this project. As supervisor of this research I will ensure that the research is carried out according to the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants.

Supervisor's Signature ______________________ Date: 7/5/2013

Print Name STUART FOSTER

GENERAL STAFF RESEARCH/EVALUATIONS

Declaration for General Staff Applicant

I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and discussed the ethical analysis with my Supervisor. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. The information contained in this notification is to the very best of my knowledge accurate and not misleading.

General Staff Applicant's Signature ______________________ Date: ____________

Declaration for Line Manager

I declare that to the best of my knowledge, this notification complies with the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and that I have approved its content and agreed that it can be submitted.

Line Manager's Signature ______________________ Date: ____________

Print Name ______________________

Massey University
Te Kunenga ki Pūrehuroa

SCREENING QUESTIONNAIRE
TO DETERMINE THE APPROVAL PROCEDURE

(Part A and Part B of this questionnaire must both be completed)

Name: Raque Kunz
Project Title: Hacking the Hackers

This questionnaire should be completed following, or as part of, the discussion of ethical issues.

Part A

The statements below are being used to determine the risk of your project causing physical or psychological harm to participants and whether the nature of the harm is minimal and no more than is normally encountered in daily life. The degree of risk will then be used to determine the appropriate approval procedure.

If you are in any doubt you are encouraged to submit an application to one of the University's ethics committees.

Does your Project involve any of the following?
(Please answer all questions. Please circle either YES or NO for each question)

Risk of Harm

1.	Situations in which the researcher may be at risk of harm.	YES	NO
2	Use of questionnaire or interview, whether or not it is anonymous which might reasonably be expected to cause discomfort, embarrassment, or psychological or spiritual harm to the participants.	YES	NO
3.	Processes that are potentially disadvantageous to a person or group, such as the collection of information which may expose the person/group to discrimination.	YES	NO
4.	Collection of information of illegal behaviour(s) gained during the research which could place the participants at risk of criminal or civil liability or be damaging to their financial standing, employability, professional or personal relationships.	YES	NO
5.	Collection of blood, body fluid, tissue samples, or other samples.	YES	NO
6.	Any form of exercise regime, physical examination, deprivation (e.g. sleep, dietary).	YES	NO
7.	The administration of any form of drug, medicine (other than in the course of standard medical procedure), placebo.	YES	NO
8.	Physical pain, beyond mild discomfort.	YES	NO
9.	Any Massey University teaching which involves the participation of Massey University students for the demonstration of procedures or phenomena which have a potential for harm.	YES	NO

Raque Kunz

Informed and Voluntary Consent

10. Participants whose identity is known to the researcher giving oral consent rather than written consent (if participants are anonymous you may answer No).	YES NO
11. Participants who are unable to give informed consent.	YES NO
12. Research on your own students/pupils.	YES NO
13. The participation of children (seven (7) years old or younger).	YES NO
14. The participation of children under sixteen (16) years old where active parental consent is not being sought.	YES NO
15. Participants who are in a dependent situation, such as those who are under custodial care, or residents of a hospital, nursing home or prison or patients highly dependent on medical care.	YES NO
16. Participants who are vulnerable.	YES NO
17. The use of previously collected identifiable personal information or research data for which there was no explicit consent for this research.	YES NO
18. The use of previously collected biological samples for which there was no explicit consent for this research.	YES NO

Privacy/Confidentiality Issue

19. Any evaluation of organisational services or practices where information of a personal nature may be collected and where participants or the organisation may be identified.	YES NO

Deception

20. Deception of the participants, including concealment and covert observations.	YES NO

Conflict of Interest

21. Conflict of interest situation for the researcher (e.g. is the researcher also the lecturer/teacher/treatment-provider/colleague or employer of the research participants or is there any other power relationship between the researcher and research participants?)	YES NO

Compensation to Participants

22. Payments or other financial inducements (other than reasonable reimbursement of travel expenses or time) to participants.	YES NO

Procedural

23. A requirement by an outside organisation (e.g. a funding organisation or a journal in which you wish to publish) for Massey University Human Ethics Committee approval.	YES NO

Raque Kunz

Part B

FOR PROPOSED HEALTH AND DISABILITY RESEARCH ONLY

Not all health and disability research requires review by a Health and Disability Ethics Committee (HDEC).

Your study is likely to require HDEC review if it involves:

- **human participants recruited in their capacity as:**
  - **consumers of health or disability support services; or**
  - **relatives or caregivers of such consumers; or**
  - **volunteers in clinical trials; or**
- **human tissue; or**
- **health information.**

In order to establish whether or not HDEC review is required: (i) read the Massey University Digest of the HDEC Scope of Review standard operating procedure; (ii) work through the 'Does your study require HDEC review?' flowchart; and (iii) answer Question 24 below.

If you are still unsure whether your project requires HDEC approval, please email the Ministry of Health for advice (hdecs@moh.govt.nz) and keep a copy of the response for your records.

24. Is HDEC review required for this study?	YES NO

Select the appropriate procedure to be used (choose one option):

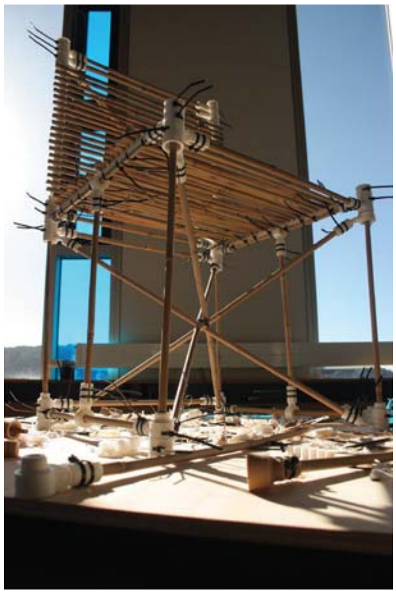
If you answer **YES** to any of the questions 1 to 23 (Part A) and **NO** to Q24 in Part B	If you answer **YES** to question 24 (Part B)	If you answer **NO** to all of the questions in Parts A and B*
↓	↓	↓
Prepare an application using the **MUHEC Application Pack**	Prepare an application using the **Health & Disability Ethics Committee Application Form**	Prepare a **Low Risk Notification** ** Note- researchers who are new to the University, new to research with human participants or for whom Committee approval is desirable are welcome to send in a full MUHEC application, even if the Screening Questionnaire questions have all been answered "no".*

↓ ↓

GO BACK TO APPROVAL PROCEDURES, STEP 4, AND DOWNLOAD THE INFORMATION REQUIRED.

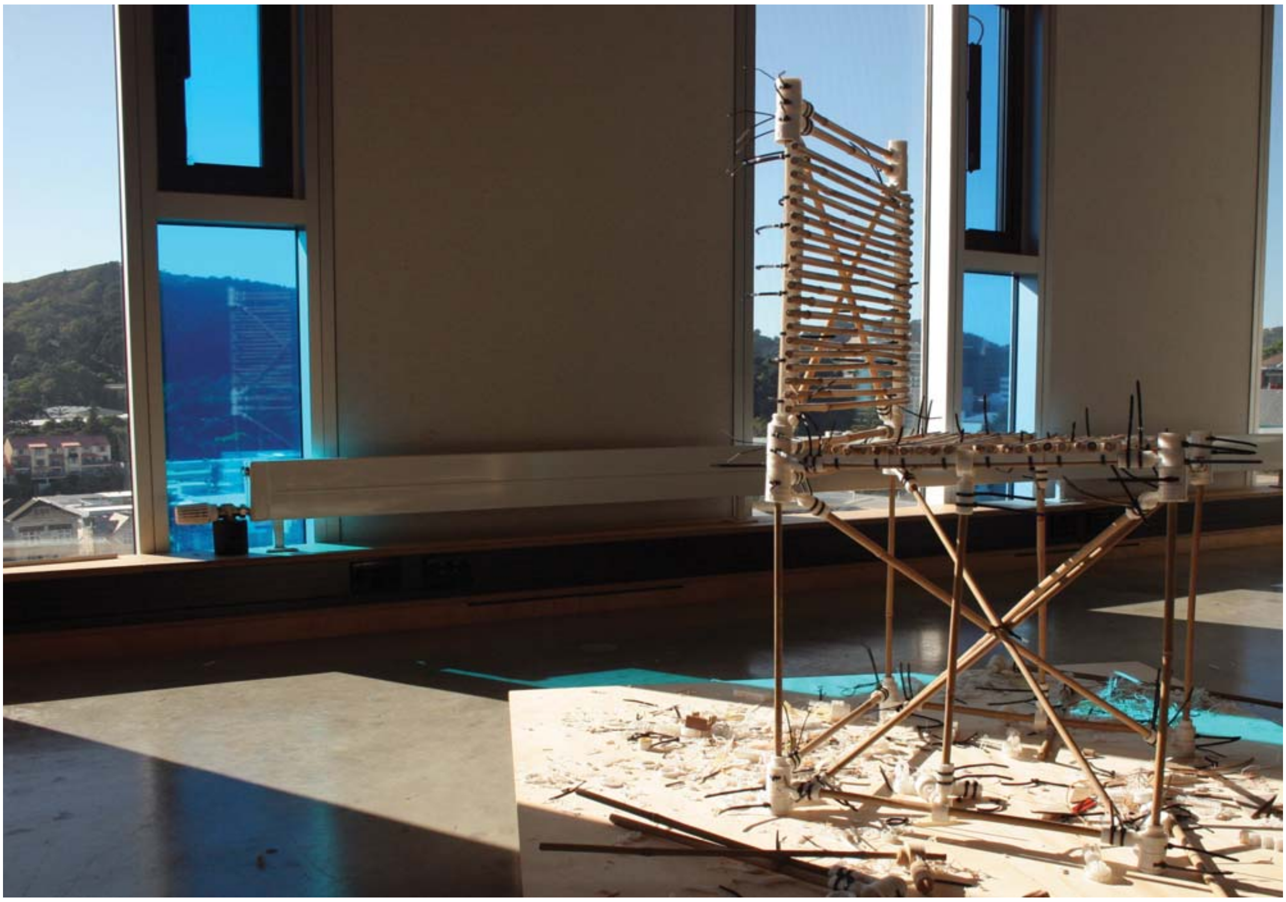
http://www.massey.ac.nz/massey/research/research-ethics/human-ethics/approval.cfm

Raque Kunz



Photos of the “M” exhibition, Massey University, Wellington, February 2014

Photos of the “M” exhibition, Massey University, Wellington, February 2014



The Jansen Joint chair
Massey University, Wellington,
February 2014.