Printing the future? An analysis of the hype and hope of rapid prototyping technology

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1. Setting the scene: old or new?

3D printing is not a new technology. Stereolithography, the first rapid protyping process, was invented by Chuck Hall, of 3D Systems Corporation, and has been used in large scale manufacturing industries for since 1984. It is regularly used in aerospace, medical, dental, automotive fields.

According to the Wohler's Report (2012) over the last 24 years, industrial and professional 3D printing revenue growth rate has been 26.4% and is expected to continue to grow until 2019. The total industry revenue is $1.7billion.

There are four types of 3D printing (Flattery 2009). 3D printing involves 'layering a powder substrate and binding it with pigmented glue'. Fused Deposition Modelling 'creates models by heating and extruding a filament of plastic material'. This is apparently one of the cheaper forms. Stereolithography is a solid imaging process which 'produces models by tracing a beam of UK light over a photosensitive pool of liquid' and Selective Laser Sintering brings together 3D printing and lasers.

Over the last five years 3D printing manufacturers have started to focus on smaller, cheaper and lower end products for small business and individual users. The last year in particular has witnessed the growth of 'desktop' consumer-friendly 3D printers specifically designed for home and office use. It is indicative that there were less than ten 3D printers exhibitors at CES in 2013. This year there were more than 20 (Nunes and Downes 2014). Accordingly, prices have dropped to as low as USD $500 although the majority are around USD $1000-$2000, which means they are not yet mass-market but appealing to early adopters and various prosumer groups.

A desktop 3D printer (such as MakerBot) currently takes around 30mins to print a mobile phone-sized object and software either comes with these devices or is downloadable via open-source online resources. Many of these devices although apparently ready-to-se-out-of-the-box still require some assembly (thereby requiring some basic knowledge, skill and tools).

This shift in supply has corresponded with growing demand emerging from the maker movement (ie Maker Faires, Instructables and spike in popularity with open source and collective DiY practices (ie. Fablabs, Hackerspaces. These groups, spaces and events offer a chance to gain hands-on experience with this new technology. An example is the 3D Printer Village at the 2013 New York World Maker Faire which boasted 'the largest collections for hobbyist printers in the world' (Makerfaire 2013). Events like these are not just for hobbyists but also provide opportunities for manufacturers to hawk their wears and large scale technology organisations such as Intel to showcase their engagement (Hoffman 2013). This also shapes whom and for what purpose this technology is seen as relevant and compelling – ie. predominantly white and male.

While makers and hobbyists and artists are amongst the first to use the devices, analysts' argue that consumer sales are growing (Lomas 2013). 'Analysts expect worldwide shipments of mass market 3D printers, already a billion dollar business, will nearly double from last year to almost 100,000 units in 2014 and double again in 2015' (Nunes and Downes 2014).

2. Changes to the market

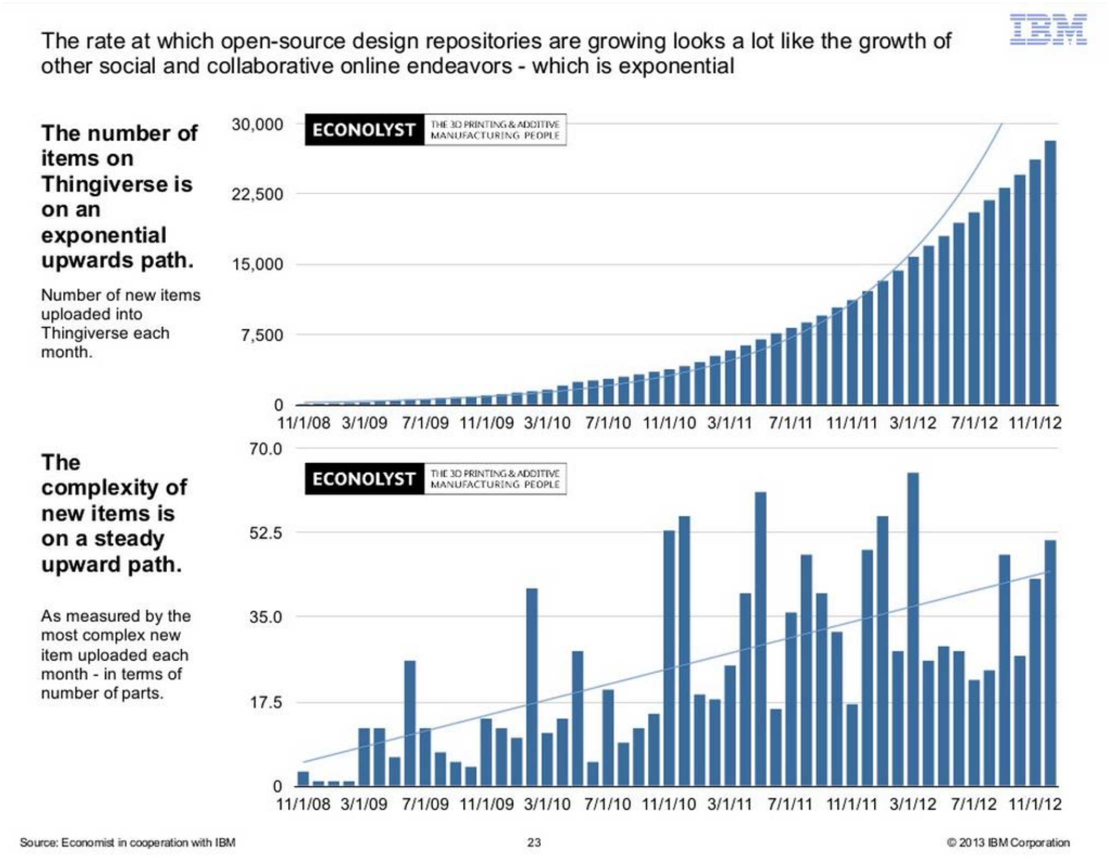
3D printing devices have become cheaper, smaller scale and more easily accessible by small business and individuals outside large scale manufacturing processes. This has been the result of advances in the technology, availability of sophisticated software and associated skills, new materials and distribution of information on the internet.

Cost	3D printers have been out of reach of hobbyist market due to prohibitive costs. 2008 saw a dramatic growth of personal devices, which are those priced under $5,000, but more typically in the $1,000 to $2,000 range. This market segment has grown from 355 units in 2008 to an estimated 23,265 units last year'. (Wohlers 2012). Raw plastic material (PLA) has also drastically reduced in price - £30/ cartridge
Size	A gradual reduction in printer size to that of inkjet printer while the scale of print production is growing (average. 5.5"cube)
Language	Marketing vernacular has been drawing on the language of Desktop Printing – suggesting a desire not just for parallels with the size, use and cost of this familiar consumer device but also its seemingly seamless narrative of a consumer trajectory from outside to inside the home
Software	Sophisticated CAD skills are no longer required to use machines. Some devices come with consumer oriented software. Others are available open source.
Information	Communities of knowledge share open access information - online resources, community hackerspaces
Distribution	Growth of large familiar technology distributers become retailers for 3D printers and 3D printing services

3D printing is currently being accessed (in UK, US and Aust) via three main channels:

Individual purchase	3D printers are available for purchase in multi-national retailers - predominantly in the US, rolling out in the UK and much slower in Australia	Microsoft to sell Makerbots in US Amazon 3D printers and supplies In July 2013, Maplin became the first UK high street chain to sell 3D printers (Maplin 2013) Officeworks started to supply 3D printing materials in Australia from Jan 2014.
Point-of-use service provision	Purchase of 3D printing services at multi-national retailers	MakerBot experience Stores (De Zeen 2013d; Makerbot Stores 2013) In 2013, UPS and Stratasys team up to provide first 3D printing retail service (De Zeen 2013e)
Shared communities of use/ knowledge/ skills	Membership at collective DiY/ maker spaces/ school / university	Fab Labs Hackerspace Thingiverse - an open source design site run by Makerbot Community 3D printing failure tumblr (Tumbler 2013)

The complexity of objects made with consumer 3D printers has been growing. A study by IBM and The Economist examined the growth rate of Thingiverse from 2008-2012 and found that both number and the complexity of new items uploaded to the site were steadily increasing (On 3D Printing 2013).



Source: IBM (2013)

3. Why is 3D printing important? What might it replace?

Consumer-friendly desktop sized 3D printers promise new users that they can quickly prototype a site-specific three-dimensional design that would otherwise be costly, time-intensive and require the knowledge/skill of a range of people:

<u>- Different manufacturing processes</u>

Lipson and Kurman argue that 3D printing eases 'the tyranny of economies of scale' (Lipson and Kurman 2013).

> *'Economies of scale are the invisible foundation that supports our modern industrial economy. Economies of scale are what make mass-produced products profitable' (ibid, p23)*

They posit that 3D printing usurps the canon of tradition manufacturing processes which are based on complexity, assembly and distribution of mass-produced economic systems in the following ways:

Manufacturing complexity is free	Zero skill manufacturing
Variety is free	Compact, portable manufacturing
No assembly required	Less waste by-product
Zero lead time	Infinite shades of materials
Unlimited design space	Precise physical replication

- Lower costs

Michigan Technology University researchers conducted a study looking at the costs associated with 3dPrinting and found that printing common items at home was cost-effective in comparison to purchasing of mass produced items. They provide examples of shoe innersoles, toothbrushes, showerheads, phone covers, razors, garlic press and other replacement parts. They also looked at the possibilities of corner stores equipped with 3D printers to print objects on-demand

- Reduced supply chains

Other analysts focus on the environmental/logistic impacts of 3D printing over conventional manufacturing. Wigan (2013) has argued that 3D printing impacts on the often hidden costs of distribution and supply chains.

- New efficiencies/ sustainability

3D printing promises to enable printing at the site of the printer thereby reducing travel and waste, and contributing to sustainability.

- Potential for on-demand customisation

Opportunity to respond to changing conditions with site-specific and timely printing. Eg. Key logistical problems in military contexts - 'Unmanned aerial vehicles can be made overnight – print-crash-reprint' (Goggin 2013).

- Personalisation

Different business models/market models indicate a reduction in price can be predicted but it is more difficult to predict how the adoption will occur. Will this be a piece of technology that people have in their homes and/or will corporations build things on demand (locally)? Which one will end up driving 3D printing more?

- Flattened hierarchy of creative application

New players in market previously inhibited by hierarchical barriers to entry. Eg. independent R&D producing inventive solutions to problems such as prosthetic arms/ limbs. Also, 3D printed projects on crowd sourcing funding such as Kickstarter present ways in which people are using the technology to make things and profit from them in different ways (A simple search on Kickstarter or projects involving 3D printed products reveals a substantial result - an example: https://www.kickstarter.com/projects/604459465/3d-printed-bomb-suit-figure-eod?ref=live)

4. Stubborn technological practices?

- Existing ecosystems?

The frequent comparison between 3D printing potential and that of the desktop printing masks some obvious differences as well as a raft of complications. Evoking the history of the desktop printer suggests the kind of whole ecosystem transformation that took place in publishing. It is important to remember however that that transformation took more than 30 years and is still on going and has hardly been seamless or straightforward.

Furthermore the area of printing and publishing has been subject to wholesale transformation throughout more than 500 year history. Not withstanding the ultimate goal of publishing - the act of transferring ideas to others – remains unchanged. The critical question/s then would seem to be what underlying goal is it that 3D printing supports:

- Is it the production of an object or objects?
- Is it alternative range of customised objects?
- Is it about a broader range of producers?

What are the stage gates? For instance, desktop printing did not be adopted evenly across Australia, nor will the means by which 3D printing will be maintained, repaired or replaced. The problem of distribution and production will remain.

- Different intermediaries?

Photography, as a series of technologies and systems, presents an interesting comparison. The shift to digital photography lowered costs, and widened participation and distribution beyond conventional pay-for-service provision. It initially promised new relations that circumnavigated conventional corporate intermediaries – ie. film and printing service costs. Yet, as many have argued film is superior in many ways to digital (Towne 2012). But the conversation shifted to ‘convenience’ and digital photography fit into and feeds a larger complex visual culture and socio-technical system of online communications.

While it is still possible to print quality digital prints, at home and also in high street shops, on the whole, this practice has shifted. Once ‘photos leave home’ (Cohen 2005), moving out of the domestic and into the public, the meaning and use of photography shifts, bringing to bear different interpretations of sharing, audiences, public and private spaces, politics and power dimensions. In terms of 3D printing, the opposite is the case - continuing decrease in size, cost and increase in availabilities of materials and software is moving this technology into the home and in doing so rendering visible new relationships with everyday practice. What will connect with/becoming critical for 3D printing in the home which it didn’t in the industrial context?

<u>- Just because we can, will we?</u>

Convenience and personalisation are common themes evident across broader socio-technical spectrums - medicine, transport, communication, entertainment etc. While some things are being designed to suit the individual, and narrowed in terms of their targeting, it is not always the case. Some things are becoming more open and public. Twitter, for example enables the public broadcasting of private ideas and observations. However, not everything gets broadcast just because there is freedom to do it. Similarly, 3D printing moving into the home does not mean that everything will be printed just because it can. As has been shown in many new tech studies, people continue to carve out, via social, cultural and gendered relationships, where and how tech get used. (Forlano 2008).

<u>- Bad design is *still* bad design</u>

A 3D printer is a tool. It is not a magic piece of technology that produces ideas. Rather it is a design method that relies upon a larger ecology of context, problem identification, technologies and skills.

> *A bad design is a bad design however you make it and if you don't understand the reasons why it is a bad design, then 3D printing it won't help you (Fanning 2013).*

<u>- Two-part tariff model</u>

The two-part tariff is a familiar economic model for an attractively cheap durable platform (ie. printer, razor, mobile phone) with high cost consumables (ie. ink, blades, service package). The first encourages consumers to purchase and the second commits them to a system of practice, with the latter being at a price premium thus ensuring long terms sales. 3D printers are a technology and practice that can be seen to fit this conventional model – the hardware is increasingly becoming cheaper for domestic application and the consumable (filament plastic or resin) in many cases is governed by the make of the hardware and can be proprietary technology, which in turn shapes the continued commitment by the user.

- Same stories? Same technological imaginaries?

As Bijker and Law (2012) have argued:

> *'Technologies do not… evolve under the impetus of some necessary inner technological or scientific logic. They are not possessed of an inherent momentum. If they evolve or change, it is because they have been pressed into that shape'.*

A study of 3D printing, as it emerges, in Australia offers a chance not only to observe and understand but also to intervene in what shape it takes. These are not already fixed, universal or one-size-fits-all artefacts or systems.

Another stubborn technologic practice that needs to be considered is how key market leaders communicate and represent the technology. Key voices of 3D printing, such as MakerBot, give the impression that they are influenced by sci-fi. gaming and military iconography that attract and reinforce a particular target audience (ie. predominantly white and male) and in turn produces a specific technological imaginary. This emerges in the ways they narrate and design new versions of the tech:

> *Unlike the jerry-built contraptions of the past, the Replicator 2s are sleek, metal, and stylish: MakerBot CEO Bre Pettis likens the design to "Darth Vader driving Knight Rider's KITT car while being airlifted by a Nighthawk spy plane." There is also the lighting. Oh, the lighting. "LEDs are part of our core values as a company," Pettis jokes. The new machine will glow in any hue—"to match the color of your couch," he says, "or like something in the movie Tron."*
>
> *When Star Trek captain Jean-Luc Picard wanted a hot beverage, he'd simply tell the Enterprise Replicator to make "Tea. Earl Gray. Hot." It's no coincidence that MakerBot chose the same name. The tea itself is still a ways off, but the cup? You can make it today. (Anderson 2012).*

The questions to ask when interpreting these kinds of narratives and 'stylish' designs are: Although this technology purports to speak to everyone, and open up a wider audience for making, who does it actually include and exclude? How might this technological imaginary operate to prevent different kinds of people from participating? How might it reinforce stereotypes of technology users? How and why is it being pressed into a particular shape and how 'could it be otherwise' (ibid).

An interesting case study for comparison is the advent of the car. Clarsen (2008) presents a detailed study of the history of women's enthusiastic engagement in motoring and mechanics from 1880s and explains how and why it is that we as a (Western) society perpetuate the forgetting of this history.

In addition to having to compete with apparent natural male competence and the visual culture of car advertising that reinforced the notion of women's technical incompetence, Clarsen writes about how 'there was no language available to help us understand a specifically female experience of technical competence or to articulate the challenges that we faced in an auto repair world that was firmly gendered male' (ibid, preface p.ix).

This is not to say that 3D printing is already and firmly gendered male, but that questions need to be asked about the unmarked (stubborn) technology category, especially when key market players present images of themselves and narratives that firmly reflect and produce particular versions of the technology use and its potential users.

Source: Makerbot.com

5. Rhetoric and hype

Much like other new digital technologies, 3D is imbued by rhetoric of radical transformative change on manufacturing, creativity and design and the impacts this will have on our everyday life (Arthur 2013).

A sample over the last few years:

> **2011:** *Soon – really – it will be possible to print out products at home ranging from appliance parts to shoes. You will be able to have that dishwasher part made just for you instantly. This promises to empower a new wave of design and customization fueled by our personal taste and imagination (Savitz 2011)*

2012: *Just as the Web democratized innovation in bits, a new class of 'rapid prototyping' technologies, from 3D printers to laser cutters, is democratizing innovation in atoms (Anderson 2013).*

2013: *3D printing: not yet a new industrial revolution, but its impact will be huge. 3D printing will allow production on the small-scale to be as efficient as large scale production - its existence and growth will both challenge and complete traditional manufacturing (Chalmers 2013).*

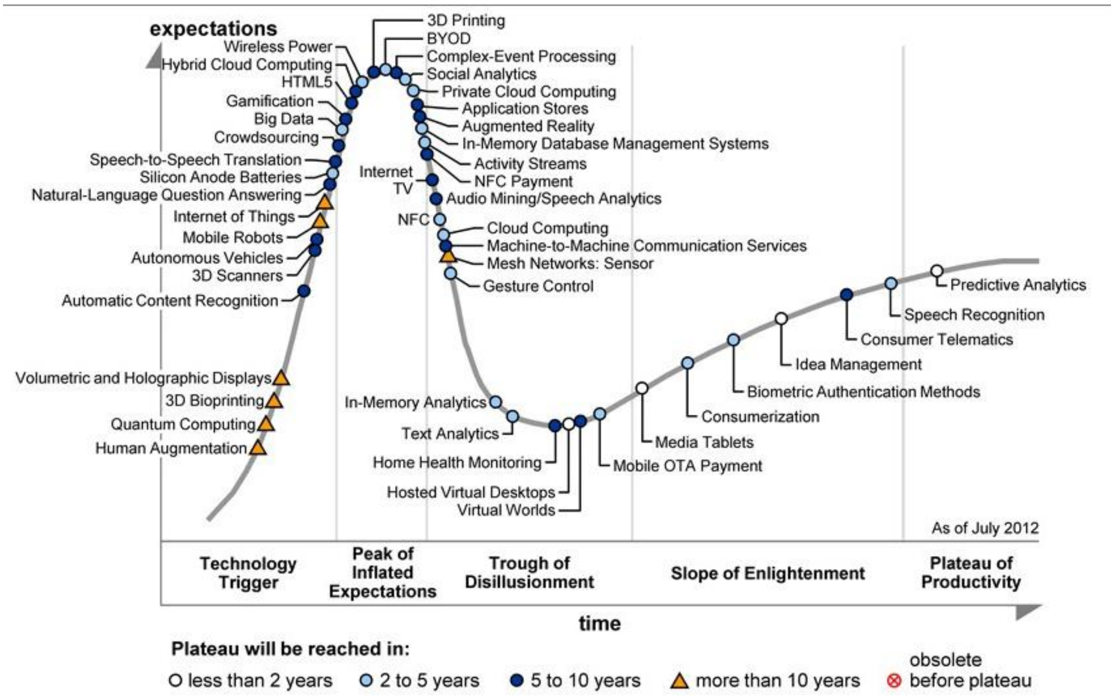
2013: *In a 3D printed future world, people will make what they need, when and where they need it… Like the magic wand of childhood fairy tales, 3D printing offers us the promise of control over the physical world. 3D printing gives regular people powerful new tools of design and production. People with modest bank accounts will acquire the same design and manufacturing power that was once the private reserve of professional designers and big manufacturing companies (Lipson and Kurman 2013).*

2014: *Just like digitisation of other products (music, movies, books), 3D printing is going to be very disruptive, as it enables digitisation of objects. Just like what happened with other 'digitalised' industries, 3D printing is going to threaten the position of established firms and create opportunities for newcomers. In this context, business model innovation is going to play a critical role in the success or survival of firms affected by this new set of radical technologies (Rayna and Striukova 2014:120).*

These commentators envision a future where we will be able to print anything that we need – clothes, cars, furniture, food, medical devices, weapons and more.

Although many media column inches have been dedicated to discussion about its potential transformative impact and there has been a significant availability in cheaper, smaller and more efficient devices, it is nevertheless the case that 3D printing has yet to live up to its hype. Market expectations still far exceed economic and productive realities.

Garter Analysts (2012) have produced technology hype graphs since 1995. 3D printing is currently at the 'Peak of Inflated Expectations'. They forecast that this technology will plateau in 5-10 years. For comparison Speech Recognition is located on the 'Plateau of Productivity'. We recognize the usefulness and application of this technology in terms of 'Siri' but it has been around for a much longer period.



Source: Garter Analysts (2012)

These views are substantiated by many critics:

> Most *industry views are that mass 3D printing "will take another 10-15 years to make major inroads" (Wigan 2013).*
>
> *Some have argued that the hype might actually damage the potential of 3D printing with many new users disappointed with current results (Fanning 2013).*
>
> *It also currently takes a range of skills to use (Heritage 2013).*

Others argue that 3D printing is a gimmick that cannot live up the hype and 'will go the way of virtual reality' because regardless of how interesting some of the applications currently are it cannot reproduce goods with the same complexity as conventional manufacturing processes.

> *The desire for 3-D printing to take over from traditional manufacturing needs to be recognized for what it is: an ideology. Getting all of our goods from a box in the corner of our home has attractive implications, from mass customization to "the end of consumerism." With stakes like those, who wouldn't want to be a true believer? (Mims 2012).*

Allen writes about the empty rhetoric of the 3D printing 'revolution' from a hands-on perspective of a practitioner with significant commercial and industry experience and founder of a 3D printing company:

> *The main issue lies with raised expectations, build quality, price and usability (Allen 2013)*

Allen (2013) outlines what he considers to be the major failings of the technology as it currently stands:

- Cost: there is no economy of scale. Everything costs according to the use of materials.
- Speed: 3D printing is not quick
- Usability: A constellation of skills and technologies are needed before you can print
- Machine range: a range of printers have a range of outputs – not all are suitable for home printing
- Materials: 3D printers print with plastic and yet most of the objects in our lives are made up of multiple materials.

Despite this, Allen remains a keen supporter of 3D printing but argues that its most significant impact will be most felt in low-volume high-end machine printing for aerospace and medical fields and not for the domestic market.

The application of 3D printing for medical and dental use generates significant media attention. A Guardian article 'Medical implant and printable body parts to drive 3D printer growth' (Butler 2014) cites research that posits that the printing of new body parts will generate a $6bn market by 2025. This forecast re-iterates Allen's argument above and even the journalist acknowledges the gap between this particular version of high-end low-volume 3D printing future and the current state of popular 3D printing which 'is better known to British households for its ability to replace broken crockery or produce awkward figurine "selfies".'

Dabbs (2014) is even less enamoured by the medical breakthroughs:

> *The popular press, in the meantime, embarrasses itself repeatedly by reporting on non-stories about the capabilities of 3D printing. The price of 3D-printed prosthetic limbs with moving parts is one such. While the very idea of producing affordable artificial body parts customised exactly to the individual body in question is thrilling, the reality is less so. The principal reason that a 3D-printed prosthetic is so much cheaper than existing types is that the charitable person doing the 3D printing is doing it for free. Wow, only $400 for a new hand? Actually, that's $400 just for the plastic. The CAD modelling, setup, the 3D printer itself, electricity, workspace rent and labour – these jobs can take hours or even days to complete – were offered at no cost by a charitable fellow in the hope of going to heaven.*

One of the more interesting approaches to 3D printing is Rayna and Striukova (2014) who explore is in relation not just to what outcomes are possible via 3D printing but what it might mean from a business perspective: 'One of the objectives is to demonstrate that 3D printing technologies are not only enabling business model innovation, but also have the potential to considerably change the way business innovation is understood and carried out' (2014:120).

They discuss how small ideas have gained exposure and scalability via crowd funding platforms such as Kickstarter and 3D printing enables businesses that operate like this to respond to demand rather be caught out by the ebbs and flows of traditional forms of production and distribution. Fundamentally, they argue that 3D printing might catalyse disruptive changes not only to what is made but also to how businesses operate.

6. What is 3D printing's killer app?

Source: (Alter 2014) - 3D printed objects at CES 2104

The 'killer app' is jargon in the IT industry for the idea that a successful technology is driven by an intended or unintended popular or "killer" application. Currently 3D printing is generating hype for its potential to do many things but not really currently doing anything exceptionally well.

Some continue to forecast 3D printing's killer app:

DIY makeup could be 3D printing's killer app – Davis (2014)

Many others believe it is a technology that is still searching for it. Olivera (2013) writes*: 'an endless variety of colourful plastic knick-knacks and doohickeys that look neat but have no real practical use.… the average person, who might wonder why the trend has built up so much hype without a compelling reason to own one'.*

Similarly Alter (2014) at this years Consumer Electronic show (CES) wrote: *'While 3D printing has many uses in business and design, nobody at CES made a persuasive case for what anyone would do with it in a home, other than make toys, dolls and iphone cases'.*

7. Regulation and IP

Major anxieties surrounding 3D printing concern regulation and IP. Although it has always been possible in various ways, there are fears that users will have an advanced ability to infringe copyright, patents and design rights of objects through the production of unauthorised reproductions.

The Electronic Frontiers Australia (EFA) foresee a 'pushback' from large-scale manufacturing to the threat of 3D printing by new entrants into the market.

> *Due to the creative destruction that new technologies such as 3D printing may wreak on 'traditional' manufacturing industry, and despite its potential economic, environmental and social benefits, we are likely to see pushback and lobbying from incumbent manufacturers and their masters to strengthen intellectual property law and enforcement in the same way as happened for digitised content.*

However, they also envision the potential of the 'democratisation of the new technology:

> *In the midst of moral panic over 3D printed guns, Angela cautioned that we should not lose sight of the opportunities that the increasing affordability of 3D printing may bring by democratising the means of production into the hands of the many rather than large, centralised, often offshore industry (Lawrence 2013).*

The 3D printed handgun is the most provocative and debated case study for regulatory issues.

3D printers can potentially produce objects that circumnavigate regulatory systems – ie. weaponery. The debate was was triggered in 2012 when Cody Wilson, a University of Austin law student, co-founded the group 'Defense Distributed' to 'promote ideas about universal gun ownership and designed a 3D printed handgun and made the computer drawn plans available online. Although this gun was designed to fire only once and officials – such as the NSW Police Force – have experimented and found that the potential for fatality and injury was shared by both the intended victim as well as the perpetrator due to the inefficacy of the design, nevertheless it is viewed as 'an emerging threat' (Hopewell 2013).

In May 2013, the NSW Police Force, concerned with illegal firearms and shootings in Sydney, held a special press conference on the topic of 3D printed guns. Police Commissioner Andrew Scipione discussed experiences of printing and using a 3D printed gun. He re-iterate general concerns about the 'threat' of 3D printed guns and expressed fears of it fatally hurting not only the intended victim but also the shooter, as one of the experiments had catastrophically failed in practice.

> *'[3D-printed weapons] are truly undetectable, truly untraceable, cheap, easy to make. [This] weapon cost us $35 to make. We made that on a base entry level 3D printer. That printer cost us $1700. It truly is a home printer for so many people to make untraceable weapons. It is an emerging threat.' [ibid]*

A significant issue is the fear that 3D printing drastically reduces the barrier to production thereby reducing the impact of existing regulatory measures of gun control, license and registration systems. Made in plastic, there is also the potential of these weapons being invisible to current detection systems.

Interestingly, the 3D printer company Stratasys responded to this initial use of their 3D printer by taking back their equipment, arguing that Wilson violated the legal use of their 3D printer in two ways – he did not have a firearms manufacturers license and that they do 'not knowingly allow its printers to be used for illegal purposes'.

> *Constitutional experts have stated that although banning the actual manufacture, sale, and possession of plastic weapons is feasible, restricting the schematics of the printable weapons is a violation of the First Amendment (Marks 2012).*

Wilson countered that his group's aim was to 'disseminate a printable gun design online, not print guns per se' (ibid). The 3D printed gun has catalysed significant debate as it challenges conventional regulatory control of weapons given it is being distributed not as an object but as a series of plans and instructions. There has been a range of guns printed to greater and lesser success since then (Gibbs 2102; Watson 2013).

This is an interesting case when considered in relation to the search for 3D printing's 'killer app'. Printing guns on home 3D printers that 'might' work demonstrates an application that appeals to a specific user group. Alter (2014) puts forward the argument that just as the porn industry catalysed advances in video players and cameras, the internet and other digital technologies, it is not unrealistic to consider 3D printing being driven by the small arms industry.

This provides perhaps one reason for why the concept of 3D printed weaponry has generated such a intense debate and discussion (and fear), when in the reality of buying a gun in the US is very easy. Also, as many have illustrated, these weapons currently pose more danger to the printer/maker than to any one else (BBC 2014).

The gun issue is of course not the only use of 3D printers to raise the issue of copyright and IP.

> *We should promote the technology while also ensuring that we have strong enforcement mechanisms and penalties, both domestically and internationally, to punish bad actors who abuse the technology by producing items that would be illegal regardless of how they were created (Bradshaw et al 2010).*

8. Possible futures? Different models?

Government regulators could clamp down on gun design files/ open source information systems in similar ways to how they seek out music/movie file sharing.

Electronic Frontier Foundation have argued that the case of the 3D gun should not lead Governmental 'moral panics' that crush entrepreneurial potential of the new technology:

> *If intellectual property law can be kept in check, 3D printing may bring about a new abundance of information to add to that created by digitised content, but this time regarding physical objects. Given the fact that it is impossible for the state apparatus to control fully this technology, we may have to live with the disadvantage of this decentralisation, namely the means to make socially undesirable objects. However, we must not let this on the one hand lead to even more useless intellectual property laws that cannot be enforced anyway, and on the other to stopping the beneficial uses of 3D printing (Lawrence 2013).*

An alternative model is provided by Chinese political support for grassroots technology communities and individuals in the form of a new economic space whereby large-scale manufacturers are collaborating with small independent makers/ entrepreneurs. This example debunks the conventional myth of top down technology innovation as sole large scale economic system

> *What this shows is that makers, manufacturers, and VCs are invested in the "professionalization of make," while approaching it from very different positionality in terms of resources, power and knowledge (Lindtner 2012).*

9. What is next? Future uses?

Like many new and novel forms of technology before it, 3D printing is poised for mass-market adoption in the US. It has strong advocates and champions, the right amount of buzz and hype, and a slow but steady drumbeat of ancillary investments in the eco-system. It is also tightly linked to significant recognized successful game-changers like crowd-sourced funding and the Maker Movement. However, for it find true and last success, it will need to one or two abiding and overwhelming wins. A reason, beyond novelty, for people to embrace its early complexity, and relatively high price, for examples, Quicken on personal computers, SMS on mobile phones, etc. Until that clear value proposition can be articulated to consumers, the hype will persist and the technology will not find mainstream market success.

It is far more likely that 3D printing might find its way to niche success and impact in the short term. Early experiments with 3D printing in the medial space – for organs, tissues and dental materials – are already seen as successful (Choi 2013).

10. 3D printing in Australia

Q. What are the potential impacts of 3D printing on Australia's future?

3D printing promises a way to respond to changing conditions, the tyranny of distance, complexity of supply chains and rising costs – all factors that relate well to the Australian context. However the promise of 3D printing will take time and effort to realise. Important issues related to IP, branding, regulations and sustainability need to be addressed and managed. While 3D printing offers to manifest objects at the site of printer, printers will not be implemented evenly across Australia. The problem of distribution and production will remain.

Q. What are the key determinants (in Australia now, and in the foreseeable future) of industry's uptake of 3D Printing and to what extent are these capable of influence by government policy?

The trajectory of past technologies is informative for how 3D printing might roll out in Australia. Arguably, 3D printing will be one in a long line of new technologies whose adoption curve follows a well established pattern in order to achieve the promise of 3D printings bridging of distance and resource accessibility we might need to contemplate Governmental interventions akin to those seen with internet accessibility, electricity service delivery, TV signal boosting and the on-going challenges with mobile phone backhaul, including subsidies, mandates and/or enhanced offerings.

Studies such as Bell's Thinker in Residence 'Getting Connected, Staying Connected' bring to life the trajectories of independent yet interconnected technologies that promise radical transformative change and useful reminders of the critical lens needed to view and understand them in cultural contexts of use (Bell 2009). Similarly critiques of technology adoption curves in Australian can be found in Lally (2002), Goggin (2004) and Jungnickel (2013).

> *'… a story about the role digital technologies swill pay in shaping South Australia. But somewhere in here there are stories, too, about how these technologies aren't really changing anything at all. And we have to be critical, smart and engaged enough to know the difference' (Bell 2009:11).*

Source: Fab Lab Adelaide

Q. What are the opportunities, barriers and determining factors for new or different uses of 3D Printing across Australia's SCDSES?

Opportunities
• 3D printing has the potential to impact a range of Australian businesses • Centralized hubs of knowledge, resources, access to devices and shared skills are critical in learning about/ adopting 3D printing - in US, there are Maker Faires, shops, stores, easily accessed tech – don't have to buy the device first. Tech demo's are pivotal to understanding and use! 140,000 people flock to CES every year to see, touch and play with new tech. This huge tech industry still relies on getting devices into people's hands. • Adelaide launched the first Australian Fab Lab, proving to be a successful model for exposing the broader public to 3D printing • 3D printing fits with Australian landscape and global positionality- ie. distance, cost, distribution of goods and repairs. However an awareness to the larger ecologies of technological use and misuse is imperative. Also fits with ideas of national culture and identitiy- ie. hands-on, DiY, make-do ethic, open to failing, experimenting, having-a-go.

- Australia already has a history of situated and infrastructural experience in Additive Manufacturing [AM] - from 1990s - that could be re-appropriated for new and innovative use. One of the findings of the Wohlers (2011) report was the existence of 390 AM systems in Australia that had yet to be applied to part production use.
- The Wohler (2011) report also put forward the argument of "CEO DR Clarke that Australia would gain much from focusing 'on making products at the high-value end of the global market" and not just exporting raw materials. Additive Manufacturing is one way that this could be realized.

Barriers
• Few current ways for broader consumer market to access or try 3D printing (compared to UK, US) • Limited local access – at the time of writing, only one main distributor. It remains easier and cheaper to buy overseas and import, which results in issues with warranties, returns and repair (ironically) of the device itself • Slow internet connections - limited access to online resources. The larger ecology of this new tech is, by default, also limited – ie. hubs of knowledge, community knowledge, internet connections, distribution models. 3D printing also requires good ideas, design skills, electricity, software, computer skills, materials etc • 3D printing is always and already nested within a larger constellation of forces. It cannot be extracted from the ecosystem of computation, digital literacy, manufacturing, distribution and also a variety of installation protocols. • Conventional regulatory frameworks – ie. there are benefit as as well as disadvantages in treating this new technology according to other conventional regulations – i.e. not being open to how it changes the rules

Q. How should all these questions be considered by Government in an on going fashion in the future?

- Understand current additive manufacturing infrastructures/ use/ skills/ systems already in place and how these might be open to part production application and high-end – See. Wohler (2011) and CSIRO argument for Australia "making products at the high-value end of the global market" rather than exporting raw materials.

- Understand the role of the collective maker movement in Australia – same, different to US/ China/ UK? How Australians approach tech differently to other cultures – often new adopters or different adopters with different adoption curves and ecologies of use.

- Guiding committee with representation from multiple user groups to explore other case studies of use (in US, China). Conduct a study of the narratives and visual culture of 3D printing to see how and in what ways it is being pressed into shape for and by particular audiences, who might benefit and is being left out. 3D printing success stories are not just case of trickle down. Innovation is trickle up too.

- Explore 'choice' and what it means to different groups. How does it relate to convenience? Is it empowering or can it lead to paralysis? Eg. For comparison the UK vs US health system defines choice very differently. The former (currently!) recommends via referral specialist treatment to patients, while the latter opens up the market to enable patients to 'choose' the best treatment and supplier.

11. Current Australian 3D printing use/rs

Distributors	Officeworks is the first Australian retailer to sell a 3D Printer (3D System's Cube for $1499) (Pearce 2014). Depending on shipping, this device is cheaper to buy in US (Hopewell 2014).
Service providers	Australia's first 3D printing store opened in the Rocks, Sydney
Communities	Fab Lab - http://fablabadelaide.org.au/ Hacker spaces
Other	First symposium on the social and cultural impact of 3D printing - http://3dprintingindustry.com/2013/12/11/review-3d-printing-social-cultural-trajectories-symposium/ Education –3D printers into school curriculum.

12. A selection of popular devices on the market (2014/15)

Maker Bot Replicator - 5th Generation

Manufacturer:	www.makerbot.com
Size:	52.8x44.1x41cm Comes assembled for immediate use Designed to look good in an office – 3.5cm full colour display Weight – 16kg
Cost	USD$2899
Material	Renewable plastic - PLA filament – with no peeling, curling, sliding or shrinking. 32% power required to use PLA than last MakerBot PBS filament. Available in an array of colours
Software	Free downloadable MakerWare software: http://www.makerbot.com/makerware/ App and cloud enabled and remote monitoring
Resolution	100 microns layer resolution and (7522 cubic cm) 456 cubic inch build volume. This is 11% larger than Makerbot Replicator 2– same as a layer of printer paper. 24.6 x 15.2 x 15.5 cm (37% bigger than original MakerBot)
Other	One of the first producers of machines for hobbyist market 4th generation MakerBot just released Sharing website - Thingyverse.com – where users share and show their work ABS and PLA filament is £20-£50/kg

Velleman K8200

Manufacturer:	http://www.maplin.co.uk/3d-printer
Size:	Size of an inkjet printer
Cost	£700
Material	Comes with 5m of recyclable plastic - PLA Replacement cartridges cost £29.99 for 1kg of PLA

Software	Comes with free software
Resolution	Dimensions of printable area: 200 x 200 x 200mm
Other	Comes in different colours - black, white, blue, red, orange, green, yellow and pink – the cartridge can be changed in the middle of the print A smartphone case will take 30mins to print

Afinia H-Series

Manufacturer:	http://www.afinia.com/
Size:	
Cost	USD$1200
Material	ABS plastic Filament ($31.99/kg) ($.02-.05/cm3)
Software	3D software provided
Printing	5" cube
	One of the most successful producers after MakerBot Designed to provide an 'out of the box printing experience' Due to low entry point used mostly by schools, hobbyists and small biz

Formlabs Form 1

Manufacturer:	http://formlabs.com/
Size:	8kg, 12 x 11 x 18inches
Cost:	USD$3299
Material:	Formlabs Resin – 1lt bottles $149
Software:	Free downloadable software - http://formlabs.com/pages/software
Printing:	Different process to standard 3D printing process – it doesn't used a plastic wire but rather a liquid as a base material. Therefore it doesn't require heat. A pan fills with liquid and as the laser hits the material, it cures and forms the object. It takes longer but more detail is possible. 125 x 125 x 165 build volume

3D Systems Cube 3rd Generation – two versions (heavy duty Cube X and hobbyist Cube)

Manufacturer:	3D Systems
Size:	The hobbyist version is small and light – designed for desktop
Cost:	Cube X - USD$2799 - $4,400 Cube - USD $1299
Material:	Cube X – Three colours, ABS, PLA Cube - Single colour ABS and PLA
Software:	Cubify Invent software – designers do not need to know or use CAD. Costs extra $49
Printing:	Cube X - basketball size objects Cube - 5.5 x 5.5 x 5.5 inch
	Wifi enabled – people can print remotely

Da Vinci

Manufacturer:	XYZ Printing – backed by New Kinpo Group, one of the largest manufacturing companies in the world
Size:	
Cost:	US$499
Material:	Uses fused filament fabrication (FFF) in 12 colours
Software:	Comes with software
Printing:	7.8 x 7.8x 7.8 in
	WiFi and cloud enabled

The Buccaneer

Manufacturer:	http://pirate3d.com/
Size:	25 x 25 x 35

Cost:	USD$347
Material:	1.75mm PLA
Software:	Free easy software
Printing:	Cloud WiFi printing, mobile enacted 15 x 10 x 12cm Build Volume
	Kickstarter funded project - http://www.kickstarter.com/projects/pirate3d/the-buccaneer-the-3d-printer-that-everyone-can-use ($100,000 goal/ $1,438,765 pledged)

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