2013

3D, SF and the Future

Thomas Birtchnell
University of Wollongong, tbirtchn@uow.edu.au

John Urry
Lancaster University, UK

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Abstract

This article assesses the use of 'Science Fiction' (SF) in visioning or prototyping the potential economic and social consequences of so-called 3D printing. What is becoming clear to many commentators as well as science fiction writers is how rapid prototyping, or 3D printing more generally, could permit many final objects to be made near to or even by consumers on just-in-time 'printing' machines. This revolution in making would have many implications for the economy-and-society in the future by seriously augmenting, or possibly replacing, current systems of manufactured production, long-distance transportation and consumption. These 3D technologies have featured in SF works, including Neal Stephenson's The Diamond Age, Ian McDonald's Brasyl, Charles Stross's Rule 34 and Cory Doctorow's Makers. The article reports on current research seeking to understand the implications of what may be a major new sociotechnical system in the making. Some creative uses of SF are presented in a professional workshop setting. As well the article documents the use of SF as a methodological prototype in forecasting alternative scenarios of the future. SF prototyping could be a powerful tool in the social science repertoire when put into action in forecasting possible technology and business futures.

Keywords

sf, future, 3d

Disciplines

Arts and Humanities | Law

Publication Details

Birtchnell, T. & Urry, J. (2013). 3D, SF and the Future. Futures, 50 (June), 25-34.

Thomas Birtchnell (Corresponding Author)
University of Wollongong
Email: thomas_birtchnell@uow.edu.au
Address: Sociology, School of Social Sciences, Media and Communications,
University of Wollongong, NSW, 2522, Australia

John Urry
Lancaster University
Email: j.urry@lancster.ac.uk
Address: Sociology, Faculty of Arts and Social Sciences, Lancaster University,
Lancashire, LA14YT, UK

1. Science fiction is now a viable methodology in the social sciences and policy.
2. The technique of Science Fiction prototyping is usefully applied to 3D printing.
3. Science fiction writers are already ahead of the game in thinking about the future and these techniques are tapped as a resource for analysis.
4. We examine four futures where 3D printing plays a significant role and furnish these with creative Science Fiction Prototypes.
5. Science Fiction Prototyping is a powerful tool for aiding scenario-building workshops.

3D, SF and the Future

This article assesses the use of 'Science Fiction' (SF) in visioning or prototyping the potential economic and social consequences of so-called 3D printing. What is becoming clear to many commentators as well as science fiction writers is how rapid prototyping, or 3D printing more generally, could permit many final objects to be made near to or even by consumers on just-in-time 'printing' machines. This revolution in making would have many implications for the economy-and-society in the future by seriously augmenting, or possibly replacing, current systems of manufactured production, long-distance transportation and consumption. These 3D technologies have featured in SF works, including Neal Stephenson's *The Diamond Age*, Ian McDonald's *Brasyl*, Charles Stross's *Rule 34* and Cory Doctorow's *Makers*. The article reports on current research seeking to understand the implications of what may be a major new sociotechnical system in the making. Some creative uses of SF are presented in a professional workshop setting. As well the article documents the use of SF as a methodological prototype in forecasting alternative scenarios of the future. SF prototyping could be a powerful tool in the social science repertoire when put into action in forecasting possible technology and business futures.

Keywords
3D Printing, Additive Manufacturing, Science Fiction, Prototyping, Travel, Mobilities

1. Introduction: Prototyping the future

Corporate futurist Brian David Johnson presents 'Science Fiction (SF) prototyping' as an unorthodox, yet core, method in futures work for the computer processor corporation, Intel. As he points out, thinking about the future trajectories of current technological innovations is the bread and butter of these companies where final products appear many years after patents have been submitted and exhaustive testing and prototyping conducted.[1 p. 31] He presents SF prototyping as more than just an experimental indulgence—a guilty pleasure of sci-fi fans like himself—but instead as an emergent tool of the trade in professional forecasting. He describes a 'prototype' in this context as 'a story or a fictional depiction of a product'.[1 p. 12] SF in this reading is not just a resource to draw upon for possible imaginings of future worlds, but also a technique in itself, allowing the generation of scenarios through the development of characters, plots and narrative stories. Johnson is quick to emphasize that these 'stories are not about technology, megatrends or predictions' but rather how the 'future is about people'.[1 p. 5]

This idea of bringing ‘people’ into professional forecasting scenarios chimes well with recent social science experiments in futures work. For instance, the ‘Sixth International Conference on Intelligent Environments’ held a session on ‘Science Fiction Prototyping for Research Innovation’.[2] For social scientists the usefulness of SF prototyping is not only to fantasize about (or fetishize) speculative technologies, a role fulfilled eagerly by the media, but also to encourage vatic insights into the possible unintended consequences and social practices emerging from people’s varied engagements with ‘technology’ and involvement in innovation. This helps to bring people’s social practices into various forms of thinking and planning about the future, from policymaking to marketing.[3]

The term ‘prototyping’ is significant here in both social science methodology and the specific topic of this paper. The focus of the research examined is ‘rapid prototyping’. This is to be found in many settings whereby objects need to be previewed and modeled physically, before being produced on a mass scale in a workshop or factory.[4] Prototyping and modeling remain the main forms of investment and growth for 3D printing, although this is changing with investors and technologists growing increasingly excited about the wider possibilities of 3D technologies as discussed below.[5]

Rapid prototyping derives from a range of ‘printer’ technologies allowing the local production of objects, much in the same way as 2D printers allow the generation of paper documents in offices and homes often distant from where the text has been ‘designed’. Rapid prototyping can be seen as a tentative stage in a wider adoption and engagement with 3D printing throughout contemporary societies and this is how it has been represented in many SF accounts. SF is then ‘ahead of the game’ in envisioning this radical future for rapid prototyping.

The debate about how SF and Futures should work together has a long heritage, particularly in this journal, and has been recognized as useful in foreseeing the social consequences of technology.[6] Indeed, it has long been argued that futurists “should note the agreement between artistic vision and scientific research”.[7] The use of vignettes as powerful devices has been recommended as a strategy for futures work.[8] This is fortified by recent examples of this technique in business visioning.[9] “What both science fiction and the futures workshop have in common is some kind of immersion of the reader or participant in imagined future worlds”[10 p. 888] to better ‘‘value and embed the depth and meaning of people’s experiences into the systems and processes of ongoing city planning, development, and policy making.[11 p. 427]

The important role of SF in futures work is not only found on the fringes of debate. Fictional stories have featured with good effect in the UK Government’s Foresight reports. One of the authors was involved in a novel approach to assessing the possible futures of transport and mobility in one of these exercises.[12] In the report *Intelligent Infrastructure Futures - Towards 2055* four scenarios of different worlds were explored and in each a fictional vignette was deployed. This was called ‘An Urgent Delivery’ whereby the character ‘Mike’ attempts to deliver a package in the radically different worlds imagined within each scenario: ‘His client was expecting 24/7

service, but the world of bits and world of atoms are different, Mike mused'. [13 p. 25]

This use of creative fiction in policy and planning contexts, in order to imagine the social aspects of future worlds, has subsequently appeared in other related academic scenarios work we have been involved in relating to future transport systems, climate change and oil depletion.[14]

In this paper we describe similar experiments relating to the current state of play of rapid prototyping and its possible future impacts upon the movements of objects and people. We link the development of rapid prototyping and more generally 3D printing to fictional futures and highlight the possible ways these visions might interestingly inform forecasting and scenarios building. We then highlight the invaluable role creative SF prototyping played in examining scenarios and collaborating with experts within engineering, design, consultancy and policymaking.[1] Finally, we detail the fictional 'stories' we experimented with and conclude with a discussion of the possible methodological benefits this approach yields for social science.

SF is now recognized as both a valuable asset for thinking about the future in general terms and a possible method for specific inquiries into how people engage with technologies and the degree to which business shapes people. Fictional devices enhanced this research into 3D printing and its potentially awesome consequences.

2. Rapid Prototyping and 3D Printing

There are now various machines enabling the printing of many such 3D shapes, the main differences being in how the layers of the print are built up as they are deposited one on top of the other as the printer releases material from a container or cartridge. There are both low-end consumer level printers available for less than a thousand pounds and high-end industrial printers costing millions. As materials are stratified so a 3D object is produced. Each layer is in effect a digital slice generated through a given computer-aided design. Every next layer is added until the object is fully printed or 'manufactured' with an extruder (fused-filament), chemical agent (binder) or a laser (sintering/melting) changing the state of the material. This process is technically known as 'additive' manufacturing, by contrast with most previous 'subtractive' manufacturing processes that involve cutting, drilling or bashing wood or metal or other materials.

Such 3D printing was initially developed during the 1980s and 1990s to produce prototypes of an object before tooling up a workshop or factory to produce thousands or more copies of the 'real' object. Manufacturing individual prototypes is very expensive but 3D printing is much cheaper. As 3D printing developed, so it was realized that a much wider range of shapes and materials could be produced in quantity and not just the prototypes of 'real' objects. Something like one-fifth of additive manufacturing is now of final products, rather than prototypes, with this figure rapidly increasing. Some are foreseeing 3D printing and additive

[1] This analysis and the science fiction vignettes are drawn from an ESRC-funded research project and workshop on Technologies and Travel, grant number ES/J007455/1.

manufacturing as heralding a techno-utopian ‘third industrial revolution’ for the rich North,[15] others a dystopian era of far greater ‘creative destruction’ than ever before.[16]

Objects now ‘printed’ include medical implants, car parts, jewellery, football boots designed for individual feet, furniture, lampshades, batteries, parts for aircraft, stainless steel gloves, dental crowns, customized mobile phones, bionic arms and soon even artificial blood vessels.[17] Alongside the diversification of objects being printed there are also a growing number of websites offering repositories of designs and online services in a range of possible materials. These online services range from open source and peer-to-peer aggregators of user-submitted designs to multi-national businesses with sophisticated supply chains and products ranging from household objects and novelties to luxury items.

There are important advances taking place in printers and the various components that are part of them—guided extrusion nozzles and laser beams; motherboards, power supply units, memory chips and processors; and housing, frames and build trays. Materials are fed into printers in order to be made into objects and these can be powders, liquids, solids and gases. Materials are derived from various resources including metals, petroleum, minerals and even food. Common material feedstocks are resin, ABS, nylon, carbon, titanium or steel.

Some future innovations are likely to include machines able to print mixed materials at the same time; the printing of active systems such as batteries, circuits, actuators and assembled machines; organic printing of stem cells, organisms and cultures; infrastructure printing of buildings, large structures and vehicles; and *in situ* printing inside the body, in space, in deep oceans, or whilst in motion. The range of materials that can be 3D printed is increasing rapidly. Future advances in materials can be sorted into five distinct groups: rubber materials, hard plastics, polyurethane-like materials, temperature-resistant materials and opaque and transparent materials.[18]

Such 3D manufacturing has potential cost savings. These savings include customizing objects for particular consumers, printing or manufacturing on demand, being able to make small modifications to products at almost zero cost, saving on raw materials since little gets thrown away and the local adaptation of design so as to suit particular environments. There are also significant possibilities of recycling both the unused powder and existing objects.[19]

But the biggest saving is that consumers can manufacture on their own ‘printer’, or on one nearby, many objects they need or desire. This would go against the grain of the current ways government policy funds and supports manufacturing through big loans to major carmakers and manufacturers. Instead what would be required are small injections of investment to support the quick manufacturing of complex objects through 3D printing.[20] If this idea of small, dispersed centres of innovation came to fruition, 3D printing shops on the high street or in shopping centres or possibly in the home could proliferate, all serving distinct functions and demands. Some would be niches and others would dominate. Overall there are many possibilities for a much greater localization of manufacturing—for some non-critical products the capacity to scan the object and then make endless copies, an “infinite aisle”, by or near

consumers would produce large cost savings and reduce transport-related emissions and oil use, assuming that roughly the same number of products is being manufactured worldwide.[21 p. 226]

This could be epochal since it involves a completely new system transforming the very notion of manufacturing in a "hugely creatively disruptive" way.[22] Already estimates are being made that the global 3D printing market will reach approximately US$3 billion by 2018 according to the executive summary of the report '3D Printing—A Global Strategic Business Report' by Global Industry Analysts.[23]

But there may be forming a system here where 'manufacturing' is relocalized and undertaken on a small scale. This would be similar to the innovation found in the Internet whereby music or films or books are accessed and downloaded by consumers.[24]

Potentially vast savings in transportation costs could mean that at some point low cost manufacturing centres, now for the most part sited in Asia, would no longer possess the comparative advantage in manufacturing. Digital objects can travel almost for free although oil is the basis of many powders used in such printing/manufacturing. Conversely there could be an intensification of transport as demand for raw materials for printing is added to the vast movements of made objects by freight.

So then a system innovation would be highly significant. Geels describes how major innovations in science and technology tend to be very wide-ranging and not confined to the 'technical'. System innovations, such as the transformation of manufacturing, involve not just changes in technical products, but also he says: 'policy, user practices, infrastructure, industry structures and symbolic meaning etc.'.[25 p. 165] This could lead to an 'after the factory' stage of development.[26] Web-based digital technologies could play a central role in global networks of digitally transferable and downloadable files containing designs and blueprints that home computers could then build, or print, anywhere and out of anything.[27] Does 3D printing have the capacity to bring home some at least of the offshoring of work that characterized the past thirty years?[28] Is additive manufacturing a world-changing innovation that would generate a new long wave of sociotechnical change? These are obviously immense topics and in order to help think about these, we turn to fictions of the future.

3. Fabricators in SF

There are significant examples of scientists being influenced by the stories of writers. In many of these cases the fiction writer works in dialogue with scientific inquiry extrapolating in ways scientists are unable to do as well as think through the social consequences of technology and innovation. One famous example is Jules Verne in his 1865 story *From the Earth to the Moon.* Three weapon designers, the Gun Club, build a space cannon, the *Columbiad*, loaded with powerful ammunitions explosives in order to launch their craft to the moon. The 'fathers of modern rocketry', Robert Goddard, Konstantin Eduardovich Tsiolkovsky and Hermann Oberth, were apparently all directly inspired by Verne's ideas as to how to realize space travel.[29 p. 15]

Perhaps the most commonly referenced science fiction 3D printer is the *Star Trek: The Next Generation* 'replicator' alongside a 'bio-matter resequencer', which

produced usable material from waste. These devices have a range of designs to be produced on file. The replicators on the space ships produced both food as well as spare parts including uniforms, clothes, toys and souvenirs although weapons are prevented by safety protocols. And in *Star Trek: Deep Space Nine* industrial replicators even produce ships and vehicles. The replicator was even referenced by the company Makerbot, naming one of its flagship printers after it. Interestingly, the replicators in Star Trek also produce food, something being pioneered by researchers at the University of Exeter with a chocolate 3D printer.[31]

Neal Stephenson's *The Diamond Age* includes graphic descriptions of diamond vacuum chambers housing 'matter compilers', which resemble 3D printers in being able to create prototypes, except with the added twist of creating objects from 'feeds' of molecules augmented by nanotechnology.[32] The Feed resembles the Internet carrying both molecules and energy to distributed compilers in a decentralized concept of production. This is a hi-tech future where sophisticated machines produce objects of unparalleled precision in localized forms of manufacturing.

In Ian McDonald's science fiction *Brasyl* shops called 'Atom Shops' print "necklaces, hats, earrings, formal masks, body armor, watches, costume shades, I-clothing".[33 p. 120] In this future 3D printing is a method of procuring unique objects, such as shoes, tailor-made and custom fitted to the body. This is a vision of community printing where roaming facilities provide individuals with access to customized goods, often forgeries of branded products.

Charles Stross's *Rule 34* is a world of unmonitored and illegal fabs being used for near-future crime narrated in a street patois. Fabbers take design templates from repositories and extrude on police monitored home printers all sorts of objects from coffee coasters to children's toys. Unmonitored fabs are used for all sorts of illicit projects from portable drug factories to printed handguns.[34]

The book *Makers* by Cory Doctorow concerns a future of post-industrial manufacturing where a shift has taken place in the US from industrial, outsourced production to local manufacturing using high-end 3D printing based on venture capital-funded bureaus and small businesses.[35] This is a world of business failures where the niche uses of printing for only prototyping do not pan out into wider commercial success.

4. Researching futures: Four fictional futures for 3D

We constructed four SF accounts of the future drawing on media commentaries, twitter feeds, science fiction and insights from experts in the public domain from conferences, interviews and opinion pieces. The Futures Company facilitated the workshop held in April 2012 with around twenty-four 3D engineers, consultants, designers and policy-makers responding to and developing these fictional futures.

Four scenarios to 2030 were developed as self-contained 'worlds' determined by their position on two axes of uncertainty: people's engagement with 3D printing and the degree of its corporate-ization. The first axis measures the affordability of the technology, the capacity for users to learn and master everyday functions, and for

people to develop social practices around the technology as it becomes ‘normal’. The second axis concerns the degree to which large corporations dominate the development of 3D printing or whether groups and individuals within civil society are more prominent. This relates to various issues, of intellectual property and patent rights, the sources of innovation, the nature of organizations, patterns of co-production or hierarchical systems with distinct roles of inventors, developers and managers.

In plotting these four distinct worlds on these two axes attention was paid to the systems and challenges emerging within societies up to 2030, including the impacts of climate change and energy scarcity. The participants were briefed about the scenarios through fictional stories sent to them by email and also included in documentation presented in the workshop. In the next section we set out these four fictional futures, futures that are somewhat SF in tone and drawn from fictional and factual accounts of various future developments.

4.1 Desktop factories in the home

The first scenario *Desktop Factories in the Home* is drawn from media speculation around a home innovation occurring in a similar fashion to the ubiquity of desktop Personal Computers (PC) where individuals are engaging with technology on an everyday and personal basis. Corporate control over the innovation has been reduced by open source sharing of designs and technologies and piracy. In this scenario 3D scanners and/or printers are ubiquitous in the home and made available for individuals to engage with a range of external suppliers of designs and high-end products, particularly if desktop powder sintering units, such as the ‘Blueprinter’ from ApS-Denmark or the University of Twente’s ‘Pwdr’ open-source laser sintering printer, leave the lab and enter the home.[38]

The character is introduced to highlight the important areas 3D printing would impact upon, namely, education, childhood and family life.[39] We imagined, in the same fashion as the early days of home computing, there would be competing demands for printers in the home. Children would lead adoption of these products through their curiosity as well as their introduction to the medium through school projects and technical classes:

> My name is Ben and I was born in 2020. I'm trying to finish my homework but my sister, Lucy, is using the printer again for the new bracelet she's been designing all weekend. Everyone at school has a 3D printer at home now (we finally got one last year) and the teachers regularly give us assignments to design and print out all sorts of things to bring to class.

We then provided an example where some potential social issues might play out. For ubiquitous 3D printing in unregulated settings (the home) there are many possible

unintended consequences for Intellectual Property (IP). Indeed, it was a similar home revolution in peer-to-peer (P2P) websites and transferrable digital music files, which had major consequences for the global music industry. These challenges emerged not from the corporate sector, but from small startups founded by young users, sometimes at school: Shawn Fanning, co-founder of Napster, who initially built the site to share his music with close friends around the country, is a case in point. For 3D printing the unregulated sharing of digital files printable as physical objects is a strong possibility:

> Today we worked on a history project to imagine how medieval villagers built their towns. My job in the group was to print out what I thought the village smithy might look like. I cheated a little, going on to a peer-to-peer website with my dad and downloading a replica from an archaeological survey, then messing about with it to make it my own; I hope the teacher doesn't realize!

The wider world in the scenario was also introduced and the limitations of the technology were made clear based on current trajectories of innovation. For instance, the laser sintering, or electron-beam melting, printers are unlikely to be found in the home any time soon and this ruled out metal products being produced by consumers themselves. Thus, it was necessary to stress other manifestations of the technology alongside the desktop printers in the home:

> My dad is a real expert: he works in one of the local factories where they have electron-beam printers. He designs and prints motorbike parts in steel. I wish I could come into his work and use one, but he says it's too dangerous and you need proper training.

The prototypes also played the role of introducing possible ideas about alternative business visions in this scenario. One idea raised in interviews with experts prior to the workshop was manufacturers of complex products, such as white-goods, making online repositories available to their customers of parts. These databases would carry downloadable designs, which product-owners could browse via identification numbers, and replace modular non-critical parts themselves after printing them out at home. There are many issues with this such as the relative part strength of 3D printed objects, delamination due to the relatively weak layering process and the downsides of 3D printing versus injection moulding.[40] Repositories would allow the diagnosis and addressing of simple issues most likely under warranty, more complex materials and electronics would still require repair by specialists:

> I only have an hour on the printer, as my mum also wants to use it to make a part for the dishwasher, which is broken. She will go onto the manufacturer's website, put in the part's identification number, and print out the new bit. Hopefully the part will just click into place although it's never that easy in real

> life and sometimes she complains to my dad that we should buy a new dishwasher:

By using characters and plots the vignettes created a space in which to imagine wider social practices and also engage in systems thinking. In this example the notion of a ‘circular economy’ is tested where a complementary 3D ‘shredder’ allows printed objects to be recycled with consequently new ways of doing everyday tasks. As well, the vignette comments on the possible impacts of current business models—companies selling expensive printer cartridges compatible with only single models—and their development in future to similar technologies:

> I think she would like one of the new shredders, which you just throw your old knives and forks into instead of washing them up. Mum says it's much cleaner and more convenient and scolds my dad for making us live in the dark ages! Last week I got into trouble because I printed out my little smithy nearly 20 times to see what it would look like as I made each modification. My dad says the printer cartridges are really expensive and that it's wasteful and bad for the environment to use so much material on things I don't need. You can get cartridges everywhere now, even in the local corner-store. The companies who make the printers also make the cartridges.

The vignette also introduced some backcasting, suggesting the future and working backwards to see how it might come about. In this case the logistics of a future distribution service for materials is prototyped:

> A couple of years ago they changed the size of one of the most popular models and everyone had to go out and buy a new one! We have started to buy our cartridges online and they are delivered by the mail to our house. My dad says that this is how many of the objects we now print used to be delivered and it would be difficult because you'd never be at home when they arrived so you'd have to pick them up from the local post office instead. The cartridge designers cleverly made them the same size as the mail-slot on our door so the cartridges can be pushed through.

Finally, the vignette also highlights some unintended consequences of this future, such as waste stemming from taken-for-grantedness of 3D printing:

> Next year we will get a local recycling station so we can just take the unwanted objects down to them to get shredded into more printer stock. Our shed is full of all the old bits and bobs we are always printing out and breaking.

> I couldn't imagine life without a printer at home. Where else would I get all the toys, tools, clothes and things we use around the house and at school? I can't imagine how they managed before home printing.

4.2 Localized manufacture

This second scenario presents a vision of a future of high-end printers being made readily available locally with high individual engagement in the processes involved. These would operate in a corporatized free market so competition between bureaus for customers would be fierce. This would impact both retailers and customer and more significantly global systems of production. 3D Creations new pilot operating within Milwaukee's first 3D printing retail and service bureau in a niche example of this future now.[41] The character describes in detail the shift that occurred due to this innovation:

> My name is Amran and I was born in 2007. The shift seemed to just happen without anyone realizing. It was shopping-as-usual but behind the scenes everything was changing. In the back of the shopping centres the inventories, pallet jacks, shelf stackers all pretty much disappeared over night. In their place appeared rows of complicated looking boxes with little screens showing off even more complex insides. The technology seemed second nature to staff already used to printing paper. But these printers now produce most of the things we all want to buy with the added bonus of offering custom designs. Hardly any products say Made in China anymore except ones you pick up in the charity store or on computers and those kinds of things.

The character in this vignette describes the experience of shopping for shoes and describes new financial systems as well as social issues around how consumers might be drawn, or reject, this new innovation: 3D scanning allows customization but this form of manufacturing is not as 'rapid' as anticipated:

> Today I am going to buy some new shoes for a job interview. You can model the shoe you want online and then go and pick it up from the nearest outlet. I've already paid for it online with my credit card, but instead of selecting home delivery, I chose to try it on in-store instead. They have a policy where if it doesn't fit perfectly according to the scan I submitted for my feet they'll print another one. They also scan your feet in-store as well if you don't have your own scans, although the shoes don't print out instantly (now that would be cool); instead, you have to come back the next day.

The wider system is introduced, here involving the aggregation of retail shops into single suppliers printing a range of products. As well the production of alternative kinds of products derived from customization and demands for bespoke designs, foretelling new business visions based on mass-customization rather than mass-production:

> Many of the outlets print multiple products so you can collect toys for your kids as well as your shoes from the same place. I have an important meeting so I want some shoes that look good, but they've got to be comfortable too. I have

> brought along a piece of my Great Grandmother's old dress from the 1920s. The colour and design is just amazing. I'm hoping the store assistant will be able to scan it and print me some shoes to match.

In this scenario the engagement of individuals with the technology is high, so that it is anticipated in the vignette that they are peer producers in the design process, a part of a business vision rather than a self-led movement. Here possible inspirations for involvement include comfort, convenience and aesthetic qualities. This might bring up some ‘nostalgic’ social practices, which supplant mass-production:

> Of course, the comfort is important too. A couple of months ago I had some shoes printed and they fitted like a glove –it's amazing to the see the inner sole with the same curves and dimensions as my foot. My Grandfather used to say this is how they did it in the old days—everyone would have their own wooden 'last' carved to match their foot. He says it's surprising how long people tolerated ill-fitting shoes!

Implicit in 3D printing is the complex geometries and possibilities for individual expressions, which makes business visioning around the innovation particularly amenable to creative prototyping in highly corporatized scenarios. Business visioning through vignettes in this context allows normal situations, the trying on of a shoe, to be juxtaposed with more futuristic practices—laser scanning and sintering:

> My friend Ruth buys her own personalized glasses. She orders the lenses then prints the frames to the exact measurements but with completely different frames. It's become part of her identity to try out a new colour or design of glasses every week and the lenses just slot in and out with a click! Sometimes the store manager will take people into the back room to see the shoe being printed. The little kids just love seeing the laser printing out their shoes layer by layer.

As well, other relevant business interests can be flagged where innovation might take place and overlaps occur in the future between different visions. This is the case with medical 3D printing:

> I work for a biotechnology firm and we use bio-printers to make organs and other transplants. Often I’m struck by how the processes are in many ways quite similar. I just wish they could print my shoes instantly instead of having to wait!

4.3 Community crafts

This third scenario is drawn from examples there are now of co-production and collaboration in places of low corporate influence, such as libraries, government buildings, collectives, public/private partnerships, museums, galleries and so on. Emphasized in this scenario is low individual engagement so that the role of mediators and middle-people is paramount, either technical personnel or information managers. The use of 3D printing in community settings without profit is already being trialed in places. The Fayetteville Free Library (FFL) initiative ‘3D Printing@

The Library' in New York is one such example organized by community mediators. And this is the inspiration for this vignette, where the character Jill goes to her local library to print:

> My name is Jill and I was born in 1997. Tonight after work I am looking forward to going to the local library for my weekly crafting group. A couple of years ago the council gave the library a big grant to purchase the new range of large multi-material 3D printers in a special centre designed for the community.

The power of vignettes lies in capturing current technological issues in society and transposing them into the future. In this case issues arising from interaction with mediators, who engage with the technology on behalf of the users, and also in the use of a shared non-corporate community space:

> At first, I was intimidated by the large machines (standing as tall as me against the wall) although they do look a lot like the centralized paper printer we had down the hall in my office, which always seemed to be going wrong and jamming! These printers all seem to work fine, except once when a young man tried to mix in his own materials; we found out he was trying to print using ground flour! From now on the technicians all watch the younger users really closely. I think they are also afraid of illegal and pirated items being printed. One of the printers still smells a little like burnt bread.

In this scenario it was important to convey to the workshop participants the axes of uncertainty behind its design. In order to show relatively low engagement with the technology, the character's interaction with the library personnel and equipment is depicted, particularly emphasizing assistive technologies in support of the, most likely, underpaid or volunteer mediators:

> There is a digital information officer on-hand most days to assist with converting the files we bring in from home or, for those of us who are real beginners, getting us set up on the computers the library provides for people in the community who don't have software at home. The software in the library combines together all sorts of templates in an easy to use interface. You simply select the object you want to make from a list, which you can change as much as you like with the haptic controller. The software on these library computers is far simpler than my home program, but I prefer the convenience of designing in my own time, so I attended a special course the library also offers once a month; I was so excited about what I learnt that I ran out and bought one of the small handheld 3D scanners! The first thing I scanned was my dog and the librarians all laughed when they saw the life-size replica emerging from the powder with its bemused expression.

As in the other scenario vignettes the wider systemic attributes of the 'world' are a crucial feature to convey to the workshop participants, including materials and the transportation of resources for printing. The use of creative prototypes was instrumental in exploring these landscape features:

> Once a week the library gets a big delivery of new cartridges for the printers and a special technician comes in to replace them and take away the empty ones. Our group meets the day after the delivery so we never have any problems with running out of materials. Apparently they come straight from a special oil refinery on the coast, which produces both petrol and feedstocks for the regional market. Seeing the oil company's logo on the side of the truck certainly raises some eyebrows about the environmental aspects of what we are doing.

As this scenario's principal ideas were of 'community' and 'crafts', and these ideas were lost in translation somewhat within the prosy report-style brief, playing with science fiction gave us an edge to getting our ideas across, through embellishing terms with cursory subplots. One area we flag is hobbyists and enthusiasts driving innovation, such as printing model trains: [42]

> The craft group is as much a social occasion as anything else. We all bring in homemade cakes and have many tea breaks while the printers are working. We all help each other out and there are so many eclectic interests. My crafting friend Michael is running a small home business and sells his own range of model train accessories. We all marvel at the incredible detail of the houses and railway stations. He assures all his clients the parts he sells them are unique. Every month we have a local maker-fair where we all have stalls selling our items and other homemade things.

As in the other scenarios, unintended consequences could be examined through the vignettes, in this case alternative financial systems and bartering. And counterpoints could be made to other 'worlds' highlighting their distinctness, as in the reference to desktop units:

> There is a special online system for bartering at the market. You can trade for produce or other crafts tax-free instead of using cash currency, which we all think is marvelous as it keeps everything local. I once looked into buying a desktop printer, but these are too small and the quality and texture of the products isn't as nice. They are a bit of a gimmick. And I wouldn't want to go without my weekly craft group.

4.4 Only prototyping

Here the fictional narrative imagines a future where the world has not developed as the technology optimists envisaged. A transport example here would be Concorde, where the fastest and most advanced passenger plane was not remotely as successful as the much more mundane mass Boeing 747. In the field of communications the relative failure of video conferencing would be similar in that the hype has not been so far realized, with many problems of standardization, maintenance and consistency similar to those specified below. The fiction ends with the bubble bursting somewhat similar to the dot.com bubble bursting in 2000:

> My name is Juliet and I was born in 2004. I read about 3D printing in the news and that's why I got together a bunch of friends and an angel investor to put together a garage of industrial printers. We'd been tinkering around with

> Makerbots and other open source small footprint desktop printers for a while and we decided to start a niche bureau drawing on our IT and engineering experience. We were inspired by how the company 3D Systems had gone from a garage to a multinational company almost overnight. We wanted to be part of the next computer revolution, although at the time we'd forgotten about the dot.com bubble.

In this dystopia 3D printing has not met expectations of a renewal of manufacturing in the global North. It explores some possible reasons why this might not take place and also introduces some of the geopolitics around this possible innovation:

> Our idea seemed risk-free. There would no inventories, no transport and importation costs and no difficult sub-contracts with factories in China. Our idea, we thought, was sound. Building companies always need to have complicated scaffolding and they often have to purchase small steel parts in bulk or at great expense individually. We promised to print small runs of unique steel parts with amazingly quick turnarounds and all done locally. Nothing shipped over from China.

By using character monologues the future is personalized, which is useful in a dystopia where small niche variables can lead to unintended consequences:

> But once we'd actually bought the printer things started to go wrong. First, the company kept messing about with the cost of the materials. We'd been assured that the feedstocks would always be affordable, but hadn't realized just how much powder we'd go through. Then another company who we sourced materials from started changing the size of their orders. We had to source alternatives from elsewhere and have not been satisfied since then that it's worked out well for us.

As in the other vignettes inferences are drawn from the present, in particular the paper printer. In a world with low engagement on the individual level the reliability and intuitiveness of the technology plays just as an important role in its adoption as the products it might enable. This issue is captured in the vignette:

> Then the printer completely broke. There was some issue with the warranty contract and we couldn't get consistent repairs. It just kept on breaking and this added delays to our orders. Then the technician the 3D printer supplier had trained for us left to work for a competitor. We could barely turn the thing on let alone refine and often re-engineer the custom objects supplied by customers. In some cases we'd have to cancel jobs because we couldn't get their file format to work with our machine.

In business visioning of a dystopia careful attention also needs to be paid to hype cycles, trends and fashions as well as technological pitfalls. And there is as well ‘black swans’—events which are unforeseen but have massive consequences for society. One possible black swan experimented with in this vignette is the use of complex geometries and laser sintering of metals in high risk products:

> We weren't alone in being disappointed in how 3D printing has panned out. The market was saturated with desktop prototypers, middle range machines and other start-up bureaus. Quite a few bureaus shut down for lack of consumer interest and difficulties with machines. When it emerged that the aeroplane, which broke up in mid-air over the US, had been using 3D printed parts the game was up. Consumer sentiment, and investor support, crashed. Who knows if in the future it'll take off driven by some demand we don't yet know about? But at the moment it appears that the bubble has burst.

5. Conclusion: Business visioning

This article has thus demonstrated the use of SF in particular and fiction more generally in visioning the potential social and economic consequences of so-called 3D printing. 3D printing could permit many final objects to be made near to or even by consumers on just-in-time 'printing' machines. This revolution in making would have many implications for the economy-and-society in the future by seriously augmenting, or indeed replacing, current systems of manufactured production and consumption all occurring at a distance.

We have also seen how 3D technologies have featured in various SF works, from *Star Trek: The Next Generation* to Cory Doctorow's book *Makers.* 3D printing is also emerging as a subject for social science research alongside creative fiction and will undoubtedly produce further food for thought.

The paper reports on research seeking to understand the implications of what may be a major new sociotechnical system in the making. We developed four fictional accounts of alternative scenarios of the future. These four stories were used in a scenario workshop to engender debate and discussion amongst 3D printing experts—technologists, entrepreneurs, activists and commentators. The science fiction/creative prototyping vignettes were well received by the participants and the extracts used in the workshop blended into the other futures methods used on the day. They also gave the workshop organizers a shape for the four future worlds enabling them to focus in on the specificities exclusive to each scenario. There can be no doubt that in thinking the future these fictional accounts were productive. SF prototyping is a powerful tool in the social science repertoire when put into action in prototyping futures and planning for the range and degree of variables emerging over the next couple of decades that have at their core 3D printing.

Notes

[1] B.D. Johnson, Science Fiction Prototyping: Designing the Future with Science Fiction, Morgan & Claypool Publishers, San Francisco, 2011.
[2] V. Callaghan, S. Egerton, B.D. Johnson, Workshop Proceedings of the 6th International Conference on Intelligent Environments, in: R. López-Cózar, H. Aghajan (Eds.), IOS Press, 2010.
[3] E.S. Watson, P. Mika, Matt, The Dynamics of Social Practice: Everyday Life and How It Changes, Sage Publications Ltd, London, 2012.
[4] N. Hopkinson, R.J.M. Hague, P.M. Dickens, Introduction to Rapid Manufacturing, in: N. Hopkinson, R.J.M. Hague (Eds.), Rapid Manufacturing: An Industrial Revolution for the Digital Age, John Wiley & Sons, Chichester, 2006, pp. 1-4.
[5] P. Seitz, 3D Printers Graduate from Prototypes to End Products, http://news.investors.com/SiteAds/Sponsorship.aspx?page=/NewsAndAnalysis/Article.aspx&position=sponsorbtn1&identifier=IndustrySnapshot&tile=2&ord=3251192575744998, 2012, Date Accessed: 20 August 2012
[6] D. Livingston, Science Fiction as a Source of Forecast Material, Futures, 1 (1969) 232-238.
[7] P. Suedfeld, L.M. Ward, Dark Trends: Psychology, Science Fiction, and the Ominous Consensus, Futures, 8 (1976) 22-39.
[8] I. Miles, Stranger Than Fiction: How Important Is Science Fiction for Futures Studies?, Futures, 25 (1993) 315-321.
[9] G. Graham, Interaction Space, in: Creative Science, CsF11, Nottingham, England, 2011, pp. 1-10.
[10] R. Love, Robot Futures: Science Fiction and Futures Studies Methodologies in Action, Futures, 33 (2001) 883-889.
[11] N. Collie, Cities of the Imagination: Science Fiction, Urban Space, and Community Engagement in Urban Planning, Futures, 43 (2011) 424-431.
[12] G. Lyons, J. Urry, Foresight: The Place of Social Science in Examining the Future of Transport, in: Evidence-Based Policies and Indicator Systems 11-13 July, London, 2006, pp. 11-13.
[13] A. Curry, T. Hodgson, R. Kelnar, A. Wilson, Intelligent Infrastructure Futures the Scenarios – Towards 2055, in, Foresight, London, 2007.
[14] J. Urry, Mobilities, Polity Press, Cambridge, 2007.
[15] P. Markillie, A Third Industrial Revolution, http://www.economist.com/node/21552901, 2012, Date Accessed: 22 April 2012
[16] A. Peters, The Third Industrial Revolution - a Response to the Economist | Opendemocracy, http://www.opendemocracy.net/openeconomy/aaron-peters/third-industrial-revolution-response-to-economist, 2012, Date Accessed: 27 April 2012
[17] K. Moskvitch, Blood Vessels Made on 3D Printer, http://www.bbc.co.uk/news/technology-14946808, 2011, Date Accessed: 15 January 2012
[18] M. Silverman, How Does 3D Printing Work, Anyway?, http://mashable.com/2012/08/01/how-does-3d-printing-work/, 2012, Date Accessed: 16 August 2012

[19] C. Ricca-Smith, Could 3D Printing End Our Throwaway Culture?, http://www.guardian.co.uk/technology/2011/nov/17/3d-printing-throwaway-culture, 2011, Date Accessed: 4 January 2012
[20] V. Wadhwa, How to Save the Global Economy: Think Small - by Vivek Wadhwa, in: Foreign Policy, FP Group: The Washington Post Company, Washington DC, 2012, pp. 1-2.
[21] C. Anderson, The Long Tail: How Endless Choice Is Creating Unlimited Demand, Random House Business Books, London, 2012.
[22] A. Done, Global Trends, Palgrave Macmillan, Basingstoke, 2012.
[23] M. Raby, 3D Printing Market to Hit $3 Billion by 2018 - Slashgear, http://www.slashgear.com/3d-printing-market-to-hit-3-billion-by-2018-23239870/, 2012, Date Accessed: 3 August 2012
[24] J. Rifkin, The Age of Access: How the Shift from Ownership to Access Is Transforming Modern Life, Penguin, London, 2001.
[25] F.W. Geels, Multi-Level Perspective on System Innovation: Relevance for Industrial Transformation, in: X. Olsthoorn, A.J. Wieczorek (Eds.), Understanding Industrial Transformation: Views from Different Disciplines, Springer, Dordrecht, 2006, pp. 163-186.
[26] S. Fox, After the Factory [Post-Industrial Nations], Engineering & Technology, 5 (2010) 59-59.
[27] H. Lipson, This Will Change Everything, http://www.newscientist.com/issue/2823, 2011, Date Accessed: 3 January 2012
[28] G.F. Davis, Re-Imagining the Corporation, in, The University of Michigan, Ann Arbor, 2012.
[29] H.E. McCurdy, Space and the American Imagination, JHU Press, 2011.
[30] J. Verne, From the Earth to the Moon, Barnes & Noble Publishing, New York, 2005.
[31] L. Hao, C.Y. Kong, 3D Chocolate Printing Technology | Choc Edge Limited, http://www.chocedge.com/Technology+PVFUTXdBVE02a25jdmRXWjBGMlk, 2012, Date Accessed: 20 August 2012
[32] N. Stephenson, The Diamond Age, Penguin Books, London, 2012.
[33] I. McDonald, Brasyl, Gollancz, London, 2007.
[34] C. Stross, Rule 34, Hachette UK, London, 2011.
[35] C. Doctorow, Makers, London, HarperCollins, 2009.
[36] K. MacLeod, Ken Macleod Interviews Cory Doctorow at #Edbookfest 2011, http://www.youtube.com/watch?v=qpn9jLkucLQ&feature=youtube_gdata_player, 2011, Date Accessed: 3 July 2012
[37] M. Linz, Scenarios for the Aviation Industry: A Delphi-Based Analysis for 2025, Journal of Air Transport Management, 22 (2012) 28-35.
[38] D. Scott, An Open Source Powder Based 3D Printer : Is Desktop Laser Sintering on the Horizon?, http:///blog/archives/1559-An-Open-Source-Powder-Based-3D-Printer-Is-Desktop-Laser-Sintering-on-the-Horizon.html, 2012, Date Accessed: 19 August 2012
[39] D. Barlex, M. Stevens, Making by Printing – Disruption inside and Outside School?, in: PATT 26 Conference, Technology Education in the 21st Century, Linköping University Electronic Press, Linköpings universitet, Stockholm, Sweden, 2012, pp. 64-73.

[40] A. Dean, 3D Printing in the Home: Reality Check, http://develop3d.com/features/3d-printing-in-the-home-reality-check, 2012, Date Accessed: 19 August 2012
[41] J. DePinto, M. Juranitch, 3D Creations, http://3dcreationsllc.com/, 2012, Date Accessed: 14 August 2012
[42] TrainTalkTv, Ttv 020 West Coast Railway Museum, Makerbot for Railroad Modelling, Supertrain Train Show - Youtube, http://www.youtube.com/watch?v=Kh8mDk4yrGc&feature=player_embedded, 2011, Date Accessed: 12 September 2011