Making Culture

The Spaces Of Community Personal Fabrication.

Byera Hadley
Travelling
Scholarship
2014

THE FUTURE IS HERE AND IT'S IN A MAKER SPACE.

COMMUNITY & COLLABORATION	NEW MODES OF PRODUCTION	CITIZEN EMPOWERMENT

Contents

Photo @ Hatch Makerspace

Photo @ The Makers Place

> ***"We are all designers now, its time to get good at it.***
>
> Chris Anderson (2013)

introduction

Imagine a city whose inhabitants have a direct hand in shaping their environment ensuring additions address specific social issues. Imagine communities that don't rely on imported goods or generic mass market solutions to solve personal problems. Imagine a household whose possessions are unique and tailored exactly to their life's needs. Imagine bodies clothed in personally designed and crafted fabrics customised for body shape and self expression. The means to make is the key to these speculative scenarios and is seen in this study as an act of empowerment.

This project, "Making Culture" was initiated after identifying a global trend in the increased affordability and access to digital tools for design and fabrication. Some are predicting a shift in the means of production, from large industrial companies back to the everyday public, not seen since before the advent of modern capitalism (Rifkin 2015).

Increased innovation in digital manufacturing machines has caused them to get smaller and more affordable. The effects of these two factors in the realm of making is analogous to the democratisation of software development due to the internet. The creator of the Fab Lab foundation Neil Gershenfeld has identified that an emerging democratisation of digital fabrication is allowing a shift from the ability to manipulate bits, to that of atoms (Gershenfeld 2006).

In this project I use "Personal Fabrication" as a blanket term for digital making. Within maker culture there are many types of maker groups, so in order to bring them all together I adopted Neil Gershenfeld's nomenclature. Put simply, maker spaces, Tech Shops, or hacker spaces as many were previously known, provide physical locations and access to digital tools for empowerment to develop. These spaces allow communities of people to form with shared social and cultural values. "Making Culture" examines the communities and the virtual and physical spaces that develop around digital making. The study identified key case studies in the US and Australia that represent this emergence in order to learn how they operate and what they achieve.

In order to geographically concentrate case studies in the United States, two cities, Boston and San Francisco, were chosen to provide complimentary and contrasting observations. Boston is the home to the world's first Fab Lab, has a very strong grass roots maker community, and has the conditions for entrepreneurship around digital technology and fabrication. San Francisco on the other hand is the epicentre of the American Tech and self titled "Maker Pro" industry whose aims are to profit through the culture of making.

The spaces identified and visited all similarly occupy forgotten, unwanted or awkward parts of the city. They re-use and adapt existing architecture, opportunistically inhabiting space, geographically distributed by economic real estate forces. Inside these spaces varieties of people engage in making projects whilst connecting socially, seeking common goals, observing collective codes of

3D printed signs lead the way to Adelaide's hidden away Fab Lab.

> ***"The real strength of a Fab Lab is not technical; it is social."***
>
> Neil Gershenfeld (2012)

behavior, and sharing knowledge and experiences through participation and collaboration.

This study is intended to be read as both a source of information in engaging with digital fabrication and the maker movement, and a critical assessment into its capacity for transformative change here in Australia. It is divided into discrete sections that explore particular areas of significance identified live in the field.

Tools, explores the digital equipment utilised by maker communities and offers insight into the fabrication processes they make possible.

Case Studies, describes the spaces visited in the study through data collected in observations, photographs and conversations.

Movements, delves into the social structures that were identified amongst the spaces and attempts to identify differences in their motives.

Types, highlights and categorizes the typologies of space the maker movement is inhabiting.

Context and connectivity, assesses the importance of context for the emergence of maker communities and addresses the significance of connections, or networks, in their comparable success.

Outcomes, summarises what is made in the maker spaces visited and pays attention to their potential to effect society beyond.

Maker Con / Maker Faire, is a journal of my experiences at the MakerCon conference and Annual World Maker Faire held in San Francisco in May 2015.

LANDCRUISER CUSTOMISATION at the San Mateo World Maker Faire .

Tools Of Personal Fabrication

Making Culture, was proposed on the observation that digital fabrication tools were becoming more affordable in society, and therefore would start to have social influence. This section will explain what these tools are and what they can achieve in the hands of a novice.

Software

CAD (Computer Aided Design) software provides the vital link between having ideas and realising them through digital fabrication machines. Computers cannot design their own forms (yet) but do communicate with fabrication machines using specific code languages. Equally fabrication machines cannot simply manipulate materials without clear production instructions, this is where CAD comes in.

In the 2D domain there are two types of software, those that manipulate lines (vector) and pixels (raster). For use in digital fabrication a vector line is of most use as it provides information about paths, and therefore can be used to guide a CNC router or laser axis. 2D methods are useful when making is through a process of layering, such as contouring or rib modelling.

Some CAD packages can also compute and visualise 3d objects which provide different workflows and techniques for generating form. Broadly they can be split into professional and consumer packages based on complexity and capability but free student copies and trial licences (and cracks) mean that there is considerable cross over. Overall there are two 3d modelling paradigms that exist, software that utilise NURBS (Non Uniform Rational B-Splines), and those that manipulate Polygon Meshes.

Once virtual 3d form has been created it must be translated into an understandable set of instructions for fabrication machines. While some industrial design software have this built in it is generally the role of CAM (Computer Aided Manufacturing) software. The file format a machine understands depends largely on the open or closed attitude of the machine maker. Within an open culture generally CNC routers and laser cutters work via DXF files for 2D or gcode for 3D.

In 3d printing the general format is STL but as competition has increased in consumer printers some companies have sought to create proprietary formats that rely on bespoke software to interpret this initial STL file. Those with sense have realised that moving the opposite way and using an open and consistent file format means that there is transferability with designs.

There are a few types of software which connect the two worlds of CAD and CAM. Programmes like Solidworks or Fusion 360 provide direct file to factory translations and go as far as to simulate how your design can be made through different manufacturing processes. Whereas 3D modelling allow you to just design, these software packages allow testing and fabrication to be simulated reducing wastage of materials in unnecessary prototypes.

These packages have been created for the professional designer in mind, however there are similar but simplified packages marketed to the amateur and in particular school children. Autodesk's free 123D suite of desktop and mobile device apps is integrated with content and fabrication services and provides an entry into 3d modelling and fabrication.

The exciting aspect of software and its continual innovation is that what currently seems like complex software that only professionals use will soon be the norm for the generation brought up with these at their disposal.

For a full list of software see
www.3ders.org/3d-software/3d-software-list

1

Subtractive Fabrication

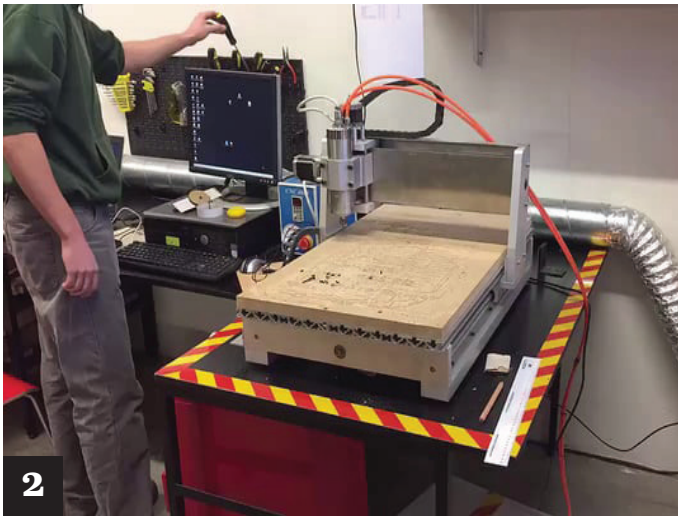
Machining processes that remove material come under the category of subtractive fabrication with variation in the method of removal. Subtractive as the name suggests creates waste and therefore should be chosen in relation to the materials being manipulated and desired quality of output.

Laser cutters use a focused laser beam to burn away from sheet material and can be used on anything non flammable of thickness relating to the power of the laser. My experience was that the laser cutter was the workhorse of the maker space and generally the tool that generated the highest amount of interaction. As David Byworth of Adelaide Fab Lab put it, "the laser cutter is the water cooler of fabrication tools" where everyone gathers to talk about projects.

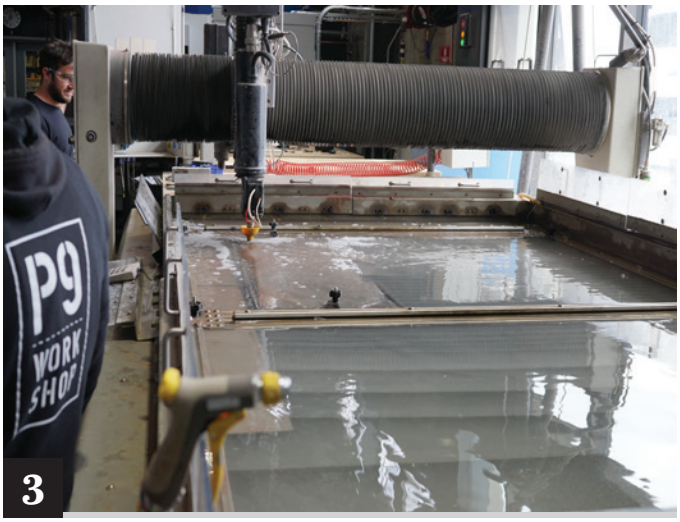
A laser cutter has two axis's (x,y) and two simple modes, burn partially, which can create score marks, and burn fully which cuts all the way through. Creative output is generally of three types, flat sheet patterns, planar constructions, or layered form. The tool is popular for cutting out templates of parts to then combine and produce form.

If makers want to deal with larger, harder or thicker sheets of material, or want 3D shapes formed then they must use a Computer Numerically Controlled (CNC) Router. Simply put this is a drill bit that rapidly revolves to remove material. What separates it from laser cutting is that the depth of material removal can be controlled. Most CNC routers are 3-axis with x (left right), y (forwards backwards) and z (up down) directions, with flat beds that come is different sizes. In my study the most popular router was the Shopbot which comes in sizes ranging from a desktop machine (cutting volume of 0.6m x 0.4m x 0.08m) to manufacturing scale machines (3.66m x 1.52m x .15m).

Some spaces employing advanced manufacturing techniques contained CNC routers with 5-axis, the two

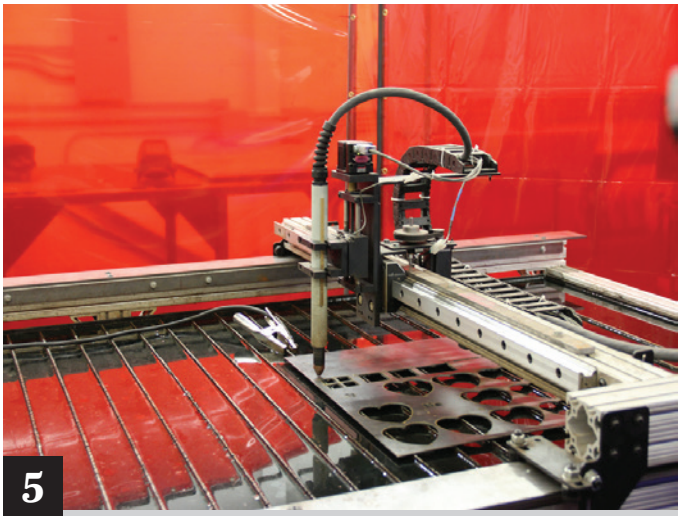


2



3

4



5

extra being a rotation around the x-axis (the A-axis) and around the y-axis (the B-axis). As CNC routers can manipulate large and hard material they are ideal for producing large elements for projects or very detailed surface treatments. They can also assist in other making techniques such as vacuum forming or cast moulding.

The dirty cousins of the laser cutter, and CNC router are the water jet cutter and plasma cutter. The former uses high pressure jets of water with mixed abrasive to cut extremely hard materials that are sensitive to high temperatures. The latter uses heat through a localised blow torch to remove sheet metal.

The above provide examples of fabrication processes that have transferred from the factory into the maker space. The Vinyl cutter on the other hand comes from the automation of more craft based techniques. In the maker space the vinyl cutter offers an entry point into CNC control and is popular for cutting patterns in fabric and creating vinyl sticker decals.

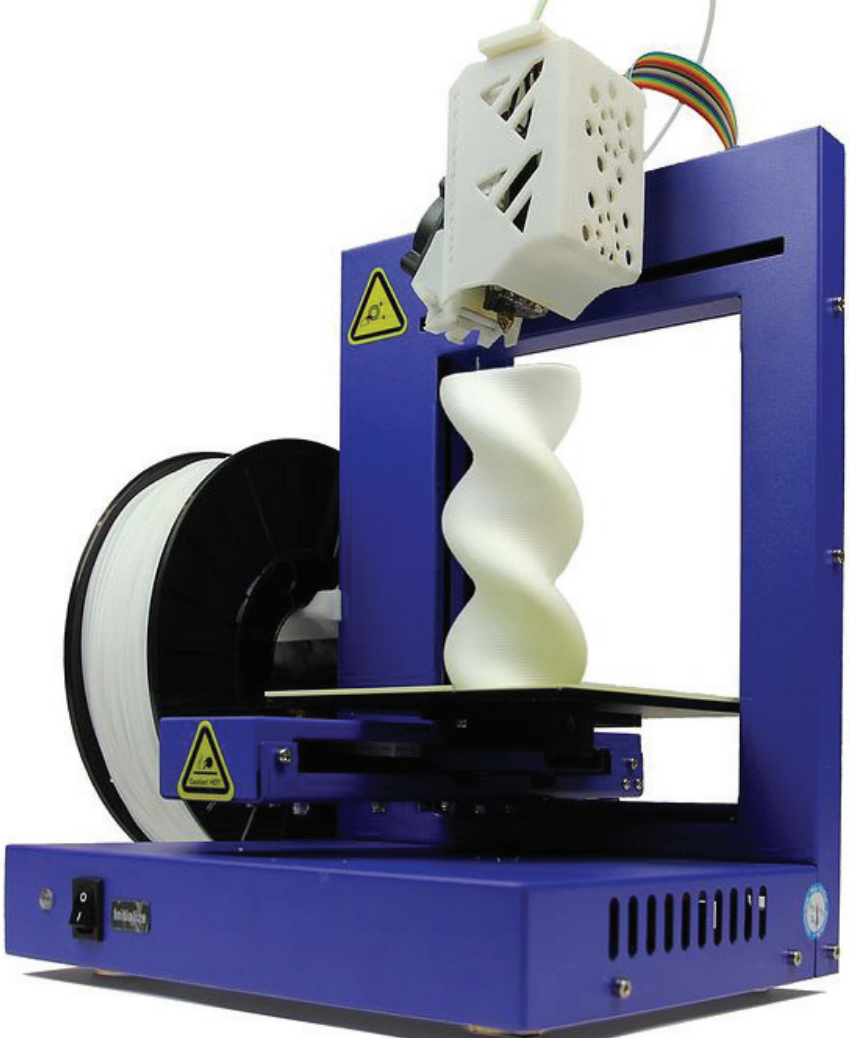
1. Laser cutters

2. Desktop CNC router

3. Water Jet Cutter

4. Multiple Axis CNC router

5. Plasma Jet Cutter



1. UP Plus 2 FDM 3D Printer

2. Formlab SLA 3D Printer

3. 16 Hertz Delta Printer

4. Kamermaker used to create the Dutch Canal House

1

Additive Fabrication

The industrial revolution and its associated manufacturing machinery relied on subtractive processes, milling, machining, lathing, to create objects for mass production. The 3D printer has created a paradigm shift in making as it allows material to be gradually added in three dimensions and reduces material waste.

At its basic level 3d printing is a deposition of material in three axis, x and y for a layer of material, and z to build layers. There are different ways that machines achieve this 3-axis maneuverability and how material is deposited, but ultimately the outcome is a facsimile of a 3d model created in a CAD package.

3d printers differ in the material they process, and the way print heads are directed to deposit material. With each there is an associated difference in technological advancement and as a result, price.

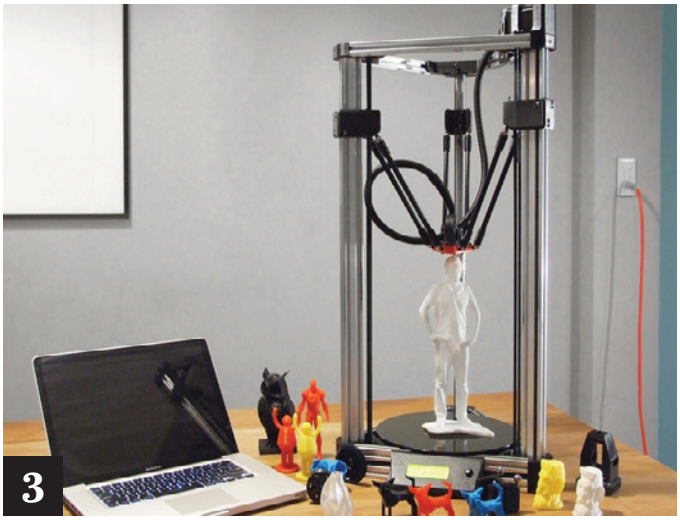
In the maker spaces I visited, all had fused deposition modeling (FDM) machines which are the types that have come down in price enough to enter the consumer market. Within this category there are two types of printing mechanism, the flat bed which mimics the inkjet x,y axis's but with a z direction, and the delta printer which uses a hung set of arms that triangulate to print in space.

There are approximately 240 different types of FDM 3d printer available in the consumer market with varied quality. Experience from my visits showed that there seemed to be a few trusted brands, which either by reputation or sponsorship, seemed to repeat everywhere I went. These printers were the UP Plus, Makerbot, Ultimaker, Printrbot and Dremel. All of these can layer up thermoplastic filament, either PLA of ABS, but in some cases could also print wood or metal based filaments.

A step up in the technology stakes brings makers to the process of Vat Photopolymerisation which produces solid 3d form by accurate activation of liquid material. Within this process there are printers that use Stereolithography (SLA) to transform liquid ultraviolet curable photopolymer resin into solid using an ultraviolet laser, and Continuous Liquid Interface Production (CLIP) that uses changing pulses of UV light and oxygen for a faster build.

These printers are currently entering the consumer market and large companies such as Autodesk have invested in the technology, in addition to start ups such as Form Labs, Kudo 3D and FSL3D. Innovation potential lies in the liquids


2


3

employed to print and bio hacking labs such as biocurious are exploring printing with living material.

At the high end of 3D printing spectrum are machines that use binder jetting or powder bed fusion technology to either glue or melt small particles of material with a laser. These two processes produce the highest quality and are currently only accessible through 3d printing services such as Shapeways or Sculpteo.

What all of these processes and associated technologies share is that they generally have a limited volume in which to print. As a result they are mostly employed to create discrete objects associated with product design, but this is changing. At Makercon a larger printer called Gigabot was showcased capable of printing within a 2.1 cubic metre space. This changes the scalar capacity of 3d printers and makes it useful to produce larger building components.

I visited an example of this at the Dutch Design exhibition showing at the San Francisco Museum of Craft and Design. A 3d printed fragment of a house project by Dus Architects shows what a construction utilising this technology could look like. Dus worked with Ultimaker to upscale their desktop printer into one called a Kamermaker capable of very large bioplastic printing. Their ambition is to eventually allow potential clients of new house projects to customize open designs online, before having them fabricated and assembled on site.

If the Kamermaker is the large scale version of the standard desktop 3d printer, then 3d printing robotic arms using direct energy deposition represent the scaled up version of the delta printer type. Projects by Gramazio & Kohler provide examples where robotic arms are used to deposit material from a nozzle in situ. Recently this deposition has been pushed further by research such as the Stonespray project that are redefining the method that 3d printed material is deposited.


4

Electronic Prototyping

Although not technically a fabricating tool electronic prototyping is having the same democratising effect on electronics and allows amateurs to create their own complex systems from affordable kits of parts. They are an extremely popular aspect of maker culture and have their own specific communities around the available technologies.

Products like the Arduino, provide low cost physical computing platforms based on a simple microcontroller board, and in Arduino's case a devoted development environment for writing software for the board.

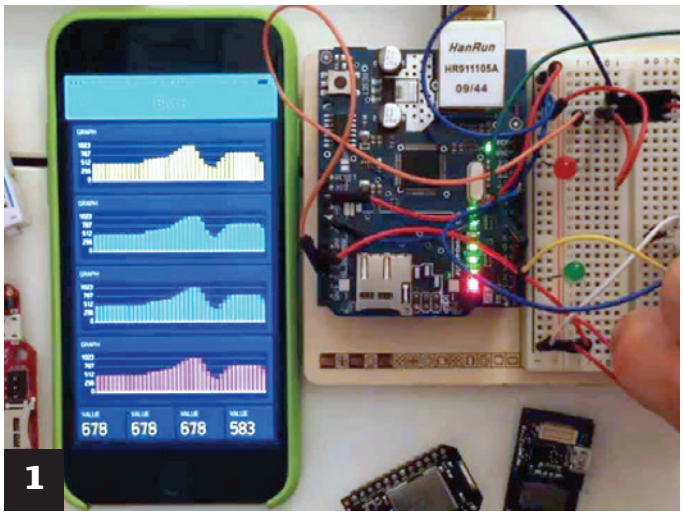
Arduino was introduced in 2005 as micro controllers became small and affordable enough to enter the consumer market. Micro controllers were previously the domain of professional engineers but are now accessible by artists, designers and home project hobbyists. At the same time the size and cost of sensors has reduced dramatically opening up the possibilities of collecting and transmitting data and connecting virtual and physical environments.

In addition to Arduino, which is a micro controller working via uploaded code instructions, there are now micro computers such as Raspberry Pi, Beagle Bone and the Intel Edisson which need their own operating software.

Within the maker spaces I visited DIY smart devices were one of the most popular projects users were engaged in. At one end of the technical scale projects utilised sensors and connectivity to send messages to phones, or automate home processes. At the other end, and in particular for young people, there are prototyping platforms that can provide automation simply through different module combinations.

Platforms such as Little Bits and Sony's Mesh allow quick inventions to be prototyped via connected inputs (buttons, switches, and sensors) and outputs (motion, light, sound and data signals). The SETC Fab Lab and Hatch maker space had invested in this platform and used their capabilities to construct personal stories around kinetic models.

These prototyping software machines provide local processing of data supplemented by connectivity to the internet allowing systems to communicate with one another. The resulting "Internet Of Things" promises connectivity of anything in the world which can send, process and receive data. Objects designed for specific purposes can become "smart objects" as they receive information about their environment, or data related to their function collected by other networked objects.



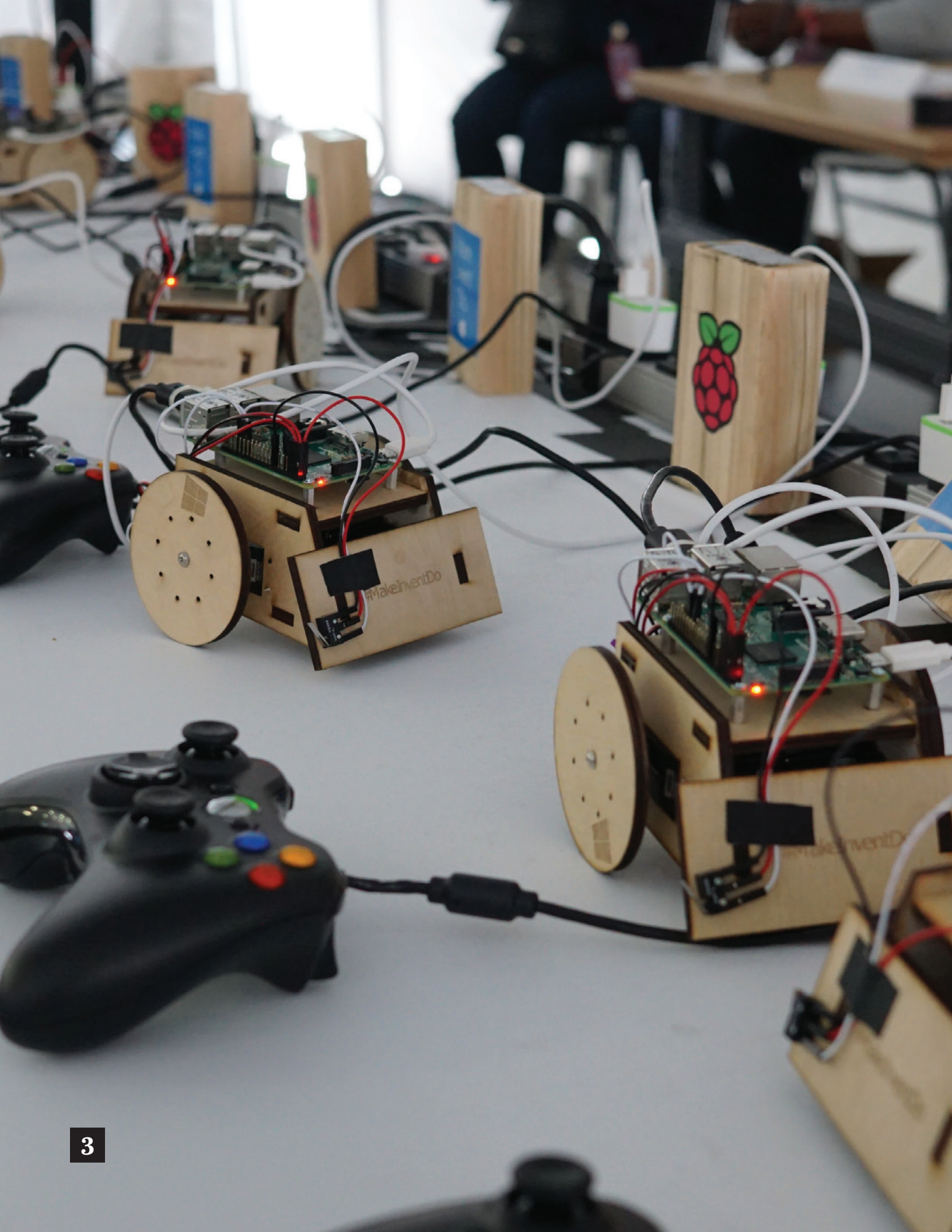
1


2

1. Arduino Microcontroller

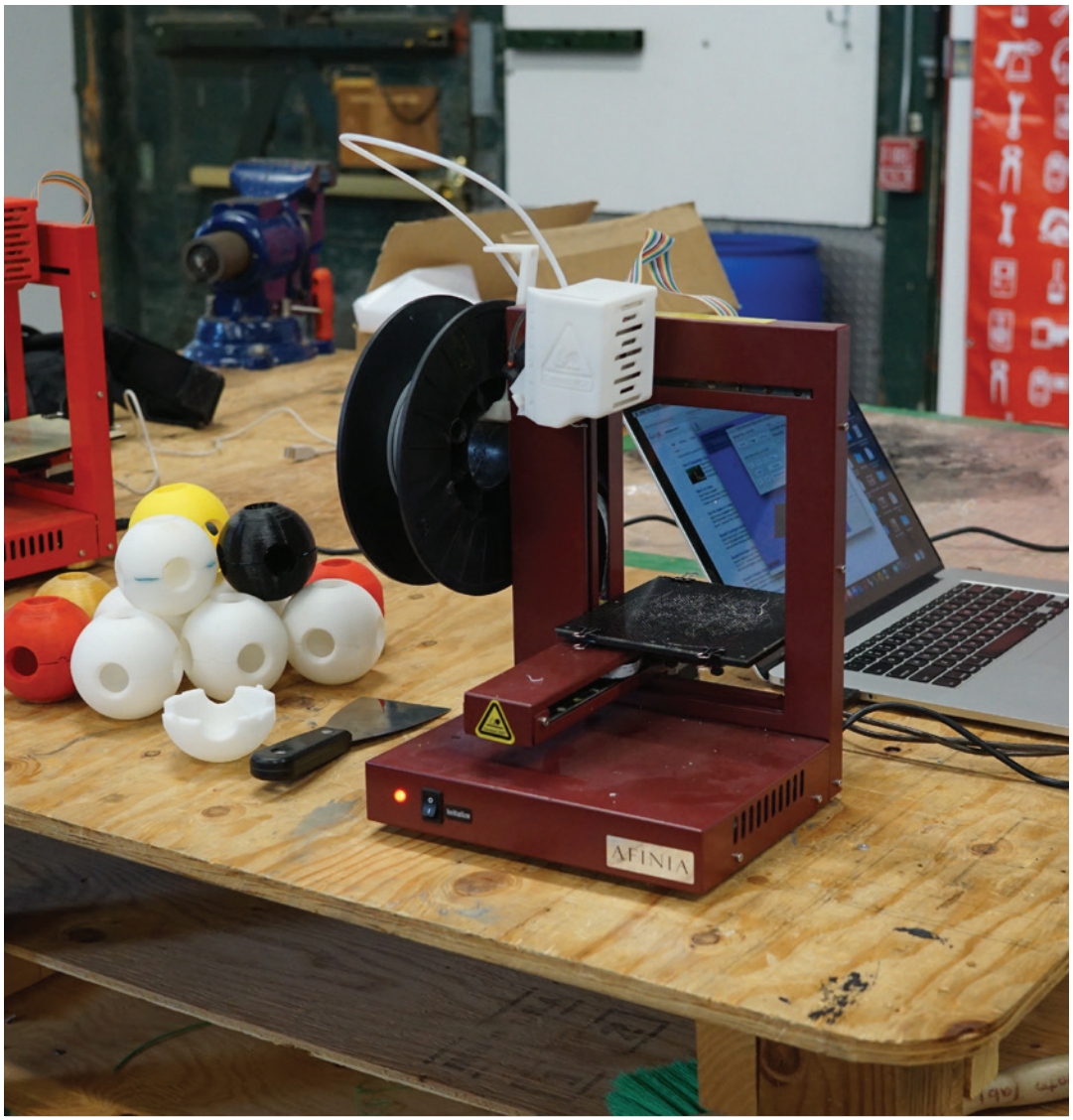
2.Intel Edison Micro Computer

3. Rasberry Pi Micro Computer

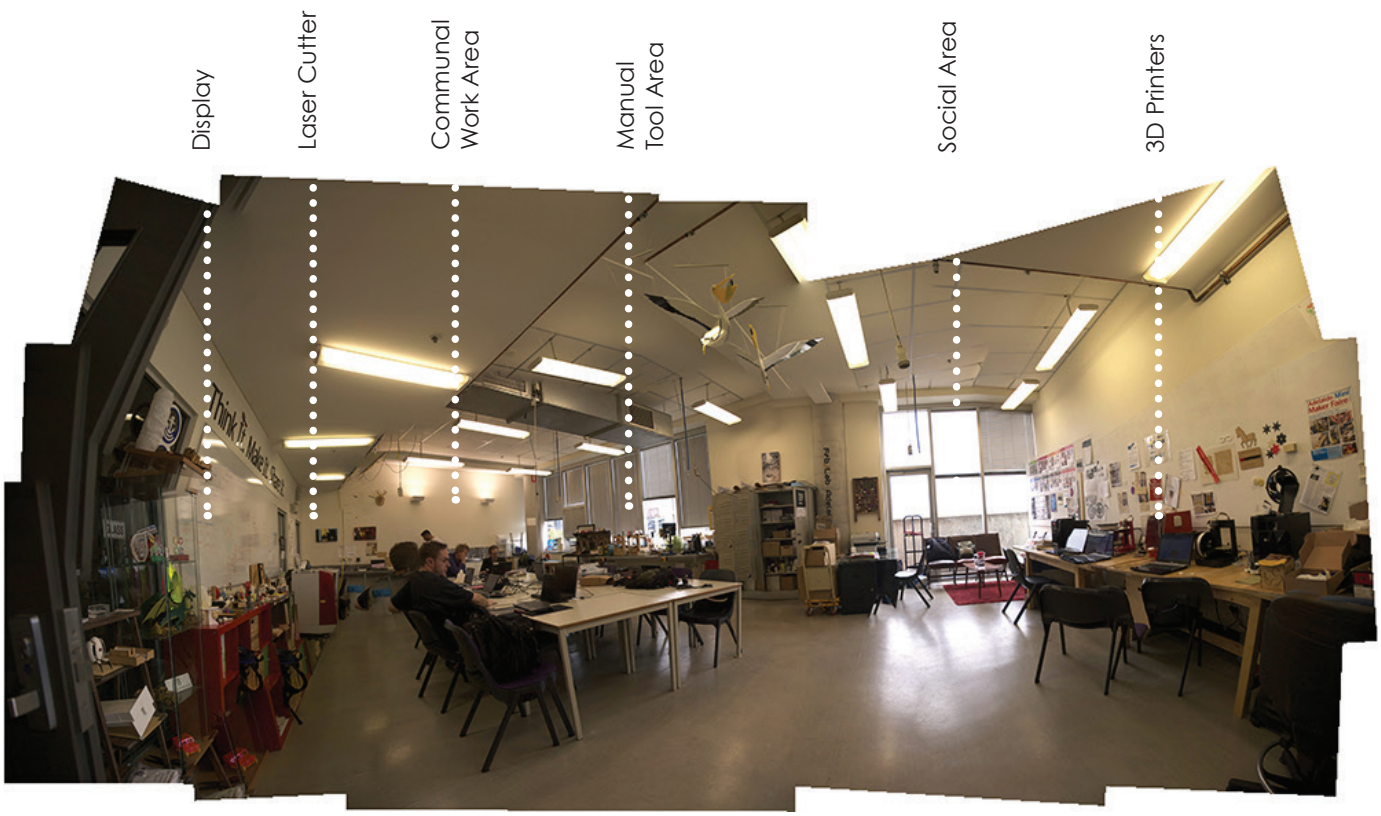


3

Case Studies



This study identified 17 personal fabrication spaces across four cities, and two countries, from which to study the community spaces of digital making. What follows is a description of my visit to each of the spaces , ordered chronologically within each destination.



Adelaide Fab Lab

3D printing attracts most visitors at the fab Lab

Adelaide Fab Lab is hidden away in the Adelaide College of Arts building on Light Square, in the North West corner of the city CBC. It is Australia's first Fablab and was set up in 2012 with funding from the Australian Network for Art and Technology (ANAT) and the South Australian Government Department of State Development.

What initially started as a clever use of ANAT marketing budgets, buying a Thingamatic 3d printer and showcasing its potential across the city, quickly expanded into the setting up of a dedicated FabLab and then consequently Australia's first Mini Maker Faire (more on Maker Faires later).

The current form of the FabLab is as a "squatter space" , as David Byworth the Fablab's manager put it, within the Hassell designed Adelaide College of the Arts (ACA). They were generously given a workshop space by ACA and are sandwiched between other workshops ranging from fashion to traditional lino printing on the second floor of the building. In a conversation with David he said this was an important aspect of the current Fablab, both for building a community of users and maintaining an energy around personal fabrication.

Currently the Fablab has approximately 1,400 members of which a half are regularly active. The space's initial and rapid success owes a lot of credit to Adelaide's Hackerspace who have been active in the city since 2010. Their network of users combined with skilled and enthusiastic volunteers have enabled the Fablab to grow into a self sustainable enterprise.

The Fab Lab launched with a week long workshop run by Zoz Brooks, an engineer

specializing in robotics and rapid prototyping and presenter of the TV show Prototype This. From this initial event it gained enough publicity and participants that the Fablab immediately had willing volunteers to supervise the space when active (currently two days in the week). The volunteer staff are critical for Fablab, in David's experience it was the digital machines that initial encourage people to visit, but the volunteers engagement, help and energy that created regular members.

However David has trouble retaining the fantastic people who offer up their time without the access to financial rewards as the Fab Lab is a not for profit operation and relies solely on public funding. David noted that the more commercial centres that exist in the US, like Tech Shops (more on these later), don't have this problem as the people involved are paid staff and are invested in the success of the space.

In terms of the space David's main concern was over air quality and noise with clear distinction between clean (3d printing) and dirty (laser cutting) fabrication. The open plan layout of the space is important for the spreading of ideas through conversations, but training and workshops were very hard whilst equipment was being used. The space currently has six UP 3D printers, a Trotec 300 laser cutter and engraver and a vinyl cutter. David felt the best situation would be to physically and audibly, but not visually, separate the quieter and generally more collaborative design stage from the more individual equipment use fabrication stage.

The software used in Adelaide's Fablab tends to be as open source as possible to allow access for users outside of the space opening hours, but has had to invest in programmes such as Abobe Illustrator, Solidworks or Corel Draw in order to avoid errors in using particular machines.

This Fablab has been running for two years and has already had number of successes. The highest profile success is Voxie Box. Two guys called Will and Sean attended the first Fablab workshop and from that initial contact with others and gaining of fabrication skills were able to create some prototypes of an idea they had been working on for a while, effectively a holographic entertainment system (think R2D2 in star wars). Unfortunately they were not able to obtain funding for development of their idea in Australia and moved to New York, their product is now proudly part of the "Made in New York" (http://wearemadeinny.com/) initiative.

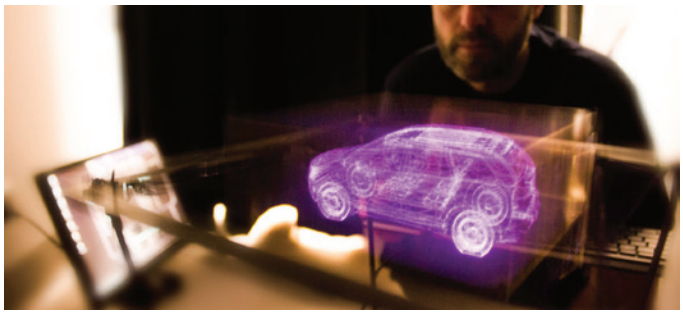
David pointed out that the Fablab serves as a place where ideas are brought in by users and engaged in through a network of skills, time and energy. One great example was of a vet approaching the Fablab Adelaide with the idea of 3d printing a bone of a dog to be operated on at a critical stage of an operation. After printing and subsequently practicing on it the Vet carried out a successful transplant.

Two years on the Fablab is at a critical junction, it has arguably outgrown its space at the College of Arts but its lack of revenue generation means that it can't just choose which next commercial space to locate to. David's view of the Fablab's future is as a connector of people, skills and tools for private education institutions. Rather than siding with a particular institution, such as the ACA, David and the Fablab team have approached universities to fund the space so it can act as a neutral making facility for their use, with the added benefit of having access to potential research grants.

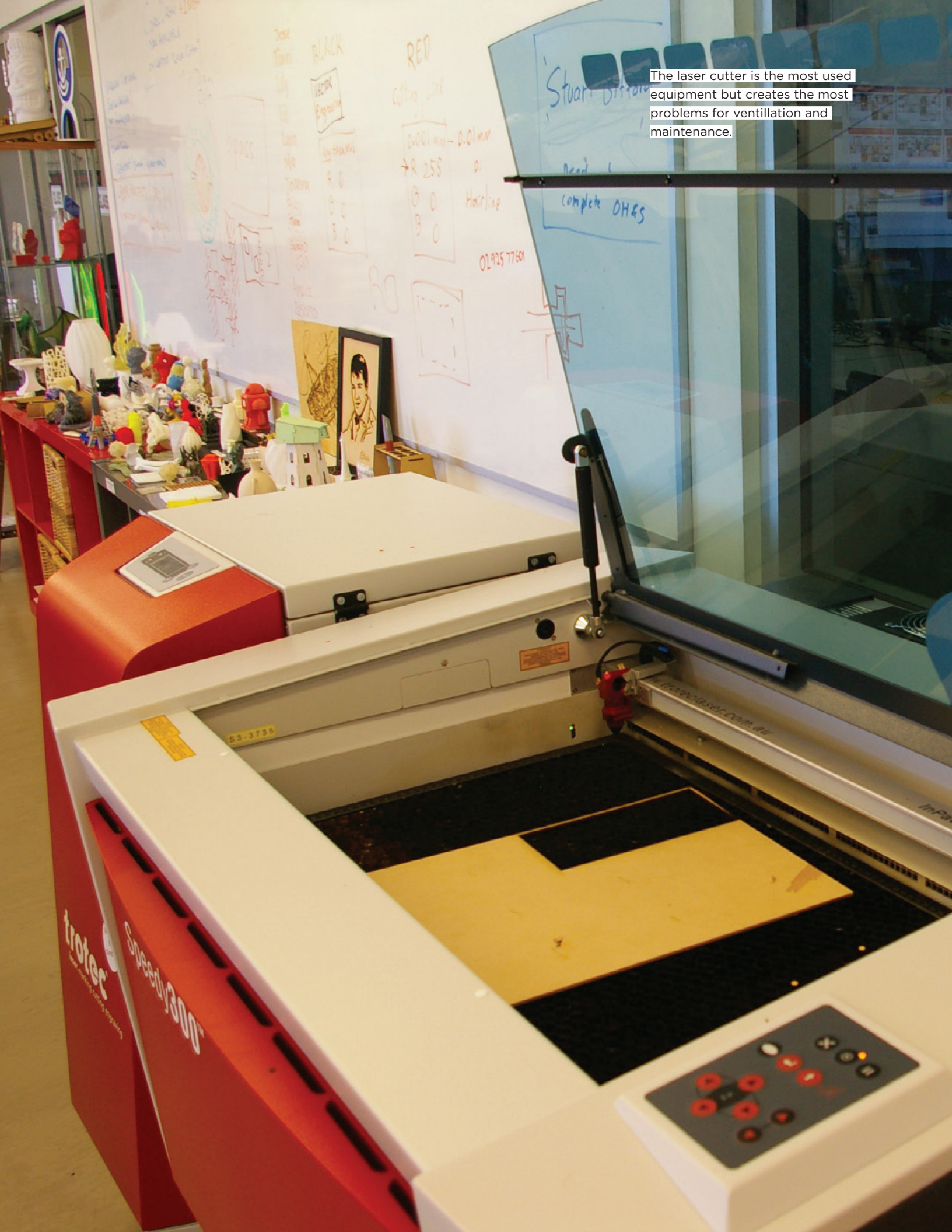
In addition there is also an opportunity for space at a new development at Tonsley where an ex Mitsubishi car production plant is being converted into a precinct that aims to attract entrepreneurs from mining, energy, construction, clean technology and health http://www.tonsley.com/

Finance is the critical aspect for the Fablabs survival and David has identified a number of revenue streams that allow equipment and space to keep running without threatening the Community Open Access model of the Fablab. Services could include making or designing for others, STEM education for schools, remote learning telecasts or specialised week long residencies.

What struck me most about the Fablab is the importance of its staff / volunteers who are critical in fostering participation and setting the expectation of achievement for potential users. Through their energy and skills the public have access to a space where they can introduce and test ideas, learn new digital tools and develop the confidence to either develop further or move onto other projects.



Fab Lab Adelaide members entrepreneurial success - Voxibox - http://voxiebox.com/



The laser cutter is the most used equipment but creates the most problems for ventillation and maintenance.

Adelaide Innovation Hub

A Located in the heart of Adelaide, the new City Library is anything but conventional. In contrast to the usually visible presence of traditional libraries, this library is hidden away down a side street and nestled on the 6th floor of Rundle shopping mall. It is a space that consolidates a number of previously distributed libraries and has called the mall home since 2014. As the library refurbishment is so recent a new approach was been taken and aside the standard physical space for books and reading are hubs that facilitate creativity, reflection, discovery, collaboration and production.

One of these hubs is the Innovation Lab and provides a very modest maker space providing three 3D printers, five 3Doodler pens, one laser scanner, two PCs and one laptop. The lab is only 20 metres squared and can hold around eight people sitting at tables but it is a focal point of the building. The day I visited I was able to speak with Mathew Croucher who volunteers to supervise the fabrication equipment, teach others how to use them, and answer any questions they have about the technology.

Mathew, a Mechanical Engineer by trade, was volunteering at the lab as he had found himself at the forefront of 3d printing through his own personal explorations in the technology. As an unpaid participant he was keenly aware of the difficulty in attracting people to give up their spare time. In his case, although he was apprehensive to admit, his motivation to help lay along side an entrepreneurial project he is running called Innovation Systems. This business provides corporate training and advice around 3d printing and fabrication, so it was a logical fit for Mathew to be able to give up his time.

Our conversation was enlightening and made me appreciate the realities of providing free information and services to communities. Ultimately those with the greatest knowledge, who have invested time into understanding the field, cannot be expected to provide charitable services. Libraries should explore public / private partnerships (in a capitalist economy context) in order to balance economic needs of their volunteers, provide free services to the community whilst generating innovation within the technological field.

I visited the lab during a drop in session where computers and printers operate on a first come first serve basis. On other days the lab operates as a sessional maker space where a booking can be made for up to five people to generate and produce 3d designs. These private sessions with a dedicated facilitator provide an introduction to 3D printing, modelling, scanning, 3Doodler pens, or for those already familiar, an opportunity to learn more through a personal project.

In observing the users in the innovation lab it was obvious that personal projects were the key to engagement. While freely available 3d forms are available through websites like Thingeverse and provide a gateway to using the 3d printers, it was the personalising of designs through 3d modelling software and immediate physical production that were most popular.

THE INNOVATION HUB makes use of operable shelf / walls to seperate space and showcase visitors work

> ***"Adelaide the library is no longer purely the holder or curator of data archives, it is now also a public provider of connectivity to a network of information and a means of production.***

Although small at the moment it seemed there was potential for new ideas and solutions to be developed by users once the tools are learnt, and for them to be instinctively shared which made this space significant within the library.

Through the Innovation Lab the library is no longer purely the holder or curator of data archives, it now provides connectivity to a network of information and a means of production for creativity.

The Innovation Lab in Adelaide's library acts as a technology showcase for 3d scanning and printing

Sydney Makers Place

During the 2014 Sydney Maker Faire I got chatting to Mel Fuller who is part of Three Farm a social design enterprise based in Sydney. The group specialise in education programs that explore Life Cycle Thinking, Computer Aided Manufacturing, Assembly Techniques and 3D Design. The company is focussed on the democratisation of manufacturing, specifically additive fabrication, as vehicles to explore the cultural benefits of teaching design thinking.

Recently Three Farm were offered space to open a maker space through Renew Leichhardt, a non profit focussed on regenerating the Italian Forum in the heart of the suburb. They started the impressive "Makers Place" a community facility providing public access to equipment, knowledge and space. Their aim is to provide the conditions to think, make, play, teach and learn, and allow members to prototype, fix, modify & hack, up-cycle, run workshops, host & attend events and collaborate on meaningful projects. Their design philosophy ties into the concept of the circular economy and the Makers Place is the spatial embodiment of this approach.

The suburb of Leichhardt has experienced a marked shift in demographic and is today made up of primarily young families of mixed cultural backgrounds. The spaces of Leichhardt, which were designed to cater for an older and Italian ethnicity, have subsequently suffered as dining out and large group socialising has declined.

Renew Leichhardt was set up to try and re-stimulate the public space of the suburb through possessing real estate from land lords who had been happy to leave spaces empty to achieve negatively geared tax concessions. Three Farm were offered an old dining space in the heart of the Italian Forum from which to set up. An extensive DIY renovation was carried out by the team and furniture was up-cycled from wooden stacking palettes into benches, desks and shelving. A number of milk crates were donated to the space and in combination with a stash of crates gained from a previous events the team painted them white and converted them into seats, tables and storage opportunities.

Within the Makers Place they have a dedicated digital fabrication area, that combines a number of donated and borrowed 3D printers with desktop PCs containing sponsored Autodesk software. An electronic vinyl cutter was one of their first pieces of equipment and provides an easy introduction into digitally making for all members of the space, not to mention the ability to create numerous decals for the walls.

In a separate back room is a more traditional workshop with sanders, saws and a potters wheel. Divided from the main space but viewable via a wall of milk crates it provides a slightly dirtier but controllable environment to the rest of the space. The white crate divider also provides storage space for the members of the Makers place but is at a premium with only a few days allowed per project.

The main space is open plan to allow rearrangement of tables for project collaboration or teaching conditions. Along the wall a new library is organically growing to provide reference into all things maker, sustainable material and life-cyle information. At the opposite end of the space

MAKERS PLACE
clever and considered use of materials and novel uses of everyday objects create an environment of creative exploration.

kitchen facilities and wall space are provided to showcase members projects and communicate with the community.

The $45 monthly fee helps to cover operation costs but as this relies on a built membership base the Makers Place sought sponsorship partnerships. These are invaluable to the success of the space as the pressures of economic forces in Sydney can be stifling for socially focussed entrepreneurial activity.

Mel kindly showed me around the space before it opened to the public at 2pm. As visitors arrived the bi-folding doors opened to enable Makers Place to expanded out into the public forum providing seating and much needed greenery into the sparse and empty space. The folding back revealed small cabinets of 3d printed and hand crafted curiosities available to buy with proceeds going direct to the members responsible. A cabinet further into the space held a selection of DIY robot kits for sale, part of a robot making event that the Makers Place holds.

As Three Farm are so heavily involved in creating community events it is no surprise that Makers Place has such a rich selection of organised happenings around making. 3D printing, electronics workshops for girls, yarn bombing, technology workshops and balloon mapping are just a few of the events that the space were putting on at the time for the public.

As a result Maker Place and Three Farm have an impressively large number of connections within Sydney's making community.

This network is critical to Three Farm's social ambitions as it enables open sharing of information and helps alleviate the pressures of running a non-profit organisation.

MIT Hobby Shop Cambridge, MA

Buried in a basement of MIT University lies the Hobby Shop. The facility was set up in 1938 with the ideology that all students at the time (all male) should have a hobby outside of study. The fully equipped wood and metal shop is used to teach students the art of thoughtful design and learning by doing.

Although originally located in a room in the basement of MIT's engineering building, today's space is in the basement of 120 Massachusetts Avenue, building W31. It subsequently has no windows, low ceilings and cramped space for over head ventilation and services. It is a refurbished space with the Hobby Shop moving into its new home in 2013.

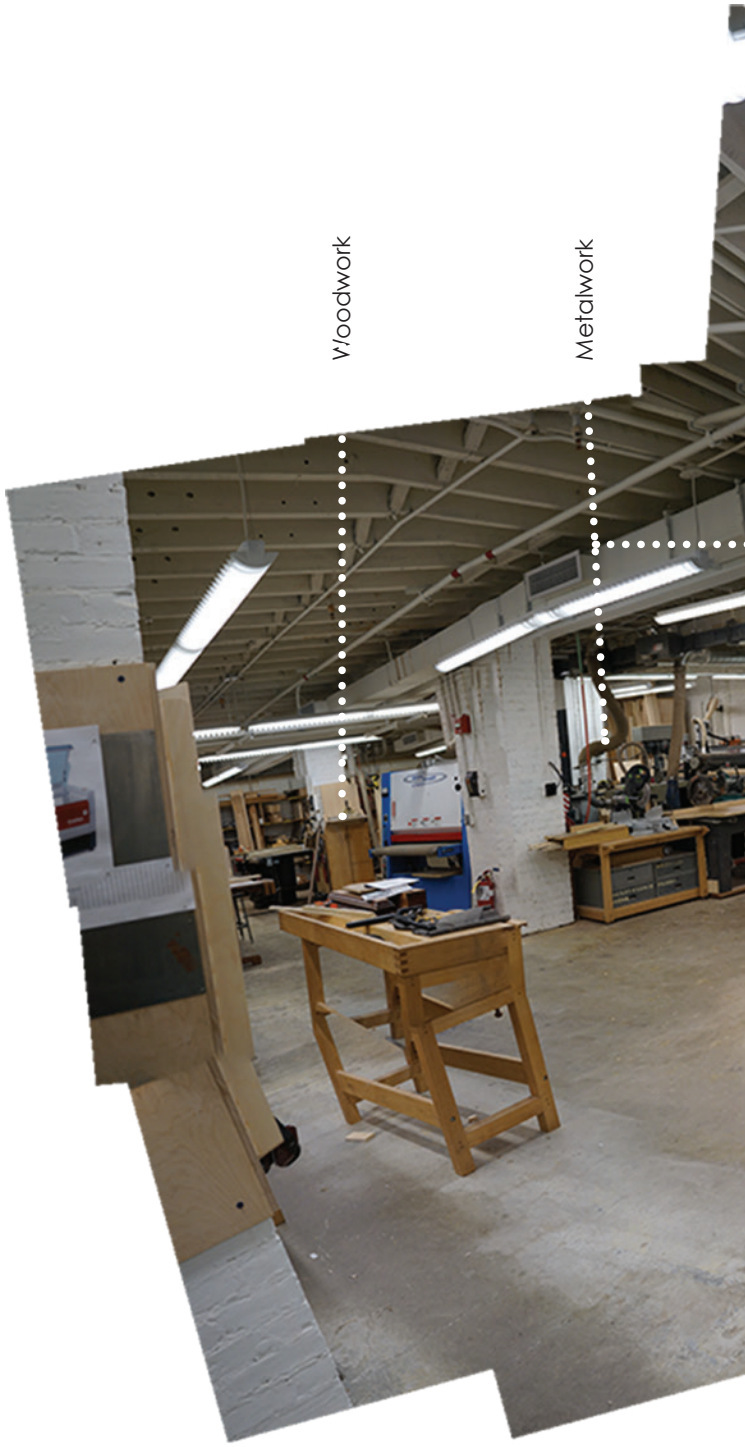
Brick columns divide the workshop and provide bays for equipment and wall space to surround workspaces and storage. The in-between space is used for circulation while the perimeter is utilised for workbenches and storage. It is safe to say that the space is not custom designed but things are arranged with a logic of material process with wood and metal working as separate sections.

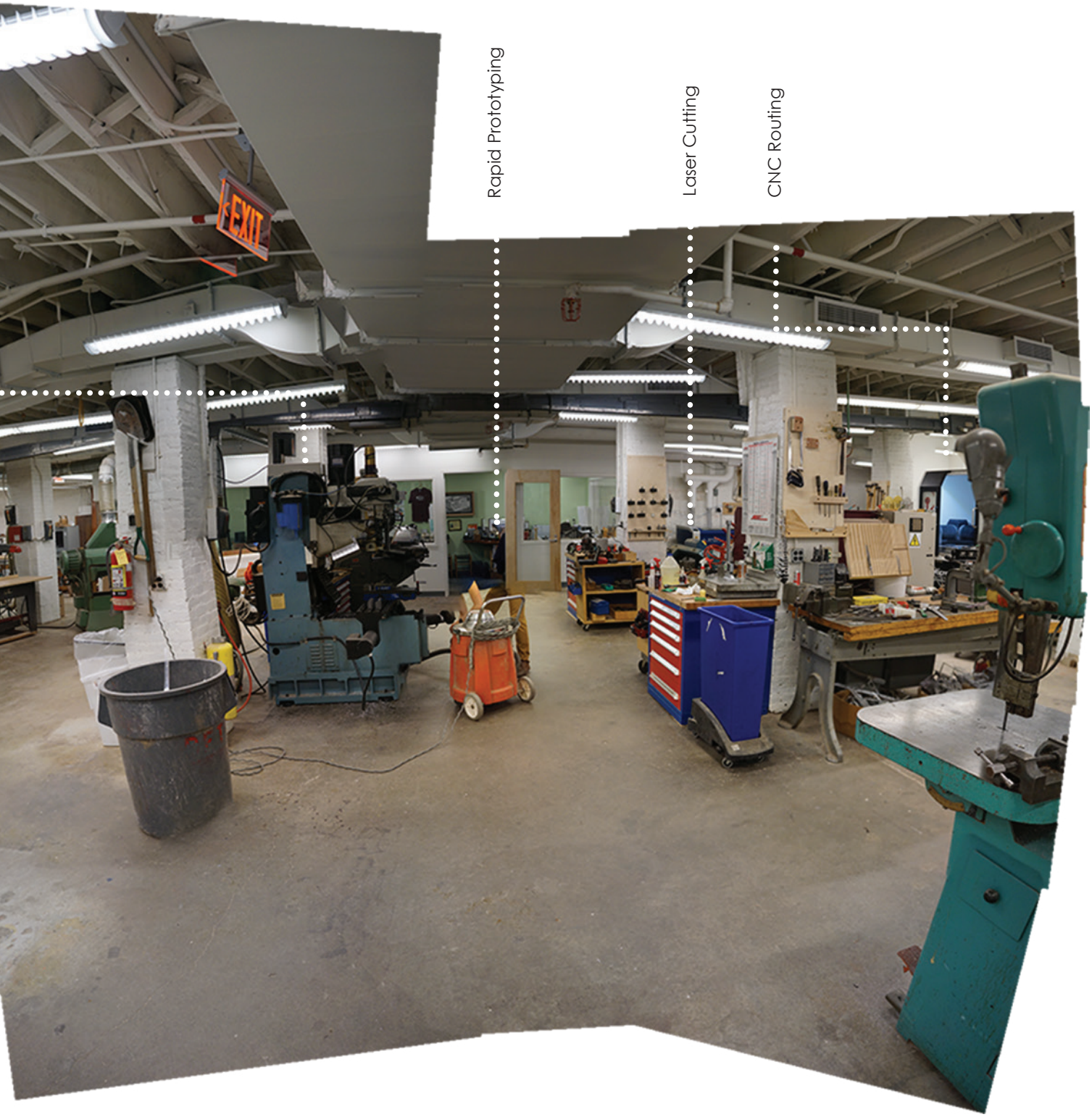
The Hobby Shop operates as a traditional workshop with mainly manual fabrication processes. Ken Stone, a member of MIT alumni and the workshop manager since 1991 felt that this was an important distinction and had the opinion that digital machines removed the need to fully know how to make things. This doesn't mean that the space was without digital machines though, it contains a Laser cutter, CNC router, water jet cutter, 3d printer and dedicated computer terminals. For Ken it meant that before using the digital, members must first learn the manual techniques.

Funding for the space is organised around crowdfunding within the university and a successful campaign had provided a new laser cutter. MIT has its own web platform for funding and the laser cutter campaign raised $10,000 from student and alumni contributions. Whilst promising that the campaign was successful and enough people were willing to support it did suggest that the small joining fee required to use the space is not quite enough to sustain a cutting edge workshop.

Although membership is open to all students of all levels of abilities the core of users were from science and engineering courses as these subjects do not typically provide making facilities. Ken described most projects as mixtures of small scale solutions to personal or course set problems. He said he detected common threads around the space with students working together on projects, such as helicopter drones, or furniture.

Proudly Ken described the largest project produced out of the Hobby Shop, an airplane. Built in 1994 by John Urbahn, a Nuclear Physicist PHD student, it was made from wood, metal and fabric and built in the workshop over three years.

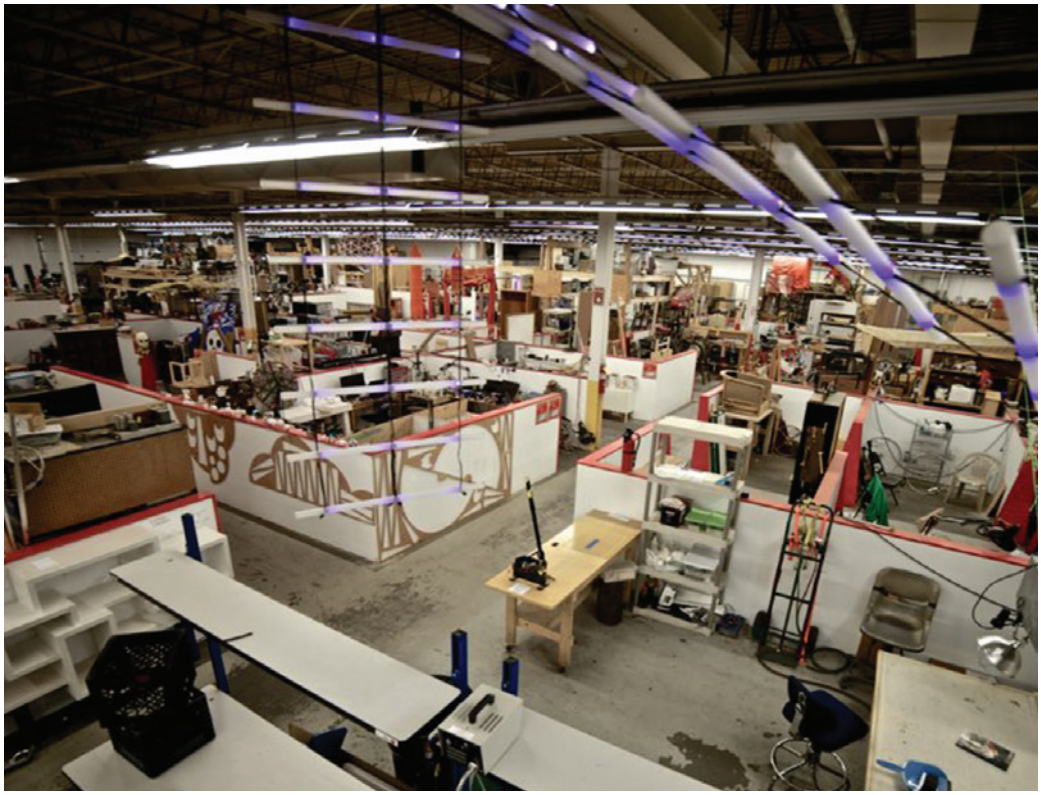




HOBBY SHOP cramped conditions in the basement are utilised by zoning around structure and material process.

Artisan's Asylum Somerville, MA

In the north of Boston lies the city of Somerville. Once a thriving area of heavy industry involving meat packing, dairy processing, ice and food distribution, it is now a hot bed of creative pursuits. A period of rapid deindustrialisation with an associated decline meant that the city had abundant empty space. The area is now home to many artists who have helped to economically and aesthetically regenerate the area.



ARTISANS ASYLUM apparent chaos is actually a compartmentalised collection of personal projects.

The Artisan's Asylum is a massive maker space that utilises a 40,000 square foot (3,716 sq m) old Ames Safety Envelope warehouse and provide space and equipment for all types of making, learning and working. It has around 250 monthly members and combines communal space for fabrication with private rental cubicle studios.

My access to the space was generously provided by Chris Sledziona, a member of the space who uses it to develop personal projects as an outlet for his creativity. The enormous maker space provides primarily three types of experience for users, with a related increase in access to the buildings space. For temporary users there are classes held by established makers covering skills and specific project outcomes such as welding or building bike frames. For regular makers there are work areas, dedicated training and access to production tools. "Shops" are organised into material or fabrication process and cover computer labs, rapid prototyping, welding shop, wood shop, machine shop (metal), screen printing, jewellery and lighting, and fabric. For the serious pro makers there are the private studios which add a city like dynamic to the facility.

The studios are offered on an availability basis but Chris pointed out that the proximity of designers and makers meant that common ground was found and through collaboration and inspiration areas of specific interests had emerged. The combination of all this activity created the appearance of a type of emergent flea market where content reflected the users interests and extroverted personalities. The effect is a space of multiple informal meeting spaces where a network of making activities unfold.

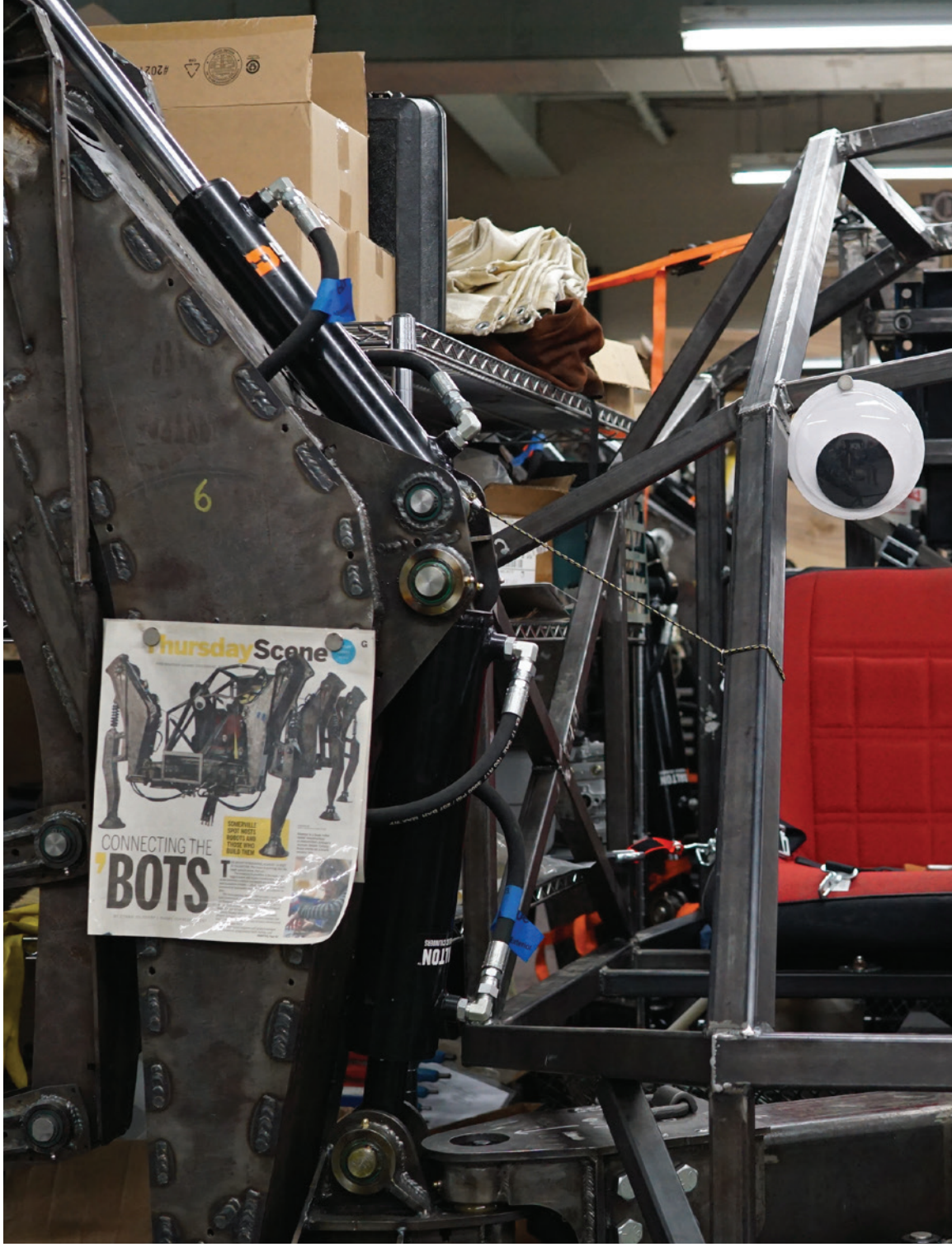
In experiencing the space I was surprised by the energy at 7pm on a Monday evening. Chris explained that for the regular users the community generation of ideas, projects and knowledge is the main reason people pay to use the space, more than the availability of tools. Access to keen like minded people with varying experience and interests in a controlled environment create unexpected opportunities and outcomes.

Sharing is encouraged and the provision of knowledge, ideas, time, energy and in particular tools is critical to the space's success, so much so that offering up equipment for others to use receive sav-

ings on rental costs. Chris did explain that this could have a knock on effect as if anything was accidentally broken through general use, it was the owners responsibility and cost to fix it.

The private studios of the Artisan's Asylum set this maker space apart from the other case studies I visited. What could be seen as a peculiar monetising of space in an environment of open sharing and collaboration in fact creates the conditions for the space's most enduring quality, personalisation. The ownership and responsibility of space, with the combination of access to the means of production produces a surprising array of making activities. During the time I was there I witnessed electronic prototyping, furniture and lighting, jewellery, a boat, a gallery space for punk art work and a gigantic pneumatic mechanical spider, each with their own spatial requirements and personal solutions.

The centre also offers its workshop to surrounding businesses for its employees to participate in making. The provision and access to small scale manufacturing equipment is so attractive that a entrepreneurial hardware technology incubator called Greentown Labs located itself directly across the road. Resident start ups use the facilities to develop prototypes that would have until recently been sent away to be produced else where in America or even overseas.



ARTISANS ASYLUM yes its an enormous mechanical spider

> ***"for the regular users the community generation of ideas, projects and knowledge is the main reason people pay to use the space, more than the availability of tools.***

Cambridge Hack Space

The Cambridge Hack space was one of two "Hacker Spaces" included in the travel study, the hackerspaces.org define them as "community-operated physical places, where people share their interest in tinkering with technology, meet and work on their projects, and learn from each other". Cambridge Hack space was chosen because of it's unique position within a co-working space called Industry Lab. Out of working hours a modest fabrication area holding 3d printers and a CNC machine, expands into a larger open plan space where members of their community can help each other with personal projects.

I was welcomed in by Anna and Richard, two of the organisers of the collective. Although the community space is only open once a week they are among a few core members who have 24/7 access to the space. The Hackspace events are then an opportunity to connect with others in the Cambridge or Boston region who wish to share projects they are working on with each other, with beer. Most meetings are chances to indulge in technology with other interested and enthusiastic people, however some weeks there are designated workshops and presentations when the open meeting room converts to become a stage or event space.

Generally the hacking was based on around electronics and software but whilst I was there one of the members was gluing up and clamping some furniture they had designed for a new apartment. Anna and Richard were very clear that community was their main motivations for organising the meet ups, they have their own interests. Anna is a keen knitter and Richard was developing a home automation device, they would be exploring these anyway but their enjoyment was increased through sharing. The community provides a social connection over shared interests and a critical mass of people that generates opportunities for involvement in external events.

Whilst talking to the users and being shown around the space it was evident that web technology plays a significant role in its success. The website meetup.com provides a communication channel to new and current members, and is popular within the tech savvy Boston population. It also serves to connect to other events organised around other interests, for instance Richard was also a member of a hardware startup, PHP and Internet Of Things events which complemented his own making interests.

I was only able to experience one hackspace meet up and although the crowd was primarily male and around 30 years old their overall membership base contains a balance of genders and wide spread of ages.

CAMBRIDGE HACK SPACE
flexibility is key to make use
of transient shared space.

> ***The community provides a social connection over shared interests and a critical mass of people that generates opportunities for involvement in external events.***

Boston Public Library

There are two sides to the Boston Public Library, on Copley Square the library is the 1895 building designed by Charles Follen McKim and contains vaulted ceilings by Gaustavino. The other is a 1972 extension designed by Phillip Johnson which provides space for large open areas for collections and working, in contrast to McKim's traditional cellular room layout.

The Johnson extension is currently being refurbished and part of the development introduced a space exclusive to young people, teen central. Part of this space is given to a small maker space holding 3d printing and scanning tools, and a computer lab with access to software such as Adobe Creative suit and Autodesk.

I was shown around by Anna and Dave who supervised the space and organised classes and activities to attract and engage young people. They explained the ambition of the "hang out place" is to provide a means for self expressions and creation of personal identities. They consider making as significant as reading and socialising as important activities within this process.

The space had only just opened and had so far not attracted the regular visitors they had hoped for but those who were there were keen to explore the software and create digital artefacts within the lab. There position within the library meant that many young people did not know they existed, but they

The computer lab and associated 3d scanning / printing facilities provide avenues for digital creativity.

BOSTON PUBLIC LIBRARY design purely for teenagers making provides an useful technique for self expression

Digital Lab

felt that the space would soon attract regular visitors through word of mouth.

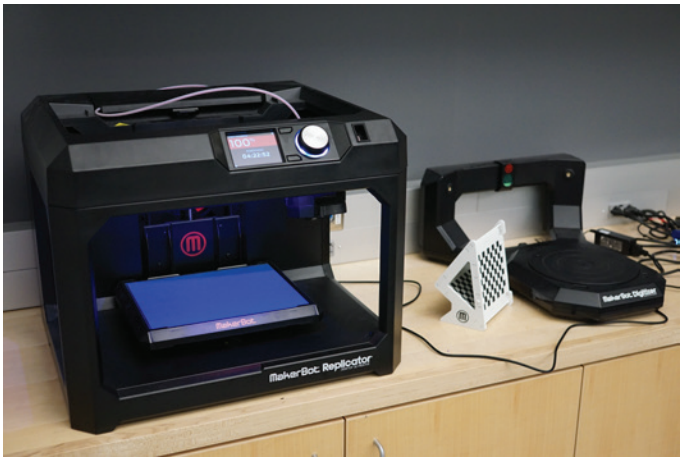
Dave explained that the fabrication equipment had not been used that often so far as users did not realise they were free to use, or know what to do to use them. While I was there an example of this happened, a girl asked what the 3d printer was and asked if she could see it work. When told it printed 3d objects she looked disappointed as she thought she would have to make something in 3d before getting to use the machine.

Dave introduced to her to Thingiverse a tool which he said had changed the way young people view and approached the technology.

Thingiverse allows people who have designed digital 3d objects to share them to a large online community, for free. 3d files are free to download and then edit and modify. It is encouraged that these new outcomes are then shared back to the community to produce an evolution of 3d forms. The website provides a digital commons of open source 3d printable objects.

> ***"the "hang out place" is to provide a means for self expressions and creation of personal identities.***

Although he did concede that at the moment the printer was mainly being used to create easily available mass market products such as iPhone cases, but he could see that as software skills increased output would become much more personal and more in line with what he had experienced at the nearby FabLab.



Free facilities to 3d scan and print anything.

Laser Cutters

Tools

Vinyl Cutter

Computers

3D Printers

Electronic Prototyping

"Teenagers are the best resource we have. Get them learning the tools and techniques, allow them to get creative, they then inspire by being role models

Mel King

Boston Fab Lab

The Fab Foundations Jean-Luc Pierite

In Neil Gershenfeld's book "Fab" Mel King plays a pivotal role in the emergence of the Fab Lab movement. Mel has a fascinating history which I won't go into, best read the book, but these days he is the figure head of the South End Technology Centre (SETC) in Boston. It is home to the worlds first Fab Lab a digital fabrication lab providing laser cutters, 3d printers, CNC routers and access to 3d modelling software.

The centre was originally set up by Mel in order to provide access to digital technology for Boston's underprivileged and marginalised communities. The Fab Lab has continued that tradition providing the means, particularly for children and teenagers, to engage with technology that normally would not be accessible. In their own words the lab allows them to:

"Recruit and train persons in computer technology who have been excluded from the technological revolution and are at an increased risk of joblessness. Encourage community residents to use information technology as a means of personal and professional development. Help residents move from being consumers of information to producers and creators of knowledge." 1

The area of South End in Boston is a socially, culturally and economically diverse neighbourhood with noticeable inequality on the streets. The centre provides a location for the local community to connect by dropping in or organised events, with only the cost of materials needing to be covered.

Fab Labs are not for profit, so they have to generally utilise whatever space is offered and get efficient with it, the SETC Fab Lab is the embodiment of this approach. Crammed into approximately 4mx4m space they manage to fit in all the equipment above (2 epilogue laser cutters, Roland Vinyl cutter, 8 macs (running Mac OS, Windows and the open source Linux Ubuntu), Modela CNC router for creating circuit boards, an UP and Makerbot 3d printer and a space

devoted to electronic prototyping. The most surprising tool they have is an enormous Shop Bot CNC router that is hidden behind heavy duty plastic drapes.

The Fab Lab Foundation, which emerged out of the rapid growth of fab labs globally, provides the infrastructure and information from which to start a Fab Lab anywhere and is open to anyone to access2. On the day of my visit I encountered Jean-Luc Pierite, the logistics and communications manager at the Fab Foundation, participating in a Fab Academy web cast that regularly stream globally. The Fab Academy is the distributed education model of Neil Gershenfeld's MIT class "How to Make (Almost) Anything", and is directed by Neil himself. The live online video lectures and discussions, as well as digital content provides advanced digital fabrication instruction through hands on projects and access to technological tools and resources through Fab Labs.

The Fab Lab space itself is very cramped, but fully functioning as a flexible digital fabrication workshop. This Fab Lab is almost 10 years old now so it can be forgiven for looking well used. All around the space small objects offer insights into projects that have taken place in that time, from laser cut glasses to 3d printed key holders. Storage is essential and squeezed into every available space, to the extent that chairs are stacked under desks and projector screens are hidden away in anticipation of the space transforming into a compact teaching room.

Jean-Lux was very kind in showing me around the facilities and explained how all the equipment integrated into a learning experience, moving from digital 3d design through to subtractive or additive fabrication and then communication. The academy course is not free so it is expected that knowledge is shared within fab labs by those lucky enough to be enrolled. This distribution of skills and peer to peer teaching is vital to the growth of fab labs and generally those running the fab labs themselves are the ones to graduate from the course.

For Mel and Dr Susan Klimczak, South End's Education programme organiser, peer to peer is the key to a successful and sustainable community around making. At the SETC young adults are recruited during their summer break to learn about creative technology and then teach out into the community. The programme uses interaction with technology as a source of individual expression and a technique through which to construct and communicate personal narratives.

The mentor programme has been so successful that is has spread to established programmes at local Maddison Park and McKinley schools. Recently McKinley built its own in house Fab Lab, while Maddison Park benefits from MIT's mobile Fab Lab. This converted truck carries a CNC router, laser cutter, hammers, saws and an inventory of parts with which to build and visits schools and community centres within Boston to try and inspire youth through making.

1 Every part of the Fab Lab is utilised and tools such as laser cutters and 3d printers

2 Customised items of storage and furniture have been made via the CNC router.

Bolt, Boston

If Boston's Fab Lab provides an example of emphasis in social over technical, then Bolt offers the antithesis. Here product innovation is the critical aspect of their maker community.

Within the context of the United States Economy, tech start ups are big business. Maker spaces in general provide an entry point into realising entrepreneurial ideas, but they can only facilitate development of ideas to a certain point. Bolt in Boston and recently San Francisco is a working space and venture capital fund for start ups developing products that operate at the intersection of hardware and software. The reason I wanted to include such a space into the study was to see what transformative effects the integration of digital fabrication is having on business communities.

Located in China Town in Boston, and occupying a spacious building that once housed light industry. The area is experiencing gentrification as real estate prices drive out many Asian Americans. Tech start ups are part of this economic force, new companies cannot afford high rents of the city so inhabit the lower rental spaces in less central locations. Currently investment in digital hardware products is high so many companies are emerging.

Bolt provides an initial home for such start ups with the added element of high level digital fabrication machinery. The Bolt space itself is very considered and designed to offer everything needed to run a successful and networked business. The top level is a shared open plan office, where companies create their own clusters of desks and laptops, whilst downstairs is where all the small scale prototyping and manufacturing happens.

The space is laid out as a collection of very high end digital fabrication machines each with a particular function in the development of products. CNC milling and machining (subtractive forming), Rapid Prototyping (3d printing, laser cutting, Vacuum former, Urethane casting) and Electronics each have place and are arranged in the order of their place in the development chain.

Design in this space is centred around preparing for mass manufacturing and represents a hyper capitalist paradigm within this study. Access is restricted to employees of companies who make it through the stringent pitch process at Bolt, but those who use the space and equipment must become proficient, independent and responsible. These lucky few not only have access to the means of production but also gain the knowledge of how to scale up and distribute their output.

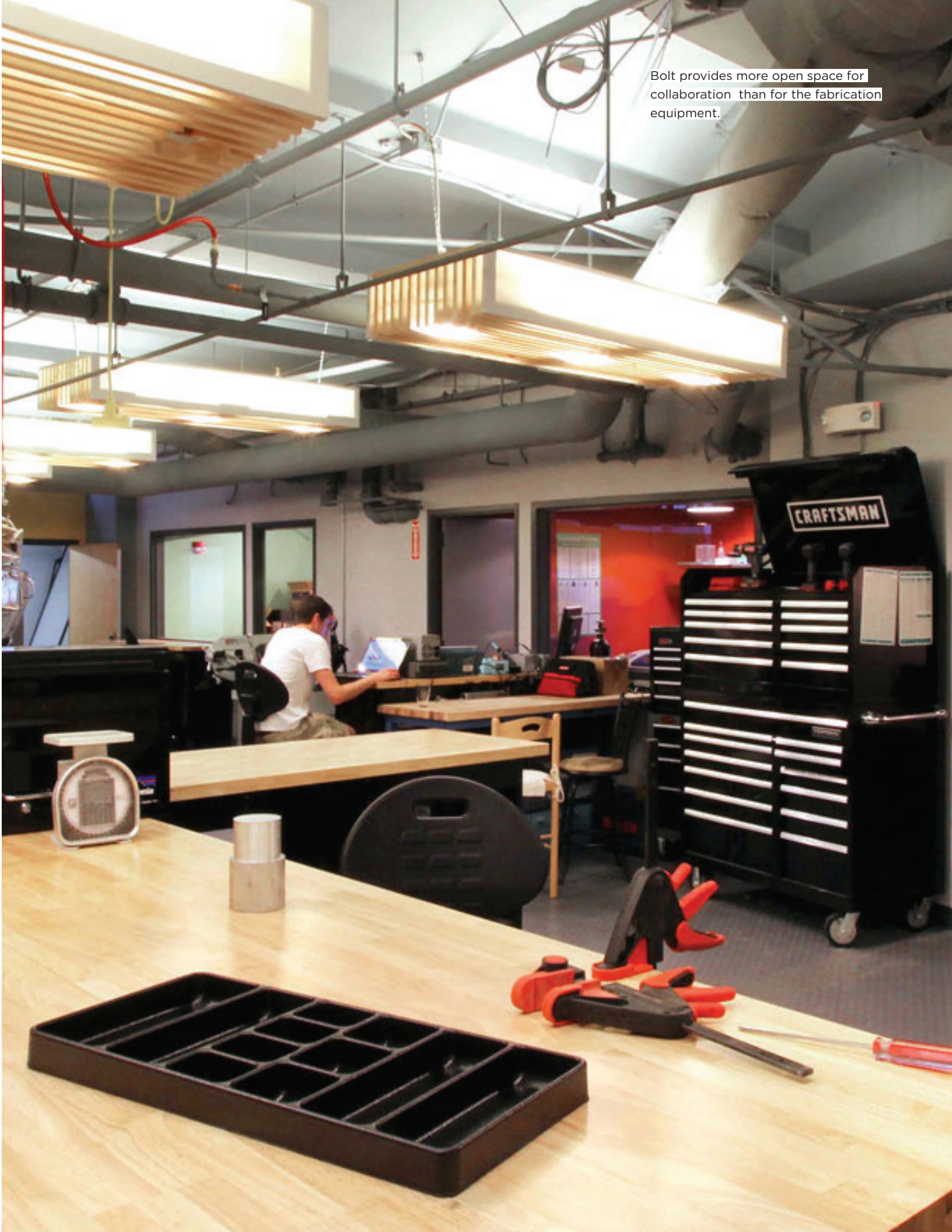
Those start ups who are successful and become established more often than not move into adjacent building space in order to stay connected to other hardware companies. Rental prices increase as these spaces become desirable and demand increases, thus the original population has been driven out. I witnessed the same in the South Of Market (SOMA) area in San Francisco where companies like Twitter and AirBNB have moved in and prices have consequently risen.

Bolt represents something a little foreign in this study, a community of profit driven makers utilising exclusive space and equipment, making mass market solutions. The visit highlighted the position such spaces hold in the wider ecosystem of making. If the knowledge and skills they generate could filter down into more amateur making practice through volunteering or worksops, the sophistication of personal design solutions would increase and perhaps an associated perceived value in design?

All the furniture at Bolt has been fabricated in house

Light boxes designed by the directors of Bolt provide inspiration for making.

A dedicated space holds high end additive and subtractive rapid prototyping tools.



Bolt provides more open space for collaboration than for the fabrication equipment.

Danger Awesome Cambridge, MA

Throughout my visits to maker spaces or hacker spaces there was generally a trend towards inhabiting unwanted pockets of space, this made Danger Awesome (DA) stand out from the crowd. DA's home is an old shop in Cambridge MA and engages directly with the commercial expectation its position creates.

DA is a maker space with a difference, it is economically sustainable. This is because it has two sides to its personality, on the high street it provides a fabrication service and retail store front for digital craft, while in an adjacent basement it provides space for entrepreneurs to develop and make ideas. In the words of Nadeem Mazen, the co-creator of DA with Ali Mohammad, the combination is trying to move production and innovation away from the privileged rich and make it available to the average person on the street.

Mazen, as well as being a graduate of MIT and running a digital media consultancy, is also a local Cambridge councillor so has his ear firmly to the ground when it comes to social and technology trends. They spotted that the maker movement is blurring the boundary between consumer and producer, so where better to do this that in the belly of consumer behaviour.

DANGER AWESOME benefits from a highly visible position on the street.

The service bureau at street level serves as the home for their two laser cutters, vinyl cutters and numerous 3d printers. DA's intention is for this to be a space of on-demand production, as well as learning for those wanting to do it themselves. I had a hard time imagining the teaching aspect in this as space was very cramped and most available space was devoted to product placement.

The presentation of craft objects available to buy, whilst suggesting a focus on consumption rather than production, does offer examples of what is achievable from digital fabrication techniques and a useful showcase. Personalisation and customisation is DA's unique selling point and a powerful and lucrative advertisement for the maker movement.

This aspect of digital craft is important to the success of the space and one which DA emphasises. They see their efforts within an historical lineage of manufacturing innovation in Boston, looking back to metal smiths of colonial Massachusetts. In the contemporary case flint lock rifles and horseshoes have been replaced by trending objects gleaned from Etsy or Pinterest.

The basement co-working space works on a membership basis and provides access to the same kind of machines but trained how to use them. On my visit I spotted a wood working facility, material storage, co-working desk space and 3d printers.

Danger Awesome are in its early stages and I sensed it was still trying to balance the dichotomy of con-

DANGER AWESOME view from the doorway

sumption and production. Danger Awesome provides a case in this study where both geographic location and business model are critical in providing a sustainable source of small scale digital fabrication.

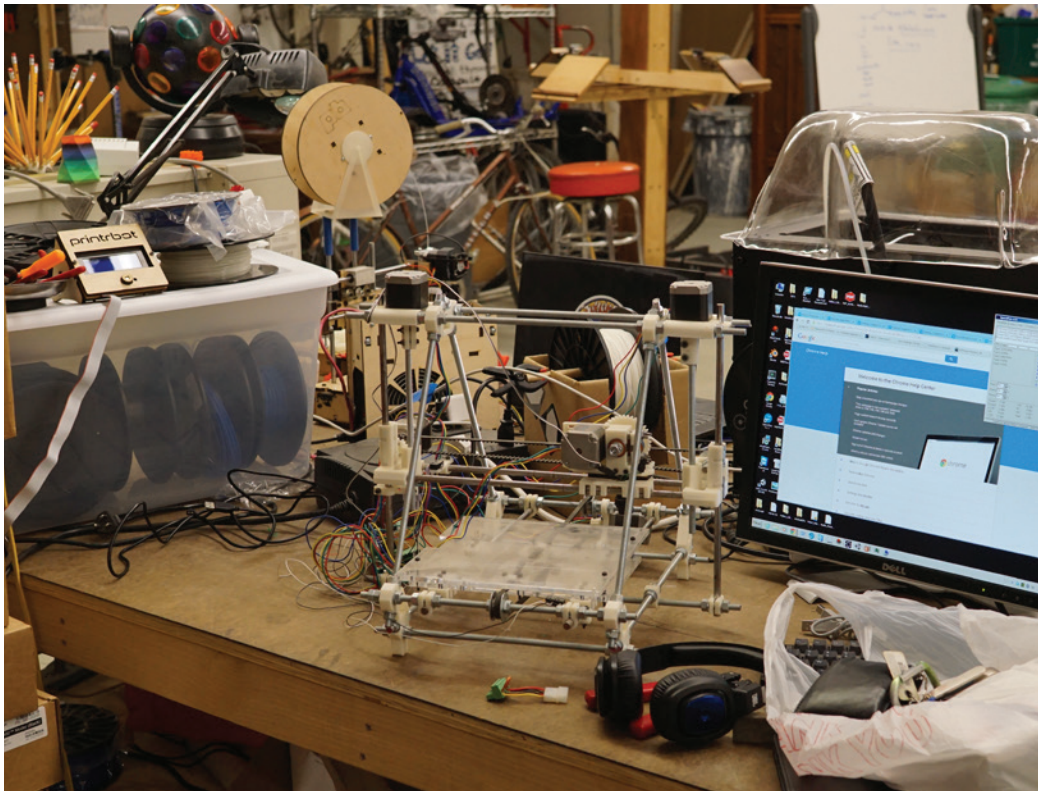
> ***"Danger Awesome is different from Fab Labs, in that we are economically sustainable***
>
> Nadeem Mazen

lowell Makes Lowell, MA

While Boston, Cambridge and Somerville have multiple maker spaces within their boundaries there are a number of other locations within greater Massachusetts that have their own unique making stories. One such place is Lowell, a 70 minute train ride from Boston. Lowell has a very interesting history which connects with the ambitions and potential the maker movement is known for, a third industrial revolution. The city is known as the birth place of the original American Industrial Revolution. Francis Cabot Lowell, whom the city is names after, was part of the initiative that brought industrialised manufacturing to America in the form of textile machinery. He studied mechanised looms on visits to factories in Lancashire, UK, memorised the systems and subsequently reproduced them back in his native country.

By the 1900s Lowell was the largest industrial complex in the US but soon after started to decline and suffered particularly badly during the great depression. Migration has always been part of the citiy's past and it has a rich racial and cultural mix. Today the city is a thriving university town and has a proud arts and crafts community evident in the numerous independent shops in the city centre.

Lowell Makes resides in the storage facility of a retail building connecting the main Merrimak Street with Lee Street, where Lowell Makes have their entrance. I visited on a Wednesday evening for their open house session, but the space is accessible for members throughout the week. After walking down into the basement it was clear to see that Lowell Makes loves making and engaging with the community. A notice board summed up their agenda: what would visitors like to invent, make, do, design, learn, create, build, teach? The space is packed to the brim with projects such as DIY bikes, DIY 3d printers, computers, electronics, wood work.



LOWELL MAKES the space is crammed with ongoing projects.

As a non-profit, shared community workshop they receive lots of donations in discarded tech, and as a result have to find homes for all the pieces of equipment; storage is definitely a premium.

The space was set up by Eric, John and Kamal, who are scientists and engineers by trade and met at a class in the Mill Cities Leadership Institute (formerly the Sandbox Leadership Institute). Sadly Kamal, who I had been in contact with, had passed away a few days earlier from a farming accident which was a shock. I was shown around by the very friendly John Noto who gave me an overview of the operation.

Initially conceived as a Hacker space, Lowell Makes decided to brand themselves as a maker space as they were worries that the negative perception in the media might reduce their ability to attract a broad cross section of the population. While it was obvious that the regular members present on the night could quite easily fit into the Hacker stereo-

type, I arrived at the space at the same time as a lady in her 60s who wanted to learn about the 3d printers for her grand children.

Every inch of the space is utilised but perhaps not in the most efficient manner. The effect is a cluttered but visually rich environment of objects and tools, each seemingly in the middle of making action. There are distinct clusters in the maker space that compartmentalise 3d printing, metalshop, woodshop, electronic prototyping, leather working, stage design and pottery. The main space is saved for communal seating where the open night was focussed around personal projects, and a bottle of bourbon. Tables provide space to temporarily spread projects out for discussion, and lounge seats offer an alternative environment to engage in relaxed conversation, referencing a book, or immerse in a computer game.

The building they inhabit has other floors free and they next plan to expand to offer more classes for the residents of Lowell. The maker space is completely underground and as such has no natural light into the space. The community workshop rents the space but it is not hard to see that they must get a good deal.

This is the notable aspect of maker spaces: organisations that survive on very little funding, driven by enthusiasm and social contact, opportunistically inhabit the spaces that no one wants. Surely if Lowell Makes was visible the engagement with the street would be greater and visitors increase, but this is perhaps not what this maker community wants. It is a kept secret, a space to hide away and indulge in making for personal gratification and safely store away the collected and constructed treasures.

For a city with such a rich history of manufacturing and craft Lowell Makes seems the perfect vehicle to encourage participation and engagement with personal fabrication to stimulate economic regeneration. Its success depends on backing by the city to provide opportunities for funding and space. My visit suggested a latent creative economy which could blossom given the right economic, cultural and social policies.

LOWELL MAKES a large and chaotic space.

Hatch Makerspace Watertown, MA

Libraries are becoming significant stakeholders in providing spaces of personal fabrication across the world. Institutions that were traditionally responsible for providing information for consumption now must engage with modes of production as the desires of society move towards increased generation of knowledge.

Once such maker space is Hatch which is associated with Watertown public library in Watertown, Massachusetts. While you would expect this to be housed within the building of the library it is instead located within the Arsenal Project a commercial endeavour to redevelop the Arsenal shopping mall in Watertown.

The Hatch public workshop is an initiative of the library with the theory that it can tap into the customer base of the mall and connect a new type of audience into the library facilities as a whole. At its inception Hatch identified a vital missing provision of making and associated facilities within public schools and wanted to test the willingness of young people to engage in making outside of school hours. For the mall owners their hope was that some of the maker movement's perceived cool would attract more people to the mall and stimulate economic regeneration.

Janet Buck, who has an architecture background, runs the workshop, organises events and teaches classes within the space. She described the maker space as a test bed for teaching making skills and a space that can manage adaptive reuse as the movement matures.

The makerspace inhabits a small retail space that offers a front and back of house configuration with office space in between. The front area is visible to the mall circulation space and is used mainly for promotional purposes to try and catch potential user's attention. It is here that the high profile facilities live; those capable of generating curiosity such as 3D printers or Little Bits prototyping modules, as well as screens used for teaching.

The hidden back space is used for the majority of the making activity and vital material storage. Janet has a strong theme within her workshops relating to adaptive reuse and recycling and has a knack of collecting lots of discarded materials. One favourite is cardboard and she utilises its versatile properties to provide introductory projects for new members. The critical aspect for her is for the users of the space to address personal problems with their own solutions and stories explored through prototypes.

Janet had observed that her design background gave her a different approach to instruction than other maker spaces which had more engineering problem solving approaches where the first solution is the solution. Her workshops promote the use of prototypes as a non-linear design process where the act of making can stimulate new understandings, ideas and approaches.

Electronics is seen as a vital part of this and a way of linking the manual process of making with the digital processes of 3d fabrication. Users of the space are encouraged to solder their own circuit boards and connect to computers via the Little Bits kits, and learn software to visualise ideas via sketchup, tinkercad and sculptress.

Its location within the mall, albeit slightly hidden away, has had varied success. Their current location is not big enough for the ambition for the maker space, it provides a visible face but has a limited capacity. The plan is to move to a larger retail space to gain suitable facilities but is heavily dependent on market forces of retail real estate. As with any case of gentrification the regenerating force could become a victim of its own success.

If more people use the mall demand will increase for its retail spaces and Hatch could be squeezed out as rental prices rise. It would need a socially aware commercial enterprise to realise that the removal of the stimulus could result in a return to previous conditions rather than follow purely economic benefits of market based efficiencies.

LITTLE BITS investment in electronic prototyping has been popular with visitors.

WORKSPACE dedicated workstations for activities such as soldering and sewing.

Hatch benefits from a high profile position in the mall, but suffers from not being able to see into the full maker space.

Maker Media Lab San Francisco

Maker Media are responsible for the magazine Make as well as numerous books that promote DIY approaches and solutions to common problems. Their office and day to day operations are in San Francisco, but located north towards the Golden Gate Bridge, in the Palace Of Arts, they have their Maker Media Lab. Built in what is now a conference and exhibition centre, the lab is set up purely to indulge the professional and personal curiosities generated by those involved in the magazine.

The lab, which takes up a small corner of the building, has a devoted CNC woodwork shop with multiple scale shop bots, with the remaining space left for open plan working at stand up desks. A fluid arrangement allows equipment to be relocated to specific work space via ground level power points rather than continuously moving from work bench to fabrication tool. These tables also served as storage containers for materials and locations to display interesting projects.

On my visit I met Marty Marfin the Lab Manager and contributor to the Make magazine and website. He has a background in prop and set building and had a keen interest in how makers could generate innovative ideas around making music. During the summer Make media organise summer camp and always has a whole stream devoted to DIY music. Marty was enthusiastic about the potential for maker spaces to generate energy around things that would simply not be considered through the lense of commercial research/ innovation. His and the labs ideology in general was that making through sharing, hacking and adapting of ideas was critical to the outcomes of maker spaces leaving the perceived territory of unsophisticated tinkering.

While I was talking to Marty he was working on his own project, a collaboration with marine biologist Christopher Lim, to produce an artificial 3d printed Oyster reef bed. He had identified a loss of their habitat at Point Emery and Point Molate in the San Francisco Bay area, and had the idea of creating a modular system that could provide a foundation for reef replenishment. Using the lab he had explored 3d design, 3d printing of prototypes, and the creation of injection molded polymer castings to explore possible solutions.

He referred to architects such as Lebbeus Woods, Buckminster Fuller and more recently Andrew Kudless as inspiration into material and tectonic investigation. As we were discussing architectural influence in his work I was introduced to Gary Rohrbacher of Filson and Rohrbacher and AtFab

an open source furniture design company. He was based at the lab for a few days with the dutch Waag Society and One Architecture to announce the development of the Design / Fabrication Lab in Amsterdam.

This new type of makerspace would be devoted to making at architectural scales and exploring the maker city. I had caught them during a three day symposium where they were exploring themes around digital fabrication and maker culture and linking them to new entrepreneurial infrastructures and shared challenges within the construction. I made contact with Gary in between a busy schedule of sessions involving other participants such as Testa & Weiser Inc, Jelle Feringa and DUS Architects of the Amsterdam based 3d printed Canal House.

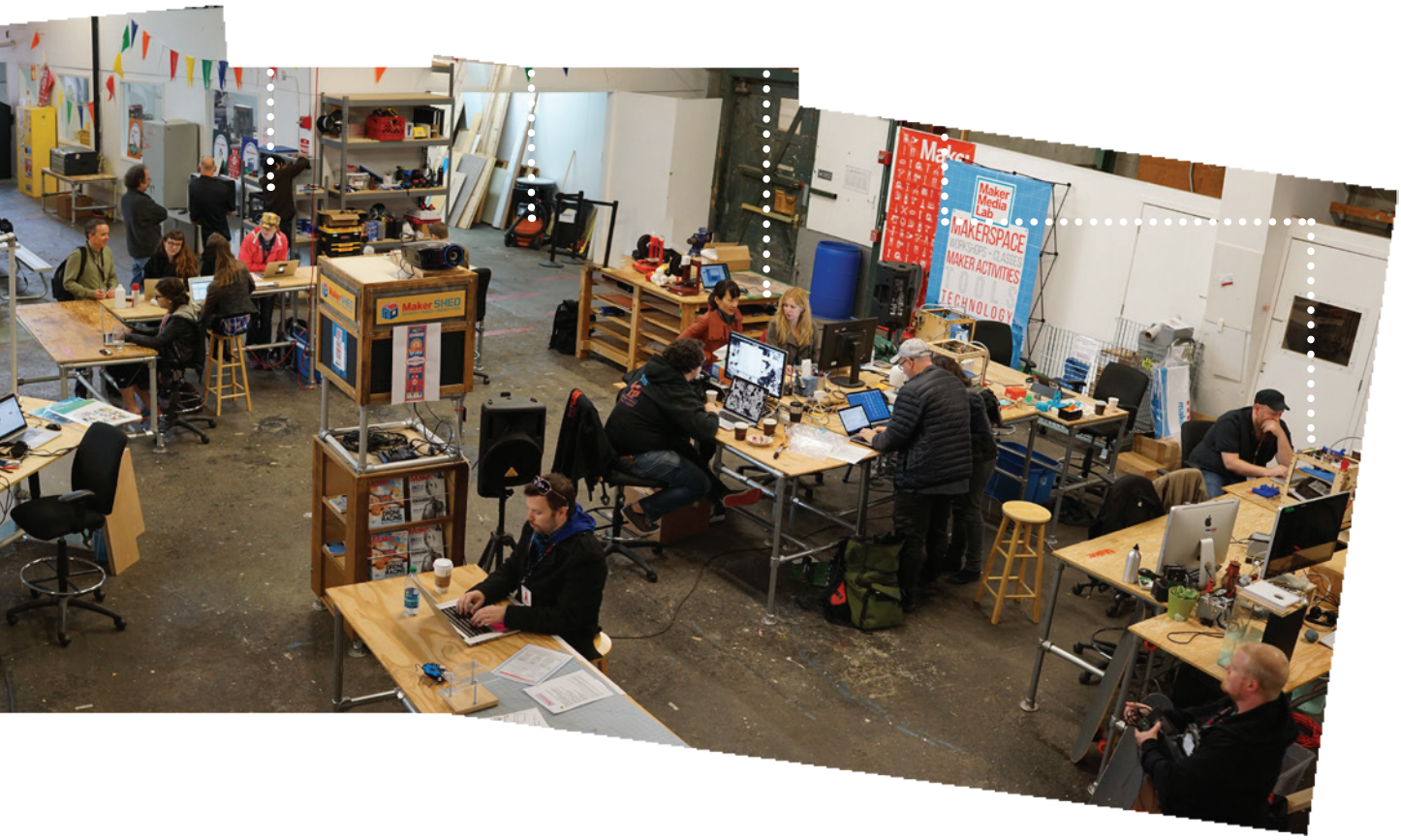
3D Printer Storage

Timber CNC Routing

Collaborative working stations

Computing

MAKER MEDIA LAB tables provide locations to place tools rather than having to work next to fixed locations



A dedicated ventilated woodwork space wih multiple sized CNC routers

Multiple moveable seating types allow choice in position and flexibility.

Autodesk Pier 9 San Francisco

Set in a converted wharf along San Francisco's Embarcadero, the software company Autodesk have built themselves a high end fabrication facility open for use by employees and selected artists in residence. The logic is clear, Autodesk make software that output data to fabrication machines, so in order to improve their software they have to understand and push the capabilities of these machines.

The facility initially served as a physical space to record content for Autodesk's Instructables website devoted to presenting and explaining DIY projects. As the machinery brought in by the company became larger and more sophisticated the focus shifted towards creative exploration and investigation.

The centre's main digital fabrication space is filled with a water jet cutter, 5-axis CNC timber router, 5-axis CNC metal router and an enormous 8-axis CNC milling machine that had to have a special reinforced concrete floor installed to avoid falling into the sea.

Beyond this double height space with overhead circulation gantry, there is a woodworking space, leading to a metal workshop. Up a level brings you to the rapid prototyping lab where 3d printers and laser cutters sit together. What marks Pier 9 from the other spaces I visited was the variety of equipment available, each with its own strength in making. For example different laser cutters provide different wattage power strengths and different bed sizes to cut through differing materials and provide varied finishes.

Back across the gantry of the fabrication lab the facility culminates in an office space and separate electronics workshops, a test kitchen, an industrial sewing centre as well as smaller specialty project areas.

The tour of Pier 9 was quick and I could tell our guide had better things to do (like make things) but it was possible to get a sense of the creative energy of the users through the projects in progress and on display. On my visit I experienced an artist creating a 3D printed vinyl record, product and fashion prototypes being assembled and the outcomes of 3d printed materials and fabricated geometry experiments.

Autodesk also have an office on Market Street in San Francisco and within it have a gallery for all the projects they create in Pier 9, along side the software tools that help achieve them. The company are extremely public and sponsor events throughout the city boosting communities of interests into innovation and generation of ideas.

They realised the potential of digital fabrication and high tech manufacturing early and are fostering connected communities to provide distributed research and development across multiple design fields.

Autodesk provides an interesting example of a software company, focussed on computer bits and running agile and flexible work practices, but one that creates things made out of atoms and is reshaping how products are developed and distributed.

PHOTO BY AUTODESK

The main fabrication space at Pier 9 hold machinery usually associated with light industry usually unacces-sible to the public.

Tech Shop, San Francisco

While in San Francisco I stayed in the SOMA (South Of Market) district of the city. After the 1906 earthquake the area developed around light and heavy industrial zoning. Today it attracts many software and hardware companies that flock to San Francisco for its successful entrepreneurial culture and loft style real estate.

In amongst the many industrial buildings and empty parking lots sits the Techshop, a membership based workshop that aims to provide a sustainably funded space and provides access to tools and software for the creative community.

There are currently eight Techshops around the US and they provide something a little different from the other maker spaces I visited on the trip. Imagine a gym for making and you are not far from the business model of this organisation. Overall it serves as part fabrication and prototyping studio, part hackerspace and part learning center and has access to over $1 million worth of professional equipment.

The company claims to be a community-based workshop and prototyping studio with a mission to democratize access to the tools of innovation, but it is hard to believe when access is $200 a month or $1650 a year.

This price limits membership to only those wealthy enough to afford an expensive hobby, or others investing in an entrepreneurial activity, this is where Techshops excel.

Using the example of software, maker spaces generally utilise open source programmes for ease of access and sharing, Techshops on the other hand are sponsored by Autodesk. This move could be seen in two ways: one is that Autodesk want to contribute to the local creative community, or they target Tech Shop users as potential customers for home licences.

In the case of Tech Shop, community relates to a working community that already exists in the SOMA district. Rather than generating a collective as hacker or maker spaces generally aim to do, they have tapped into an existing infrastructure of creative industries and employees who have ambitions to make and improve their skills. This point of distinction explained why the users of the space, when I visited, did not seem to know each other, and were concentrating on personal projects utilising time they had in the space.

On my visit I was shown around by Liz, one of Tech Shop's "Dream Consultants" who are expert technicians of the equipment and represent certain professional making backgrounds. Liz's speciality was metal work and taught classes on Tig and Stick welding in one of Techshops many organised classes. In order to use the tools provided by the space you must first do a training course structured

around groups of tools.

These grouped tool sets unlock use of the space and mean users do not have to learn everything in order to make projects. The groups of tools relate to the spatial arrangement each Techshop follows. A factory like dirty space holds woodwork and metalwork machines plus industrial CNC machinery such as water jet cutters and routers. The large machines must be supervised at all times when in use and costs around $3 per minute to rent on top of membership.

In a separate cleaner and more laboratory like space is the digital prototyping facilities which provide open plan tables for work and collaboration.

Separate adjacent office space can be rented to local businesses, this is particularly popular with hardware start up companies. Type A machines are such a company who developed a 3d printer whilst renting in the Techshop. They had just vacated one of the offices and their influence was plain to see with a number of Type A 3D printers within the larger prototyping space.

This space caters for serious makers typically working on career changing ideas and provide machines which bridge the gap between consumer and high end manufacturing. The Techshop is very similar to the offering of Bolt without the pressure of expected returns on investment. Storage is critical and members have temporary access to lockable storage whilst working on project. Desk space appeared

TECH SHOP fills the need of making facilities for professionals.

to be on a first come first serve basis with many projects in progress reserving space. The overall building is a converted factory and has large openable windows which are perfect for the function of the space and the temperate San Francisco climate.

An interesting part of the prototyping space was a computer linked permanently to the US Patent and trademark office for those wanting live help with getting their ideas to market. It struck me that the Techshop offers the opposite of what a Hackerspace provides, the former catering for the market based mechanisms of the capitalist economy whereas the latter is based upon open sharing and social capital. Both interestingly produce entrepreneurs but I would expect that Techshop attracts those who are more interested in joining the system than subverting it.

Beyond prototyping the Techshop provides considerable communal social and teaching space. Just like a gym it provides the conditions to connect with other users as much as it does with engaging in activity and provides opportunities for different group sizes to congregatete and discuss ideas. Notice boards cover the walls advertising internal and external events and meet ups serving to promote networking in the community.

The tour culminated in the reception area which serves as the security point and the public face of the space. The public can gain access to this area and view some of the things created in the Techshop to hopefully become inspired. Objects such as a foldable canoe which was developed in house, and CNC manufactured furniture offer a flavour of what the Tech Shop offers.

The public can also access a retail store providing materials for general making projects and for use in the facilities. From the reception they also offer a 3D print service for members and non-members alike. Operating like a 3d print shop objects are printed for a fee, but there is no DIY access to this machine.

A Techshop gallery is located two buildings east from the main Techshop but was unfortunately closed the day I visited.

The gallery provides space for members to exhibit their work and for internal or external events to be held. Although the gallery did not appear to be particularly utilised it seemed to be a potential interface with the wider community, whilst providing publicity for the enterprise. If opened up for other niche interest groups, such as web design, it would widen the network and create collaborative opportunities for members.

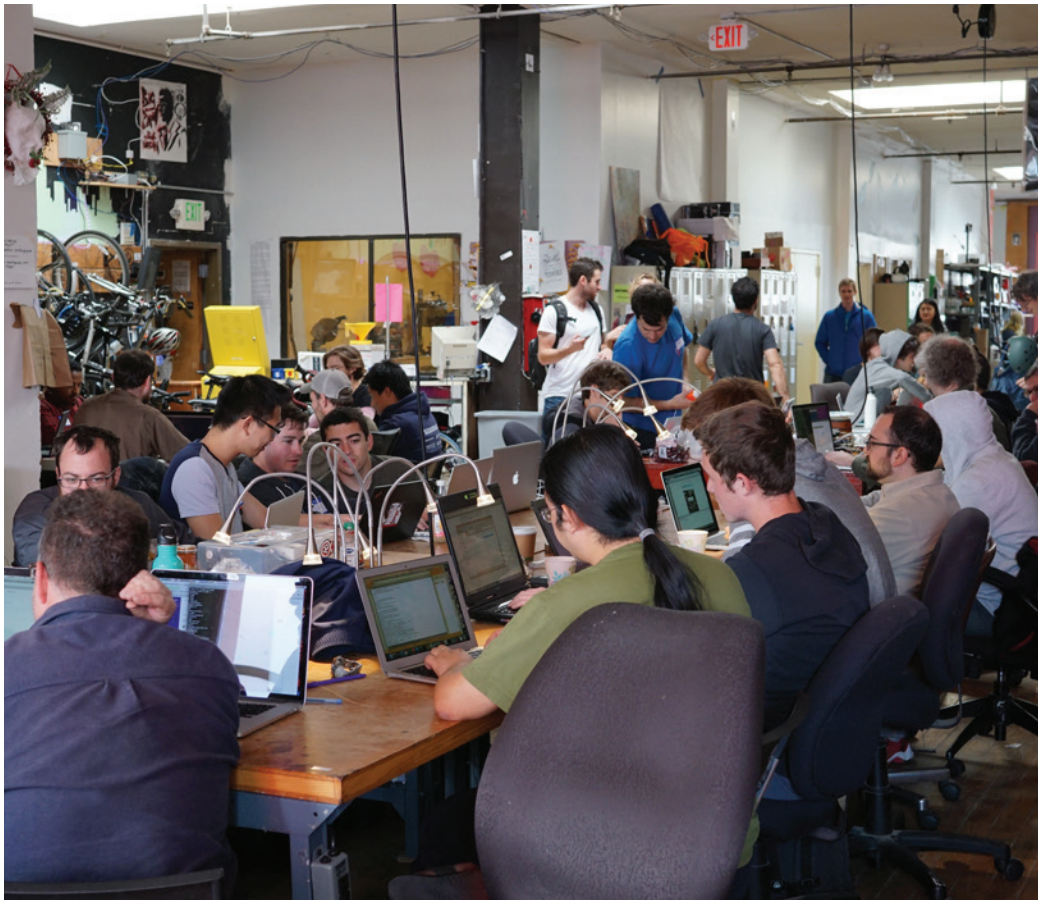
Noisebridge, San Francisco

The mission district of San Francisco is a predominantly middle class but ethnically diverse area of the city. It is under immense pressure from gentrification caused by the expanding tech industry, but a large artist population continues to thrive despite increased rental prices.

On Mission street above a Mexican produce shop sits the Noisebridge hackerspace. The predominantly open plan space is 483 square metres and provides room for computer software programming, making hardware, 3D Printing, woodworking, art, science, craft, robotics and sewing to name a few. Hackerspaces generally differ from maker spaces in terms of a bias towards software projects. However many maker spaces are simply hackerspaces that re-branded avoiding the sometimes negative connotations of the "hacker" and broadening their demographic appeal.

In the context of hackerspaces, "hacking" relates to a process of creative reuse, in contrast to the unlawful access to software systems with which the media and governments are obsessed.

Noisebridge functions as a "hackerspace" through the technical-creative projects it facilitates and also how its membership structure works. The organisational hierarchy is flat with responsibility for the space down to those using it at the time, and the social and behavioural



code is based on one main rule, "be excellent to each other". Generally all major decisions are made by consensus but if a member wants to do something they must base the decision on "do-ocracy", i.e. make sure people are happy with you doing it. The outcome is a very open, self organising space where members are free to explore whatever they want in respect to their fellow hackers.

I arrived at Noisebridge on a sunday afternoon to find it packed full of people, music playing and the space full of conversation. Thin and long, the space connects two facades that allow lots of light into a collaborative area on the West and a teaching / eating area on the east. The west is functionally divided into zones of particular activity focus with a central space for collective activity. The provision of lighting on each table, plus multiple overhead bulbs, suggested many late night sessions of hacking, reliant though on holding a key to the space.

I found the do-ocratic rule out the hard way by taking photos without asking those in the space on the day. However while it was mentioned it was not a problem and I was welcome to stay. I was lucky to time my visit on the same day as a "hackerthon", an intense period working on particular collaborative projects. This day the hackerthon was around making "stupid shit" which doesn't need much explaining. There was an anarchic feel to the activities on the day with equipment, books, people spread everywhere and it was inspirational.

Whilst walking around the space my instinct was to seek out the "manager" of the space but soon realised that no one was in charge. The realisation was quite enlightening that this large collection of people acting as joint custodians

NOISEBRIDGE central space is used for collaboration and computing with tools and storage on the periphery.

for the space providing a public space to explore slightly subversive activities. This access however is dependent on an $80 a month membership status and, as I learnt, open to a lot of abuse.

I managed to get talking to one of the members who spent more time than most in the space and by virtue of this he seemed to hold more social capital. Ruben explained to me that in the early days of Noisebridge the ethos of welcoming the street into a self organised space ended in some very tense moments as visitors attempted to exert dominance over the space and in one case used their floor as a toilet. This for Reuben was the critical thing about the hacker-space that was so appealing, that its anarchic nature bordered on the chaotic.

Ruben had travelled extensively visiting other hacker spaces, particularly those in Berlin, which Noisebridge was initially based upon. The idea of simply opening your doors to the street and allowing anyone in initially made me nervous but Ruben explained that this was what the hacker movement was about, inclusion without prejudice. If you enter into the space and engage with the code of conduct you are immediately part of the community, but if personal benefit outweighs input then you will be asked to leave.

On the day of the hacker-space, the space was filled with mainly white males in their 20s and 30s. The organiser of the hackerthon, Will, had promoted the event through his university social networks and website meetup.com so visitors were generally from within an associated demographic. When I asked Reuben about the cross section of members he agreed with the observation of a male bias but said that it really depended on the activity organised at any one time. Other sub cultures of hacking were actively encouraged but relied on the energy of someone to mobilise that particular niche community.

I really enjoyed my visit to Noisebridge and feel I would be drawn to it if living in San Francisco. What surprised me most was the level in freedom provided for making and the intensely open and collaborative culture that had developed around it. The subversive but highly social behaviour at Noisebridge was inspiring and intriguing to think about its possible effect on mainstream culture.

Making Movements

The case studies visited in this study were identified to provide different community motivations each providing catalysts for personal fabrication spaces to form. This chapter interrogates these motivations, the resulting communities and explores the spatial implications.

In Neil Gershenfeld's article "How to Make Almost Anything" he identifies that the real strength of Fab Labs are not technical; it is social.In this study I visited two Fab Labs, one in Australia and one in the US. The SETC Fab Lab in Boston was the first and illustrated just how much can be achieved from limited but efficiently utilised space for digital fabrication equipment and space to collaborate.

The two Fab Labs in this study cannot be compared in terms of their social or economic contexts, but they both share an ambition to provide a space to explore and share personal making projects to citizens of all ages. Where as the SETC Fab Lab holds a corner of a basement of an old town house in Boston, the Adelaide Fab Lab utilises teaching space donated to them by the Adelaide Collage of Arts. Both make desk space to sit and talk a priority and use clusters of desks to make sure users can sit and face one another.

ABOVE:
Adelaide Fab Lab

OPPOSITE Susan at Boston Fab Lab showing kids how to use conductive playdo

It is stated in the Fab Foundations guide to setting up a Fab Lab that "90% of a student or user's time is spent designing on the computer" so it is not surprising that this has such a significant spatial impact.

Social Education

In order to be part of the Fab Foundation a Fab Lab must be free and inclusive to all members of society. Funds can be generated by a variety of methods but a percentage of time must be devoted for free access and drop in sessions.

Initially Fab Labs were conceived as a way to extend the educational outreach of Gershenfeld's MIT class and have consequently spread across the world. The Fab Academy now provide remote teaching via video link to all these affiliated spaces. The class seeks to educate how to use the digital fabrication tools at hand, but on personal and meaningful projects.

At the Boston Fab Lab the teaching of the Fab Academy is taken a stage further where young students of the programme are employed to go into schools and teach younger children and generate a sustainable cycle of learning and teaching. The programme has proved so successful that Fab Labs have been set up in the schools involved meaning legacy of influence can hopefully be established.

Here in Australia the Makers Place take as much of

> ***"The class seeks to educate how to use the digital fabrication tools at hand, but on personal and meaningful projects***

a social focus as the Fab Labs, but are not part of the foundation. Makers Place and its parent company Three Farm use design and making across multiple communities to help gain autonomy and strength through self-identity.

If Fab Lab represents a laboratory of digital fabrication, then maker spaces are the factories. Artisan Asylum and Lowell Makes both emerged out of the Hackerspace movement, but have gravitated towards a focus on creativity and entrepreneurism, rather than activism.

Creative

As such the maker spaces visited had generally longer standing projects and highly personalised additions to the interior of their space. Users of these facilities were typically more inwardly focussed, concentrating on individual pursuits and creative endeavours. In these two cases it resulted in a compartmentalisation of space allowing personal storage and ownership over a particular space.

Hackerspaces, despite the negative image produced by the media relating to cyber crime, provided the most enthralling of spaces I visited due to their open and subversive atmospheres.

Subversive

Although neither of the two hackerspaces I visited knowingly promoted criminal activities, they had a freedom and a shared connection in making (or breaking) that stood out. Although Noisebridge provided the more extreme example, both had few rules and instead relied on self regulation and honesty to maximise freedom in movement, interaction and open sharing.

Entrepreneur

Techshop, the surprisingly unfordable "democratiser" of fabrication, sits rigidly within the entrepreneurial camp. However where it gains in making technology it lacks in the spatial identity seen in maker spaces. Users in these spaces were serious, generally working on projects for capital gain, and reflecting the motivations of the service they were using.

In contrast to Noisebridge, it is clear at Tech Shop who owns and manages the space. Limited time on machinery and a highly regulated environment remind the users who the space belongs to and who you are paying for access to technology. The two libraries I visited, Boston and Adelaide, introduced digital fabrication facilities due to a conscious engagement with production as a cultural generator, and recent capital investments through refurbishment. Boston library, the larger and more established of the two, combined rapid prototyping within a larger computer lab. This space contained CAD software providing young people a complete design to production fabrication workflow to learn from and experiment.

Knowledge

Adelaide Library's community base means it is not able to provide equivalent facilities or space, but it is still able to engage users in designing and prototyping their own artefacts. Through the design and making of 3d models users are given the free knowledge to progress and are introduced to an alternative to consumerism.

In both cases knowledge is facilitated through computers, enabling those who engage and learn the opportunity to generate personally and potentially culturally significant artefacts.

Fabrication Services

Danger Awesome proved to be the most surprising case study , and perhaps for the wrong reasons. What I expected to be a community led digital making space turned out to be a more retail focussed fabrication shop comparable to a print or copy shop. While I was a little disappointed that making skills and community was not as prioritiesed I appreciated the type of fabrication it provided, and the economic context it operated. In the future not all spaces with digital fabrication machines will be open to feely use, someone who has a digital file will in many cases just want to go and get it produced rather than hanging around waiting for it to be created.

The aspect I found disappointing was that through making for others it disengages with the overall ambition of personal fabrication where users can gain autonomy

through their making activity. Nadeem, one of the directors at Danger Awesome is critical of the Fab Lab concept explaining that it was completely unsustainable as a business. While this is most likely true as Fab Labs need funding to survive, he misses that Danger Awesome operate as custodians for a culture rather than purely a business model. If free or low cost access to digital fabrication is not provided then the "democratisation" of making that Danger Awesome promote is just marketing speak.

During my study I spoke to many people who felt that maker spaces within corporate companies will become a more common occurrence in the next few years as business leaders seek to provide creative outlets for their employees. The two examples I visited are slightly different in that the companies, Bolt and Autodesk, are directly involved with the maker movement. They are both examples however, where corporate money provides the highest level funding and produce the greatest innovation.

Corporate

The interesting aspect for maker spaces within companies is the possibility for employers to engage with disruptive consumption patterns. Potentially, if employees can make their own things and not have to rely on consumption of mass produced goods, then why will they work to pay for them?

A more likely outcome, however, is that a maker space, and allocated usage times, will provide incentives to work. If companies allow time and space for making they could find themselves the beneficiary of new and unexpected ideas that could feed into the economic success of the business.

NOISEBRIDGE on the day of visiting were hosting a "Hack stupid shit" hackerthon.

Types

The spaces included in this study are all bound by a common spatial situation, they are all adaptive reuse of architectural types. In this section I aim to highlight the typologies that have been adapted to suit the needs of maker communities and wether these original spatial intentions work for their new residents.

Classrooms

Adelaide's Fab Lab sits with the College of Arts (ACA) designed by Hassel Architects which is home to TAFE level creative arts training. The building itself consists of a wonderful multilevel atrium that feeds open plan classroom space along the perimeter of the building. The Fab Lab is on the fourth floor providing great access for students but no visibility to Adelaide's street life.

The classroom type actually serves the fabrication space well with an open plan rectangular layout, wall space, and large windows for natural light. High ceilings offer a feeling of space and the opportunity to feed power lines down to serve central working desks. The only difficultly the Fab Lab experiences is extraction for the laser cutter but a bit of HVAC hacking (with ACA's support) had brought some relief to this problem.

Basements

While classrooms bring the benefit of being located near to students and demand, it isn't the only type of space educational institutions have available. MIT's Hobby Shop inhabits a basement within building W31, a Gymnasium which was once a state armory designed by Hartwell Richardson & Driver. The basement is rectilinear with regular columns every three metres, solid brick construction and 3.2 metre high ceilings.

The basement could be seen as the perfect place for fabrication, isolated for noise, ceiling space for services and extraction, and pockets of space to locate and organise machinery. The basement type also suffers from a publicity problem. The Hobby Shop it is so hidden that it relies on street signage to catch attention and guide you through a maze of corridors. The subterranean space also creates issues for extraction with circulation having to be forced upwards, not to mention no available natural light.

Offices

Offices provide an interesting type of spatial use due to their transient nature. An office is mainly used during the day, but unless someone is working late these spaces are left empty and unused at night. At Cambridge Hackspace this scenario is utilised. After working hours are over at the co-working space Industry Lab the group move in to use the communal meeting area and small workshop in which to explore personal projects.

Similar to a function room of a community centre this vacated meeting space provides the physical connection for the Hack Space's members. A small raised platform offers a focus to the workspace for holding lectures, or hosting music performances.

Post Industrial

By far the most popular type of space experienced in this study are the pockets of building fabric left vacant through the redistribution of industrial activity. Within this typology I identified two subtypes, those that embraced the industrial and those that have refurbished to suit their needs. Of the former The Artisan Asylum (AA) is an example of making that aligns itself with the original paper factory aesthetic of the building. Although all types of making occurs at AA it is the large metal based mechanical projects that sit so naturally within the sparse fabric of the building.

The original factory needed to maximise floor space for production processes and the AA today benefits from this ambition. Interestingly, it is the secondary layer of studio cubicles which generates a variety and texture within the space not experienced anywhere else.The building of the AA provides a basic column framework from which secondary configuration and customisation of space is produced from 1200mm high stud walls.

The latter subtype is defined by Autodesk's Pier 9 and Techshop who have both refurbished industrial buildings to create new hybrid spaces. In Autodesk's case the pier's long finger like form and cast iron sub structure provides a free plan, always close to the building perimeter, from which to construct necessary thresholds. Such an original spatial condition has allowed Autodesk to incorporate light industrial activities adjacent to offices catering to creative pursuits as well as social spaces.

Libraries as a spatial type are significant as these are the types that are currently the most engaged in making through digital fabrication. If considered through the traditional notion of a library, commonly quiet and compartmentalised spaces for individual knowledge consumption, the incorporation of making could not seem

The Artisan Asylum's interior is very stripped back. Stacked cubicles provide work space and above head storage.

more out of place. It is the contemporary re-configuration of libraries as generators and distributors of culture that has attracted new modes of cultural engagement and community involvement.

Libraries

Boston and Adelaide are both examples of where this shift has happened and although, at this stage, only 3d printing is provided it is the combination of the means to design (digital modelling software) and the means to produce that provide alternative avenues for learning and creation.

An example in Australia of a fully provisional fabrication space in a library exists in the Edge, a provision from the State Library of Queensland. It aims to encourage creative pursuits to generate experimentation and innovation. Its Fabrication Lab is set up in the basement of the 2007 building designed by Donovan Hill and Peddle Thorp. Here a full suite of sewing machines, Hand Tools, Soldering Irons, 3D Printers and CNC Machines offer opportunities for creative exploration on top of an organised design education platform called Auxiliary Design School.

In this study if a basement provided the least visible example of fabrication space, then retail offers the highest. Four very different making business models which inhabit different retail contexts gave insight into this typologies suitability.

Retail

Danger Awesome squeezes into an high street shop, with a secondary basement space that connects to the streetwalk. The space is small and as a result 3d printers, laser cutters and fabricated goods dominate the floor are. Its cramped nature means that it is not very suitable for open access but it is extremely visible and was full of curious people viewing the fabricated goods, the machinery and asking questions.

If viewed as an attempt to publicise the uses of digital fabrication, Danger Awesome's spatial set up is very successful. Large windows that once provided natural light serve as perfectly proportioned lenses into the world of 3d printing. The retail typology in this case is extremely beneficial with a capacity to connect to the street, advertise to street traffic and become an accepted addition to the commercial landscape.

Adelaide's Fab Lab reside in a converted classroom. Whilst more space is needed it works well for their requirements.

Boston Public Library's Teen Central Makerspace benefits from funding but is hidden away within the building.

Of course in America not all retail environments are open air streets, there are also malls, lots of malls. One in particular, Arsenal Mall in the Watertown area of greater Boston, was bought in 2013 and the Arsenal Project was devised to incrementally develop to adapt to the needs of the local residents and visitors. Through community input, support, and combined resources it aims to develop a more relevant base of services and redefine the potential of a modern mall.

Their first addition to the traditional retail base was the Hatch Makerspace. Its addition has been successful in tapping into the young population who pass time at the mall and attracting groups of people to participate in free workshops. Although the Arsenal Project had brought a maker space into its mall it hadn't allowed Hatch to augment the interior mall's space which I felt was a missed opportunity. The future of a maker space within a mall could be

to use it as source of ideas and a test bed for new types of public / private space.

This was definitely the case with The Makers Place in Sydney. They inhabit a previous cafe / restaurant space and when the Makers Place is active they expand out into the Italian Forum via DIY furniture made from stacking pallets. These pieces of furniture are on wheels facilitating relocation anywhere in the public space and producing possible reconfigurations and informal meeting points.

The Maker Media Lab is housed within the Palace of Fine Arts building in San Francisco. Exhibitions and conferences come and go but a corner of the great exhibition hall remains a laboratory for DIY making. The strange stage set like building, that mimics a ruined Roman palace, was once the home to the Exploratorium, a museum based around informal education for arts and science, that has since moved to one of the San Francisco's piers. It left a legacy of discovery in arts and science and the Maker Media Lab uses this link to its advantage. Its location within an environment that attracts such a variety of networked people visiting events means it acts as an important advertisement for maker culture and the media brand as a whole.

Exhibition

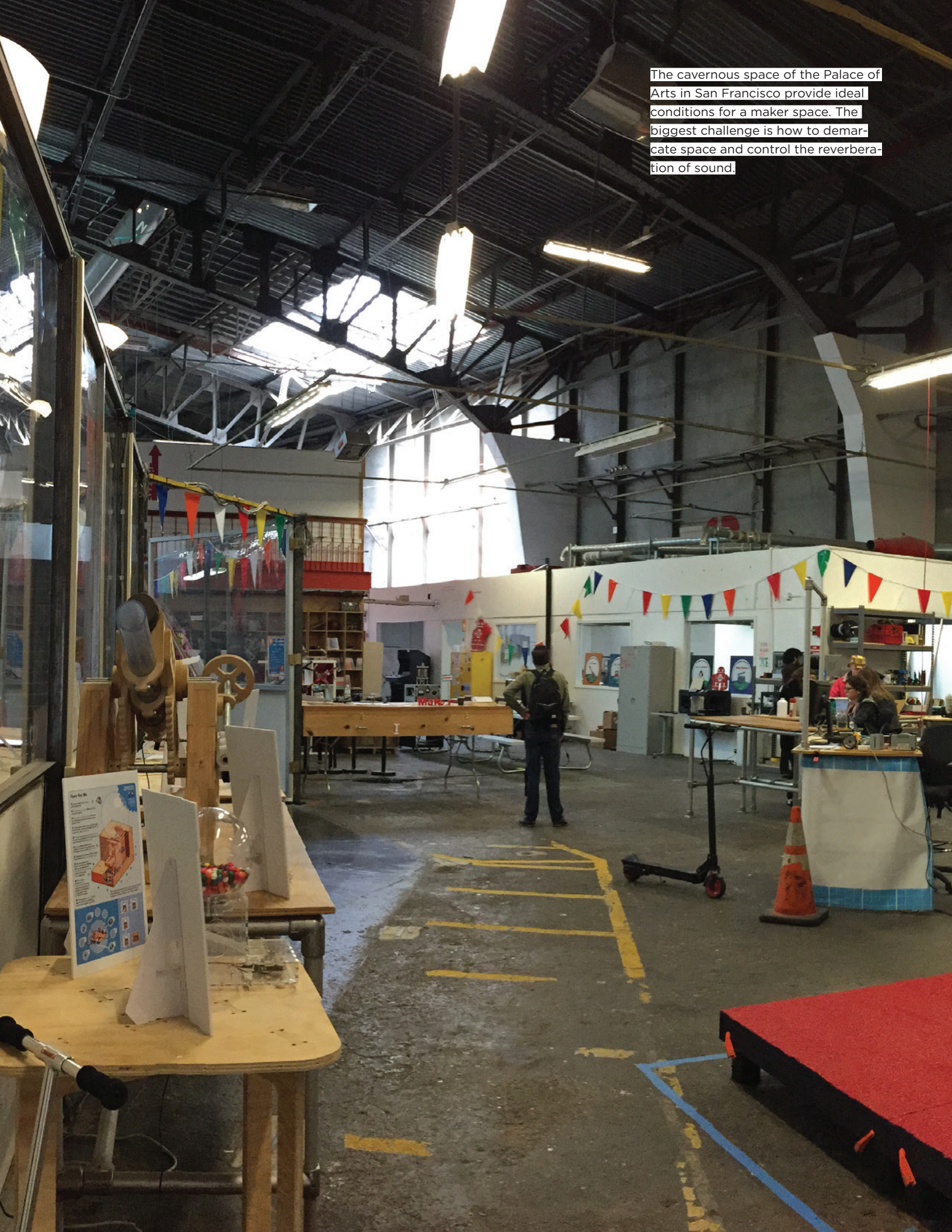
If the exhibition typology offers the greatest provision of scale then the South End Technology Centre or Boston Fab Lab situated in a converted town house provides the least. The ex-residence sits within the larger complex called Tent City, named after the activist movement which saved the area of mixed income housing from being demolished during 1960s "urban renewal". The Fab Lab's location in the South End Technology Centre was an opportunistic move but I felt that the domestic scale of space was totally ill equipped to house fabrication machines and provide enough space for teaching. However, this does not mean that the Fab Lab is unsuccessful, far from it.

The Fab Lab's location is very important, it is right in the middle of an area which experiences high inequality and it provides an important resource to these residents. The area is residential therefore to stay within it, it must adapt, which it has tried to do but needs more space. The residential scale could also help to provide a familiar environment for the many young people it primarily serves. I doubt the Fab Lab would be as successful if located within a warehouse or office as perceptions around how to behave and act would be impacted by the space.

Residential

The Makers Place make great use of the operable walls originally planned for alfresco dining

Furniture making projects allow the space to expand out into the Italian forum



The cavernous space of the Palace of Arts in San Francisco provide ideal conditions for a maker space. The biggest challenge is how to demarcate space and control the reverberation of sound.

Context & Connectivity

All the maker spaces visited during my research trip were located within particular urban contexts. Each space had its own specific set of internal desires but were also part of larger set of virtual and physical networks. In this section I explore the case studies at an urban scale looking at their contexts and connectivity in relation to the benefit to maker culture and possible knock-on effects.

My visit to Boston couldn't have avoided coming into contact with University education with MIT and Harvard playing such a significant role in the city. MIT's Hobby Shop is em-

Education

bedded in the heart of the MIT campus and benefits from the large student population the institute attracts. The space is faculty non-specific and as such benefits from a mix of interests and approaches to creativity. Its place within the campus means it is specific to MIT students but they are also part of the larger community of Boston and bring with them particular views on society and culture.

As the Fab Lab movement came out of the MIT centre for Bits and Atoms, the SETC Fab Lab in South End has strong links with the academic institution. The context for the Fab Lab is primarily residential and its users are young people from this culturally mixed neighborhood. The aim of the centre is to provide opportunities for engagement and inclusion in an environment of growing inequality in living and education. Through this it is connected to marginal underprivileged ethnic groups and via its successful education programmes into making it links to other community spaces and public schools in the area.

In contrast, the context of the Central Business District offers opportunities for more privaledged members of society. The associated networks of the corporate worlds offer connectivity that benefit certain sub groups of makers. In Boston Bolt provided an example of CBD location and due to

Business

the high rent the making activities are focussed around producing profit. In this context connectivity is limited to exclusive networks of entrepreneurs and investors.

Social inclusion is at the back of the minds of venture capitalists and thus the activities of Bolt only benefit those fortunate to develop a successful product.

In most urban contexts the CBD defines the centre of the city and acts as a magnet for economic activity. Industrial sites in contrast inhabit peripheral locations in the city, or

Peripheries

close enough that transport infrastructure and real estate forces render them unsuitable for their original inhabitants. Subsequently these post industrial spaces offer the largest unimpeded space from which to operate and examples like The Artisan Asylum and Pier 9 showed this. In both these cases interesting symbiotic relationships seemed to exist with other creative industries located in proximity. In Pier 9's case a central access road acted as a mini creative complex stretching out into the San Francisco bay, and in the Artisan Asylums tech start ups had moved close to use their facilities.

The high street is synonymous with medium to small scale retail conditions and lower densities than a CBD environment. Shop units, generally attached to residential types have a direct connection to the street scape and are designed to achieve an optimum visibility to pedestrians. A retail customer base pre-exists and the example of Danger Awesome shows that it is a good model from which to launch. The problem lies in the economic forces that work to distribute retail tenancies based on supply, demand and business turn over. A

Traffic Corridors

community focused organisation will struggle to meet rental pressures without incorporating an element of trade into its business model. If it can balance the pressures then a retail context offers symbiotic relationships with other retail ventures, such as arts and crafts materials, or co-working spaces that require production facilities.

These pressures are no more felt than in a mall and Hatch makerspace. The Arsenal project use Hatch to attract new types of consumers / producers into the retail environment but if success results in larger visitor numbers the demand for retail space and real estate prices will

Public Space

shift. Left to a capitalist cost benefit analysis Hatch would have to make way for higher paying rent. Community engagement and personal alignment with a space does not stem from purely economic attraction factors. It would be interesting to study the transformation Hatch has on the greater mall and on local communities during the project's life, and whether it is given a role to play once the mall's new identity has been formed.

Making Outcomes

If maker culture is to become a significant driver of innovation and cause a shift in economic paradigms then it is important to assess whether its output is significant. This is hard to assess as this study only explored the spaces of making rather than the space of use. However I was able to view and critique what existed as either projects in process, exhibitions of artefacts or left over prototypes.

The nature of things created varied across all the spaces, there was an immediate difference between those facilities which catered for regular member access, and drop in access. Spaces like Artisan Asylum had capacity to make and store large projects with the benefit of seven day access. The projects on show ranged from money making creative pursuits to hobby level play with electronics or materials.

Fab Labs in comparison catered for shorter intense making sessions. Here "hobby" style making was prevalent with examples of prototyping for flying drones or 3d character design for role play games. As the name suggest, The Hobby Shop also had a similar outcome, with a focus on small highly bespoke projects to address personal problems.

For maker spaces like Lowell Makes, it seemed that the more projects on the go the better. Rather than striving to create particular outcomes it seemed enjoyment was generated within the community from tinkering or taking things apart to learn. The projects tended to be more electronics based or hand crafted and proudly on show within the space.

The Hackerspaces were very different in their appearance: one a adapted office after hours; and the other a dedicated space for 24/7 activity. What they both shared was a focus on electronics and software based explorations making it hard to guage sophistication of output. However Richard, the founder of Cambridge Hackspace was in the process of creating a very polished home sensing and security kit with the hope of going into commercial production.

There are examples of commercially successful outcomes across all the spaces, but none quite as much as Bolt and Techshop which focus on entrepreneurial activity. In both these spaces examples were hard to come by as ideas and prototypes were so guarded and secretive.

This was in contrast to maker spaces catering for a younger audience, like Hatch and the Boston and Adelaide Public libraries. Output in these cases were crafted around the open sharing of digital 3d models allowing a focus on fabrication. These spaces act as gateways to making and the opportunity to borrow, creatively change and then share back is a quick and satisfying process. Objects on show in these spaces provided glimpses into the personal interests and identities of their creators but also highlighted a worrying trend regarding consumption and waste.

Digital fabrication in its utopian guise has the potential to allow humans to produce only what they need, to provide mass customisation in contrast to mass production of identical objects. The advent of the 3d printer promises the ability to produce almost anything to demand, but it also threatens a prospect of mass wastage caused by free data and abundant material. The presence of multiple yoda heads and other throw away consumer objects on display in these spaces indicated an unfortunate translation of a consumerist mindset into what should be about creation.

DANGER AWESOME present the possibilities of digital fabrication as both aspiration and product.

> ***"the freedom to explore what is personally motivating is what connects all of the making spaces visited during my travel.***

Danger Awesome, in its role as a custodian of fabrication, provided the most abundant selection of customised output ranging from laser cut jewellery and craft objects to assorted engraved materials and clothing items. Etsy.com provides a virtual market place for creatives to sell personal craft, in comparison Danger Awesome provides a more tangible version, but without the range of choice the website offers. Inspiration for objects within their retail section appeared to have come from sources such as Etsy or Pinterest. This raised the ethical question

FAB LAB BOSTON uses making to enable young people to construct identities around personal interests.

of wether any of the products were customsed in the computer or merely copied from visual examples?

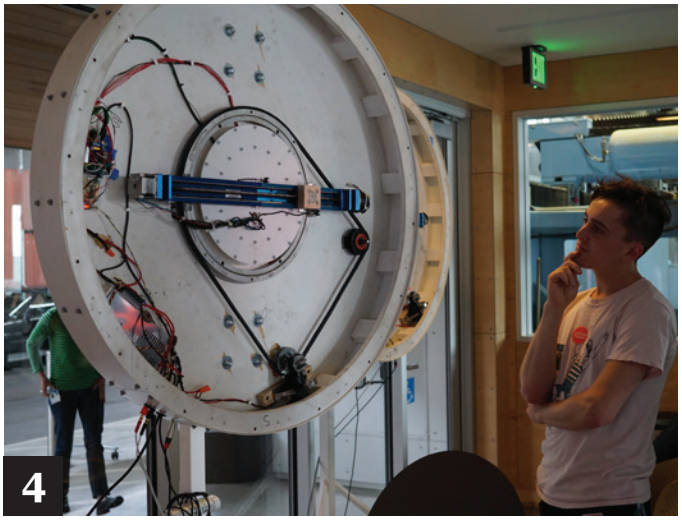
At the Boston Fab Lab digital prototyping and fabrication is used in integrated education programmes for young people. Technology is used as a means to express themselves, build personal identities and communicate narratives around their life experiences. One example given to me by Dr Susan Klimczak, Youth Education Director at the centre, was a workshop employing the modular prototyping platform Little Bits. One group created a chain of kinetic moments and designed objects to describe their experience with food trucks in the city. The resulting narratives highlighted the discrimination caused by high food prices and geographical bias within the city. What are seen by city planners as innovative and "distributed" supplies of food, actually exclude social groups through their economic model and location behavior.

Those maker spaces set up specifically for developing DIY projects, namely the Maker Media Lab and Pier 9, provided the greatest evidence of the future of creative making. At the time of my visit the Maker Media lab had users engaged in making CNC desk furniture, electronic projects, skateboards, gumboil machines, drones and 3d printed oyster reefs. Effectively, the future is explored in this lab and the incentive is high to develop engaging projects to publish in the Make Magazine.

This is not to presume Make magazine represents the maker movement. Make is a very successful business which fits neatly into the capitalist paradigm of production (magazines, books, kits, events, conferences) for consumption which sits at odds with the potential of personal fabrication. Make does provide free tutorials and examples of what can be achieved which helps attract engagement with making.

At Pier 9 the incentive is just as high but for artists, given the freedom to explore and test the sophisticated fabrication machines. The only requirement from the artist-in-residence programme is that a tutorial must be developed and posted on the instructables website. This freedom has produced experimentation and innovation in 3d printing, geometry, and 3d modeling. The entrance to Pier 9 contains a number of previous projects completed by residents. On the day of my visit the space was dominated by a large pair of googley eyes that used mechanical parts coupled with electronic automation to create eyes that follow you around the room.

I think the freedom to explore what is personally motivating is what connects all of the making spaces visited during my travel. There are no deadlines, no expectations and no preconceptions only exploration, learning and self-expression through making.



1. Achitects at the Artisan Asylum create topographic models using layers laser cut plywood.

2. MIT's Hobby Shop was born from the attitude that all students needed a "hobby". Output is as a result extremely varied.

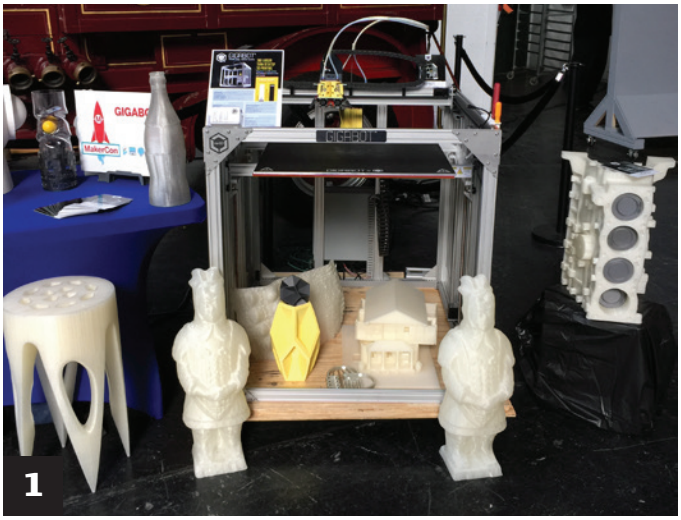
3. Tech Shop San Francisco use their reception area to showcase projects developed by members. This includes furniture, 3d printers and a foldable canoe.

4. Pier 9 provide high end equipment for experimentation for designers and artists. On the day of my visit one artist was building a pair of automated googley eyes.

5. At Bolt prototypes of products developed by entrepreneurs show the level of making sophistication and development of ideas.

Maker Con & Faire

After my travel around Boston and San Francisco I spent a few days attending a conference exploring the business side of making, and visited the world's largest Maker Faire (so far).



My research trip was organised around the timing of the 2 day MakerCon conference, held in San Francisco. The conference explored the business side of maker culture and the emergence of a Make Media coined term "Maker Pros".

Day 1 started slowly with a business start-up competition and series of entrepreneur talks but the afternoon saw some very inspiring keynote presentations, in particular one by Bethany Koby of Technology Will Save Us.

I was drawn to Bethany's talk not jut because she's an American ex pat who has been working with the UK organisation NESTA, or that her company is an exciting design-led, technology start-up focused on learning, but that they have designed awesome and delightful kits that I would want my children to discover making and technology.

The afternoon provided conference goers with the chance to move into breakout sessions which concentrated on specific areas of Wearables and the Internet of things, Hardware Manufacturing and Product Design and development. I sat in on the Internet of Things panel discussion but unfortunately learned very little about how makers could engage in DIY wearables or the innovation of this technology because they all seem to be closed systems.

It seems so locked up in proprietary platforms that have their own data types and storage systems that exploring open source avenues within this space is limited. Luckily I bumped into Kate Hartman at the end of the day, one of the wearables panel members, who is the assistant professor of the digital futures programme at OCAD in Toronto. I was interested to talk to her about possible connections between data recorded by the body and the experience of architecture.

Ending the day I sat in on a discussion organised by Make San Francisco, about how makers and product designers can become domestic producers allowing micro manufacturing to inhabit the city. The discussion involved Patrick Buckley of DoDo Case (who I have bought an

1. Product Showcase - Gigabot

2. Technology Will Save US

3. Open Desk Start Up

excellent DIY VR from), Steven Heintz from Quirky, Dorian Ferlauto of Britehub and Alexander Micheal Snyder. It was interesting to hear the benefits and drawbacks of using local manufacturing here in San Francisco and gave some hope that cities can start to attract small scale manufacturing and regenerate making and craft skills to increase their cultural and economic value.

Day 2 of MakerCon started with an interesting discussion about Maker cities which involved Dale Dougherty of Make Media and Peter Hirshberg of Re:imagine Group who unfortunately only had 20 minutes to talk about the impact of makers on the city. Peter showed a few images from the Urban Prototyping festivals that happened last month in San Francisco and used a series of events, workshops, exhibitions, and panels to generate civic engagement with the city. The Market Street prototype festival

challenged residents to rapidly prototype and present solutions to the most pressing issues in the city.

This panel represented the first session that connected to architecture and introduced a new mode of using the skills and ingenuity of citizens, and the power of open data in spatial problems.

Straight after was a presentation by Ben Upton about the Rasberry Pi a small linux based computer that works via a computer monitor and keyboard / mouse. It was invented in Cambridge (UK) and continues to operate out of the successful tech industry the city has nurtured. It was interesting in terms of access to technology, which in turn influences the access to CAD software and ultimately the means of production.

The Rasberry Pi uses the open source Linux operating system which is developed by a massive collaborative community and powers 98% of the world's super computers and most of the servers powering the Internet. With The Internet Of Things (IOT) being one of the hot topics at MakerCon it was interesting to see a low cost tool that could enable connectivity of physical objects with the networking power of the web.

On a normal day a talk by Massimo Banzi about the future and dramas at Arduino may have stolen the show but on day one that accolade was shared by Geal Langevin, and Dr Glenn Green. Geal is the French artists who created an open source robot InMoov. The Robot can be 3d printed on a 12x12x12cm area bed and when connected to a laptop and microphone can follow commands, speak back and move in an un-nervingly human way. Looking very similar to the robot from the Will Smith film iRobot the InMoov's body is made from 3d printed parts that achieve a tectonic system of body parts.

If InMoov stole the show for scifi fantasy, Dr Glen Green of Michigan University did it for pragmatic life saving. Mr Green, a paediatric surgeon has explored 3d printing technology to create splints to hold open tracheas in children suffering from Tracheobronchomalacia. The 3d printing uses material which disintegrates after a few years allowing the throat to hold itself open after a period of time and not rely on the foreign structure. All that was just in the morning session!

In the afternoon there were breakout sessions and I was interested to hear about the Makerspaces stream and the impact of making which definitely had a more socially aware conversation than the rest of the conference. Gary Rohrbacher of Filson Rohrbacher and AtFab, an open source furniture design company, announced the development of the Design / Fabrication Lab in Amsterdam, a makerspace in collaboration with the Waag Society and One Architecture (https://waag.org/en/project/designfabrication-lab) devoted to making architecture and the maker city.

Surprisingly he was in San Francisco for a three day symposium with other collaborators other participants such as Testa & Weiser Inc, Jelle Feringa and DUS Architects. They were based in the Maker Media Lab exploring advancements in robotics, additive and subtractive fabrication technology, the rise of Maker Culture, Open Design, Maker Spaces and new entrepreneurial infrastructures.

My travel in the US culminated in the 10th annual World Maker Faire held south of San Francisco in San Mateo. This year on top of the standard Saturday and Sunday opening days the Faire opened on Friday for a limited preview. This was my second Maker Faire, after Sydney, which was dwarfed in comparison by the scale of activity even on the preview day.

The concept of a Maker Faire is effectiviely a large scale show and tell show. What makes them remarkable is their pulling power for making communities of all shapes and sizes. As the name suggests this world faire brought communities involved in maker culture from all around the globe, but in the tradition of American "world" events, most of these were from the US. The event was split between ten zones covering grass roots involvement through to high tech start ups and maker products.

I was only able to make one quick circuit of the site in the four hours available so I was keen to see what architecturally related maker projects there were in amongst the standard fire breathing robots and 3d printers.

Everywhere I went on this trip I saw Strawbees, normally these little strips connect straws to create geometric forms, but at the Faire Strawbees Mega provided the means to build your own Buckyminster Fuller geodesic dome. Mega connectors are 3d printed components that link plastic plumbing tubes and create large geometry. While this was not groundbreaking it did indicate that maker demand lay in making larger scale projects.

Robots and micro computers were the big attractors at the event ranging from cardboard turtles and drawing bots to sophisticated 3d printed humanoids. Large brands such as Intel and Microsoft were noticeably present around the show suggesting that the maker movement was now worthy of big business investment.

In amongst the businesses and community groups sat a few architecture / design schools. Diablo college of architecture and engineering produced a CNC routed surface of an interference patterns which received a lot of attention. It demonstrated how small scale machinery could create larger scale assemblies. As expected there was an obvious difference between this work and the hacker / maker space output, but it was interesting to consider how these ideas might inform community projects away from the faire.

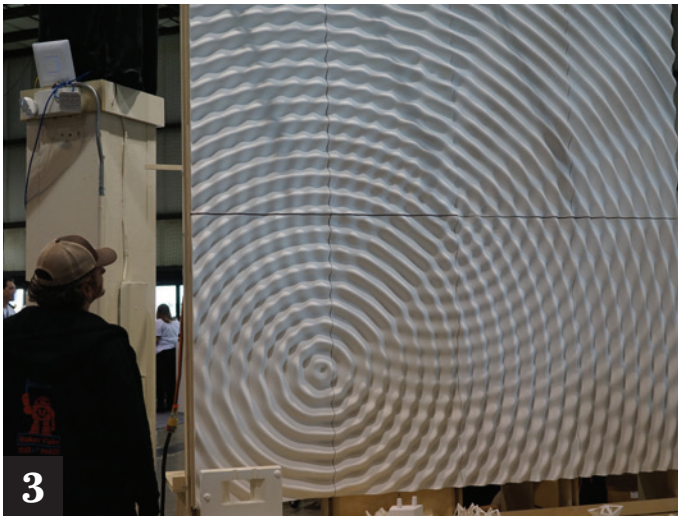
My main take away from the Maker Faire was how economically and commercially astute it seemed with many point of sale opportunities and products on sale. The vision of a future where maker culture could eradicate a dependancy on consumer products was not evident at Maker Faire, in fact the opposite. Companies jostled for attention to market and sell products to a keen maker consumer audience. These products offer a hybrid approach,

consumer goods that allow customisation or invention through combinations of parts. Making in this sense still provides choice, just for those not ready to fully leave the capitalist paradigm.

This may have been a slightly cynical view after weeks of experiencing independent making but at the Maker Faire capitalism felt very alive and well rather than being "disrupted" by collaboration and sharing. This is understandable given Make Media's role in the event. The event made me realise that the maker movement and "Make" brand should not be confused. While Make's magazines and books undoubtedly provide important information and inspiration to the movement, it is ultimately commercially motivated. The maker movement needs to try and operate away from economic forces and continue its focus on social and cultural activities.

1


2


3

4

1. The Strawbees Mega showcase by Swedish based startup Strawbees.

2. The open source 3d printed humanoid InMoov by artist Gael Langevin.

3. Diablo college of architecture's large scale CNC milled interference pattern.

4. In amongst the commercial activity some subversive workshops took place, in this case free lock picking.

Conclusions & Toolkit

In the last year the Byera Hadley travel scholarship has enabled me to gain a invaluable insight into the growing culture of DIY making and has already provided a catalyst for future focus. I am extremely grateful to the award and hope my experiences will provide inspiration for Australian based making communities.

To conclude the project I want to highlight the major findings from my study through a starting tool kit of things to consider if you wish to start your own. This is the first big decision

Movement

to make, what will your making community be focused on, will it be social education, creativity, hacking, entrepreneurial, knowledge, fabrication service or even corporate motivations?

Of course there are other reasons for forming a community around making but the reasons and outcomes need to be clearly defined. A network is critical to the success of a maker space so look to start to connect with other people around shared interests, or tap into existing groups using online groups, forums or wikis.

At first volunteers will be critical to the initial success of the space so look to form a group of people all committed to creating a maker space so you can share the responsibility.

A maker community can initially emerge through

Type

digital connections, but there must ultimately be a physical space to eventually inhabit. This is the second important decision, what and where?

All the communities I visited had particular types of space they inhabited. All had to adapt and reuse space originally designed for other uses, each with their own benefits and draw backs.

"I think the attraction of the maker movement is the autonomy and freedom to explore personal interests.

If choosing an ideal from classrooms, basements, offices, factories, libraries, retail, exhibition and residential the best would be a combination of the scale and flexibility of a factory, with the visibility of retail. The worst type were basements and I felt that the Hobby Shop and Boston Fab Lab suffered from the restrictions of their inherited spaces.

The type of space, and its given context and connectivity are closely linked. While there may

Context & Connectivity

be less choice in finding a location for a maker space regarding type, there can be different opportunities in connectivity. In my visits decisions on location were mainly based on available and affordable real estate meaning that unless you are opening an entrepreneurial space like Bolt, or are tied to a University you will typically be inhabiting an area in need of regeneration.

In the city you live, first identify areas of perceived need for regeneration (not gentrification) where rental prices are low. Within this look for opportunities such as connections to education or existing community services, high pedestrian traffic areas, high visibility or opportunities to expand and inhabit the surrounding environment to attract people in.

The makers spaces that were able to physically or virtually connect to universities, businesses, peripheral creative activities, urban corridors or public space gained most from increased visitors and participation.

Tools

When setting up a maker space it would be tempting to immediately go out and buy a few desktop 3d printers to get started. What this study identified though is that it is better to save up for a laser cutter. Ideally get both but if a choice has to be made reach for the lasers. The reason is that the laser cutter can help achieve 2d and 3d making projects while the printer, as its name suggests, works best with 3d. While the 3d printer does one job well, the laser cutter's versatility makes its more useful.

Before both of these however there needs to be access to traditional hand tools to help fix up the space. This should develop into a dedicated tool storage with accompanied robust surfaces to prepare and work with materials.

Materials are critical to making. Each making project starts with a consideration of how material can be manipulated into form. Experienced makers learn what different fabrication processes enable and come to understand the material's capabilities. The spaces which explored this further, such as The Makers Place in Sydney, produced the greatest variety of interesting outcomes.

The Makers Place provides information about material life cycles and the circular economy to educate its community about restorative and regenerative practices of making. Curated wall displays and projected information also provide a source of inspiration and examples of making techniques to engage with.

As the first digital tools arrive you will need powerful computers in order to communicate with your new machines. The ideal scenario existed at the Fab Lab Boston who offered Apple iMac computers running mac OSX, Windows, and Ubuntu, an open source operating system. This setup provides access to any type of software allowing your community to develop preference and skills for particular tools. If this is not viable then look to obtain PCs that are as powerful as you can afford, from which you could also run open source software.

Funding

In order to set up a maker community you must consider money, as space, equipment, staff, maintenance and facilities all need capital. The reasons for forming a community usually tie closely with funding opportunities but unless your community is set up to generate money it will be the hardest factor to manage.

In this study funding sources ranged across membership plans, public investment, university funding, retail, fabrication services, teaching, donations and private sponsorship. The success of these was heavily dependent on the contexts the spaces were located in, but those who could tap into a number of revenue streams were the most financially comfortable.

Of these only public or private funding sources provide a true "democratisation" of making as economic discrimination is avoided. Unfortunately this model in isolation is not sustainable and unless you are tied to a benefactor who can invest their own wealth, you will need to look for other sources of income.

Membership was the most popular revenue source and has the flexibility to adjust as new equipment and opportunities are introduced. On top of membership, those sources of income which helped to solidify community such as workshops and special events were the first to be incorporated.

Overall sources of income were highly determined by the socio economic characteristics of their communities. In comparing Boston Fab Lab with San Francisco's Tech Shop the former would be disadvantaging their community members if events or workshop fees were introduced, whereas the latter it would be expected, by its mainly professional members, to attract the necessary experts and equipment.

Danger Awesome provided the most financially astute and sustainable business model through diversification of revenue streams including retail, fabrication services and co-working opportunities. Unfortunately this strong entrepreneurial energy seemed to lose sight of the DIY aspect and "democratisation" of access to personal fabrication of which is claimed to belong.

Social Structure

As a community grows you will need to address how it functions socially and culturally. This decision has an important influence on how your community will perceive their common ownership in the space and affect users behavior.

In this study's experience there were two main types of social hierarchy, the owner / user and owner / owner. The owner / user seemed to work well within restricted or private space where user behavior needed to be controlled. Owner / owner however was the most interesting, such as the hackerspaces visited, where permission and rights were equal to all. The drawback with this was potential for abuse as it relies on the honesty and integrity of a community's members.

For me the most inspiring spaces fostered as flat a social hierarchy as possible. Those that could shift roles of teacher or owner (position of power) to student or user within their members, rather than relying or set roles, had the strongest community identities and greatest knowledge sharing.

Once a space has been found, it must be configured to welcome in community

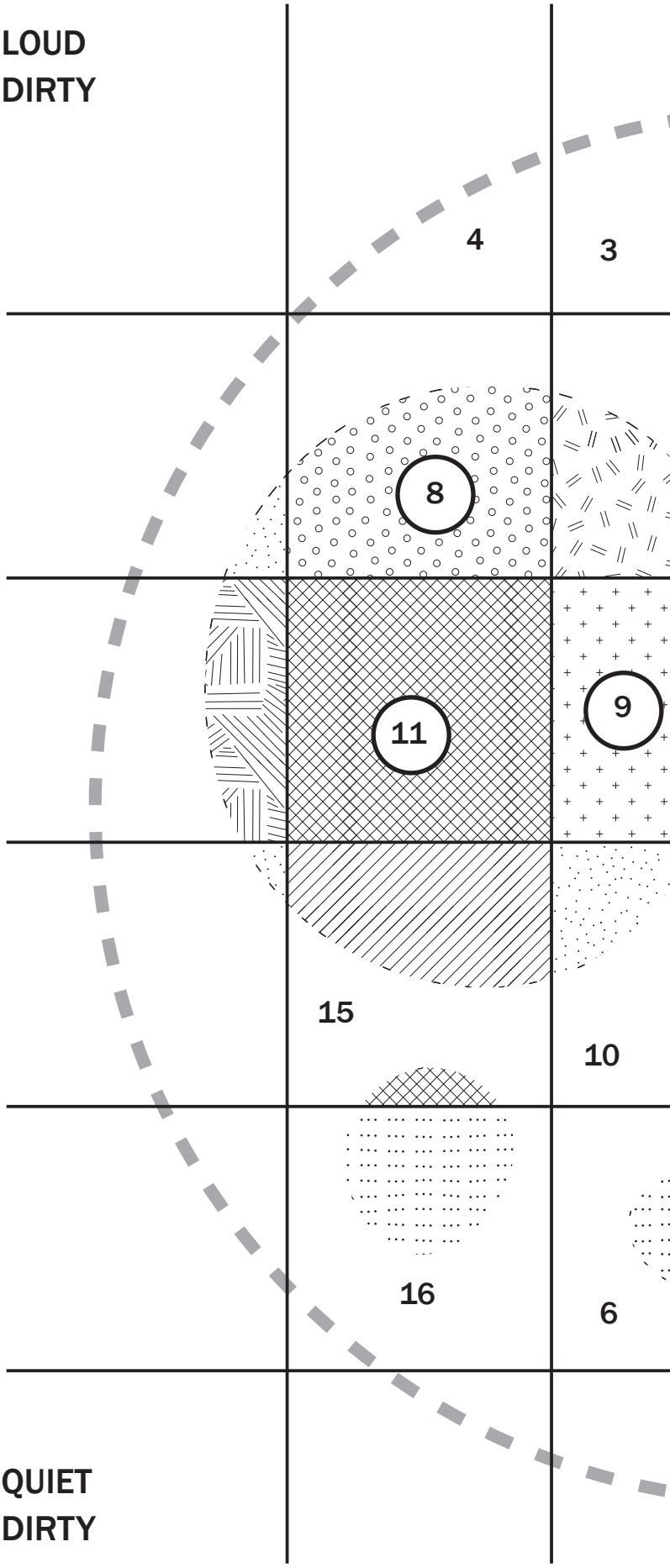
members,maximise making potential and foster optimum collaboration.

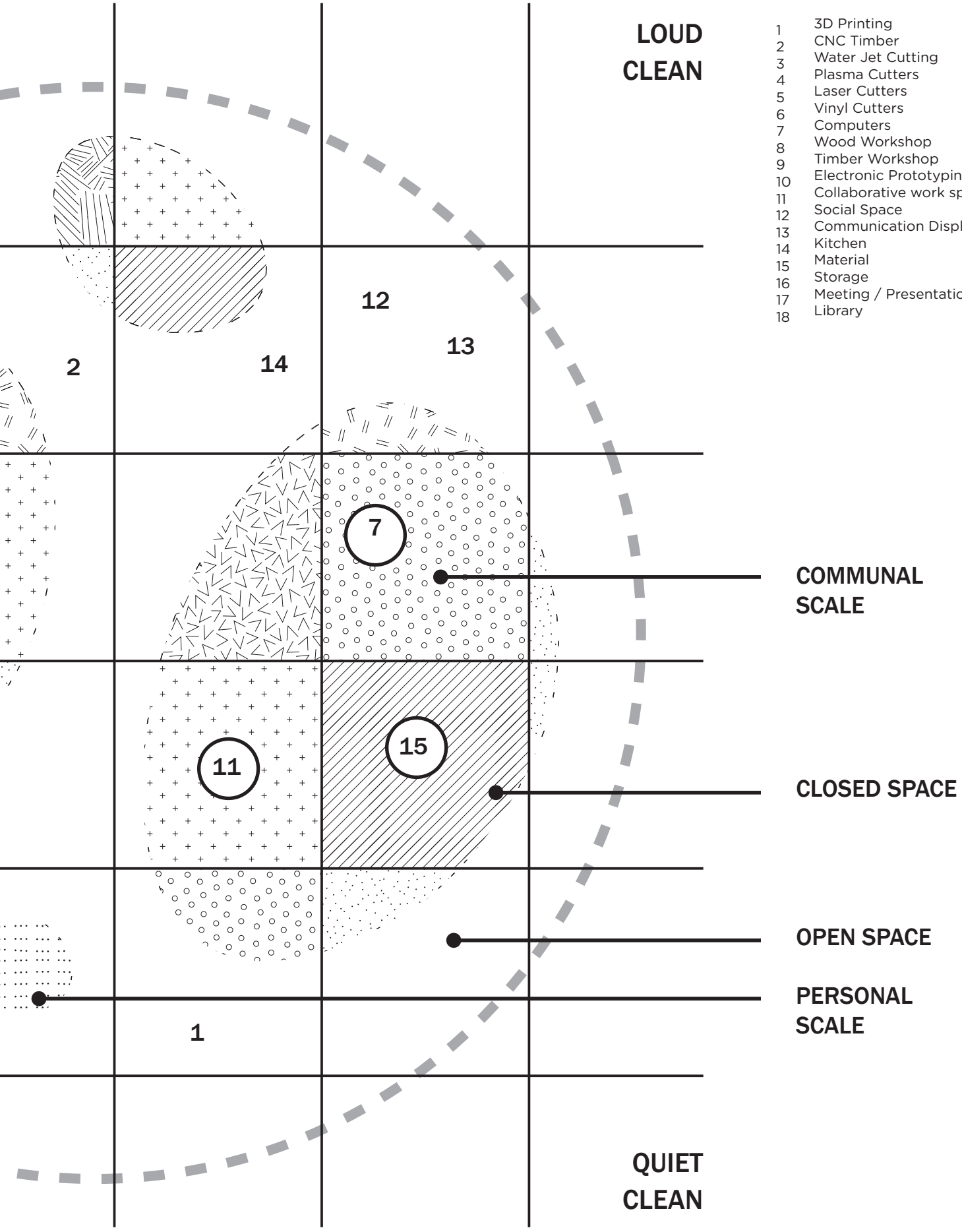
Layout

Observations and feedback indicated that a system of zoning is essential in maker spaces to provide necessary spatial conditions for thinking, socialising and making.

Decisions for this zoning should be guided by a consideration of certain spatial performance dualities, loud / quiet, clean / dirty, open / closed, personal / communal. Each of these should be viewed as a sliding scales, and used to overlap and create a variety of spatial conditions. In general, larger machines such as CNC mills and laser cutters will require ventilation so it is advisable to locate this close to building perimeters.

The aim should be for flexibility so lighting, ventilation, work surfaces etc, should be able to be moved enabling different reconfigurations of the space. In a week your space could be hosting electronics and soldering, timber fabrication, digital design skills, or 3d printing workshops. It is unlikely you will have the luxury of dedicated space for all of these things so the ability to rearrange is important. Ideally the only fixed elements would be storage, lots of storage, to allow materials to be collected and recycled and for users to progress projects in their own time without fear of them visiting the bin.





1 3D Printing
2 CNC Timber
3 Water Jet Cutting
4 Plasma Cutters
5 Laser Cutters
6 Vinyl Cutters
7 Computers
8 Wood Workshop
9 Timber Workshop
10 Electronic Prototyping
11 Collaborative work space
12 Social Space
13 Communication Displays
14 Kitchen
15 Material
16 Storage
17 Meeting / Presentation
18 Library

Overall the range of making projects across the study was surprising. It was hard to predict what I would see in each space because activity aligned itself so closely with the personal interests of the community or the organisers of the space. General noticeable trends were sub-groups of making interests based on age with younger people engaging more with gaming, 3d printing and drone based projects.

Significantly, women were not represented in the maker spaces as much as men. They seemed to participate in the same types of making projects, but also engaged with hybrids of traditionally perceived female crafts such as robotically controlled sewing and 3d embroidery. While these were also open to men, spaces like Tech Shop and Boston Fab Lab used them as ways of introducing digital fabrication to female members.

The strength of the maker movement lies in the freedom and variety of interests of its members who have the naivety of non experts, but boundless enthusiasm and appetite for knowledge. Without the right guidance and inspiration though this can also be its biggest hindrance with a risk of the same types of 3d printed objects being reproduced without any thought. The last stage therefore is to think about what your community will want to engage with, both individually and collectivity, through identifying problems that surround everyday life, or engaging with more experienced makers practices.

Outcomes

The introduction of varied design / fabrication practices at different scales will offer an insight into what is possible with the tools available, and create the conditions for new and novel ideas. Along side this it is important that the community you form realise the potential in combining tools for personal fabrication. For example this could be a project that combines a laser cut casing with a digitally prototyped interface, or CNC routed furniture with 3d printed connection components.

It is important to display the achievements of the community to generate pride in their achievements, and open possible revenue opportunities.

Personal Fabrication for Architecture?

Ultimately the attraction of facilities for personal fabrication comes down to the autonomy and freedom it offers to explore personal interests in making. In this study the majority of projects were small in scale and could be summarised as either employing engineering or industrial design approaches. This is not surprising as the maker movement emerged through the sharing of science and engineering projects with keen amateurs.

What if maker spaces could also engage with architectural problems, using design thinking and personal spatial intelligence? Although I unfortunately did not experience this in my study the potential for architect involvement, to offer expertise along side engineers, software developers and industrial designers, is significant. This input could reconfigure how makers approach their built environment and generate enthusiasm in shaping its future.

Community spaces of personal fabrication are avenues for knowledge, idea transfer and potential innovation. They promote learning, collaboration and in most cases in this study, sharing. They should install a confidence in their members to realise that anything they need can be designed and fabricated by themselves, and in doing so address personal and collective needs.

About The Author

Chris Bamborough is a designer, researcher and educator. He is currently a PHD candidate exploring the territories of architecture, amateur making and digital culture.

Acknowledgements

I would like to express gratitude to the Byera Hadley Scholarship for their generosity, and to the Architects Registration Board NSW for their support in making this project possible.

I would like to thank Mal Booth, the UTS University Librarian, for being my mentor, sharing his wide ranging social network and extensive information sources about maker culture.

This study would not have been possible without the time and warm welcome of those involved in the spaces I visited.

Adelaide

David Byworth - Fab Lab
Gavin Artz - Department Of State Development
Alison Kershaw - Fab Lab
Mathew Croucher - Innovation Lab

Boston

Mel King - Founder of South End Technology Centre (SETC)
Dr Susan Klimczak - Education Director at the SETC
Ken Stone - Workshop Manager at MIT's Hobby Shop
Chris Sledziona - Designer / Fabricator at Artisan Asylum
Elizabeth Dobrska - Director of Marketing at Bolt
Nadeem Mazen - Co-founder of Danger Awesome
John Noto & Kamal Jain - Co-founders of Lowell Makes
Anna & Richard Hawthorn - Co-founders of Cambridge Hackspace
David Kiersh - Youth Technology Coordinator at Boston Library
Janet Buck - Manager at Hatch Makerspace

San Francisco

Rubin Starset - Noisebridge
Jacob Hennessey-rubin & Noah Weinstein at Autodesk Pier 9
Marty Marfin - Manager at Maker Media Lab
David Scheltema - Author at Make Magazine

Sydney

Melissa Fuller Co-founder of Three Farm / The Makers Place

References & Resources

Chris Anderson (2013)	Makers: The New Industrial Revolution London: Random House
Cory Doctorow (2012)	Makers, Harper Collins
David Lang (2013)	Zero To Maker; Learn (Just Enough) to Make (Just About) AnythingMaker Media
Jeremy Rifkin (2015)	The Zero Marginal Cost Society; The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism. Palgrave:Macmillan
Neil Gershenfeld (2006)	Fab: The Coming Revolution On Your Desktop - from personal computers to personal fabrication New York: Basic Books
Neil Gershenfeld (2012)	How to Make Almost Anything The Digital Fabrication Revolution Foreign Affairs Volume 91 Number 6
Scott Doorley & Scott Witthoft (2012)	Make Space; How to set the stage for Creative CollaborationWiley

How to Make a Makerspace
https://artisansasylum.com/how-to-make-a-makerspace/
Creating a Makerspace Business Model
http://makezine.com/2013/06/04/making-makerspaces-creating-a-business-model/
The Makers Manual
http://www.psfk.com/report/makers-manual
The Makerspace Playbook
http://spaces.makerspace.com/
How to Build Your Maker Space
https://www.edsurge.com/research/guides/how-to-build-your-makerspace
6 Strategies for Funding a Makerspace
http://www.edutopia.org/blog/6-strategies-funding-makerspace-paloma-garcia-lopez
The Makery
http://www.makery.info/
Setting Up a Fablab
http://www.fabfoundation.org/fab-labs/setting-up-a-fab-lab/
Maker Space Community
https://makerspace.com/

Guerilla Makerspaces
http://guerrillamakerspace.squarespace.com/#what-is-gms
Make Magazine
http://makezine.com/
Fab Lab Inventory
https://docs.google.com/spreadsheets/d/1U-jcBWOJEjBT5A0N84IUubtcHKMEMtndQPLCkZCkVsU/pub?single=true&gid=0&output=html
Maker Con
http://makercon.com/
Maker Faire
http://makerfaire.com/
Fab Lab Conference and Symposium
http://www.fab11.org/
Peer 2 Peer Wiki
http://p2pfoundation.net
The Maker Map
http://themakermap.com/