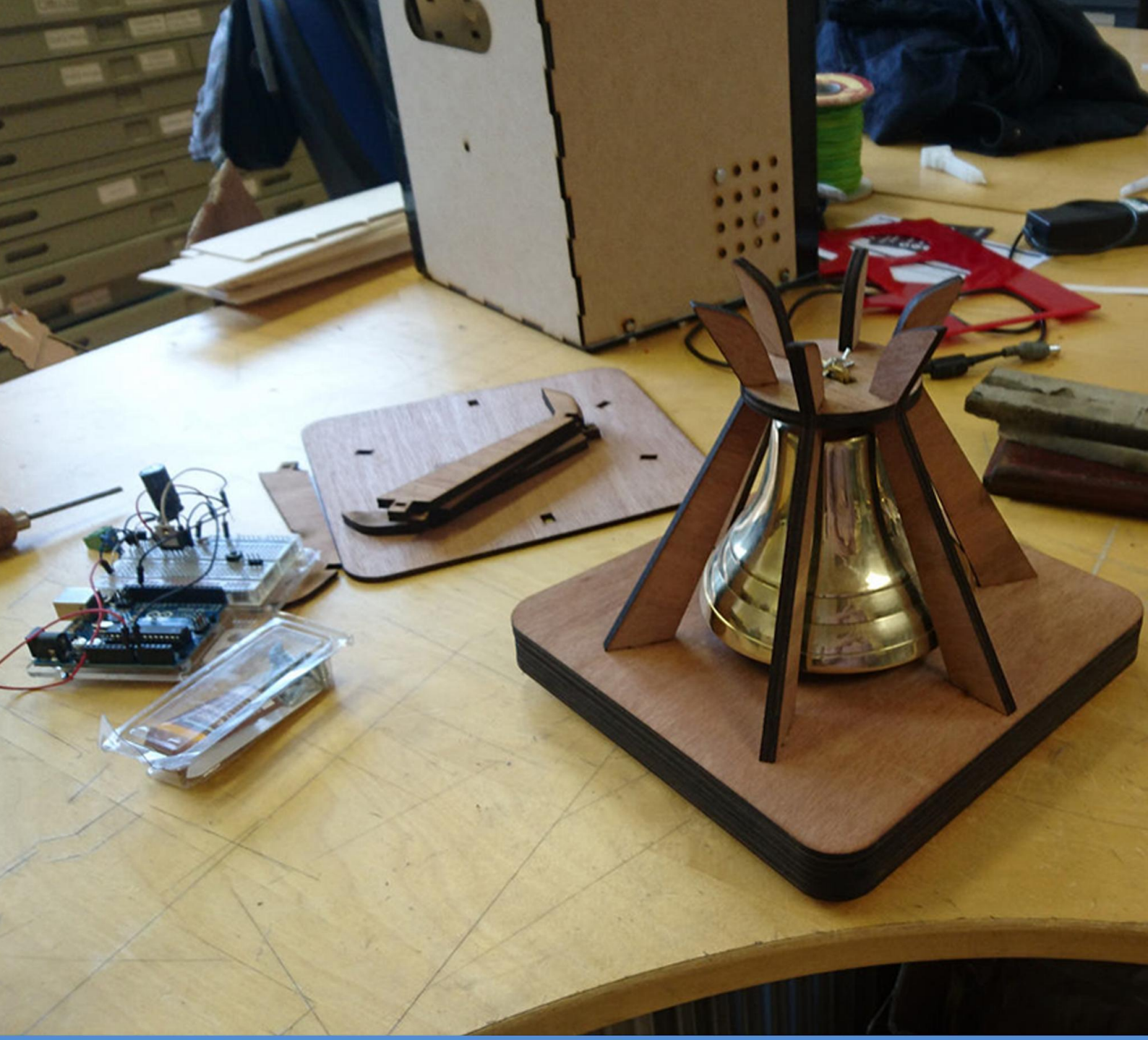

Indie Manufacturing
Final Report

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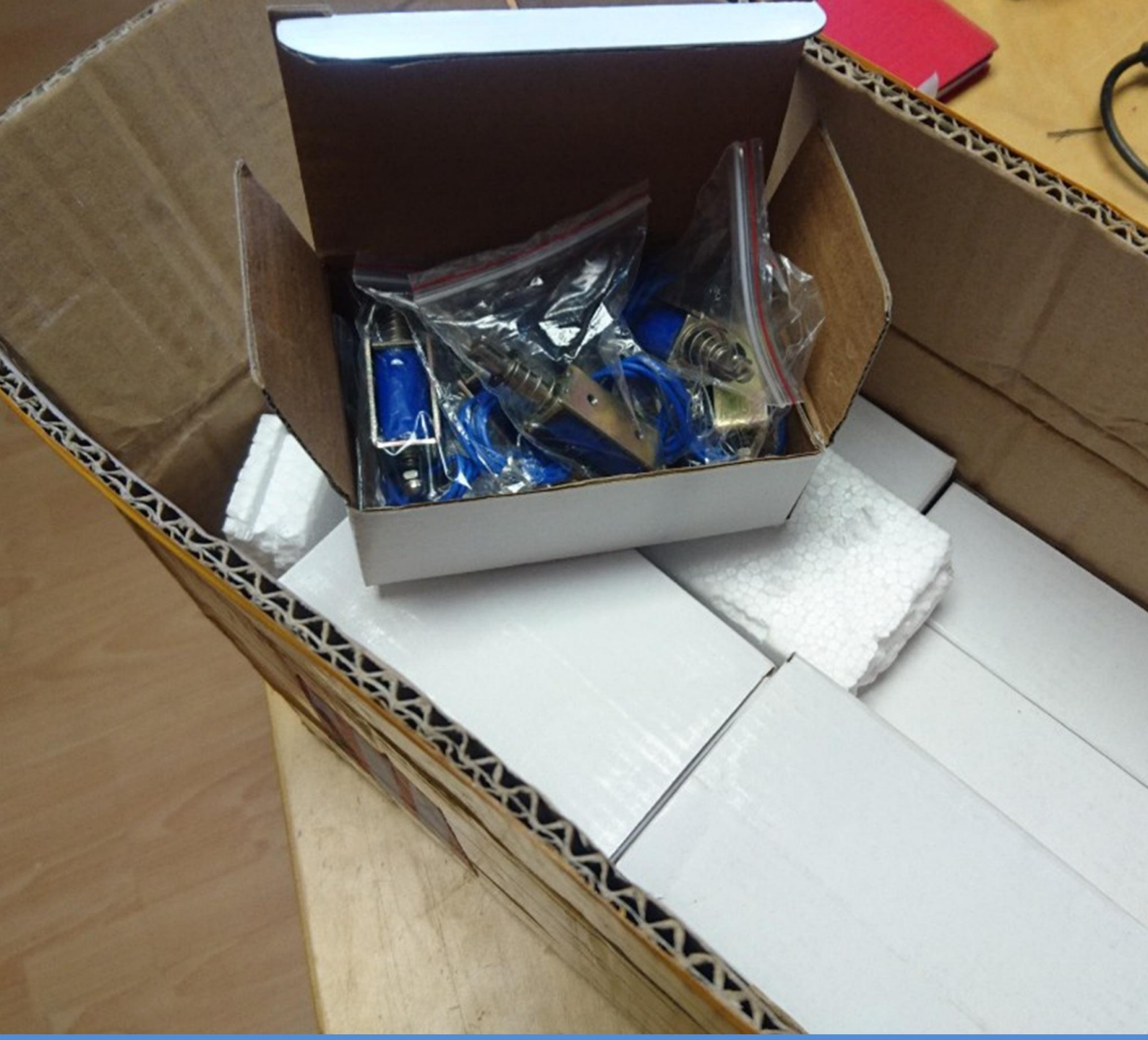
This is the final report for the Indie Manufacturing project. It is accompanied by a website which expands upon the work of the report. It contains a project log, additional articles published during the project, interviews and further background reading.

It also holds the ongoing live version of the suppliers map and details of the continuing product development on the Ackers Bell.

You can visit the site at **http://indie.mcqn.com**



About the Indie Manufacturing Project

Indie Manufacturing is part of the Royal College of Arts Future Makespaces in Redistributed Manufacturing research project and is funded by The Engineering and Physical Sciences Research Council (EPSRC).

Indie Manufacturing sets out to explore and identify the challenges of scaling manufacturing from a one-off design easily created in a makerspace to hundreds and thousands of units. Is massive capital outlay and manufacturing in China the only option or can the networks of knowledge within maker communities and local SME manufacturing companies provide an alternative route for the indie manufacturer?

To investigate these issues we used a combination of mapping, interviews with aspiring indie manufacturers, and participatory action research.

Our mapping investigated ways to find local manufacturing services and factories which might help individuals looking to scale their volume of production beyond hackspaces and makerspaces. We combined that with on-the-ground research in industrial estates across the Liverpool city region and community engagement to seed an open data set of manufacturing resources.

To test our findings we took one of MCQN Ltd's product ideas from prototype through into production, checking that firms in the supply chain will really work with small makers and letting us discover other unforeseen hurdles in making that maker-to-indie-manufacturer transition.

ABOUT THE AUTHORS

Adrian McEwen is a technologist and entrepreneur based in Liverpool. He has been connecting devices to the Internet since 1995—first cash registers, then mobile phones, and now bubble machines and lamps. He founded MCQN Ltd., an Internet of Things product agency. His book Designing the Internet of Things was published by Wiley in late 2013.

Andy Goodwin was Research Manager at Open Labs, Liverpool John Moores University. Andy spent eleven years working with companies to help them develop new products and services whilst encouraging and supporting collaborations between diverse communities and the University.

Both Adrian and Andy are two of the co-founders of DoES Liverpool and have been active participants in the emergence of the maker movement over the past eight years.

ABOUT DOES LIVERPOOL

DoES Liverpool is a hybrid co-working/makerspace and home for tech start-ups in Liverpool. Located in the heart of Liverpool it offers desks and workshop space available to rent by the month or by the day. The workshop is well equipped with a range of electronics equipment, 3d printers, vacuum former, CNC mill and laser cutters. DoES

also organises a number of regular and semi-regular events and hosts a number of events organised by different people.

Most importantly DoES Liverpool is a community. The current membership is approaching 450 people with a diverse range of skills and interests.

DoES Liverpool has also been described as an exploration agency which provides the hard and soft infrastructure to let people explore new technology, their business, artistic practice or hobby.

WHAT IS AN INDIE MANUFACTURER?

We use the term Indie manufacturing to describe a small but growing number of companies that want to create products on their own terms. It is a nebulous and constantly evolving term that captures a number of common elements of the people, products and processes involved in this type of manufacturing.

Typically indie manufacturers will be:

- People who want to ship products. They are not looking to sell or licence their invention to a large corporate.
- People who wish to produce at volumes that are greater than those that can be created by hand but less than those required to make mass manufacturing economically viable. The choice not to mass manufacturer is often based on ethical principles but sometimes it is a purely financial decision.
- They require additional resources or outsourcing to fulfil their orders. This may be through hiring in additional talent or outsourcing.
- Although they share many of many of the same characteristics with traditional small manufacturers, Indie Manufacturers are different in that they are constantly striving for new ways to fill gaps in the skillset and production practices.
- People who have rejected the traditional 'start up' Venture Capital and Accelerator options and instead prefer to let their businesses grow organically; manufacturing at their own pace and scale. Indie manufacturers do not lack ambition they simply want a more responsive production process that can scale or shrink in line with demand.
- Indie manufactures come from a diverse range of backgrounds but they often have no formal product design or manufacturing training.
- Indie manufactured products often have a mass manufactured aesthetic but don't need to be produced in massive volumes.

The potential for Makerspaces to become hubs of innovation and production has been identified by numerous researchers.

> *'The maker movement creates a hybrid of digital and face-to-face community interaction and has been cited to empower individuals by creating access to tools and technology that democratize the means of production. The promise is that these spaces enable communities, including those facing social and economic challenges, to create jobs, innovate, and grow small businesses.'*
>
> *Britton, 'Democratized Tools of Production: New Technologies Spurring the Maker Movement"*

"The Maker Movement could theoretically enable a hybrid form of production that combines the scale and efficiency of mass-manufacture with the benefit to local economies provided by small craft businesses. New startups, of course, have incredible flexibility in adopting new production models that support local communities."

Waldman-Brown, 'Can Manufacturing Be Democratized?', A Nation of Makers, 2016

What is clear to people who work out of makerspaces is that they are encountering a growing number of makers who have the desire to move to producing their wares in larger volumes. Whether the original Makerspace raison d'être of creative partnering alongside shared resources and reduced costs allows Makers to more easily transition from one-off bespoke products to small scale manufacturing has only recently become a focus of serious study.

The Manufacturing Startup Landscape

The path to scaling production of software and electronics is well understood within the maker movement, however the route to scaling the remaining components of consumer electronics devices is only known at the extremities—handmade craft at one end, and capital-intensive mass-manufacture at the other. From our conversations over the last 8 years we knew a number of makers who had products with the potential to sell in volume but the cost of electronics certification and the high capital outlay required for manufacturing prevented many of them turning their one-off item into something more widely available. There is a common perception amongst makers that an 'accelerator' is the only route available for them to transition from a maker to a hardware production company.

We wanted to explore if the accelerator/investment/manufacturing in China route was the only option available. Could the networks of knowledge in maker communities and local SME manufacturing companies provide an alternative route and, in turn, develop a more responsive supply chain? Are there options in between these and if so what are they? What role do makerspaces play in this?

ACCELERATORS – THE 'TRADITIONAL' APPROACH

Over the last decade start-up accelerators have become a prominent feature of the tech landscape. Originally focused on the web and mobile sectors this approach is now being applied to different sub-sectors but many of the characteristics remain constant regardless of outputs.

Common Characteristics of accelerator programmes usually include:

- An open but competitive application process.
- Pre-seed investment usually in exchange for equity in the company.
- A focus on teams not individuals. Teams usually have a technical background.
- Cohorts are supported in batches or classes.
- Full time but time limited support (usually 3-6 months) consisting of intensive mentoring and support.
- Extensive networking programme to meet other investors and advisors.
- Intensive mentoring by industry experts / successful founders who can provide business and product advice.

Adapted from Cohen 'What Do Accelerators Do? Insights from Incubators and Angels', Innovations, 8 (2013), 19–25)

Brad Feld, Founder of the TechStars programme, argues that the point of an accelerator is to accelerate the 'learning by doing' process—'*speeding-up the learning cycle in a time-constrained format. In this way, founders compress years' worth of learning into a period of a few months. Finally, when an accelerator program is active, it concentrates a lot of activity in a particular community in one place—generating vibrancy around innovation, and giving various ecosystem actors exposure to one another in a dynamic environment.*'

One important feature of note is that in most cases a programme's survival depends on the success of its participants. The usual measure of success is that the company scales massively and is extremely profitable or the original shares are sold via IPO or company acquisition.

In purely financial terms software accelerators have had some notable successes including Airbnb, Dropbox, Heroku and Reddit. As such they have received a great deal of attention from policy makers, investors and educators looking to replicate these successes. It is estimated that there are now over 2000 accelerator programmes globally. However, it is only recently that they have attracted researchers looking to explore how effective these programmes are. There remains very little research available that quantifiably measures which programmes are more effective and why (Hallen et al 'Do Accelerators Accelerate? A Study of Venture Accelerators as a Path to Success?', Academy of Management Proceedings, 2014 (2014))

Despite the lack of evidence, accelerator programmes are now being adopted widely outside of the software industries. A recent trend has been the creation of accelerators targeting hardware products for mass production (often in China). This trend has been driven largely by VCs looking to invest in product development companies. Between 2010 and 2014 there was a thirty fold increase in the amount of investment by VCs into hardware start-ups and this growth has continued into 2015/2016 (Quintero, "Who Invests in Hardware 2016.")

> *"Hardware will never be as easy as software, but as long as start-ups and investors are prepared for these differences, the potential to build world-changing hardware companies is higher than ever."*
>
> *'Hardware Is NOT the New Software', Ben Einstein, 2014*

Hardware product accelerators build upon the software accelerator model and offer product development specific support. A typical hardware product accelerator offer includes:

- Seed investment for equity.
- Engineering – Support from electrical, mechanical, firmware, and manufacturing engineers.
- Mentoring – lectures, workshops, and events
- Dedicated office space
- Prototyping labs
- Industrial design links
- Manufacturing links – often via a trip to Shenzhen, China, including tours of manufacturers and suppliers.
- Contacts, help and advice via a network of alumni, mentors, and partners
- Fundraising – sit-downs with key investment companies.

Note: A number of these programmes no longer explicitly call themselves accelerators. This is partly due to the fact that the product development process, even accelerated, usually takes many months or years.

Name	**Location**	**Focus**
HAX	San Francisco/Shenzhen	Future Of Manufacturing, Health, Robotics, Lifestyle Devices & Consumer Electronics, Infrastructural Innovation
brinc.io	Hong Kong, Barcelona	IoT, Drones
Berlin Hardware Accelerator	Berlin	Electronic hardware products
Lemnos Labs	San Francisco	Not specified
Startup Bootcamp IoT | Connected Devices	London	Consumer and industrial IoT products
R/GA IoT	London	"Impactful connected products"
EcoMachines Incubator	London	Energy, cleantech, transportation and industrial high-tech fields.
Buildit	Estonia	Electronic hardware products
Industrio	Trentino, Italy	Electronic hardware products

The perception amongst some makers that an accelerator is the only route available for them to transition from maker to a hardware production company is perpetuated by the accelerators themselves. As a representative of the Betaspring Accelerator, Rhode Island, US states:

> *"Just as computing started with hobbyists and computer kits in the 70s before becoming a gigantic industry, PhysTech is on the cusp of emerging from the maker culture to revolutionizing the way that we make, buy, customize and interact with the things around us."*

Miller and Bound, 'The Startup Factories. The Rise of Accelerator Programmes to Support New Technology Ventures'

(NESTA, 2011)

Being a new relatively new phenomenon there is scant evidence of their effectiveness over traditional manufacturing approaches. Whilst there may be merit in focusing a company's efforts on rapid iteration and speeding the product development through an

accelerator programme the need to mass produce and to provide a return to investors can be unappealing to some makers.

ALTERNATIVES TO THE HARDWARE ACCELERATOR MODEL

We wanted to explore if local alternatives could be found to the myriad of services an accelerator offers. In particular:

- How can makerspace communities support makers who want to build a product business?
- Are regional supply chains an easier route for medium-scale production? Can they be developed into a more responsive supply chain for businesses wanting to produce hundreds rather than tens of thousands of units?
- Can a makerspace fulfil the role of a bespoke prototyping facility?
- How can makers improve their manufacturing literacy and acquire specific domain knowledge?
- Can a distributed maker network supply the extensive network of useful contacts – particularly suppliers and manufacturers, in a similar way to an accelerator programme?
- What are the barriers to makers and traditional manufacturing companies discovering them, sharing knowledge of them, and taking advantage of them?

MAKERSPACES

Few participant-led makerspaces are formed with a specific business generation agenda. Most tend to be formed around people with shared interests who want access to resources too expensive for an individual to purchase. As such they are about democratizing production and innovation.

Despite this, there are people within the maker community who have the ambition to grow large businesses, or who get 'dragged into it' by being around those with business ambitions.

The term *makerspace* covers a broad spectrum of spaces and approaches, governed by a blend of the surrounding landscape and the interests of the founders and early members, but almost all contain some level of commercial activity.

At one extreme, running a business from the space is tolerated; in a space like DoES Liverpool it's an important part of the space but community/personal use is just as important; and others such as Makerversity and Building Bloqs are solely focused on professional makers.

As a result, makerspaces offer a lot of the support provided by accelerators and incubators, it just isn't explicitly called out as such. The general business support comes from being surrounded by a group of peers who are happy to share details of their accountant, or trade tips over invoicing and finding staff. The makerspace itself provides

the office space and prototyping facilities. Rather than mentors there is the community itself, made up of all sorts of people with a huge variety of skills and backgrounds. Similarly, the community's network of contacts will rival (or surpass) that of an accelerator when it comes to getting things made.

There are two main areas where makerspaces are different to accelerators: business development, especially sales and marketing, and staff paid to run the space and maintain the community.

Accelerators have a strong focus on the business side of the participants—identifying the market to address, honing the proposal and pitch, etc. and assuming (rightly or wrongly) that the team has the skills to deliver. Makerspace members tend to view the sales, business development, etc. in terms of a cost of doing business, and aim to minimize that cost rather than maximizing their return on it.

Harder to quantify, the lack of paid staff means that the support isn't on hand to answer questions on demand. There's a cost to the community member providing the support, in giving up their time to contribute to the community; and also a cost to the person asking for support as they need to negotiate when and how they get access to it. Both of these costs are hidden, often as much to those paying them as to any observers.

BOOTSTRAPPING

Despite significantly reduced barriers to entry for hardware product development it is still of a magnitude slower and more expensive than software development. For this reason seed capital, allowing a team to focus solely on development, remains one of the key attractions of accelerator programmes.

How to free up enough time to focus on product development is a key challenge for aspiring indie manufacturers. A number of alternatives to equity investment have been identified as a route to growth for software companies and many of which can be applied to product companies.

Route to Growth	**Pros**	**Cons**
Bootstrapping	Don't lose equity or take on large debts	Growth can be slow. It can be more difficult to get external advice.
Bank loans	Don't lose equity	Difficult to obtain pre-revenue or without security.
Soft-start (using consulting projects for early stage funding)	Don't lose equity Can lead to new intellectual property	No direct customers, so difficult to get feedback.
Government funding	Don't lose equity	Often reliant on match with

		subject areas in calls for proposals. Slow approval process. May require relocation or come with other strings attached. Often bureaucratic reporting procedures
Friends and family	Can be quick	Emotional pressure

Miller and Bound, 'The Startup Factories. The Rise of Accelerator Programmes to Support New Technology Ventures'

(NESTA, 2011)

The Many Faces of Indie Manufacturing

In order to test some of our assumptions we interviewed a number of people who we considered fit our definition of indie manufacturers.

Our initial aim was to interview people from a variety of backgrounds not just makerspace residents. We also wanted to interview people with a range of product types, either in development or in the market, not just electronics hardware products. Due to interviewees' availability and time constraints, the resulting set of interviews had a bias towards electronics hardware product companies.

- Damon Hart-Davis — Open TRV — thermostatic radiator valves
- Ben Ward — Flood Network — IoT enabled flood response
- Adrian McEwen — MCQN Ltd — Ackers Bell
- Patrick Fenner — Deferred Procrastination — Push to Talk
- Oliver Hall — Ultamation — DMX lighting control box
- Glyn Hudson — Open Energy Monitor — open-source energy monitoring tools

As we interviewed more of the "indie manufacturers" or aspiring "indie manufacturers" the one clear trait that they shared was how different they were from all of the other "indie manufacturers" we'd interviewed. Each company was at a different stage in their development and each person was approaching the process in a different way.

Open TRV are completely focused on massive scale to have the greatest impact on climate change—with the resultant trade-offs of having (some of) production in China and looking for investment in order to achieve that. OpenEnergyMonitor are running at the same climate problem but are building tools to amplify the efforts of others and growing organically.

Push to Talk and Flood Network are both steadily scaling up the number of devices deployed, but Patrick is driven by the technical skills and is seeing how the business side develops, whereas Ben's work is driven from the market side and is looking for the technical skills to help him achieve that.

Finally, MCQN Ltd and Ultamation show the difference in focus between product-led and agency-led companies. Both are balancing product development with client projects and using some of the income from the client projects to fund the product work; however, where MCQN Ltd will at times forgo client work in order to push ahead with the Ackers Bell, in contrast Ultamation place higher importance on client work.

Interleaving the product development with client work is a frustrating but necessary evil when bootstrapping. Alongside the year of development of the Ackers Bell, for example, MCQN Ltd has undertaken twelve pieces of client work, such as one-day speaker engagements; short, focused technical projects; and longer-term occasional consultancy.

Such an approach slows the rate of development of the product but is perfectly possible. If you are lucky, or can plan things carefully, at times you can use the client work to fill in the natural delays introduced by the lead times of physical manufacturing.

This variation in approaches to manufacturing and in stages of development in the business means that they have all taken different types of support from makerspaces and the maker community.

Deferred Procrastination and MCQN Ltd have drawn on the support most heavily, being based as companies inside a makerspace—using the prototyping facilities, the expertise of the community and, at times, the network as an informal channel for picking up client work.

Ultamation are less heavily involved in the community, contributing as and when they can, and using the makerspace to gain access to shared tools that they wouldn't justify owning themselves.

For Flood Network and OpenEnergyMonitor the benefit comes more from the community than from the physical makerspaces and kit. They work within their respective communities of interest to share their findings, learn from others, and find people with whom to work.

Supporting such a range of activities would be difficult for accelerators, which assume that people are ready to be taken through a reasonably standard programme of activity; whereas it is easily absorbed into the non-formalised support available in a makerspace.

Most of the people interviewed had encountered difficulties in finding and engaging manufacturers. To quote Oliver Hall: "if there was a directory somewhere of companies in the North West that do PCB manufacturing it would be great". Oliver had also approached the local business-support arm of the council without any success and, as we found with our mapping activity, it was through individual recommendations and trawling round industrial estates that he uncovered the suppliers who could help him out.

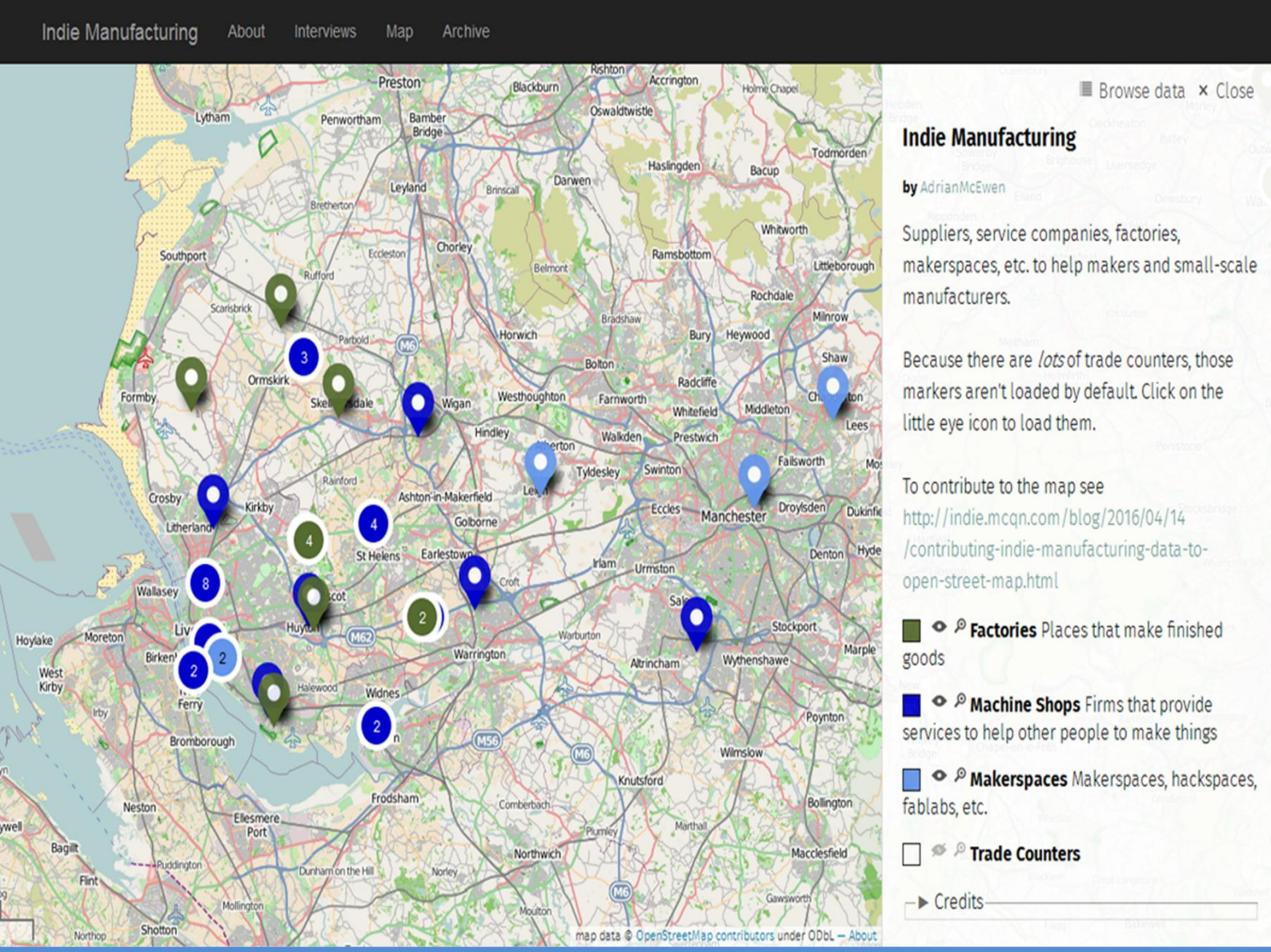
Discovering the companies is only the first half of the battle, you then have to get them to talk to you. Sometimes that's because the job isn't big enough to be of value to the supplier; sometimes it's the (perceived or actual) workload required to educate the maker in commissioning the work; and most of the time you don't find out why as you just don't get a reply. Patrick Fenner summed it up nicely when asked what would be helpful from manufacturers:

> *"An increasing openness to very small customers. I realise it's not something every manufacturer needs to take on but where manufacturers are able to look to smaller customers that is likely to be a market that's beneficial for them.*
>
> *Manufacturers who are able to explain what they do a bit more and be able to provide access into what they do makes it easier for somebody to ask them to do something."*
>
> Patrick Fenner, Deferred Procrastination

"I then just started using Google and I actually ended up walking down the Dock Road one day. I walked down all the industrial units looking at companies because there's loads of metal fabricators down there and I knocked on a few doors and one company said thanks for coming to see us but it wasn't what they do. However, they put me in touch with a company further up the docks.

I went to see them and they were exactly what I wanted and they were amazing and again that gave me another lift in terms of what Liverpool's doing because everyone's going on about how there's no manufacturing any more—there bloody well is—and these guys were state of the art as well, they've got laser cutters like you wouldn't believe."

Oliver Hall, Ultamation



Mapping Supply Chains

Having a current and accurate overview of manufacturing activity across the City Region is of benefit to both makers, indie manufacturers and policy makers. The traditional approach to acquiring and disseminating this information has been to commission consultants to conduct a 'mapping exercise' and then develop a directory website to host the data. Inevitably this site soon becomes out of date and withers because there's no funding for the ongoing gardening of the data.

A comprehensive mapping exercise of the whole region was outside the scope of this project, much less the ongoing maintenance. We decided that we should focus our energies on seeding a data set. A number of approaches were used to identify a range of manufacturing companies which would be of value to indie manufacturers.

As a starting point SIC Code data on actively trading manufacturing companies was exported from FAME and Company House databases. Company density and activities were then visualized in a Geographical Information System to help identify areas worthy of closer investigation. Whilst useful for this kind of coarse analysis there are a number of problems with using SIC codes for identifying a single company's manufacturing activity (Lewis & Sherry 2015). SIC codes are sometimes incomplete and often do not reflect the company's actual activities.

With the limited success of the SIC code mapping we spoke to organisations with a remit to support the manufacturing sector. These included:

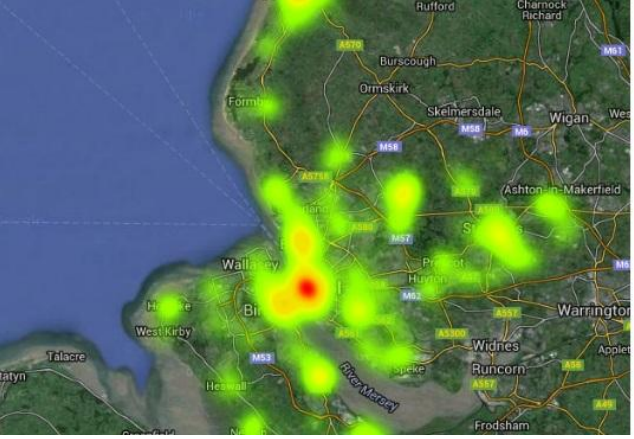
- Manufacturing business engagement officers based within the 3 of the 6 borough councils in the Liverpool City Region. All three officers were new in post and had limited knowledge of the manufacturing landscape in the City Region.

- The Advanced Manufacturing team at the Liverpool Local Enterprise Partnership (Liverpool LEP). The LEP team shared a small subset of their manufacturing database pre-selected by them based upon their personal knowledge of the companies and their willingness to take part in this research. However the LEP data is also based on SIC codes and as one of the team explained:

  > *'SIC Codes are notoriously poor identifiers of what companies actually do. By their classification we have no large manufacturing companies in several of our boroughs, when we know quite clearly that we do.'*

- Colleagues within two local Higher Education Institutions with a business engagement remit. Both institutions claimed to have customer relationship systems which detailed manufacturing companies across the region however there was a reluctance to share this data for data protection reasons.

Despite the limited availability of primary data it was possible to identify areas with high manufacturing activity that were worthy of further investigation. The map created formed the basis of the final part of the mapping research—physically touring the industrial estates of the City Region, identifying potential companies of interest and



speaking to company owners to try and understand their relevance to indie manufacturers.

The Liverpool City Region is made up of the boroughs of Liverpool, Wirral, Halton, St Helens, Knowsley and Sefton. Manufacturing hotspots within each borough were identified and then toured by car, bicycle and on foot. It was originally envisaged that each borough would take one day to tour with 20 minutes allotted for informal interviews with targeted business owners. In reality some boroughs offered sparse pickings and were toured in a matter of hours. Others had a far higher density of companies of interest and required multiple visits over a number of days.

Having started to gather useful data the challenge then became how to record and disseminate this knowledge. A further challenge we were keen to address simultaneously was how could this data set remain available after the project had finished, how could it become self-sustaining and who might be the custodians of such a data set.

From the outset we recognised that mapping a region's capabilities is just a first step in helping to connect people and its value is soon lost if not embedded within a community to maintain and extend the map. Rather than duplicate effort we looked at ways that we could add to the commons rather than build yet another silo of information. By adding to an existing project it was hoped that it would make it easier to get more people engaged in the ongoing process of collecting and growing community knowledge.

The data collected can be split into two broad categories:

1. Objective - These are facts about the businesses and their activities where there is just one correct answer. Things like the opening hours; the company website; or the processes and materials they deal with.
2. Subjective - These are harder to quantify and lean nearer to opinions about the businesses. How easy are they to deal with? Are they happy working with small production runs? How small is a small production run?

Objective data is easier to capture, and it's more obvious where it could live. Open Street Map—the well-established community for collecting and organising geographic data—should be a good fit as a repository for this. They already had a decent subset of the information we'd be gathering, and methods for agreeing upon and adding new attributes. Plus the infrastructure—in people, servers, and tools—to support the dataset in the long term.

To promote the mapping we ran training sessions with makers and indie manufacturers to show them how they could populate the map. If these people adopted the map then there was the possibility of the rest of the global mapping community taking our ideas on board and over time building a worldwide map of suppliers and makers.

Collecting and storing the subjective data proved a far harder challenge. Arguably this is the information that is of more use to makers and indie manufacturers as it is the knowledge and experiences of community members who, during their endeavours, have discovered useful resources, supplies and facilities. Over time the community builds up a store of folk knowledge consisting of useful contacts, personal experiences and domain knowledge that makes an approach easier when talking to a company with a different domain expertise.

Capturing this subjective data was beyond the scope of this project but, arguably, it is of the the most value to makers and indie manufacturers. Projects like Make Works (https://make.works/) in Scotland and Birmingham and Just Got Made (http://www.justgotmade.com/) undoubtedly offer a far richer source of information but they also require significant resources to create and maintain them.

KEY LESSONS

There are lots of small manufacturers still making things in the Liverpool City Region.

Things which approach being a commodity and manufactured in the UK are increasingly difficult to find.

Many of the firms discovered during the mapping exercise have limited external visibility outside their networks however they are well connected within them. Once a route into these networks is discovered we found that the vast majority of staff were happy to share their domain knowledge and to signpost to relevant parts of their network.

A significant number of companies discovered have no online presence at all.

Marketing literature from manufacturing companies assumes extensive domain knowledge and this can appear to be a barrier in approaching them. In reality we encountered no company that wasn't willing to spend time explaining what they do and how they do it.

Pioneering indie manufacturers are already building links between the maker and manufacturer communities. Often these pioneers are taking the same approach of going around door to door looking for particular products and services. This information is difficult to capture in a way that can be disseminated to the wider community. Discovery often relies on serendipitous conversations with well-connected members of the community.

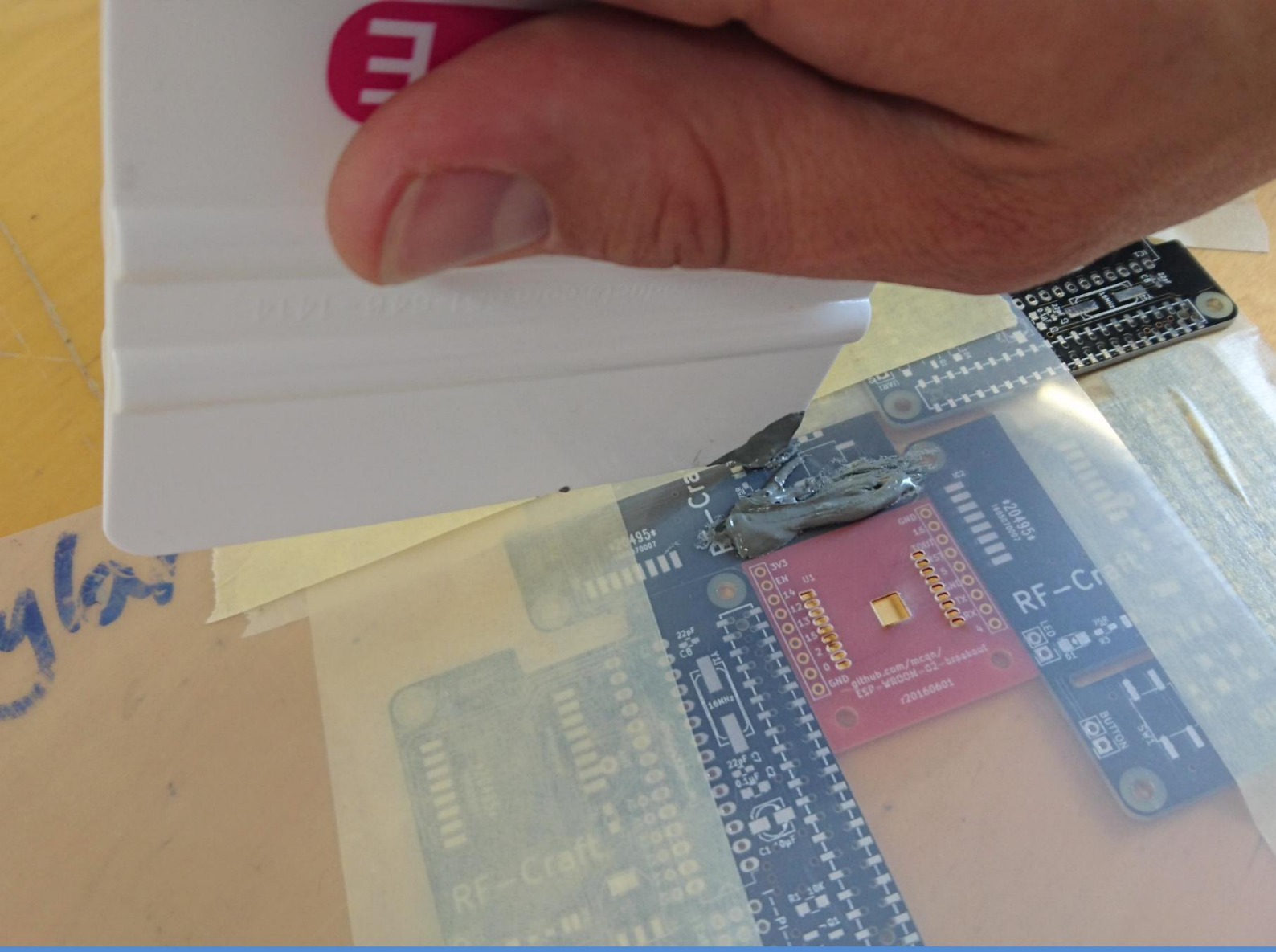
Mapping provides a useful starting point for finding suppliers. Combining it with community knowledge is better. Qualifying findings with the direct experiences of peers allows you to refine your choices and is by far the best option.

Despite a relative shallow learning curve for OpenStreetMap, using it still led to difficulties in populating and extracting data from the map. Assuming that the map is of value then a simpler and more time efficient mechanism for capturing information is required if makers are to adopt it.

Pioneering indie manufacturers in particular appeared reluctant to populate the map. This may have been due to the time (real or perceived) required to add their findings or it may have been due to them not valuing the platform. As such we remain unconvinced that a self-sustaining community driven store of manufacturing knowledge can be developed in the way that we originally envisioned without ongoing resourcing.

One of the proposed activities in the project was to take small groups of aspiring indie manufacturers on tours of local, but interesting, manufacturing companies. These 'Epic Trips' have worked well in the past forging new links between companies and makers and help to increase the literacy between the two groups.

Although the manufacturers we spoke to seemed very keen to participate initially it soon became apparent that it would not be possible once it came to setting dates. Interestingly this applied equally to companies discovered during the mapping and companies who already had close relationships with the maker community. This is not a criticism of the companies approached it merely highlights the competing priorities and time pressures on them.



Getting Our Hands Dirty (or Taking a Product to Manufacture)

In our experience of talking to local manufacturers they are broadly encouraging and interested in working with members of the maker community. However, we have also found that once you get beyond hypothetical partnerships and try to create actual partnerships you often run into issues such as volume of production or disconnects in language which result in the partnership foundering.

To tease out these issues, and also identify other challenges in moving from one-off production into low volume manufacturing, we followed one of MCQN Ltd's product ideas through into production.

We identified a selection of possible products which were under consideration by MCQN Ltd and developed them to varying levels of prototype (concept, partially-tested prototype, fully-tested prototype).

From there, we selected one to take into production and study further. The components and processes involved in manufacturing the product were used to inform the mapping activity and in turn were also informed by the results of the mapping.

PRODUCT CHOICES

During that discussion I drew this Venn diagram (overleaf) on the whiteboard. Our aim within the project (and to be fair, it's pretty much the MCQN Ltd aim with all of our products) was to find something at the intersection of things I want to make, things that people want to buy, and things that can be made locally.

WORTHY VS DESIRABLE

Before we get into unpicking each of those categories, we want to make a brief diversion into something that didn't make the Venn diagram.

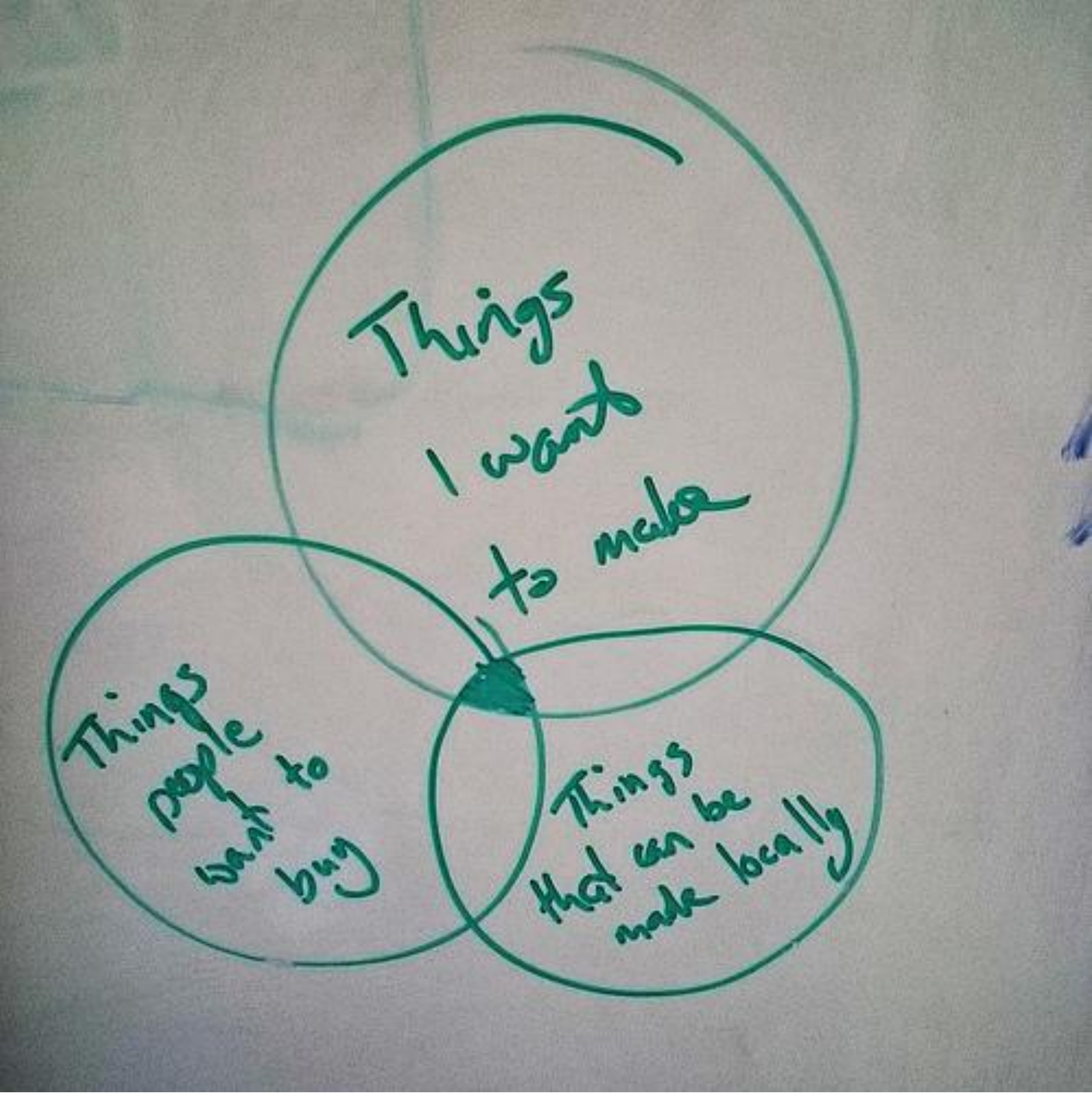
In wider discussion about the project with James and Hannah at the RCA, we talked about the need for the product to be something useful.

That may not have been the exact term used, but the overall point was that the product should solve real problems. Stuff that matters. Nothing frivolous.

We understand—and agree with—the sentiment, but over the past eight years of working on hardware products Adrian has found that it isn't that simple.

MCQN Ltd's first two product-ideas-that-made-it-to-prototype illustrate the difference nicely. Mazzini aimed to give you an itemised electricity bill to see exactly where your energy usage went; and Bubblino is a bubble machine that watches Twitter and blow bubbles when it finds a tweet you're interested in.

Mazzini was the important, worthy product idea, yet after living with it (and additional, whole-house energy monitoring) for months Adrian realised that he didn't care about the data it was gathering. And if he—as someone who'd learnt how to build circuits wired



directly into the mains electricity in order to gather the data—wasn't interested, trying to foist them onto everybody else would just result in generating masses of e-waste.

To tackle climate change head on he'd need to find a better idea.

In contrast, Bubblino is very much a fun product. Initially conceived as a way to demonstrate the Internet of Things for a conference talk, it struck a chord. Eight years later they're still delighting people, helping them better understand connected devices, and bringing brief moments of joy into their lives.

We found that using the categories listed by Bruce Sterling in his last viridian note is more useful when evaluating product ideas. Bruce defines four categories of objects:

- beautiful things
- emotionally important things
- tools, devices and appliances that efficiently perform a useful function
- everything else.

He frames them as ways to consider all your possessions as an individual when deciding what to allow into your life (and what to rid yourself of), but we can turn it round for the manufacturer too. You should avoid producing anything in the "everything else" category; the emotionally important isn't for you to define; which leaves us with the tools, etc. providing a useful function and also allows items that are beautiful, and that enrich people's lives.

We aren't going to stop making stuff anytime soon, and people will always want ornament and aesthetically pleasing objects in their world. It is not enough for just the important, world-saving products to be built in a sustainable and ethical manner. We need to show how all products could be made this way, and make that the new normal.

THINGS I WANT TO MAKE

Which brings us to "things I want to make".

With the variety of client work that MCQN Ltd undertakes providing masses of inspiration, there are no shortage of product ideas sat around at varying levels of development. Some are little more than random thoughts; some are sketches in a notebook or snippets of code that test the basic premise; others are background projects that are chipped away at when time permits and inspiration strikes; and some make it through to finished prototypes.

The purely software ones are the easiest to get finished and launched, but are also the trickiest to find business models for—especially given a dislike of advertising as a funding model and a geek's aversion to the hard sell. Anyway, they aren't relevant in a project looking at manufacturing…

Given Adrian's background, most of the rest fall into the category of connected devices, the Internet of Things. Not all though, some contain no electronics at all. They do tend to involve software somewhere along the lines though—in these cases it's generally used alongside the recent possibilities with digital fabrication to enable mass-customisation or data-driven design.

In the connected device bucket, MCQN Ltd is less interested in sensors to automate and improve the efficiency of business, and drawn more to devices which imbue our surroundings with delight and help us escape from glowing digital rectangles. Trying to reconnect us with the physical world without disconnecting us from the online.

THINGS PEOPLE WANT TO BUY

This is obviously an important category for potential products to fall under.

Given that connected devices, especially those aimed at non-geeks, are quite a new phenomenon it helps massively to have a physical prototype to show to people.

The process of developing the prototype gives you plenty of opportunities to share what you're working on and discuss what people feel about it. With luck you'll also gain some early orders.

Beyond that, we're all still exploring what the market for the Internet of Things is going to be (rather than blindly accepting the wild predictions of the market analysts). That's something that this project could really help—allowing makers to scale up more gradually will let them better match supply with demand.

THINGS THAT CAN BE MADE LOCALLY

Here we have the meat of the research. How much of a product can still be made locally (when local isn't the markets, workshops and factories of Shenzhen)? Are there different choices of materials which will alter the answer to that? Does manufacturing in the UK make products more expensive? If so, by how much?

INITIAL CANDIDATES

So, out of all that thinking and possible avenues to explore, four likely candidates emerged.

Bubblino is the oldest product from the MCQN catalogue that's still on sale, but is currently only geared up to very small-scale production. Author and futurist Bruce Sterling calls that approach (and cites Bubblino as) "hacker craft".

There is definitely a market for it—the steady sales with no effort from me proves that. Scaling up production would allow me to spend time to update the technology and design decisions to reduce the price, no doubt further increasing demand.

However, the bubble machine mechanism is a key and reasonably intricate assembly, which would lead us straight into the complicated world of plastic moulding. The obvious way around that would be to continue to buy off-the-shelf bubble machines and modify them, but that likely leads to more of the product being made in the Far East.

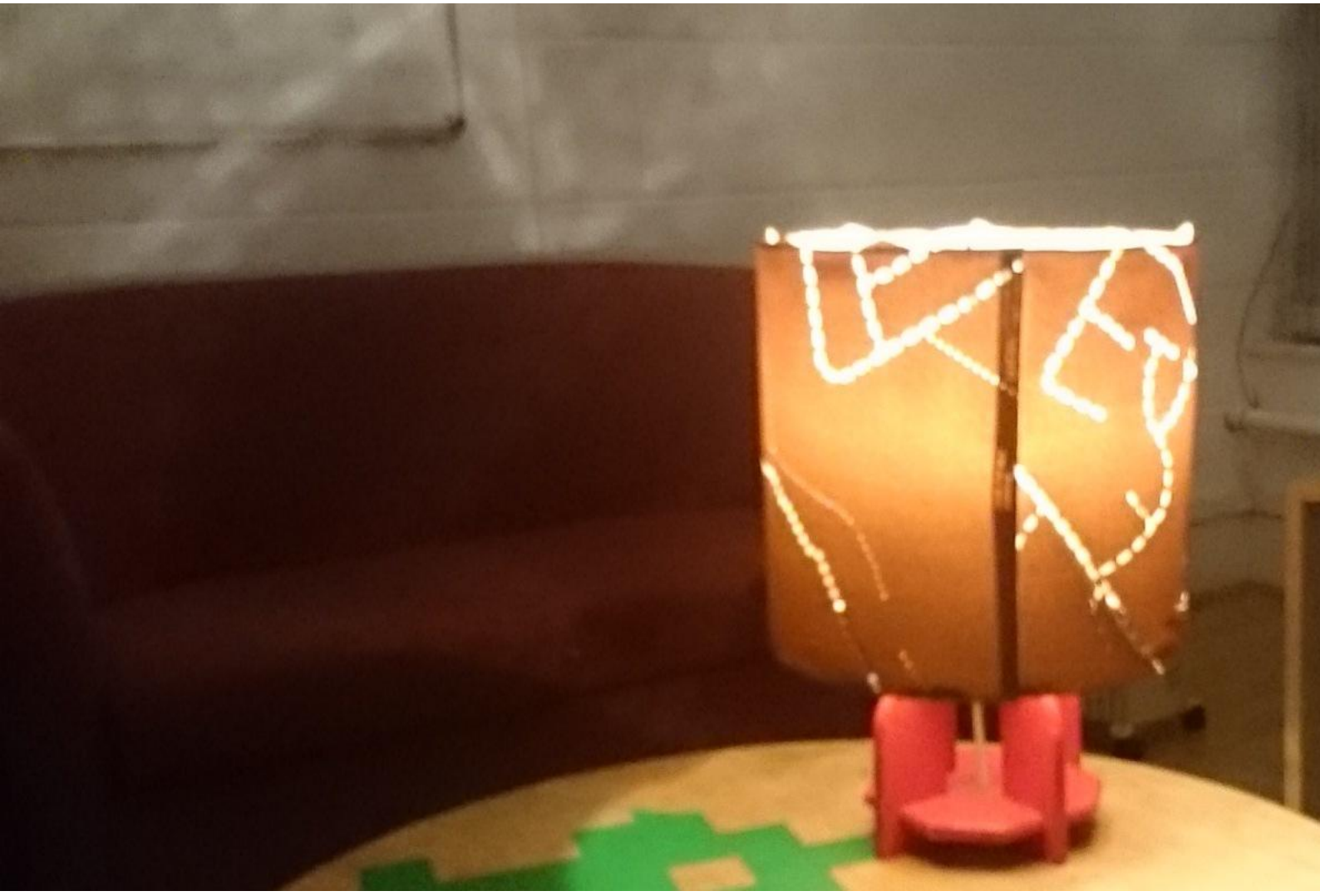
Streetlamp. This is the only product idea in the list that doesn't include any electronics. It was born out of a separate project which used OpenStreetMap data to engrave maps with the laser-cutter. That sparked the idea for laser-cutting custom map-based lampshades.

Although there would be work to do in building the software—a website to allow people to choose the map area for their lampshade and then the back-end processing system to feed into production—this would be the simplest product to bring together.

It also lends itself well to local manufacturing and it would be interesting to pick at any issues arising from the mass-customisation side. Plus there is more flexibility in the materials used—would that let us better explore the sustainability or recycling angle?

The Ackers Bell. The last two product ideas both come from the company's interest in alternative ways of bringing what is happening online out into the real world.

Broadly-speaking we can divide this into two categories: discrete notifications and awareness of continuous data.



The Ackers Bell (like Bubblino) is a connected device to help with the first category. It is a physical bell, which is struck whenever one of a pre-defined event occurs online—you make a new sale from your online store; gain a new follower on Twitter; your build system fails an automated test…

There is already one Ackers Bell out in the world. ScraperWiki commissioned the original a few years ago, and use it to let them know whenever they gain a new customer for PDF Tables.

The design aesthetic for the bell eschews plastic in favour of wood and brass, neatly side-stepping the complexity of plastic manufacturing. It should lend itself to smaller-scale production through techniques like CNC routing or laser-cutting.

Continuous Notification. Our final candidate addresses the second online-display-in-the-real-world category and shows the current value of a metric that changes over time. So, for example, your house's current energy usage; or the number of people on your website; or the amount of coffee left in your Internet-connected coffee pot.

This is the least-well-formed product in the set. Although it's a concept that has been knocking around the MCQN studio since 2010, that design was just a simple dial. More recently some alternative designs have been sketched out, along with consideration to how they might be built, but nothing has been prototyped yet.

CHOOSING WHAT TO MAKE

There are good arguments for and against choosing any of the ideas above as the one we should pursue.

For a six-month project, avoiding the complications of electronics manufacture would make most sense. However, given the high percentage of makerspace-originated products which involve circuit boards, we decided that digging into the thornier questions around electronics manufacturing in the UK and electronic component supply chains was more useful than (necessarily) having the product on sale before the research ended.

From our mapping we had identified a number of firms across the city region providing CNC machining of wood, but only a single injection-moulded plastic manufacturer. That lent weight to favouring the Ackers Bell over Bubblino in the choice of which product to make. It was also the easiest to explain to people, which isn't to be underestimated with something that is destined to be sold—just in conversations about the project in general we ended up with a number of people added to the order book.

Those were the key points which led to Adrian choosing the Ackers Bell as the product to make. We wanted to surface the challenges and possibilities in all product development, not just those well-suited to local or distributed manufacture—MCQN Ltd is an Internet of Things studio, so must either resolve the issues with how and where electronics are made or decide to completely change its line of business.

The strong indicators of customer demand for the Ackers Bell show that it wouldn't just be contributing more e-waste to the world, and the more complex processes involved in its production are ones which can both scale in order to meet demand—minimizing waste—and utilise local companies and expertise.

DEVELOPING THE PRODUCT

DEVELOPMENT TIMELINE

This section shows the key steps and milestones in the development of the Ackers Bell product. The steps are colour-coded to indicate the aspect of development to which they pertain.

Key:

- **Research**
- **Software/firmware**
- **Supply chain**
- **Physical design**
- **Electronics**

Makerspace facilities helped this step

Maker community/network helped

03/2012

Ackers Bell Commission

The Ackers Bell started life as a commission, rather than a product, for ScraperWiki (now the Sensible Code Company). There were initial discussions then about developing a product version from it, but it was left on a back-burner until a more suitable (both in price and functionality) WiFi module could be sourced.

10/2015

Indie Mfg Project Start

Our research project with the RCA was confirmed.

20/1/2016

Frame/Case design

The design files for the first bell frame were produced, and prototyped in MDF on the DoES Liverpool laser-cutter. Largely a reproduction of the design for the original Ackers Bell, with a few changes to improve the striking mechanism location and provide a better sound from the bell.

Design sketches for alternative frame design

4/2016

Solenoid test firmware written

Software written to let me try different firing times for the solenoid when testing the mounting points on the frame.

17/4/2016

Design sketches for alternative frame design

More designs for the bell frame sketched out, to explore different aesthetics and reduce the complexity of the assembly process. Working somewhere with a laser-cutter in the next room it's trivial to make things like a bell stencil to make the sketching process easier.

25/4/2016

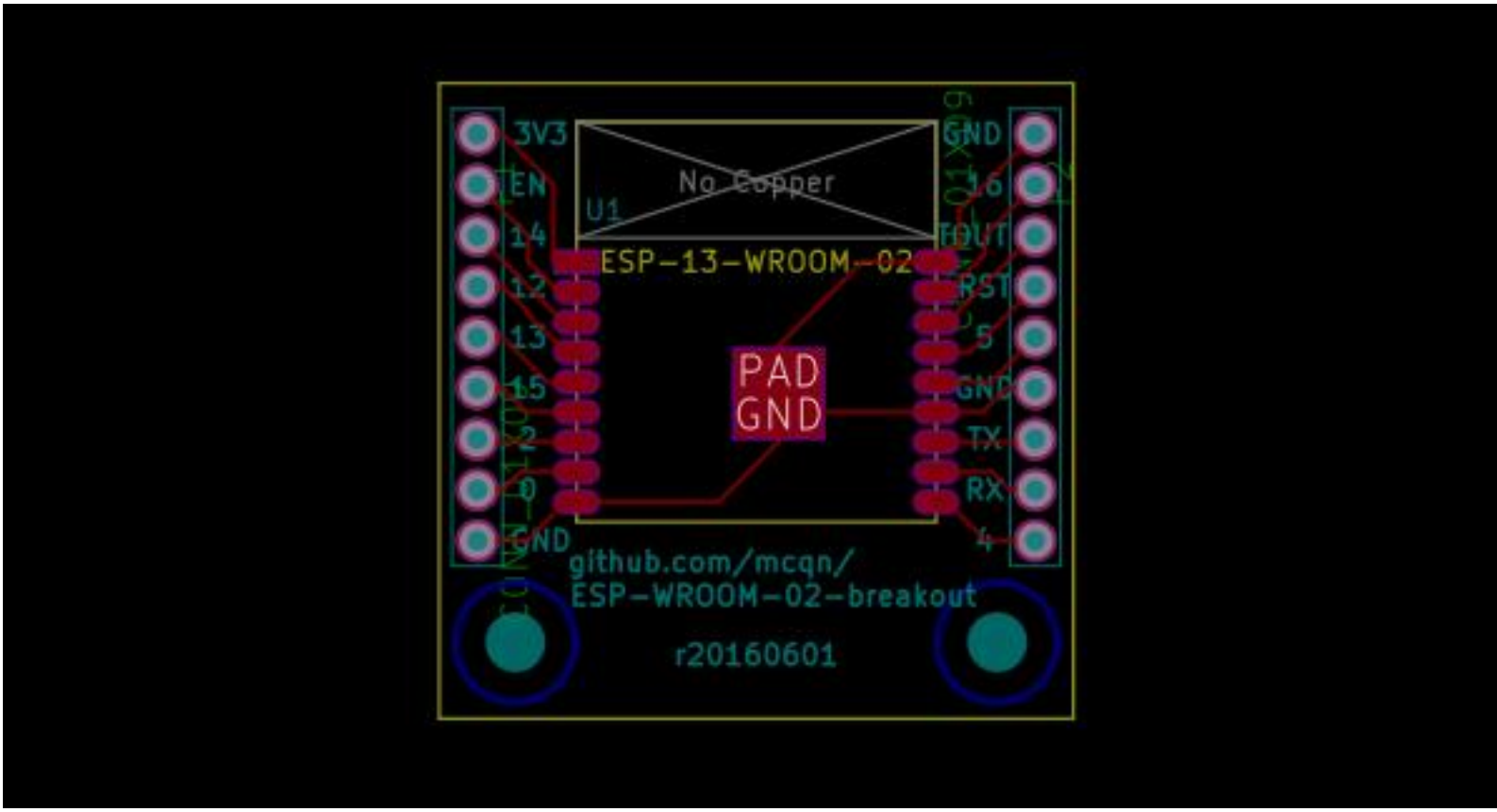
Identify FCC compliant ESP modules

Trawl the Internet, and in particular Aliexpress and Alibaba, to find a source of ESP8266 modules with correct FCC/CE certification. Using a pre-certified module will reduce the cost and complexity of the certification testing for the finished product. Order a few modules to test out.

5/2016

Design ESP8266 breakout Printed Circuit Board (PCB)

The ordered ESP8266 modules are in a surface mount package. For easier testing we designed a tiny breakout PCB to allow for easier prototyping. The design is released as open source in case it's of use to anyone else.



Tiny breakout PCB design for easy prototyping

9/5/2016

Frame prototype revision 2 cut and assembled

27/5/2016

Product shortlist drawn up

Drew up the list of MCQN Ltd product ideas which could be candidates for investigation during the Indie Manufacturing research project.

Second revision of the frame prototype assembled

6/2016 **Product chosen**
Decision made that we'll look at the Ackers Bell.

2/6/2016 **Commission manufacture of ESP8266 breakout PCBs**
Small run of a few breakout board PCBs ordered from one of our potential final UK manufacturers.

22/6/2016

Initial prototype of through hole circuit firing solenoid

Built up a solenoid firing circuit to provide a larger pulse of current when the solenoid is triggered. Initially developed on an electronics breadboard, then transferred to prototyping board, so all using through-hole (rather than surface mount) components. Uses a different ESP8266 module (not FCC-certified) already available on a breakout board.

24/6/2016

Prototype unveiled at Liverpool MakeFest 2016

First fully assembled prototype, using the through-hole prototype circuit, is shown to the public at Liverpool MakeFest.

8/7/2016

Solder up ESP8266 breakout board

Using the workshop at DoES Liverpool, we laser-cut a mylar stencil to enable application of the solder paste, and then used the reflow oven to solder the components to the breakout PCB.

ESP8266 breakout board soldered up

19/7/2016

Identify bell manufacturers

Having failed to find any bell manufacturers in the UK, we looked further afield. Requested quotes, minimum order quantities, and more details from a number of potential suppliers.

21/7/2016

Find freight forwarders

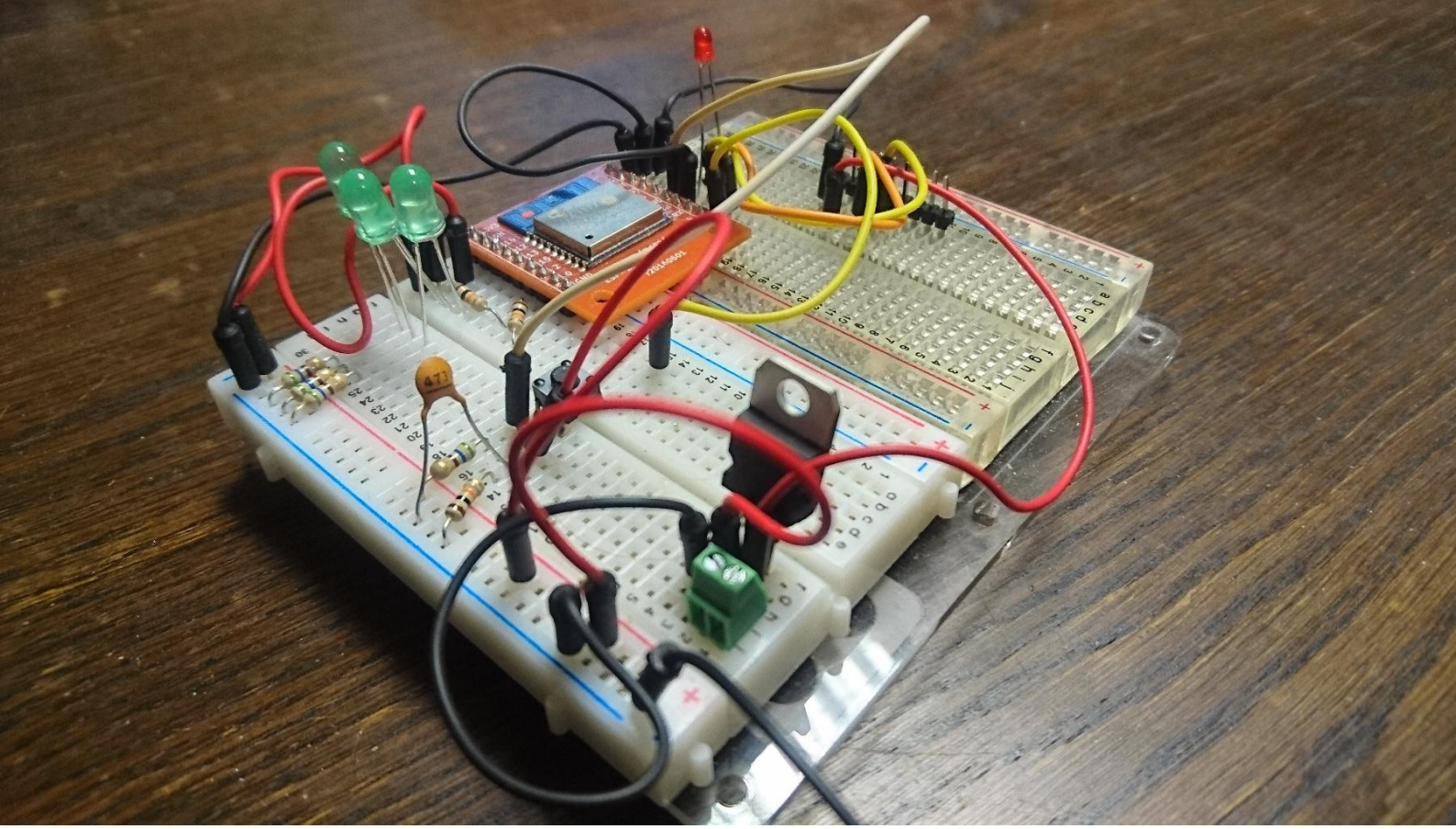
Through the maker community, we found a local freight forwarding company to deal with the intricacies of shipping 100 kilograms of bells from India: having them packed into a container, put on a ship to the UK, processed through customs, etc.

The chosen freight forwarding company

23/7/2016

Identify solenoid suppliers

Find suppliers of the correct solenoids, get pricing, minimum order quantities and shipping details.



Functional prototype (breadboard)

25/7/2016 — **Order ESP8266 modules**

Place the order for the reel of ESP8266 modules from the manufacturer.

25/7/2016 — **Order bells**

Choose the bell manufacturer and place the order for the bells. They're made to order and so won't be shipped immediately.

27/7/2016 — **Order solenoids**

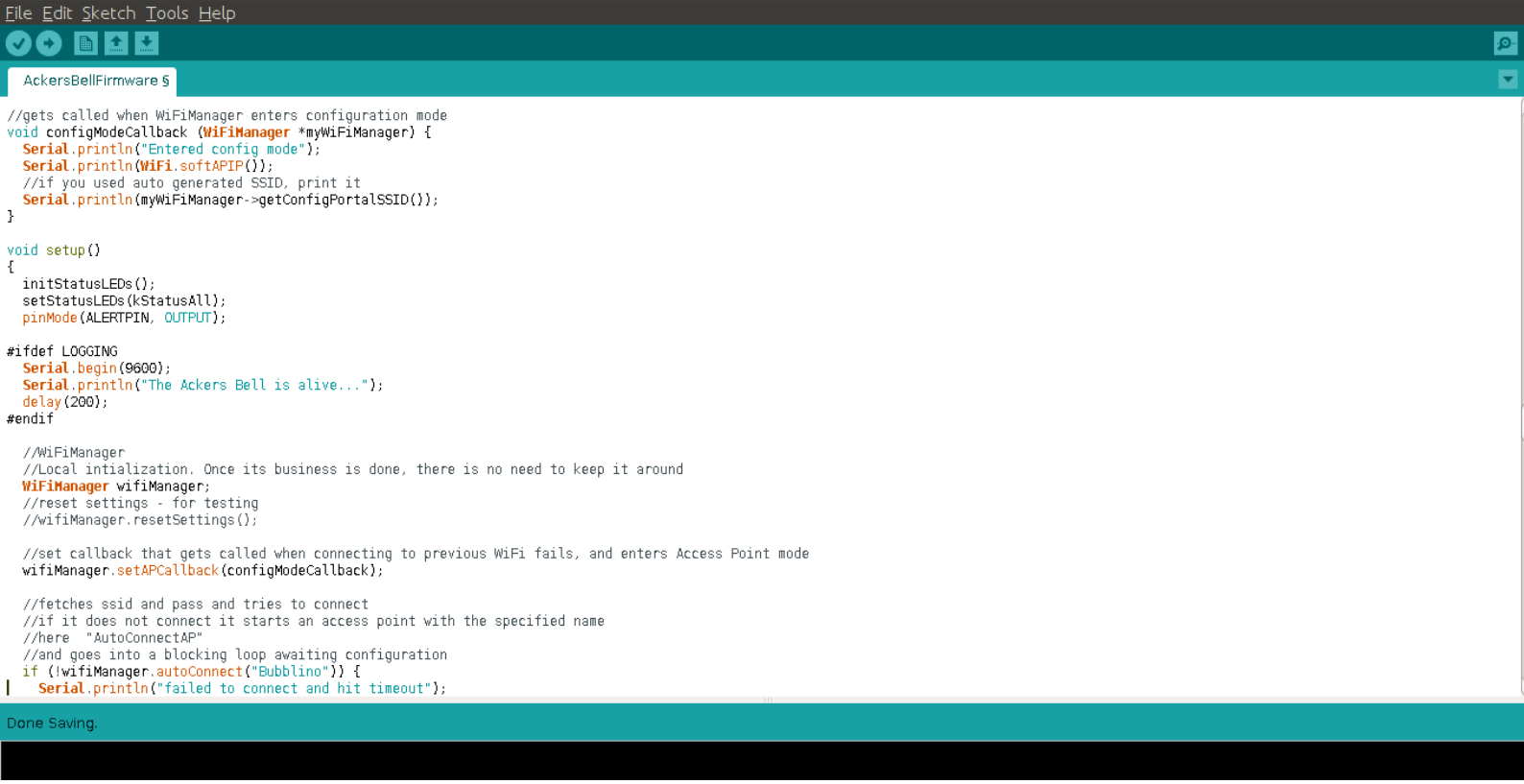
Choose the supplier for the solenoids and place the order.

15/9/2016 — **Initial bell shipping date**

The bells were quoted with a six-week lead time and so this was the initial delivery date to the port in India.

9/10/2016 — **Functional prototype (breadboard)**

Build up a through-hole circuit using the correct ESP8266 module (on the breakout board PCB), including the LEDs used to communicate status and error conditions to the user.



9/10/2016 — **Functional prototype test firmware written**

Write the test firmware to exercise the functional prototype.

10/10/2016 — **Revised bell shipping date**

No reason given for the delay, but the freight forwarders advised of a new delivery date to the port.

18/10/2016 — **Web service architecture designed**

The physical product is paired to an online service which provides a user-interface for the bells' owners to configure how it operates and then a range of back-end services and APIs to connect the bells to a range of relevant Internet sites to provide the trigger to ringing the bell: Google Analytics, Shopify, Twitter, etc. The first step in building that service is to lay out its general architecture—key components and so on.

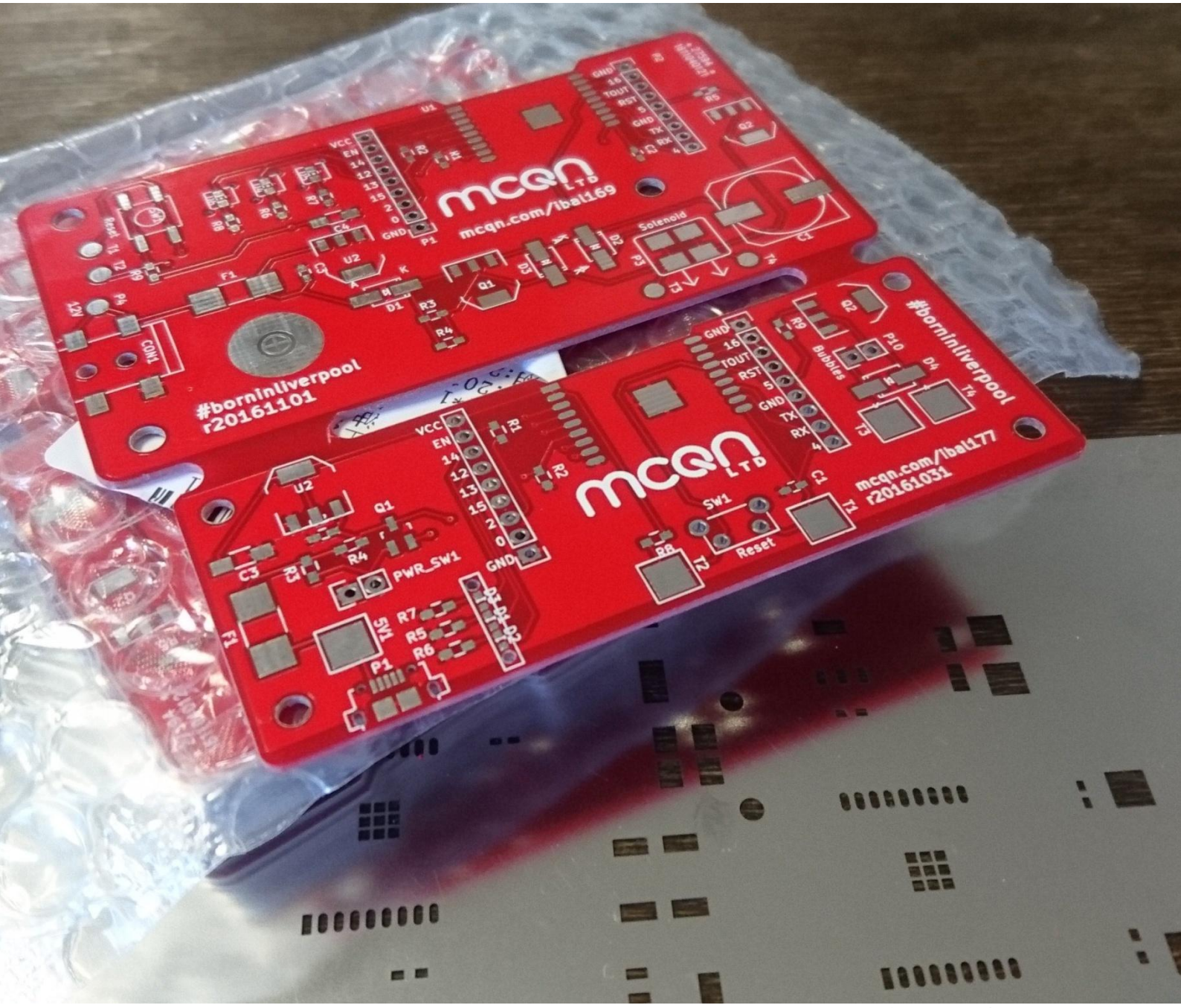
26/10/2016 — **Web service user and device framework built**

The first steps in the web service are built up, putting in the key foundational components.

2/11/2016

Surface-mount design of PCB

The functional prototype circuit is translated into a surface-mount version, including identifying a number of new components where the through-hole versions aren't available in surface-mount packaging. A small run of PCBs to this design are ordered, to allow us to check that the new design works before getting quotes for full PCB manufacture and assembly. Having had problems with the previous PCB manufacturer on a separate project, these are ordered from China as the other candidate UK suppliers only deal in higher quantities.



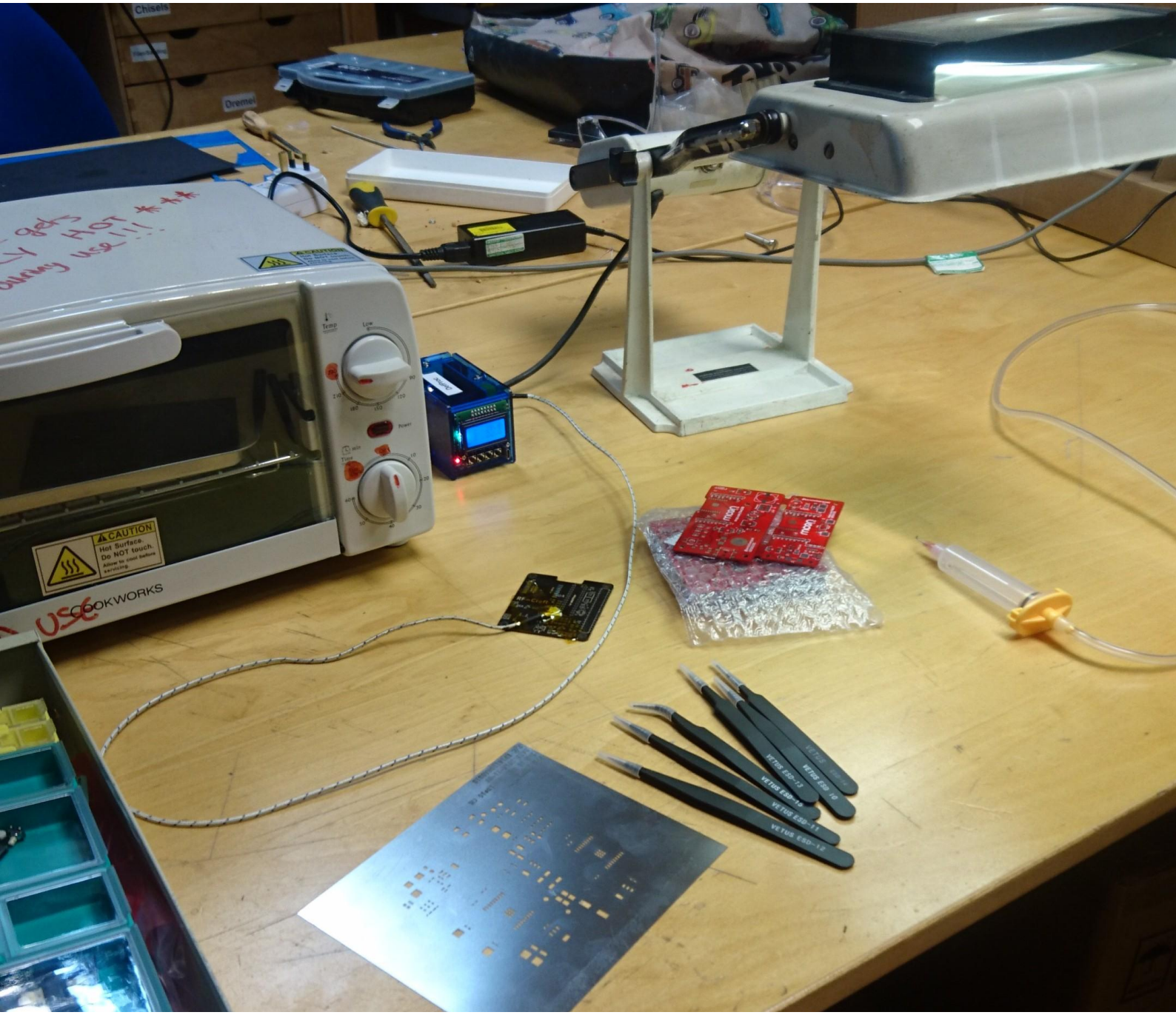
Freshly delivered test PCBs

29/11/2016 **Test surface-mount PCBs arrive**

The test PCBs are delivered. They are panelized with a PCB for a different project as there was room on the order's board size and we didn't want to waste the space.

30/11/2016 **Actual belling shipping date**

The bells have finally left the factory and are loaded on board the MSC Luciana at Mumbai.

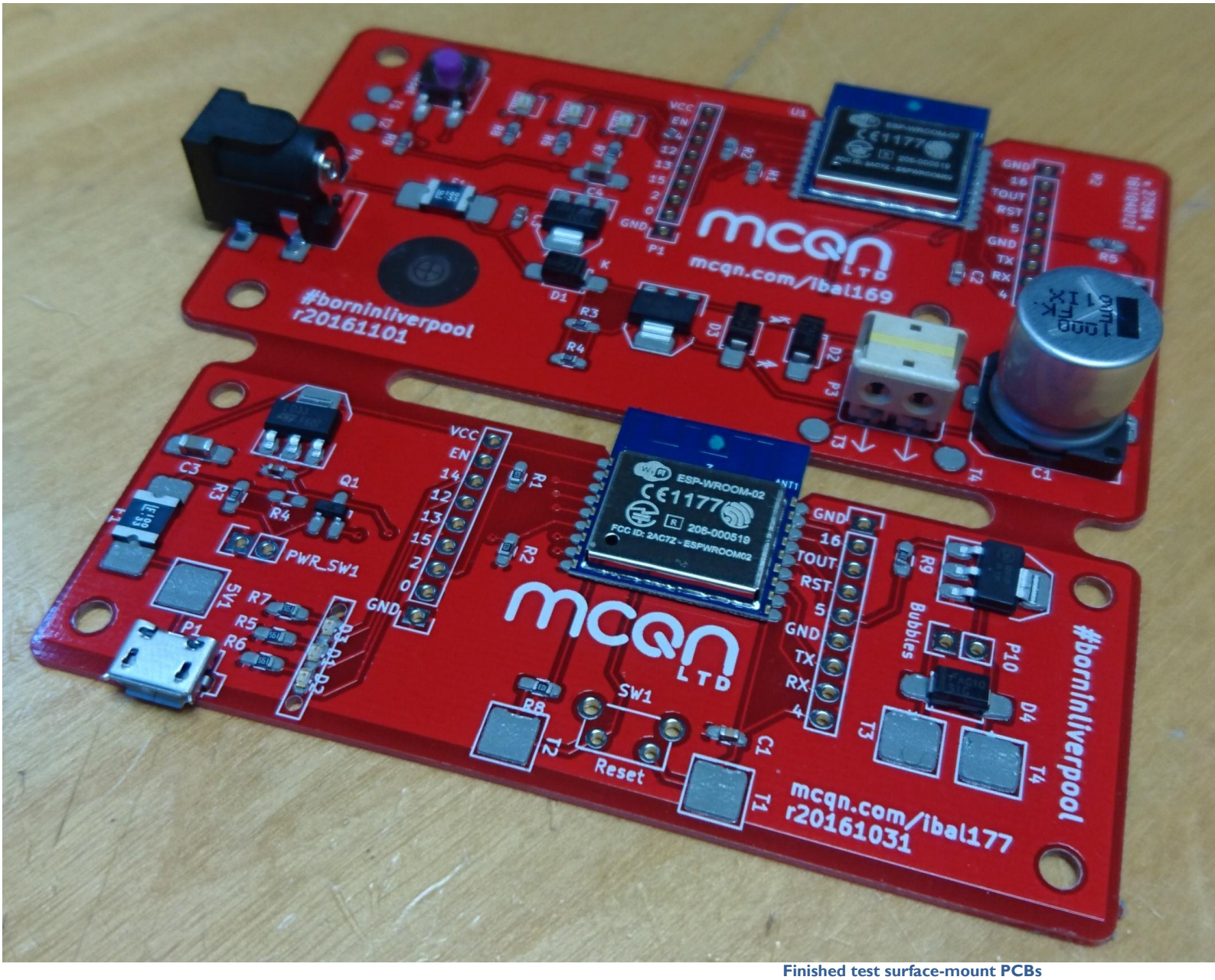


Assembling the test surface-mount PCBs

8/12/2016

Assemble the test surface-mount PCBs

Using the DoES Liverpool reflow soldering set-up, we built up a couple of the test PCBs for testing.

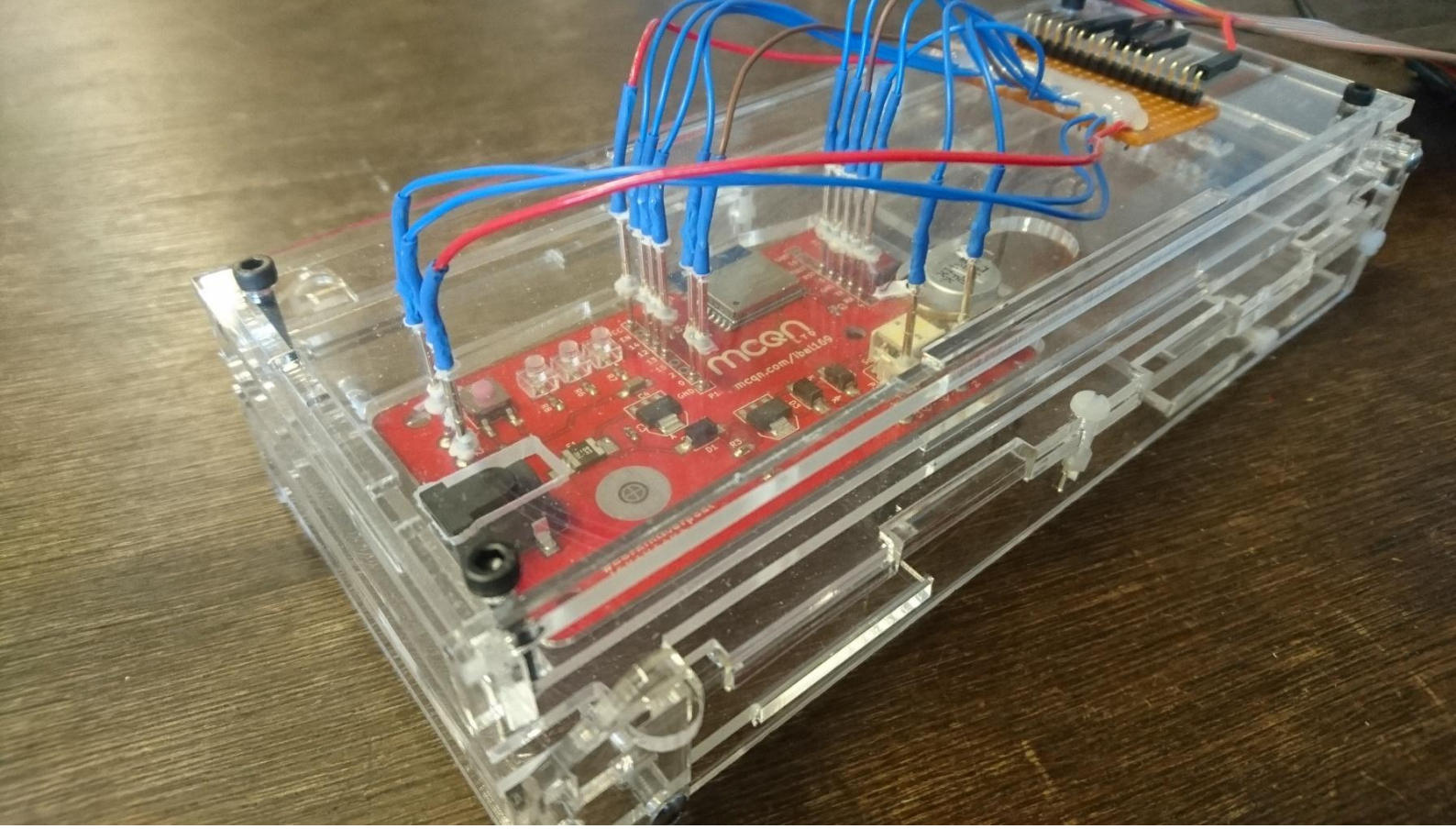


Finished test surface-mount PCBs

/12/2016

Programming jig built

Using the OpenFixture tool shared within the maker community we designed a jig to hold a number of pogo-pins (sprung-loaded pins to allow easy temporary connection to test points on a PCB) to a set of pre-defined test points on the PCB. The jig is then made from clear plastic cut on the laser-cutter. The jig allows the ESP8266 module on the PCB to be programmed with the relevant firmware. Initially, it's the basic functional prototype firmware to enable the surface-mount circuit design to be checked.



Test PCB being programmed in the jig

22/12/2016 **Surface-mount circuit design debugged**

A couple of bugs in the circuit (a mistake with the power connector, and a resistor missed off the reset circuit) are identified and solutions worked out. Fixes are applied to the PCBs in order to get the test boards working so they can be used in other prototyping activity while the fixes are applied to the PCB design and new PCBs to test are ordered.

22/12/2016 **Bells arrive in the UK**

MSC Luciana docks in Felixstowe and the container holding the bells is unloaded.

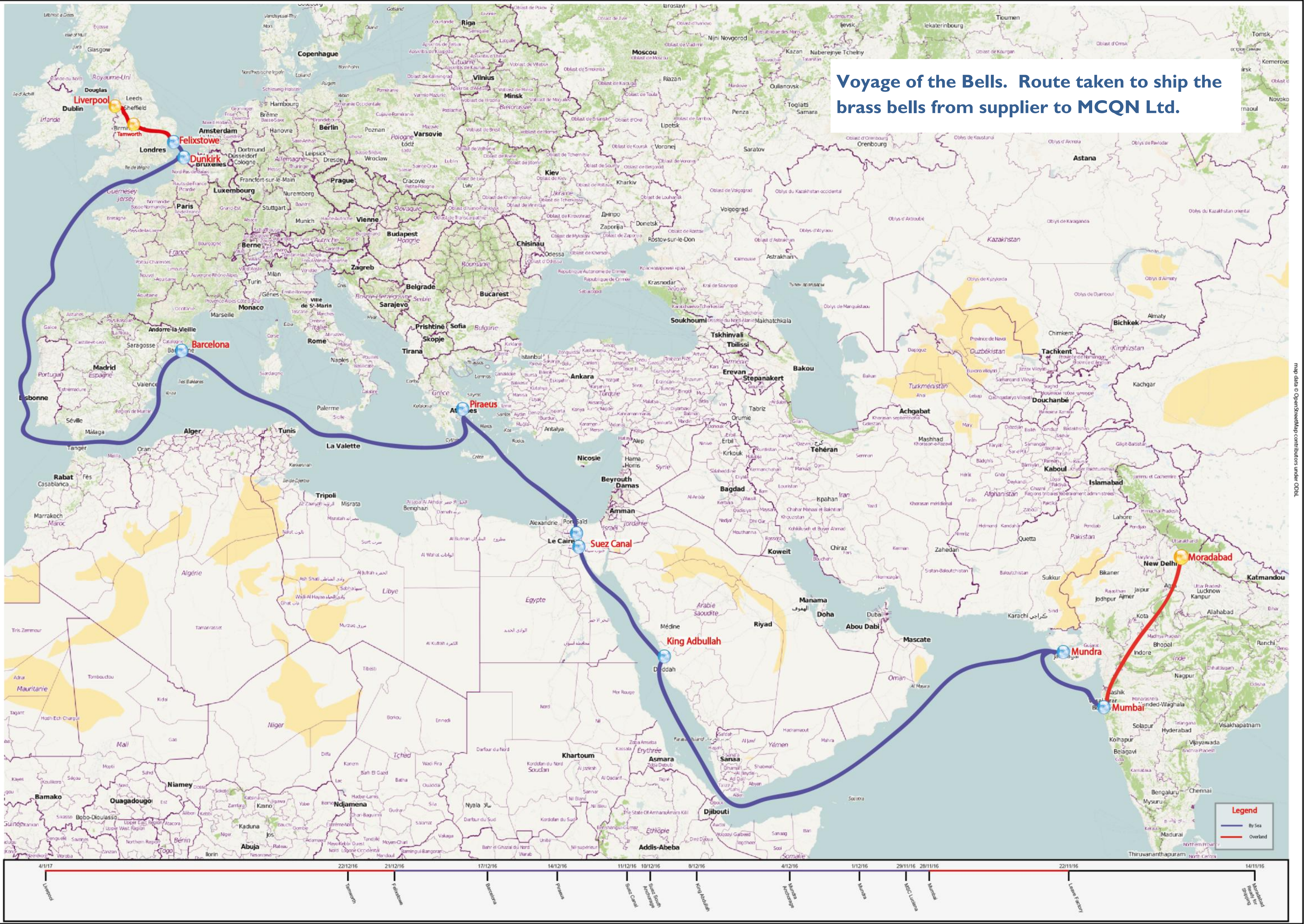
4/1/2017 **Bells are delivered to MCQN Ltd**

Ten boxes of bells arrive on a pallet at the MCQN Ltd office in Liverpool.

8/1/2017 **Surface-mount PCB revision 2 designed and ordered**

The bugs in the initial surface-mount design are fixed and a small batch of test boards ordered.

Voyage of the Bells. Route taken to ship the brass bells from supplier to MCQN Ltd.



Bells arrive at MCQN Ltd

16/1/2017 **Indie Manufacturing research report finished**
This report is written, completing the research project.

16/1/2017 **Web service: Twitter notification engine built**
Add the ability to trigger bells ringing from a Twitter search.

18/1/2017 **Over The Air firmware update code written**
Finish the code to allow the firmware to be updated after the product has shipped, to allow us to fix bugs and add new features without recalling all the devices.

24/1/2017 **Web service: Shopify notification engine built**
Add code to connect to the Shopify API to let users trigger the bell whenever they make a sale.

27/1/2017 **Frame designed for manufacture**

The current frame design is one that is easily laser-cut as that's the prototyping tool we had to hand. It's more likely, although not fully decided, that the production frames will be cut on a CNC router. A design for that will need to take into account the diameter of the cutting tool (no sharp inside corners) but will also be able to take advantage of cutting to varying depths.

30/1/2017 **Production firmware written**

Finish the firmware to ship on the devices, with the relevant error reporting through the status LEDs, code to ease entering the WiFi details, factory reset option, and obviously code to talk to the cloud service.

1/2/2017 **Surface-mount PCB revision 2 delivered**

Receive the new batch of PCBs.

10/2/2017 **Production model assembled and tested**

Solder up the new PCBs and assemble a few full as-will-be-delivered-to-customers units.

17/2/2017 **PCBA quotes obtained**

Assuming the second revision of the PCB works as expected, we can now contact the candidate companies to do the PCB manufacturing and pick-and-place assembly (the A in PCBA) and get quotes for delivering complete, populated and soldered circuit boards.

20/2/2017 **Production partners chosen**

Decide which of the PCBA companies to use, who will do the CNC routing of the frames, etc.

21/2/2017 **Certification testing completed**

Once we have some examples of the production model ready we can then choose a testing house and have them run through the various electronics tests to confirm that it meets the relevant regulations. The CE marking is a self-certifying step, but using a testing house gives peace of mind and is generally a prerequisite for any product insurance.

27/2/2017 **Web service: Google Analytics notification engine built**
Add the ability for users to trigger their bell whenever a Google Analytics goal is achieved.

8/3/2017 **Web service: third party notification API built**
Provide an Application Programming Interface (API) to allow third-party software developers to write code that will trigger a user's bell, thus allowing far more service integrations than we would be able to write in-house.

15/3/2017 **Packaging designed**
Work out how the bells will be held safe during shipping, and design any additional information to include in the box: getting started instructions, etc.

4/2017 **Refine assembly procedures**
We expect that there will be steps in the assembly process that can be improved and/or automated, so during the assembly of the initial batch there will be some reworking of the procedure.

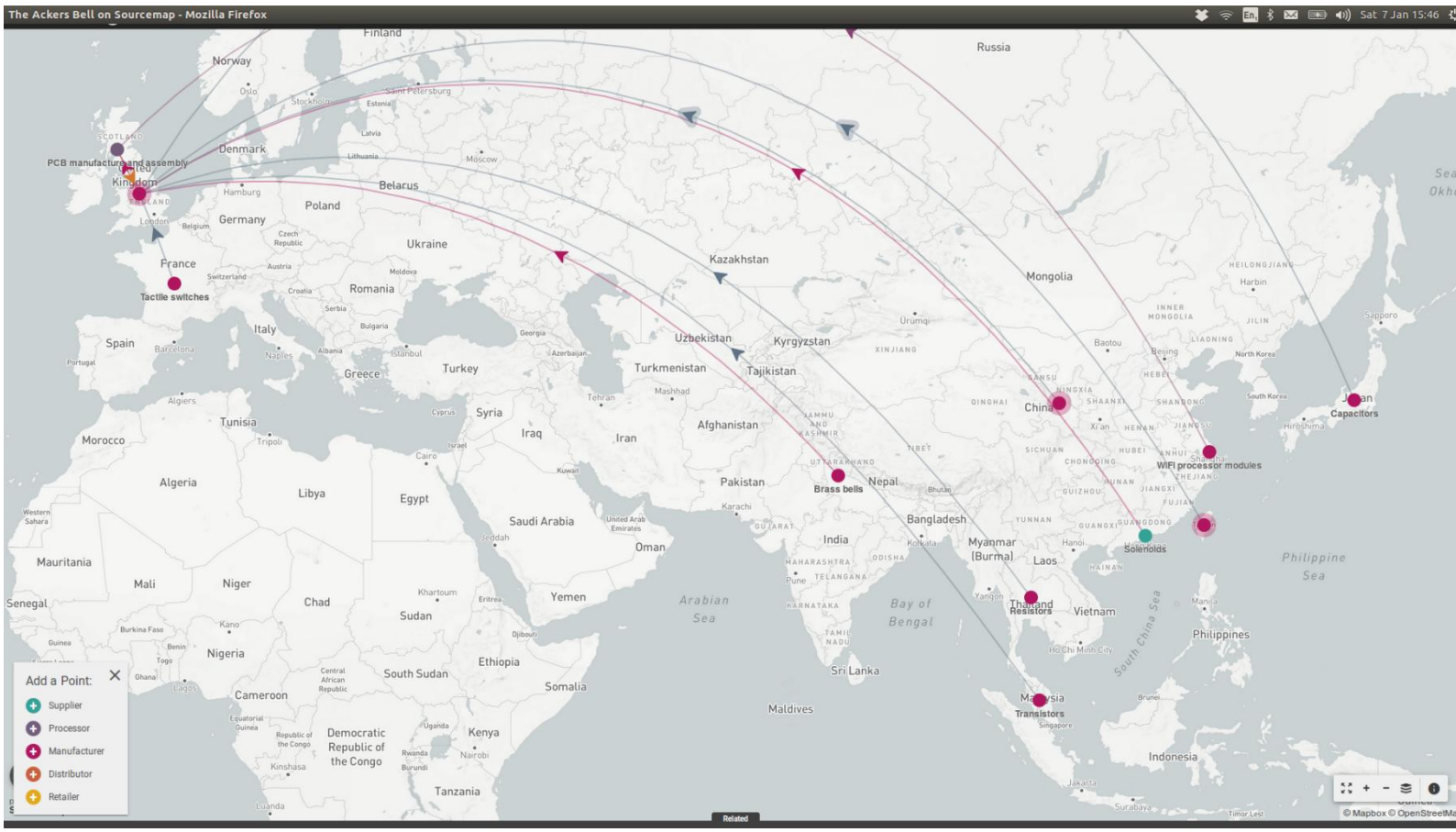
4/2017 **Automate programming**
The programming jig will allow the firmware to be flashed onto the ESP8266 modules. The PCB has been designed to allow a number of additional tests to be performed while the board is in the jig. Rather than do all of the work to fully automate the programming and testing, initially it will be a more manual affair and then we can add the automation and testing to the places where it's needed, once we've seen that.

FINDING SUPPLIERS

A consumer electronics device contains a large number of different parts and depends on a variety of processes to turn those parts into a finished product. The Bill of Materials (BOM) for the Ackers Bell runs to 36 rows: everything from the wood used for the frame, through nuts and bolts to hold it together, and the resistors, transistors, etc. for the circuit to the the mains power supply module.

In keeping with the focus of this research on local supply chains, our search for suppliers started each time in Liverpool, and widened incrementally to the North-West, then nationally and finally internationally.

Resolving the tension between the product you want to make and minimizing its geographic footprint involves massive compromise. For some of the components the geography of your suppliers is chosen for you. This is especially true for the myriad electronic building blocks that make up a circuit board.



As can be seen in the supply chain map above, the only electronic component which isn't sourced from the Far East—not solely China, also Malaysia, Thailand, Taiwan and Japan—is the tactile switch from France. Most of those components weren't sourced from those countries directly; there are nearer local distributors who act as staging posts on the route from factory to production.

These distributors remove the hassles of importing the components directly and greatly reduce the number of suppliers with which you would otherwise have to engage. They also provide a "geography of legality" if you will, in providing peace-of-mind or actual legal protection that the certified modules (especially for key safety components such as mains power supplies) bought are genuine.

Two of the key electronic components were still sourced directly from China.

The selection of solenoids available from the bigger UK distributors didn't provide anything suitable for this application, and sourcing via eBay—for the initial one-off test components—either gave access to Chinese vendors directly or to small-volume resellers in the UK. As that provided no advantages, we found distributors in China to deal with directly via Alibaba.

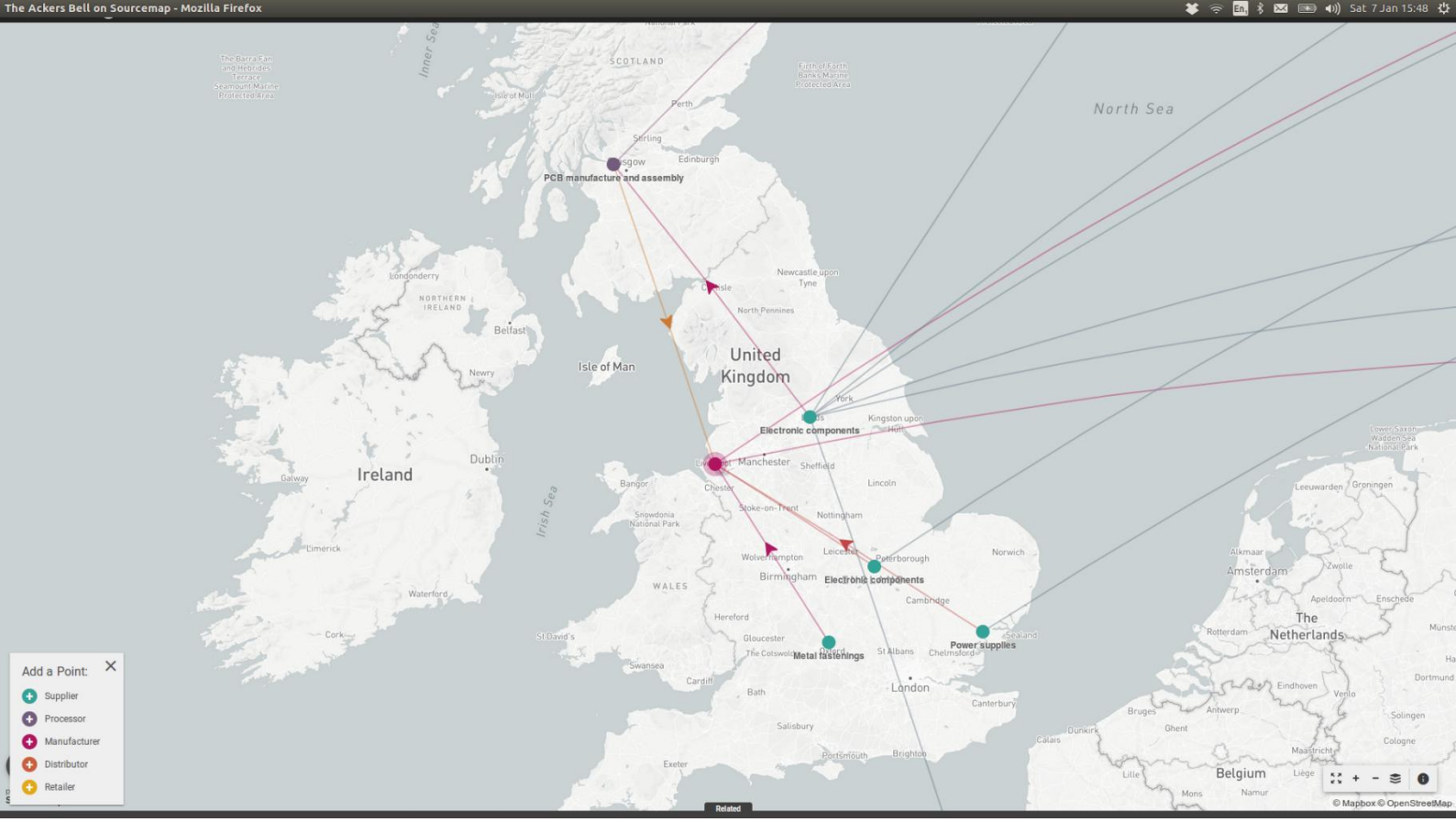
The core ESP8266 module is more readily available direct from China than from UK suppliers (the UK sources tend to focus on breakout board options for individual makers). Alibaba throws up many, many options, but lots have dubious certification markings. Through the UK maker community we were put in touch with a trusted Chinese-based reseller who could source FCC-certified modules for us, however, we had also approached the manufacturer directly and their MOQ (Minimum Order Quantity) was low enough that it was cheaper and easier for us to deal with them.

The other major component sourced from abroad was the brass bell. Our searches for bell foundries in the UK discovered only those making precision musical instruments, which were prohibitively priced. Widening our search, almost all roads led to India. We contacted a number of Indian manufacturers for quotes, and chose based on a combination of responsiveness, price and the design detailing of the bells.

Ordering direct from the factory gave more control over the exact specification of the bells. Usually they are delivered complete with a brass bracket to allow fixing to a wall, and contain a brass clapper with a braided rope to enable the bell to be rung. For our application these were unnecessary features which would require additional steps in the product assembly process to remove them. Dealing with the manufacturer rather than a distributor meant we could have them intervene in the manufacturing process to omit their inclusion, removing a potential waste stream and reducing the shipping weight.

This customisation wasn't a seamless process. The initial explanation of the desired changes wasn't too tricky, but when the samples turned up a few weeks later it turned out they'd missed a vital step in drilling and tapping a mounting hole. That was harder to explain via email than it would have been in person. It may also have contributed to the otherwise unexplained three month overrun on the initial delivery date.

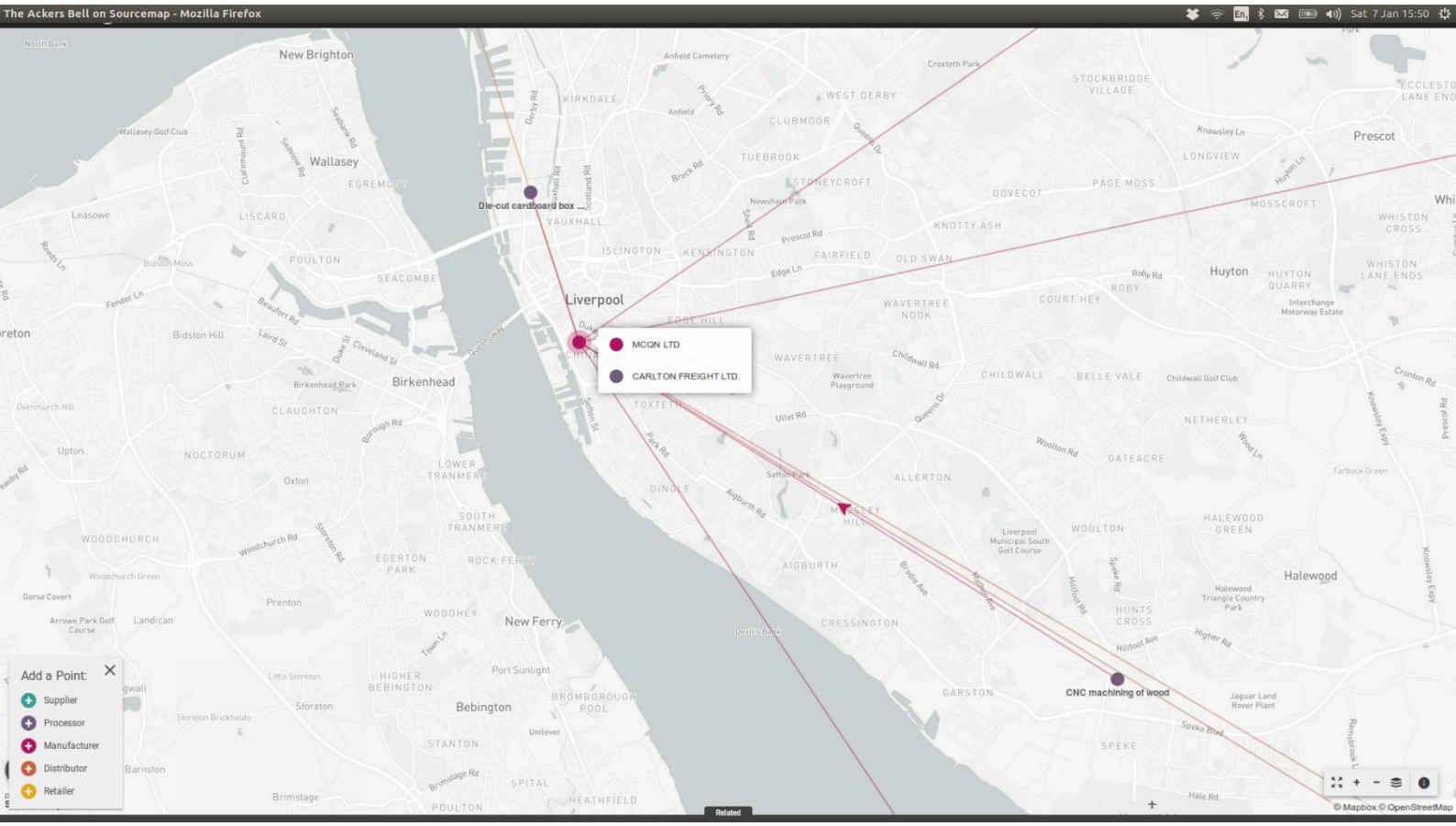
At this scale of operation there's very little the indie manufacturer can do to further investigate the supply chain. By going directly to the manufacturer you at least find out a little more about where they're based, through a distributor the best you manage is generally a manufacturer name and the "country in which last significant manufacturing process was carried out". Details of the constituent materials, their source, or worker conditions are all opaque.



Aside from the customisations to the bells, the bespoke manufacturing processes will all be performed in the UK.

Our mapping activity didn't uncover any PCB manufacturers in the Liverpool region, so all of our candidates for PCBA came via recommendations from the maker community. As useful as the recommendations of who to use was the recommendation of who to avoid. Sadly, during the project we've also moved one of the recommended companies into the not-recommended list. We used them for the breakout boards, as they offer a small batch service as well as larger orders. However, on a client project, Adrian had cause to use them again and their communication and tardiness in resolving a problem in the initial production process means they're off the shortlist for use with the Ackers Bell. At least the problem gave Adrian the opportunity to try one of the other candidates out instead.

We did find some local CNC machining operations through our mapping. Through them we learnt an important lesson in the importance of "getting out of the building". It's something that Oliver Hall highlighted too in our interviews. There's an element of luck to it—you need to speak to the right person at the firm, usually one of the more technical staff as they'll have more of an interest in what you're trying to achieve—but going to talk to people at the "best guess" supplier on your list will either lead to them being able to help, or to them helping you to move forwards regardless. They'll give you additional knowledge over the specifics of the tools or processes you need (and how that differs from their offering) and usually a couple of better contacts to try next because you're now tapping into their network, and their network is much better than yours for their specialism.



Despite this, once again the DoES Liverpool community trumped the mapping. Through incidental conversations in and around the makerspace, we found three good possibilities for the CNC machining of the wooden frames, including the one selected.

The wood being used falls foul of the same opacity of the supply chain as the electronics components, though. FSC certification is the best option for trying to ensure sustainable sourcing but there real difficulties in traceability.

The full interactive version of the supply chain map can be explored by visiting https://open.sourcemap.com/maps/585e9cfa396e750727dae6bf.

KEY LESSONS

- **Get out of the building**. It will build your network, give you more leads and make you more literate: you'll end up with better language & knowledge to frame with next supplier
- **Finding the right person to talk to is essential (but hard).** There is more value (for makers) in talking to the technical rather than sales staff, but naturally the latter are easier to reach. Even when you get introductions from public sector/support organisations, they often only know the sales people
- **Beware the Maker stigma.** Makers often make the incorrect assumption that they don't know anything when approaching suppliers; suppliers often have an (initial) incorrect assumption that makers don't know anything because their language is wrong. However, in the main, people are really friendly once you get over the "dancing round the handbags"
- **Global supply chains have better infrastructure than local supply chains.** There's a whole infrastructure from Alibaba to freight forwarders set up to help international shipping. There's no local equivalent
- **A map is only part of the answer**. And a small part at that. Mapping a region's capabilities is just a first step in helping to connect people and its value is soon lost if not embedded within a community to maintain and extend the map. It would be useful to look for alternative ways to help people discover and connect with local supply chains
- **Make more complex things closer to you.** Off-the-shelf parts can as easily be bought internationally as locally. As your level of involvement in customising the production process for an item increases, so does the benefit of having it closer to you geographically
- **Supply chain opacity.** There is no easy way to chase supply chains beyond "Country in which last significant manufacturing process was carried out"
- **Supply chain transparency trumps nearness.** Knowing where things come from and the conditions of their manufacture is more important than it being local
- **Making hardware takes time.** Adding an extra level of due diligence for ethical, sustainable or local-manufacturing takes even longer
- **Don't underestimate the maker community's black book.** The effective black book from the maker community's network is thicker, better and more local than an accelerator's, particularly for people who are bootstrapping and so don't need/want routes into venture capital
- **Difficult global choices.** The only option for not making certain products globally is not making certain products
- **There's no such thing as an Indie Manufacturer.** There are almost as many different ways of structuring and scaling your business as there are businesses. However, you can say the same about "start-ups"

Wrap-up and Recommendations

Andy: What recommendations would you make to aspiring indie manufacturers?

Adrian: Get out of the building. It's easy to put off talking to suppliers because you don't feel as though you know enough, or have the right language, or whatever. For the main part people are friendly and helpful—those who aren't you won't want to work with anyway. Talking to suppliers and manufacturers will improve your "manufacturing literacy", giving you new knowledge and understanding. It will also expand your network of potential suppliers as they'll have better routes into the network of manufacturers—particularly if the firm you're talking to can't provide what you need.

Those links to people and the knowledge of how to make things is increasingly useful as the complexity of the process rises. For well understood and well defined parts of the product—off-the-shelf components; standardized procedures—it doesn't matter too much whether the supplier is in another continent; the more you need to intervene in the production process, or specify customisations, the more valuable it is to be able to sit face-to-face with someone and either check their work or point out features of a prototype.

Team up with other indie manufacturers to host makerspace versions of the accelerator "demo days". Work with the local support organisations to find the right sort of people to invite.

Andy: What have been the major challenges in getting this far? How has the maker community helped address these challenges—if it all?

Adrian: Consumer Internet-connected products are complex, combining software, electronics, firmware, and industrial design. Building one while based in a makerspace gives you access to a whole raft of experts who are happy to help out: software developers, engineers, artists and designers.

They also share skills in using their tools, and the tools themselves, allowing easier and quicker development of prototypes and the creation of tools and jigs to use during the manufacturing process.

The biggest challenge is how long it takes to develop hardware.

Bootstrapping means that development is stop-start as it is often punctuated with the need to fit in consultancy or agency work to bring in cash.

Not that VC (or similar) funding would be a panacea. Parts of the product development process have long and unpredictable timescales, for example, the bell manufacturing quoted a six-week lead time followed by three weeks shipping. That's already most of the length of a typical accelerator programme, and in reality it took over five months from order to delivery.

Finally, trying to develop products in a more considered manner—manufacturing locally or more ethically or sustainably—takes longer than if you can just take the easiest route.

Andy: What have been the major challenges when dealing with manufacturers?

Adrian: Finding the right people to talk to and getting to talk to them!

Makers are generally hands-on and practical people who don't have any formal design or industry experience or education. That makes it harder to communicate with manufacturers as they don't know the right language or terms to use when initially engaging with them.

This manifests in two ways: first in getting the manufacturers to take you seriously and even respond to your enquiries; and then in discussing the work to be done. If you can get access to the technical staff then you'll have a more productive discussion about your product and how changes to the design will make manufacturing easier (or harder).

People assume that public sector support organisations can help with finding suppliers and making introductions but they often have a limited knowledge of the firms on their patch—particularly the smaller ones that a maker would deal with. In addition they usually operate in a landscape that places non-technical officers in the position of gate-keeper, with the same result of preventing the makers from reaching the technical experts at the suppliers.

Andy: What could be done to make some of the local manufacturing options more visible and easier to access?

Adrian: I'm not sure. It's a huge problem but one without a simple solution. For buying things internationally there's a whole infrastructure in place, from Alibaba.com to help you find the suppliers through to services like freight forwarders to help with shipping and navigating customs and importing.

The nearest equivalent for local supply chains is the tacit knowledge embedded in the maker community. However, this only scales as quickly as people can do projects needing new expertise and suppliers, and the knowledge is difficult to share.

We need the manufacturers to understand the importance of an online presence. It's so much harder to find people if they don't have a website or some sort of contact details on the web.

Andy: Can you elaborate on why you went to India and China for some components?

Adrian: Although there are still many, many manufacturing firms and suppliers in the UK, certain items aren't made in the UK—or in Europe—any more. It's possible to work with UK suppliers and distributors for these items, but even then the factories making the actual components are still in the Far East.

For certain classes of products—such as electronics—the only option for not making them globally is not making them at all.

Andy: Does that then throw up other challenges?

Adrian: Definitely, on the ethical side. One element of local production is that it's a shortcut for a known (and understood by the maker) level of working conditions and product regulations. When you're then manufacturing globally it becomes more important to know where things are sourced and the conditions of their manufacture.

It's almost impossible to understand the sourcing for electronic components beyond the "Country in which last significant manufacturing process was carried out" detailed by the distributors.

Andy: What recommendations do you have for organisations that offer support to makers, indie manufacturers and the manufacturing sector?

Adrian: Don't build new silos. Find ways to work with, promote, and support the existing maker communities rather than duplicating workshops full of kit.

Anyone working in business support roles—whether at university business engagement departments; the council; local enterprise partnerships, etc.—should look to make introductions between relevant companies whenever they encounter them in their work.

Embed the support personnel in the community rather than expecting the community to come to the support organisation. The people you really want to reach will be too busy getting on with things to bother looking for your door. Regularly spending the day working out of the local makerspace will give you a much better understanding of what support is needed, and will mean the community is more likely to welcome it when offered.

Look for ways to connect local manufacturing and maker communities. At a level of individuals and staff rather than managing directors and makerspace administrators.

Have manufacturers run sessions—talks or factory tours, for example—to educate makers on the details of their manufacturing processes and capabilities. Learning about the process is easy enough, but there's lots of nuance once you dig into it: for example, the difference between matrix versus pod-and-rail beds on CNC routers. Explore the

opposite, where makers explain newer technologies such as 3d-printing, laser-cutting and physical computing to manufacturers.

Encourage UK companies to sign up to Alibaba, so they're as easy to find as someone in China; and as I mentioned earlier, get them to create even a simple website!

Help the maker community better understand the non-technical sides of manufacturing, such as distribution and sales, or certification.

Andy: How useful was the map in identifying potential suppliers/partners?

Adrian: In its present form the map was of limited use. If it continues to provide a place for the community to store and share the basic information about who they've used—although for that to happen adding new information needs to be easier—then it will serve as a good addition to the knowledge held by the community itself.

It let me find some suppliers who improved my understanding of the processes required, but the most likely partner companies I'll use for production have all come via recommendations from the maker community.

Andy: Would that benefit from further research then?

Adrian: Yes, looking for alternative ways to help people discover and connect with local supply chains would be really useful.

A key question that remains unanswered is how you capture tacit knowledge within both maker and manufacturing communities. How do you find ways to link the two, without the result relying on single points of contact or significant and ongoing investment.

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