BOOK OF

PEER PRODUCTION

SPECIAL FSCONS EDITION

SOCIALLY USEFUL PRODUCTION

THE CUNNING OF INSTRUMENTAL REASON

AUTHORITY IN PEER PRODUCTION

BECOMING MAKERS

HACKLABS AND HACKERSPACES

BOOK OF PEER PRODUCTION

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INTRODUCTION TO BOOK OF PEER PRODUCTION

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The Book of Peer Production is an off-spring of the *Journal of Peer Production*, an open access, peer reviewed journal dedicated to investigating the emergence of peer production as a new mode of production. Characteristic of peer production is that the output is orientated towards the further expansion of the commons; while the commons, recursively, is the chief resource in this mode of production. In fact, the commons and peer production are two names for describing the same thing: a particular kind of labour relation. This labour relation is predicated on voluntary participation and the self-selection of tasks. Participants may be driven by a variety of motivations, for instance, self-fulfilment, peer recognition, developing new skills, or something else again. We may call such motivations *intrinsic*. The high degree of intrinsic motivation in commons-based peer production is proportionate to a relatively low degree of *extrinsic* motivation. That is to say, monetary compensation for labour expenditure. This is testified in the willingness among participants to relinquish exclusive proprietary rights over the results of their labour in favour of public ownership licenses. Starting from this ideal type, we set out to scrutinise the inconsistencies and contradictions of peer production, placing emphasis on its hybrid co-existence with dominant forms of (wage) labour and property relations. A key area of investigation are cases where the output of the community is appropriated by a private rights holder. Commons-based peer production is thus turned into a model for exploiting free labour.[1] We invite contributions from as many perspectives as possible in this discussion. The overriding goal is to conceptualise what peer production is and could become, as a step towards building a more just and sustainable future.

In keeping with the topic of the journal and the book, we seek to position ourselves in-between the grassroots initiatives and discussions taking place on the Internet, driven by practitioners and activists of various kinds, and the theory and critiques coming out of academia. We are thus obliged to say some words about the match, and mismatch, between the concept of peer production and the academic world. This leads on to a much larger and thorny question: the state of the contemporary intellectual landscape. This has been brilliantly mapped by a French sociologist, Razmig Keucheyan, in his book *Hémisphère gauche. Une cartographie des nouvelles pensées critiques*. Leaning on Perry Anderson's diagnosis, Keucheyan makes two key points: first, it must be recognised that the New Left was defeated by the neo-liberal counter-offensive. Under the current circumstances, its ideas and tactics are a roadplan for continued failures. Second, it is clarifying to compare leading critical intellectuals of the early 20th century with their contemporary counterparts. Rosa Luxemburg, Trotski, Lenin, Lukàcs, Korsch and Gramsci combined incisive political analysis with the leadership of political organisations. There are still a handful of intellectuals closely associated with far-left micro-parties; in present-day Europe we have the late Daniel Bensaïd in France and Alex Callinicos in the United Kingdom; in Latin America, one may think of Álvaro García Linera, vice-president of Bolivia since 2006, and of Subcomandante Marcos of the Mexican Zapatista Army of National Liberation (Ejército Zapatista de Liberación Nacional or EZLN). But the overwhelming majority of present-day intellectuals with a critical bent (the writers of this introduction included), are state employees in the service of the university system. From this observation Keucheyan concludes:

> This does not mean that contemporary critical intellectuals are not engaged, or that they are less radical than classical marxists. But, aside from their engagement, they are academics, which cannot fail to influence the kind of theories they produce.[2]

The claims about an ascendant mode of peer production seems to point in the opposite direction. As a counterpoint to the academisation of debates and politics, alternative forums and meeting places flourish where practitioners and activists reflect over their practice and its wider, societal implications. No-one personifies this stance better than Richard Stallman. His ideals of autonomy, creativity, sharing, and cooperation have been advanced through the creation of GNU software, the General Public Licence (or "copyleft") and the Free Software Foundation. Those achievements have been coupled with an independent production of ideas, manifestos, forecasts and strategic plans. Recall the promise for the future that concludes the *GNU Manifesto*:

> In the long run, making programs free is a step toward the post-scarcity world, where nobody will have to work very hard just to make a living. People will be free to devote themselves to activities that are fun, such as programming, after spending the necessary ten hours a week on required tasks such as legislation, family counseling, robot repair and asteroid prospecting. There will be no need to be able to make a living from programming.[3]

1 For a more on peer production, see: Vasilis Kostakis and Michel Bauwens (2014) *Network Society and Future Scenarios for a Collaborative Economy*. London: Palgrave. On the risk of exploitation of free labour, see: (ed.) Trebor Scholz (2012) *The Internet as Playground and Factory*. New York: Routledge.

2 Keucheyan, R. (2010) *Hémisphère gauche. Une cartographie des nouvelles pensées critiques*. Paris: La Découverte.

3 Stallman, R. (1985) *The GNU Manifesto*. Available: http://www.gnu.org/gnu/manifesto.html/

Trained social scientists are bound to react with a wry smile when reading the references to asteroids and robots. Most likely, they will proceed to formulate a critique of the logocentric, techno-deterministic, Western and/or patriarchal hacker culture.[4] We invite such critiques as part of our collective undertaking to reflect over peer production. Having said that, a critique is not complete unless the critic includes himself/herself in his/her analysis. As we saw, the position of the critic largely overlaps with that of the professional academic. One bias of this profession is a generalised anxiety not to be perceived as naive, against which the critical stance serves as an antidote. What is problematic here is that this attitude accords so well with the ironic, post-ideological hegemonic order of the day. In contrast, the convictions expressed by Richard Stallman and like-minded people have been rewarded with striking successes on the ground. The creation of peer production projects such as Project Gutenberg, Wikipedia and the many offshoots of GNU/Linux are some cases in point. Those accomplishments stand out all the more as the traditional left is struggling to come up with an adequate response to the mounting crisis of the capitalist system. Post-1989, the space for thinking and debating alternatives to neoliberal and/or keynesian capitalism is steadily shrinking, also within the left. It is in this light that historically and sociologically informed studies of the peer production model become urgent.

Inquiries of the sort have been pioneered by Oekonux and the Peer-to-Peer Foundation. They have been involved in concurrent theory development, free software production and community organising, a mixture that has fostered conceptual creativity. The Oekonux project, originally launched in 1999 in Germany, has been at the forefront of critical theorising about peer production. In the view of Oekonux members and sympathisers, the Marxist critique of the capitalist mode of production (where the proletariat seizes the means of production through state power) is superseded by a peer production critique (where the wage labour relation and commodity production are replaced with commons-based production). The proponents of the Peer-to-Peer Foundation share many of the same concerns and analysis without being as closely tied to the Marxist tradition. The initiative to start the *Journal of Peer Production* came out of discussions at the Fourth Oekonux conference in Manchester in 2009; our ambition was to create a forum that accommodates these different perspectives.

It is fitting that the book has been produced in connection with the Free Society Conference and Nordic Summit (FSCONS). Since its beginning in 2007, FSCONS has been a rallying point for everyone interested in bottom-up technology development and its wider, societal implications. Equally fitting is it to have the book published on Nordic Summer University Press, a forum for independent thinking and self-organisation for more than 60 years. The same aspiration is expressed by the authors of this volume. In the opening chapter, Adrian Smith documents the story about *The Lucas Plan*. When workers in the U.K. arms industry faced layoffs in 1970s, they proposed to take over the factory and repurpose it for 'socially useful production.' In the next chapter, Johan Söderberg investigates an open source 3D printing project that set out to abolish the need for market exchanges. The ambitious goal of the project is compared with a longer history of utopian engineering thinking. George Dafermos demonstrates in his study of the FreeBSD project that a complex engineering project can be scaled up without it requiring traditional divisions of labour and associated hierarchies. The chapter by Austin Toombs, Shaowen Bardzell and Jeffrey Bardzell traces the many paths that leads to the adoption of a ”maker” identity. Maxigas' chapter, finally, calls attention to a tradition of Hacklabs, often set up in squatted buildings on the European continent, that predated the latest wave of Hackerspaces. The disappearance of that history in the collective representations of hackers is linked to the marginalisation of the more confrontational politics of Hacklabs. This leads us to a common theme in all of the chapters in this volume. Namely, the need for independent reflection and scholarly work to restore to our collective memory foregone and forgotten traditions of utopian technology development. Restoring that memory is a first step towards bringing about a different future.

4 Kreiss, D., Finn, M. & Turner, F. (2011) The limits of peer production: Some reminders from Max Weber for the network society. *New Media & Society* 13(2): 243–259

TECHNOLOGY NETWORKS FOR SOCIALLY USEFUL PRODUCTION

ADRIAN SMITH

Abstract: Though largely forgotten now, Technology Networks were community-based prototyping workshops supported by the Greater London Council from 1983 until 1986. They emerged out of a movement for socially useful production. Recalling the radical roots and conflicted experiences of the workshops brings to the fore issues still relevant today: tensions between prototyping activities for business development as distinct from more critical technological agit prop for political mobilisation; working at equitable relations between codified, formal expertise versus tacit, experiential skills; and the influences of broader political and economic changes and wider movements for alternatives. After careful historical contextualisation, lessons are drawn for workshops today, but which will inevitably play out differently, hopefully after learning from the past.

INTRODUCTION

With unemployment reaching one in eight workers, and manufacturing in steep decline in the city, Londoners voted an avowedly socialist Labour council into power in 1981. Left-wing leaders of the Greater London Council (GLC) were committed to a radically alternative economic strategy compared to the 'free-market' right-wing agenda of the Thatcher government nationally. The GLC quickly instituted a Greater London Enterprise Board (GLEB) committed to job creation, industrial democracy, and socially useful production.

Amongst GLEB's first acts was the creation of Technology Networks. These community-based workshops shared machine tools, access to technical advice, and prototyping services, and were open for anyone to develop socially useful products. GLEB's aim was to bring together the 'untapped skill, creativity and sheer enthusiasm' in local communities with the 'reservoir of scientific and innovation knowledge' in London's polytechnics (Greater London Enterprise Board, 1984b, p. 9-10). In keeping with the political ideals underpinning the initiative, representatives from trade unions, community groups, and higher education institutes oversaw workshop management.

Technology Network participants developed various prototypes and initiatives; including, electric bicycles, small-scale wind turbines, energy conservation services, disability devices, re-manufactured products, children's play equipment, community computer networks, and a women's IT co-operative. Prototype designs were registered in an open access product bank freely available to others in the community; and innovative products and services were linked to GLEB programmes for creating co-operative enterprises. Similar workshops were created in other Left-controlled cities in the UK.

Ideas and enthusiasm for these workshops drew upon a wider movement for socially useful production, which in turn drew together strands of thought and activism from broader social movements, old and new. These included, workplace democracy and alternative industrial plans, community development activism, left environmentalist networks, radical scientists and alternative technologists, and, to a lesser degree, feminism. Workshops were conceived in movement terms of providing human-centred, skill-enhancing machine tools; developing socially useful products; and democratising design and production. As such, workshop aspirations extended well beyond local prototyping and manufacturing: Technology Networks were an attempt to recast innovation and inscribe it with a radical vision for society.

A history of Technology Networks provides a longer view on two questions motivating this book on peer production:
– *Are rapid prototyping practices changing the relationships to technology, research and development, and innovation?*
– *How do shared machine shops interface with the political economy of contemporary capitalism?*

In another chapter of this book, Maxigas demonstrates how situating the distinct historical genealogies of hacklabs and hackerspaces in earlier autonomist movements improves appreciation of the strategic issues confronting those spaces today (Maxigas, 2014). Similarly, this chapter provides historical perspective on issues relevant to community workshops now (Tosh 2008). Features in Technology Networks are not only relevant to FabLabs, Hackerspaces and other workshops, but also to current ideas and practices in participatory design and critical making (Tosh 2008; Smith *et al.* 2013; Maxigas, 2014).

The argument here is that Technology Networks, reflecting the wider movement for socially useful production, contained tensions in terms of social purpose, cultures of knowledge

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production, and political economy. The social tension was between spaces for product-oriented design activity, and spaces for network-oriented social mobilisation. The cultural tension was between professional and codified technical knowledge and the tacit knowledge and experiential expertise of community participants. And tensions in political economy - between socialism-in-one-space and the neo-liberal turn nationally and internationally – meant insufficient (public) investment was available to develop initiatives into significant economic activity, and especially without transforming the initiative into capitalist form.

A key lesson from this history is that radical aspirations invested in workshops, such as democratising technology, will need to connect to wider social mobilisations capable of bringing about reinforcing political, economic and institutional change. Otherwise, as we see in the case of Technology Networks, diminished versions of these ideas and practices will become captured and co-opted by incumbents.

The movement for socially useful production generated its own literature, supportive and critical, and which this study has drawn upon. Archived material was also accessed in relation to the meetings and conferences, programmes and organisations, artefacts, lobbying, and other repertoires of action generated by the movement (e.g. film, reports, media articles). The author has posted two examples on the web: one is a promotional booklet for Technology Networks produced by GLEB in 1984 (Smith, 2014a); another is a 1978 film documenting the Lucas workers' alternative industrial plan, available here (Smith, 2014b). Interviews were also conducted with protagonists and observers from the time. Finally, a draft of the history was circulated for comment, correction and reflection amongst a wider group of people with first-hand experience of the movement (Smith, 2104).

The paper is organised as follows. The next section describes the wider movement for socially useful production from which Technology Networks emerged. The section thereafter describes the creation and operation of Technology Networks, as well as discussing some of the tensions that existed. The last section considers whether and how lessons then might be relevant for community workshops today and concludes by reiterating how any radical aspirations for workshop practices needs to connect cultural developments with wider social movements and influence reinforcing political and economic change. Something easier said than done.

THE MOVEMENT FOR SOCIALLY USEFUL PRODUCTION

In introducing a book about his involvement in socially useful production, Mike Cooley (1987) quotes Karl Marx from *Capital* to evoke the spirit of the movement, and to give Cooley's book its title, *Architect or Bee?*

> A bee puts to shame many an architect in the construction of its cells; but what distinguishes the worst of architects from the best of bees is namely this. The architect will construct in his imagination that which he will ultimately erect in reality. At the end of every labour process, we get that which existed in the consciousness of the labourer at its commencement.

Ideas about labour process, skill, design and technology were at the heart of the movement for socially useful production. The movement sought a more democratic human relationship with technology that furnished tools for people to become architects in a deliberated societal vision, rather than perpetuating a situation where humans became scientifically managed bees tending machines in the service of capital (Cooley 1987). As Veronica Mole and Dave Elliott put it, activists wanted,

> [...] to present a vision of an alternative paradigm that prefigured a different role for technology in society … To do this it is necessary to produce both a critique of the current shape and aims of existing technologies together with examples of alternatives that could lead to social and technological change (Mole & Elliott 1987, p.82)

Mike Cooley was an industrial designer and trades union shop steward at Lucas Aerospace. He was aware of arguments and initiatives for industrial democracy, and a firm believer in creativity inherent to all people. It was at Lucas, and through the development of a worker's alternative plan for the company, that ideas for socially useful production found practical expression. It was a focal experience for many, and gave an impulse for the wider movement.

Grassroots trades union origins of socially useful production

Like many in manufacturing in the UK at the time, workers at Lucas Aerospace were facing redundancy and the decline of their communities in the face of industrial restructuring by capital, international competition and relocation, and increasing technological automation in design and production. In January 1976 workers published an Alternative Corporate Plan for the future of Lucas Aerospace. This innovative measure anticipated management cuts to thousands of jobs. Instead of redundancy, workers argued their right to socially useful production.

The Lucas Plan was unusual in that, through careful analysis of skills, machinery, work organisation, and economic potential, workers *themselves* proposed innovative alternatives to closures. It took a year to put the Plan together, including designs for over 150 alternative products. The plan contained economic analysis; proposals for training that enhanced and broadened skills; a less hierarchical restructuring of work that broke divisions between practical shop floor knowledge and theoretical design engineering knowledge. It challenged fundamental assumptions about how design and innovation should operate.

Half of Lucas Aerospace's output supplied military contracts. This business area depended upon public funds - as did many of the firm's other activities. Moreover, UK governments had since the 1960s been financing the 'rationalisation' of manufacturing sectors, and paid the welfare benefits of those who became unemployed as a result of this restructuring. Activists argued state funds would be better put to investing in socially useful production. Arms conversion arguments attracted interest from the peace movement and social activists more widely. Additional proposals in the Plan, such as for human-centred technologies that enhanced skills rather than displaced labour, and for socialised markets for products, caught the attention of those associated with the Left. Here was a practical example for connecting new forms of trades unionism and grassroots initiative with ideals for democratic socialism (Wainwright & Elliott, 1982).

The workers themselves, and especially their leaders in the Shop Stewards' Combine Committee, suspected (correctly) that the Plan in isolation would convince neither management nor government (Lucas Aerospace Shop Stewards' Combine Committee, 1979). Both eventually rejected it. In the meantime, and as a lever to exert pressure, the workers launched a political campaign for the right of all people to socially useful production. The Plan assumed a symbolic role for alternative possibilities within a wider critique of the restructuring capital that was closing so many industries in the UK (Bodington *et al*. 1986).

Connecting with old and new social movements elsewhere

Aspirations for socially useful production permitted alliances between workers and the new social movements for peace, environment, community activism and women. As such, the movement for socially useful production consisted of an unusual (and sometimes uneasy) mix of people and organisations. Their ideas for design and innovation arose through a combination of unorthodox trade unionists revitalising arguments for industrial democracy and worker's control, and in so doing meeting with newer social movements for community activism, peace, radical scientists, and feminism. The latter had become prominent features in social and political life over the course of the 1970s.

Combine committees of shop stewards at other companies met to develop their own plans in response to redundancy threats. These included workers at firms like Vickers, British Aircraft Corporation, Dunlop, Parsons, and Chrysler (the latter proposing diversification into products for the Third World) (Speke Joint Shops Stewards Committee,1979; North East Trade Union Studies Information Unit, 1980).

The movement connected with initiatives internationally (Rasmussen, 2007). In West Germany, for instance, the metalworkers union drew upon the Lucas experience to inform Alternative Product Working Groups established in a number of firms, including Blohm & Voss, AEG, VFW, MBB, Krupp and MAK. Workers proposed combined heat and power systems, transport systems, and, at Voith in Bremen, designed tyre-recycling equipment. In an attempt to progress to prototypes, and help diffuse alternative initiatives, Innovation and Technology Centres were set up in Bremen and Osnabrück in collaboration between trade unions, universities and local authorities.

Over the next few years, practical initiatives for socially useful production emerged from the bottom-up, in shop floors, in polytechnics, in local communities, and in workshops (Collective Design/Project, 1985; Blackburn *et al.* 1982). The new movements advanced overlapping, yet different, demands. Consequently, there were various strands to thinking and activism.

The first strand derived from the specific aims of the newer social movements. So, for example, socially useful production should focus on developing environmentally sound technologies, and produce devices for peace rather than weapons for war. Feminists raised gender issues as important absences in a framing of socially useful production arising initially in a male-dominated sector of manufacturing. Gendered perspectives within industry needed to be confronted; socially useful production should look beyond manufacturing settings, and recognise the importance of consumption activities as well as production in other sectors, including the undervalued services provided in homes (Huws, 1985; Liff, 1985).

Activists within radical science, centring on the British Society for Social Responsibility in Science, were also drawn to discussions about the Lucas Plan (Reilly, 1976). Demands for more socially responsible technologies resonated with radical scientists' questioning of the institutional interests and priorities setting technological agendas in society (Asquith, 1979; Levidow, 1983). Some were drawn to Marxist analysis of the structures of science and technology, whereas others looked to the cultures and practices of knowledge production in society (Asdal *et al*. 2007). What they shared was an interest in how the Lucas workers and emerging movement were trying to develop a very different framework for design and innovation. The movement for socially useful production was consequently not framed solely as a campaign for jobs and products, but rather about the culture, structure, locations and direction of innovation in transformed societies.

Participatory design and the democratisation of production

Movement arguments challenged establishment claims that technology progressed autonomously of society, and that people inevitably had to adapt to the tools offered up by science. Activists argued technology was shaped by social choices over its development, and those choices needed to become more democratic, more open to plural knowledge, including tacit and practical expertise, public decisions about the funding of product research and development, participation in design and innovation processes, and popular planning for social markets (Cooley, 1987).

The movement clearly found its first expression in the workplace. Here, technological change, particularly computer integrated manufacturing (CIM), was seen to be deskilling and displacing workers (Brödner, 1990; Noble, 1979). The Lucas Plan and Technology Networks at GLEB were an inspiration for trade unionist and researcher projects in Scandinavia developing their Collective Resource Approach to participatory design (Ehn, 1988). These trade unionists and researchers saw nothing automatic in the development of automated systems (Rauner *et al*. 1988; Piore & Sabel, 1984). Automation required oversight, debugging and adaptation; systems designed without thought for user skills resulted in serious failures, as well as resistance from operatives; and production programming in centralised offices could be inflexible, and lead to slow and costly re-tooling that was unresponsive to customer demands (Brödner, 1990; Cherns, 1976; Senker, 1986). The practical know how underpinning such complex tasks provided potential levers for exerting worker influence over the design and implementation of new technology. Computer-controlled machinery should allow programming on the shop floor, machines should enhance rather than substitute operator skill and initiative, and production should be organised by teams of workers who schedule the work required (Rosenbrock, 1989). Significantly, workers themselves should be involved in the design methodology for these socio-technical systems (Ehn, 1988).

As such, the socially useful framing expanded to argue democratic control and direct participation was required over the design, development and social use of technology (Cooley, 1987; Ehn, 1988). Since the notion of 'usefulness' was a matter of negotiation, workers and communities had to be involved. Design, development, investment and marketing decisions were a matter for participation, debate and negotiation. Brian Lowe at the Unit for the Development of Alternative Products in the West Midlands put it,

> The central feature of socially useful production is the development of ideas and organisation forms that encourage involvement, generate self confidence and release new found or rediscovered skills during the examination of how productive resources should be used to meet social needs. Initiatives promoting socially useful production must, in turn, be extremely responsible and very supportive throughout the complete process if working people are to successfully take on the tasks and challenges of responding with alternative plans. (Lowe, 1985, p.69)

Ideas about participatory design embraced community development and popular planning. The movement soon found institutional support amongst the leadership of a handful of radical local authorities, such as the Greater London Council, and who were able to provide resources and facilities for putting ideas into practice. Mary Moore from the London Innovation Technology Network described the aim as,

> [...] making sure that what you do is going to be of real use to the intended users which means somehow getting them to take part in the design process rather than just pop in with a product when you've produced it [...] So you wouldn't just market-research a new product, which puts users in a passive role. You'd actually get them in the workshop and enable them to learn more about how such things are made and designed and repaired and modified. (quoted in Mackintosh & Wainwright, 1987, p.214)

The desire to produce in a socially useful way, and to place skills, design and production technologies at the service of communities rather than capital, found a willing audience amongst community activists and the Left. Community workshops were a crucible for this unusual amalgam. Early in the career of their Technology Networks, GLEB wrote,

> Already there is no shortage of proposals for products and services [...] to excite interest, widen horizons, and ensure a continuing flow of practical and job-creating challenges to economic fatalism (Greater London Enterprise Board, 1984a).

This quote is quite typical in blending practical, object-oriented activity with aspirations for alternatives to capitalism (Linn, 1987). But it was a blend that also introduced tensions into Technology Networks.

TECHNOLOGY NETWORKS

Metropolitan local authorities under the control of the Left of the Labour Party in the early 1980s were supportive towards socially useful production. Some provided space for community workshops. Activity at the Greater London Council in the form of its Technology Networks was the most intensive in this respect; though other workshops included the Unit for the Development of Alternative Products (UDAP) in Coventry and the Sheffield Centre for Product Development and Technological Resources (SCEPTRE).

Establishing the Technology Networks

The Labour Party manifesto for the GLC elections in 1981 included the following commitment,

> Groups of workers such as the Lucas Aerospace Shop Stewards' Committee have, with the support of the Labour Party, began to develop ideas on alternative production – using technologies which interact with human skills; making goods which are conducive to human health and welfare; working in ways which conserve, rather than waste, resources. [...] We believe that these initiatives – which constitute a fundamental rejection of the values inherent in capitalist production – must be supported by a Labour GLC. We shall therefore be prepared to assist groups of workers seeking to develop alternative forms of production, with finance, with premises, or in other ways. (Labour Manifesto, Greater London elections, 1981, quoted in Mole and Elliott, 1987, p.81)

Once in office, council leaders created the Greater London Enterprise Board (GLEB) to implement proactive economic policies aimed at fighting unemployment and revitalising industry, including through worker and community initiative (Eastall, 1989).[1] The alternative plan was neither dedicated to community workshops nor socially useful production, but nevertheless provided an institutional space as well as political and economic resources for workshop activists. GLEB had an annual budget of £32 million. Given the Left political orientation of the council, GLEB's enterprise agreements and funds sought worker involvement and favoured co-operative forms of business development (Murray, 1985; Greater London Enterprise Board, 1984a).

Mike Cooley was hired as Technology Director for GLEB. Sacked by Lucas Aerospace, whose management rejected outright the worker's plan for their company, Mike's new position at GLEB provided a platform for him and the movement to continue to promote ideas and activity in socially useful production. Mike's team, drawn from the movement, created five Technology Networks with a GLEB budget of £4 million. Each provided facilities for prototyping socially useful products. Thames Technet was based in the South East of London, and the London Innovation Network (LIN) in the North East. The others were London Energy and Employment Network (LEEN), the London New Technology Network (LNTN), and Transnet (focusing on transport).

All workshops provided physical spaces, access to shared machine tools, and assistance from technical staff to local communities, workers, and co-operative enterprises. Attempts were made to recruit staff who, *'appreciate the tacit knowledge of local residents and workers'* (Greater London Enterprise Board, 1984b, p.12). Workshops were governed by representatives of local communities, trade unions, tenants groups, and academia (Cooley 1985).

1 Enterprise boards were also created by Labour authorities in the West Midlands, Sheffield, West Yorkshire, Lancashire and Merseyside. Each attempted to leverage private sector funding in addition to public funds, including (local authority) pension schemes. The GLC went furthest in its socially useful conditions attached to investments.

Participatory prototyping

Seeking to break down barriers between workshop staff and local communities, Network sites were sought away from "alienating" polytechnic campuses. The workshops provided walk-in venues open to anyone. Problem-focused training was linked to issues affecting the community. For example, training at LNTN explored how communities could use ICT networks to share information; augment their knowledge through expert systems; and, co-ordinate more effectively. A women's co-operative was established to address gender bias in the microelectronics sector. Training was provided for groups from developing countries as part of the GLC's Third World Information Network (whose procurement arm went on to pioneer Fair Trade systems). Sharing of knowledge and prototypes was encouraged through a "product bank,"

> Each centre contributes a product-bank of innovations patented by the networks for use by working people and for socially useful purposes. Machine-banks, consisting of second-hand machinery refurbished as part of a training programme, will be available for use by client enterprises (Greater London Enterprise Board, 1984b, p.12)

Profit-making enterprises paid royalties on non-exclusively licensed products. This contributed to Network running costs and cross-subsidised the socially useful mission. Other sources of revenue came from the public sector, through provision of useful products and services, and returns from the spin-off development of co-operative enterprises under the wider activities of GLEB. Successful prototypes were developed,

> As a result of all these activities, a product bank has now been built up containing some 1500 products at various stages of development, from the idea or concept to prototypes to ideas in production. The product bank is exciting, especially the way it has been developed. Special-interest groups concerned about energy conservation have been able to develop product ranges. The disabled have shown great creativity not only in thinking up alternative products for themselves, but in designing and, in many cases, making them. (Cooley 1987, p.146)

One example from the energy domain was user-friendly, electronic controllers designed to improve energy efficiency. The controllers were fitted to large refrigerators at the GLC headquarters. However, refrigerator manufacturers resisted ideas about wider commercialisation. The design reduced the need for lucrative after-sales servicing contracts. Marketing challenges like these could prove intractable. Some prototypes, including IT manufacture, and toys for schools, did go into successful local manufacture. Others, such as an electric bicycle, found developers and investors in other countries, including Germany and Italy. However, for many prototypes, even where a commercial market looked promising, the investment required to move into manufacturing was often beyond the means of GLEB, and financial institutions were either not interested or refused to locate production in London (Palmer, 1986; Rustin, 1986).

Commercial pressures

Recognising the difficulty of developing products so directly, the Product Bank idea was adapted along commercial lines. A Technology Exchange was created that matched prototype designs to firms seeking new products or processes. This technology transfer service opened up to commercial technology offers. Learning from the limitations of Lucas and GLEB Technology Networks, and involving people from both initiatives, the Technology Exchange provided catalogues and exhibitions to subscribers internationally. It won support from the European Community and UNIDO. According to Brian Padgett from the Exchange, the problem with the Lucas Plan and Networks was that many viable prototypes and designs were frustrated by dependency upon unsympathetic manufacturers and investors (interview, 2013-10-07). The Exchange opened things up to a wider network of potential developers, but also span off in a very commercial direction. It operated until 2002.

Technology Exchange was deemed a success amongst the business-oriented participants in the Technology Networks. GLEB provided office space to a UK appropriate technology programme under the auspices of ITDG. The latter actively promoted a business-oriented approach.[2] They brought in business leaders and expertise, such as John Davis from Shell, and linked to their interest in small enterprises (Davis & Bollard,1986; McRobie, 1981). In contrast to more radical aspirations, the business emphasis rested unsurprisingly in using workshop facilities to develop small enterprises (Palmer,1986).

Some enterprises clearly had socially useful orientations. Brass Tacks, for example, repaired and reconditioned furniture and domestic appliances for distribution to disadvantaged households. The Technology Networks helped Brass Tacks to design and manufacture replacement components on a bespoke basis. Brian Padgett recalled other Network activities,

> We introduced a waste paper recycling activity producing art papers and the low - cost injection mould-making business which later transferred to commercial premises. We also introduced a polymer stamp making system, using a UV hardening process, coupled to an affordable rotary label printer, a recycling system for sheet glass offcuts using a thermal sagging technique, etc. etc. All of these were very much in the area of Socially Useful Products but aimed at small start-ups with low capital cost. (personal correspondence, 2013-11-05)

Nevertheless, investment at scale remained difficult.

Technological agit prop and social mobilisation

A different, more radical framing sought to direct workshop activity towards addressing political and economic issues, including the difficulties under capitalism of redirecting investment for social use value (exchange value). In some cases, activism took the form of 'technological agit prop', in which prototyping technologies remained a focal activity, but were presented as a catalysing device for mobilisation around associated political, economic and social issues (Cooley, 1987). So, for example, projects involving new microelectronics would be encouraged to debate the threats of automation, and the skill-enhancing possibilities of more human-centred shaping of new technologies. Practical difficulties for investment in the latter provided

2 Intermediate Technology Development Group – initiated by Fritz Schumacher and inspired by his ideas. John Davis of Shell was involved in the UK programme.

a material critique of capitalist innovation (*cf*. Braverman, 1974; Noble, 1979) as well as demonstrating through practical example the possibilities for more socially useful alternatives.

Developing prototypes and enterprises in workshops was all well and good, but more radical activists considered commercial investment dependencies to result in participants working as bees for capital, rather than architects of their own economic activity. A more radical agenda sought in the workshops a mobilisation of popular activity for a fuller and deeper transformation towards socially useful production. Reflecting from their position in popular planning at the GLC, Maureen Mackintosh and Hilary Wainwright wrote,

> GLEB, for its part, put an increasing emphasis on commercial skills and product development, worried that money might be wasted, and the networks not survive, if products were not produced and marketed fast enough. They saw the products themselves as providing a sort of 'technological agitprop' capable of stimulating a further input by example. They argued that such practical demonstrations of the potential for socially useful job creation had to take priority over open-ended outreach work [...] Network staff, members, and users, however, take a more complex view than this. They acknowledge the importance of commercial skills, and having a plan of development of the networks. But they see on the whole a too early concentration on new products as counterproductive. What GLEB calls 'outreach', they see as the essence of networking, and the factor which can in the end generate real innovations. While recognising the tensions, they [network staff] see them as creative: the only way to democratise inputs to technological development. (Mackintosh & Wainwright, 1987, p.212-213)

Starting in 1983, LEEN was one of the first workshops to manifest prototyping-mobilisation issues. As various community, tenant, and energy organisations became involved in the network, bringing different experiences, so the focus of the workshop opened up. As Veronica Mole and Dave Elliott explained,

> It was found that the rationale for the establishment of the networks, the promotion of alternative products and the provision of access to workshop and technical facilities leading to socially-useful employment was not the main problem regarding energy related issues discovered by LEEN. In the field of energy at least at the local level the main factor is not the lack of socially-useful technologies; rather the technology exists, but what is required is the political, institutional and financial commitment to the redistribution of resources that would allow the implementation of these technologies. (Mole & Elliott, 1987, p.87)

Strategy shifted towards building a campaign, with local authority support, that would put pressure on central government to invest in existing energy conservation technologies addressing community needs (London Energy and Employment Network, 1986). Susie Parsons from LEEN explained how,

> Partly in light of these problems, many people involved in the technology networks quickly came to the conclusion that they had other useful roles besides product development. One of these was the use of existing technology to provide services to people, and helping people to understand and use existing technology more effectively. (Mackintosh & Wainwright, 1987, p.208-209).

Mobilising groups under a 'Right to Warmth' campaign, LEEN provided energy audit and advice services for people, which included developing convenient energy monitoring and modelling devices, and assembling packages of energy conserving technologies for installation in homes. The campaign drew attention to particular needs in apartment blocks, and organised community energy initiatives aimed at job creation through community energy co-operatives (Greater London Enterprise Board, 1984b).

The innovative activity here was more about new forms of political organisation than socially useful prototyping. The experience at LEEN illustrated, for example, how householders had tacit knowledge about the thermal performance of their homes. Monitoring expertise developed at LEEN codified into a technically valid form (acceptable to public authorities) something that householders already knew: their homes were damp, cold, and inadequately heated at great cost. Conversely, it required the knowledge and skills of tenants associations, community organisers, and the households themselves to mobilise a political campaign to win the public funds for the requisite technical remediation. All were mobilised through the process, but it is worth emphasising how the technical experts would not have been able to implement their techniques and devices without the power of the tenants' campaigns. The workshop provided a space through which a combination of practical reasoning, technical expertise, and political linkages could be mobilised.

Community workshops elsewhere were on a similar journey. Brian Lowe at UDAP in Coventry explained how,

> The original relatively simple aims of establishing technical feasibility of alternative products has widened to encompass a much broader activity. The Unit has now become absorbed into and became a distinct but constituent part of the popular planning movement. (Lowe, 1985, p.68)

This more radical purpose was at odds with more business-oriented interests in Technology Networks. Tensions emerged between those looking to the development of revenue through commercialisation of prototypes and services, a view associated with GLEB boards overseeing the networks, and the popular planners seeking to mobilise the networks for socialist transformation.

Innovation cultures

The challenges to realising a more politically oriented form of participatory design ran deep. 'Constructing an open door to planning and decision making procedures is not enough' (Linn, 1987, p.116). The networks, and the resources for design, prototyping, and production development needed to be culturally as well as physically accessible to Londoners. Materially speaking, that meant transcending the daily demands on peoples' energy and time by providing them with the resources to participate when they wanted, and on their terms. Culturally, it meant the gradual process of building more egalitarian relationships that crossed lines of expertise, class, race and gender. Staying physically open during evenings and weekends was helpful, but enabling specific groups to use workshops required arrangements thought through carefully with those groups (such as, say, some women, particularly where religious or ethnic backgrounds restricted free association with men).

Workshop practices, attitudes and expectations needed open reflection to overcome unintended exclusions. GLEB appointed Boards overseeing the networks were accused of having, '[...] employed high numbers of technically experienced trade-union men whose language, bureaucratic ways of working and emphasis on the product rather then the community process act to exclude even technically qualified women.' (Linn, 1987, p.121). The practicalities of bringing diverse communities together with engineers, machinists, and designers proved considerable. As Mary Moore put it, 'You will not find this group coming together naturally after a CND3 demonstration or a football match, for a quick drink or an exchange of ideas.' (quoted in Mackintosh & Wainwright, 1987, p.214). Democratising decisions involves the negotiation and resolution of conflicts, between different groups of workers, between producers and consumers, between professionalised expertise and grassroots knowledge, and across other divisions including class, gender and race (Blackburn *et al.* 1982).

Some Networks did attend to the cultures of innovation and developed more inclusive and horizontal practices (Clark, 1983). However, the Networks alone could not resolve deep-seated divisions in society. Pam Linn at ThamesNet described vividly, for example, the intimidating power relations in play when an unemployed grassroots innovator met the executives of a large manufacturer suspected of pirating his design for safety lighting (Linn, 1987). That said, participating in workshops could be and was transformative for many people.

The decline of Technology Networks

Methodologies developed and fine-tuned in the workshops provided early experience in practices of participatory design and community development that went on to be useful in other areas. But the opportunity to progress further in Technology Networks was short-lived. Hostile to radical local authorities, the Conservative central government abolished the GLC in 1986. The Thatcher government curtailed local government powers and budgets over economic planning more generally. In the polytechnics too, reductions in funding and a harsher environment eroded academic-activist alliances. Anti-trade union legislation and the decline of unionised manufacturing sectors also weakened alternative possibilities.

Some community workshop initiatives struggled on with reduced support, but those that did had increasingly to adapt to a commercial logic, such as the Technology Exchange, and training activities that aligned service provision to the needs of private enterprise and capital (Eastall, 1989). Socially useful ideals for demystifying new technology (with a view to empowered democratic participation) were dropped. The provision of skilled operatives for firms could be inserted more readily into the spirit of enterprise that Thatcherism was trying to cultivate.

GLEB's Networks proved to be the high water mark for the movement for socially useful production. The experience of the workshops and movements was ultimately one of being overwhelmed and appropriated by more powerful political and economic forces (culminating in our present neo-liberal hegemony). The more challenging attempts at social shaping were closed down, such as direct democratic control of the technology development process, while other elements were co-opted and reconfigured by capital, such as ideas, methodology, and artefacts for flexible specialisation and user-centred design in manufacturing (Asaro, 2000). Activists tired, or moved on.

Nevertheless, the movement had pointed to the social processes that shape technology, and insisted through the workshops that people have a right to participate in those shaping processes. What was practiced was a critique of naturalising views amongst political and economic elites about the apparent autonomy and neutrality of technological change. In so doing, activists anticipated ideas and analysis that was to consolidate into science and technology studies and participatory design over the coming years.

DISCUSSION

Technology Networks explored the possibilities and limitations for communities to exercise direct agency in technology development. Technology Networks enabled citizens to engage in extra-discursive ways, and offered spaces where material projects were connected to reflections on wider social, economic and political relations. Workshop aspirations for socially useful production may have proven to be more elusive than the capabilities actually cultivated, but they were nevertheless aspirations that nurtured workshop spaces in an otherwise hostile political economy, and provided an early site for debating relations between technology and society, as well as more grounded design and innovation practices

Difficulty prizing open technology institutions means ostensibly socially progressive practices can become co-opted by more narrowly sectional interests. This was the experience in Technology Networks, and has subsequently been noted for participatory design more generally. Reflecting on his own involvement, Rasmussen recalled how developments over time, '[...] focused on the micro-level only. The societal perspective of the Lucas Workers' Plan or the attempts made by Greater London Council in the 1970s and 1980s get lost.' (Rasmussen, 2007, p.491). Asaro's (2000) history of participatory design makes a similar observation (*cf.* Sanders and Stapper, 2008, p.7). As originally conceived, the development of work groups, use of mock-ups, and other design practices aimed for the democratisation of the workplace, and wanted to furnish working-class communities with the capabilities to influence technology development (Ehn, 1988; Brödner, 2007). Projects like that of the Geezers illustrate just how rich a set of methodologies have developed for revealing everyday democracy in technology, but they often remain situated in constraining institutional settings.

3 Campaign for Nuclear Disarmament.

Considered in an historical light, then the kinds of democratising cultural changes sought by some in workshops today, are seen as having to connect also to institutional transformation and, ultimately, political economy. The eventual transformative effect of workshop practices rests in the degree to which they can disperse their practices into society through social movements, and push them out in to state administration and (socialized) markets. Grassroots fabrication needs to link to social movement, just as the Lucas shop stewards and Collective Resource Approach attempted when linking to workers movements. And any cultural shift needs to translate into political and economic reinforcement.

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THE CUNNING OF INSTRUMENTAL REASON: REPRODUCING WEALTH WITHOUT MONEY, ONE 3D PRINTER AT A TIME

JOHAN SÖDERBERG

ABSTRACT: The paper investigates the relation between two approaches for transforming the world, one wedded to the development of technology and industrial revolutions, the other stressing popular mobilisation and articulation of conflict. This discussion takes foothold in a case study of a low-cost, open source 3D printer called "Rep-rap". The aim of the Rep-rap project, as explained by its founder in a programmatic paper titled "Darwinian Maxism", is to spread a self-reproducing 3D printer to the masses. It is hoped that this will undermine the market in 3D printers as well as markets in every other kind of goods that could be printed on such a machine. In short, Darwinian Marxism is a roadmap for transcending existing market society. The ideas of the hobbyists in the Rep-rap project is compared with a longer history of utopian thinking among engineers, beginning with the French revolution and leading up to the cyber-political imaginary of the 1960s counterculture.

INTRODUCTION

In 1866, a librarian in Lyon offered the following explanation to the birth of socialism,

> Socialism was introduced into silk-weaving workshops with the mechanics of the Jacquard loom; it profoundly modified the habits, interests and material and moral circumstances of weavers. (Monfalcon, 1866, p.365, my translation)

The librarian made the remark with the strongest disapproval. He was writing a chronicle over Lyon's history and was now describing the violent uprisings by artisan weavers that had shaken the town thirty years earlier. As he saw it, the Jacquard loom had raised the living standard of workers, thereby encouraging them to ask for ever more compensation and to become recalcitrant. What interests me with the quote above is not the claim that the Jacquard loom improved the standard of living of the weavers, nor that their radicalism owed to an excess of affluence as opposed to a deprivation of it. Both of those claims are questionable, to say the least (*cf*. Strumingher & Bolo, 1978). Of greater concern for my argument in this paper, is that the quote connects the introduction of a new technology with the birth of a political, even revolutionary, idea: that of socialism. Still more intriguing, the technology in question is the famous Jacquard loom. A a series of technical improvements that had been made over the course of the previous fifty years in the Lyon weaving district had culminated in this machine, nowadays hailed as the world's first computer. The mechanics of the loom were guided by punched cards. A century and a half later, punched cards were still used to control machinery tools in heavy industry (Noble, 1986). It is the same principle of controlling the movements of a tool head with the help of pre-written instructions, i.e. software code, that lies at the heart of 3D printing. As for socialism, Adrian Bowyer launched the open source 3D printer project Rep-rap with a programmatic paper, where he stated the following,

> So the RepRap project will allow the revolutionary ownership, by the proletariat, of the means of production. But it will do so without all that messy and dangerous revolution stuff, and even without all that messy and dangerous industrial stuff. (Bowyer, 2004)

The revolutonary bravado in the quote above aligns with a long tradition of utopic engineering thinking, where the market is expected to soon be rendered obsolete by the progressive application of human reason to nature. This promise comes in at least two versions. One tendency, epitomised by the 'red cyberneticians' in Soviet Union, primarily objects to the irrationality of the price mechanism, and wants to substitute the market with computers for the task of allocating resources (Dyer-Witheford, 2013). The second tendency, to which Rep-rap project arguably belongs, looks forward to the day when wealth is so abundent that scarcity will have been superseded, and markets with that. But the quote above testifies to something more, also prevalent in engineering thinking throughout the ages. Namely, a malaise towards conflicts of values and interests that might errupt in violence. To avoid this scenario, emancipation must be derived from the manipulation of natural laws that evolve independently of human consciosness and deliberations. This corresponds with a vision where market society, or whatever part thereof held

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to be undesirable, stands to be surpassed through a (second, third...) industrial revolution. The opposite understanding of revolution locates human freedom in a radical break with the past and with the chain of causality that rules in nature. The word "revolution" can alternatively be read out as "politics". What is at stake, then, is two different understandings of how to think and do politics. The first approach prescribes technological development as a means for promoting social change, the second puts faith in popular mobilisation and the articulation of conflict. My intent is *not* to contrast the two ideas of revolution/politics in order to find one of them (*i.e.* the engineering one) in fault. Instead the paper discusses their common historical roots and inter-dependencies. There was a time when the politics of the engineer and the politics of the social reformer/militant were not clearly separated and set against one another. As I will come back to in the paper, the parting of ways had something to do with the rebellious weavers in Lyon, the first computerised workers in the world. If I choose to put stress on commonalities instead of divergences, it is partly because the two ways of thinking and doing revolution/politics seem to be about to converge again. Geeks and engineers are forced to engage in parliamentary politics in response to intellectual property laws and related enforcement regimes. Social movement activists, in return, are compelled to become acquinted with natural science and engineering in order to make sense of the social conflicts that are the order of the day (Kirkpatrick, 2004; Dunbar-Hester, 2012).

My discussion takes foothold in a case study of the Rep-rap project conducted over a 2-year period. It draws on interviews with 11 people designated as "core" developers in the Rep-rap project, representing about half of the core teme in those days. In addition, the CEO:s of four of the first start-up companies (B-f-B, Makerbot, Ultimaker, TechZone) have been interviewed together with some other key participants and promoters of the project. A secondary source of information has been the texts published on discussion forums and blogs dedicated to the development project. Elsewhere I have investigated the hands-on practices and designs of the hobby-engineers (Söderberg, 2013b). I will leave this important question to the side here. Another concern which I have dealt with previously and which I will only mention in passing is the legal considerations of distributed 3D printing (Söderberg & Daoud, 2011). In this paper, my focus is on the ideas and vindications animating the Rep-rap project. In the first part of the paper, I will describe the ideas behind the Rep-rap project. In the second half, I will compare those ideas with a longer history of utopian and political engineering thought. Towards the end of the paper I tease out some observations about the possibilities of thinking revolution/politics in an age of unbounded, instrumental reason.

A PROGRAM OF DARWINIAN MARXISM

Among the machinery tools that furnish personal/desktop manufacturing, the low-cost 3D printer is the crown jewel. It was the Rep-rap project that set off a booming, low-end market in 3D printers. The principle behind the Rep-rap 3D printer is that a material (usually plastic) is melted and put down in layers to build a three-dimensional object. This offers a highly versatile manufacturing process without, in contrast to many other fabrication methods, involving toxic chemicals, emitting dangerous fumes, or requiring high-voltage electricity. In short, 3D printing is ideal for hobbyists working at home (Ratto & Ree, 2012). This technical consideration is intertwined with the political claims and visions behind the project. The political claims attached to the Rep-rap project are part of a larger, utopic imaginary among a 'geek public' (Kelty, 2008). What makes the Rep-rap project stand out, besides the technology itself, is that these ideas have been elaborated upon in a programmatic text.

The vision of the initiator, Adrian Bowyer, shared by at least some of his closest collaborators, is to disrupt established patterns of industrial production, global distribution networks, and mass consumption. In its place they envision a new regime of decentralised, peer-to-peer manufacturing (Bauwens, 2005). This transformation is framed within a biological and evolutionary imaginary. Everything hinges on the capability of the 3D printer to print (most of) its own parts. With such capacity, the growth curve of the machine park of 3D printers becomes self-reinforcing. That is to say, existing 3D printers can be used to build new 3D printers. The wider implication thereof was sketched out by Adrian Bowyer in a text subtitled 'Darwinian Marxism'. The pivotal idea in the paper is that once the 3D printer is capable of making its own parts, the machine will start to mimic a key feature of living beings: self-reproduction. The name "Rep-rap" is an abbreviation of self-REPlicating RAPid prototyper. Tribute to biological science is paid in the names given to the official versions of the Rep-rap 3D printer: the first generation of 3D printers was called Darwin, the second Mendel, then Huxley.

The claims made on behalf of the Rep-rap project have been enthusiastically received by segments of the geek public, although, unsurprisingly, others have reacted with staunt scepticism. The sceptics have usually taken aim at some technical hurdle. For instance, only half of the parts for the 3D printer can be printed, leaving out the most complicated parts, such as microelectronics and motors. And even if the day comes when every single part can be printed, a human being will have to assemble the parts. Hence, a frequently recurring objection to the Rep-rap project has been that its claims about building a self-reproducing machine is hyperbolic (Perens, 2008). Bowyer had already anticipated this objection in his paper. He riposted with the idea of "symbiosis". The machine can be said to reproduce itself if we allow for a more distributed view on reproduction. The 3D printer reproduces itself in symbiosis with the user. The human being is willing to assist in the reproduction of the machine because she is rewarded with consumer goods. This is analogous to the way the wasp assists in the reproduction of orchids in exchange for nectar. Now it might sound as if Bowyer had rendered meaningless his initial claim about a machine capable of reproducing itself. But a more interesting critique of 'Darwinian Marxism' can be developed than putting in question its technical feasability.

Bowyer's idea of symbiosis has a bearing on another kind of objection, which, no doubt, spring to mind to historians or social scientists from the moment he or she hear about a 'self-reproducing 3D printer'. To such a reader, the claim will sound uncannily similar to an old engineering fantasy: that of the fully automated factory (Turner, 2008). That potential objection too must be qualified when the notion of symbiosis is called upon. The human being has been enrolled in the reproduction process of the machine, albeit, one crucial aspect is being left out. Namely, her existence as a conscious, thinking being. The strenght of the wasp-orchide synergi consists in that it draws exclusively on her instincts. The historian or social scientist may therefore insist upon the historical continuity with the automatic factory, where the human has been degraded to an appendage of the machine. This critique is not without merit, but it fails to grasp the whole picture, because concious decision making re-enters at a different level of the equation. The point with having a self-reproducing 3D-printer is that the critical parts for the machine can be made on a second machine, which is to say, on the machine of a second hobbyist (Olliver, 2010-05-04). What is at stake, in other words, is the 'functional autonomy' of the collective of hobbyists. I borrow the term *functional autonomy* from the labour historian David Montgomery and I use it in exactly the same way he did. He documented worker struggles in nineteenth century factories and where the worker collective often had *de facto* control over the production process. They had a functional autonomy *vis-à-vis* the factory owner thanks to their superior familiarity with tools and practices. Montgomery showed how the reorganisation of existing work practices and production processes, in large part through the introduction of new technology, had contributed to undermine the functional autonomy of workers (Montgomery, 1976). Its logical end-point, of course, was the fully automated factory.

In the case of the Rep-rap community, the risk of losing functional autonomy is as acutely felt as it was in nineteenth century workplaces. But the significance given to technology and automation has been diametrically reversed. Furthermore, the threat does not come from an employer, narrowly speaking, but from start-up firms and venture capital. A quick example can serve to illustrate my claim. When the second-oldest start-up firm, Makerbot Industries, was created by a former core team developer, Zach Hoeken, the new company inherited the stock of electronic boards which had been entrusted upon him as director of the non-profit Rep-rap Foundation. Makerbot Industries thus became an obligatory passage point for hobbyists wanting to build a Rep-rap 3D printer. At the time, Makerbot Industries was enmeshed in the Rep-rap community and had a high level of credibility in the open hardware community. Nevertheless, the hobbyists had misgivings about being dependent on the good-will of a single firm. It spurred a vast number of secondary development projects of alternative electronic boards, out of which a few were tailored for the needs of production at home. In theory, at least, the possibility of homebrewing the electronics ensured that no single firm would be in control over this critical component. In practice, the option of making electronics at home was limited to a handful of very resourceful hobbyists (Markus Hitter, 2011-09-11). The lack of technical skill among average users is an overriding constraint in the design of the machine, and the weakest link in the user-machine or wasp-orchid symbiosis, which supposedly will propel the horizontal distribution network. It is in this light that one should see the long-term goal of the Rep-rap project, to automate away the skills required of users of 3D printers (Söderberg, 2013b). The long-term goal is to go from electronics boards that can be etched in an acid bath at home, to a machine capable of printing conductive materials and with that its own electronics. Objections about the technical feasibility of such a scenario can be left aside for now. The point I want to make is that automation in the Rep-rap community has taken on the opposite signification compared to what it had to the workers in the nineteenth century factory. Automation is pursued by the hobbyists with the aim of preserving the functional autonomy of the community *vis-à-vis* firms and venture capital.

The first commercial machines took the design of Rep-rap 3D printer wholesale, including the open, modular mechanical construction and the use of standard rolls of filament. As was known from before, by the example of the market in ordinary printers, long-term profitability would not come from selling machines, but from selling ink/plastic. The first step taken by firms to enclose the plastic source was through conditions introduced in the warranty. Customers were thus obliged to buy their filament from official vendors or have their warranty suspended. To be fully effective, however, a lock-in of plastic sales had to be hard-wired into the architecture of the machine. This required a non-modular machanical design fixing the critical component, the extruder head, through which the filament is fed (Higgs, 2011-11-03). What proprietary source code is to free software developers, plastic filament delivered in cartridges is to the 3D printing hobbyists. In much the same way as having access to source code is the life-blood of the free software community, the Rep-rap community relies on access to filament, because the sharing of plastic parts hinges on that the raw material is cheap. Losing that and the community will be degraded to an appendage of a cartridge. Anticipating this danger well in advance, one core developer expressed confidence that the community would be able to work around any technical constraint,

> When people try to make money, more specifically when they try to put something in the way so that you have to go through them to do something interesting, the project generally tends to fall apart. But that does not happen with Rep-rap because it is specifically designed to reproduce itself. So you could not really put yourself in the way and demand money. (Olliver, 2010-05-04)

The quote illustrates that the engineering goals, to foster modularity in the design and reproduction of critical parts, are integral to the agenda of the Rep-rap project, as well as showing an awareness of the constraints under which this political program must be put in place. The adherents knew that their ideals had to be realised through the market, or not at all (Sells, 2010-05-07). When the first two entrepreneurs arrived and made inquiries about selling a modified version of the Darwin printer, they were strongly encouraged to do so (Adkins & Major, 2009-11-26). This pragmatic attitude towards involving for-profit ventures coalesces with broader trends in social movement activism, post-1989. The Rep-rap project differs, however, in that it has adopted pragmatism while maintaining a long-term vision about transcending the market economy. Paradoxically, the undoing of markets and firms will come about through a co-existence with the same. This argument about the possibility of working through-and-against the market is constructed on top of the idea of evolution. In this case, evolution is applied to the self-propagation and 'natural selection' of 3D printers. The presupposition for these evolutionary laws to work is that user-individuals are lured by their consumer impulses into a symbiosis with the self-reproducing machine. The inspirational source behind this assumption is easy enough to identify, neo-classical economic theory. But the choices of the user-individual will not aggregate spontaneously to make up a new market. Quite to the contrary, when every home has been furnished with an ubiquous manufacturing process unit (*i.e.* a 3D printer), then most market exchanges will have been rendered superfluous. The centrality of this idea for the hobbyists is suggested by the by-line of the Rep-rap project: wealth-without-money. Some more clues are given by Ed Sells, formerly a PhD candidate working in Adrian Bowyer's laboratory, second person to have joined the Rep-rap project, and mastermind of the Mendel generation of the 3D printer. Pondering over the scenario that HP or some other multinational company will try to outmanouver the Rep-rap project, he develops the following counter-scenario,

> I think that Adrian has hit on a mechanism which is so unbelievable powerful. When you got something making itself, it is scary from the point of view of HP [⋯] Self-reproduction wins over anything else, over any linear production. Rep-rap exposes the fact that if you got a 3D-printer, it can make itself. So HP will go: "well, we are not going to make any money here". And the fact that Adrian has made it open source from day one means that there is nothing to stop people designing around someone [*i.e.* HP] coming in. I dont think you can stop Rep-rap except if you get on safe distance and nukes it. (Sells, 2010-05-07)

The quote testifies to the confidence and idealism that flourished in the Rer-rap community in the early days. In hindsight, of course, with the market in low-end 3D printers being more or less divided up between two multinationals, Stratasys and 3D Systems, the forecast is unconvincing. But the reasoning behind it is worth expounding upon a bit further, because, despite recent set-backs, it is the only logically stringent road-plan to abolish money that we have on offer at the moment. Ed Sells alludes to two factors believed to give the Rep-rap community an edge over commercial vendors. The first is the possibility to design around any chokepoint imposed by a firm. The case with the Makerbot Industries and the home-built electronics examplifies this claim. The second is the speed by which the 3D printer will spread and develop. This point needs to be elaborated a bit further. While components for a Rep-rap machine can be printed on either another Rep-rap machine or a commercial 3D printer, this does not work the other way around. The firms have no interest in designing their 3D printers in such a way that the product could alternatively be made on a Rep-rap machine. To underline this point, the commercial 3D printers are called "Rep-straps" by the hobby-engineers. Rep-strap is the name given to machines which can be used to build (or "bootstrap") Rep-rap machines, but cannot make copies of themselves. This asymmetry is believed to give the Rep-rap 3D printer an advantage over commercial derivatives. As the market for commercial Rep-straps grows, the population of Rep-rap printers (and with that, the Rep-rap community) grows with it. Potentially, at least, the community will grow faster than the market, since the Rep-rap project benefits from the above mentioned one-directionality in the diffusion of 3D printers (Bowyer, 2009-11-24).

In the paper on Darwinian Marxism, a thought experiment is proposed where the output of a self-printing 3D printer is compared with an injection molding machine. The latter technique is an industrial standard for mass production of consumer goods. In the long run, and provided that the question of exhaustible resources is bracketed, self-replication will numerically overtake mass production. This will happen by the same force as exponential growth outdoes linear growth. A quick reality check demonstrates that out of the estimated 80,000 desktop 3D printers that were sold in 2013 globally (Stratasys, 2013), the overwhealming majority being of the Rep-strap sort. Indeed, even when acknowledging the exceptional growth of the Rep-rap community over the years, the growth curve did not take off until some centralisation in the design and in the distribution of key components had been introduced (Higgs, 2011-11-03). These caveats aside, what must be given to Bowyer is that now there exists a theoretical answer to the question that has shipwreck innumerable socialist and anarchist dreams: How can an alternative economy be coordinated where the goods are delivered as efficiently as in the current, centralised and industrialised market economy? Furthermore, if the brute, numerical advantage acclaimed for decentralisation fails to convince the reader, another line of argument points to the superior dynamics of an open innovation process. This idea originates in open source-guru Eric Raymond's iconic catch-phrase: 'add more eyeballs and all bugs are shallow'. In other words, innovation will accelerate faster the more people get involved in the process of discovery. This ensures that the greatest diversity of perspectives is at hand, thereby increasing the chances of finding a novel solution to an old problem. Starting with this observation, Raymond inferred that an open and decentralised development process will win out over a closed and/or centralised development process (Raymond, 1998). The hobby-engineers in the Rep-rap project have integrated this idea within the narrative about evolutionary biology. Diversity is a prerequisite for natural selection, and natural selection ensures that the best technical option will prevail over faulty designs. When the design is closed behind intellectual property claims, diversity is stifled and the engineering project runs into an evolutionary dead-end (Prusa, 2011-09-19).

Not everyone in the Rep-rap project, perhaps not even the majority, subscribes to the ideas about evolutionary laws sketched out above, though the most influential and active developers do. Likewise, not everyone cares about the stated goal of contributing to large-scale, economic and social change. Just as with other hobby-engineering projects, the joy of tinkering with technology might be the most enticing reason for people to be involved (Kleif & Faulkner, 2003). Other motives are the possibility of getting a 3D printer at a cut-rate price, and, increasingly, the growing business opportunities within a booming consumer market for 3D printers. However, the possibility of harboring such diverging viewpoints under one and the same roof is part of what makes the call for diversity so appealing. Diversity is not just seen as a principle leading to superior technical sollutions. It embodies the ethical and political values which constitute the raison d'être of the Rep-rap project. The value of diversity is set against the current mode of centralised mass production. Furthermore, on a day-to-day basis, appeals to diversity are part and parcel of project management. Conflicts between members of the core team over design choices and long-term strategies are commonplace. Under the sign of diversity, developers are encouraged to wander off to design-and-let-design. The assumption is that natural selection will sort out the wrong from the right (Prusa, 2011-09-19; Sells, 2010-05-07). In fact, the vindication of "diversity" does roughly the same work for the hobbyists as the notion of "pluralism" did for the 1990s alter-globalisation movement or post-2008 protesters. Both words signify the antidote of party lines, ossified ideologies, and secterianism.

Just as with pluralism and tolerance, however, the value of "diversity" has an Other. Paraphrasing Herbert Marcuse's memorable expression, this Other can be named "repressive diversity" (Marcuse, 1969). Almost from the start, objections were raised on the Rep-rap discussion forum about the second name in the phrase 'Darwinian Marxism'. The concern was that newcomers would feel excluded by it (General Forum, 2007-08-27). The by-line of the project 'wealth-without-money' and a quote from *Guardian* stating that Rep-rap would 'bring down global capitalism', both initially fronted on the website, were later removed. All the while, tensions are growing in the Rep-rap community in proportion to the growth of a consumer market in 3D printers. The pattern is known from other social movements that have tried to gain a leverage in society by making alliances with for-profit ventures. Success is often bought at the price of having the original goals diverted (Hess, 2005). A turning point came in autumn 2012 when Makerbot Industries announced that it no longer allowed the community to access the design of its latest products. Indignation ran wild on the Internet, and some called for Adrian Bowyer to intervene. In part defending himself against the accusation that he was too lax in enforcing the open license policy, Bowyen responded as follows,

> When it comes to the success or failure of RepRap, moral beliefs, legal constraints and the flow of money are almost completely irrelevant. It is the evolutionary game theory that matters. (Bowyer, 2012-09-21, Makerbot blog)

The actions and intents of the hobby-engineers are irrelevant to the unfolding of an impersonal, cumulative causation, abiding only to the laws of evolution, which nevertheless, paradoxically, is moving towards the social transformation acclaimed by the hobbyists. To an unsympathatic reader, this probably sounds like a convenient way for the engineers to excuse any opportunistic venture they might choose to embark on, such as Bowyer's shares in Makerbot Industries, publicly declared in the same message. A former member of the core team recalls that Bowyer informed the other team members about his investment at the same time as they learned that the firm had been started by another core developer, Zach Hoeken. What cohesive policy to adopt towards firms not playing by the rules was left hanging in the air after that (Higgs, 2011-11-03). In the absence of community enforcement of the license, a norm of free-for-all, *enrichez-vous* has taken its place. As much is suggested from the negative reactions provoked by stray attempts on the discussion forum to name-and-shame a firm sensed to be out-of-line with the license requirements. The person in question can expect to be reprimanded in turn for his lack of appreciation for diversity. That this has a downside, even when judged by the criterias of 'evolutionary game theory', is suggested by a comment from another core developer. Interviewed in *Reprap Magazine*, he was asked if commercialisation held back any aspect of development,

> Yes, I think the majority of people wanting a 3D printer want something cheap, easy to build and operate with good print quality and care little about it being self replicating, so naturally there aren't many people working in that direction. (Palmer, cited in: Hodgson, 2013, p.29-30)

The aggregation of spontaneous choices does not, by nature as it were, point to a self-reproducing machine. Someone must first rig the game, and keep it rigged, for the right kind of evolution to unfold, starting with the choice of licensing regime. On this, Antonio Gramsci's observation on mechanical determinism, a fellow traveller of the worker movement, seems applicable. He warned that it lead to 'passive and idiotic self-sufficiency' in a movement, especially among the rank-and-file towards the party leadership, but he also admitted that it gave fortitude in times of setbacks (Gramsci, 1999, p.646). It is the last remark by Gramsci, I believe, that explains the strong approval of Bowyer's response among devotees. His text was copied and favourably cited on numerous other forums. The underlying message is that not only the actions of the hobby-engineers are made irrelevant by evolutionary game-theory, but so are counter-actions by vested interests. Given that the playing field is heavily tilted in favour of the latter, as exemplified by law and money in the quote above, the appeal to an extra-social, higher instance becomes very attractive (Söderberg, 2013a). It follows that grand-scale social change can be had without a direct confrontation with the powers-that-be, which is to say, without a messy and dangerous revolution. In fact, the hobby-engineers have stumbled over a recipe for social change that has waxed and waned in leftist thinking over the last 200 years. Namely, the idea that the System can be changed through a withdrawal from the same. A first wave of withdrawal was attempted already by the followers of Fourier, Cabet and Saint-Simon in the aftermath of the miscarried French revolution (Corcoran, 1986). In *Eighteenth brumaire of Louis Bonaparte*, Karl Marx succinctly described those experiments as attempts to seek salvation 'behind society's back' (1937, p.9). Marx considered this proposition to be an absurdity. In his view, it was society, or, to be more precise, social relations, that acted behind the backs of individuals. Darwinian Marxism is a program for rigging the laws of evolution in order to smuggle social change behind the backs of society and individuals alike. It seeks to transcend capitalism through the 'cunning of instrumental reason'.

HISTORICAL OVERVIEW OF ENGINEERING IDEOLOGY

The ideas outlined above are fairly consistent with the orthodox Marxism associated with the Second International. It laid down that human emancipation would march hand in hand with the gradual advancement of science and technology. Increases in social wealth flowing from ever-more powerful forces of production provided an assurance in the last instance that capitalism would eventually be transcended. What is the dream of having a 3D printer, capable of printing almost everything including a copy of itself, if not a manifestation of the forces of production at its apex? The extent to which this vision conforms with Karl Marx's thinking is an object of intense, philological debate. According to one position, the scientism characteristic of Second International Marxism originated in

Friedrich Engels' own texts and/or in his editing of Marx's manuscripts post-mortem (Levine, 1973, *but cf.* Gouldner, 1980). Intriguingly, Engels too turned to nature in search for laws (of dialectics) which would strengthen his case that capitalism was a transient phase in human history. Perhaps then 'Darwinian Engelism' would have been a more appropriate heading for the political program of the Rep-rap project (Engels, 1987).

That said, faith in the emancipatory potential of science and technology was not a trait specific to late nineteenth and early twentieth century Marxism. Those ideas were a common heritage of the Enlightenment, and its firstborn children were the engineers. Another idea vindicated in this milieu was the elevation of nature as a metaphor for thinking the possibility of social change. In the eighteenth century, as the epistemological framework of the Enlightenment developed, French engineers begun to discern dynamic forces in nature. The dynamism was taken as a model for their concept of technical efficiency. This interpretation was charged with political undertones, because nature thus understood was contrasted with the blockages and inefficiencies of the feudal order (Jakobsen, *et al.* 1998; Picon, 2009). Henri de Saint-Simon excelled in this line of thinking. Initially an enthusiastic supporter of the French revolution, he became dismayed by the bloodshed that it had unleashed. He greeted the embryonic industrialisation of France as a force that could complete the task that the political revolution had left unfinished, that is to say, to eradicate *ancien régime*. Against the feudal order he marshalled the productive members of society, what he called the "industrialists". Under this label he grouped bankers, patrons, artisans, craftsmen and workers, without registering the emerging lines of conflict between these different groups (Saint-Simon, 2012; Musso, 2010).

This ambiguity was inherited by Saint-Simons' followers, where one wing courtised bankers and factory owners, while the other wing sympathised with the growing mass of pauperised workers. Indeed, the word "socialism" is commonly attributed to Pierre Leroux, a prominent member in the latter tendency. In-fighting and the eventual suppression of the socialist wing of the Saint-Simonians coincided with the first uprising of the weavers in Lyon in 1831 (Musso, 1999, p.111). The Saint-Simonians had hurried to Lyon to profess their utopian ideas to the workers. As a consequence, they were singled out by state authorities as troublemakers responsible for the uprising (Rude, 2007; Musso, 2010). The historian Pierre Musso has suggested that the state repression that followed encouraged the remaining Saint-Simonians to change their rhetoric and style of thinking. The role of struggle in the social transformation that they professed was played down. Social change would instead come about through the development of communication networks, chiefly railways and channels. This proposition resonated with the strong presence of engineers educated at École Polytechnique (Musso, 1999). From now on, the articulation of conflict was opposed to cooperation for the common good. Decision-making should be entrusted to those who were most knowledgeable and impartial, by which was meant – the engineers (Savigear, 1971).

The split of the Saint-Simonians, catalysed by the uprising of Lyon textile workers and ensuing state repression, could be assigned as the historical moment when the two approaches to revolution/politics parted ways. One path stressing political mobilisation and articulation of conflict as a means of changing the world, the other path playing down overt conflicts while smuggling in social change through the manipulating of the laws of nature, including the nature of fellow human beings. In 'geek publics', the same tension often crystallizes in a "hacktivist" and a "techie" camp. It is exemplified in the stand-off between Free Software Movement and Open Source Initiative (Berry, 2004), in the split between hacklabs and hackerspaces (Maxigas, 2014), and, indeed, in the various fractions found in the Rep-rap project. What is crucial to note here is that this tension does not simply play out between two well-defined and opposing camps. The same polarity is reproduced within the discourses and strategies of respective camp. After all, the techie who affirms bare, incontestable facts over loose opinions and values is, while doing so, making an appeal to a certain kind of value (Gillespie, 2006). Reversely, when the moment comes to translate the political assertions of the hacktivist into a substantial change in the world, the question of efficiency must be addressed.

The inclination among engineers to anchor their ethical and political claims in nature was given a new impetus with the breakthrough of evolutionary biology in the second half of the nineteenth century. In countries where the *ancien régime* lingered on, for instance in Germany, the publication of *On the origin of species* was greeted by the bourgeoisie as an ally in their struggle against the aristocracy. Later on, when the central conflict lines had shifted, and the bourgeoisie confronted an ascending working class, the meanings invested in "nature" changed as well. Natural selection was now called upon to prove that market competition was a mere reflection of the eternal order of nature (Pannekoek, 1912). The name to mention here, of course, is Herbert Spencer. His writings on social Darwinism became immensely popular. Spencer's influence on his contemporaries should be stressed, because today his name evokes little but hostility or disinterest. Perhaps it is no accident that Spencer was an engineer by training (Sharlin, 1976). Edwin Layton goes as far as to argue that social Darwinism was the founding ideology when the engineering profession constituted itself in late nineteenth century. Although the ideas of the engineers were never developed into a single, coherent doctrine, certain ideas recurred over and over. Key was the assumption that nature and society are governed by laws which are accessible to human knowledge. Those laws were held to be immutable and incontestable. But this was not understood by the engineers as a limitation on their freedom to act. On the contrary, it was through the manipulation of nature's laws that the engineers could exercise influence over society. Layton underlines that the popularity of these ideas surged at a time when the subordination of the engineering profession under corporate bureaucratic hierarchy was being consolidated in America. Having the feeling of being under threat, social Darwinism was called upon to assure the professional values and identity of the engineers (Layton, 1986, p.55).

Layton goes on to argue that the same ideology was extended and codified with Taylorism half a century later. The scientific doctrine of Frederick Taylor was passed off as a means for improving effectivity in industry. It was at the same time a program for solving ethical questions in a context of intense class conflicts. Taylor and his followers believed that they had discovered immutable laws about management which had the same force as nature's laws. They imagined the engineer to be an impartial judge and interpreter of those laws. The engineer was thus lifted above the messy world of politics. In particular, he was imagined to stand above the conflict between workers and managers. It was the anti-political outlook of the engineer which made him suited as an arbiter in politics. This worldview provided the germ of what would a few decades later develop into the notion of an end to class conflicts and ideological strife (Maier, 1970).

The name of Frederick Taylor evokes images of satanic mills and factory despotism. Just as with the deterministic laws of nature, things looked differently from the vantagepoint of the engineers. Coupled with Taylor's promise of increasing industrial production was a bid for enlarging the autonomy of the engineering profession. This would come at the expense of blue-collar workers, needless to say, but it would also restrict the autocratic, outdated and unscientific rule of managers (Zussman, 1985, p.6; Layton, 1986, p.139). Scientific management demonstrated the shortcomings of the manager,

> [...] who merely cracks his whip over the heads of his workmen and attempts to drive them into harder work for low pay. (Taylor, 1911, p.58).

Of course, there is no arguing against the fact that Taylor's chief contribution consisted in having dismantled the functional autonomy of worker collectves on the shop-floor. In his writings, however, there was enough of ambiguity to allow some of his closest disciples to put an anti-corporate spin on scientific management. This points us to a split in the conception of rationality that runs from Saint-Simon to the Rep-rap hobbyists today. Rationality defined on technical grounds and oriented towards the production of social goods, the engineering position, comes up against pecuniary rationality defended by economists, managers and owners. The most systematic elaboration of this cleavage is found in the essays that make up Thorstein Veblen's *The engineers and the price system*. Although himself not an engineer, Veblen was inspired by ideas that he had encountered among engineers, and he influenced some of them in return (Stabile, 1986; Knoedler & Mayhew, 1999). Intriguingly, he too drew on Darwin and laws of evolution as rhetoric resources, and he pitched it against economics and the economic science of the day. Free markets had become obsolete in modern society and was now holding back progress, he charged. In an industrial society, the engineers were the ones best qualified to take informed decisions about the future of mankind. Writing shortly after the revolution in Russia, he famously called for a 'Soviet of technicians' in America (Murphree, 1959; Veblen, 2001, p.83). Veblen had a decisive influence on the Technocracy movement that surged in the wake of the Great Depression. They professed the imminent downfall of the price system and advocated emergency preparations to accomodate a more rational society based on the principles of science (Adair, 1967). Traces of the Technocracy movement remains in the hobby-engineering communities till this day (*cf*. Wallace, 2007).

Truth to be told, Veblen's agitation failed to enflame the larger collective of engineers. This can probably be put down to that their occupational standing were closely tied up with that of the industry and the business community. In their practices, the engineers had become attuned to efficiency as the purpose of their professional endeavors. Efficiency and functionality were facts of life against which there could be no quarrel. Thus they were at the mercy of a received definition of efficiency. After all, the supreme test of the soundness of an engineering solution was the market (Zussman, 1985, p.121). The internalisation of the rationales of the business community begun already with the first day of training to become an engineer. Behind this outcome stood deliberate efforts to put the engineering schools, first established in the nineteenth century in America, under the influence of local business communities. For the historian David Noble, the education of engineers was the crux in ensuring the reproduction of engineering subjectivity. The potentially disruptive practices of the engineers could thus be channelled towards entrenching existing relations of domination and exploitation (Noble, 1977).

From time to time, the engineering professions made attempts to assert their autonomy against the influence excersiced upon them by business community. It can be seen in periodic struggles for control over the engineering associations in the US in the nineteenth and early twentieth century, or in the creation of an initiation ritual for Canadian engineers at the same time, scripted by no lesser writer than Rudyard Kipling. Ultimately, however, the independence of the profession was undermined by the revolving doors between engineering jobs and the upper echelons of management. Edwin Layton concludes his study of engineering ideology with the observation that it was not free market forces that angered the engineers the most. What they were truly wexed about was bureaucracy in their workplaces. Once more, one can trace a lineage going all the way back to Saint-Simon and his opposition to state bureaucracy, which he associated with the vested interests of *ancien régime*. He rallied against the improductive members of society, by which he meant the nobility, the clergy and the military, who were exempted by state buraucracy from contributing to the overall advancement of mankind (Saint Simon, 2012).

ENGINEERING IDEOLOGY MEETS CYBER-POLITICS IN THE REP-RAP PROJECT

The Rep-rap project has grown out of, and, subsequently, recruits many of its followers from, mechanical engineering departments. Concurrently, the values and methodologies behind the development project relies heavily on software engineering. In the Rep-rap project, the emergent field of computer programming is reconnected to more a classical engineerging tradition. I will limit my discussion about the history of software engineering to highlight a few continuities which are reflected in the Rep-rap community, especially as regards the anti-bureaucratic thrust. The influence of the 1960s counter-culture on the then nascent computer profession has been explored in many earlier works and need not to be recited again (Markoff, 2005; Flichy, 2007). A couple media scholars have stressed how this strain of utopianism espoused free marketeering in a joint opposition to hierarchies and bureaucracy. Alan Liu disapprovingly calls this phenomenon *cyberpolitics*. He argues that the detournement of cyberpolitics into a form of high-tech libertarianism was inscribed from its inception. The main achievement of scientific management was not the subjugation of blue-collar workers under factory despotism, he writes. It was the creation of a new strata of white-collar workers with a persona perfectly modelled after the dogmas of scientific management. This product of Taylorism merged with its radical Other, countercultural 'bad attitude'. Thus was created the strange amalgam which is cyberpolitics (Liu, 2004).

While finding Liu's argument compelling, I ask myself if cyberpolitics is more culpable than any other of the detournements of the Left coming out of 1968. For instance, Nancy Fraser has made similar observations in relation to second wave feminism. The ideas espoused by the feminists of this generation were from the outset susceptible to being recuperated by an ascending neoliberal world order (Fraser, 2009). Be that as it may, the centrality of communication networks in late capitalism is indisputable and bestows a heightened importance to the cyber-political imagination. The software engineer has become the harbinger of the dreams of 1968 in an inverted, nightmarish form. Accordingly, opposition to bureaucracy translates into an attack on those institutions which guarantees stable employment conditions. The anti-authoritarian penchant of the counter-culture is gratified when the challenge is directed against allegedly undemocratic experts and liberal professions. Foreshadowed in Saint-Simons' tirade against the state, cyber-politics take aim against the employment security that shelters professionals from being exposed to the "democratic" test of market demand (Turner, 2006; Barbrook, 2007).

Removing the demand for the labour of others was always part of the job description of an engineer. In the haydays of the mechanical/industrial engineer, however, this task was undertaken with a word of regret or apology. Perhaps it was said that new jobs would be created elsewhere in the economy or that overall wealth would grow thanks to labour-saving machinery (Bix, 2000). Not so with the cyber-political avant-guarde where the attack on employment security is carried out with a messianic zeal. The filesharing debate is a case in point. Although the music corporations are the the designated target of politicised filesharing activists, there are consequences for professional musicians too. The busking artist is often heralded as a proof of the fact that money can be made on musik without contracts and legal protections. What impact filesharing has had on the market for music, and, subsequently, musicians, is a lengthy topic that I cannot enter into here (Oberholzer-Gee & Strumpf, 2007; Anderson, 2011). What I want to suggest is that the employment situation for musicians is indicative of where the job market is heading for many other professions. A case in point is industrial designers, who have already begun to discuss among themselves what will remain of their profession once a consumer market for 3D printers takes off (Atkinson, 2010). To the enthusiasts of 3D-printing, the same outcome is anticipated as a democratisation of design, a field soon to be emancipated from "experts" (Nipe, 2009-12-23). When I asked Adrian Bowyer if the realisation of the goals of the Rep-rap project would not result in a massive, downward pressure on salaries, he concurred. That must not be such a terrible thing, he added, since the people affected would not have to buy so many things when they have a 3D printer in their home (Bowyer, 2009-11-24).

Adrian Bowyer's answer must be anathema to anyone with a trade unionist perspective. Not the least when taking into consideration that the predecessor of 3D printing technology, that is, numerically control machinery tools, was introduced in heavy industry with the stated purpose of weakening the metal worker union (Noble, 1986; Scranton, 2009). More charitably interpreted, Bowyer's answer testifies to that the Rep-rap project has set the target higher than a mere redistribution of wealth corresponding to a 'trade union consciousness'. Nothing less will do than the abolishment of commodified labour, a future of wealth-without-wages. Of course, everything hinges on that atoms too, and not just labour, are set free (free as gratis). It must be granted to the hobby-engineers that they have not exempted themselves from the forces which they are partly responsible for unleashing. Indeed, their collective existence as a community of *hobbyists* is presupposed by an ongoing crisis of the engineering profession. As a former dean at MIT, the historian Rosalind Williams is well situated for reflecting over this crisis. From the ever-more evanescent engineering curriculum taught at MIT, she sees a faundering of the identity of the profession as a whole. She offers several explanations for this, but stresses a particularly important one: the disappearance of the institutional settings within which life-long engineering careers used to unfold. Granted, precarious labour demand is a condition that the students at MIT share with many other young workers. The engineering students distinguish themselves in having so fully internalised the contemporary imperatives of work life. William is concerned that the entrepreneurial outlook adopted by her students errods the public commitments which were part and parcel of the old identity of the engineering profession (Williams, 2003).

The crisis of the identity of engineers is reminiscent of the prognoses made in the 1960s and 1970s about a proletarisation of the 'middle levels'. It was then predicted that the engineers would follow in the footsteps of craft workers. As the rank of engineers swell, their jobs would be routinised, their salaries and status would fall, and the level of unemployment would climb. In this bleak prognosis laid a glimmer of hope that the engineers would then be pushed to side with blue-collar workers (Holbrook-Jones, 1982; Zussman, 1985; Braverman, 1999). If I hesitate to affirm the proletarisation-thesis, despite some indications in support for it, it is because the engineers are likely to be doing a lot better than most other precarious entrepreneur-workers. In the same brushstroke as labour markets are undercut by technological change, the demand for technical expertise is renewed. It is noteworthy, though, that there are now trained engineers in excess of what the industry can absorb, out of which a trinkle spend their surplus time and energy on community-centred projects, for instance, to develop an open source 3D-printer. A minority among them do so in pursuit of idealistic and utopic goals. To the latter, their outside-position *vis-à-vis* corporate bureaucracy is what has enabled them to develop a technology at odds with institutional logics and constraints. This position strongly resonates with the ideas in 1970s Alternative Technology movement (Smith, 2005). While Rosalind Williams' terminal diagnosis for the professional identity of engineers sounds plausible, the conclusions she draw from it needs to be qualified. Even when the engineering identity was bracketted up by life-long institutions, the profession vacilliated between, on the one hand, representing itself as a defender of public interest and/

or human reason, and, on the other hand, internalising the particular interests of the business elite and the prospects of raising to this rank. The labour historians mentioned above attributed this ambiguity to the undecidedness of the class position of the engineer. Like the blue-collar worker, the engineer is subjugated to the dicipline of industrial organization, like the manager, he/she exercises discretion and authority over others. The ambigous position of the engineer is further exacerbated by entrepreneurialism. The anticipation of one day being bought-out by venture capital transforms the most radical and sincerely felt enunciation to market hype *ex ante*.

In the paragraphs above, I have argued that the intellectual and political heritage of mechanical/industrial engineering and the more recent influx of ideas from software engineering and cyber-politics have come together in the Rep-rap project. Those ideas can be mobilised against the irrationality of the price mechanism, or they can be flown as a banner of free marketeering. This ambiguity is exacerbated with the foundering of the institutional brackets of the engineering profession. Engineering ideology was formulated at a time when the profession was asserting itself against both workers and managers. Nowadays, the *avant-guarde* position among engineers is found at the frontline of deprofessionalisation. Nothing illustrates this better than the figure of the hacker, from which the Rep-rap project borrows extensively. By definition, the hacker is an outsider *vis-à-vis* institutions and professions. The hacker, having 'set free' software development from the constraints of corporate hierarchies, is himself set free from contractual employment. What the hacker has done to himself and to software development, the hobby-engineers strive to do for everyone else, *i.e.* to everyone working with design and manufacturing of physical goods.

CONCLUSION

The article started out by noticing that there are two related but partly opposed ideas about revolution, and, by extension, politics. One idea prescribes social change through the development of new technology, whereby clashes between opposing interests can be shortcircuiting. The other idea stresses popular mobilisation and articulation of conflict, possibly culminating in a violent uprising. Truth to be told, the track record is not particularly promising for any of them. As for the technology-induced revolution, David Noble identified the key question to be asked more than 30 years ago: How can it be that everything seems to change all the time while nothing essential moves? He looked for an answer in the engineering schools that reproduced a certain engineering subjectivity. Assuming that Noble was right, what is one to make of the current deprofessionalisation of engineering practices, testified in the existence of an ever-expanding community of *hobby* engineers? The same observation holds for education. The hacker personifies a learning process that has escaped established engineering curriculums and corresponding educational institutions. As the Mentor put it in his famous manifesto from 1986, the hacker rejects the pre-chewed chunks of knowledge spoon-fed to him by teachers.

The Rep-rap project sets out to provide one piece of the puzzle in a larger infrastructure for peer-to-peer manufacturing. With such an infrastructure in place, engineers can by-pass fixed capital. It is a roadmap for an "exodus" of engineering practices from wage labour relations and (which is the same thing) commodity production. The role assigned to self-reproduction in this larger scheme of things, although framed in an imaginary of evolutionary laws and technical determinism, testifies to the very opposite, the importance of design choices. The kind of 3D-printer that can reproduce itself (in symbiosis with human beings) has been designed to ensure the functional autonomy of the community *vis-à-vis* firms and venture capital. The opposite scenario unfolds if the community relies on a Rep-Strap, that is to say, on a 3D printer where critical parts can only be made with large capital investments. From that moment onwards, the need arises for a return on investment, which prompts rationalisation, giving rise to hierarchy, employees, and so on. Optimistically, it could be said that the open source Rep-rap 3D-printer, when combined with other tools in a larger peer-to-peer infrastructure, meets the criteria laid down by Herbert Marcuse, as to what would constitute a new technology,

> The technological transformation is at the same time political transformation, but the political change would turn into qualitative social change only to the degree to which it would alter the direction of technical progress – that is, develop a new technology. (Marcuse, 1964, p.227).

The Rep-rap project, for all its pragmatism, was started with the goal of transcending capitalism. In contrast, when social movements have endorsed pragmatism and micropolitics, they have typically come to terms with the present as an unsurpassable horizon for their politics. Students at engineering departments, insulated from post-modernist self-doubt, never stopped dreaming about a radically better tomorrow. This heritage from *lumières* might prove important, because, from environmental science to computer hacking, a growing influence of engineering cultures and geek publics on traditional social movements can be detected. Activists issued from social movements and professional social scientists have something to offer to geek public in return. Social theory is required to articulate conflicts unfolding behind the back of individuals. State and corporate bureaucracies are clearly visible targets for hackers and hobby-engineers. Those institutions which seemingly arise spontaneously out of the aggregation of individual choices, that is to say, markets, are not always so. At times, engineers have denounced the price system as contrary to a rational and scientific organisation of society. At other times, price is just a fact of nature, from which evolutionary laws can be deducted, and the efficiency of a technical solution measured. When the latter standpoint wins the day, the market disappears from view, and all the fervour is directed against bureaucracies, state regulation and, with that, employment security. The risk is then overbearing that the dream about wealth-without-money will be realised in its nightmarish form, as work-without-wages.

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Batist Leman, 2009-11-12. Promoter of Rep-rap in Flanders. Initiator of a hackerspace in Ghent, Belgium.

Bre Pettis, 2011-09-20. One of three founders of Makerbot Industries, the second oldest company selling Rep-rap derivatives. New York, USA

Chris Palmer, aka Nophead, 2010-03-17. Made key contributions to the extruder head, among other things. Holds the record in selling Rep-rap printed parts. Manchester, England.

Ed Sells, 2010-05-07. Former PhD student of Adrian Boweyr at Bath. Principal architect of the Mendel Rep-rap design, Auckland, New Zeeland.

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Rhy Jones, 2009-11-26. PhD student of Adrian Bowyer at Bath. Developes multiple materials for printing. Bath, UK.

Vik Olliver, 2010-05-04. Built the first proof-of-concept of Rep-rap, among many other things. Auckland, New Zeeland.

INTERNET RESOURCES

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AUTHORITY IN PEER PRODUCTION: THE EMERGENCE OF GOVERNANCE IN THE FreeBSD PROJECT

GEORGE DAFERMOS

Abstract: This paper examines the articulation of authority in peer production projects, focusing on the transformation of the FreeBSD Project's governance structure over fifteen years of development. Catalysed by the growing criticism of the distribution of authority in the project, the adoption of the elective principle for the selection of the FreeBSD administrative team brought about a shift in the conception of leadership from the informal rule of a self-selected group of veteran developers to the democratic authority of an elected group that is revocable and bound to formal rules. Since, FreeBSD has evolved a collectivist governance system, based on a direct-democratic, consensus-oriented process of decision making. Furthermore, in keeping with the normative standard of individual autonomy of action, FreeBSD did not attempt to manage increased scale by supervising developers' work process but rather tried to achieve coordination through the standardisation of the induction process for new developers and of outputs through frequent building. This outcome discredits the notion that supervisory hierarchy is the inevitable consequence of expanding size, showing that the response of an organisation to structural changes depends on the moral values espoused by its members.

INTRODUCTION

Research interest in computer software produced and distributed freely over the Internet by voluntary associations of hackers known as free and open source software (FOSS) projects has been constantly increasing during the last ten years. Breaking with many established assumptions about how software should be developed, FOSS projects have captivated the attention of organisation theorists: because of the volunteer character of participation in FOSS projects, their administrators, 'must resort to other governance mechanisms than those available to firms that pay developers to work' (von Krogh & von Hippel 2006, p.979) and so in this environment authority, 'is persuasive, not legal or technical, and certainly not determinative' (Benkler 2006, p.105). Yet this does not mean that no authority exists: for, 'no social system can operate on a continuous basis without support from some mode of authority' (Harrison 1960, p.233). In view of the fact that FOSS projects have no coercive apparatus through which to mobilise development resources and impose compliance with their rules and norms, how is authority articulated on their development?

LITERATURE REVIEW

Early studies of hacker culture stressed hackers' disdain for bureaucratic organisations and their opposition to centralised authority, pointing out that their activities encapsulate a definite morality – known as the *hacker ethic* – which exalts the joy and autonomy inherent in intrinsically-motivated activities as well as the free sharing of knowledge that lays at the heart of the hacker community (Levy 1984). Interestingly, in spite of the passage of time, the character of hacker morality has not changed, as more recent studies (e.g. Hinanen 2001; Weber 2004) have shown.

The academic discourse that has emerged more recently centred on the organisational characteristics of FOSS projects. Benkler (2006) coined the term *commons-based peer production* to underline, on the one hand, the centrality of a common property regime in enabling FOSS projects and, on the other, the informal and collegial character of participation in them. According to Weber (2004, p.159–164), their governance consists in a combination of leadership practices and cultural norms which define who has the legitimate right to redistribute modified versions of the software and make decisions about which contributions are to be included in public distributions. This type of governance – which Demil and Lecocq (2006) call 'bazaar governance' – represents an institutional framework for work organisation that differs fundamentally from how coordination is effected in hierarchies, markets and networks, largely on account of the low level of social control in this environment (Demil & Lecocq, 2006, p.1453). Markus (2007) pointed out that the aim of governance in FOSS projects is (a) to incentivise participation and (b) to facilitate task coordination in the development process. de Laat (2007) called attention to the evolutionary character of FOSS governance. While work coordination in small projects is achieved informally through the 'mutual adjustment' of participants, larger projects, due to the coordination costs at-

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tendant upon the expansion of scale, require more elaborate means of coordination. Thus, in contrast to the spontaneous organisation characteristic of small projects, large projects cannot do without some measure of systematisation of rules and work procedures.

In the space of the last ten years, a significant number of works have explored the governance of large FOSS projects. Shah's (2006) study showed that, as, 'heavy-handed control deters participation' (p.1008), the governance structure affects decisively the number of developers that are attracted to a project. The developers of the project, which she investigated, remarked that, 'they choose their own tasks and set their own schedules', underlining the role of freedom and creativity in spurring them to participate (p.1007). According to Mateos-Garcia and Steinmueller's (2008, p.336) study of Debian, the source of authority in FOSS projects is, 'knowledge of purpose and technique acquired and demonstrated through participation'. Prolific developers are rewarded with reputation for their sustained contribution, thereby permitting them to, 'exercise authority over the project, and if not its participants, then at least their contributions' (Mateos-Garcia & Steinmueller, 2008, p.336; see also de Laat, 2007, p.167). O'Mahony and Ferraro's (2007) study of Debian looked at the transformation of its governance system catalysed by conflicts between the project leader and the community of maintainers over what was perceived as a lack of legitimacy of his authority. The resulting "reform" combined, 'elements of democratic and bureaucratic control' (p.1099) to prevent autocratic rule and nourish a conception of leadership based on consensus-building. In addition to establishing checks upon the leader's authority, Debian devised a new recruitment process to ensure that new recruits possess not only the right skills but also views that are consistent with the socio-political goals of the project (also see Mateos-Garcia & Steinmueller, 2008, p.339). On the same wavelength, O'Neil (2009, chapters 7 and 9) introduced the term *tribal bureaucracy* to denote, on the one hand, Debian's, 'rejection of market economy [...] in favour of cooperative production' and, on the other, its resolve to demarcate the authority of the project leader through a limited form of bureaucracy.

RESEARCH METHODOLOGY

The FOSS studies by Mateos-Garcia and Steinmueller (2008), O'Mahony and Ferraro (2007) and Shah (2006) demonstrate clearly the penetrating insights that a longitudinal study permits by covering a time-span in which the project has grown considerably so that the the relationship between scale and mode of governance can be examined in a rigorous manner. Dealing with longitudinal data, of course, implies a case study research design, a research strategy commonly used to understand dynamics within single settings (Eisenhardt, 1989, p.534). Thus, our inquiry adopts a case study research design centred on the FreeBSD Project, which was chosen because (a) its scale has increased dramatically over time and (b) the informal and non-hierarchical character of its development process has been underlined in prior works (*e.g.* Holck & Jørgensen, 2003/2004; 2004). The sources of secondary data on which we draw include prior organisation studies of FreeBSD, past surveys of FreeBSD developers published in the literature, and documents (related to the development of FreeBSD) released by the project or published by its developers. Our primary data sources consist of activity logs collected from FreeBSD's publicly-accessible software repository (which we analysed to assess the number of active developers over time) and observations of project-related activities as manifest on mailing lists used by FreeBSD developers.

In this environment, as noted, authority cannot be coercive, for persons in authority are deprived of the means by which to impose themselves upon the other project members. To be able to exercise any influence over the management of the project, their authority must be perceived as being *legitimate*. The question how authority is legitimised in FOSS projects is therefore crucial. For the purpose of analysing the type of authority that emerges in collaborative enterprises manned by volunteers, we draw upon Max Weber's (1947) classical analytical framework: although about a hundred years have elapsed since its original publication, the emphasis it lays upon the bases of legitimisation of authority as the central organisational feature and its capacity to analyse informal and volunteer organisations makes it ideally suited to the task at hand. Such an approach also facilitates the comparison of our findings with those of other researchers, as it figures prominently in the literature: studies looking at how authority is articulated in FOSS projects often use the same analytical framework – the same concepts and categories – that Weber pioneered for the study of authority in groups (*e.g.* Himanen, 2001; O'Mahony & Ferraro, 2007, O'Neil, 2009).

EMPIRICAL SETTING

FreeBSD is a free/open source[1] operating system descended from the Berkeley Software Distribution (BSD), the version of Unix developed at the University of California at Berkeley. The first version of FreeBSD was released in December 1993. Since, FreeBSD has been established as the most popular BSD-descendant with a proven track record in mission-critical deployments,[2] thriving on the contributions of a community of software developers spread the world over. Though development effort is heavily concentrated in North America and Europe (Spinellis, 2006), FreeBSD development takes place in thirty-four countries on six continents (Watson, 2006).

The organisational structure of FreeBSD is inherited from BSD, often credited for codifying a template for what is now known as the open source development model (Leonard, 2000). This structure has a *core team* at its centre: a small group of programmers who control access to the codebase, vested with authority to grant or revoke the right to integrate changes into the project's code repository. Spreading out from them are the *committers*, who have the right to check in changes, framed by the wider community of *outside contributors*. Outside contributors advance to the ranks of committers when their nomination by an existing committer is approved by the core team, which alone has authority to grant commit privileges.

Committers focus on either of the three main areas of development at FreeBSD: *src* (kernel and userland), *ports* or *documentation*. Indicatively, a breakdown of the 275 committers who made commits in 2002 reveals the following specialisation: 201 src committers, 144 ports committers and 41 docu-

1 FreeBSD is distributed under the terms of the FreeBSD license.

2 See: http://www.bsdstats.org and BSD Certification Group (2005).

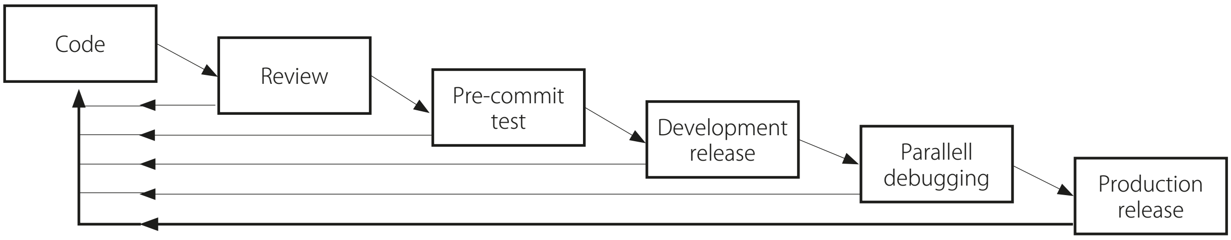


Fig. 1: Change integration process (Source: Jørgensen 2001)

mentation committers (Saers, 2005; see also Watson, 2006).[3] Their age varies between 17 and 58 years, with a mean age of 32 and median age of 30; the standard deviation is 7.2 years (Watson, 2006).

Although FreeBSD is a volunteer organisation and committers receive no remuneration for their contributions, many of them are professionals working in the IT industry. Therefore, it is not surprising that, for some of them, working on FreeBSD is part of their professional work. In a survey of seventy-two FreeBSD committers (constituting thirty-five percent of all committers) conducted in 2000, twenty-one percent said that work on their latest contribution had been fully paid for, and another twenty-two percent partially paid for (Jørgensen 2005, p. 233). Warner Losh, sitting member of the core team, is one of them. In his opinion, getting paid to work on FreeBSD is not uncommon. As he says, 'my current employer, for example, allows me a certain amount of time each month to work on FreeBSD bugs that impact our ability to deploy a system. These get fed back into the base FreeBSD from time to time. Many other people are in a similar situation' (Losh interviewed in Loli-Queru, 2003). For other FreeBSD committers, however, the importance of economic incentives should not be over-emphasised, for, as former core team member Greg Lehey says, 'a lot of people are motivated more than by money to work on FreeBSD. It is their hobby or passion. They find an itch to scratch using FreeBSD and FreeBSD benefits' (Lehey interviewed in Loli-Queru, 2003).

Like other large FOSS projects, FreeBSD has a parallel development structure. There are two simultaneous development processes underway, crystallised in two different branches of the software. The *stable* branch represents the official released version, aimed at a stable and bug-free product. The *current* branch,[4] on the other hand, is experimental: it is where most cutting-edge developments and significant changes (e.g. new features) are first tried out. Fig. 1 illustrates the development model based on the process by which changes are integrated in the project repository.

Prior to committing their changes to the code repository, committers are expected to ask for community review (FreeBSD 2011d). This practice usually generates a relatively modest amount of feedback,[5] based on which they either have to revisit their code or proceed to testing it on their own systems (by doing a trial build).[6] Next, they commit the changes to the current branch, from which a development release is built and made available for download every few hours. This release is tested and debugged concurrently by many more users and developers who download the software, resulting therefore in significant improvement. Once sufficiently tested and deemed mature enough, the code is merged by the committer in the stable branch, from which a production release is made about every four months. The process, despite its incremental character, is recursive: each stage might require of the committer to return to his code for further changes, thereby re-initiating the process. Naturally, as developers work mostly individually,[7] the model is used concurrently by multiple developers (Holck & Jørgensen, 2004; Saers, 2005; see also Jørgensen, 2001; Stokely, 2011; Watson, 2006).

THE EMERGENCE OF GOVERNANCE

Informal governance phase (1993–2000)

FreeBSD evolved for the first seven years without any formal means of representing its contributors in project governance.[8] During this *informal governance phase*, following the tradition established by BSD, 'those who hacked most became part of the "core group" or "core team"' (Lehey, 2002). In 1993 the core team had thirteen members: the tree founders of the project – Jordan Hubbard, Nate Williams and Rod Grimes – and the most active then-committers. Hubbard served also as the project's president until 1997, which position was, 'originally created [...] to give ISVs and other corporate contacts a more official-sounding person to talk to'. In 1997 he resigned from the position which he also abolished, claiming that it had created, 'the illusion of a "super core member" [...] [and] false expectations of authority' (Hubbard, 1997). Growth was continuous throughout this period. Three concurrent phenomena – the growth of peripheral contributors without commit rights, the increase of (*src*) committers from 16 to 138 persons and the growth of the codebase – attest to the dramatic expansion of scale underway.

3 The subsequent analysis focuses on *src* committers alone. This choice was made on the grounds that the other two areas of work on FreeBSD (*ports* and *documentation*) pertain less to new code development and more to peripheral, though necessary, activities.

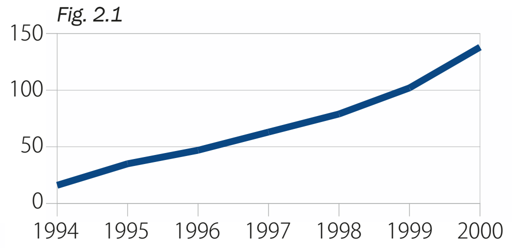
4 FreeBSD-Current is also known as HEAD or trunk.

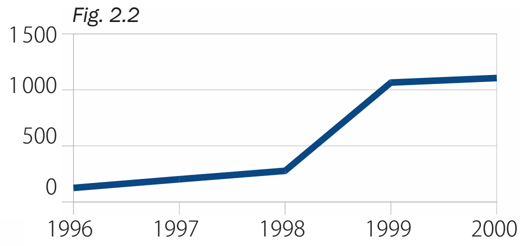
5 In a survey of seventy-two FreeBSD committers (constituting thirty-five percent of all committers) conducted in 2000, eighty-six percent said they received feedback from two or more reviewers (Jørgensen, 2001).

6 Doing a build is an automated process by which (human-readable) source code is compiled to an executable program. If the compilation fails, then the build is said to be broken.

7 In a survey of seventy-two FreeBSD committers (constituting thirty-five percent of all committers) conducted in 2000, '65% said that their last task had been worked on largely by themselves only, with teams consisting of 2 and 3 committers each representing 14%' (Jørgensen, 2001).

8 We employ the term *governance* to refer to, *'the use of institutions, structures of authority and even collaboration to allocate resources and coordinate or control activity'* (Bell, 2002) in the project. Our employment is akin to that used in international relations, as, *'in that context, "governance" is not government, it is typically not authoritative, and in fact it is not about governing in a traditional sense as much as it is about setting parameters for voluntary relationships among autonomous parties'* (Weber, 2004, p.172).





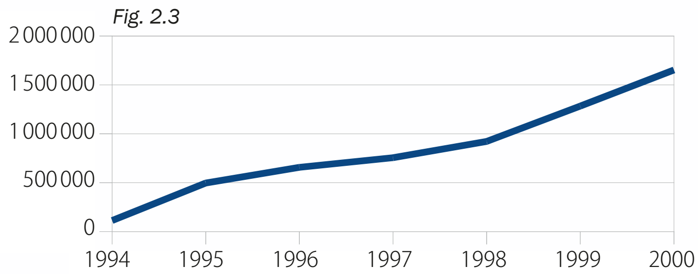


Fig. 2.1: FreeBSD (src) committers, 1994–2000

Fig. 2.2: FreeBSD contributors, 1996–2000

Fig. 2.3: FreeBSD codebase evolution (Lines of Code, cumulative), 1994–2000

This period was however accompanied by a criticism of project governance. Many committers felt that the composition of the core team no longer reflected merit and that its members were prone to abusing their power. In 2000 dissent could no longer be channelled into a manageable form of mediation with the core team. When a prominent committer entered into a confrontation with a core team member, accusing him of trampling on his changes, the situation spiralled out of control, threatening to tear the project apart. In the discussion that ensued on the project mailing lists, Hubbard outlined a number of possible reforms, including the dismantling of the core team, and called for a vote. The proposal was well received by the base of committers, who elected by vote to adopt an elected core team model, based on bylaws[9] that were drafted to regulate elections (FreeBSD, 2000; Lehey, 2002).

Approved by a vote of active[10] committers (passed by 117 yes votes to 5 no votes [Lehey, 2002]) on 28 August 2000, these bylaws established criteria of eligibility (all active committers), the size of the core team (nine members), the periodicity of elections (fixed at every two years) and the conditions under which: (a) early elections are held (on the petition of 1/3 of active committers or if size of core falls below 7), (b) a core team member or committer can be expelled from the project (by a 2/3 vote of core) and (c) these bylaws can be modified (FreeBSD 2002). The first core team formed in that way consisted of five former core members (Satoshi Asami, David Greenman, Jordan Hubbard, Doug Rabson, Peter Wemm) plus four new ones (Greg Lehey, Warner Losh, Mike Smith, Robert Watson).

The institutional evolution of FreeBSD is reflected in a series of documents which the project released with a view to imparting structure to what was until then largely an informal development process. The first version of the *Committer's Guide* (FreeBSD, 1999), which laid down guidelines for regulating committers' conduct, was published in 1999 amidst a climate of rising discontent with project governance. The first version of the *FreeBSD Developers' Handbook* followed in August 2000 – a month before the first core team election – with information geared to new committers about circumnavigating FreeBSD's development model.

In sum, conflicts over the distribution of authority and concerns of a perceived illegitimacy in its exercise by the core team led to the adoption of an elected core team model in 2000. This institutional restructuring along with the bylaws drafted to regulate elections created a democratic basis of legitimacy for the authority of the core team. Closely related with this reform was the attempt to more elaborately define the scope of development activities, crystallised in the release of the first version of the Committer's Guide in 1999 which elucidated the process through which changes are integrated in the repository and outlined committers' behavioural code.

DEMOCRATIC GOVERNANCE PHASE (2000–TO DATE)

The first core team election by vote in September 2000 ushered in the next phase in the institutional evolution of the project, that of *democratic governance*. In 2002 elections were held again as the core team was left with six members following the resignations of Satoshi Asami, Jordan Hubbard and Mike Smith.[11] The new core team had five new members (John Baldwin, Jun Kuriyama, Mark Murray, Wes Peters, Murray Stokely) and four from the previous one (Greg Lehey, Warner Losh, Robert Watson, Peter Wemm). Of its nine mem-

9 The *core bylaws* do not make up what is normally understood by the term *constitution*: they specify the mode of elections and the duration of the incumbency, but unlike a constitution they make no reference to the principles on which the core team shall be established, the manner in which it shall be organised or the powers it shall have, save for establishing the right of committers to recall the core team by triggering an early election. Some of those questions are dealt with in other documents released by the project. For example, *The FreeBSD Committers' Big List of Rules* clarifies that the authority of the core team is restricted to the task of managing commit privileges: 'In all other aspects of project operation, core is a subset of committers and is bound by the same rules. Just because someone is in core this does not mean that they have special dispensation to step outside any of the lines painted here; core's 'special powers' only kick in when it acts as a group, not on an individual basis. As individuals, the core team members are all committers first and core second' (FreeBSD, 2011d). On the whole, questions related to the distribution of authority in the project were – and still are – the epicentre of *conflict*: for instance, the reason why decisions are made by consensus does not lie in some formal rule forbidding the core team from making decisions autocratically, but in the vigorous resistance of committers against core team decisions they regard as conflicting with their own will (Lehey, 2002).

10 *Active* are considered committers who have made at least one commit in the last twelve months.

11 See Lehey (2002) for the reasons cited by Hubbard and Smith.

bers, only one – Peter Wemm – was part of the original core team. Elections have been held four more times since. The last one in 2010 resulted in the following core team: John Baldwin, Konstantin Belousov, Warner Losh, Pav Lucistnik, Colin Percival, Wilko Bulte, Brooks Davis, Hiroki Sato and Robert Watson. The transition from a self-selected group of veteran committers to an elected one reinforced the already extant tendency toward the systematisation of rules and development procedures.

Indicative of the ongoing formalisation of rules and procedures is that increasingly more of them are being written down as shown by the continuous updates of the FreeBSD Handbook, the Committer's Guide and the Developers' Handbook. More interesting, for the purposes of our analysis, is that this process is closely connected with the exigencies of conflict management. No example illustrates this better than the conflict in February 2002 which erupted over changes made by a committer to the SMP[12] code without the permission of John Baldwin, SMP's most active then-developer. The core team intervened immediately asking him to remove his changes from the repository under the threat of revoking his commit privileges. He complied and asked the core team to resolve the issue. The core team, after a month of discussion and consultation with committers on project mailing lists, decided to delegate authority to Baldwin to approve or reject changes to the SMP module as he saw fit, and then used the experience to formulate rules for suspending commit rights, thereby creating a standard discipline procedure with set offences and penalties,[13]

1. Committing during code freezes results in a suspension of commit bits for two days.
2. Committing to the security branch without approval results in a suspension of commit privileges for 2 days.
3. Commit wars will result in both parties having their commit bits suspended for 5 days.
4. Impolite or inappropriate behaviour results in suspension of commit bits for 5 days.
5. Any single member of core or appropriate other teams can implement the suspension without the need for a formal vote.
6. Core reserves the right to impose harsher penalties for repeat offenders, including longer suspension terms and the permanent removal of commit privileges. These penalties are subject to a 2/3 majority vote in core.
7. In each case, the suspension will be published on the developers mailing list.

However, in order for the decisions of the core team to be received as legitimate, they must be consistent with the consensus of the opinions of the committers. Characteristically, in June 2002 the core team received another complaint about the same committer. He had again committed changes to an area of the codebase without the approval of the committer who was responsible for it. The core team decided to suspend his commit privileges for five days in accordance with the above disciplinary rules. But 'public reaction was unfavourable': the decision was censured for being politically-motivated, as core elections were underway and the suspended committer was a candidate. Under these circumstances, the core team was forced to reprieve the suspension after two days (Lehey, 2002).

The transition to the elected core team model, though it appeased concerns of an illegitimacy in the distribution of authority in the project, did not eradicate conflicts. A case in point is the conflict in 2003 between the core team and Matt Dillon, a prolifivc committer, which led to the revocation of the latter's commit rights. According to the explanation given by two members of the then-core team, this decision was dictated by social, rather than technological, considerations: Dillon had repeatedly violated FreeBSD's code of conduct: his behaviour clashed with the collective way of doing things (Slashdot, 2003). A few months later, Dillon announced his decision to "fork" FreeBSD – that is, to make a copy of the codebase and start independent development – thus creating an alternative project called DragonFly BSD (Dillon, 2003). Dillon, for his part, claimed that he did not launch a new project because of his strained relations with FreeBSD committers, but due to reasons of difference of opinion regarding the technical direction of FreeBSD (Biancuzzi, 2004). Although Dillon's 'ostracism' illustrates clearly that not all conflicts are amenable to resolution, it also suggests that the freedom to fork a project (which FOSS licenses ensure) mitigates the potential for conflicts. Organisation theorists know well that easy access to the exit option dampens the emergence of conflicts: the potential for conflicts in a group is drastically reduced when members can easily walk out, disengaging themselves from it (Hirschman, 1970). Forking is nothing but an extreme example of the exit option: in this way, disputes over the direction of technical change in the project that do not admit of resolution are effectively 'translated' into alternative development lines (see FreeBSD core team interview by Loli-Gueru, 2003).

This period – just as that before it – is marked by rapid growth. The massive expansion of scale is illustrated from the increase of (*src*) committers from 138 in 2000 to 209 in 2005 (by 2010 the total number of committers had increased to 388 [FreeBSD, 2010d]). Although the expansion of scale brought about a significant increase of coordination costs, the increased need of coordination within the group did not lead to the introduction of direct supervision, meaning an internal hierarchy where contributions are processed upstream through "gatekeepers". Rather, it prompted changes in the direction of increased *standardisation*: namely, the standardisation of committers' induction process and of outputs through frequent building (Holck & Jørgensen, 2003/4; Jørgensen, 2007).

A standard argument of organisation theory is that work coordination in a small group may well be informal, based on the 'mutual adjustment' of group members. However, as the group gets larger, it becomes less able to coordinate informally. Thus, control of the work passes into a single individual and direct supervision becomes the chief means of coordination (Mintzberg, 1993, p.7). But FreeBSD, in spite of the increase of committers, made no attempt to supervise their work process. Rather, it opted to standardise their *skills*[14] by standardising the process through which outside contributors are inducted into the project. The process is as follows: a committer proposes to

12 The goal of the SMP project was to introduce parallelism into the kernel so that FreeBSD could be run on multiprocessor computer hardware architectures.

13 Table 1: Rules for the suspension of commit rights (Source: FreeBSD 2011d; Lehey, 2002)

14 '*Skills* are *standardized* when the kind of training required to perform the work is specified' (Mintzberg, 1993, p. 6).

the core team to grant commit rights to an outside contributor, based on the latter's history of contributions.[15] Usually, the committer who vouches for a new member becomes his mentor, assuming responsibility for everything his *protégé* does in the project. The mentor is in a sense his supervisor: he is responsible for reviewing and approving his changes prior to being committed to the repository. The mentorship period has no specific duration and ends when the mentor "releases" officially the new committer. By that time, the new committer is supposed to have developed a strong grasp of project goals and mastered the requisite technical and interpersonal skills (FreeBSD, 2011a; Lucas, 2002). It can be easily seen that the standardisation of the recruitment process is designed to harmonise the coexistence of fiercely independent individuals within the committers group by reducing the scope of conflicts related to the integration of changes (Watson, 2006). It achieves this by building into the committers-to-be the 'work programs' and the bases of coordination. Thus, on the job they appear to be acting autonomously, just as a surgeon and an anaesthesiologist need hardly communicate when they meet in the operating room, knowing through their training exactly what to expect from each other. By virtue of cultivating a *homogeneity of values*,[16] the recruitment process ensures that the conduct of new committers is compatible with the collective way of doing things.

To reduce the need for active coordination, FreeBSD also resorted to standardising *outputs through frequent building* (Holck & Jørgensen, 2003/4; Jørgensen, 2005; 2007). Doing a 'software build' refers to the process of converting human-readable source code into executable code that can be run on a computer. A successful build therefore implies that a working version of the software can be "built" from the evolving codebase. In addition to testing whether the evolving product is kept in a working state, software companies do frequent builds to facilitate team coordination, 'the key idea is that one large team can work like many small teams if developers synchronize their work through frequent "builds" and periodic "stabilizations" of the product' (Cusumano & Selby, 1997, p.262). FOSS projects are not an exception (Krill, 2011). FreeBSD uses three so-called Tinderbox servers that automatically build the most recent version of the software every few hours.[17] The results are posted on the world wide web and on project mailing lists, notifying committers of 'tinderbox failures'. This is focal to the project's use of mailing lists because committers see the effect of the most recent changes and so can pinpoint which change is responsible for breaking the build. As broken builds result in halting further development until the bug causing the breakdown is found and fixed, a key rule for committers is to make no changes that cause the build to fail (FreeBSD, 2011d). This rule, by specifying a criterion of performance that the work of committers is required to meet, achieves the standardisation of the results of their work. Compliance with the rule reduces the need for active coordination among committers, for, 'with outputs standardized, the coordination among tasks is predetermined, as in the book bindery that knows that the pages it receives from one place will fit perfectly into the covers it receives from another' (Mintzberg, 1993, p.6). Similarly, FreeBSD committers coordinate with each other in terms of definite performance standards: they are expected to commit changes that do not break the build; how they do this is their own business.

To more effectively accommodate increased scale, the project proceeded to a series of further measures. First, in 2001 it started using *quarterly status reports* to give contributors an overview of the various development activities in progress. Second, from 2003 onwards increasingly more development activity migrated from CVS to Perforce and later on to the Subversion revision control environment because of those environments' superior support for parallel development. By 2006 Perforce had replaced CVS as the development site of experimental features, while the Subversion server is where development work on the *src* tree is currently taking place (FreeBSD, 2011a; Long, 2010; Watson, 2006). Third, the project tried to decouple the work of different (groups of) committers by organising the development of important new features as independent subprojects with their own project manager (Holck & Jørgensen, 2003/4, p.46). In this way, experimental features are developed in a Perforce revision control environment and merged into the main repository only when they are mature enough (Long, 2010). Fourth, the project placed a great importance upon developer events, encouraging its contributors to attend them. In fact, one of the activities for which the FreeBSD Foundation was set up in 2000 is event sponsorship.[18]

In this period roles and responsibilities are increasingly decoupled from individual committers and delegated to teams. In the informal governance phase, to take one example, one person – Satoshi Asami, known as "Mr Ports" among FreeBSD developers – was responsible for the entire ports collection. In 2001, he was replaced by the Ports Management Team.[19] Similarly, the position of Security Officer expanded into the Security Officer Team in 2002.[20] While FreeBSD machines were administered in the first phase by two or three persons, an admin team was formed for this purpose in the latter phase. In the informal governance phase, public relations were entrusted to one person – the FreeBSD president – who was responsible for interfacing with corporate contacts. Following the abolition of the presidential position in 1997, the task was picked up by the marketing team and, since its founding in 2000, by the FreeBSD Foundation. Every change we have enumerated so far – from the systematisation of rules and procedures to the formation of administrative teams charged with tasks formerly carried out by one person – attests that there is a contingent relationship between the governance structure and the scale and maturity of a FOSS project.

15 This part of the process has been formalised since 2002: the FreeBSD website outlines the exact steps would-be mentors must follow to propose a new committer (FreeBSD, 2011c).

16 Organisations which, 'generally refuse to legitimate the use of centralized authority [...] to achieve social control', commonly resort to such a, 'selection for homogeneity', as shown by Rothschild-Whitt's (1979, p.513-4) classic study of collectivist organisations. This homogeneity is, of course, reinforced by the *self-selection* characteristic of participation in collectivist organisations (Mansbridge, 1977, p.336).

17 The results of the daily build process are accessible online at: http://tinderbox.freebsd.org. Indicatively, on 21 June 2011, tinderbox machines performed builds of the current version and of six officially released versions of FreeBSD on nine different hardware platforms.

18 According to one of the project founders, developer events contribute to relationship-building and effective conflict management (Hubbard, 1998a).

19 The Ports Management Team currently numbers eight members.

20 The Security Officer Team currently numbers eleven members.

THE IMPERATIVE OF AUTONOMY

Although the adoption of the elective principle altered the mode of project governance, it did not affect the work organisation of committers. The process by which changes are integrated in the repository remained the same. Its main feature – the ability of committers to integrate changes directly to the repository – did not change. How is it possible, given the dramatic increase of participating committers over time, that the expansion of scale did not result in supervisory hierarchy? In other words, how is the autonomy committers enjoy accounted for? In the first place, developers come to work in FreeBSD because it offers them substantial control over their work, thus indicating that the governance structure of the development process is an important motivating factor (Jørgensen, 2005, p.122). In a survey of seventy-two FreeBSD committers, more than eighty percent of them said they were encouraged by the freedom to commit code directly to the repository, for they do not feel they are, 'under the whims of a single person' (Jørgensen, 2005, p.233; see also Jørgensen, 2001; 2007).

Bearing in mind FreeBSD's historical background, the significance its developers attribute to their autonomy is hardly surprising. FreeBSD is descended – via BSD – from Unix, which was developed in a radically informal and anti-bureaucratic fashion. When AT&T's BTL withdrew from the Multics project, whose aim was the development of a multi-user operating system, some BTL employees took it upon themselves to bootstrap their own without any support from their employer. So was Unix born. Its development was from the beginning autonomous from BTL, dispensing with its supervision. This, however, served to strengthen the feeling of solidarity among the growing number of users at american universities, turning thus the development of Unix into a truly collaborative enterprise (Pfaffenberger, 1996; Raymond, 2003; Ritchie, 1984; Salus, 1994). The subsequent development of BSD at the Berkeley campus of the University of California similarly shunned bureaucratic principles of organisation, pioneering a model which revolved around a group of programmers called committers on account of their power to make changes to the codebase,

> The committers were a group of people we trusted to commit stuff...The notion was that you didn't have all these autocratic controls...we didn't need to tell people not to do that; we didn't have to administratively keep them from doing things they shouldn't be doing. We had set up a culture as well as a structure (McKusick quoted in Leonard, 2000).

In addition to animating the development of Unix and BSD, the principle of autonomy is focal to the model of Internet governance evolved by the hacker community. The prototype of this model is the Internet Engineering Task Force (IETF): formed in 1986, it is the closest thing there is to an institution responsible for the development of Internet standards. Its founding belief is as follows, 'We reject kings, presidents and voting. We believe in rough consensus and running code (Clark, 1992; Hoffman, 2010).

Deciding whether to adopt or reject a standard through *rough consensus* means that while unanimity is not required, 'strongly held objections must be debated until most people are satisfied that these objections are wrong' (Hoffman, 2010). In practice, though there is no fixed percentage, most proposals that are accepted have the support of no less than ninety percent of the working group (Bradner, 1999). Similarly in FreeBSD, as committer Joseph Koshy (2010) says, 'formal specifications and design documents are seldom used [...] Clear and well-written code and well-written change logs are used in their place. FreeBSD development happens by "rough consensus and running code"'.

Undeniably, modern advances in communication technology – in particular, the massive diffusion of the Internet – have revolutionised the scope of decentralised software development by enabling a far greater number of people than ever before to participate in projects like FreeBSD. However, though the role of the Internet in bridging geographical distances and slashing communication costs should not be overlooked,[21] by itself it does not suffice to provide an adequate interpretation of the course of action FreeBSD took to respond to increased scale. The Internet enables new organisational configurations, but does not determine how authority will be distributed in them. The way in which questions of governance – in all organisations, not just FOSS projects – are decided is intimately related to moral beliefs about how to organise effectively. The analysis of the historical and cultural context in which FreeBSD development is embedded brings into sharp focus a broader normative standard with reference to which hackers act. It shows that the motive of autonomy attributed to the conduct of FreeBSD developers accords with recognised normative patterns. Their freedom to commit changes directly to the repository makes sense in terms of accepted norms, as does their imperviousness to taking orders. The role of autonomy as an organising norm explains why the dramatic increase of committers did not lead to the introduction of supervisory hierarchy. The exercise of authority in FOSS projects cannot be understood apart from the influence of the normative standard of autonomy. Under no circumstances is the conduct of bearers of administrative authority – the core team in the case of FreeBSD – allowed to infringe upon developers' autonomy of action, making thus impossible the adoption of organisational configurations which seem to contravene this fundamental principle.

AUTHORITY AND LEGITIMACY

Max Weber's classic analysis of the sources of legitimisation of authority provides a lens through which the historical transformation of FreeBSD's governance structure can be viewed. According to Weber (1947, p.124–125), no authority system is stable unless it is based on the belief of those subject to it in the legitimacy of their subordination. He distinguishes between three types of *legitimate authority*. (1) The first type is that of *legal* (or *legal-rational*) authority. In this case, 'obedience is owed to the legally established impersonal order' (Weber, 1947, p.328) so those subject to legal authority 'owe no personal allegiance to a superordinate and follow his commands only within the restricted sphere in which his jurisdiction is clearly specified' (Giddens, 1988, p. 58). Persons

21 A discourse which has been very influential in shaping contemporary theorising holds that IT-enabled organisations can enlarge in scale whilst retaining the advantage of flexibility peculiar to small organisations. For some classics in this literature stream, see Castells (2001), Malone & Laubacher (1998) and Tapscott (1996).

in authority occupy a "position" or "office", to which they are appointed. Their organisation is hierarchical, 'each lower office is under the control and supervision of a higher one' (Weber, 1947, p.331). (2) *Traditional* authority is based on the sanctity of age-old rules and powers handed down from the past, such as that which is exercised by village elders in small rural communities. (3) *Charismatic* authority, Weber's third type, is that which is recognised by those subject to it as interlaced with the extraordinary abilities of the leader, 'by virtue of which he is [..] treated as endowed with supernatural, superhuman, or at least specifically exceptional powers or qualities' (Weber, 1947, p. 358). To this type belongs the authority exercised, for example, by prophets and religious leaders over their followers or by heroes in war. The claim to legitimacy in charismatic authority is founded upon the belief in the authenticity and uniqueness of the leader's mission, for which he supplies proof through his prodigious feats: hence the prophet has to perform miracles and the war hero triumphant military exploits. The administration of groups subject to charismatic authority is not carried out by "officials" but by the leader's disciples who share in his charisma. There is no such thing as career or promotion, no salary, no benefice. There is only a "call", a "mission" or "spiritual duty": the leader's administrative staff is summoned to the charismatic mission. There is no hierarchy: the leader merely intervenes when he considers the members of his staff inadequate to the tasks they have been entrusted with. There is no system of formal rules or precedents handed down from the past, 'the genuine prophet, like the genuine military leader and every true leader in this sense, preaches, creates, or demands new obligations' (Weber 1947, p.361).

As a general rule, FOSS projects, 'are created with few traditions to guide them and so do not inherit a traditional basis of authority' (O'Mahony & Ferraro, 2007, p.1081). They do not rely upon a legal-rational basis of authority either, as there is no authoritative division of labour. But when authority cannot be validated through tradition or hierarchy, its justification often turns on the charisma of its bearers. The leadership of Unix had, without doubt, a charismatic character during its early development at AT&T. From its inception in 1969 until the mid-70s, the development of Unix is closely connected with the names of Ken Thompson and Dennis Ritchie. In recognition of their important role in the making of Unix, they both have risen to mythical status in hacker folklore. The FOSS literature has the tendency to present them as individuals endowed with extraordinary abilities (*e.g.* Raymond 2000). The same charismatic qualities are attributed to their successor Bill Joy, who coordinated the subsequent development of Unix at Berkeley from 1977 until 1982. As one of his Berkeley colleagues describes him, 'He had an infectious enthusiasm about him, where he would just get the people around him to do stuff' (McKusick quoted in Leonard, 2000).

The rule of charisma is however ephemeral. Because of its disdain for the routine and the everyday, it is impossible for charisma to survive unless it undergoes a profound modification. Its 'routinisation' therefore implies the devolution of charismatic authority. It is not hard to discern the occurrence of this transformation in BSD. The project already counted more than five years of development by the time Bill Joy – who arrived to Berkeley in 1975 to attend graduate school and spearheaded a software development effort culminating in what became known as BSD – stepped down in 1982. In the wake of his departure, Sam Leffler, Joy's second-in-command, took over the responsibility of completing the release of 4.2BSD. But because, 'he was not appointed to Joy's post [by the team of graduate students and staff researchers working on BSD at Berkeley known since 1980 as the Computer Science Research Group or CSRG for short] and felt slighted by this' (Salus, 1994), he soon left for Lucasfilm.[22] Following the release of 4.2BSD in August 1983, Leffler was replaced by another member of CSRG, Mike Karels, who was joined by Kirk McKusick in December 1984. Under their leadership, the project evolved an organisational structure with a core team at the centre and a wider base of committers surrounding it (Leonard, 2000). The type of authority relationship that emerges from the routinisation of charisma, according to Weber, is determined in large part by how the 'succession problem' is resolved. In the case of BSD, the successor was not nominated by the predecessor. Nor was he self-selected: in spite of his professed willingness to take on the leader's role, Leffler was not "appointed" to this position by the CSRG and soon stepped down. On the contrary, the fitness of his substitute for the position, Mike Karels, as well as that of Kirk McKusick, was validated through his designation by the CSRG. The issue of succession was not raised again in BSD. With Karels and McKusick as project coordinators, a two-tier organisational structure began to take shape in which leadership, rather than being vested in a single person, was entrusted to a self-selected group of heavily involved developers. This set the stage for an important reinterpretation of the charismatic principle. Instead of being restricted to the person of the project leader, the "gift of grace" was extended to a leading cadre of hardcore developers.[23] FreeBSD inherited this conception of charismatic authority from BSD along with its organisational template.

When the FreeBSD project was launched in 1993, the core team included thirteen individuals. The development of FreeBSD was – and is – based on a group of programmers who are called committers because of their ability to make changes to the codebase. Committers organised themselves as an *informal meritocracy*: the most active committers were invited by the core team to join its ranks and outside contributors who regularly sent useful patches were offered commit rights. Granting commit rights to an outside contributor amounted to recognition of the technical expertise that his patches demonstrated. Similarly, inviting a committer to join the core team reflected the recognition of his outstanding contribution to FreeBSD and brilliance in coding. Authority was derived from technical competence, acquired and demonstrated through participation in the project.

Although the conception of merit in the project did not change, the criticism of the selection process of the core team and its prerogatives became more virulent over time. Its thrust was, on the one hand, that the core team had degenerated into a gerontocracy of veteran FreeBSD developers which no longer reflected merit in the project and, on the other, that members of the core team abused their power to serve their

22 Currently, Leffler is a FreeBSD committer and a member of the FreeBSD Foundation's board of directors.

23 Weber recognised that *'it is possible for any type of authority to be deprived of its monocratic character, which bonds it to a single person, by the principle of collegiality'* (Weber, 1947, p.392).

own ends. When in 2000 a prominent committer announced his intention to quit the project because a core team member was trampling over his work, the criticism of the core team turned to an open conflict that rapidly took on alarming proportions. The intervention of one of the project founders at this point was of decisive importance. He suggested a number of alternative reforms and called on committers to vote. They responded to his call, deciding by vote to adopt an elected core team model. Core bylaws were drafted shortly thereafter to regulate elections.

The transformation of charisma set off by the application of the elective principle to the core team selection was in this case fuelled by the rupture between the committers and the core team. The conflict that manifested itself through the growing criticism of the distribution of authority in the project brought about a shift in governance toward an electoral process for the selection of the core team. As a result, the core team, whose legitimacy rested on its members' charisma, then became the core team thanks to the confidence of committers. The introduction of elected core team members entailed a radical alteration in their position: they became the 'servants' of those under their authority. The passage of leadership from a self-selected group to a freely elected one signified that from now on committers were free to elevate to power and depose as they pleased. Whereas the recognition of the charisma of the core team was so far perceived by committers as a consequence of its legitimacy, it now began to be considered as its basis. Legitimacy was in this sense democratised.

The reconfiguration of the governance system brought about by the transformation of charisma limited the authority of the core team in four important ways. First, the sphere of its authority was circumscribed: the role of the core team was restricted to managing commit privileges and mediating in the event there is a serious disagreement between committers. Second, it was made accountable to the community of committers: the core team is required to defer to their wishes, making only decisions that reflect the consensus of the opinions of committers as manifest on mailing lists. Third, its term of office was specified: new elections were to be held every two years. Fourth, project leadership became revocable: the core bylaws invested committers with the power to trigger an early election, thereby recalling the core team. All these traits correspond to the type of governance Weber calls *direct democracy*: the short term of office, the liability to recall, the restricted sphere of jurisdiction, the obligation to render an accounting to the general community of committers and submit to it every important question (Weber, 1947, p.412-3). Direct democracy is characteristic of groups which, in order to preserve their members' autonomy, attempt 'to dispense with leadership altogether' by reducing 'to a minimum the control of some men over others.' In that sense, direct-democratic forms of governance are inherently *anti-authoritarian* (Weber 1947, p.389).

In FreeBSD, more specifically, the anti-authoritarian transformation of charisma that culminated in the adoption of a direct-democratic mode of governance limited the authority of the core team through the introduction of elements of democratic and legal-rational rule. The principles of consensus-oriented decision making, the limited duration of office and the liability to recall are all institutional safeguards drawing their justification from the sovereignty of the will of committers. The premises for delimiting the authority of the core team by specifying its sphere of jurisdiction are, on the other hand, bureaucratic par excellence. Authority in a bureaucratic organisation is distributed and legitimised only within the particular sphere of the office (Weber, 1947, p.330). The authority of the core team is likewise restricted to a specific field: it can be exercised only in matters touching commit rights and committer disputes (FreeBSD, 2011d). The use of so-called *hats* in the project – that is, of assigning clearly circumscribed areas of responsibility to certain committers – is also indicative of a stripped-down form of bureaucratisation as is the tendency toward the formation of teams that take on the role formerly held by a single committer (*e.g.* Ports Management and Security Officer teams).

Weber (1947, p.390) remarked that, 'the anti-authoritarian direction of the transformation of charisma normally leads into the path of rationality', as the setting up of an administrative organ that functions reliably invariably involves the systematisation of rules and procedures, fuelling thus the progressive bureaucratisation of the group. Yet the authority of the core team does not belong to the bureaucratic type. If bureaucracy is understood as a, 'clearly defined hierarchy of offices' (Weber, 1947, p.333), then core team members are not bureaucratic types. Since there are no officers on the core team, core team members are not integrated in a hierarchical order: they have no superiors who influence their "promotion" to the core team or supervise their activity. In contrast to bureaucratic organisations which mobilise their members through remunerative incentives, participation in FreeBSD is voluntary and unwaged. Although many committers are professionals in the IT industry,[24] their involvement in FreeBSD cannot be regarded as a career, as conventionally understood. For there is no career advancement in FreeBSD: outside contributors can become committers and committers core team members, but that is hardly analogous to moving up in a multi-layered hierarchy of ranks. In fact, the aim of FreeBSD's governance system is to eliminate the division of labour that separates decision making labour (administrative tasks) from executive labour (performance tasks). Not only is the core team, in addition to its managerial duties, expected to be producing code but, more crucially, decision making rests on a *consensus* process in which all project members can participate. For decisions to be taken as binding and legitimate, they must carry the consensus of the group behind them. And so to ensure that committers can participate in the process of formulating problems and negotiating decisions, all issues are discussed on project mailing lists.

What, for Weber, differentiates bureaucracy from other forms of organisation is that it allows for regular control of operations over time. That is what, in his view, makes bureaucracy "rational". According to Foucault (1975), whose work deals more extensively with the theme of time-space control, the distinguishing feature of bureaucratic organisation – whether in schools, barracks, factories or hospitals – is that the use of an individual's time and space is constantly monitored and

24 Indicatively, in a survey of seventy-two FreeBSD committers (constituting thirty-five percent of all committers) conducted in 2000, 43% said an employer had paid for all or part of their time spent on their latest code contribution. (Jørgensen, 2001).

controlled. Every individual is assigned its "proper place" and has certain duties to perform at any particular moment. This type of administrative authority, Foucault says, connects discipline directly with utility: its goal is to ensure that the use of an individual's time is channelled solely into those activities that the administrators consider useful. By contrast, participation in FreeBSD is not subject to such forms of control. The project does not keep any record of the time committers dedicate to it. Committers participate in their free time, deciding themselves when they will work and for how long. Moreover, their geographical whereabouts are irrelevant: they may work on FreeBSD from the privacy of their homes or from any other place. As seen from the standpoint of time-space control, FreeBSD wholly dispenses with the "discipline" characteristic of bureaucratic administration: no attempt has ever been made in the project to supervise the individual activities of committers or control with any means the use of their time or space.

The divergence of FreeBSD from the bureaucratic model can also be illustrated from the form of social relationships in the project. While social relations in bureaucratic organisations are based on the formal roles held by their members as laid down by an authoritative division of labour, relationships between FreeBSD developers are far more holistic, affective and personal.[25] For committers, FreeBSD is a *community*; a fraternity of peers. While bureaucratic organisation separates the "official" from the "personal", these two dimensions fuse together in the ideal of community that FreeBSD aspires to (O'Neil, 2009, p.175). In Weberian terms, the orientation of social action in FreeBSD is value-rational: that is, social conduct is based on definite moral values. The actions of individuals are directed to an overriding ideal: being part of the hacker community that coalesces around the development of FreeBSD (*cf*. Torvalds, 1998). That is not to say that their actions are not informed by pragmatic considerations, chiefly that they want the fruits of their labour to be used by as many people as possible (Hubbard, 1998b). But relationships between people in FreeBSD – as is typical of collectively-run volunteer organisations (Rothschild-Whitt, 1979, p.514) – are seen as of value in themselves. Arguably, it is not on account of holding some office that core team members are recognised as figures of authority. Although their opinion may well carry more weight in discussions occurring on project mailing lists than that of other committers, this is not the result of their 'powers of office' but rather of the respect and trust given them by committers for their substantial contribution to the project. Prior studies have shown that collectivist organisations find such inequalities of influence, 'acceptable in circumstances in which those who exercise power exercise it in the interests of others (usually because their interests are identical with those of others)' (Mansbridge, 1977, p.326). Hence, the reason why committers accept that some of them exert more influence than others is because that influence is seen as compatible with their own interests. Some traces of charismatic authority can still be detected in this relationship: the trust of committers in core team members is, to a certain extent, of an emotional type; and the persuasive authority of core team members is legitimised mainly through the recognition of the authenticity of their technical charisma by committers.

For Weber, the transition from the autocratic selection of the core team to its democratic election by vote signals the end of charismatic rule, as its subjection to norms and rules invariably involves the loss of genuine charismatic authority. Charisma abhors permanent forms of organisation and formal rules. Its claim to legitimacy lies in 'the conception that it is the duty' of those subject to charismatic authority to recognise its uniqueness and act accordingly (Weber, 1947, p.359–60). This conception of authority is no longer representative of FreeBSD. The election of the core team by and amongst committers resulted in changing the basis of its legitimacy. The recognition of charisma is no longer treated by committers as a consequence of the legitimacy of authority but as the basis upon which it rests. While legitimacy formerly rested on the 'duty' of committers to recognise the technical charisma of the core team, it became democratic in the latter period with the application of the elective principle: the authority of the core team was no longer validated by the charisma of its members but by the will of committers. Legitimacy was thus 'democratised'.

FreeBSD resulted in a direct-democratic governance system in which the distribution of authority is validated by the will of committers. Although that type of governance includes elements of bureaucratic authority, as the authority of the core team is delimited by mechanisms that reinforce bureaucratic values (such as the functional specificity of authority), its source of legitimacy is fundamentally democratic: it is justified by the imperative to preserve the sovereignty of the committers' will rather than by its adherence to an impersonal hierarchical order. It is important to observe that the transformation of charismatic to democratic authority did not modify the conception of merit in the project, which remains anchored in technical competence, acquired and demonstrated through project participation. What changed markedly however is the conception of leadership: leadership is no longer conceptualised as the informal rule of a self-selected group of heavily involved committers, but as a democratically elected group of committers that is revocable and subject to formal rules.

CONCLUSIONS

We analysed FreeBSD's institutional evolution by distinguishing two phases, based on their corresponding mode of governance. While from 1993 until 2000 FreeBSD had no formal means of representing its contributors in project governance, and leadership consisted in a self-selected group of veteran committers, in 2000 the growing criticism of the distribution of authority in the project brought about a shift toward an elected model, according to which project leadership is exercised by nine persons elected biennially by and amongst committers. Considering the dramatic increase of committers over time, the transformation of the governance system – and the systematisation of rules and procedures that runs parallel to it – suggests that a project's governance structure is contingent upon its scale and maturity.

The transformation of the governance system, however, did not affect the mode of work organisation of committers in the

25 One may wonder how is it possible that developer relations in FreeBSD are "personal", given that their interactions occur predominantly in a computer environment. After all, long distance relationships seem rather impoverished, if not shallow, compared to relationships that are based on physical copresence. It is instructive in this connection to refer to the emphasis Marshall McLuhan (1964) laid on how the diffusion of electronic telecommunications would transform the globe into a 'global village', signalling the return of humanity to a tribal-esque form of sociality. For McLuhan, the effect of telematic technology on social interaction is profound: as its scope is no longer determined by geographical proximity but by affinity, it becomes possible for relations of a more remote kind to be experienced as meaningful and personal.

development process, in spite of the remarkable expansion of scale. While organisation theory predicts that as a group grows larger it becomes less able to self-organise and so is compelled to turn to supervisory hierarchy as a means of coordination, the expansion of the committers group was not accompanied by changes in that direction. Rather, the project resorted to standardising (a) the induction process for new committers and (b) outputs through frequent building. This line of development cannot be understood apart from the influence of the normative standard of individual autonomy of action: it can be accounted for only by bearing into mind that an important reason why hackers are attracted to FreeBSD is the freedom of committers to add changes directly to the repository. The centrality of the autonomy principle elucidates the intervening motivational link between the observed activity – the course of action FreeBSD took to manage increased scale and achieve work coordination within an expanding group – and its meaning to the actors involved. A basic principle of the hacker ethic is to 'mistrust authority – promote decentralization' (Levy, 1984). Hackers espouse the view that the ultimate effect of centralised authority is to strangle the creative potential inherent in self-regulating individuals, thereby acting as a check upon their free development. As the activities of hackers are driven by an acute sense of independence, it is not conceivable that they would adopt organisational configurations which contravene their autonomy.

The normative significance of individual autonomy explains why authority in FOSS projects cannot be coercive. Naturally, that is not to say that no authority exists. In FreeBSD it consists in control of the ability to make changes to the codebase. Considering that no authority relationship is stable unless it is recognised by those who submit to it as based on some legitimate order (Weber, 1947), we examined how authority is legitimised in FreeBSD, contrasting it with Weber's categories of legitimate authority. We found that legitimacy shifted from the quasi-charismatic authority of a self-selected group of heavily involved committers to the democratic authority of an elected group that is revocable and bound to formal rules.

However, none of Weber's categories captures sufficiently the character of authority in FreeBSD. If authority is defined as a relationship in which an actor obeys a specific command issued by another, as Weber (1947, p.152) defines it, then FreeBSD is essentially an *organisation without authority*. There is no such thing as giving or following orders in FreeBSD. The administrative organ of the project – the core team – cannot tell committers what to do. When a decision needs to be made, it is made collectively by consensus. If, in the Weberian tradition, we take the basis of authority as the decisive organisational feature, then the mode of organisation of FreeBSD is collectivist, based on direct-democratic procedures of decision making. Seen from the perspective of the division of labour in the project, FreeBSD is decentralised and anti-hierarchical: tasks are self-selected by committers as their needs and interests best dictate. The resulting division of labour is spontaneous in the sense that it emerges from the choices of the committers rather than from a central designer. Their rejection of supervisory hierarchy is analogous to the autonomy from managerial control other professionals enjoy on account of being expected to exercise judgment and discretion in their daily work, but there is a fundamental difference: while professionals working in organisations, even in the most 'adhocratic' ones,[26] are invariably subject to some measure of hierarchical control (Bendor *et al.* 2001, p.173), hackers have totally ousted hierarchical authority from their organisational frame. Committers work without supervision, shouldering themselves the ultimate responsibility that the modifications they make to the codebase have been adequately tested and do not clash with the work of other committers. Consequently, FreeBSD illustrates, 'a production process that doesn't rely on managers' (Hamel, 2007, p.208). In FreeBSD those who work also manage.

To close this study, it seems appropriate to ask whether this mode of work organisation is likely to spread to other economic sectors. To attempt to answer this, we must take into consideration two characteristic specificities of FOSS. First, the means of FOSS production – computers and software tools – are widely distributed. Certainly, that is not the case with many fields of human industry: not all tools humans use to work and create are equally accessible. Second, participation in FOSS projects for most contributors lies outside the realm of labour determined by necessity: the livelihood of the vast majority of FOSS developers does not depend on their FOSS work; they participate voluntarily in their free time. For most people, by contrast, work is an activity borne out of necessity: the need for food, clothes and shelter, without which life perishes and dies, forces them into work relationships which otherwise they would never have accepted. Looked at from this perspective, the ability to participate in FOSS production communities – and more broadly, in peer production projects – appears to be a luxury available only to a privileged few. In a sense, peer production is an adaptation not to scarcity but to abundance (Raymond, 2001, p.81): individuals do not engage in peer production for reasons of immediate survival; their goal is to satisfy their intellectual rather than material needs. It is highly improbable that members of peer production projects would have been able to enjoy the equality in decision making and the autonomy of action they do had not been for the fact that they are economically independent of each other. That could not be further from the actual condition of most people today who are forced to follow commands for the sake of money. The participative nature of peer governance requires that participants are not bound by relations of economic dependence. Thus, what effectively precludes the generalisation of this mode of governance is the existence of huge disparities in economic power in contemporary societies. Consequently, without their eradication, the milieu of peer production is doomed to be no more than an island of libertarian culture in a sea of authoritarian organisations.

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26 Some organisational theorists have remarked that bureaucratic structures are unsuitable for the coordination of professionals who must exercise judgment and discretion during the performance of their duties, as their work demands decentralised 'structures [which] are designed largely to leave those people free to work as they know how' (Mintzberg & McHugh,1985). Such organisational structures are often referred to in the literature as organised anarchies (Cohen *et al.* 1972) or adhocracies (Mintzberg & McHugh, 1985).

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BECOMING MAKERS: HACKERSPACE MEMBER HABITS, VALUES, AND IDENTITIES

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Abstract: This paper explores factors that lead to individuals' adoption of the maker identity reproduced by a small-town hackerspace. This paper presents the findings of a 15-month ethnography of the hackerspace and a series of targeted interviews focused on the self-made tools of that hackerspace. These findings indicate that the formation of our subjects' maker identities are shaped heavily by the individual's ability to: use and extend tools; adopt an adhocist attitude toward projects and materials; and engage with the broader maker community. We also consider how a maker identity manifests itself in both making processes and visual stylizations of projects. We present and explore the formative roles of materials, the significances of imprecise tactics such as "futzing," and the role of the hackerspace as a special place where "normal" attitudes and practices are suspended in favor of an alternative set.

INTRODUCTION

In recent years, there has been a surge in cultures of making, from DIY, craft, and repair to hacking, 3D printing, digital fabrication, and electronic tinkering. Many of these cultures of making are supported in diverse ways by the Internet, from the sharing of patterns and code libraries to social tools supporting the creation and maintenance of social groups of interest. Coinciding with and supporting these cultures of making are new educational environments (*e.g.* The Maker Education Initiative, the Fixit Clinic), conventions (*e.g.*, Maker Faires, and less-branded maker gatherings), shared working/hobby spaces (*e.g.* hackerspaces, Makerspaces, Techshops), local meetups and events (*e.g.* FutureEverything, Ars Electronica) and online knowledge exchanges and alliances (*e.g*. Creative Applications Network, LilyPond, Instructables, and Ponoco.com) that support the activities and ongoing learning of these hobbyists.

Not surprisingly, this emerging culture of making is increasingly of interest to research communities, including the authors' field of Human Computer Interaction (HCI), as well as Science and Technology Studies, Cultural Studies, and others, for reasons including the following: making's relations to technical innovation; embodiment in new forms of technology-mediated collaboration; asserted potential for increased democratization of technology use, innovation, and production; asserted potential for enhanced educational experiences concerning technological fluency through maker education initiatives; and so forth. In HCI, this research includes studies of online communities of expert amateurs (Bardzell, 2007; Kuznetsov & Paulos, 2010; Pace *et al.* 2013); examinations of digital fabrication methods and their connections to technological innovations (Mellis *et al.* 2013; Mota, 2011); practices of appropriation in everyday life (Rosner & Bean 2009; Wakkary & Maestri, 2007, 2008; Tanenbaum *et al*. 2012); the distribution and adoption of open-source toolkits (Buechley & Hill, 2010; Mellis & Buechley, 2012a); creative reuse and repair of everyday objects (Jackson, in press; Maestri & Wakkary, 2011; Rosner *et al*. 2013); the education of both children and adults on issues concerning technological fluency (Buechley, 2010; DiSalvo *et al*. 2008; Mellis & Buechley, 2012b); how handwork relates to the aesthetics of self-expression as well as the politics of material resource use (Bardzell, 2012; Rosner, 2011) and general presentations of these makers and hackers as new kinds of users with whom HCI should be familiar (Bardzell *et al.* in press; Mota, 2011; Tanenbaum *et al.* 2013; Wakkary & Tanenbaum, 2009).

The present work contributes to the growing body of research on making through an empirical study of the development of the maker identity shared by members of a small town hackerspace. We access this identity formation through a long-term engagement with the hackerspace, as well as through targeted interviews focused on the *ad hoc production tools* fashioned by the hackerspace's members. These tools are often lightweight, off-beat, inexpensive, unpolished, and pragmatic. They showcase makers' spontaneity, intuition, style, and their familiarity with the hackerspace and the materials, tools, and other resources it has to offer. Often they highlight their makers' frustration with the limits of existing tools and therefore they reflect not only purposefulness but also an expression of the maker in that moment. Interestingly, we have found that in some cases what hackers call "tools" are not even tools at all, at least not in any obvious sense, which suggests that among other things hacking involves re-conceptualizing certain basic vocabulary. These self-made tools provide a unique level of access to understanding more deeply the individual's claims to the maker identity. We argue that the formation of this maker identity is informed by three primary factors in this hackerspace: (1) the development of a tool and material sensibility; (2) the cultivation of an adhocist attitude as an approach to making in general; and (3) engagement with the maker community, both in the space and on a larger scale.

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KEY CONCEPTS

Maker Identity and the "Established" Maker

Throughout this paper we discuss the process of adopting a 'maker identity.' With this, we refer to a plurality of identifications with the modern maker movement, from people who perform DIY home repair and craft activities, to people who subscribe to *Make magazine* or regularly peruse Instructables.com and imagine building projects, even if they never do. Our conceptualization of the maker identity is influenced by related characterizations described as the Expert Amateur (Kuznetsov & Paulos, 2010), the Everyday Designer (Wakkary & Tanenbaum, 2009), Makers (Anderson, 2012) and Hackers (Levy, 2010). Each of these identities describes people who build things for themselves, sometimes as part of an anti-consumerism statement, but often for a practical outcome. We view each of these identities as variant formulations of a potential maker identity, which we define throughout this paper as incorporating a collection of attitudes, skills, behaviors, practices, and expressions around DIY activities.

We distinguish the more general maker identity from what we refer to as an "established" maker. Maker-ness manifests in degrees, which range from one who occasionally participates in DIY activities and can consider herself a maker, to one who regularly and actively creates her own situations for DIY activities, who we would consider to be more established. All of the participants included in this study are members of a local hackerspace and, due to the nature of the hackerspace, we categorize as those who have adopted or are working to adopt this identity. In this paper we refer to the members of the hackerspace as "makers," even though the members themselves use "maker" and "hacker" interchangeably due to common misconceptions and negative baggage associated with "hacker." Throughout this study we have recognized the gradual evolution the makers of the hackerspace undergo from one degree of maker to another, constantly striving to become even more of a maker. But how exactly does one become an established maker? What sets this identification apart from those who are happy to simply follow the steps of an Instructables document without creating their own? Our broader research agenda explores these questions through investigating the process of becoming an established maker, and this work contributes to that line of research through an investigation of tools the makers make for themselves.

Tools, Users, and Self-Made Tools

This study relies on three separate formulations of "tool." The first is our everyday understanding of "tool," which we used early on to recognize the importance of the roles tools, specifically homemade tools, played in the space. We saw this kind of making as one that separated the kinds of making found in the hackerspace from forms that can exist easily outside of the space and, therefore, as a way in to investigating the process of becoming an established maker in this context. In this operational definition, an artifact is a tool if it is used in a process of creation separate from its own creation. In other words, we identified these tools based on whether they were used by the maker to create other artifacts.

The second formulation of "tool" is based on an emic account of the concept from the hackers themselves. When we began interviewing the members about the tools they have created in the space, we were careful not to impose our interpretations of what constitutes a tool, instead allowing them to interpret what "tool" meant for them and judge which of their projects would count. This allowed us to expand on our own notion of "tool" while staying true to an insider's perspective of the concept. As noted in the introduction, the emic account of "tool" surprised us, because it seemed much more inclusive than we anticipated.

This surprise prompted us to consider formulations of "tool" available in the research literature, which constitutes our third formulation. This literature includes works about tools from sociology, education, architecture, art, critical theory, and information design. Tools are instruments we encounter and use to accomplish tasks. Art historian Howard Risatti (2007) defines tools as, 'something used directly by the hand with an intention to make something by doing something to material' (p.49-50, emphasis in original). They are instrumental and have a pragmatic function, since they are used to make other things. A tool to McCullough (1988) is, 'a moving entity whose use is initiated and actively guided by a human being, for whom it acts as an extension, toward a specific purpose' (p.68). Tools are manually operated and are in Risatti's words, 'kinetically dependent' in that they require us or something else to activate their function (2007, p.51). When such an operation stops, tools cease to work; accordingly, a tool is, 'something with a 'tooling' potential and that a thing becomes a tool in the process of being put into action, of being put to "work"' (Risatti, 2007, p.43, emphasis in original). Synthesizing, these formulations suggest that tools are material objects that are put to work through intentional human action, and that their potential is latent except when they are used.

Such a description of tools reveals three additional characteristics about the relationship between tools and tool users: that tools direct our sensual engagement, that they require practice for mastery, and that identifying the right tools for the tasks at hand demands reasoned judgment. These activities are necessarily context and medium-dependent. As an example, consider a well-equipped shed and in exactly what ways it is conducive to gardening. Through practice, a gardener knows how to operate a single tool for a particular medium, and when necessary, can select appropriately a combination of different instruments (*e.g.* lopping shears, pole pruners, hedge shears, and pruning saws, *etc.*) to trim overgrown branches. For McCullough (1988), tools, 'come to stand for the processes. This symbolic aspect of tools may help you clarify your work [...] Holding a tool helps you inhabit a task' (p.61). There is a reciprocal relationship between work and the tools that are used to make it (Gelber, 1997).

Tools are also prosthetic, because they extend and enhance human capabilities. Sennett (2008) makes a distinction between *replicant* and *robot* tools. Replicant tools mimic human abilities while supplementing and amplifying them in specific ways. A spatula is a replicant tool because it expands our capacity for heat tolerance, allowing us to handle food beyond the body's natural ability, while nonetheless mimicking the manual behavior of flipping and arranging objects on a sur-face. A robot tool is 'ourselves enlarged: It is stronger, works faster, and never tires' (Sennett, 2008, p.84–85). A car can be seen as a robot tool because its power moves us quickly, and we tire of riding in it far sooner than it tires of transporting us.

In addition to extending our physical capabilities, tools also position us in the social world. As Illich (1980) writes, 'An individual relates himself in action to his society through the use of tools that he actively masters [...] To the degree that he masters his tools, he can invest the world with his meaning' (p.22). Tools are thus future orienting, providing mechanisms for users to envision and then to bring about future worlds.

Summarizing this research, tools connect human understanding to the material world through the possibility of change; they extend or augment, sometimes radically, human capabilities; they require us to change our physical behaviors, skills of imagination, and judgment to learn how to use them well; and, if all of this happens, they empower us to envision and pursue new futures. We argue that the development of this kind of tool sensibility is an integral part of becoming a maker, as it has a profound impact on an individual's perception of their abilities. Research on hacker's and maker's tool use can reveal much about how an individual develops such an identity, and because, as we will demonstrate, self-made tools are especially expressive of their makers, their creation and use is an especially fruitful area for empirical inquiry.

Adhocism

Our interest in the concept of adhocism began as the result of our observations in the hackerspace, where maker activities could be characterized as informal and ad hoc. Rather than plan an entire project, they often relied on an assumption that they would be able to solve problems as they arose, and worked with more generalized guidelines informed by their experiences in the hackerspace. After many months of ethnographic work and the building of our emic understanding of the ad hoc activities in the space, we began to develop an etic understanding of adhocism, which we were then able to use as another lens for studying the tool making activities and behaviors of the makers.

Architectural theorist Charles Jencks and architect Nathan Silver (2013) define *adhocism* as 'a principle of action having speed or economy and purpose or utility, and it prospers like most hybrids on the edge of respectability' (p.vii). Throughout their book, adhocism is presented simultaneously as a legitimate production strategy and as its own product style for finished products, be they architectural designs or NASA's space equipment. As a production strategy, adhocism focuses on efficiency, economy, approximation, adaptability, and pragmatism, often drawing on 'an available system in a new way to solve a problem quickly and efficiently' (Jencks & Silver, 2013, p.vii). As a product style, adhocism visually foregrounds the juxtaposition of these available systems, making explicit their connections and differences while showcasing their hybridity. Our conception of adhocism for this study focuses primarily on the former characterization. It is also influenced by the work of Lucy Suchman (1987), enabling a consideration of the situatedness of the maker's actions without necessarily labeling the adhocism we observe in those actions as intentional. The notion of adhocism as revealed in this hackerspace is closely associated with the maker's judgment throughout the making process—the judgment required to choose appropriate tools or methods to complete the project, the judgment used to decide whether to purchase or make a required piece of the project, and the judgment used to determine if the maker has the required competencies to complete the project. An adhocist project is not planned out ahead of time, but carries the assumption that each piece of the problem will be figured out as it becomes important. There is an overall sense of the big picture of the project, but it is seldom expressed as more than just a sense. As we have seen throughout this study, the adhocist attitude common to many of the projects we investigated is more than simply an approach but is also an identity expression, 'we work in this way because we can.'

RESEARCH APPROACH

Floraville, the fictional name of the small town in question, is a small Midwestern American city of around 80,000 people. Its hackerspace began in the summer of 2010 by a group of friends in a basement working on projects together, sharing their tools and know-how, after a robotics-centered club to which they belonged disbanded. As community interest in making grew, the group eventually moved to a shared workspace with another DIY-related group in town, thus becoming the first official hackerspace in the state. The space features up to 30 official dues-paying members (between 19 and 50 of age, including 2 females, one of whom being the founding member) and a handful of regular visitors sharing 1,400 square feet (130 square meters) of workspace and donated and/or purchased tools of different kinds. About 7-9 members use the space regularly to work on projects.

The 15-month ethnographic study took place on site at the hackerspace from October 2012-December 2013. One member of the research team made, hacked, and tinkered alongside regular hackerspace members, gradually taking on tasks for the group, such as providing hands-on soldering and craft workshops to local making enthusiasts and youths as well as accompanying visitors on tours of the space, etc. The ethnographic work resulted in 3-5 hours of direct weekly engagement for a total of about 180 hours of direct contact, generating data in the form of jottings, field notes, photos, and audio/video recordings of special events.

We also conducted expert interviews of seven hackerspace members who create their own tools for tackling specific making/hacking tasks. The interviewees (all white male, between 19-40 of age) were recruited based on their participation in the space (because we were embedded in the group, we could easily identify those who are tool makers). The toolmakers had various careers as programmers, web and apps developers, and even one cyclotron operator. Whenever possible, interviews were conducted in the hackerspace where the tool making took place. Some interviews were done at local coffee shops and the homes of the interviewees, based on their preferences. All participants' names have been changed. The interviews were minimally structured, intending to draw out conversation as informally as possible. As broad conversation guides, we asked our interviewees to tell us about their backgrounds and experiences with making; specifically, questions centered on (1) how/why/when tools were made, (2) material engagements, strategies, and their ideation and construction processes, (3) the roles these self-made tools play in specific projects in particular and the hackerspace in general, and (4) the perceived value and meanings of these self-made tools to the makers. The expert interviews produced 12 hours of recordings, notes, and photos of the tool-making processes and the actual tools. We transcribed all video and audio content for analysis.

Data analysis was conducted through a procedure known as *explication de texte*, or close reading, an analytical method that originated in the humanities (Ogden & Richards,1923) and which involves the careful examination of diction, rhetorical devices, style, and other formal and thematic elements in a text. In the data interpretation phase, two researchers conducted their close readings independently of one another to identify an individual set of themes. Subsequently, the entire research team collaborated to combine, refine, and distinguish among themes before arriving at the critical synthesis of quality, described in the ensuing sections.

SEVEN CASES: MAKERS AND THEIR TOOLS

To investigate the development of a maker identity, we will explore seven cases of makers and their tools. These cases are presented *in situ* to demonstrate how the individual maker relates to the maker community at large, their understanding and extension of tools, and how these behaviors function within an adhocist perspective on maker activity. Following the rich description of these seven cases, we propose a set of factors that allow a maker identity to emerge: (1) a sensibility toward tool use and creation, (2) a viewpoint that is shaped by an adhocist attitude with an underlying confidence and identity security, and (3) a strong relationship with a local community of makers.

As described above, an intimate relationship exists between tools and their users; tools (especially self-made tools) come to represent the individual and her creativity and ingenuity, which goes beyond the final, built artifacts into issues of identity and self-expression. Our ethnographic fieldwork quickly revealed instances of ad hoc, ingenious tool-making, grown out of makers' agitation and pragmatic concerns for the fact that existing tools are not fit-for-purpose—they are, for instance, not good enough, too hard to use, overkill, unavailable, etc. The challenges led to a process of impromptu reinterpretation, adaption, and/or improvisation of materials and devices at hand to fashion the right tools for specific purposes. They often are modified versions of familiar tools, built to better fit the purpose at hand, and many are based on plans for similar tools found online through a variety of resources, such as Instructables, YouTube videos posted by other makers, and hackerspace wikis. These self-made tools represent their makers' adoption of the maker identity by showcasing: their abilities with tools and materials at hand; their adhocist attitudes toward production processes; and their engagement with the maker community.

Mike: Lock Picking Tools

Mike, an undergraduate student at the local university studying computer science, is a lock picking hobbyist. Lock picking is seen as a sport to those in the security and hackerspace communities. Mike made several lock picking tools for his hobby. The first, a tension wrench, is a small piece of metal used to apply tension to a lock while it is being opened by a pick, which Mike made by hammering a piece of metal he found on the floor of the hackerspace into a shape that complemented the other tension wrenches he owns. His second tool, a bump key, is a key blank he filed down to an estimated average of where the pins in a lock need to be set for it to open. The bump key is "bumped" while placed in a lock to set the pins in the right place and open the lock. Bump keys can work very quickly for certain situations, but are more of a novelty tool than a practical one because there is a high risk of permanent damage to the lock.

Nolan: RS232 Cable and Bubble Etcher

Nolan is a server administrator at Floraville and is one of the board members of the hackerspace as well as one of its founders. He modified an RS232 cable to connect an LED marquee to his computer, and built a bubble etcher for etching printed circuit boards (PCBs). The marquee came from a yard sale and did not have the proper cables for programming it; Nolan's self-made tool fixed the problem and eliminated the need to search for a replacement part, which would have been difficult to locate. Described by some of the hackerspace members as 'a proper hack,' Nolan's RS232 cable was created by splicing open an extra straight-through cable, soldering it to the inside of a connection jack, and soldering parts of it to itself to mimic the 5 volt connection signal the proper cable would have communicated. Nolan's second project, the bubble etcher, is a tool used to speed up the process of etching PCBs while also requiring less etchant solution (in this case, hydrochloric acid), resulting in an overall more sustainable solution than traditional etching methods. This self-made bubble etcher is made from two pieces of plexiglass, an aquarium bubbler, plastic tubing, and silicone caulking, and is based on several designs Nolan found online.

Drake: PDUs and LED Lighting Tools

Drake works for a contracting company in town that builds software and robotics solutions for the government, and in his spare time he builds his own robots. Robotics projects, like many other large-scale electronics projects, consist of a variety of electrical components, each with its own electricity needs. To satisfy these needs, these projects often require power distribution units (PDUs), which distribute the electricity from the power source to match the specific requirements of each component. For his robots, Drake often makes his own PDUs by soldering together the proper components on a custom circuit board. Though each PDU is a one-off (unless a future project requires the exact same kind of power distribution), self-made PDUs can be less expensive and their customizability for specific project needs make them more effective in doing their jobs. Fused with his passion for LEDs, Drake also made unique LED lighting instruments for his experimental hydroponic system, powered using PDUs he built and complete with heat sinks (i.e., a passive heat exchangers that cool devices by dissipating heat into the surrounding medium) appropriated from previous projects or found materials.

George: Power-Generating Bicycle and Metal Pulleys

With a background in electronic engineering, George operates a cyclotron during the day and has been tinkering with power generators for decades. His signature self-made tool, an electricity-generating stationary bicycle, has been used locally in several public events as an example of alternative energy sources (*i.e.* it generated enough electricity for George's wife to telework from home when they were snowed-in with no electricity from the grid). The bicycle power generator is a stationary bike with a set of pulleys and motors that together generate electricity through induction when the pulleys are activated. George appropriated the stationary bike frame and welded parts of it together with the help from a fellow hackerspace member who owns the welding equipment in the space. George also machined the pulleys that are integral to his bicycle power generator out of cubes of aluminum using the metal lathe and the milling machine.

David: Sharpening Jig and Push Tools for Table Saws

David is an application developer who has made several tools specifically for public use in the hackerspace. These tools are intentionally made from spare pieces he found around the space, and in David's own words, the tools 'cost nothing but time' to create. When the hackerspace received a set of dull wood lathe chisels, David created a sharpening jig to attach to the bench grinder, making it easier to sharpen the wood lathe chisels by holding them at a steady and constant angle. In his second project, motivated by his concerns for the safety of his fellow members, David made several push tools (i.e., tools that are used to push materials across the table saw) to reduce risk of injury while using the table saw. These push tools mimic commercially available push tools, but they were made from scrap pieces of wood found in the space.

Charles and Joshua: Buddipoles

Charles and Joshua are both amateur radio operators (also known as "Hams"). Charles telecommutes as a developer for a popular operating system, and Joshua is a freelance developer. Together Charles and Joshua own several portable high frequency antennas known as "Buddipoles." Charles built his homebrew, modular Buddipole by following the plan for them created and shared freely online by its creator known as "Budd W3FF" in Redding, CA. Joshua put his Buddipole together from a kit he ordered online. Common materials include stainless steel telescopic whips, PVC pipes of varying lengths, PVC adapters, insulated speaker wires, electrical connectors, antenna adaptors, alligator clips, and banana plugs, among other things. These Buddipoles work well on any band from 10 to 80 meters, and operate as a portable high frequency antenna—a Ham setup that used to be incredibly difficult to achieve as high frequency antenna are generally stationary.

BECOMING A MAKER

We now turn to our synthesis of the individual cases of makers and their tools to present a set of factors that appear to contribute to the formation of a maker identity. These include the development of a tool and material sensibility; the adoption of an adhocist attitude toward make projects and tool use; and an engagement with a local community of makers.

Developing a Tool and Material Sensibility

Earlier, we referred to the development of a tool sensibility as an integral part of becoming a maker. We define this tool sensibility as being comprised of a deep understanding of existing tools and how they are used, an ability to judge which tools are the most appropriate for the task at hand, and a sophistication concerning the materials and medium available to the makers.

Learning to use their tools

Our participants expressed an emphasis on practice and extensive engagement. When describing others' astonishment at his accomplishments, Nolan comments,

> When you see people who put out lots of successful projects, what you don't see are all of the failed projects. For every one that's successful, there's at least a dozen that are not, for various reasons.

This emphasis on working on many projects as the way to develop as a maker was present in all of our interviews and was clearly observable through hackerspace activities. In addition to a general practice of making, it was clear that knowledge about how to use specific tools is important to members of the hackerspace. We saw this emphasis in the workshops and classes put on by the hackerspace members and in the focus on the tools given during visitor tours, but we saw it most clearly in the self-made tool projects we investigated. To be able to make a self-made tool, a maker must first have an embodied understanding of the limitations of existing tools. Oftentimes the impetus of tool making comes from the constraints of existing tools, and Drake's tools demonstrate this. Drake rationalizes making his PDUs this way,

> There is no board that's going to do exactly what I need [it] to do. There's not going to be a single board that has the number of pinouts that I need [...] a good form factor. Building and constructing [one] myself is going to be more beneficial than trying to hack and slash something into my rover.

Existing tools challenge Drake in that they are not fit-for-purpose, which as Sennett observes, 'send the message of clarity, of knowing which act should be done with which thing' (2008, p.194). By thinking with and through the limitations of imperfect tools, Drake is empowered to make his own. Moreover, as summarized earlier, tools are future orienting. While they may lack tooling potentials, these imperfect tools nonetheless act as catalysts that activate Drake's intuition and imagination into different possibilities. Sennett (2008) describes these possibilities as, 'grounded in feeling frustrated by a tool's limits' (p.209-210), and Jencks and Silver (2013) agree, 'In technology, inadequacy, not necessity, is the mother of invention' (p.107). The makers' abilities to recognize inadequacy in their tools in the first place is part of what makes them makers, and is a skill they develop through extensive engagement and a deep understanding of their tools.

Learning to judge a tool's appropriateness

When working in a small machine shop environment like this hackerspace, the ability to use specific tools is only half of the battle: knowing which tool to use for the job is an important type of judgment that hackers develop by becoming familiar with the tools available to them, and through them the possible abilities on which they can capitalize. George describes his process of creating an impromptu pulley for his bicycle generator as a casual experience, 'I just went over there and I had never used a metal lathe before in my life and what was it, about an hour or two hours later I've got a pulley.' He makes it sound as if the knowledge for creating this pulley just came to him, but we know from our observations that George spends a large part of his time at the hackerspace in the shop area near the metal lathe, where he can watch and engage with Nolan, who regularly works on the lathe. This experience participating in the shop and observing others' activities helped him develop a sense for which tools are appropriate for which jobs. Even though this was George's first time using the metal lathe, he knew what it could be used for from watching others use it. With this knowledge he was able to create his own tool, demonstrating his familiarity with the tools and materials in question, as well as the tool's role in enabling George to be future-orienting: he could imagine the creation of this pulley *because* he knew how this tool worked.

Materials and medium

Intimately related to this development of a tool sensibility is the familiarity with a particular material. In the case of the makers in Floraville, metals, wood, plexiglass, and other everyday materials both inspire and constrain their creativity. We see from our data time and again that the process of tool making is very much driven by toolmakers' intimate and deep respect for the medium they work with. In Drake's own words:

> I do a lot of light mods. Love LEDs, love the colors, love the whole photoelectron effect. I think it's a lot of fun, very interesting. And I learn-- through that obsession, I learned a whole lot more about light than I thought I ever would have. There are six distinguishing units of measurement for light, which a lot of people just didn't know.

Drake's personal knowledge about LEDs is given an outlet: he knows what he can pull out of them and what they can do for him. Similarly, Nolan's projects demonstrate a high level of sophistication and familiarity with the material within which he works. Toolmakers' understandings of materials, as McCullough observes, do not come from something abstract and theoretical, but is grounded on direct involvement with them, oriented toward 'workability and practices' (McCullough, 1988, p.196). Nolan's modified RS232 cable is case in point. To connect to the LED marquee, he needed a cable that could create a bridge between their computer and the marquee using RS232 protocol. Nolan's extensive engagement with—and knowledge of—straight-through cable enabled him to appropriate the technology in this *ad hoc* way.

This familiarity with the material possibilities available to a maker is especially helpful when it comes to navigating the physical environment of the hackerspace. Jencks and Silver (2013) discuss the importance of "browsing" in any information system (p.177), and a hackerspace full of tools and materials can certainly be considered such an information system. Without a sense of the material possibilities available to the maker, the materials strewn about the hackerspace would be seen as just another mess, instead of as a possibility for a project. As a lock-picking enthusiast, Mike is intimately familiar with the material requirements of his tools. The tension wrench he created came from a piece of steel he found on the floor of the space which he then hammered into the shape he needed to complement his other tools. Without the level of familiarity he has developed with his tools and the materials they are made out of, the piece of steel on the floor could have easily been overlooked.

As with Drake's and Nolan's projects, we recognize in Charles and Joshua's antenna projects—both the buddipole projects and the other antennas they have built over time—that engagement with materials is personal, and the conversations between the toolmakers and the materials (*i.e*. materials 'talking back') unfold over time. Charles related his experience developing his interest in Ham radio and building his own antennas:,

> [...] so building antennas, tweaking antennas, designing my own, you know, that's always been a fascination. I think that actually grew from being a broke teenager trying to get into the hobby and needing an antenna on the cheap··· I looked into well you can take this wire and if it's the right length, and situate it in the right direction it works just as well.

Building on his engagement with the materials and understanding of how antennas work, Charles was able to work within a set of constraints to build his tool and further develop his interest in Ham radio while also developing his skills as a maker.

One of the ways we see the importance of this overall tool sensibility is through how the makers are identified within the hackerspace by the tools they can use and the skills they have. Many of the members are introduced to visitors through a description of their capabilities, projects, or which tools they own in the space. For example, George is introduced as an electricity expert and through his bicycle generator project. Charles as a Ham, Drake as a roboticist, Mike as a lock picker, and David as "laser-man," because of his recently acquired expertise with the laser cutter. These tools become identifiers for individual makers in the hackerspace, and the makers are reflexively seen as tied to these tools. Developing this experience with tools and medium helps solidify one's identity as a maker, but can also act as a barrier if this level of understanding, practice, or involvement is not reached. John was a regular visitor of the hackerspace for a few weeks, and even eventually became an official member, before he suddenly stopped showing up. John had a hard time seeing himself as a maker, and commented once while looking at one of the products of the machining workshop during a visit, 'I need to get in on this, I don't know how to do anything. Where do you have a list of all the classes?' Shortly after this comment John stopped coming to the space and stopped paying dues. His lack of a connection to the larger tools and their capabilities was a barrier to feeling like a maker that he was not able to overcome in his short time at the space. It is possible that John would have been less intimidated by his lack of experience if other members had made it clearer to him, as they had with other new members, that none of them started out knowing how to use these tools or what to do with them either; they developed those skills over time through practice projects, prolonged engagement, and with a 'good enough' attitude toward their finished projects.

Cultivating an Adhocist Attitude

The skills to actually pick out and use a set of tools and materials are an important part of becoming a maker, because ultimately makers make things. However, the personality and the attitude required to really become an expert maker can be even more important. When asked which skills or processes he relies on continuously throughout his making process, Charles, who grew up making his own antennas for his amateur radio hobby, said,

> It's hard to say skills more than it's I would say just my nature of curiosity and wanting to tinker. It's not really a skill. It's just a personality trait, I guess… Maybe the biggest skill there is just knowing how to research and figure out the skills that I'm missing.

For Charles, making is not just a way to get by or be frugal, but is also an experience that plays on his personality. We argue that this adhocist attitude centers on practicality as a motivation, practicality as an identity constraint, and an underlying confidence in abilities.

Motivating Practicalities

For the makers at this hackerspace, practicality is an approach to and motivation for making. This relates to Jencks' and Silver's (2013) distinction between practical adhocism, which they describe as relying on 'ad hoc means,' with intentional adhocism, or using 'ad hoc ends' (p.110). The distinction here is between working to create an artifact through a set of ad hoc processes and working to create an artifact that represents a purposeful conglomeration of other artifacts juxtaposed in one entity. In this hackerspace, adhocism is a means for navigating, overcoming, or building on the constraints of the make projects while also working to remain practical on various fronts, including both monetary and time limitations. In many cases, simply buying the parts for a project can be the most frugal decision, even if the part could be made relatively easily. We see this approach in Drake's schema for when to purchase his PDUs. Where Mike says: 'The thing I have the most of is time, not money' about his decision to make his lock picking tools, Drake offers a different and more nuanced perspective,

> If it weren't my money, then I would always buy. Because there are enough modules out there that you could make it fit, you could make it work. And there are companies who will fabricate individual integrated circuits for you if you told them what you were looking for... [But when it is my money] if it can be quickly found cheap and delivered quickly, then purchase [it], but if it's something that's really arbitrary or if it's something I need now and I have parts on hand, I build it myself.

Drake is open to purchasing tools as long as they are, 'cheaper to buy than it is worth my time [to build].' Tool making for Drake is thus a premeditated act, where he must regularly work through a series of contingencies involving self-imposed resource constraints.

We have seen with both Drake's and George's tools how the incompleteness and limitations of the materials and resources are commonplace in this hackerspace, and how as tool makers they have a very pragmatic attitude toward such constraints, and in fact, rely on them to give rise to creative expressions. George relates a conversation he had with a group of high school students when he demonstrated his electricity-generating bicycle at a local high school. When questioned by students about the bicycle's gear ratio, George comments that, 'sometimes it's a case where what you have on hand is what you use rather than going out and buying or whatever.' For a tool such as the bicycle electricity generator, a higher gear ratio would be more effective, but George has to (and enjoys) working with what is available and is at peace with having a 'good enough' final product. As Gauntlett (2011) observes, 'the best tools are not merely "useful" or "convenient" additions to everyday life, but can unlock possibilities and enable creative expression, which are essential components of a satisfactory life' (p.172). We have seen this play out in the processes our makers use to create their tools, where the methods that are "convenient" are discarded for what can result in a more creative expression.

With his sharpening jig, David shares a similar sentiment to George's about working within constraints and being at peace with a 'good enough' solution,

> It seemed silly to buy or spend too much time on a more elaborate jig, because we're really not a woodworking shop as much. You know, that's just an aspect. But we're not going to use the lathe super extensively.

This quote brings about an interesting characteristic of self-made tools: approximation. To some, tools made with inexpensive materials, scraps, and found objects or even junk laying around in the hackerspace are perfectly acceptable as long as they are made 'well enough' or 'close enough.' In other words, while these self-made tools might not be perfect, they are nevertheless optimum for the context and means. Jencks and Silver (2013) argue that, 'approximate solutions are very often the best when requirements are multiple or complex' (p.119), and here we see that multiple and complex limitations, such as a need for efficiency or frugality, can also be met through approximate solutions.

Practicality as an identity constraint

Practicality can also play out as an identity constraint, where practicality and frugality are often desired expressions of projects, even if the process of obtaining that expression ends with an overall less frugal or less efficient output. This is especially true of the projects that Charles works on relating to his ham radio hobby. His stories about how he got his start with this hobby, and how he started developing as a maker, begin with creating his own antennas just to be able to participate. But now that he's older and that barrier no longer exists, he still makes many of his own antennas. For him, having a homemade antenna plays into the sport of making. He says, 'half of the fun is actually talking to someone on, you know, across the country and across the world, on pieces that I've actually built myself.' This sport focuses on the appearance of frugality and practicality, even when the process of making these tools and products might actually end up costing the maker more in the long run. Through participating in this "sport," the makers are expressing an affiliation with pragmatism and adhocism, even if it's not actually the case.

One of the primary limitations we have seen with this predilection towards practical adhocism is the fact that there are no general-purpose tools created in the space. Rather, every tool we have seen is created as fit-for-purpose, to inhabit a specific part of the making activity. Creating a more general-purpose tool would require a focus on the creation of the tool itself, instead of the focus we have seen on the solution to a problem. Another limitation we have identified with this focus on practical adhocism is the narrowed scope of what activities can and cannot exist in the space. If the activity is not already happening in the space, or it is not an activity closely tied with the broader maker culture and publicized online in various venues such as Instructables, *Make magazine*, or Adafruit, then it is very difficult for that activity to gain traction within the hackerspace. This limits the potential reach of the space to those who self-select into this particular subset of the community. For example, other making subjectivities that could exist in this space but do not as of yet include: makers who mend or create their own clothes, makers who focus on gourmet foods, makers who bind their own books, makers who write, *etc*.

In Futz We Trust

Each of the self-made tools we investigated in this study and much of the ethnographic data demonstrate a high level of optimism and confidence on the part of the makers. Some of this optimism can be attributed to the tool and material sensibility described in the previous section, but we also see this attitude coming from a demonstration of trust in the maker's adhocist process. When working on a project, the makers avoid planning out each step of the make process (sometimes explicitly and deliberately), instead relying on the belief that they will be able to figure out what needs to be done at each stage of the project. A common phrase to be heard around the hackerspace, especially when discussing possible group projects, is, 'We're a hackerspace, surely we can think of something.' Playing into this trust in their ability to know how to research what they need to know when the time comes is the comfort in knowing that their projects are approximate solutions that only have to be 'good enough' for their purposes. In fact, an overly meticulous or powerful project could be seen as overkill. The hackerspace also demonstrates a clear acceptance of failed projects as a legitimate and necessary form of practicing one's skills.

The emphasis on confidence is further established through how hackerspace members approach maker education for children. Jennifer, one of the founding members of the space who also organizes many of the space's events, characterizes her favorite part about the bug bots class she leads every year at the children's museum as "futzing," saying, 'you have to futz with them, and I like that.' This idea of futzing refers to tinkering with the bug bots while building them because they are not particularly well designed on purpose so that the children have to tinker with them and take charge of how pieces should be bent and configured to make sure that their bug bot actually runs well. The exercise forces them to develop enough trust in their judgment to be able to perform that level of tinkering without fear of failure, while also accepting a certain level of approximation, learning when to stop "futzing" and just experiment with what they have.

A certain level of confidence is required for makers to be able to make just for the sake of making, one of the characteristics that seems to separate general makers from more established or expert makers. When describing the projects he works on, Joshua says,

> They're all useful and they all work. [But] I haven't gotten to the point of just making things just to make them, because I don't really know enough yet. Though I'm almost there. I have a couple projects in the works that I haven't made yet that probably won't be all that great or useful.

Once makers have developed enough trust in their abilities, either because they have learned to adopt this adhocist attitude full-heartedly or because they have started to view themselves as experts with the tools and materials they work with, then they start to see themselves as established makers. Drake relates the experience he had when he realized exactly what it was he already knew how to do with his robotics projects,

> Everything from there, from robotics on, has just been an extension of that mindset, that holy crap, I'm empowered. I know how to learn the stuff. I know a lot of this already. Why not just take it seriously?

For Drake, realizing he could do these projects already because he knew how to learn how to make these projects was a big step toward becoming an established maker.

A Community Focused on Tools

In addition to promoting a focus on practical adhocism and building a level of confidence among members, this hackerspace's maker attitude also emphasizes the importance of community. The members work actively to share what they know with each other, either through advice on individual projects and problems as they come up, or through creating educational opportunities in the form of workshops, classes, or shared interest groups within the hackerspace. More expert makers—with developed tool and material sensibilities and a growing demonstration of experience and expertise—act as mentors for other makers. Sennett (2008), citing Harper's *Skill and Community in a Small Shop*, discusses the role of 'sociable experts' and their ability to become mentors for other experts, enabling a transfer of knowledge that can otherwise be quite difficult to perform. We see such transfers of knowledge in the hackerspace community time and again in our observations. For example, in the process of building his bicycle generator, George relied on help from other members to weld parts of the frame together and to learn how to use the metal lathe. We also found this transfer of knowledge to often be tied up in expressions of care for other members: to express his concern for other members' use of the table saw, David built several push tools not just so they could be used for the table saw but to remind other makers to use safety tools in the first place.

In our observations it became clear that Nolan plays a strong mentorship role in the hackerspace, as he is often the subject of an informal queue of members seeking advice on various projects. When we asked him about this experience, he said,

> I really like to see someone be able to work on their own after I've helped them, and so I'm still on the phase of trying to do that. I don't know, I mean, I think I'm just kind of a run-of-the-mill geek. I know a little bit about a lot of things but not a lot except my certain specialty areas. I'm very glad that I've been able to be helpful to a lot of people in a lot of different areas.

Nathan recognizes his role as a mentor to others, and uses this privileged position to instill in his mentees a common maker ethos of independence and confidence in their abilities.

This concern for community extends beyond the borders of the hackerspace itself to the community at large in Floraville. Members of the hackerspace have worked (without compensation) to set up an annual maker convention in the town; to teach various workshops with children including soldering lessons, stop motion animation workshops, and DIY speaker workshops; and to provide a space for others to work at the hackerspace each week during the public hack nights, including access to any of the space's tools, human resources, and social activities. At the beginning of our ethnography, the hackerspace seemed to us to be very tool-focused, with a constant emphasis to visitors about what tools are available in the space, what workshops they can take that will teach them to use certain tools, and which members are experts on which tools. However, having spent over a year with them, a different social understanding of the space emerges: the space has more to do with providing a social atmosphere for its members, operating as a third space, one that is neither home nor the office, for members to relax and visit with each other, where members can work on projects that fail without fear of judgment, where members learn to engage with their materials and tools on a deep level, both through hours of practice and through learning experiences set up by more experienced makers.

CONCLUDING DISCUSSION

In this article we have presented one kind of maker out of many possible variations, focusing on the process these individuals go through to develop and cultivate their "maker-ness." We presented three primary concepts that stand out in our data as primary drivers of the formation of a maker identity: the development of a tool and material sensibility that relies on an extensive engagement and practice with tools and materials to learn how to use them well, how to judge which tools are appropriate for which situations, and to understand how to use available materials appropriately; the cultivation of an adhocist attitude, which involves learning to trust one's intuitions and judgments through a maker process and adopting practical approach to project building and learning; and developing a sense of community engagement with other makers. These characteristics set "established" makers apart from the more generalized kind of maker, who can adopt the identity after their first Instructables walkthrough or the first time they learn to use a sewing machine. What we have found is that the process of becoming such an established maker seems to rely less on inherent abilities, skills, or intelligence per se, and more on adopting an outlook about one's agency. We believe this process of becoming an "established" maker can be usefully applied to other situations, particularly those that involve individuals who have not traditionally felt empowered. To instill such a creative sensibility, along with the practical skills to act on it, appears to be one of the primary purposes of the hackerspace—an intriguing idea for researchers seeking to understand these spaces and extend their creative practices beyond their walls.

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HACKLABS AND HACKERSPACES TRACING TWO GENEALOGIES

MAXIGAS

Abstract: Hackerspaces are workshops organised with an open community model where people with technological interests can come together to socialise, collaborate, share and expand their knowledge. The last few years have seen an increased activity in this area including the founding of many new locations, increasing cooperation and discussions about the potentialities and the directions of hackerspaces. Similar spaces, however, called hacklabs, have existed ever since personal computers became widespread. Hacklabs are typically based on a political agenda. These new and old places are often seen retrospectively as part of a single trajectory and most of the discourse treats hacklabs and hackespaces as equivalent. Outlining the overlapping but still distinguishable genealogies of both hackerspaces and hacklabs will prove helpful in questioning the tendency to confound the two and can further contribute to the contemporary debates over this vibrant culture and movement. The article ends with a reflection from a strategic point of view how hackerspaces and hacklabs contribute to the production of postcapitalist subjectivities through their organisational dynamics. The findings are based on personal experiences and field work, mainly at a now-defunct hacklab in London (the Hackney Crack House) and a hackerspace in Budapest (the Hungarian Autonomous Center for Knowledge).

INTRODUCTION

It seems very promising to chart the genealogy of hackerspaces from the point of view of hacklabs, since the relationship between these scenes have seldom been discussed and largely remains unreflected. A methodological examination will highlight many interesting differences and connections that can be useful for practitioners who seek to foster and spread the hackerspace culture, as well as for academics who seek to conceptualise and understand it. In particular, hackerspaces proved to be a viral phenomenon which may have reached the height of its popularity, and while a new wave of fablabs spring up, people like Grenzfurthner and Schneider (2009) have started asking questions about the direction of these movements. I would like to contribute to this debate about the political direction and the political potentials of hacklabs and hackerspaces with a comparative, critical, historiographical paper. I am mostly interested in how these intertwined networks of institutions and communities can escape the the capitalist apparatus of capture, and how these potentialities are conditioned by a historical embeddedness in various scenes and histories.

Hacklabs manifest some of the same traits as hackerspaces, and, indeed, many communities who are registered on hackerspaces.org identify themselves as *hacklabs* as well. Furthermore, some registered groups would not be considered to be a real hackerspace by most of the others. In fact, there is a rich spectrum of terms and places with a family resemblance such as *coworking spaces*, *innovation laboratories*, *media labs*, *fab labs*, *makerspaces*, and so on. Not all of these are even based on an existing community, but have been founded by actors of the formal educational system or commercial sector. It is impossible to clarify everything in the scope of a short article. I will therefore only consider community-led hacklabs and hackerspaces here.

Despite the fact that these spaces share the same cultural heritage, some of their ideological and historical roots are indeed different. This results in a slightly different adoption of technologies and a subtle divergence in their organisational models. Historically speaking, hacklabs started in the middle of the 1990s and became widespread in the first half of the 2000s. Hackerspaces started in the late 1990s and became widespread in the second half of the 2000s. Ideologically speaking, most hacklabs have been explicitly politicised as part of the broader anarchist/autonomist scene, while hackerspaces, developing in the libertarian sphere of influence around the Chaos Computer Club, are not necessarily defining themselves as overtly political. While practitioners in both scenes would consider their own activities as oriented towards the liberation of technological knowledge and related practices, the interpretations of what is meant by "liberty" diverges. One concrete example of how these historical and ideological divergences show up is to be found in the legal status of the spaces: while hacklabs are often located in squatted buildings, hackerspaces are generally rented.

This paper is comprised of three distinct sections. The first two sections draw up the historical and ideological genealogy of hacklabs and hackerspaces. The third section brings together these findings in order to reflect on the differences from a contemporary point of view. While the genealogical sections are descriptive, the evaluation in the last section is normative,

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asking how the differences identified in the paper play out strategically from the point of view of creating postcapitalist spaces, subjects and technologies.

Note that at the moment the terms *hacklab* and *hackerspace* are used largely synonymously. Contrary to prevailing categorisation, I use hacklabs in their older (1990s) historical sense, in order to highlight historical and ideological differences that result in a somewhat different approach to technology. This is not linguistic nitpicking but meant to allow a more nuanced understanding of the environments and practices under consideration. The evolving meaning of these terms, reflecting the social changes that have taken place, is recorded on Wikipedia. The Hacklab article was created in 2006 (Wikipedia contributors, 2010a), the Hackerspace article in 2008 (Wikipedia contributors, 2011). In 2010, the content of the Hacklab article was merged into the Hackerspaces article. This merger was based on the rationale given on the corresponding discussion page (Wikipedia contributors, 2010). A user by the name "Anarkitekt" wrote that 'I've never heard or read anything implying that there is an ideological difference between the terms hackerspace and hacklab' (Wikipedia contributors, 2010b). Thus the treatment of the topic by Wikipedians supports my claim that the proliferation of hackerspaces went hand in hand with a forgetting of the history that I am setting out to recapitulate here.

SECTION 1: HACKLABS

The surge of hacklabs can be attributed to a number of factors. In order to sketch out their genealogy, two contexts will be expanded on here: the autonomous movement and media activism. A shortened and simplified account of these two histories are given that emphasises elements that are important from the point of view of the emergence of hacklabs. The hacker culture, of no less importance, will be treated in the next section in more detail. A definition from a seminal article by Simon Yuill highlights the basic rationales behind these initiatives (2008),

> Hacklabs are, mostly, voluntary-run spaces providing free public access to computers and internet. They generally make use of reclaimed and recycled machines running GNU/Linux, and alongside providing computer access, most hacklabs run workshops in a range of topics from basic computer use and installing GNU/Linux software, to programming, electronics, and independent (or pirate) radio broadcast. The first hacklabs developed in Europe, often coming out of the traditions of squatted social centres and community media labs. In Italy they have been connected with the autonomist social centres, and in Spain, Germany, and the Netherlands with anarchist squatting movements.

The autonomous movement grew out of the *cultural shock* (Wallerstein, 2004) of 1968 which included a new wave of contestations against capitalism, both in its welfare state form and in its Eastern manifestation as *bureaucratic capitalism* (Debord, [1970], 1977). It was concurrently linked to the rise of youth subcultures. It was mainly oriented towards mass direct action and the establishment of initiatives that sought to provide an alternative to the institutions operated by state and capital. Its crucial formal characteristic was self-organisation emphasising the

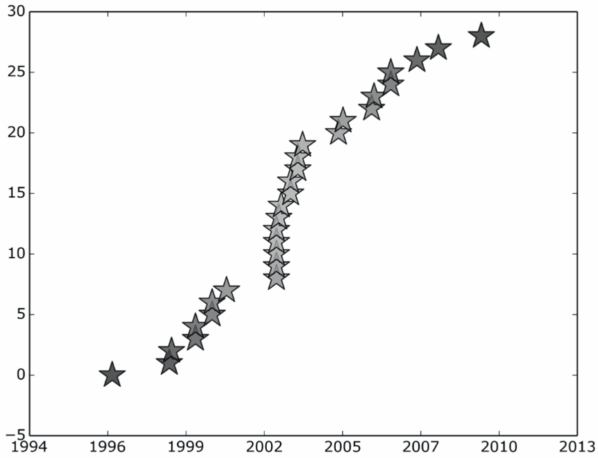

Fig.1. Survey of domain registrations of the hacklabs list from hacklabs.org

horizontal distribution of power. In the 1970s, the autonomous movement played a role in the politics of Italy, Germany and France (in order of importance) and to a lesser extent in other European countries like Greece (Wright, 2002). The theoretical basis is that the working class (and later the oppressed in general) can be an independent historical actor in the face of state and capital, building its own power structures through self-valorisation and appropriation. It drew from orthodox Marxism, left-communism and anarchism, both in theoretical terms and in terms of a historical continuity and direct contact between these other movements. The rise and fall of left wing terrorist organisations, which emerged from a similar milieu (like the RAF in Germany or the Red Brigade in Italy), has marked a break in the history of the autonomous movements. Afterwards they became less coherent and more heterogenous. Two specific practices that were established by autonomists are squatting and media activism (Lotringer & Marazzi, 2007).

The reappropriation of physical places and real estate has a much longer history than the autonomous movement. Sometimes, as in the case of the pirate settlements described by Hakim Bey (1995; 2003), these places have evolved into sites for alternative *forms of life* (Agamben, 1998). The housing shortage after the Second World War resulted in a wave of occupations in the United Kingdom (Hinton, 1988) which necessarily took on a political character and produced community experiences. However, the specificity of squatting lay in the strategy of taking occupied houses as a point of departure for the reinvention of all spheres of life while confronting authorities and the "establishment" more generally conceived. While many houses served as private homes, concentrating on experimenting with alternative life styles or simply satisfying basic needs, others opted to play a public role in urban life. The latter are called *social centres*. A social centre would provide space for initiatives that sought to establish an alternative to official institutions. For example, the infoshop would be an alternative information desk, library and archive, while the bicycle kitchen would be an alternative to bike shops and bike repair shops. These two examples show that among the various institutions to be replaced, both those operated by state and capital were included. On the other hand, both temporary and more or less permanently occupied spaces served as bases, and sometimes as front lines, of an array of protest activities.

With the onset of neoliberalism (Harvey, 2005; 2007), squatters had to fight hard for their territory, resulting in the squat wars of the 90s. The stake of these clashes that often saw whole streets under blockade was to force the state and capital to recognise squatting as a more or less legitimate social practice. While trespassing and breaking in to private property remained illegal, occupiers received at least temporary legal protection and disputes had to be resolved in court, often taking a long time to conclude. Squatting proliferated in the resulting grey area. Enforcement practices, squatting laws and frameworks were established in the UK, Catalonia, Netherlands and Germany. Some of the more powerful occupied social centres (like the EKH in Vienna) and a handful of strong scenes in certain cities (like Barcelona) managed to secure their existence into the first decade of the 21st twenty first century. Recent years saw a series of crackdowns on the last remaining popular squatting locations such as the abolishment of laws protecting squatters in the Netherlands (Usher, 2010) and discussion of the same in the UK (House of Commons, 2010).

Media activism developed along similar lines, building on a long tradition of independent publishing. Adrian Jones (2009) argues for a structural but also historical continuity in the pirate radio practices of the 1960s and contemporary copyright conflicts epitomised by the Pirate Bay. On the strictly activist front, one important early contribution was Radio Alice (est., 1976) which emerged from the the autonomist scene of Bologna (Berardi & Mecchia, 2007). Pirate radio and its reformist counterparts, community radio stations, flourished ever since. Reclaiming the radio frequency was only the first step, however. As Dee Dee Halleck explains, media activists soon made use of the consumer electronic products such as camcorders that became available on the market from the late 80s onwards. They organised production in collectives such as Paper Tiger Television and distribution in grassroots initiatives such as Deep Dish TV which focused on satellite air time (Halleck, 1998). The next logical step was information and communication technologies such as the personal computer — appearing on the market at the same time. It was different from the camcorder in the sense that it was a general purpose information processing tool. With the combination of commercially available Internet access, it changed the landscape of political advocacy and organising practices. At the forefront of developing theory and practice around the new communication technologies was the Critical Art Ensemble. It started with video works in 1986, but then moved on to the use of other emerging technologies (Critical Art Ensemble, 2000). Although they have published exclusively Internet-based works like *Diseases of the Consciousness* (1997), their *tactical media* approach emphasises the use of the right tool for the right job. In 2002 they organised a workshop in New York's Eyebeam, which belongs to the wider hackerspace scene. New media activists played an integral part in the emergence of the alterglobalisation movement, establishing the Indymedia network. Indymedia is comprised of local Independent Media Centres and a global infrastructure holding it together (see Morris, 2004). Focusing on open publishing as an editorial principle, the initiative quickly united and involved so many activists that it became one of the most recognised brands of the alterglobalisation movement, only slowly falling into irrelevance around the end of the decade. More or less in parallel with this development, the telestreet movement was spearheaded by Franco Berardi, also known as Bifo, who was also involved in Radio Alice, mentioned above. OrfeoTv was started in 2002 and used modified consumer-grade television receivers for pirate television broadcast (see Telestreet, the Italian Media Jacking Movement, 2005). Although the telestreet initiative happened on a much smaller scale than the other developments outlined above, it is noteworthy because telestreet operators reverse-engineered mass products in the same manner as hardware hackers do.

Taking a cue from Situationism with its principal idea of making interventions in the communication flow as its point of departure, the media activists sought to expand what they called *culture jamming* into a popular practice by emphasising a folkloristic element (Critical Art Ensemble, 2001). Similarly to the proletarian educational initiatives of the classical workers' movements (*cf.* Burgmann 2005, p.8 on Proletarian Schools), such an approach brought to the fore issues of access, frequency regulations, popular education, editorial policies and mass creativity, all of which pointed in the direction of lowering the barriers of participation for cultural and technological production in tandem with establishing a distributed communication infrastructure for anticapitalist organising. Many media activists adhered to some version of Gramsci's theory of cultural hegemony, taking the stand that cultural and educational work is as important as directly challenging property relations. Indeed, this work was seen as in continuation with overturning those property relations in the area of media, culture and technology. This tendency to stress the importance of information for the mechanism of social change was further strengthened by claims popularised by Michael Hardt and Antonio Negri that immaterial and linguistic labour are the hegemonic mode of production in the contemporary configuration of capitalism (2002; 2004). At the extreme end of this spectrum, some argued that decisive elements of politics depend on a performance of representation, often technologically mediated, placing media activism at the centre of the struggle against state and capitalism. Irrespectivly of these ideological beliefs, however, what distinguished the media practitioners in terms of identity is that they did not see themselves simply as outsiders or service providers, but as an integral part of a social movement. As Söderberg demonstrates (2011), political convictions of a user community can be an often overlooked enabler of technological creativity.

These two intertwined tendencies came together in the creation of hacklabs. Squats, on the one hand, closely embedded in the urban flows of life, had to use communication infrastructures such as Internet access and public access to terminals. Media activists, on the other hand, who are more often than not also grounded in a a local community, needed venues to convene, produce, teach and learn. As Marion Hamm observes when discussing how physical and virtual spaces enmeshed due to the activists' use of electronic media communication,

> This practice is not a virtual reality as it was imagined in the eighties as a graphical simulation of reality. It takes place at the keyboard just as much as in the technicians' workshops, on the streets and in the temporary media centres, in tents, in socio-cultural centres and squatted houses. (Translated by Aileen Derieg, 2003).

One example of how these lines converge is the Ultralab in Forte Prenestino, an occupied fortress in Rome which is also renowned for its autonomous politics in Italy. The Ultralab is declared to be an emergent pattern on its website (AvANa.net, 2005), bringing together various technological needs of the communities supported by the Forte. The users of the social centre have a shared need for a local area computer network that connects the various spaces in the squat, for hosting server computers with the websites and mailing lists of the local groups, for installing and maintaining public access terminals, for having office space for the graphics and press teams, and finally for having a gathering space for the sharing of knowledge. The point of departure for this development was the server room of AvANa, which started as a bulletin board system (BBS), that is, a dial-in message board in 1994 (Bazichelli, 2008, p.80-81). As video activist Agnese Trocchi remembers,

> AvANa BBS was spreading the concept of Subversive Thelematic: right to anonymity, access for all and digital democracy. AvANa BBs was physically located in Forte Prenestino the older and bigger squatted space in Rome. So at the end of the 1990's I found myself working with technology and the imaginative space that it was opening in the young and angry minds of communities of squatters, activist and ravers. (quoted in Willemsen, 2006)

AvANa and Forte Prenestino connected to the European Counter Network (now at ecn.org), which linked several occupied social centres in Italy, providing secure communication channels and resilient electronic public presence to antifascist groups, the Disobbedienti movement, and other groups affiliated with the autonomous and squatting scenes. Locating the nodes inside squats had their own drawbacks, but also provided a certain level of physical and political protection from the authorities.

Another, more recent example is the short lived Hackney Crack House, a hacklab located on 195 Mare Street in London. This squat situated in an early Georgian house was comprised of a theatre building, a bar, two stores of living spaces and a basement that housed a bicycle workshop and a studio space (*cf.* Foti, 2010). The hacklab provided a local area network and a media server for the house, and served as a tinkering space for the technologically inclined. During events like the Free School, participants, including both absolute beginners and more dedicated hobbyists, could learn to use free and open source technologies, network security and penetration testing. Everyday activities ranged from fixing broken electronics through building large-scale mixed media installations to playing computer games.

The descriptions given above serve to indicate how hacklabs grew out of the needs and aspirations of squatters and media activists. This history comes with a number of consequences. Firstly, that the hacklabs fitted organically into the anti-institutional ethos cultivated by people in the autonomous spaces. Secondly, they were embedded in the political regime of these spaces, and were subject to the same forms of frail political sovereignty that such projects develop. Both Forte Prenestino and Mare Street had written and unwritten conducts of behaviour which users were expected to follow. The latter squat had an actively advertised Safer Places Policy, stating for instance that people who exhibit sexist, racist, or authoritive behaviour should expect to be challenged and, if necessary, excluded. Thirdly, the politicised logic of squatting, and more specifically the ideology behind appropriative anarchism, had its consequences too. A social centre is designated to be a public institution whose legitimacy rests on serving its audience and neighbourhood, if possibly better than the local authorities do, by which the risk of eviction is somewhat reduced . Lastly, the state of occupation fosters a milieu of complicity. Consequently, certain forms of illegality are seen as at least necessary, or sometimes even as desirable. These factors are crucial for understanding the differences between hacklabs and hackerspaces, to be discussed in Section 3.

A rudimentary survey based on website registrations (see Figure 1 above), desktop research and interviews shows that the first hacklabs were established in the decade around the turn of the millennium (1995-2005). Their concentration to South Europe has been underlined by the organisation of yearly Hackmeetings in Italy, starting in 1998. The Hackmeeting is a gathering where practitioners can exchange knowledge, present their work, and enjoy the company of each other. In North Europe plug'n'politix, hosted first by Egocity (a squatted Internet cafe in Zurich, Switzerland) provided a meeting point for like-minded projects in 2001. A network by the same name was established and a second meeting followed in 2004 in Barcelona. In the meantime, Hacklabs.org (defunct since, 2006) was set up in 2002 to maintain a list of hacklabs, dead or alive, and provide news and basic information about the movement. A review of the advertised activities of hacklabs show workshops organised around topics like free software development, security and anonymity, electronic art and media production.

The activities of Print, a hacklab located in a squat in Dijon which is called Les Tanneries, show the kinds of contributions that came out of these places. People active in Print have maintained a computer lab with free Internet access for visitors to the social centre, and a collection of old hardware parts that individuals could use to build their own computers. They have organised events of various sizes (from a couple of people to a thousand) related to free software, like a party for fixing the last bugs in the upcoming release of the Debian GNU/Linux operating system. Furthermore, they have provided network support and distributed computers with Internet access at a European gathering of Peoples' Global Action, a world-wide gathering of grassroots activists connected to the alterglobalisation movement. In a similar vein, they have staged various protests in the city calling attention to issues related to state surveillance and copyright legislations. These actions have built on a tradition of setting up artistic installations in various places in and around the building, the most striking example being the huge graffiti on the firewall spelling out 'apt-get install anarchism'. It is a practical joke on how programs are set up on Debian systems, so practical that it actually works.

Another example from South Europe is Riereta in Barcelona, a hacklab occupying a separate building that hosts a radio studio ran by women. The activities there gravitate around the three axes of free software, technology, and artistic creativity. However, as a testimony of the influence from media activism, most projects and events are concentrated on media production, such as real time audio and video processing, broadcasting and campaigning against copyright and other restrictions to free distribution of information. The list of examples could easily be made longer, demonstrating that most hacklabs share similar ideas and practicesand maintains links with alterglobalisation politics, occupied spaces and (new) media activism.

To summarise, due to their historical situatedness in anticapitalist movements and the barriers of access to the contemporary communication infrastructure, hacklabs tended to focus on the adoption of computer networks and media technologies for political uses, spreading access to dispossesed and championing folk creativity.

SECTION 2: HACKERSPACES

It is probably safe to state that hackerspaces are at the height of their popularity at the moment. As mentioned in the introduction, many different institutions and initiatives are now calling themselves *hackerspaces*. At least in Europe, there is a core of more or less community-led projects that define themselves as hackerspaces. The case of hacklabs have already been described, but it is merely one example from the extreme end of the political spectrum. There are a number of more variations populating the world, such as fablabs, makerlabs, telecottages, medialabs, innovation labs and co-working spaces. What distinguishes the last two from the others (and possibly also from fablabs) is that they are set up in the context of an institution, be that a university, a company or a foundation. More often than not , their mission is to foster innovation. Such spaces tend to focus on concrete results like research projects or commercial products. Telecottages and telehouses occupy the middle of the range- They are typically seeded from development funds to improve local social and economic conditions through ICTs. Even makerlabs are sometimes commercial ventures (like Fablab in Budapest, not to be confused with the Hungarian Autonomous Centre for Knowledge mentioned above), based on the idea of providing access to tools for companies and individuals as a service. Fablabs may be the next generation of the hackerspace evolution, focusing on manufacturing of custom built objects. It is framed as a re-imagining of the factory with inspiration from the peer production model (MIT's Center for Bits and Atoms, 2007). What sets hackerspaces apart — along with most fablabs — is that they are set up by hackers for hackers with the principal mission of supporting hacking.

This is therefore the right point in the paper to dwelve on the social and historical phenomena of hacking. This is not to say that hacklabs — as is indicated by their name — would be less involved in and inspired by the hacker tradition. A separate study could be devoted to these two movements' embeddedness in the free software movement. However, since both movements are contributing to an equal extent but in different ways, this aspect will not be elaborated here at length as the contrast would be more difficult to tease out. It is hence assumed that much of what is said here about hacker culture and its influence on the hackerspace movement applies equally to hacklabs.

The beginnings of the hacker subculture are well-documented. Interestingly, it also starts in the 1960s and spreads out in the 1970s, much like the history of the autonomous movement. Indeed, in a sense it can be considered as one of the youth subcultures which Wallerstein attributes to the *cultural shock* of 1968 (2004). In order not to be lost in the mythology, the story will be kept brief and schematic. One hotbed seems to have been the university culture epitomised by the MIT Artificial Intelligence Laboratory and cultivated in half a dozen other research institutes around the USA. Another one was the phreaker scene that found its expression in the Yippie spinoff magazine TAP. While the former were working on engineering breakthroughs such as early computers and operating systems, as well as on networks precursoring the Internet, the latter were doing the opposite: reverse-engineering information and communication technologies, which mainly meant telephone networks at the time. In 1984 AT&T was broken into smaller companies — the Baby Bells, but not before important parts of the network had been shut down by phreakers (Slatalla & Quittner 1995, Sterling, 1992). The same year saw the last issue of TAP and the first issue of the still active 2600 magazine. The university culture was preserved in the *Jargon File* in 1975 which is still maintained (Steele & Raymond, 1996). It was the inventor of cyberpunk, William Gibson, popularised the term cyberspace in his novel Neuromancer. He thus inspired the cyberpunk subculture which gave a complete — if not "real" — Weltanschauung to hacker culture. The idea of a dark future where freedom is found on the fringes and corporations rule the world spoke to both the university hackers and the phreakers. The stars of the phreaking underground had been persecuted by law authorities for their pranks on the communication giants, while Richard Stallman — 'the last of the [first generation of] true hackers' (Levy, [1984] 2001) — invented free software in 1983 and set out to fight the increasing privatisation of knowledge by corporations, as could then be seen in the expansion of copyright claims to software, the spread of non-disclosure agreements, and the mushrooming of start-up companies.

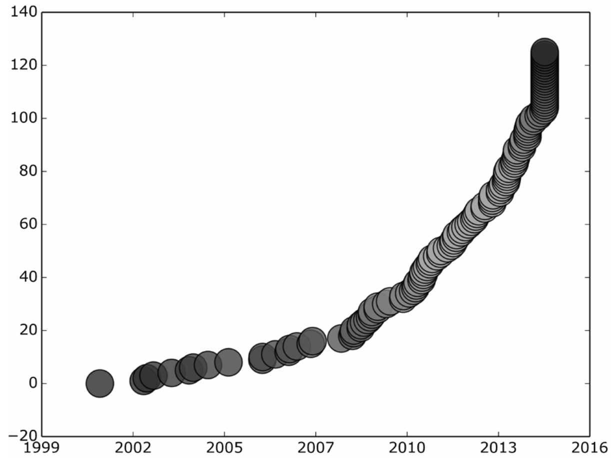

Fig.2. Years when hackerspaces were started, self-reported data from the database of hackerspace.org community website

The history of the hacker movement in Europe has been less well documented. An important instance is the Chaos Computer Club which was founded in 1981 by Wau Holland and others sitting in the editorial room of the taz paper in the building of Kommune I., a famous autonomous squat (Anon, 2008, p.85). The Chaos Computer Club entered into the limelight in 1984. Hackers belonging to the club had wired themselves 134,000 Deutsche Marks through the national videotex system, called Bildschirmtext or BTX. The Post Office had practical monopoly on the market with this obsolete product, and claimed to maintain a secure network even after it had been notified about the exploit. The money was returned the next day in front of the press. This began the Club's tumultuous relationship with the German government that lasts until today.

In their study of the hacker culture, Gabriella Coleman and Alex Golub have argued that as far as it hangs together, this subculture manifests an innovative yet historically determined version of liberalism, while in its manifold trends it expresses and exploits some of the contradictions inherent to the same political tradition (2008). They concentrate on three currents of hacker practice: cryptofreedom, free and open source software, and the hacker underground. However, they do not claim that these categories would exhaust the richness of hacker culture. On the contrary, in a review article in the Atlantic, Coleman (2010) explicitly mentions that the information security scene has been underrepresented in the literature about hackers. The three tendencies identified in their text differ slightly from the classification I am suggesting here. Stallman's legal invention and technical project cemented free software as one pillar of hackerdom for the coming decades. The exploits of the phreakers opened a way for the hacker underground where its initial playfulness developed in two directions, towards profit or politics.

In Europe, the stance of the Chaos Computer Club paved the way for independent information security research. Admittedly, all of those approaches concentrated on a specific interpretation of individual freedom, one which understands freedom as a question of knowledge. Moreover, this knowledge is understood to be produced and circulated in a network of humans and computers — in direct contrast to the version of liberalism associated with romantic individualism, as Coleman and Golub observes. Therefore, this is a technologically informed antihumanist liberalism. Hackers carve out different positions within these parameters that sometimes complement and sometimes contradict each other. The free software community sees the universal access to knowledge as the essential condition of freedom. The hacker underground wields knowledge to ensure the freedom of an individual or a faction. *Gray hat* information security experts see full disclosure as the best way to ensure the stability of the infrastructure, and thus the freedom of communication. Full disclosure refers to the practice of releasing information and tools revealing security flaws to the public. This idea goes back to the tradition of 19th century locksmiths, who maintained that the best locks are built on widely understood principles instead of secrets: the only secret, to be kept private, should be the key itself (Hobbs, Tomlinson & Fenby, 1868, p.2 cited in Blaze 2003; as well as Cheswick, Bellovin & Rubin, 2003, p.120). The idea that freedom depends on knowledge and, in turn, knowledge depends on freedom, is articulated in the hackers aphorism attributed to Stewart Brand: 'Information wants to be free.' (Clarke, 2001).

During the course of the 1990s the hacker world saw the setting up of institutions that have been in place up until now. From all three sub-traditions mentioned above have grown distinct industries, catering to fully employed professionals, precarious workers, and enthusiasts alike. The Electronic Frontier Foundation was established in 1990 in the United States to defend and promote hacker values through legal support, policy work and specific educational and research projects. It occupies a position very different but comparable to the Chaos Computer Club in Europe. Early EFF discourse like John Perry Barlow's *A Declaration of the Independence of Cyberspace* invokes the Western movie narrative of an indigenous territory prone to be occupied by the civilising East. It is littered withreferences to the Founding Fathers and the U.S. Constitution (1996). Conferences, gatherings and camps addressing the three tendencies above became extremely popular, similarly to how the film industry increasingly relied on festivals. The Chaos Communication Congress has run from 1984 and is now the most prominent event in Europe, while in the USA H.O.P.E. was organised in 1994 by the people around the 2600 magazine, and is still going strong. Hacker camping was initiated by a series of events in Netherlands running since 1989. These experiences solidified and popularised the hacker movement and the desire for permanent hacker spaces was part of this development.

As Nick Farr (2009) has pointed out, the first wave of pioneering hackerspaces were founded in the 1990s, just as were hacklabs. L0pht stated in 1992 in the Boston area as a membership based club that offered shared physical and virtual infrastructure to select people. Some other places were started in those years in the USA based on this "covert" model. In Europe, C-base in Berlin started with a more public profile in 1995, promoting free access to the Internet and serving as a venue for various community groups. These second wave spaces 'proved that hackers could be perfectly open about their work, organise officially, gain recognition from the government and respect from the public by living and applying the Hacker ethic in their efforts' (Farr, 2009). However, it is with the current, third wave that the number of hackerspaces begun to grow exponentially and it developed into a global movement of sorts. I argue that the term hackerspaces was not widely used before this point and the small number of hackerspaces that existed were less consistent and did not yet develop the characteristics of a movement. Notably, this is in constrast with narrative of the hacklabs presented earlier which appeared as a more consistent political movement.

Several accounts (*cf.* Anon, 2008) highlight a series of talks in 2007 and 2008 that inspired, and continue to inspire, the foundation of new hackerspaces. Judging from registered hackerspaces, however, the proliferation seems to have started earlier. In 2007 Farr organised a project called Hackers on a Plane, which brought hackers from the USA to the Chaos Communication Congress, and included a tour of hackerspaces in the area. Ohlig and Weiler from the C4 hackerspace in Cologne gave a ground-braking talk on the conference entitled 'Building a Hackerspace' (2007). The presentation defined the hackerspace design patterns, which are written in the form of a catechism and provide solutions to common problems that arise during the organisation of the hackerspace. More importantly, it has canonised the concept of hackerspaces and put the idea of setting up new ones all over the world on the agenda of the hacker movement. When the USA delegation returned home, they presented their experiences under the programmatic title *Building Hacker Spaces Everywhere: Your Excuses are Invalid*. They argued that *'four people can start a sustainable hacker space'*, and showed how to do it (Farr *et* *al*. 2008). The same year saw the launch of hackerspaces.org, in Europe with *Building an international movement: hackerspaces.org* (Pettis *et al*. 2008), and also in August at the North American HOPE (Anon, 2008). While the domain is registered since 2006, the Internet Archive saw the first website there in 2008 listing 72 hackerspaces. Since then the communication platforms provided by the portal became a vital element in the hackerspaces movement, sporting the slogan, 'build! unite! multiply!' (hackerspaces.org, 2011). A survey of the founding date of the 500 registered hackerspaces show a growing trend from 2008 (see Figure 2 above).

Notably, most of these developments focused on the formal characteristics of hackerspaces, for instance how to manage problems and grow a community. They emphasised an open membership model for maintaining a common workspace that functions as a cooperative socialising, learning and production environment. However, the content of the activities going on in hackerspaces also shows great consistency. The technologies used can be described as layers of sedimentation: newer technologies take their place alongside older ones without it becoming entirely obsolete. First of all, the fact that hackers collaborate in a physical space meant a resurgence of work on electronics, which conjoined with the established trend of tinkering with physical computers. A rough outline of connected research areas could be (in order of appearance): free software development, computer recycling, wireless mesh networking, microelectronics, open hardware, 3D printing, machine workshops and cooking.

From this rudimentary time line, it is evident that activities in hackerspaces have gravitated towards the physical. The individual trajectories of all these technology areas could be unfolded, but here the focus will be on microelectronics. This choice of focus is merited because microelectronics played a key role in kickstarting hackerspaces, as evidenced by the popularity of basic electronic classes and programmable microcontroller workshops in the programme of young hackerspaces. Physical computing was layed out by Igoe and O'Sullivan in *Physical Computing: Sensing and Controlling the Physical World with Computers* (2004), and had a great impact on the whole computing scene. This new framework of human-machine interaction stressed the way people behave in everyday situations using their whole body, and opened the way for exploratory research through the construction of intelligent appliances. The next year O'Reilly Media started to publish *Make Magazine* which focuses on do-it-yourself technology, including tutorials, recipes, and commentary. Among the authors one find many of the celebrities of the hacker subculture. 'The first magazine devoted to digital projects, hardware hacks, and DIY inspiration. Kite aerial photography, video cam stabiliser, magnetic stripe card reader, and much more.' (Make Magazine, 2011). In Europe, Massimo Banzi and others started to work on the invention of Arduino, a programmable microcontroller board with an easy-to-use software interface. This amateur-friendly microcontroller system became the staple of hackerspaces and artists' workshops and initiated a whole new generation into rapid prototyping and electronics work. To put it together, physical computing provided a theoretical area to be explored, and the Arduino became its killer application, while *Make magazine* and similar media facilitated the spread of research results. It is open to speculation how this trend fits into the bigger picture of what seems to be a shift in sensibilities in society at large. If the 1990s was marked by a preoccupation with discourses and languages, preeminence is now given to materialities and embodiedness.

The Hungarian Autonomous Center for Knowledge in Budapest is a fairly typical third wave hackerspace. It was founded in 2009 after a presentation at the local new tech meetup, itself inspired by the hackerspaces presentation in Berlin (Stef, 2009). The location is comprised of a workspace, kitchen, chill-out room and terrace in an inner city cultural centre which hosts ateliers for artists along with a pub and some shops. The rent is covered by membership fees and donations from individuals, companies and other organisations. Members are entitled to a key, while visitors can look up when the space is open thanks to a real time signal system called Hacksense. It displays the status of the lab on the website, the twitter account and a database. Thus, visitors are welcome any time, and especially at the announced events that happen a few times every month. These include meetings and community events, as well as practical workshops, presentations and courses. In line with the hackerspaces design patterns, orientating discussions happen weekly on Tuesdays, where decisions are made based on a rough consensus. Hackathons are special events where several people work on announced topics for six hours or a whole day. These events are sometimes synchronised internationally with other hackspaces. However, most of the activity happens on a more ad-hoc basis, depending on the schedule and the whim of the participants. For this reason, the online chat channel and the wiki website are heavily used for coordination, documentation and socialisation. Projects usually belong to one or more individual, but some projects are endorsed by almost everybody.

Among the projects housed at Hungarian Autonomous Center for Knowledge, some arepure software projects. A case in point isf33dme, a browser-based feed reader. f33dme is a popular project in the hackerspace and as more people adopt it for their needs, it gets more robust and more features are added over time. Although this is nothing new compared to the free software development model found elsewhere, the fact that there is an embodied user community has contributed to its success. There are also 'hardware hacks' like the SIDBox, which is built from the music chip from an old Commodore C64 computer, adding USB input and a mini-jack output. This enables the user to play music from a contemporary computer using the chip as an external sound card. An ever expanding 'hardware corner' with electronic parts, soldering iron and multimeters facilitates this kind of work. There is also a 3D printer and tools for physical work. The members are precarious ICT workers, researchers at computer security companies, and/or students in related fields. It is a significant aspect of the viability of the hackerspace that quite a few core members work flexible hours or work only occasionally, so at least during some periods they have time to dedicate to the hackerspace. Some of the activities have a direct political character, mostly concentrating on issues such as open data, transparency and privacy. Noteworthy are the collaboration with groups who campaign for information rights issues in the European Parliament and in European countries, or helping journalists to harvest datasets from publicly available databases. The hackerspace sends delegations which represents it atevents in the global hackerspace movement, such as the aforementioned Congress and the Chaos Communication Camp, and smaller ones such as the Stadtflucht sojourn organised by Metalab, a hackerspace in Vienna (Metalab, 2011).

To conclude, the emergence of hackerspaces is in line with a larger trajectory in the hacker movement, which gradually has gained more institutional structures. The turn towards the physical (mainly through utilising micro-controlers) marked the point when hackerspaces became widespread, since development and collaboration on such projects is greatly facilitated by having a shared space. While most discourse and innovation in the community was focused on the organisational form rather than the political content of hackerspaces, such less defined and more liberal-leaning political content allowed the movement to spread and forge connections in multiple directions without loosing its own thrust: from companies through civil society to a general audience.

SECTION 3: HACKLABS AND HACKERSPACES

Having outlined the parallel genealogies of hacklabs and hackerspaces, , it is now possible to contrast these ideal types with each other and make some comparative observations. For the sake of brevity, only a few points will be highlighted in this section. Hopefully, these will further clarify the differences between labs and spaces and provide some useful critierias for further research.

An interesting occasion presented itself in 2010 for making a direct comparison between the Hackney Crack House hacklab and the Hungarian Autonomous Center for Knowledge hackerspace. I then had first hand experience of the distinct ways in which the hacklab and the hackerspace developed and presented one and the same artifact. The artifact in question is called *Burnstation*. Even a brief sketch of the different directions in which Burnstation was developed can serve to illuminate some key points deriving from the conceptual and historical genealogies put forth above. The Burnstation is a physical “kiosk” that enables the user to browse, listen, select, burn to CD or copy to USB audio files from a music database (Rama Cosentino & platoniq, 2003). The original Burnstation was invented in the riereta in Barcelona, which started as a hacklab with a media focus in 2001 and became institutionalised in 2005, when it received funding from the local authorities — which means it is more of a hackerspace nowadays. Underlying this transformation, it is also registered on hackerspaces.org. The many variations of Burnstation have been displayed publicly in various exhibition contexts as well as being widely used in hacklabs and hackerspaces.[1]

The most striking difference between the two recent reimplementations of Burnstation is that in the version built by the hacklab people, the original concept was altered so that the music collection includes exclusively Creative Commons licensed material that can be freely distributed to an anything-goes library, including many files which are illegal to copy. The message was therefore changed radically from the consumption and celebration of the fruits of a new kind of production regime to one that emphasised piracy and transgression. The

1 Snapshots of the original Burnstation and its two derivatives (figure 4 [Rama *et al*], figure 5 [HCH] figure 6 [H.A.C.K]) are available here: http://peerproduction.net/issues/issue-2/peer-reviewed-papers/hacklabs-and-hackerspaces/

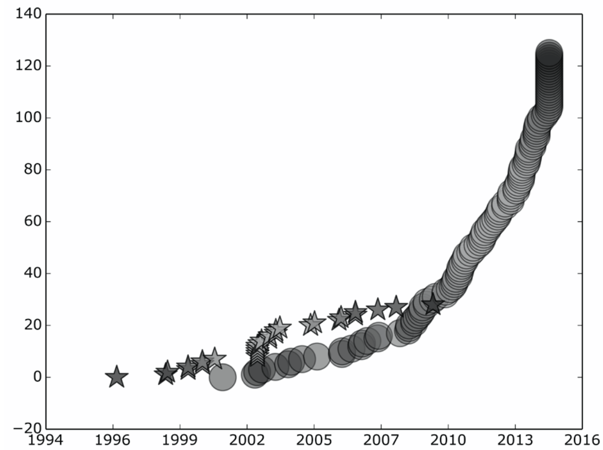

Fig.3. The two previous figures superimposed for the sake of clarification.

public display of the installation was a statement against the Digital Economy Act that just came into force in the United Kingdom. The act criminalised file sharing and threatened to suspend Internet access in cases where intellectual property rights were violated (Parliament of the United Kingdom, 2010). Thus the installation was promoting illegal activity in direct opposition to the existing state policies — which was not as controversial as it sounds since the venues and exhibitions where it was on show were themselves on a frail legal footing. In contrast, the Burnstation developed by the hackerspace appeared in an exhibition on the 300th birthday of copyright in a prestigious institution, showcasing the alternative practices and legislative frameworks to the traditional view of intellectual property rights.

Another aspect of the difference between the two installations was apparent in the solutions for user interaction. The hackerspace version was based on an updated version of the original software and hardware: a user-friendly web interface running behind a touch screen. The hacklab version, on the other hand, reimplemented the software in a text-only environment and had a painted keyboard, providing a more arcane navigation experience. Moreover, the exhibited installation was placed in a pirate-themed environment where the computer could only be approached through a paddling pool. The two different approaches correspond to the two broad trends in interface design: while one aims at a transparent and smooth experience, the other sets up barriers to emphasise the interface in a playful way. To conclude, the hackerspace members created an alternative experience that fitted in more smoothly into the hegemonic worldview of intellectual property and user-friendliness, while the hacklab crew challenged the same hegemonic notions, foregrounding freedom and desire. At the same time, it is plain to see that many factors tie the two projects together. Both groups carried out a collective project open for collaboration and built on existing results of similar initiatives, using low-tech and recycled components creatively. Ultimately, both projects marked a departure from preconfigured and consumerist relations with technology. In different ways, their interventions sought to put in question existing copyright law.

Generally speaking, technological choices made in the two types of spaces described above seem to be conditioned by two factors: the historical lineage and the political-cultural surrounding. Since the hacklabs bloomed at a time when

Internet access and even computers were a scarce resource and desktop computing with free software was not trivial, their contribution in the area of access and network technologies was crucial. Moreover, their contribution to technological development and political messages — for example in the case of the Indymedia network — fitted into the pattern of the alterglobalisation movement, while sharing some of the same defaults. Similarly, a few years later, hackerspaces pushed the limits of currently available technology by embracing and advancing microcontrollers and 3D printers. At the time of writing, they are the only spaces where a general public can freely access and learn about such devices, although it is not clear whether these will become as ubiquitous in daily life as computers and networks. The important difference is that the hackerspaces are not embedded and consciously committed to an overtly political project or idea. Of course this does not prevent political projects from being undertaken in hackerspacesIn the best of cases, the absence of an openly declared ideology will potentially lead to a wider diffusion of the project. In the worst case, however, the lack of a political consciousness leads to the reproduction of dominant power structures orientated towards white middle class tech-savvy males, a claim to be investigated below.

A more abstract issue to address in order to highlight the structural differences between hacklabs and hackerspaces is their policy and practices towards inclusion and exclusion. On the one hand, the autonomous or anarchist orientation of hacklabscontrasts sharply with the liberal or libertarian orientation of most hackerspaces. On the other hand, since hacklabs are more integral to a wider political movement, non-technological aspects play a bigger role in how they are run. A concrete example is that while sexism and similarly offensivebehaviours are mostly seen as legitimate reasons for excluding an individual from hacklabs, in hackerspaces such issues are either highly controversial and discussed at length to no avail (as in Metalab) or simply a non-topic (as in H.A.C.K.). Still, a lecture and discussion at the latest Chaos Communication Camp found that although hacker culture is still overwhelmingly male-oriented, it has become more and more welcoming to women and sexual minorities in the last decade (Braybrooke, 2011).

The different priorities of hacklabs and hackerspaces can be demonstrated with their diverging policies on wheelchair accessibility. While the hacklab in London described above was not wheelchair accessible, a ramp has been built for the house itself to be so. Discussions about open training sessions included the issue, and a temporary computer room was planned on the ground floor. In a similar vein, the hackerspace called Metalab in Vienna was made wheelchair accessible, and even a wheelchair toilet was installed that a regular visitor was using. However, with time it was decided that the darkroom would take the place of the wheelchair toilet, practically excluding the person from the space. A similar change occurred with the shower, which was taken over by the expansion of the machine workshop (Anon, 2011). This affected a more or less homeless person who most often came to the hackerspace to play chess. These decisions show the reversal of an exceptionally inclusive social and spatial arrangement because of a prioritised focus on technology, coupled with the primacy assigned to collective interests over minority needs. Hacklabs, especially if they reside in occupied spaces, are less inclined to make such decisions, partly because of the ethos of the public space that often comes with occupations, and especially in social centres. However, it has to be notes that while accessibility and non-discriminations are legitimate grounds for debate in hacklabs but not necessarily in hackerspaces, as the above example shows even hacklabs have made little practical progress on the issue.

Finally I would like to make apoint about the political impact of these diverging constellations, and ask to what extent and in which ways they contribute to and support postcapitalist practices, movements and subjectivities. The hacklabs gave a technological advantage to grassroots political movements, pioneering access to information and communication technologies and innovative solutions in an era where access was not available to most people as a consumer service. On the downside, those initiatives often got stuck in what has could be called an 'activist ghetto' or an "underground", which meant that even the Burnstation project described above was only available to a limited social group. Through a process that Granzfurthner and Schneider describe as the capitalist co-optation of the fertile resistance inherent in such scenes (2009), the hackerspaces managed to go beyond these historical limits and forged important connections. The latter continue to have a lasting impact through the technological artifacts — both abstract and physical — that they create, as well as the innovation and most importantly the education that they practice. The case of 3D printers, which according to Jakob Rigi can revolutionise production processes and create the conditions for a society based on craftsmanship rather than factories, is but one case in point (2011). Moreover, thanks to their more open dynamics, hackerspaces can foster collaboration between a wide range of social actors. For the hacker culture that has managed to catapult itself to the front pages of international newspapers in the last few years, it is of immense significance to have acquired a global network of real workshop spaces that provide an infrastructure. In the current global political atmosphere dominated by an array of crises, this scene shows vitality and direction. However, as the superuser command says, 'With great power comes great responsibility'.

The appreciation of history is not about passing judgement on the old and the dead, but it is there to inspire present efforts. As *Théorie Communiste* argues, each cycle of struggle brings something new based on what happened before, thereby expanding the historical limits of the struggle (Endnotes, 2008). Perhaps the political potential of hackerspaces lies precisely in the fact that they have not become a social movement and therefore not limited by the conventions of social movements. They stand at the intersection of the dystopian 'geeky workshop paradises' (Granzfurthner and Schneider, 2009) and the utopian reality of genuinely contestant spaces that have wide impact. If more hackers can combine the technological productivity of the 'hands-on imperative' (Levy, 2001) and the wide possibilities of transversal cross-pollination of hackerspaces with the social critique of the hacklabs, there is a world to win.

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