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

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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 re-

production 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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INTERVIEWS

Adrian Bowyer, 2009-11-24. Initiator of the Rep-rap project, author of *Darwinian Marxism*, Bath, UK.

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.

Erik de Bruijn, 2009-11-11. Core developer of Rep-rap and founder of the firm Ultimaker, Eindhoven, Netherlands.

Forrest Higgs, 2011-11-03. Former core developer of Rep-rap, initiator of Tommelise 3D printer. phone interview.

Gustav Nipe, 2009-12-23. Promoter of Rep-rap in Sweden. Initiator of the Swedish Pirate Partys' 'Pirate factory', Lund, Sweden.

Ian Adkins & Iain Major, 2009-11-26. Founders of Bits-from-Bytes, the first firm based on selling Rep-rap derivatives, Clevedon, UK.

Josef Prusa, 2011-09-19. Principal architect of the Prusa Rep-rap design, New York, USA.

Lambert Anders, 2011-09-19. One of two founders of Techzone, New York, USA.

Lawrence Kincheloe, 2009-11-10. Promoter of open manufacturing. phone interview.

Markus Hitter, aka Traumflug, 2011-09-11. Maintainer of Gen 7 electronics. phone interview.

Nick & Bruce Wattendorf, 2011-09-18. Promoters of Rep-rap in the New England area, built the third Rep-rap Darwin machine in the world, New York, USA.

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

Hydraraptor http://hydraraptor.blogspot.com/

Clanking replicator http://www.3dreplicators.com/

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