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ORIGINAL ARTICLE

Open hardware as an experimental commercialization strategy: challenges and potentialities

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ABSTRACT

This article discusses a recent knowledge transfer (KT) case of CERN flagship open source hardware (OSH) technology commercialization for high frequency trading time stamping purposes. The case seems at first sight as KT success story par excellence: it enables viable business model without eroding market prices, increases the industrial innovation adoption clockspeed, and the technical complexity and operational importance of the adopted technology are high. However, questions of development community engagement, and sustainability of the core OSH technology and infrastructure resourcing models are raised, as they are of essence and actuality for the fast-growing CERN OHS community.

Keywords: Open source hardware; knowledge transfer; commercialization; community engagement; R&D&I resourcing.

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INTRODUCTION

Once separated by distinct development models and dissemination strategies, "open innovation" and "open source" projects have increasingly converged in their experimental practices. CERN is one of the major examples in which "open dissemination" models were first tried through institution-wide policies for privileging Open Source-based mechanisms for software, research data, and hardware. More recently, the proposal for "experimental innovation" was developed in the context of successful horizontal collaboration for the development of extremely large scientific instruments, such as the Atlas detector (Boisot, Nordberg, Yami, Nicquevert, 2011). This experience set the groundwork for the establishment of "experimental innovation" as a productive mode for advancing open and multi-directional dissemination from and to CERN in relation to its surrounding ecosystem (Mäkinen, Steinert, Vignoli, Birkinshaw, & Nordberg, 2017).

In this context, Open Source Hardware[1] technologies have increasingly assumed an important role, constituting both a set of new concepts, legal tools, and collaborative development practices in the sciences (Kauttu & Murillo, 2017; Pearce, 2015). Yet, most of these experiments are understudied and little is known in the literature on knowledge transfer mechanisms beyond the evidence of its potential effective diffusion and economic impact.

The question of socioeconomic impact assessment is one of the open questions. Much of what is discussed is based on "fear, uncertainty, and doubt" concerning community dynamics and economic potentialities of Free and Open Source hardware technologies. And very few empirical studies have been conducted with important exceptions such as the study of OH as an industrial practice (Bonvoisin, Mies, Boujut, & Stark, 2017) and the dynamics of OSH development in the context of Open Hardware-based instrumentation for the sciences (Pearce, 2017).

The work presented here is based on a research collaboration for the study of Open Source Hardware at CERN. Since 2017, we have been collaborating in the process of data collection and analysis of sociotechnical, legal, and economic dynamics of Free and Open Source hardware development. For the purposes of our collaboration, we contributed a survey and collected ethnographic data, such as interviews, as well as quantitative data on the CERN OSH repository and key development mailing-lists. In addition, qualitative and quantitative data was drawn from two very distinct Open Source Hardware cases: White Rabbit network technology development at CERN and its recent commercial application at Deutsche Börse. These cases are compared and contrasted by their

[1] Open Source Hardware (OSH) refers to tangible artifacts – machines, devices, or other physical things – whose design is made publicly available so that anybody can study, modify, distribute, manufacture, and sell the hardware based on that design (see: "OSH - Definition of Free Cultural Works"). In the European Organization for Nuclear Research (CERN), OSH namely refers to electronics designs (see: "OSHWA - Definition of Free Cultural Works," 2016).

differences in how the projects are economically sustained, what the community engagement dynamics are, how the competition/collaboration dynamics play out and how the supporting infrastructures are organized.

This paper is meant as a discussion opener to advance understanding of the potentialities and challenges related to the quest of seeking socioeconomic impact through experimental Open Source Hardware commercialization strategies.

SOCIOECONOMIC IMPACT OF OPEN SOURCE HARDWARE

One of the key open questions concerns the economics of Open Hardware within and beyond CERN. It is often asked if OSH can enable, for example, viable businesses at different scales without involving a public organization as a customer and/or R&D&I partner. There is strong evidence which suggests that several economically-sound OSH businesses already exist in various domains: from education to scientific instrumentation, consumer electronics to citizen science projects. The open question is rather to understand the dynamics involving community, educational, scientific, and commercial projects as they intersect through Open Hardware development in various ways. (Cuartielles, 2015; Díaz, 2015; Kasprowicz & Brona, 2015; Katz, 2015; Ros, 2015; Seidle, 2015).

The literature on the sociocultural and institutional dynamics of Free and Open Source technologies demonstrate, for instance, that projects are fundamentally organized around a tension between community, loosely-structured dynamics of collaboration and coordination of highly technical work and more structured forms of organization around companies and foundations (Currie, Murillo, & Kelty, 2010; Feller, Fitzgerald, Hissam, & Lakhani, 2007; Kelty, 2008; West & Gallagher, 2006). These dynamics are constitutive of an "ecosystem" of Free and Open Source development. Here we suggest that, in order to understand Open Source Hardware dynamics, it is important to situate existing projects in “OSH ecosystem framework” and think with existing cases, instead of for instance extrapolating from somewhat analogical business cases in the domain of Open Source Software (OSS) development. This is because there are fundamental differences in OSH vs OSS ecosystems’ operational environments, such as the relation to copyright law, to mention one; When creating open source software, a copyright protection arises automatically upon creation of the end product – that is – the code. However, this mechanism does not in most of the cases work for the OSH creation, as copyright generally is not applying on a three-dimensional utilitarian product (albeit it would apply to its design documentation - we will soon discuss more in detail the open hardware licensing in another dedicated article). (Beldiman, 2018; Katz, 2012, 2015; Rosen, 2005).

For our purposes, we focus on the question of how knowledge transfer strategies could benefit from "open hardware" dissemination strategies. To explore this question, we will describe a recent commercial adoption case based on on the flagship Open Hardware project at CERN (White Rabbit) comparing and contrasting it with a basic set of variables:

A. Economic viability: How is the hardware project and product sustained?

The importance of this dimension relies on the centrality of *value-substitution assumption* that is part of the public understanding of Open Hardware. In some reported Open Hardware adoption cases the economic value has been extrapolated from the value of similar proprietary technology. Hence, such reported cases rely on an, what we call, “substitution value assumption”: had there not been on OSH alternative, proprietary technology with comparable properties and functionalities would have been adopted. Hence, an important remaining question is whether we can find evidence of existing cases where open hardware technology has replaced an equivalent existing proprietary solution?

Open hardware can also be identified as an immaterial property strategy for any company, lowering the barriers of entry to markets in which the company is already engaged. Consequently, the prices and profit margins could be jeopardized. Hence, these dynamics could become an issue in particular in situations where product’s specificity and complexity rise – that is, in practical terms – when dealing with operationally critical and technically complex products. Therefore, another important question is whether we can find evidence of situations where complex, operation-critical OH adoption(s) have taken place on free market place without compromising the economic viability? (Díaz, 2015; Hippel & Krogh, 2003).

B. Community engagement: What kinds of community participation the project / product allows?

Beyond the user-centric aspect of OH innovation models, FOSS provides strong evidence for why expert developers dedicate their time and direct their enthusiasm towards open projects (Hippel, 2017). There are, of course, many drivers into this observable empirical reality, such as the importance of belonging in community, returning to the community what was given by it (“gifts that are too large that cannot be fully repaid”), reputational gains, professional development, educational dividends, networking opportunities, and so forth. (Belenzon & Schankerman, 2015; Benabou & Tirole, 2003; Hars & Ou, 2001; Hertel, Niedner, & Herrmann, 2003; Lakhani & Von Hippel, 2003; Lerner & Tirole, 2002; Roberts, Hann, & Slaughter, 2006; Von Krogh, Haefliger, Spaeth, & Wallin, 2012).

An important question, however, related to community engagement in Open Hardware-based knowledge transfer is, whether the development community engagement will remain strong as commercially-centered products are developed in the open? Existing cases point, for example, for the *debacle* of Open Hardware-based companies as they have turned to the commercial sector and closed their technologies. The controversial case of the promising company "Makerbot" is a case in point. It went from being one of the most important community-based startups to being acquired by a big company (Stratasys) and invested in not only patenting technologies that have been claimed to be produced by the community (which would be otherwise not only ethically problematic but, in theory, unpatentable), but also becoming a case of "turning their backs" to the very community that provided the company with their knowledge input and their sustainability. Makerbot went from being the leader in consumer-facing 3D printing manufacturer to a marginal company with meager returns with inexpressive market share. Several elements are key to this story, being the most important the fact that the company identified in the competition a risk and not a potential benefit for advancing community-based 3D manufacturing, leading to the closing of their platform and their community backlash. (Anderson, 2016).

C. Competition / collaboration dynamics: How community projects and company OH-based products and projects intersect and feed-off each other?

One of the key dynamics we observed in conducting qualitative and quantitative studies of OSH has to do with their strong "coopetitive dynamics", where collaborative and competitive dynamics represent strong vectors of OSH development. One of the claims to be empirically tested is that OSH serves as a knowledge transfer strategy to speed-up innovation clockspeed. It is basically an assumption that is transported from the FOSS context into the emergent space of OSH development: one of the distinctions between Free and Open Source versus proprietary technologies is how the former allows for much faster innovation clockspeeds. However, technology transfer experts remain strongly divided on this matter: as proprietary immaterial property strategies give a limited-duration exclusivity for exploiting the R&D&I phase results, and to cover the development phase costs, the closed immaterial property advocators tend to claim it to result in more efficient innovation processes. Without discussing further this debate here, we point out that there are supposingly very few R&D&I leaders left these days who could afford ignoring the importance of the talent pool, enthusiasm, efficiency, and simply the huge number of contributors open source user innovators, and strong FOSS communities represent on innovation ecosystems. The same seems to hold true for Open Hardware projects, but it needs further empirical verification.

From the OSS side, a well-known example of efficient community dynamics is Linux development, where experts collaborate on a common Open Source base for competitors who innovate on top of the Open platform. Other emergent dynamics have also demonstrated that once large proprietary companies are increasingly interested in investing large sums to join Open Source develop, which is attested by the recent acquisition of the biggest repository of open source software project repositories, GitHub. One urgent pending question remaining is whether we can find evidence of open source hardware knowledge transfer strategy to result in speeding up innovation clockspeed? Our assumption here is that the answer to this question is relying on the study of coopetitive dynamics.

D. What are the supporting structures of OSH projects and products?

Finding the right balance of public R&D&I players', companies' and possibly even venture capitalists' resourcing for setting up adequate supporting structures, thereby enabling FOSS communities to grow and flourish, is a major question every significant OSH community needs to address. We have identified the following conditions sine quipus non, an open source hardware community could not efficiently support efficient development activities: 1) Virtual & physical collaboration space(s), 2) Accessible (both financially and in terms of usability) digital design tools, 3) Well-functioning and legally sound framework clarifying the reciprocal licensing conditions for the contributor community.

3. Open Hardware at CERN and the White Rabbit project

Open source hardware has been introduced as a knowledge transfer mechanism in 2009 through the "Open Hardware Repository" for electronics designers at experimental physics facilities. Currently, the Repository hosts more than 100 collaborative projects and more than 1200 units based on the CERN designs have already been produced for over 100 different end-users (Nilsen & Anelli, 2016). Moreover, a legal framework, "Open Hardware License" (OHL), was put in place in 2011 ("CERN Open Hardware Licence - Cernohl - Open Hardware Repository," 2016). The OHL essentially gives anyone the right to freely exploit hardware designs with the reciprocal condition that new developments are published under the same terms. In our estimates, the lead expert user and designer community around CERN OSH projects consist of a little over 200 members worldwide with varying degrees of involvement.

White Rabbit is a CERN "flagship" OSH project: a deterministic Ethernet-based network for general purpose data transfer and sub-nanosecond accuracy time transfer. The project currently has some 32 committed partner organizations globally, out of which each is using the technology to various and very differing precision timing applications. (Lipinski, 2017).

Case: CERN White Rabbit technology commercialization at Deutche Börse

As mentioned in the introduction, the White Rabbit technology for control and timing networks has recently been applied as state-of-the-art time stamping solution at Deutsche Börse. The prototype project has been going on for the past two years and its result suggest this technology is outbeating – in terms of performance, security and development costs – the existing GPS technology-based time stamping technologies. Consequently, Deutsche Börse is now officially implementing the CERN White Rabbit technology.

Deutsche Börse currently has 200 paying clients engaged with high-frequency trading, and to whom extremely fast, precise and legally sound financial transaction time stamping is of essence (e.g. in situations where multiple mutually correlating asset prices start to very rapidly evolve, and thus ultra-fast automated position modifications are crucial). The current monthly pricing for the customers for this service is €400, and Deutsche Börse plans to charge this same price for the White Rabbit based time stamping services in the future. Moreover, Madrid stock exchange is also currently considering implementing this very same technology with help of a Spanish WR service provider, 7Solutions, and there are many stock exchanges in the world... (Diaz, 2018; Lohr, 2018).

CONCLUSION

In the light of the before-described recent OSH commercialization case at Deutche Börse, it seems that even operationally critical and technically challenging OSH technology can become economically an attractive option to proprietary technology – including in free market environment. In addition, OSH technology seems to be able to increase innovation adoption clockspeed: in the case presented, the White Rabbit technology replaces the formerly dominant GPS based time stamping technology, subject to spoofing and jamming risks, while introducing to the high frequency trading industry a novel technological solution with improved reliability and performance. However, even if OSH proved itself as a successful knowledge transfer and technology commercialization strategy in short run, it is of utmost importance, that R&D&I leaders take into careful consideration the OSH community dynamics to not lose its momentum. After all, the key asset an open source hardware knowledge transfer strategy arguable offers, is the highly committed and enthusiastic developer community.

In order to enable further commercialization knowledge transfer success stories key questions within the CERN OSH community seem to be now to find, on one hand, the right balance for enhancing contributor community dynamics while enabling commercial subprojects, and on the other hand, enable sufficient resourcing for the core technology and infrastructure developments. Well-functioning and affordable digital design tools, up to date, purposeful, and easy-to-use legal framework, and well-functioning virtual and physical collaboration spaces all require constant resourcing. Furthermore, the importance of sufficient resourcing for talented designers to create new – and constantly improve existing – OSH technologies goes without saying. Sometimes, like in the case of CERN described here, the initial OSH R&D&I infrastructure investments can mostly be covered by singly source public R&D&I funding. However, as the communities grow and create increasing number of successful not-for-profit and commercial subprojects, there are novel rising questions, such as: how to contribute a fair share back to the core technology development, and what that “fair share” should be in practise?

Hence, the question for further studies remain whether the open hardware community is willing to engage with for-profit enterprises, and in particular – arguably – with cases engaging with highly aggressive business practices, such as high-frequency trading? And, vice-versa, will the now raising private sector OH adopters play the game with gentlemen’s rules – and give a fair share back to the development community to keep and speed up the high-frequency innovation clockspeed?

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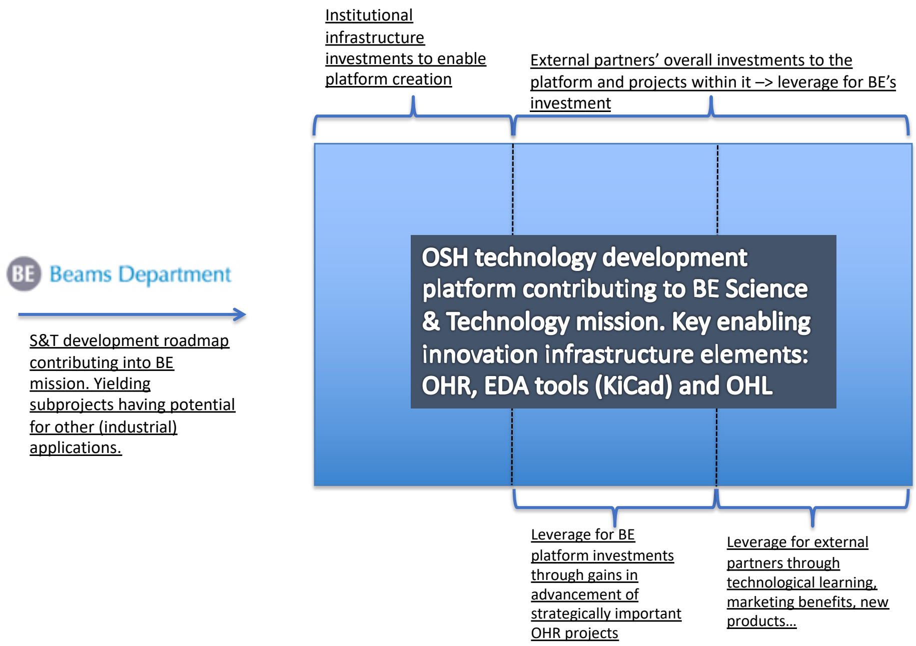

Fig. 1: Illustration of CERN OSH ecosystem's "supporting structures" based on CERN-BE Expert interviews. CERN has a small, but extremely influential and active community, which was made possible by institutional support and public funding. For the time being, OSH is essentially used at CERN for collaborative debugging and public distribution of electronics designs and, in particular, with gateware, firmware, and other hardware design files. (Serrano, 2015; Van Der Bij, 2015).

Table 1: Knowledge transfer dynamics of CERN White Rabbit open hardware technology commercial adoption at Deutsche Börse.

	Economic viability	**Community engagement**	**Competition-Collaboration dynamics**	**Supporting structures**
White Rabbit Not-for-profit community	Relying namely on CERN R&D&I funding. However, seeking options to create larger community engaging more - also financially - into the development of the core technology.	Very high. Community constantly growing globally. Question mark: will the increasing community – including for-profits - contribute a fair share back to the core technology development?	Projects benefit from the professional, highly committed engineering community.	Publicly funded EDA tools, legal framework, virtual collaboration space (open hardware repository) and physical collaboration spaces (CERN & partner laboratories' technology development infrastructures).
Deutsche Börse - White Rabbit adoption	Free market place market pricing (OSH technology adoption not eroding customer pricing). Cost-efficient R&D&I thanks to the development community.	Question mark: Will the not-for-profit development community wish to contribute into aggressive business applications?	Increased innovation clockspeed (open hardware based timestamping solution disrupting the GPS based dominant design used by the trading industry).	Privately funded in-house R&D&I infrastructure.

REFERENCES

Anderson, I. (2016, April 29). How I watched a Brooklyn start-up sellout: The downfall of MakerBot as seen from the inside. *Brokelyn*.

Beldiman, D. (2018). From Bits to Atoms: Does the Open Source Software Model Translate to Open Source Hardware? *Santa Clara High Technology Law Journal*, *35*(2), 32.

Belenzon, S., & Schankerman, M. (2015). Motivation and sorting of human capital in open innovation. *Strategic Management Journal*, *36*(6), 795–820. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/smj.2284/full

Benabou, R., & Tirole, J. (2003). Intrinsic and extrinsic motivation. *The Review of Economic Studies*, *70*(3), 489–520. Retrieved from http://restud.oxfordjournals.org/content/70/3/489.short

Boisot, Nordberg, Yami, Nicquevert. (2011). Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment at the LHC. Oxford University Press.

Bonvoisin, J., Mies, R., Boujut, J.-F., & Stark, R. (2017). What is the "Source" of Open Source Hardware? *Journal of Open Hardware*, *1*(1), 5. https://doi.org/10.5334/joh.7

CERN Open Hardware Licence - Cernohl - Open Hardware Repository. (2016, October 3). Retrieved October 3, 2016, from http://www.ohwr.org/projects/cernohl/wiki

Cuartielles, D. (2015, June 8). CERN Open Hardware Study Interview, Arduino, The United Stated of America.

Currie, M., Murillo, L. F. R., & Kelty, C. (2010). Free Software trajectories: from organized publics to formal social enterprises? Retrieved from http://peerproduction.net/wp-content/uploads/2013/07/Currie_Murillo_Kelty_Original.pdf

Díaz, J. (2015, August 31). CERN Open Hardware Study Interview, Seven Solutions, Spain.

Diaz, J. (2018, July). *WR results in 7S and the University of Granada*. Retrieved from https://www.ohwr.org/projects/white-rabbit/wiki/oct2018meeting

Feller, J., Fitzgerald, B., Hissam, S. A., & Lakhani, K. R. (2007). *Perspectives on Free and Open Source Software*. The MIT Press.

Hars, A., & Ou, S. (2001). Working for free? Motivations of participating in open source projects. In *System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on* (pp. 9–pp). IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=927045

Hertel, G., Niedner, S., & Herrmann, S. (2003). Motivation of software developers in Open Source projects: an Internet-based survey of contributors to the Linux kernel. *Research Policy*, *32*(7), 1159–1177. Retrieved from http://www.sciencedirect.com/science/article/pii/S0048733303000477

Hippel, E. von. (2017). *Free innovation*. Cambridge, MA: The MIT Press.

Hippel, E. von, & Krogh, G. von. (2003). Open source software and the "private-collective" innovation model: Issues for organization science. *Organization Science*, *14*(2), 209–223. Retrieved from http://pubsonline.informs.org/doi/abs/10.1287/orsc.14.2.209.14992

Kasprowicz, G., & Brona, G. (2015, July 8). CERN Open Hardware Study Interview, Creotech, Poland.

Katz, A. (2012). Towards a Functional Licence for Open Hardware. *International Free and Open Source Software Law Review*, 41–62. https://doi.org/10.5033/ifosslr.v4i1.69

Katz, A. (2015, July 27). CERN Open Hardware Study Interview, Moorcrofts, The United Kingdom.

Kauttu, P., & Murillo, L. F. (2017). Open hardware as an experimental innovation platform: preliminary research questions and findings. *CERN IdeaSquare Journal of Experimental Innovation*, *1*(1), 26. https://doi.org/10.23726/cij.2017.462

Kelty, C. (2008). *Two bits : the cultural significance of free software*. Durham: Duke University Press.

Lakhani, K. R., & Von Hippel, E. (2003). How open source software works:"free" user-to-user assistance. *Research Policy*, *32*(6), 923–943. Retrieved from http://www.sciencedirect.com/science/article/pii/S0048733302000951

Lerner, J., & Tirole, J. (2002). Some simple economics of open source. *The Journal of Industrial Economics*, *50*(2), 197–234. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1467-6451.00174/full

Lipinski, M. (2017, October 10). CERN The White Rabbit Project. Retrieved from http://white-rabbit.web.cern.ch/

Lohr, A. (2018, June). *White Rabbit in Financial Markets Time Distribution in Deutsche Börse's T7® Trading Network*. Power Point presented at the 10th White Rabbit Workshop - 6-7 October 2018, CERN. Retrieved from https://www.ohwr.org/projects/white-rabbit/wiki/oct2018meeting

Mäkinen, S. J., Steinert, M., Vignoli, M., Birkinshaw, J., & Nordberg, M. (2017). Inaugural Editorial: Experimentation in Innovation Studies. *CERN IdeaSquare Journal of Experimental Innovation*, *1*(1), 1. https://doi.org/10.5170/cij.2015.92

Nilsen, V., & Anelli, G. (2016). Knowledge transfer at CERN. *Technological Forecasting and Social Change*, *112*, 113–120. https://doi.org/10.1016/j.techfore.2016.02.014

OSHW - Definition of Free Cultural Works. (2016, October 3). Retrieved October 3, 2016, from http://freedomdefined.org/OSHW

Pearce, J. M. (2015). Quantifying the value of open source hardware development. *Modern Economy*, *6*(1), 1. Retrieved from http://search.proquest.com/openview/b4afff5ed983ca57c09005a51bf49aab/1?pq-origsite=gscholar

Pearce, J. M. (2017). Emerging Business Models for Open Source Hardware. *Journal of Open Hardware*, *1*(1), 2. https://doi.org/10.5334/joh.4

Roberts, J. A., Hann, I.-H., & Slaughter, S. A. (2006). Understanding the motivations, participation, and performance of open source software developers: A longitudinal study of the Apache projects. *Management Science*, *52*(7), 984–999. Retrieved from http://pubsonline.informs.org/doi/abs/10.1287/mnsc.1060.0554

Ros, E. (2015, July 20). CERN Open Hardware Study Interview, Seven Solutions, Spain.

Rosen, L. E. (2005). *Open Source Licensing Software Freedom and Intellectual Property Law*. Prentice Hall.

Seidle, N. (2015, July 8). CERN Open Hardware Study Interview, SparkFun, The United States of America.

Serrano, J. (2015, July 7). CERN Open Hardware Study Interview, CERN BE, Switzerland.

Van Der Bij, E. (2015, September 7). CERN Open Hardware Study Interview, CERN BE, Switzerland.

Von Krogh, G., Haefliger, S., Spaeth, S., & Wallin, M. W. (2012). Carrots and rainbows: Motivation and social practice in open source software development. *Mis Quarterly*, *36*(2), 649–676. Retrieved from http://aisel.aisnet.org/cgi/viewcontent.cgi?article=3039&context=misq

West, J., & Gallagher, S. (2006). Patterns of open innovation in open source software. *Open Innovation: Researching a New Paradigm*, *235*(11). Retrieved from http://infojustice.org/download/gcongress/openaccesstoresearch/west%20article.pdf