Developing standards for Open Hardware: Exploring controversies and boundaries

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According to technology industry pundits, Google is likely to begin making more of its Android operating system proprietary, rather than open source (. This has provoked concern from advocates of open source software and open knowledge who fear that this is another version of the ‘enclosure’ of commons-based knowledge. In this context it is worth asking: what does openness mean? Is an ‘open system’ or ‘open source’ required to be absolutely based in commons? To be non-proprietary? How might this ‘openness’ apply to contexts outside of software? This paper positions ‘openness’ as something between re-usable software code, institutional transparency, and expanded opportunities for participation, providing a socio-technical framework that we can use to understand the impacts of the expansion of openness from software to hardware.

Most attempts to 'open' hardware have been focused on digital electronics, and primarily on extensions of software licenses and standards that make them applicable to hardware environments. Open hardware is used by artists, amateurs, publicly-funded organizations including CERN, as well as being manufactured and sold as part of emerging “long tail” business models. There are numerous proposals for hardware standards, licenses, and reforms to patenting processes that attempt to make hardware design more ‘open’. What kinds of standardization and governance activities are developing related to hardware, within the sphere of digital electronics. The different communities of practice involved in open hardware development currently pursue a range of different licensing and standardization efforts. Rather than converging on a shared set of practices, this risks fragmenting the development of open standards and processes for hardware projects, and open hardware communities are at least in part defined by the contentions they create around these issues.

Drawing from the STS perspectives of Susan Leigh Star, we can interpret these struggles as attempts to create and negotiate boundaries. This paper presents the result of a three-year long study of the development of open hardware licenses. Based on interviews, document analysis and participant observation at open hardware conferences and other events, it analyses how proposals for licenses serve to demarcate boundaries between different interpretations of open hardware, particularly when the licenses are interpreted as not applying to particular “edge cases. It further investigates the relationship between the way standards are interpreted, and the

balance between different forms of knowledge and authority, notably the "constituted authority" of institutions versus the "adaptive authority" of loosely connected online groups (see Mansell, 2013), and analyses the ways that these different forms of authority connect with greater "openness" of knowledge production and application.

Four factors within the contemporary communicative environment create greater complexity with respect to knowledge: a more extensive networking of both communications capacities and communicative practices (Castells, 2009), and a resulting change in 1. Modes of access to knowledge; 2. Modes of distribution of knowledge, and 3. Modes of collaboration related to knowledge. These factors can increase the openness of these knowledge production environments, possibly creating a new framework for innovation. These practices are of course connected with the expansion of the internet, but the change has been not only technological but social. As Mansell and Steinmueller point out, "Intermediation in both physical and electronic space is giving rise to many new patterns and modes of communication and information exchange. Some observers claim that these new developments contain the seeds for revolutionary changes in all aspects of social and economic life, including the processes of knowledge creation and application" (2002; p. 2).

These revolutionary changes include conflicts between different forms of knowledge: Mansell (2013) outlines competing frameworks for citizen science, noting that the potential for collaborations between professional scientists and untrained "citizen" scientists produces conflicts between different forms of knowledge. While scientific institutions valorize constituted knowledge curated and structured by the kinds of entities they recognize, increasingly there is another type of scientific knowledge being created – based in an adaptive, bottom-up form of knowledge creation that draws on the activities of loosely coordinated groups. Mansell points out how, within the scientific field, crowdsourcing and digital curation of scientific practices might provide meeting points for these two forms of knowledge. Drawing on this conceptual foundation, I define openness as the ability to integrate constituted and adaptive knowledge.

1. Design processes and Frameworks for Design

The possibility of openness and balancing of different knowledge forms has a

significant impact on the innovation process. As a facilitator of future design culture and engagement, open hardware licenses join a set of other normative and cultural structures that are reformulating the expectations about how design and innovation happens, stressing the collaborative aspects of knowledge production. These cultural shifts include the rise of a "sharing economy" (John 2013), the expansion of freely available information through efforts aimed at releasing the control of intellectual property (Lessig, 2006) and the expansion of collaborative spaces for design and creation work, including FabLabs and hackerspaces (Hermann and Buching, 2013; Hunsinger, 2011). This culture of "open" production joins initiatives aimed at opening up other conceptual areas, including the "opening up" of scientific knowledge production beyond institutional spaces and in ways that encompass distributed online groups. These cultural shifts began with an interest in promoting openness with relation to *information*, since much of this could be digitized and duplicated at minimal cost*:* increasingly, it is also applying to *knowledge*. A hardware or design project is "open" when there is adequate knowledge about how it has been designed and how it could be built.

Opening design has created contestations between constituted and adaptive forms of knowledge, and between different value systems. Social science has presented two diverging modes approaches to studying these processes. Within social studies of science and technology, these processes of design have primarily been considered in terms of how specific bounded social worlds adapt technology to their own cultural frames, or how they interpret particular technologies based on their values (see Star, 2010). Other social science traditions are more focused on the construction of normative frameworks for governing technologies (see Mueller, 2010) by specifying which values (for example, human rights, privacy, accessibility) should be represented in the design of new technologies. This paper's case study integrates these two perspectives by examining how a the cultural actors involved in "open hardware" create licenses that reflect their own values, but also try and institute governing principles for open hardware design and distribution – a task that is particularly difficult because of the many ways these practices are interpreted by the cultural actors.

1. a. Social Worlds and Boundary Objects

Scholars of science and technology are often particularly interested in the way that technologies are interpreted by social worlds or communities of practice. This "interpretive flexibility" (Bijker, 1995) illustrates the way that the meaning and indeed the use of technologies are constructed by different groups of people, who often have very different ideas of the value of that technology. These groups, or "social worlds" are defined in part by their intrinsic cultural practices with respect to technology. Put another way, the social worlds of open hardware are comprised of people who might otherwise have very different cultural backgrounds and interests, but who share distinct perspectives on open hardware practice. One way to observe how this interpretive flexibility works is in relation to what Star (1989; 2010) calls a "boundary object": a "sort of arrangement that allows different groups to work together without consensus . . . . These common objects form the boundaries between groups through flexibility and shared structure—they are the stuff of action. " (Star, 2010 p. 602). These objects develop organically in situations where groups have overlapping information and work requirements, and are characterized by the language that people use to describe their work with respect to the object.

Boundary objects do not have to be physical objects but instead are often organizing principles: Star and Greisener (1989) observed how repositories structured within libraries provided ways for amateurs and professions to work together on the same collections, even though they had radically different ideas about what was appropriate scientific knowledge. The structure of the library, with its repositories structured into a catalogue, provided the ability for the amateurs to pursue one kind of scientific practice and the professionals another. In the contemporary world, various technical and social changes have intensified this simultaneous amateur/professional knowledge production. Boundary objects are therefore frameworks for organization and understanding that are situated between groups who don't agree with each other.

Star (2010) describes how sometimes boundary objects are 'ill-structured' in these relationships, although they can become better structured when social worlds with a strong shared identity work on them. However, groups that operate without consensus move back and forth between these less and more structured interpretations. Finally, when processes scale up, boundary objects become infrastructure and standards. As

Star (2010) notes, this final characteristic of boundary objects has not been well studied, and the process of license proliferation and license standardization for open hardware provides a perfect opportunity to do so. Furthermore, the case provides an illustration of how the transformation of boundary objects to infrastructure also interacts with the process of negotiation between constituted and adaptive knowledge. Bowker and Star (2008) have investigated the ways that classification and standards become instituted into infrastructures of knowledge – a phenomena that is also at work in the efforts to finally determine how open hardware should be defined, designed and distributed.

I would argue that based on the contemporary features of increasingly networked distribution of knowledge, access to knowledge and collaboration around knowledge, a more complex knowledge ecosystem is emerging, which is a more extensive version of the kinds of knowledge environment that Star described in her work. In this situation, more and more objects emerge on more and more boundaries. I would argue that under these circumstances we should move away from describing some interpretations as "well-structured" and some as "ill-structured", since this implies that there is some essential underlying structure to these objects that must be respected. Instead I would argue for a development of the concept that respects the more extensive complexity of knowledge relationships. I would propose that we should instead think of a spectrum running from a firm interpretation of a boundary object towards a more flexible one. Thinking about this kind of spectrum provides two advantages: first, it gets away from a presumption that things somehow need to be "better" structured in order to be good; and second, it lays out the groundwork through which we can analyse where more "openness" occurs, and where it is valuable.

2. Methods for Studying Boundary Objects

The "boundary object" that I am considering here is not a single "object" at all. In keeping with the way that Star considers boundary objects, I am thinking about the concept of an "open hardware" license as a boundary object operating between approximately three different social worlds. These social worlds agree (for the most

part) that open hardware needs some kind of licensing framework to govern the design process, but they also adopt the license in variously ill-structured and well-structured ways.

My observation of the social worlds and boundary objects related to open hardware began in 2008 with the observation of one proposed strategy for identifying and distributing open hardware (published as Powell, 2012). It extended to participant observation of a number of physical meetings of open source hardware advocate, including the Open Hardware Conferences in 2010 and 2011, the Open Knowledge Foundation conferences of 2009, 2011 and 2012, and finally, to membership on mailing lists dedicated to the discussion of and finally creation and refinement of, licenses related to open hardware. For the past three years I have been part of this community of practice, learning about and participating in creating licenses and standards. This form of "participatory competence" promises more robust research results but also accountability, especially to the people who identify themselves as engaging in open hardware development as a form of knowledge activism.

2. a. Cultures of Open Hardware

In my first study of open hardware cultures (Powell, 2012) I described how several social worlds began to define cultures and practices of open hardware, including a culture that wished to reproduce the dynamics of open source software, where sharing of intellectual property and a reputation economy contributed to a capitalist appropriation of the software knowledge commons. This was not the only social world identified – other ways of interpreting open hardware included focusing on the opportunity for sharing open design to inspire greater innovation and entrepreneurship, or stressing the new opportunities for knowledge sharing outside of institutional structures, including a hope that this would disrupt other hierarchies of knowledge including the balance between knowledge developed in the Global North and that in the Global South. Within each of these social worlds, a license or standard for open hardware might be associated with a different self-identified need: for entrepreneurs engaging with conventional ideas of intellectual property, a license might be interpreted as protecting work from imitation or exploitation. For advocates of open knowledge, a license might make a political statement about the accessibility

of information or the interest in creating opportunities for collaboration; for creators of digital electronics within the DIY market, a license might cede permission to customers to integrate their products with others.

There are various reasons why people embrace the context of open source in contexts beyond computer software. As a form of collaborative production it connects with cultures of cooperative production that include, for example, the expansion of hackerspaces and fablabs where people share physical space, materials and knowledge about design and production. Research on hackerspaces and fablabs suggest that these locations of open production and exchange provide opportunities for creative exchange and innovation that might challenge not just traditional forms of knowledge production like the training that happens in jobs and at school (Hunsinger, 2011). In Western and non-Western contexts alike, hackerspaces and fab labs provide places to experiment with and share ideas and practices related to technology, as well as influencing broader cultures of innovation (Lindtner, 2013). Within their physical spaces, this sharing can happen organically and informally. Facilitating the same kinds of sharing outside a hackerspace has become one of the reasons that many within this movement support the idea of creating frameworks for sharing the designs of hardware objects. Hackerspaces and their cultures of tinkering are fun, and extend the kinds of social organization that valorize contributions to knowledge commons. They are part of a broader set of practices in which peer production of knowledge comes to replace institutionalized production of knowledge.

2. b. Licenses as Cultural History

In keeping with this cultural history, many open source hardware licenses are derived from open source software licenses, and enthusiastically supported by open source advocates. However, in 2011 CERN, the European high-speed physics lab, began work on an open hardware license. The license was intended to allow the lab to release its electronics designs publicly, in keeping with the way that it was already releasing the open-source software its members created. The lab also wanted to create a virtuous cycle of open innovation by requiring its suppliers to provide open designs for the products provided to the lab. These interventions link open hardware with the rhythms of institutional research, including the requirement to demonstrate the use of public funds and the monopolistic power that such a large institution can exert over its

suppliers. Since 2012, the CERN license has also been the focus of a crowd-sourced development over a mailing list, involving a number of open hardware experts. The new version of the license was published in July 2012, amid speculation from across the open hardware community as to whether, in fact, this or any license was indeed necessary.

The creation of open source hardware licenses has revealed a significant amount of interpretive flexibility among various social worlds, and a surprising amount of contention between the 'adaptive authority' of flexible peer production communities and the 'constituted authority' of institutional knowledge. These contentions are not necessarily straightforward. For example, licensing itself is an appeal to constituted authority, whereas CERN's shifts in its business culture appeal to the adaptive authority of peer producers, whose expertise improves its electronics, but with whom the developers also exchange knowledge.

The contention between constituted and adaptive knowledge in effect calls into question the need for open hardware licenses, as well as opens debates about their ideal structure and function. In the first instance, the contention has resulted in a proliferation of licensing documents related to open hardware, including the trademarking proposals discussed in Powell (2012). Secondly and paradoxically, some people resist the licensing of open source hardware altogether. This process links with a related dynamic wherein questions of authority are negotiated between institutional bodies – CERN as well as associations of open hardware producers – and the loose networks of individuals who share things online, either by using or resisting the use of this license.

3. Contesting licenses by definition

The first open hardware licenses were attempts to codify a set of appeals to adaptive authority. A member of the Tuscon Amateur Radio Project, developed an open hardware license in 2008 as his contribution to the amateur radio project. He explicitly intended his contribution to provide a way to make electronics designs subject to the same 'viral' propagation as software code licensed under a GPL-type license. At the time, technology journalists reported that they were not sure how the license could actually be applied (Paul, 2008). Yet the influence of open source

software culture combined with the development of consumer electronics kits like the Arduino, an electronics prototyping kit, opened up a market for open-source electronic components. Beginning in 2009, an "Open hardware Summit" and accompanying 'Maker Faire' for hardware producers brought together hundreds of people. Many of these people subsequently collaborated on creating an "open hardware definition" that would definition was intended to be broad, but it was also intended to take stock of the possibility for significant changes to business models.

The definition was the first attempt to establish a shared identity for the several social worlds, and was written by an international group of collaborators including Ayah Bdier, one of the first successful female open hardware designers, Bruce Perens, who had created similar definitions for open source software and open standards. The process of establishing the definition was collaborative and collective, but the resulting document reveals some of the confusion about how open hardware practitioners should engage with dominant ideas about intellectual property:

> In promoting Open Hardware, it is important to make it clear to designers the extent to which their licenses actually can control their designs. Under U.S. law, and law in many other places, copyright does not apply to electronic designs. Patents do. The result is that an Open Hardware license can in general be used to restrict the *plans* but *not* the manufactured devices or even restatements of the same design that are not textual copies of the original. The applicable section of copyright law is 17.102(b), which says: *In no case does copyright protection for an original work of authorship extend to any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described, explained, illustrated, or embodied in such work.* (emphasis added) (Open Hardware Definition, 2010)

This definition illustrates the contention about what open hardware might be. It reflects a conflict between the protection of intellectual property, which some hardware entrepreneurs perceived as being essential in order to protect their business, and the release of intellectual property controls on design specifications in order to

inspire greater collaboration or to address inequalities in knowledge production and exchange. Open hardware definitions balance conventional interpretations of intellectual property protection, attempting to demonstrate how licenses can both "open" and "protect". Early on in the process of introducing open hardware licenses, this tension was primarily addressed by addressing each individual intellectual property issue separately. As a result, contemporary open hardware licenses fall into three general categories: licenses based on the principles of copyright, licenses based on the priniples of patent law, and licenses that generally specify attribution of designs without specifying a legal mechanism. The copyright licenses tend to be based on the GPL, or on Creative Commons, while the patent-based licenses attempt to specify sharing of the designs or manufacturing processes. One distinct limitation to all of these licenses is that they have boundary problems: it is difficult to specify the extent to which design schematics must be kept open, and difficult to specify the exact terms of attribution that should be applied to designs: this creates a number of 'edge cases' that are described by members of various social worlds as being problematic. The wide variation in individual decisions about what to make available and to whom, is one of the reasons that licenses – as well as definitions - do so much social work in defining the importance of open hardware from the perspectives of different social worlds.
that forms the core of this paper thus begins with attempts to define open hardware.

3. a. Software-based definitions

The delineations between different interpretations of open hardware licenses are often marked by arguments that make claims delineating the relationships between software and hardware, and in parallel the relationships between ideal intellectual property protection within hardware. Because neither parallel operates as a perfect reflecting metaphor, the argument's proponent must set up a specific set of claims that illustrate both the variety of ways that "open hardware" is interpreted, and the strength or weakness of the ways that licensing supports that interpretation.

The following mailing list excerpt illustrates the software/hardware parallel, and the consequences that the posting author identifies for the concept of hardware "openness":

> If we use software as a metaphor for hardware, a program's source code requires an IDE and a compiler. Releasing the source code makes something technically open, but if nobody can open it in an IDE or compile it then there's no participation. Likewise, releasing detailed blueprints and a BOM and whatnot makes a machine technically open, but if half of the machine requires a lathe and the other half requires contacts in China then it's the equivalent of not being able to open it in an IDE or compile it. . . . However, just like in software the vast majority of customers don't care whether or not something is open source. For most customers "open source" confers no value. They won't pay more for it. So a design that starts out emphasizing openness pivots to one that emphasizes value while simultaneously losing openness." (Matt Meier, Open Manufacturing mailing list, September 4, 2013)

For this person, openness is defined as the ability to completely remake a machine – including the ability to manufacture it if necessary. True openness is impossible because of the political-economics of machine production, including, potentially, the necessity to have contacts in China in order to obtain required materials.

Another similarly-framed argument develops the area of tension between "definition" and "license", but comes from the perspective of a social world in which the expansion of knowledge is the main goal of licensing open hardware (rather than reforming hardware production to resemble that of software). In this case, the author of the mailing list post begins the parallel by drawing on the copyleft features of the Creative Commons licenses, which have the same "viral" features that are taken by some open hardware advocates as essential for establishing both protection for individual intellectual property and participation within a commons.:

> The reason that Creative Commons licenses "work" in the way that they do, is because of 3 separate pieces:
>
> 1) Copyright is automatically assigned in the US, to all novel creative works. This is a LEGAL PROTECTION of the creative work.
> 2) Copyright can LEGALLY be re-assigned to other entities (in this case, a corporate entity)

> 3) The Creative Commons license is a LEGAL AGREEMENT between the originator of the work, and the corporate entity CreativeCommons.org, a Massachusetts-based 501c3 nonprofit corporation. . . .
>
> So, in order to do something comparable with hardware, we would need the same 3 bits:
> 1) Legal protection of the work
> 2) The ability to assign this protection to another entity (and an entity to receive it)
> 3) A license by which this entity
>
> It seems like we have 2) with OSHWA . . . It also seems like 3) could be pretty easily derived from the definition, if we were interested to pursue this.
>
> But getting 1) -- Legal Protection of the work . . . is tough. Copyright can protect all the descriptive files for how to make a thing, but this method of protection is weak, since function can usually be preserved even when enough description is changed to work around copyright. This is the classic complaint of cookbook authors, who find that subsequent writers can easily and legally use their recipes, as long as they substantially change or re-arrange the text which describes them. (AUTHOR, posting to OH Discussion list)

Open Hardware's cultural history lies within the open source software movement and the peer production cultures like those of hackerspaces and fab labs. Within these cultures, a high value is placed on sharing expertise and providing information to others. The relative quality of this information is often associated with the relative status of the person who is sharing it (see Benkler, 2006). The authority within the kinds of social worlds characterized by these forms of social exchange is adaptive, shifting to account for the contributions of different members and rewarding those whose contributions produce the most value for others. However, its other constituencies include those who are interested in restructuring knowledge sharing in general, as well as those trying to use 'openness' as the backbone for a new kind of economy.

As part of the process of standardizing the notion of an "open hardware license" certain types of knowledge practice associated with certain types of authority become predominant, created 'well-structured' ideas about what open hardware is. These coexist with looser or more 'ill-structured' ideas about the same topics. The following table lists the ways that constituted and adaptive authority intersect with well or poorly structured ideas about what open hardware licenses might do.

Table 1

Authority	**More flexible adoption of "licensing"**	**More fixed adoption of "licensing**
Constituted	- various open hardware associations and bodies: OSHWA, Open Society, OHANDA - conflicts between interpretations and forms (ie logo dispute)	- CERN's arguments in favour of public interest - patent reforms by WIPO and other patenting organizations - standards organizations, (ie American Standards association's standards for 3D printing
Adaptive	- various online repositories for open designs without explicit licensing requirements – sharing practices regulated by community norms: ie Thingiverse, repository for software controlled chipsets	- online repositories specifying license use; entrepreneurial propagation of "open hardware" through labeling and promotion of particular licenses (ie Edmund Scientifics spectrometry kit)

This table outlines how various forms of constituted authority form and clash through more firm or more flexible interpretations of "open hardware licensing". There is no necessary linear relationship between a well structured interpretation of "open hardware" and a reliance on constituted authority. While some sites of constituted authority like standards setting organizations and WIPO have relatively firm interpretations of licensing which proceed from their interest in maintaining existing modes of managing intellectual property including patent libraries and standards vetted by standards organizations. There are also constituted authorities that have a more flexible approach to licensing of open hardware, including the various open hardware associations. Adaptive authority can also coexist with a fixed interpretation of open hardware: some 'knowledge commons' repositories specify the use of a particular open hardware license and in some ways labeling of open hardware occupies a similar space, where open hardware comes to be defined as things labeled

as such. Of course, there are some very flexible interpretation of open hardware that align with adaptive authority, particularly repositories like Thingiverse, where the 'openness' comes from the sharing of individual documentation in almost any form.

The next section of the paper examines in detail the process of debating the most recent version of CERN's open hardware license as a way of illustrating the contention between constituted and adaptive knowledge within and across different social worlds.

4. The CERN OHL – a boundary-transcending process?

CERN developed a hardware license to support collaboration and to share knowledge. The initial framing of the project derived directly from the practices of open source software: in the initial public description of the project, project leader Javier Serrano, an engineer with the Beams Department at CERN stated that "For us, the drive towards open hardware was largely motivated by well meaning envy of our colleagues who develop Linux device-drivers," (quoted in Giampietro, 2011). However, at the same time the CERN initiative was positioned in terms of knowledge exchange and the organization's interest in promoting open science. The open source collaborative design processes that were used to create the lab's Linux-based device drivers drew on a worldwide community of software developers who shared expertise and helped CERN create the best possible drivers.

In order to try and create a similar community of practice CERN began by creating an Open Hardware Repository where designs for electronics and other physical objects could be stored, allowing designers to collaborate, in the spirit of open source software stored in repositories like SourceForge or GitHub. A license for this documentation would also keep the designs in the public domain and prevent duplication. This type of collective curation of information depends on adaptive authority where community oversight, facilitated by sharing, improves the quality of the designs. Creating a license for open hardware promises to open up the innovation space even further, beyond the repository. As a publicly funded scientific body, CERN has the constituted authority necessary to support the development of a framework for sharing knowledge and inspiring collaboration. The CERN open

hardware license thus makes a claim for the importance of constituted knowledge within the open hardware process.

To the extent that the initial proposal for the license sought to reproduce in the hardware sphere the kinds of adaptive knowledge developed among advocates of open-source software, some specific challenges remain for open hardware. The process of creating hardware incurs costs, unlike producing software. Therefore, it is not fair to expect the people who share open-source designs to remain liable for the function of devices made by others, to their plans. For this reason, the CERN OHL license limits the liability of designers, in an attempt to balance "protection" with "openness".

Despite the fact that CERN employs a fairly well structured conception of open hardware, in keeping with its status as an established research institute, the license development process attempts to involve the members of a number of different social worlds. Through a mailing list, conference presentations and conversations with experts, the CERN representatives have been seeking guidance on updating the license so that it can apply to a wider range of practices. Indeed, evidence drawn from discussion between advocates about a new version of the CERN OHL license, reveals the way that appeals to constituted or adaptive authority cut across the proposals for developing the licenses.

4. a. Appeals to Constituted Authority

The debates taking place on the mailing list were intended to contribute to the development of a new version of the CERN license that would be as widely applicable as possible. Although the license had originally been designed to support CERN's dissemination of scientific knowledge as well as provide guidance to their suppliers, it was important for the license developers (Javier Serrano along with Myriam Ayass from the CERN legal department) to work together with the open hardware community to make something that could be broadly useful across the three (or more) open hardware social worlds. Contributors to the discussion were primarily entrepreneurs or legal experts, and often their initial discussion position was to appeal to a form of constituted authority. Some commentators focused on the authority of

licenses, and suggested that the CERN license should establish stronger links with the TAPR hardware license, as suggested by one of the designers of the Arduino:

> What about the possibility of aligning this license with the TAPR one, so that they could, for example, serve as localized versions of the same license? The licenses seem very similar in intent and approach (at least to a legally-naive reader) - it would be great if we didn't have to worry about choosing between them. At a minimum, maybe there's a way to allow for compatibility between them (i.e. the ability to combine TAPR OHL-licensed documentation with CERN OHL-licensed documentation)? (Mellis, January 2012)

This posting demonstrates how standardization in licenses establishes a framework of constituted authority and also underlines how CERN, because of its coordination of licensing efforts, becomes the institutional holder of legitimacy and authority on matters relating to open hardware.

4. b. Appeals to adaptive Authority

Many of the contributors also stressed the way that the development of the license would produce desirable behavior among community members and strengthen adaptive authority. There is still a firm interpretation of open hardware licensing: these arguments stress how licenses might change the behavior of people in the community. In the excerpt below, the writer provides positive examples of community behavior 'people not willing to circumvent it at any cost', which themselves are the 'benefits' of the way the previous license was written, and in particular the 'viral' quality that ensures that any derivative of a CERN OHL licensed work is also subject to the same license:

> I know there is much thinking going on about ways to make weak copyleft a sound legal concept for hardware, but for the time being I think the writing in CERN OHL is
> the best we can do. The good news is that people not willing to circumvent it at any cost do play the game. Check out
> http://www.ohwr.org/projects/spec/wiki and

> http://www.ohwr.org/projects/powec/wiki. The former is a PCIe board licensed under CERN OHL v1.1. The latter is an extension of it (you can see its upper part is the same as that of the SPEC) licensed also under CERN OHL v1.1. by virtue of the persistence of the licence. So while the enforceability of copyleft for hardware is definitely a subject of discussion, and we might be unable to completely deal with the free rider problem, it's a fact that we're already seeing very real benefits of the wording in 1.1. (DATE)

Other appeals to adaptive authority focus on the license development process as a form of adaptive authority in itself. The message below is typical of postings that referred to the process of debating and defining licenses, offering a place to find answers to frequently answered questions and leaving open the opportunity to ask more. This short post describes how adaptive authority is developed: by individual acts intended for collective benefit:

> Hi guys,
>
> I entered this Q&A to the OHL FAQ that I just created:
> http://www.ohwr.org/projects/cernohl/wiki/FAQ
>
> Feel free to add additional Q&A's.
>
> Best regards,
>
> Erik

As much as the CERN license discussion process is linked with adaptive authority, it also continually raises problems related to edge cases.

4. c. Edge Cases

A large proportion of the mailing list traffic concerns the problems of 'edge cases', hypothetical interpretations or extrapolations of features of the CERN license. The 'edge case debate' is the community's own way of negotiating with the dialectic of constituted vs adaptive authority. These evocations of "edge cases" are evidence of

the flexible interpretation that most participants have: they conceive of open hardware as something not totally defined by its license. This lack of structure made it possible to see the fluidity between the open hardware social worlds. The difficulty in interpreting whether a more firm or fluid interpretation should be applied forms part of the negotiations between social worlds. Worries about edge cases are deliberations about the unintended consequences of a particular part of the license text: in this one, the poster quotes another article describing a limitation of the license.

> I thought this comment was astute and should be taken into account: https://lwn.net/Articles/478233/
>
> "2.1. ... By exercising any right granted under this Licence, the Licensee irrevocably accepts these terms and conditions....
> 3.2 The Licensee may use, copy, communicate to the public and distribute verbatim copies of the Documentation ..."
>
> Does this mean that using the documentation requires me to agree to the terms of the license?
>
> I would assume that the the law has no power to bind someone to a license just for reading a document, but perhaps one of the sections listed should be modified so that such binding is not implied. (Brandon Stafford: Jan 31 2012)

This comment illustrates how 'edge cases' highlight the tensions between different types of authority, particularly the encroachment of legal specifications for behavior on the actual practices of community members, which are understood to be guided by shared community norms rather than by fears of legal sanction. The worry for the writer is that the authority of the license will extend further than it needs, causing fear about the legitimacy of normal practices by 'chilling' more flexible interpretations of openness.

This very brief discussion of the ways that discussions around the CERN OHL negotiated with constituted and adaptive authority raise questions about how open frameworks for knowledge development might expand. Yet even a seemingly straightforward issue such as which logo should be used to identify open source hardware reveals the tensions between different forms of author.

5. Contentions of authority: the trademark debate

Across the open hardware communities of practice, the tensions between constituted and adaptive authority have not been resolved. Open-source hardware projects continue to use a range of different licenses to define the extent to which intellectual property is protected or shared, although some eschew licenses all together. For example, the Arduino, one of the most popular open-source hardware projects, uses a Creative Commons license for its documentation. In addition, some of the organizations that claim to represent open hardware practitioners have a similar issue with defining what they mean by open hardware. A peculiar dispute over the logo meant to be applied to physical objects defined as 'open hardware' illustrates this continuing confusion.

In early 2012 the Open Source Hardware Association and the Open Source Initiative, a body that promotes the use of open source software were embroiled in a legal dispute regarding the design of the OSHWA's logo (Figure 1 below).

(Figure 1)

The Open Source Initiative (OSI) became concerned that the Open Source Hardware logo, voted on by the open source hardware community, was too similar to its own logo (see Figure 2). The OSHWA logo had been vetted by community members through a crowdsourcing process. It is often etched into circuit boards whose designs are openly available.

(Figure 2)

The concern of OSI about the possible confusion between their marque and the OSHWA "gear" logo is evidence of continued flexible interpretation of open source hardware and of the adaptive authority associated with crowdsourcing. Under trademark law, the similarity of two marks can only become a source of conflict if there is a significant chance of confusing the two. Thus, OSI must have assumed that it was possible to conflate open source software and open source hardware, and further would have had to be concerned that identifying open source hardware with open source software would constitute a "dilution" of the open source software brand. The debate also highlighted a failure to recognize the adaptive authority of the crowd-sourced logo, which was accepted as representing open hardware designs through the support given to it by the members of the open hardware community. Supported by a sense of its own constituted authority, the OSI originally offered the OSHWA la chance to license icense their original logo (the "gearless" semi-circle) for use with hardware. However, OSHWA activists noted on their website that *"This would give OSI the means to protect their trademark. However, accepting such a license would establish OSI as the owner of the crowdsourced 'gear' logo. It would make OSI responsible for deciding where and when the logo can be used, effectively giving OSI control of defining what can and cannot be labeled as open source hardware. " (OSHWA, 2012)*

The two organizations settled in October 2012, agreeing that the OSI logo only applies to software code and that OSHWA's mark should only be used for physical objects. While this in one way firmly identifies hardware as applying to physical

object as opposed to code, it provides an example of a particularly flexible interpretation of open hardware, since it reposes on the arbitrary distinction between software "code" and intellectual property and hardware "object".

6. Infrastructural Tendencies – and barriers

The contention around the extent to which open hardware licenses should appeal to the constituted authority of institutions such as CERN or the adaptive authority of flexible groups of peers may also determine how open hardware becomes standardized or 'infrastructural'. Star (2010) argues that when boundary objects scale up they become boundary infrastructures, characterized by embeddedness, transparency, spatial or temporal reach and scope, and a taken-for-granted nature, especially within particular communities of practice. Boundary infrastructure, unlike boundary objects, is standardized. As Star (2012) writes, "Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion . . . Because infrastructure is big, layered, and complex, and because it means different things locally, it is never changed from above. Changes take time and negotiation and adjustment with other aspects of the systems involved. (Star, 2010 p. 611)

This description of infrastructure appears to align with the process that CERN followed in debating the terms of the most recent version of the OHL license. However, despite the firm interpretation of the license by CERN itself, it seems unlikely that open hardware licenses will become fully infrastructural in the sense of becoming standardized. In part, this is because significant opposition remains to the idea of a license defining open hardware, and because of seemingly insoluable edge cases. Michael Weinberg, a lawyer and advocate, summarizes the overall opposition to licensing open hardware. His argument to issues of intellectual property protection, outlining the shortcomings of using existing modes of intellectual property protection for open hardware:

> Copyright that does not protect function, trademark that needs to be applied for and does not protect function, and patents that need to be applied for and can protect functions – means that most hardware projects are "open" by default because their core functionality is not protected by any sort of intellectual property right. Of course, in this case "open" means that their key

> functionality can be copied without legal repercussion, not that the schematics have been posted online or that it is easy to discover how they work (critical elements of open source hardware). (Weinberg, 2012)

Weinberg's statement is fraught, as it contains two distinct interpretations of the importance of open hardware – one which focuses on intellectual property protection and the other that stresses open knowledge. His critique also identifies the tension between firm and flexible interpretations of licensing. A firm interpretation, at least from the perspective of intellectual property protection, would require adherence to the conventions of at least one of the mechanisms that Weinberg mentions: copyright, patent or trademark. Yet this would work in direct contravention to one of the other core interpretations of open source hardware, the idea of knowledge sharing through online posting of schematics so as to illustrate how they work. It is not this interpretation that Weinberg disputes: it is that he, along with others in the community, fears that the cultural practices of sharing are somehow under threat by actors outside the open source hardware community, who do not want to play by the rules and who thus need to be restrained through recourse to intellectual property protection. This interpretation is itself couched in an interpretation of open source hardware as an extension of open source software.

Weinberg's final position is to abandon the intellectual property protection interpretation, and to claim instead that open source software is a political rather than a legal intervention. He writes, "the "right" license can have tremendous value as a signaling device, as a public commitment, and as a way to raise the profile of openness. However, in many cases, the "right" license will be meaningless from a legal standpoint. To me, the challenge of the next year of OSHW is to find a way to scale beyond the core OSHW community, maintain a meaningful commitment to openness (whatever that ultimately means), while all the while recognizing that the license itself is largely symbolic." (2012)

In effect this is a plea for a more flexible use of the "open source hardware" concept, in order to facilitate a broader adoption of adaptive authority among a non-institutional group of participants. It clashes with the hopes for an increasingly fixed

interpretation of the role of open source hardware licenses advanced by standards setters and, to an extent, CERN.

A final tension concerns the next phase of CERN's license development. One of the main modifications within version 1.2 of the license was the removal of a stipulation that people making subsequent modifications to a design would have to inform the original designer of their modifications. The collaborators felt that insisting on this would provide burdensome to the original designers who might then receive dozens of updates to projects they had abandoned, but the CERN representatives worried that removing it would make it difficult to track the adoption of the open hardware designed within the Centre. In this case, well-structured adoption of this license counteracts the interpretation that open source hardware licenses can be a way to track and expand knowledge in the public interest.

Conclusion

The interesting thing about these attempts to build legal frameworks for open hardware is not interesting because it represents a novel new way to build electronics. It is interesting because it represents a sustained and not always easy to manage negotiation between two modes of authority for governing the production and dissemination of knowledge. As existing modes of knowledge production continue to be challenged by adaptive authority, it seems likely that more attempts will be made to create infrastructures that will standardize knowledge sharing practices. As this occurs, it is equally possible that new standards will emerge that will provide frameworks for adaptive authority, or that the fact of creating standards will create new forms of constituted authority that can accommodate both firm and flexible interpretations. In this paper, I have understood 'openness' defined as integration between constitutive and adaptive authority. The CERN OHL case demonstrates that this can occur, even if it doesn't occur to the same extent in the conflict between OSHWA and the OSI. Still as calls continue for more open innovation structures, we should closely consider whether peer produced structures are capable of considering the value of constituted rather than merely adaptive authority. This may help academics and the many social worlds engaged in 'opening' production learn how to

maintain technologies and social structures that are 'open' in the face of enclosures like the 'closing' of Android.

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