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THREE-DIMENSIONAL PRINTING AND OPEN SOURCE HARDWARE

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INTRODUCTION

Open source hardware, the physical equivalent of open source software, is a movement that advocates the public provision of hardware design documentation. For example, a purchaser of an Arduino open hardware circuit board has access to

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the full design documentation of the product, as well as the source code of all accompanying software.[1] The ambitions of the open hardware movement have been inspired by the successes of open source software. Open principles of design have been central to the creation of significant pieces of software including, to take only some of the most prominent examples, the Linux and Android operating systems. Indeed, estimates are that more than half the software acquired in the coming years will be open source.[2] While the open hardware movement remains in its infancy, it aspires to harness the open source philosophy for hardware design as successfully as those ideals have been applied in the context of software.[3]

One of the factors central to the success of open source software has been effective and enforceable licensing frameworks.[4] On a theoretical level, licenses allow open source organizations to define community norms and the boundaries of

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[1] Arduino is an "open source physical computing platform," which can be used to create hardware that interacts with the physical world. *See Introduction,* ARDUINO, http://www.arduino.cc/en/Guide/Introduction (last updated Dec. 23, 2009). The original design files for the Arduino hardware are available from the Arduino Internet website under the Creative Commons Attribution Share-Alike license, and the software is available under either the GPL or LGPL licenses. *See Frequently Asked Questions*, ARDUINO, http://arduino.cc/en/Main/FAQ (last updated Mar. 11, 2011). *See also* Brian Evans, BEGINNING ARDUINO PROGRAMMING 5 (2011). For background on the Arduino project, see Clive Thompson, *Build It. Share It. Profit. Can Open Source Hardware Work?* WIRED MAGAZINE, Oct. 20, 2008, *available online at* http://www.wired.com/techbiz/startups/magazine/16-11/ff_openmanufacturing.

[2] Rachel King, *Big Companies Open up to Open-Source Software*, WALL ST. J., Sept. 6, 2012, a*vailable online at* http://online.wsj.com/article/SB20000872396390443589304577633733725243996.html.

[3] John Ackermann, *Toward Open Source Hardware*, 34 U. DAYTON L. REV. 183, 184 (2009); Thompson, *supra* note 1 (comparing the ambitions of Arduino to those of Linux and other successful open source software projects); CHRIS ANDERSON, MAKERS: THE NEW INDUSTRIAL REVOLUTION 107 (2012). The "hardware" in "open hardware" can potentially refer to a variety of physical articles, from semiconductor chips to mechanical assemblies. This Article does not restrict the discussion to a particular category of article, but instead focuses on the range of objects that may be generated using the technology of three-dimensional printing.

[4] As stated by the Debian Group, a prominent distributor of open source software, "[t]o stay free, software must be copyrighted and licensed." *What Does Free Mean? Or What Do You Mean by Free Software?*, DEBIAN GROUP, http://www.debian.org/intro/free (last updated Mar. 19, 2013). *See also* Margit Osterloh & Sandra Rota, *Open Source Software Development – Just Another Case of Collective Invention?*, 36 RES. POL'Y 157,164 (2007); STEVEN WEBER, THE SUCCESS OF OPEN SOURCE 197 (2004) (describing business models that depend on licensing structures).

acceptable behavior.[5] More practically, legally enforceable licenses provide an effective means of enforcing those community norms and standards on non-cooperative members of the community.[6] Unfortunately, it has proven difficult to construct a license to effectively implement an open hardware arrangement.[7] This Article, however, shows how the rapidly evolving technology of three-dimensional printing can be used to construct a robust open hardware license.[8]

Those seeking to develop a sustainable model for open source hardware have struggled with both economic and legal obstacles. On the economic front, open source hardware differs in important ways from open source software. First, software can be compiled from source code and distributed at close to zero cost. In contrast, producing a piece of hardware involves a more involved and costly undertaking to source appropriate materials and structure an often-complex

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[5] WEBER, *supra* note 4 at 179 (describing a license as a "de facto constitution" for an open source organization, which, "[i]n the absence of hierarchical authority, . . . becomes the core statement of the social structure that defines the community of . . . a project").

[6] The "BusyBox" litigation cases provide an example of the enforcement of open source licenses. BusyBox is software that is commonly used in consumer electronic devices. BusyBox is licensed under the GPLv2 open source license. From 2007 through 2009, the Software Freedom Law Center, representing several of the BusyBox copyright holders, filed suit against a number of entities that distributed BusyBox software, asserting that those distributors had breached the license. *See Best Buy, Samsung, Westinghouse and Eleven Other Brands Named in SFLC Lawsuit*, SOFTWARE FREEDOM LAW CENTER (Dec. 14, 2009), http://www.softwarefreedom.org/news/2009/dec/14/busybox-gpl-lawsuit. Many of these suits ended in a settlement in which the defendant agreed to comply with the terms of the license, and information regarding a number of these settlements is available at the Software Freedom Law Center Website. *See, e.g.*, *BusyBox Developers and Xterasys Corporation Agree to Settle GPL Lawsuit*, SOFTWARE FREEDOM LAW CENTER (Dec. 17, 2007), http://www.softwarefreedom.org/news/2007/dec/17/busybox-xterasys-settlement/.

[7] Richard Stallman, the founder of the Free Software Foundation and a central figure in the open source software movement, has opined on the difficulty of creating an open hardware legal framework. *See* Richard Stallman, *On "Free Hardware"*, LINUX TODAY (June 22, 1999, 4:27 AM), http://www.linuxtoday.com/infrastructure/1999062200505NWLF. *See also* Andrew Katz, *Towards a Functional License for Open Hardware*, 4 INT'L FREE AND OPEN SOURCE SOFTWARE L. REV. 41, 45 (2012); Michael Weinberg, *Open Source Hardware and the Law*, PUBLIC KNOWLEDGE (Oct. 10, 2012), http://publicknowledge.org/blog/open-source-hardware-and-law.

[8] This Article uses the term "three-dimensional printing" to refer to a range of a computer-aided manufacturing technologies, where a digital design is used to automate the manufacture of an article in an "additive manufacturing" process. Alternative terms may also be used for some of these methods such as, for example, rapid prototyping, desktop manufacturing and CAD oriented manufacturing. *See generally* C.K. CHUA ET AL., RAPID PROTOTYPING: PRINCIPLES AND APPLICATIONS 18 (2nd ed. 2004). Additive manufacturing means that physical objects are constructed from the accumulation of a number of layers, rather than resulting from the removal of portions of raw material. *See* ANDERSON, *supra* note 3, at 90.

manufacturing process.[9] Similarly, while a work of software can be copied and distributed at zero cost, the manufacturing costs of hardware make the expense of reproduction and distribution not insignificant. Hardware manufacturers may therefore find that restrictive intellectual property protection is necessary to recoup any expenses of production.[10] Moreover, relatively small open source communities may find it difficult to compete with the economies of scale of commercial manufacturers.[11] While collaborators on a software project can easily test modifications proposed by the group, the cost of building and prototyping improvements in physical objects makes this more difficult in the hardware context.[12]

Open source hardware must also overcome legal obstacles. Open source software can rely on copyright law to support its legal structure. As copyright

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[9] Christina Raasch, *Product Development in Open Design Communities: A Process Perspective*, 8 INT'L J. INNOVATION & TECH. MGMT. 557, 568 (2011) (discussing the difficulty of sourcing parts in open hardware projects). *See also* Katz, *supra* note 7, at 51.

[10] Raasch, *supra* note 9, at 567 (noting that open hardware projects may protect certain intellectual property in order to "attract manufacturers willing to produce the design as well as component suppliers"); Thompson, *supra* note 3 (stating that "nobody is going to risk money inventing and selling hardware unless they can prevent competitors from immediately ripping off their designs"). The recent decision of Makerbot Industries to refrain from distributing some of its hardware designs provides a real world example of these concerns. Makerbot is a prominent producer of three-dimensional printers and, until recently, pursued an open hardware strategy by making all of its device designs publicly available. In September 2012, Makerbot decided to not make available certain designs of its newest printer model. *See* Rich Brown, *Pulling Back from Open Source Hardware, Makerbot Angers Some Adherents*, CNET (Sept. 27, 2012, 5:00 AM), http://news.cnet.com/8301-17938_105-57520633-1/pulling-back-from-open-source-hardware-makerbot-angers-some-adherents/. In justifying this decision, Makerbot noted that its open hardware business model resulted in competition from "carbon-copy cloning" of its products and stated that this undermined the company's "ability to pay people to do development." Bre Pettis, *Let's Try That Again,* MAKERBOT BLOG (Sept. 24, 2012), http://www.makerbot.com/blog/2012/09/24/lets-try-that-again/.

[11] Eric von Hippel, *Horizontal Innovation Networks – By and For Users*, 16 INDUS. & CORP. CHANGE 293, 311 (2007) (noting that the economies of scale involved in manufacturing may not allow open source networks to compete with commercial manufacturing); Eric von Hippel & Georg von Krogh, *Open Source Software and the "Private-Collective" Innovation Model: Issues for Organization Science*, 14 ORGANIZATION SCIENCE 209, 215 (2003). *See also* Ackermann, *supra* note 3, at 210-11 (noting such economies of scale as a justification for including restrictions against the commercial use of designs in an open hardware license).

[12] *See* Raasch, *supra* note 9, at 569 (discussing the relative infrequency of releases in the RepRap on Openmoko open hardware projects). *See also* Jim Turley, *Open-Source Hardware*, EMBEDDED (May 31, 2002), http://www.embedded.com/electronics-blogs/significant-bits/4023974/Open-Source-Hardware.

automatically protects all original software works, a copyright license is necessary for the lawful reproduction, modification or distribution of software. This copyright license can be made subject to certain conditions such as, for example, the "copyleft" conditions of the most prominent open source software license, the General Public License ("GPL").[13] The GPL grants licensees broad rights to copy, modify and distribute licensed works, only on the condition, however, that licensees make all works "based on" the licensed code available under the terms of the GPL as well.[14] This mechanism ensures that the GPL's broad rights are also granted to any improvements to the licensed code.[15] Similar mechanisms are used in other open source software licenses to ensure, for example, the continued attribution of works to their authors.[16] Unfortunately, as discussed in greater detail below, since useful physical objects are generally not protected by copyright, these relatively simple legal devices cannot be used in the open source hardware context.

Three-dimensional printing offers the opportunity to overcome these economic and legal hurdles. With regard to the economic obstacles, three-dimensional printing reduces the cost and complexity of obtaining raw materials from a variety of sources, and of constructing assembly lines and manufacturing plants. These efficiencies may allow open source communities to compete with the economies of scale of commercial manufacturers.[17] Three-dimensional printing also offers the possibility of easy and rapid prototyping of physical objects and thereby increases the opportunities for collaboration on open hardware projects.

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[13] The text of version 3.0 of the GPL is available at the Free Software Foundation website. *See* GNU General Public License, GNU OPERATING SYSTEM, http://www.gnu.org/copyleft/gpl.html (last updated Oct. 6, 2012) [hereinafter, GPLv3]. Unless stated otherwise, references in this Article to the GPL are references to version 3.0 of that license. *See* GLYN MOODY, REBEL CODE 312-13 (2001) (stating that the GPL serves as the "de facto constitution for the entire free software movement"). For a summary of United States case law interpreting the GPL, see Eli Greenbaum, *Open Source Semiconductor Core Licensing*, 25 HARV. J.L. & TECH. 131, 140 (2011).

[14] Section 5(c) of the GPL provides that a licensee "may convey a work based on" the licensed software, provided that the entire work must also be licensed under the terms of the GPL. GPLv3, *supra* note 13, § 5(c).

[15] For a brief overview of the GPL copyleft conditions, see *What is Copyleft?*, GNU OPERATING SYSTEM, http://www.gnu.org/copyleft/ (last updated Oct. 6, 2012).

[16] *See* LAWRENCE ROSEN, OPEN SOURCE LICENSING: SOFTWARE FREEDOM AND INTELLECTUAL PROPERTY LAW 80 (2005) (describing license conditions of the BSD open source software license). *See also* Jacobsen v. Katzer, 535 F.3d 1373, 1381-83 (Fed. Cir. 2008) (holding that the limitations found in the Artistic License were "enforceable copyright conditions").

[17] Von Hippel, *supra* note 11, at 313.

Against the backdrop of this economic potential, this Article describes how the technology of three-dimensional printing can also be employed to surmount the legal challenges in creating an effective open source hardware license. Section I of the Article describes the shortcomings of current open source hardware licenses, especially how such licenses fail to implement regimes to ensure that proper attribution for inventors is provided and that documentation for open source hardware designs is shared with the community. Section II provides some technological and historical background regarding three-dimensional printing, and analyzes the application of copyright law to this technology. Section III details a licensing regime that, applied to three-dimensional printing, can implement an effective and enforceable open hardware license. This section also discusses some of the advantages and disadvantages of the proposed regime. The Appendix includes a first draft of the Three-Dimensional Printing Open License, which implements the proposed open hardware licensing regime.

I
OPEN HARDWARE LICENSES

To date, several open hardware licenses have been developed. The most prominent of these include the TAPR Open Hardware License and the CERN Open Hardware License.[18] This Section details the practical shortcomings of current open hardware licenses, and then goes on to explain why these

[18] For background on the TAPR Open Hardware License, see Ackermann, *supra* note 3. A copy of the TAPR Open Hardware License is available online. *See* TAPR Open Hardware License, TAPR (May 25, 2007), http://www.tapr.org/ohl.html [hereinafter TAPR license]. For background on the CERN Open Hardware License, see Myriam Ayass & Javier Serrano, *The CERN Open Hardware License*, 4 INT'L FREE AND OPEN SOURCE SOFTWARE LAW REVIEW 71, 71-73 (2012). A copy of the CERN Open Hardware License is available online. *See* CERN Open Hardware License, OPEN HARDWARE REPOSITORY, http://www.ohwr.org/documents/88 (last visited Apr. 4, 2013) [hereinafter CERN license]. A third prominent open hardware license is the Solderpad License, a copy of which is available in Katz, *supra* note 7, at 56. The Solderpad license does not attempt to impose copyleft obligations on the use of hardware. Rather, the Solderpad license limits itself to granting permissions to use, modify and distribute a design file. *Id*. Given the limited ambition of the Solderpad license, it is not addressed in this Article. Hardware designs are sometimes licensed under documentation licenses rather than licenses specifically designed for hardware. For example, the Open Compute Project is a project founded by Facebook engineers that shares designs for scalable data center hardware under Creative Commons licenses. *See Licensing*, OPEN COMPUTE PROJECT, http://www.opencompute.org/licensing/ (last visited Mar. 30, 2013). As with the Solderpad license, documentation licenses only provide permissions to use, modify and distribute a design file, but do not impose conditions regarding hardware manufactured with that design file. For information regarding the Creative Commons licenses, see *About the Licenses*, CREATIVE COMMONS, http://creativecommons.org/licenses/ (last visited Mar. 30, 2013).

shortcomings are the inevitable consequence of the legal foundations of those licenses.

A. The TAPR and CERN Open Hardware Licenses.

The TAPR license was developed under the auspices of the Tucson Amateur Packet Radio association, an international organization which supports research and development in the area of amateur digital communications.[19] The license is intended to emulate the "copyleft" provisions of the GPL in the arena of open hardware – in other words, to ensure that licensed design documentation (and modifications to that documentation) continues to be made available under the terms of the TAPR license itself.[20] The CERN license was created in 2011 by employees of CERN, the European Organization for Nuclear Research, in order to allow groups across organizations to collaborate on hardware projects.[21] The CERN license also includes copyleft provisions.[22]

Unfortunately, neither the TAPR nor the CERN license successfully implements open hardware principles, and this failure is rooted in the tenuous legal foundations of the licenses themselves. For example, one of the fundamental goals of an open hardware framework should be the provision of design documentation to recipients of hardware.[23] This provision of design documentation allows recipients to modify and improve the hardware design. While the TAPR and CERN licenses provide that the initial recipient of an open hardware product

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[19] Ackermann, *supra* note 3, at 204.

[20] *Id*. at 205. *See also About the OHL*, TAPR, http://www.tapr.org/ohl.html (last visited Apr. 2, 2013) ("Like the GNU General Public License, the [TAPR license] is designed to guarantee your freedom to share and to create.").

[21] Ayass & Serrano, *supra* note 18, at 71.

[22] *Id*. at 72.

[23] *See* Ackermann, *supra* note 3, at 192 (stating that one of the goals of open source hardware should be that the documentation received under an open source hardware license should be "available to all"). Section 1 of the definition of open hardware put forward by the Open Source Hardware Association similarly provides that "hardware must be released with documentation including design files, and must allow modification and distribution of the design files. Where documentation is not furnished with the physical product, there must be a well-publicized means of obtaining this documentation." *Definition*, OPEN SOURCE HARDWARE ASSOCIATION, http://www.oshwa.org/definition/ (last visited Apr. 2, 2013). The OSHWA Definition is based on the Open Source Definition of the Open Source Initiative, a statement of principles for open source software, and bears substantial similarities to that definition. *Id.* The Open Source Hardware Foundation was founded in 2012 as an organization to promote open source hardware. Its board includes founders of several open hardware companies as well as prominent open hardware activists. *See Board Members*, OSHWA, http://www.oshwa.org/about/board-members/ (last visited Apr. 14, 2013).

should be supplied with design documentation, for reasons discussed below they do not provide that such design documentation should be passed on to downstream recipients.[24] Another important aim of open hardware should be the proper provision of attribution to designers of the products.[25] Attribution requirements can provide important incentives for designers, who may be assured that they will receive proper credit for their innovations.[26] Again, neither of the TAPR or CERN licenses provides that downstream recipients of hardware should receive attribution notices.[27]

While the TAPR and CERN licenses may prove useful for allowing research collaboration or amateur experimentation, they do not provide an adequate legal

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[24] The TAPR Open Source Hardware License generally requires licensees to distribute a copy of the design documentation together with the manufactured article. *See* TAPR license, *supra* note 18, § 5.2. However, the provision only applies to licensees that "make or have made" a product, and does not apply to downstream recipients of the articles. *See id.* Similarly, the CERN license provides that a licensee may distribute products developed with the licensed design documentation, provided that a copy of the design documentation is provided to each recipient of the hardware. *See* CERN license, *supra* note 18, § 4.1. This provision only applies to a "Licensee," which is defined by the license as a person "exercising rights" under the license. *Id.* at § 1. In the absence of a patent, a downstream recipient does not require a grant of intellectual property rights to distribute products and, as such, does not exercise any rights under the license.

[25] *See* OSHWA Definition, *supra* note 23, § 6 ("The [open hardware] license may require . . . attribution to the licensors when distributing design files, manufactured products, and/or derivatives thereof. The license may require that this information be accessible to the end-user using the device normally, but shall not specify a specific format of display").

[26] *See* Catherine L. Fisk, *Credit Where It's Due: The Law and Norms of Attribution*, 95 GEO. L.J. 49, 89-93 (2006) (providing an extensive discussion of the incentives created by attribution in the context of open source software development). *See also* Klaus M. Schmidt and Monika Schnitzer, *Public Subsidies for Open Source? Some Economic Policy Issues of the Software Market*, 16 HARV. J.L. & TECH. 473, 482 (2003). Even the most permissive open source software licenses contain attribution requirements that are passed on to downstream recipients of the software. For example, while the permissive BSD license does not include any copyleft obligations, it does require that distributions of the licensed software include a copy of the copyright notice and a copy of the license. *See The BSD 2-Clause License*, OPEN SOURCE INITIATIVE, http://opensource.org/licenses/BSD-2-Clause (last visited Apr. 15, 2013). Similarly, all six Creative Commons licenses include an attribution requirement. *See Attribution*, CREATIVE COMMONS, http://wiki.creativecommons.org/Attribution (last updated Jan. 26, 2010).

[27] Section 5.1 of the TAPR license provides that manufactured products must retain licensor's notices, but this requirement does not apply to downstream recipients. *See* TAPR license, *supra* note 18, § 5.1. Section 3.1 of the CERN license provides that a licensee must retain all copyright, trademark and other notices. *See* CERN license, *supra* note 18, § 3.1. Again, this provision only applies to a "Licensee", *id.*, which is defined by the license as a person "exercising rights" under the license. *Id.* at § 1. A downstream recipient does not exercise any rights under the license.

framework for the integration of open hardware in manufacturing or distribution networks. Modern large scale manufacturing is characterized by complex supply chain structures, in which the ultimate manufacturer (an "original equipment manufacturer" or "OEM") purchases components from a network of suppliers.[28] These first tier suppliers themselves integrate parts purchased from an array of second tier suppliers, and this structure continues to cascade in a pyramid form.[29] Such supply chain structures exist, to take a few examples, in the automotive,[30] aerospace,[31] computer[32] and mobile phone industries.[33] In a similar vein, a product (or spare parts for a product) may move through multiple tiers of distributors before reaching the final end user.[34] Given these arrangements, a robust open hardware framework must ensure that obligations of attribution and documentation are easily passed through complex supply chains, and that any such requirements are relatively frictionless and impose minimal transaction costs. The TAPR and CERN licenses, which do not address downstream recipients at all, do not provide an adequate framework for the easy integration of open hardware in these settings.

B. The Unsteady Legal Foundations of Open Hardware Licensing.

These shortcomings of current open hardware licenses reflect their unsteady legal foundations. Unfortunately, open hardware lacks the legal tools which allow the easy implementation of enforceable open source software licenses. Open source software licenses are generally based on copyright law. Since both the source code and compiled executable code of software are protected by copyright, a license is required to copy, modify, and distribute those works. These license

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[28] *See* JOHN MANGAN ET AL., GLOBAL LOGISTICS AND SUPPLY CHAIN MANAGEMENT 40 (2d. ed. 2012). *See also* Ronald J. Gilson et al., *Contracting for Innovation: Vertical Disintegration and Interfirm Collaboration*, 109 COLUM. L. REV. 431, 436 (2009).

[29] MANGAN, *supra* note 28, at 40.

[30] Gilson, *supra* note 28, at 438. One estimate of the automobile manufacturing industry has a handful of OEMs purchasing from six hundred to eight hundred first tier suppliers. *See* Omri Ben-Shahar & James J. White, *Boilerplate and Economic Power in Auto Manufacturing Contracts*, 104 MICH. L. REV. 953, 956 (2006). *See also* ANATH IYER ET AL., TOYOTA SUPPLY CHAIN MANAGEMENT: A STRATEGIC APPROACH TO TOYOTA'S RENOWNED SYSTEM 90-91 (2009).

[31] Tim William, *Demand Chain Management Theory: Constraints and Development from Global Aerospace Supply Webs*, 20 J. OPERATIONS MGMT. 691, 691 (2002).

[32] Gilson, *supra* note 28, at 439.*See* Jason Dedrick et al., *Who Profits from Innovation in Global Value Chains?: A Study of the iPod and Notebook* PCs, 19 INDUS. & CORP. CHANGE 81, 81 (2009).

[33] *See* Jason Dedrick et al., *The Distribution of Value in the Mobile Supply Chain*, 35 TELECOMM. POL'Y 505, 507 (2011).

[34] JULIAN DENT, DISTRIBUTION CHANNELS: UNDERSTANDING & MANAGING CHANNELS TO MARKET 11-12 (2d. ed. 2011).

permissions can be conditioned on compliance with, for example, copyleft and attribution requirements. In the hardware context, however, no copyright license is required to use design documentation to build or distribute hardware. Open hardware licenses therefore cannot use copyright law to impose such copyleft or attribution conditions. Moreover, as property rights, copyrights can be enforced against any third party – even third parties with which the copyright owner has no direct contractual relationship.[35] Open hardware licenses, however, cannot rely on copyright law to facilitate the enforcement of license conditions.

Basing open hardware licenses on patent law also presents challenges.[36] On the one hand, patents are property rights that protect against the unauthorized use and distribution of patented hardware by any third party. As a result, a patent license can require compliance with certain obligations in order to engage in these activities, and these requirements can be enforced against downstream users of the hardware. Patents, however, are expensive to obtain and costly to enforce.[37] Unlike copyrights, patents are not provided for all inventions, but only those that meet relatively high standards of non-obviousness, novelty, and utility. Moreover, the "patent exhaustion" doctrine limits a patentee's ability to impose requirements on the post-sale activities of a purchaser.[38] Given these constraints, patent law is an unwieldy tool for constructing an open hardware license.[39]

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[35] In the words of one of the original cases that enforced end user license agreements, "A copyright is a right against the world. Contracts, by contrast, generally affect only their parties; strangers may do as they please, so contracts do not create 'exclusive rights.'" ProCD, Inc. v. Zeidenberg, 86 F.3d 1447, 1454 (7th Cir. 1996). *See also* MDY Indus. LLC v. Blizzard Entm't Inc., 629 F.3d 928, 941 n.3 (9th Cir. 2010).

[36] Stallman, *supra* note 7.

[37] *See generally* Ackermann, *supra* note 3, at 194.

[38] *See* Quanta Computer, Inc. v. LG Elecs., Inc., 553 U.S. 617, 628-31 (2008) (holding that LGE's post-sale restrictions could not be enforced under patent law); Static Control Components, Inc. v. Lexmark Int'l, Inc., 615 F. Supp. 2d 575, 584 (E.D. Ky. 2009) (holding that *Quanta* barred the enforcement of post-sale restrictions on printer cartridges).

[39] Notwithstanding these difficulties, the Open Innovation Network (OIN) provides an example of using patents to create an open licensing framework. OIN is a company owned by a number of prominent technology companies which freely licenses a patent portfolio to any company or institution that agrees not to assert its patents against the Linux operating system. *See About OIN*, Open Innovation Network, http://www.openinventionnetwork.com/index.php (last visited Apr. 15, 2013) (providing information regarding OIN). OIN may be a special case that could be difficult to generalize to new open source hardware projects. The OIN was founded by companies in order to protect their prior investments in the Linux operating system from patent infringement suits, rather than to create a new open source project. *See id.* The OIN patent licenses are not used to increase the enforceability of the Linux software licenses, but simply to protect Linux from patent infringement suits. *See id.* The copyleft and attribution obligations of

Contract law could be another avenue to enforce the conditions of an open source license and does, in fact, form part of the foundations of both the TAPR and CERN licenses.[40] These licenses contractually bind the recipient of design documentation to pass on such documentation to recipients of physical hardware. The formation of a contract, however, generally requires the satisfaction of elements of offer, acceptance and consideration, so contract-based license conditions may not be enforceable against entities not party to the contract.[41] As a result, in order to bind downstream recipients, an open hardware license would need to require recipients to contractually bind all further recipients to the same obligations.[42] This chain of contracting and recontracting imposes transaction costs, which would be significant in industries characterized by long supply chains.[43] One break in this sequence of contracts would result in downstream recipients not being bound by the license terms. This inherent limitation of contract

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the Linux system are imposed by the GPLv2 software license, rather than the OIN patent portfolio licenses.

[40] Ackermann, *supra* note 3, at 205 (explaining how the TAPR license is built around both license and contract concepts); Ayass & Serrano, *supra* note 18, at 72 (stating that the license to design documentation could "be the basis on which to form a contractual relationship" on which the CERN license is built). *See also Static Control Components*, 615 F. Supp. 2d at 587 (allowing contract claims to proceed even though patent claims were barred as a result of the patent exhaustion doctrine).

[41] *See, e.g.*, Robert P. Merges, *A Transactional View of Property Rights*, 20 BERKELEY TECH. L.J. 1477, 1507 (2005) (discussing the importance of intellectual property rights to a plaintiff where there is no privity of contract). These arguments against relying on contract law in an open hardware license recall similar claims against the enforceability of the GPL. Commentators had argued that the GPL was unenforceable because it was not validly accepted by licensees under the principles of contract law. *See* HEATHER MEEKER, THE OPEN SOURCE ALTERNATIVE: UNDERSTANDING RISKS AND LEVERAGING OPPORTUNITIES 177 (2008). The counterargument of the Free Software Foundation was that the GPL would be enforceable under copyright law, regardless of whether a licensee accepted its terms in accordance with contract law. *See GPLv3 Second Discussion Draft Rationale* at n.77, FREE SOFTWARE FOUNDATION, INC. (July 27, 2006), gplv3.fsf.org/gpl3-dd1to2-markup-rationale.pdf ("[The GPL was] intentionally structured . . . as a unilateral grant of copyright permissions, the basic operation of which exists outside of any law of contract. Whether and when a contractual relationship is formed between licensor and licensee under local law do not necessarily matter to the working of the license.") [hereinafter GPL Second Draft]; Pamela Jones, *The GPL is a License, not a Contract*, LWN.NET (Dec. 3, 2003), http://lwn.net/Articles/61292/. An open hardware license based solely on contract law would not be able to rely on these arguments in favor of the enforceability of the GPL.

[42] Katz, *supra* note 7, at 46.

[43] Shahar & White, *supra* note 30, at 966-70 (discussing how OEMs in the automotive industry erected barriers to negotiations of standard form agreements).

law seems to be the reason that the TAPR and CERN licenses do not pass on requirements to downstream recipients.[44]

Contract law may prove inadequate in the open source context for other reasons. Damages for breach of contract are typically measured by the financial injury to the non-breaching party.[45] Such calculations may be impossible in the setting of open source licensing, where the material is provided without charge or for a nominal fee. Federal copyright law, in contrast, provides for remedies that are not measured by the injury to the licensor, such as the disgorgement of the infringer's profits.[46] Other remedies available under copyright law include

[44] It is possible to speculate that downstream recipients may be able to enforce the terms of an open hardware contract as third party beneficiaries. Generally, however, a third party beneficiary may only enforce the terms of a contract if the parties intended to grant the third party such right of enforcement, and neither the TAPR nor CERN licenses evidence such intent. *See generally* Melvin Aron Eisenberg, *Third-Party Beneficiaries*, 92 COLUM. L. REV. 1358, 1382 (1992). On a more theoretical level, current open source licenses generally envision enforcement by the copyright holder. *See* GPL Second Draft, *supra* note 41, at n.34 (stating that "enforcement of the GPL is always by the copyright holder"). Granting third parties the right to enforce open source obligations would introduce an unfamiliar and perhaps unwelcome dynamic. First, allowing any third party to enforce the license would expose a licensee to claims from a large range of individuals with which the licensee may have no prior or only a minimal relationship. Second, claims regarding open source obligations often depend on technical details regarding the content and use of the licensed material, details that a licensee may not want to publicize to a broad audience. In any event, enforcement by third party beneficiaries would not reach throughout a distribution chain, as the third party's claims could only be directed at the specific party that should have provided open source material to the beneficiary. Last, third party beneficiaries would likely only advance claims to obtain hardware design or software code, but would be less likely to demand attribution information.

[45] According to the Second Restatement of Contracts, "[c]ontract damages are ordinarily based on the injured party's expectation interest and are intended to give him the benefit of his bargain by awarding him a sum of money that will, to the extent possible, put him in as good a position as he would have been in had the contract been performed." RESTATEMENT (SECOND) OF CONTRACTS, § 347 cmt. a, (1981). *See also* David McGowan, *The Tory Anarchism of F/OSS Licensing*, 78 U. CHI. L. REV. 207, 216 (2011) (discussing how the difference between approaching open source license documents as contracts or license permissions affects the remedies likely to be granted by a court, with expectation damages being the default remedy for breach of contract).

[46] 17 U.S.C. § 504(b) (2012) ("The copyright owner is entitled to recover . . . any profits of the infringer that are attributable to the infringement and are not taken into account in computing the actual damages."). *See also* MDY Indus. LLC v. Blizzard Entm't, Inc., 629 F.3d 928, 941 n.3 (9th Cir. 2010) (detailing additional remedies available under copyright law in comparison to a breach of contract claim); Omri Ben-Shahar, *Damages for Unlicensed Use*, 78 U. CHI. L. REV. 7, 9 (2011) (discussing remedies available for copyright infringement but not in breach of contract). Plaintiffs in a copyright infringement action may also be entitled to statutory damages pursuant

preliminary or permanent injunctions to enjoin copyright infringement.[47] Indeed, the Federal Circuit has opined that open source licenses restrictions "might well be rendered meaningless absent the ability to enforce through injunctive relief."[48] Copyright law also provides for the possibility of attorney's fees[49] and the destruction of infringing articles,[50] both of which can prove effective weapons in the open source context. The absence or limited availability of these remedies under contract law, however, makes contract law a weak foundation on which to build an open source framework.

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to 17 U.S.C. § 504(c). *See* Software Freedom Conservancy, Inc. v. Best Buy Co., No. 09 Civ. 10155, 2010 U.S. Dist. LEXIS 75208, at *11(S.D.N.Y July 27, 2010) (granting enhanced statutory damages for copying software in violation of the GPL). Statutory damages are generally limited, however, to a maximum of $150,000 per infringed work and, as such, may not prove a sufficient deterrent. *See* 17 U.S.C § 504(c)(2) (2012).

[47] 17 U.S.C. § 502 (2012). Prior to the decision of the Supreme Court in *eBay v. MercExchange*, most courts were relatively liberal in granting injunctions to enjoin copyright infringement. *See* eBay v. MercExchange, 547 U.S. 388 (2006). *See also* H. Tomas Gomez-Arostegui, *What History Teaches Us About Copyright Injunctions and the Inadequate-Remedy-At-Law Requirement*, 81. S. CAL. L. REV. 1197, 1205-06 (2008). In *eBay*, the Supreme Court held that courts must apply traditional principles of equity in determining whether to issue a permanent injunction against patent infringement, and that the Federal Circuit could not apply a general rule that "a permanent injunction will issue once infringement and validity have been adjudged". 547 U.S. at 393-94 (internal quotation marks omitted). The practical effect of *eBay* in the context of copyright litigation is not yet completely clear. Nevertheless, commentators have noted that it remains relatively common to obtain an injunction against copyright infringement. *See* Jake Phillips, *eBay's Effect on Copyright Injunctions: When Property Rules Give Way to Liability Rules*, 24 BERKELEY TECH. L.J. 405, 420 (2009); Robert W. Gomulkiewicz, *Conditions and Covenants in License Contracts: Tales From a Test of the Artistic License*, 17 TEX. INTELL. PROP. L.J. 335, 341 (2009) (stating that "injunctive relief is common for copyright infringement but granted rarely for breach of contract").

[48] Jacobsen v. Katzer, 535 F.3d 1373, 1382 (Fed. Cir. 2008). Even so, upon remand from the Federal Circuit, the district court in *Jacobsen* stated that "there is also evidence in the record attributing a monetary value" for the infringed work. Jacobsen v. Katzer, No. C 06-01905, 2009 U.S. Dist. LEXIS 115204, at *11 (N.D. Cal. Dec. 10, 2009). The district court did not give further details or analysis regarding such evidence.

[49] 17 U.S.C. § 503 (2012) (setting forth impounding and disposition of infringing articles as potential remedies for infringement). *See also* Software Freedom Conservancy, Inc. v. Best Buy Co., No. 09 Civ. 10155, 2010 U.S. Dist. LEXIS 75208, at *15 (S.D.N.Y July 27, 2010) (ordering forfeiture of articles determined to be infringing the GPL).

[50] 17 U.S.C. § 505 (2012) (setting forth courts' ability to assess costs and attorney's fees). *See also* Lawrence Rosen, *Bad Facts Make Good Law: The Jacobsen Case and Open Source*, 1 INT'L FREE AND OPEN SOURCE SOFTWARE L. REV 27, 29 (2009) (discussing the possibility of obtaining attorney's fees in open source disputes).

Efforts have been made towards designing a practical system that would provide downstream users with easy access to design documentation. Under a process proposed by the Open Source Hardware and Design Alliance (OHANDA), each manufactured piece of open hardware could receive a registration key to be engraved or printed on the hardware.[51] Recipients of the hardware would be able to use that registration key to locate and access the specific design documentation at the online OHANDA database. OHANDA, however, only offers a system for providing attribution information and distributing hardware documentation to the initial recipient of an article. Subsequent manufacturing activities with such documentation would presumably be governed by one of the open hardware licenses described above. OHANDA thereby provides a marginally improved open hardware arrangement, but does not address the fundamental legal issues with open hardware licenses themselves. For example, the OHANDA system cannot require the provision of hardware documentation to downstream recipients.

Much of the success of open source software can be attributed to the fact that it has succeeded in integrating itself in the commercial software industry, and that open source software licenses provide robust legal structures for dictating and enforcing the terms of such integration. In the same way, a viable framework for open source hardware must be capable of incorporation in global manufacturing, and must be supported by enforceable licensing terms. Current open hardware frameworks, however, cannot easily impose documentation or attribution obligations on downstream users, and cannot enforce their terms with effective legal remedies. Even so, an open hardware license that satisfies these requirements can be built in the technological context of three-dimensional printing. The next Section reviews some technical nuts and bolts of three-dimensional printing, and provides some legal analysis of that background.

II
THREE-DIMENSIONAL PRINTING AND COPYRIGHT

A. Technology of Three-Dimensional Printing

Three-dimensional printers use digital designs to automate the manufacture of physical objects. Three-dimensional printing technologies were independently invented in the mid-1980s in a number of different countries.[52] 3D Systems, founded in 1986, was the first company to commercialize three-dimensional

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[51] *See* Juergen Neumann et al., *OHANDA Label for Open Source Hardware*, OHANDA, http://www.ohanda.org/brief (last visited Mar. 29, 2013).
[52] IAN GIBSON ET AL., ADDITIVE MANUFACTURING TECHNOLOGIES: RAPID PROTOTYPING TO DIRECT DIGITAL MANUFACTURING 34 (2009).

printing technology.[53] Since that time, more than 30 different techniques for three-dimensional printing have been commercialized.[54] The RepRap project, an open source project for the creation of inexpensive three-dimensional printers, was founded in 2006 after some of the initial patents that covered three-dimensional printing processes expired.[55] RepRap makes all of its designs and software publicly available under the terms of the GPL, such that they are available to the public to be used and improved.[56] Makerbot, for example, is a company that provides consumer three-dimensional printing machines based on the RepRap design.[57]

The three-dimensional printing process typically begins with a digital design created using computer aided design (CAD) software. This design is transferred to the printer, which breaks down the design file into a series of thin two-dimensional slices. Each slice is used as a blueprint to construct a single layer of the three-dimensional object. The physical object is constructed as each layer is sequentially laid down by the three-dimensional printer. [58]

A broad range of technologies is currently employed to lay down the individual layers in a three-dimensional printing process. "Fused Deposition Modeling," the technique used by the RepRap machines as well as those developed by other companies, involves the controlled deposit of molten plastics or metal.[59] The molten material is deposited to create a single two-dimensional slice of the physical object. This material promptly hardens to form a single layer of the object, and this process is repeated to form successive layers. "Stereolithography," the original method used by 3D Systems, uses an ultraviolet laser to harden successive

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53 *Id*.

54 CHUA ET AL., *supra* note 8, at 10; GIBSON ET AL., *supra* note 52, at 4.

55 Michael Wienberg, *What Happens When Patent Lawsuits Hit Home 3D Printing*, PUBLIC KNOWLEDGE (Nov. 27, 2012), http://publicknowledge.org/blog/what-happens-when-patent-lawsuits-hit-home-3d.

56 *See* Adrian Bowyer, *RepRap GPL License: Distributing and Copying RepRap*, REPRAP (Dec. 14, 2006), http://reprap.org/wiki/RepRapGPLLicence.

57 ANDERSON, *supra* note 3, at 94.

58 CHUA ET AL., *supra* note 8, at 10. *See also Layer by Layer: How 3D Printers Work*, THE ECONOMIST, Apr. 21, 2012, at 16, *available at* http://www.economist.com/node/21552903 [hereinafter Layer by Layer]. *See also* Ormco Corp. v. Align Tech., Inc., 609 F. Supp. 2d 1057 (C.D. Cal. 2009) (hearing an action concerned with patent infringement, while also providing a detailed description of a specific proprietary three-dimensional printing process).

59 CHUA ET AL., *supra* note 8, at 137; *Fused Filament Fabrication*, REPRAP, http://reprap.org/wiki/Fused_filament_fabrication (last visited Apr. 2, 2013) (stating that the RepRap Project uses the terms "fused filament fabrication" rather than "fused deposition modeling," since the latter term has been trademarked).

layers of light-sensitive fluid.[60] Other prominent technologies use methods similar to standard ink-jet printing to inject powder with a binding material.[61] The common denominator of this diverse range of technologies is that they all involve an "additive" process, in which the final object is constructed from accumulations of raw material, in contrast to standard "subtractive" manufacturing technology, in which raw materials are cut and molded into the desired shape.

Current technologies can use a variety of plastics, metals and ceramics to construct three-dimensional objects.[62] The additive nature of three-dimensional printing allows for the manufacture of objects that would be difficult to produce using more traditional methods, such as objects with complex geometries or internal moving parts.[63] Additive manufacturing technology can also be used to construct articles with novel combinations of materials,[64] or even generate materials with novel properties including increased resiliency and strength.[65] Companies and researchers are exploring the possibilities of "printing" electronic circuits or even biological tissues.[66] Current commercial technologies allow the

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[60] CHUA ET AL., *supra* note 8, at 10. *See also Solid Print, Making Things with a 3D Printer Changes the Rules of Manufacturing*, THE ECONOMIST, Apr. 21, 2012, at 18, *available at* http://www.economist.com/node/21552892.

[61] CHUA ET AL., *supra* note 8, at 220.

[62] *See Layer by Layer*, *supra* note 58. Shapeways, a company that provides three-dimensional printing services over the Internet, provides a variety of materials including plastics, metals and glass. *See Materials Comparison Sheet*, SHAPEWAYS, http://www.shapeways.com/materials/material-options (last visited Apr. 2, 2013).

[63] GIBSON, *supra* note 52, at 290 (describing the capability of using three-dimensional printing to fabricate complex shapes). *See also* GIBSON at 292-93 (describing the capability of using three-dimensional printing to create internal moving parts); *The Shape of Things to Come*, THE ECONOMIST, Dec. 10, 2011, at 88, *available at* http://www.economist.com/node/21541382 (describing the use of three-dimensional printing to create articles with novel geometries).

[64] GIBSON, *supra* note 52, at 295 (describing the use of additive manufacturing technology to combine materials).

[65] *Id*. at 291 (describing the use of additive manufacturing technology to create materials with unique internal structures); *Id.* at 295 (creating "heterogeneous materials with unique properties"); *The Shape of Things to Come*, *supra* note 63 (describing the use of three-dimensional printing technology to create the "fine, lattice-like internal structure of bone" and "the basic design of a plant stem – a bundle of vertical filaments of different technology.")

[66] *Layer by Layer*, *supra* note 58 (discussing biological tissues); *Print me a Phone*, THE ECONOMIST, Jul. 28, 2012, at 71, *available at* http://www.economist.com/node/21559593 (discussing electronic circuits).

printing of details a fraction of a millimeter large,[67] and some researchers have used advanced technologies to print with a resolution of hundreds of nanometers.[68]

As the technology of three-dimensional printing has matured, both free and commercial services have developed to assist consumers in taking advantage of this progress. Thingiverse, for example, provides a free Internet platform for the sharing of digital designs.[69] Users who upload designs can choose to license them under a range of terms, including open source licenses. In addition, online commercial service bureaus provide consumers with printing services.[70] These businesses offer advanced printing technology with a variety of materials. Consumers can upload their designs to the business through the Internet, quickly obtain an automatic price quote of the cost of printing, and have the printed object shipped to their address.

B. CAD and STL Files

As noted, the printing process begins with a digital design of a three-dimensional object, typically created using computer-aided design (CAD) software. The standard CAD file formats, which can be understood and modified by humans, must be translated into a format that can be processed by three-dimensional printers.[71] The STL (STereoLithography) file format is the current de facto standard for three-dimensional printing.[72] An STL file format represents the outside surface of an object with a large number of tiny triangles.[73] The STL file format provides a relatively straightforward means of describing the geometry of a three-dimensional object in a manner that can be used by three-dimensional

[67] *Materials Comparison Sheet*, SHAPEWAYS, http://www.shapeways.com/materials/material-options (last visited Apr. 2, 2013).

[68] Florian Aigner, *3D-Printer with Nano-Precision*, VIENNA UNIV. OF TECH. (Mar. 12, 2012), http://www.tuwien.ac.at/en/news/news_detail/article/7444/ (reporting that researchers at the Vienna University of Technology have used advanced printing technologies to construct a 285 micrometer racecar and approximately 100 micrometer models of St. Stephen's Cathedral and London Bridge).

[69] THINGIVERSE, http://www.thingiverse.com (last visited Mar. 28, 2013).

[70] Examples of such business include Shapeways and Sculpteo. *See* SHAPEWAYS, http://www.shapeways.com (last visited Apr. 2, 2013); SCULPTEO, http://www.sculpteo.com (last visited Apr. 2, 2013).

[71] The standard CAD file is represented in the IGES (Initial Graphics Exchange Specifications) format. For technical reasons, however. that format is not well-suited for three-dimensional printing. *See* CHUA ET AL., *supra* note 8, at 337.

[72] *Id.* at 301.

[73] *Id.* at 28. Since the development of STL, other possible file formats for representing physical objects have been put forward as attempts to correct deficiencies in the STL format. *Id.* at 338.

printers. Nevertheless, the format is not without its problems, and a number of alternative file formats or enhancements to the STL standard have been proposed.[74] Some alternatives to the STL format contain additional information, such as data regarding the color, texture and material of printed objects.[75] The relationship between CAD and STL files can be roughly compared to the distinction between software source code and object code. CAD files and source code are readily intelligible and modifiable by humans, while the STL files and object code designed to be used by computers are not.[76]

CAD designs and STL files are not computer programs in the conventional sense of the term. Software is a set of instructions for a computer to generate a specific result. In contrast, CAD and STL files are more akin to engineering or technical drawings in that they contain data that represent the contours of a specific object, but do not provide instructions to a three-dimensional printer regarding how that object is to be constructed.[77]

C. Copyright in Printed Articles and Design Files

Copyright in the physical objects created by a three-dimensional printing process will be limited. In general, copyright law does not grant protection to utilitarian objects. Section 101 of the Copyright Act provides that the design of a useful article will be protected "only if, and only to the extent that, such design incorporates pictorial, graphic, or sculptural features that can be identified separately from, and are capable of existing independently of, the utilitarian aspects of the article." The aspiration of this statutory provision is relatively clear: to distinguish works of applied art, which should be protectable by copyright, from works of industrial design, which should not.[78] The clarity of the objective, however, has been belied by the practical difficulty of implementing the distinction

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[74] *Id.* at 338.

[75] *See STL 2.0 May Replace Old, Limited File Format*, RAPIDTODAY.COM, http://www.rapidtoday.com/stl-file-format.html (last visited Mar. 28, 2013).

[76] BRE PETTIS ET AL., GETTING STARTED WITH MAKERBOT 65 (2012) (describing the limited possibilities available for modifying STL files).

[77] *See* Ormco Corp. v. Align Techs., Inc., 609 F. Supp. 2d 1057, 1071 (C.D. Cal. 2009) (describing a three-dimensional printing design file as "data file" rather than software in the context of an action for patent infringement).

[78] *See* H.R. REP. NO. 94-1476, at 54 (1976), *reprinted in* 1976 U.S.C.C.A.N. 5659, 5667 (stating that the provision is "an effort to make clearer the distinction between works of applied art protectable under the bill and industrial designs not subject to copyright protection.") *See also* Robert C. Denicola, *Applied Art and Industrial Design: A Suggested Approach to Copyright in Useful Articles*, 67 MINN. L. REV. 707, 722 (1983) (discussing the rationales for excluding industrial design from copyright protection).

in concrete situations.[79] To this end, a number of courts and commentators have proposed tests to distinguish between the copyrightable expression and non-copyrightable utilitarian aspects of physical articles.[80]

In contrast to the limited and uncertain copyright protection available for physical articles, both CAD and STL files easily qualify for copyright protection. Copyright law protects "pictorial, graphic and sculptural works," which include: "two-dimensional and three-dimensional works of fine, graphic, and applied art, photographs, prints and art reproductions, maps, globes, charts, diagrams, models, and technical drawings, including architectural plans."[81] Such files are protected by copyright law regardless of whether they are intelligible by humans or only by computers.[82]

Courts have recognized and enforced copyrights in designs, even as they have also generally held that copyright law does not proscribe the use of copyrighted designs to manufacture physical objects.[83] The manufacture of a

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[79] *See* Pivot Point Int'l v. Charlene Prods., 372 F.3d. 913, 921 (7th Cir. 2004).

[80] *Id.*

[81] 17 U.S.C. § 101 (2012) (defining pictorial, graphic and sculptural works). *See also* Victor Stanley, Inc. v. Creative Pipe, Inc., No. MJG-06-2662, 2011 U.S. Dist. Lexis112846, at *7 (D. Md. Sept. 30, 2011) (holding that defendants infringed plaintiff's copyright in manufacturing CAD files). *But see* Meshwerks, Inc. v. Toyota Motor Sales U.S.A., Inc., 528 F.3d 1258, 1268 (10th Cir. 2008) (denying copyright protection for 3D models of Toyota cars, since the models were "unadorned images of Toyota's vehicles, the appearances of which do not owe their origins to Meshwerks."). The rationale of the decision in *Meshwerks* seems to show that original 3D design files will generally be accorded copyright protection. The decision was based on the fact that *Meshwerks* did not add any creative content to the design of the pre-existing Toyota vehicles. *Id.* As such, the decision implies that 3D design files with original creative content will be accorded copyright protection.

[82] 17 U.S.C. § 101 provides that "copies" may be perceived "either directly or with the aid of a machine or device." 17 U.S.C. § 101 (2012). *Cf.* Apple Computer, Inc. v. Franklin Computer Corp., 714 F.2d 1240, 1249 (3d Cir. 1983) (affirming that the code of a computer program, embedded in a memory chip, is an appropriate subject for copyright).

[83] *See* Victor Stanley, 2011 U.S. Dist. Lexis 112846, at *9-10 (holding that defendant could not be held liable for copyright infringement for using copied technical drawings to manufacture articles, but could be held liable for the unauthorized download, transmission, creation of derivative works and copying of the copyrighted drawings themselves); Forest River v. Heartland Rec. Vehicles, 753 F. Supp. 2d 753, 760 (N.D. Ind. 2010) (dismissing claims that the use of copyrighted design drawings to manufacture a trailer constitutes copyrighted infringement, but stating that allegations concerning the copying of the design drawing themselves "state a claim for copyright infringement as to the copies (as distinct from the actual trailer)"); Gusler v. Fischer, 580 F. Supp. 2d 309, 315 (S.D.N.Y. 2008) (stating that the plaintiff "holds a copyright in a technical drawing of a useful article, which does not preclude defendants' manufacturing and marketing of the article itself"). *Compare* Niemi v. Am. Axle Mfg. &

physical object in an automated three-dimensional printing process, however, will infringe the copyright of the underlying design file. First, copyright law grants the copyright holder the exclusive right to reproduce the copyrighted work.[84] The manufacture of an object in a three-dimensional printing process will infringe this right of reproduction, since the process requires the copying of an STL file into the memory of a three-dimensional printer.[85] Second, copyright law grants the copyright holder the exclusive right to prepare derivative works of the copyrighted work.[86] The printing of a physical article from a design file will also infringe this exclusive right, since the three-dimensional printing process requires the

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Holding Inc., No. 05-74210, 2006 U.S. Dist. LEXIS 50153, at *10 (E.D. Mich. July 24, 2006) (holding that the manufacture of a machine from a copyrighted technical drawing is not copyright infringement) *with* Niemi v. Am. Axle Mfg. & Holding Inc., No. 05-74210, 2008 U.S. Dist. Lexis 25995 (E.D. Mich. April 23, 2008) (analyzing claims regarding the copying of the technical drawings themselves, with such claims dismissed for lack of evidence of copying).

[84] 17 U.S.C. § 106(1) (2012) (granting an exclusive right of reproduction to the copyright holder).

[85] *See* Mai Sys. v. Peak Computer, 991 F.2d 511 (9th Cir. 1993) (holding that loading a copy of software onto a computer's memory constitutes copyright infringement); Cartoon Network v. CSC Holdings 536 F.3d 121, 127 (2d Cir. 2008) (affirming the holding in *Mai Systems*, but interpreting *MAI Systems* to hold that the copy in the computer's memory must be more than transitory). A digital design will be resident in the memory of a three-dimensional printer for more than transitory duration, since a printer will generally hold the file (or its derivatives) in memory for the period of time necessary to print the object, which can be several hours. CHUA ET AL., *supra* note 8, at 31. The holding of *Mai Systems* applies to any copyrighted work (and not only software) that is loaded into a computer. *See* NIMMER ON COPYRIGHT, § 8.08[A][1] (stating that "input of a work into a computer results in the making of a copy, and hence . . . such unauthorized input infringes the copyright owner's reproduction right"). *See also* Jedson Eng'g Inc. v. Spirit Constr. Servs., 720 F. Supp. 2d 904, 919 (S.D. Oh. 2010) (copyright infringement resulting from unauthorized access of CAD files and technical drawings through Internet and CD-ROM); Gemel Precision Tool Co. v. Pharma Tool Corp., Civ.-A. No. 94-5305, 1995 U.S. Dist. LEXIS 2093, at *17 (E.D. Pa. Feb. 13, 1995) (holding that the defendant's creation of CNC machine files infringed plaintiff's copyright). *Cf.* Ormco Corp. v. Align Tech., Inc., 609 F. Supp 2d 1057, 1072 n.17 (C.D. Cal. 2009) (in a patent infringement claim, relying on copyright law to show that loading three-dimensional printing data files creates a copy of those files). *But see* Simon Bradshaw et al., *The Intellectual Property Implications of Low-Cost 3D Printing*, 7 SCRIPTED 1, 25 (2010), *available at* http://www.law.ed.ac.uk/ahrc/script-ed/vol7-1/bradshaw.pdf. Bradshaw states that, under the law of the United Kingdom, the copyright in a design document is not infringed by using the design to create an article in a three-dimensional printing process. *Id*. In reaching this conclusion, Bradshaw does not address or analyze the copying inherent to a computerized manufacturing process.

[86] 17 U.S.C. § 106(2) (2012) (setting forth copyright holder's exclusive right to prepare derivative works).

transformation of the CAD or STL file into a series of print-ready two-dimensional slices.[87] In other words, the owner of the copyright in an STL file cannot prevent the use of that file in a general manufacturing process. But three-dimensional printing is not a typical manufacturing process – the use of digital designs and automated manufacturing creates a physical article that corresponds directly to the specifications of the digital design, and which requires the copying and transformation of the original digital file. As such, without a license, the use of the design file in a three-dimensional printing process will infringe the copyright in the design file.

III
AN OPEN HARDWARE LICENSE FOR THREE-DIMENSIONAL PRINTING

Two aspects of three-dimensional printing can provide the foundation for an effective and enforceable open hardware legal framework. First, the printing of a physical object necessarily requires the copying of the digital design used to print that object, in the same way that using software on a computer necessarily involves the creation of a copy of that software product. Second, objects created by three-dimensional printing bear a one-to-one correspondence between the digital file and the object that is actually printed.[88] In these two respects, three-dimensional printing differs from traditional manufacturing methods.

The author proposes the "Three-Dimensional Printing Open License" (the "**TDPL**"), an annotated draft of which is attached as an appendix to this Article. The TDPL draws on the unique characteristics of three-dimensional printing to construct a license that incorporates enforceable documentation, attribution and copyleft provisions. The application of the TDPL is limited to the specific technological setting of three-dimensional printing and, as described in more detail below, may not be appropriate in all circumstances. Nevertheless, as the technology improves and is gradually integrated into a broad swath of industries, the scope of the license's application will increase. The next section describes the

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[87] *See* Victor Stanley, 2011 U.S. Dist. Lexis 112846, at *10 (D. Md. 2011) (finding copyright infringement when defendants created derivative works of CAD manufacturing files). The printer may also manipulate the file in other ways as well, to ensure that "it is the correct size, position and orientation for building." *See* GIBSON, *supra* note 52, at 5. In other situations, the printer may be required to segment a single STL file or merge several STL files. *See id.*at 45.

[88] In actual fact, there may not be an exact one-to-one correspondence between the design file and the final printed article. First, a printed article may require some amount of post-processing, such as finishing, polishing, sand-papering or coating. GIBSON, *supra* note 52, at 46. Second, certain printing technologies may require the printing of additional "supports" during the printing process to buttress manufactured articles. *Id.* at 53.

theory and structure of the license, and the section after that presents arguments in favor of and against the proposed framework, and analyzes certain limitations of the license. Matters more directly related to the specific language of the license are addressed in annotations to the draft.

A. Theory and Structure of the License

The TDPL acts as a copyright license for a digital design file and, in this sense, follows the precedent of open source software licenses. The TDPL provides that recipients of the licensed design file are granted rights to copy, modify and distribute the design file, subject to certain conditions.[89] Under this framework, as long as the recipient of the digital design file satisfies the conditions of the license, she will have the right to manufacture the designed object in a three-dimensional printing process. Without the permissions granted by the TDPL, however, the use of a digital design file in an automated printing process would involve the unauthorized copying of the design file and constitute copyright infringement.[90]

The TDPL imposes certain minimum conditions on the copying and distribution of the design file itself. These conditions are broadly comparable to similar provisions in open source software and hardware licenses, and are intended to ensure the continued attribution of the file to its author and the continued distribution of the design to downstream recipients under the terms of the TDPL itself. The license thereby generally prohibits the removal of any copyright information or other notices from the design file.[91] Second, in broad outline, the license provides that any recipient who modifies the design file must provide notice of such changes.[92] Third, the license provides that a recipient may only distribute the file (and derivative works of the file) pursuant to the terms and conditions of the TDPL.[93]

While these conditions do not materially differ from conditions in other open licenses, they can have consequential effects in the context of three-dimensional printing. For example, a design file may be structured such that certain copyright information or other notices will be imprinted on the printed physical object.[94] As the TDPL prohibits the removal of these notices from the design file, and as the

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[89] TDPL, § 2.
[90] *See supra* text accompanying notes 83-87.
[91] TDPL, § 3.2.
[92] TDPL, § 3.3(a).
[93] TDPL, §§ 3.1, 3.3(b).
[94] *See* GIBSON, *supra* note 52, at 56 (discussing software that can imprint identification information on printed articles).

printed article bears a one-to-one correspondence to the design file, the effect of this provision is that the license can require that all articles printed with the design file will incorporate specified notices. Such notices can include attribution information specifying the identity of the initial author of the file. No less importantly, such notices can include information, for example, regarding an Internet site where any recipient of the printed article can obtain the design file.[95] These notices would allow all downstream recipients of the printed, physical article to have access to the digital files needed to manufacture that article.

As noted, the TDPL also requires that a recipient who modifies the design file must communicate that fact in notices incorporated in the design. The details of this condition differ somewhat from other open licenses, and are intended to implement a copyleft obligation in the context of three-dimensional printing. The license provides that recipients may modify the design file, provided that the recipient at the same time also inserts in the design file, a notice describing where the modified design file may be accessed.[96] This new notice must also be included

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[95] TDPL, § 1.8 (stating that a Required Notice may provide "direction to a URL which displays" such attribution and licensing information). In situations where the inclusion of extensive attribution and licensing language would prove awkward or require the use of extensive area on a confined physical object, such notices could be composed of other digital means of providing such information. For example, two-dimensional bar codes could be used to provide an efficient means of directing users to the appropriate Internet site. A similar approach has recently been adopted by Thingiverse. *See Help with Barcodes*, THINGIVERSE, http://www.thingiverse.com/help/barcodes (last visited Apr. 2, 2013). Similarly, the Linux Foundation has proposed a similar means for tracking open source software components included in software products. *See The Linux Foundation Announces New Tool for Tracking Free and Open Source Software Components*, THE LINUX FOUNDATION (May 30, 2012), http://www.linuxfoundation.org/news-media/announcements/2012/05/linux-foundation-announces-new-tool-tracking-free-and-open-source-s.

[96] TDPL, § 3.4. An important feature of the TDPL is that it conditions the right to modify the design file on the concomitant insertion of this notice. In order to be enforceable under copyright law, the provisions of the TDPL must constitute conditions to a copyright license rather than additional contractual covenants. *See* Omri Ben-Shahar, *Damages for Unlicensed Use*, 78 U. CHI. L. REV. 7, 11-12 (discussing the differences between license conditions and covenants). In order to constitute a condition to the license, the provision at question must relate to an action that (a) exceeds the license's scope (b) in a manner that implicates one of the licensor's exclusive statutory rights. *See* MDY Indus. LLC v. Blizzard Entm't Inc., 629 F.3d 928, 940 (9th Cir. 2010). Provisions that condition a software user's right to create derivative works or modifications are, under this test, considered license conditions rather than contractual covenants. *Id.* at n.3. As such, the requirement of the TDPL that modifications must be accompanied by an insertion of the modification notice should constitute a condition to the copyright license rather than an additional contractual covenant. The GPL operates in the same way: the copyleft provisions of the GPL are formulated as conditions to the GPL's grant of

on the printed physical object.[97] Again, as a result of the correspondence between the file and the printed object, this provision provides downstream recipients of the printed article with access to the modified design files of the modified object. As the unauthorized use of the design file in a three-dimensional manufacturing process would infringe the copyright in the design file, a recipient of the file will not be legally permitted to use the design file to print objects unless she has complied with the requirements of the license.

B. Advantages and Disadvantages of the Licensing Framework

The TDPL licensing regime presents several advantages. First, the license is designed to allow the easy integration of open hardware into complex supply chains.[98] The license ensures that all recipients of the hardware throughout a distribution chain have access to the original design file, but this accessibility is achieved without imposing complex contracting requirements on supply chain intermediaries. Downstream intermediaries and integrators that make no changes to the design documentation should be able to market and distribute hardware, or incorporate hardware into larger articles, without concern for any legal obligations imposed by the license. In general, the license is intended to be self-executing in that the required notices should be the automated output of the three-dimensional printing process. This absence of contractual obligations, and the concomitant lowering of administrative and transactional costs, should ease the integration of open source hardware into commercial items without sacrificing access to the design.[99]

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distribution rights. In other words, a licensee is not permitted to distribute works under the GPL unless it also provides source code as required by the license. *See* Heather Meeker, *The Gift that Keeps on Giving – Distribution and Copyleft in Open Source Software Licenses*, 4 INT'L FREE AND OPEN SOURCE SOFTWARE L. REV. 29, 29 (2012). The conditions of the TDPL are structured to apply to the modification of the design file rather than the distribution of a physical object since, in contrast to the GPL's software setting, the distribution of physical articles may not implicate any rights under copyright law. *See supra* text accompanying notes 78-80.

[97] TDPL, § 1.6

[98] Several industries with complex supply chains, such as the automotive and aerospace industries, have already begun to make use of three-dimensional printing. *See* NEIL HOPKINSON ET AL., RAPID MANUFACTURING: AN INDUSTRIAL REVOLUTION FOR THE DIGITAL AGE 13 (2006). *See also supra* note 30, noting the complex supply chains in these industries.

[99] TDPL, § 4 does contain a contractual commitment not to remove any notices from any physical objects printed with the design file and an obligation to pass this commitment onto downstream recipients of the object. Unfortunately, it is unclear whether this prohibition could be achieved without resort to such a contractual commitment. The Digital Millennium Copyright

Another advantage of the TDPL regime is that it is straightforward to define the design information that must be made available. Developers of open source hardware licenses have struggled to specify the level of detail that should be provided in design documentation.[100] Arduino, for example, provides schematics and reference designs for its circuit boards, but does not provide the material composition and schematics for each individual component on that circuit board. The Arduino approach makes practical sense; the burden of disclosing the specifications of each and every component quickly becomes unwieldy, and recipients probably do not need that level of resolution in order to construct the Arduino circuit board from the design documentation. On the other hand, an effective licensing regime needs to ensure that recipients are provided with an adequate level of detail, and finding an *ex ante* definition for the proper level of resolution can prove difficult.[101] The TDPL regime, however, relies on the exact correspondence between the digital design file and the printed object to resolve this difficulty. The license simply provides that the recipient must be given access to the file used to generate the printed article. This file contains all the technical detail necessary for the recipient to print the article herself.

The TDPL recognizes that it may be burdensome to require licensees to provide continuous updates of all modifications made to the design file. To address this problem, the TDPL contains a limited exception to the requirement to provide access to modified design files. The license provides that modifications created solely for the internal use of the licensee do not trigger the requirement to include a notice in the design file.[102] The license also provides that the distribution of

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Act does contain a prohibition to "remove or alter any copyright management information." 17 U.S.C. § 1202(b) (2012). It is unclear whether this prohibition applies to notices printed on a physical object, since the statutory provision only concerns notices "conveyed in connection with copies . . . of a work or performances or displays of a work." 17 U.S.C. § 1202(c) (2012); *see* Textile Secrets Int'l, Inc. v. Ya-Ya Brand, Inc., 524 F. Supp. 2d 1184, 1201-03 (C.D. Cal. 2007) (holding that the prohibition does not apply to the removal of a tag attached to fabric). At the same time, however, the *Textile Secrets* holding was limited to a situation where there was an "absence of any facts demonstrating that a technological process was utilized in connection with . . . applying the copyright information . . . ." *Id.* at 1201, n.17.

[100] Katz, *supra* note 7, at 49-51. Katz attempts to resolve this problem by providing that an effective open hardware license could require the provision of complete design documentation, where that documentation could consist of components that are readily available with known specifications. This of course requires some judgment concerning which components should be considered "readily available." In addition, what constitutes "readily available" could change over time.

[101] *Id.*

[102] TDPL, § 1.4

physical objects printed with the design file to third parties creates a presumption that the modifications were not made solely for the internal use of the licensee.[103] The intent of these provisions is to allow licensees the freedom to experiment and test new designs without the costs of compliance with the TDPL obligations. At the same time, the provisions attempt to ensure that once a licensee begins to distribute physical objects created with the modified design file she will be obligated to make the modified design files available.

Of course, the licensing framework of the TDPL also presents theoretical and practical disadvantages. Most importantly, the copyleft provisions of the TDPL to some extent depend on the use of the design document in a manufacturing process in which the design document is itself copied.[104] Otherwise, a recipient of the design would not require a copyright license to manufacture an article based on the design and, in such a situation, the use of the design could not be conditioned on compliance with the license. This suggests that the TDPL may be most appropriate for articles that are difficult or impractical to produce in a traditional manufacturing process, or in areas in which three-dimensional printing has a comparative advantage, such as the production of complex parts, customized articles, or articles incorporating novel materials.[105] As the technology of three-dimensional printing improves and its costs decrease, the TDPL will become appropriate for a growing and diverse number of articles. Second, even traditional manufacturing is increasingly making use of computer aided design.[106] Given this growing reliance on computers in the design process, the use of a design licensed under the TDPL will most likely be in the context of a process that does incorporate CAD, even if the entire process is not automated. Unauthorized use of the licensed design in such a process would also require a license. Third, to the

[103] TDPL, § 3.3.

[104] As noted above, a limited copyright may be applicable to certain physical articles. *See supra* text accompanying notes 83-87. As such, it may also be possible to use such copyright to enforce the license conditions of the TDPL, and the text of the TDPL recognizes this possibility. *See infra* note 127. Even so, as the existence and scope of such copyrights can be contentious, the TDPL relies on the copyright in the design document instead.

[105] *See supra* text accompanying notes 63-65 (detailing the comparative advantage of three-dimensional printing in producing certain articles and materials).

[106] PETER MARSH, THE NEW INDUSTRIAL REVOLUTION 26-28 (2012) (describing the widespread use of computer aided design in modern manufacturing); ERIC VON HIPPEL, DEMOCRATIZING INNOVATION 104 (2005); Victoria Gomelsky, *Computerized Machines Aid Human Watchmakers*, NY TIMES (Sept. 4, 2012), http://www.nytimes.com/2012/09/05/fashion/05iht-acaw-hitech05.html?pagewanted=all&_r=0 (describing the "ubiquity of computer-aided design" in the Swiss watch making industry); ANDERSON, *supra* note 3, at 76 (stating that "[s]oftware is increasingly driving the design process").

extent this argument is a claim that an open hardware design can be easily reverse engineered and implemented in a separate, non-infringing design, the argument applies no less forcefully to the development of open source software.[107]

A second disadvantage of the TDPL is that copyrights in digital design files would be limited to the expressive, non-functional aspects of the file. Black letter law provides that copyrights do not protect ideas or information, but only the specific expression of an idea.[108] Furthermore, the "merger" doctrine provides that copyright law will not protect any expression that must be copied to implement a particular idea.[109] As many physical articles produced with three-dimensional printing will be functional objects, the copyright in the design document that describes those articles may be limited. And, since the enforceability of the TDPL depends on the design file copyright, the license may not be effective for useful or functional designs. Even so, the same contentions would argue against the use of open source licenses for software programs. Software, like a design file, contains both expressive and functional elements.[110] Moreover, software is typically valued for those very functional elements, rather than the expressiveness or creativity of the code.[111] Nevertheless, courts have continued to uphold copyrights for the

[107] Indeed, in designing the Android platform, Google reverse engineered and reconstructed an equivalent to almost all of the Java programming language. Generally, Java was licensed by Oracle under either the GPL or pursuant to commercial terms. Google carried out this complex and costly process in order to circumvent these licensing terms. *See* Oracle Am., Inc. v. Google Inc., 872 F. Supp. 974, 978 (N.D. Cal 2012) (stating that "Google wrote or acquired its own source code to implement virtually all the functions of the 37 API packages in question. Significantly, all agree that these implementations — which account for 97 percent of the lines of code in the 37 API packages —are different from the Java implementations."). The roots of the open source movement itself also grew out of such a feat of reverse engineering, when staff at UC Berkeley rewrote much of the Unix source code that was proprietary to AT&T. *See* WEBER, *supra* note 4, at 40. The Linux operating system also grew out of a similar attempt to bypass the licensing restrictions imposed on the source code of Unix. *See* MOODY, *supra* note 13, at 33-43.

[108] 17 U.S.C. § 102 provides that "[i]n 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." 17 U.S.C. § 102(b) (2012).

[109] For a summary of the application of the merger doctrine in the context of software programs, see Lexmark Int'l, Inc. v. Static Control Components, Inc., 387 F.3d 522, 535 (6th Cir. 2004).

[110] *See* Computer Assocs. Int'l, Inc. v. Altai, Inc., 928 F.2d 693, 704 (2nd Cir. 1992) (noting that "[t]he essentially utilitarian nature of a computer program further complicates the task of distilling its idea from its expression").

[111] *See, e.g.*, Pamela Samuelson et al., *A Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2308, 2317 (1994) ("Behavior is not a secondary by-product of a program, but rather an essential part of what programs are. To put the point starkly:

expressive elements of software files, even as they have held that such copyrights cannot protect the functional elements of a program, or the elements of a program that have been dictated by external standards.[112] Despite this limitation on copyright protection for software, the enforceability of software licenses in general, and of open source software licenses in particular, is generally accepted.[113] The TDPL should be no less enforceable than such software licenses.

A third disadvantage of the TDPL is that the license requires recipients who modify a design to maintain an accessible, online repository of the modified design. This may require recipients to bear the costs of maintaining an Internet location where such designs can be accessed, as well as incurring the administrative costs of keeping and posting historical and up-to-date copies of such designs. Even so, this requirement does not significantly differ from similar obligations in open source software licenses. For example, version 3 of the GPL allows distributors to satisfy their copyleft obligations by providing recipients with a written offer to access source code from a network server.[114] In allowing distributors to satisfy their copyleft obligations in this fashion, the Free Software Foundation has noted that the advancement and proliferation of Internet technology should ensure that this option is not too burdensome for either distributors or recipients of source material.[115]

No one would want to buy a program that did not behave, i.e., that did nothing, no matter how elegant the source code 'prose' expressing that nothing.").

[112] *See, e.g.,* Lexmark Int'l Inc. v. Static Control Components, Inc., 387 F.3d 522, 537-42 (6th Cir. 2004) (holding that Lexmark's "Toner Loading Program" was not copyrightable since the expression of the program was constrained by compatibility requirements).

[113] For a discussion of software license agreements in general, see Raymond T. Nimmer, *Copyright First Sale and the Over-riding Role of Contract*, 51 SANTA CLARA L. REV. 1311, 1322 (2011). Nimmer notes that "[i]n the digital era, all of the traditional content industries have moved to a mixed model of distribution and many new industries only use digital distributions subject to license agreements." *Id.* With respect to open source licenses, the Software Freedom Law Center, for example, has been successful in enforcing the GPL with respect to "BusyBox" software. *See supra* note 6. *See also* Software Freedom Conservancy, Inc. v. Best Buy Co., No. 09 Civ. 10155, 2010 U.S. Dist. LEXIS 75208, at *15 (S.D.N.Y July 27, 2010) (ordering forfeiture of articles determined to be infringing the GPL).

[114] Section 6(b) of version 3 of the GPL provides that a licensee that may satisfy its obligations to provide source code by providing written notice regarding "access to copy the Corresponding Source from a network server at no charge." GPLv3, *supra* note 13, § 6(b). In addition, Section 6(d) allows licensees to provide source code through a "network server" if object code was provided in the same manner. *See id*. at § 6(d).

[115] *See* GPL Second Draft, *supra* note 41, at n. 51. *See also* OSHWA Definition, *supra* note 23, at § 1 (stating that download from the Internet is the preferred method for making source

The text of the TDPL attempts to preempt another possible complication of the licensing regime. To a large extent, the scope of a licensee's copyleft obligations under the license is relatively clear: a licensee is only obligated to provide design documentation for the specific printed article. This provision should serve to alleviate concerns that the incorporation of an open hardware article in a larger product would require the disclosure of design documentation not related to the specific printed article.[116] Nevertheless, as the technology of three-dimensional printing advances and becomes more widespread, it is possible that designers would develop "hardware design blocks" – modular designs, representing self-contained hardware pieces, which could be incorporated in a more extensive design for the printing of larger, more complex objects. This would parallel the use of software libraries for the development of complex software products, or the use of intellectual property cores in the development of semiconductor chips.[117] In such event, concerns could be raised regarding the impact of the TDPL's copyleft obligations on independently designed modules. Similar questions in the arena of open source software licensing have proven to be the source of much debate and confusion.[118] The TDPL attempts to preempt such matters by providing that any design work that may be represented in a separate digital file will not constitute a

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documentation available); *The Open Source Definition*, THE OPEN SOURCE INITIATIVE, http://www.opensource.org/osd (providing that download from the Internet is the preferred method of making source code available). Section 5.2(ii) of the TAPR license also provides that hardware documentation can be distributed by providing a URL where documentation may be downloaded. On the other hand, the Software Freedom Law Center (SFLC) has opined that, for much of the world, downloading source code from the Internet is either not possible or not practical. *See* Bradley M. Kuhn et al., *A Practical Guide to GPL Compliance,* SOFTWARE FREEDOM LAW CENTER (Aug. 26, 2008), http://www.softwarefreedom.org/resources/2008/compliance-guide.html. The opinion of the SFLC dates from 2008, and as Internet technology advances and become more accessible this well-grounded objection to Internet distribution should become less relevant. While the cost to licensors of establishing and maintaining an Internet website from which users could obtain source material is not negligible, this cost could be substantially lowered through the use of community websites such as Thingiverse, in the same way that software source code is made available on community Internet sites such as Sourceforge. *See* SOURCEFORGE, http://sourceforge.net (last visited Apr.2, 2013).

[116] For example, Katz questions whether bolting a copyleft wheel to a car would require the distribution of design documentation for the entire car. *See* Katz, *supra* note 7, at 48.

[117] *See generally* Eli Greenbaum, *Open Source Semiconductor Core Licensing*, 25 HARV. J.L. & TECH. 131 (2011).

[118] *See* Malcolm Bain, *Software Interactions and the GNU General Public License*, 2 INT'L FREE AND OPEN SOURCE SOFTWARE L. REV. 165, 165 (2010) (noting that "[t]he so-called 'GPL linking' debate has been raging for the last 18 years, and probably will go on for . . . quite a few more").

derivative work of the licensed design.[119] In other words, the incorporation of a TDPL licensed "design block" inside a larger design will not cause the larger design to be subject to the terms of the TDPL.

The TDPL also attempts to address a situation where the techniques of three-dimensional printing may also be used to manufacture products on which no label could practically be attached. For example, it has been anticipated that future applications of three-dimensional printing may include the production of chemicals or even biological tissues.[120] The TDPL attempts to address such applications by providing that, in certain limited circumstances, the attribution and licensing notices may be imprinted on packaging ordinarily received by the end user.[121]

In sum, the TDPL provides a framework for licensing open hardware designs. The TDPL is enforceable under copyright law, since the use of a design document in a three-dimensional printing process not in compliance with the license will infringe the copyright in the design document. Under this framework, the licensor of a design document can be confident that the TDPL will be enforceable against downstream users of the design document, and that the law will provide effective remedies to enforce the terms of the license. In addition, all downstream users of printed articles will be provided with the attribution and documentation information made available on the printed article itself.

CONCLUSION

Open hardware proponents have expressed concern that intellectual property laws could be used to stifle the growth of three-dimensional printing. Most obviously, the physical objects created by three-dimensional printing could be the subject of patent protection, and patent law could be applied to prevent the manufacture, use or sale of those articles.[122] Other commentators have noted that copyright law could be used to restrict the use of digital designs. First, digital

[119] TDPL, § 1.3.

[120] *See 3D printers could create customized drugs on demand*, BBC NEWS (Apr. 18, 2012), http://www.bbc.co.uk/news/technology-17760085. Commentators have noted the difficulty of applying open source development principles to biotechnology. *See, e.g.*, David W. Opderbeck, *The Penguin's Genome, or Coase and Open Source Biotechnology*, 18 HARV. J.L. & TECH. 167, 198-99 (2004). The TDPL, however, allows the easy application of open source principles to any biotechnology process that uses three-dimensional printing technology.

[121] TDPL, § 3.7.

[122] Michael Weinberg, *It Will be Awesome if They Don't Screw it Up: 3D Printing, Intellectual Property, and the Fight Over the Next Great Disruptive Technology* (2010), PUBLIC KNOWLEDGE, http://www.publicknowledge.org/files/docs/3DPrintingPaperPublicKnowledge.pdf.

rights management ("DRM") and other content access restrictions could be applied to three-dimensional printers in order to ensure that such devices only construct pre-authorized designs, in the same way that such technological restrictions are already applied to other forms of digital content.[123] The Digital Millennium Copyright Act (DMCA) would criminalize the circumvention of those DRM restrictions, even as applied to legitimate uses of digital designs.[124] In addition, Internet sites that allow for the easy sharing of digital designs could be subject to infringement lawsuits unless they found safe harbor under the DMCA "notice and take down" provisions.[125]

Intellectual property law can be used to restrain the advance of three-dimensional printing, but it can also be used to ensure broader access to such technology. This Article has shown that the construction of an open hardware license is possible in the technological domain of three-dimensional printing. As with open source software, this license is based on copyright law, and should therefore be relatively easy to apply and enforce. Moreover, and again as with open source software, such a license could be instrumental in creating a "commons" where the free exchange of design information can flourish.

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[123] Fred Chasen et al., *Your Printer is Like iTunes: DRM and the 3D Printing "Revolution,"* INFORMATION LAW AND POLICY BLOG (Oct. 21, 2012), http://blogs.ischool.berkeley.edu/i205f12/2012/10/21/your-printer-is-like-itunes-drm-the-3d-printing-revolution/. Intellectual Ventures, a well-known non-practicing entity, has been issued a patent for the application of DRM technology to three-dimensional printing. *See* U.S. Patent No. 8,286,236 (issued Oct. 9, 2012).

[124] Section 1201 of the Copyright Act prohibits both acts of circumvention as well as trafficking in the tools and technologies of circumvention. 17 U.S.C. § 1201(a)(1)(A) (2012) (providing that "[n]o person shall circumvent a technological means that effectively controls access to a work protected under this title"); 17 U.S.C. § 1201(b)(1)(A) (2012) (providing that "[n]o person shall manufacture, import, offer to the public, provide, or otherwise traffic in any technology . . . primarily designed or produced for the purpose of circumventing protection afforded by a technological measure that effectively protects a right of a copyright owner under this title in a work or a portion thereof"). For a summary of concerns regarding the use of digital rights management, see *DRM*, ELECTRONIC FRONTIER FOUNDATION, https://www.eff.org/issues/drm.

[125] The DMCA safe harbor provisions protect online service providers ("ISPs") from copyright infringement claims in respect of user activity, so long as the service provider complies with specific conditions. 17 U.S.C. § 512(a)(1-5) (2012). To avoid liability, the ISP must promptly remove or block access to alleged infringing material when they receive notification of an infringement claim from a copyright holder. 17 U.S.C. § 512(c)(1)(C) (2012). Thingiverse has received at least one DMCA takedown notice in respect of a digital design. Bre Prettis, *Copyright Policy*, THINGIVERSE BLOG (Feb. 18, 2011), http://blog.thingiverse.com/2011/02/18/copyright-and-intellectual-property-policy/.

APPENDIX: THE THREE-DIMENSIONAL PRINTING OPEN LICENSE

The THREE-DIMENSIONAL PRINTING OPEN LICENSE ("**License**") has been constructed specifically for situations in which a digital design is used to generate physical articles in an automated manufacturing process, and its application may not be clear in other situations. You may not use a work licensed under this License except in compliance with these terms. You are not obligated to agree to these terms, but nothing else grants you the right to use a work licensed hereunder.[126]

1. **Definitions**. The following terms, when capitalized in the body of this License, shall have the meanings set forth below.

   1.1 "**Build Form**" means any form of the Work which is provided to any device for the manufacture of a Printed Article in an automated manufacturing process.

   1.2 "**Copyright**" means copyright and any similar right (including any rights of industrial design and any semiconductor topography rights), whether registered or unregistered.[127]

   1.3 "**Derivative Work**" means any work that is a derivative of the Work under applicable law. Notwithstanding the foregoing, a Derivative Work does not include any work that may be separately represented in a digital file that does not include any part of the Work itself.

   1.4 "**Internal Purposes**" means for internal or personal research and development purposes. A distribution of Printed Articles to third parties not under your the sole control or not working solely on your behalf creates a presumption that your modifications are not for Internal Purposes.

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[126] These annotations to the text of the TDPL describe certain drafting decisions made in creating the license. Capitalized terms used in annotations notes have the same meaning given to those terms in the body of the TDPL itself.

[127] Certain circumstances might allow for a copyright in a Printed Articles itself. Such copyrights in Physical Articles often raise disputes as to their scope and enforceability. *See supra* text accompanying notes 78-80. As such, the TDPL does not rely on such copyrights to enforce the conditions of the license. Nevertheless, nothing in the TDPL prevents a licensor from claiming that the unauthorized copying of the Printing Article constitutes copyright infringement of the copyright in the Printed Article itself.

1.5 "**Licensor**" means any individual or entity that creates or has knowingly contributed to the creation of the Work, but does not include an individual or entity that only distributes a Work or Printed Article.

1.6 "**Modified Notice**" means a notice (a) incorporating the information in a Required Notice, (b) stating that You have modified the Work, and (c) satisfying any other requirements of this License.

1.7 "**Printed Article**" means a physical article created by using digital files of the Work in an automated manufacturing process.

1.8 "**Required Notice**" means any element of a Work which provides (a) information regarding the authorship of the Work and stating that the Work is provided under this License, or (b) providing direction to a URL which displays the information listed under clause (a). A Required Notice also includes any element of a Work which causes the imprinting of the foregoing information on a Printed Article.

1.9 "**Source Form**" means the preferred form for making modifications to the Work. Source Form does not include file formats in which only minor changes (such as repair, resizing or changes of orientation may be made), such as STL file formats.

1.10 "**Work**" means any work licensed under this License and any work intentionally incorporated into a work licensed under this License.

1.11 "**You**" means any individual or entity in possession of a Work.

2. **Copyright License**. Subject to the terms and conditions of this License, each Licensor hereby grants to you a perpetual, worldwide, non-exclusive, royalty-free license under its Copyrights to (a) reproduce, modify, prepare Derivative Works of, publicly display, publicly perform and distribute the Work and such Derivative Works in Source Form or Build Form, and (b) generate Printed Articles using the Work.

3. **Conditions**. Your exercise of any rights under this License is subject to the following conditions:

3.1 You may not distribute the Source or Build forms of a Work under any terms other than the terms and conditions of this License.

3.2 You may not modify or remove any Required Notice, *provided however* that you may change the location or size of any Required Notice in the Work, or the location or size of information imprinted by a Required

Notice on a Printed Article, so long as (a) the Required Notice remains easily readable by humans in the Source Form of the Work and (b) any imprint or representation of the Required Notice in the Printed Article generated using a Work remains accessible and easily readable by humans or electronic devices.[128]

3.3 If you create a Derivative Work, you must (a) insert a Modified Notice in such Derivative Work and (b) license the Source and Build Forms of such Derivative Work under the terms of this License, *provided however* that as a limited exception you are not required to insert a Modified Notice in respect of modifications to the Work made only for Internal Purposes.

3.4 If the Required Notice of a Work contains or provides direction to a URL displaying the Source Form of the Work, then the Modified Notice must also contain or provide direction to a URL displaying the Source Form of the Derivative Work. The Source Form available at such URL must be in a format that is easily downloadable and copied, and must be maintained for at least three years from the last time you generated Printed Articles using the Work and as long as you offer spare parts or customer support for the Printed Article.[129] Any attribution or copyright information in the Required Notice may be provided at such URL location rather than in the Modified Notice itself.

3.5 If the Required Notice of a Work causes the imprinting of information onto a Printed Article, the Modified Notice must cause the imprinting of the same type of information on the Printed Article in the same location and format as the imprinting caused by the Required Notice, subject to the exceptions in Section 3.2.

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[128] The TDPL recognizes that there may be legitimate situations that require a change in the location or size of a notice on a Printed Article, including for aesthetic purposes. At the same time, the TDPL also recognizes the interest of the Licensor in ensuring that such notices remain accessible. As such, the TDPL allows licensees to change the location or size of any notice, so long as it remains reasonably accessible. The reference to "electronic devices" is intended to capture the possibility that a Required Notice will only consist of a bar code that directs a recipient to an internet location. *See supra* note 95.

[129] This requirement to maintain the URL providing the Source Form of the Work for at least three years is based on the three year time frame used in both Section 6(b) of GPLv3 and Section 5.2(ii) of the TAPR Open Hardware License. *See* GPLv3, *supra* note 13, at § 6(b).

3.6 Notwithstanding anything to the contrary in this License, you may remove a Required Notice if the Modified Notice satisfies the conditions of this License.

3.7 As a limited exception to the requirements of this Section 3, if a Printed Article is a non-solid substance then the Required Notice or Modified Notice may be imprinted on the packaging in which the end user is expected to receive the Printed Article.

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