U.S. COPYRIGHT OFFICE & LIBRARY OF CONGRESS

In the Matter of Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies	)	Docket No: RM 2014-07

COMMENTS OF STRATASYS, LTD.

IN OPPOSITION TO

PROPOSED CLASS 26: SOFTWARE OR FIRMWARE IN 3D PRINTERS TO ALLOW USE OF NON-MANUFACTURER-APPROVED FEEDSTOCK

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COMMENTS OF STRATASYS, LTD.

In connection with the sixth triennial rulemaking proceeding under the Digital Millennium Copyright Act ("DMCA"), Stratasys, Ltd. ("Stratasys")[1] submits these comments in opposition to the Petition filed by Public Knowledge and the Long Comment filed by Public Knowledge and the Library Copyright Alliance (collectively, "Petitioners") seeking to exempt from DMCA liability the circumvention of technological protection measures ("TPMs") controlling access to firmware and software in 3D printers in order to allow for the use of non-manufacturer-approved feedstock.[2]

I. INTRODUCTION AND SUMMARY OF OPPOSITION.

Petitioners' proposed exemption reflects a misunderstanding of 3D printing technologies and industry dynamics. The proposed exemption would undermine technological mechanisms that have supported the rapid innovation and increased adoption of 3D printing technologies among new classes of customers. It would also diminish the ability of 3D printing systems to serve as secure hubs for the distribution of proprietary software and designs and for the collection of critical performance and manufacturing information. Moreover, the exemption proposed by Petitioners is unnecessary because there are numerous 3D printers in the marketplace that are not restricted to a manufacturer's approved materials.

The proposed class of "3D printers" comprises various technologies that translate digital files into physical objects by adding successive layers of material, sometimes referred to as additive manufacturing. All such technologies are limited to some extent in terms of the kinds of material that can be used with a system's hardware and programming.

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[1] For the purposes of these comments, a "Stratasys" printer refers to a commercial FDM® or PolyJet™ printing system sold under the Fortus, Connex, Objet, Dimension, Mojo, uPrint, and/or Solidscape brands.

[2] Petition for a Proposed Exemption Under 17 U.S.C. § 1201 of Public Knowledge, *In the Matter of Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies*, Docket No. RM 2014-07 (Nov. 3, 2014) [hereafter "**Public Knowledge Petition**"]; Long Comment Regarding a Proposed Exemption Under 17 U.S.C. § 1201 of Public Knowledge and the Library Copyright Alliance, *In the Matter of Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies*, Docket No. RM 2014-07 (Feb. 6, 2015) [hereafter "**Public Knowledge and LCA Submission**"].

Some systems are tightly-engineered, such that the hardware and software are designed for use with specially-formulated materials, while other systems have higher tolerances and accept a wider variety of materials. Each type of system offers different benefits depending on the user and the application.

Manufacturers of systems designed for use with specially-formulated materials use TPMs to prevent a user from installing and using other materials. Such measures include verification protocols activated when a new cartridge of material is installed, as well as TPMs that prevent a user from accessing and modifying system software to adjust it to the properties of different materials. Both manufacturers and users depend upon the integrity of such systems to produce reliable, repeatable printed products, to collect accurate production and performance information, to support investment in new materials calibrated to a particular platform, and to support servicing, maintenance, and printer pricing. The proposed exemption threatens these advantages in pursuit of speculative benefits that bear little relationship to the intended goals of this rulemaking.

In enacting the DMCA, Congress sought to protect new distribution models for copyrighted materials, while avoiding significant adverse effects on fair use and other uses protected under copyright law. The triennial rulemaking proceeding was intended to be a "fail-safe" mechanism, authorizing the Librarian of Congress to selectively waive the DMCA's prohibition on circumvention of TPMs "*in exceptional cases*," when the requirements set forth in 17 U.S.C. § 1201(a)(1) are met.[3]

The Librarian should refuse to grant the proposed exemption because Petitioners have not met their burden of establishing that it satisfies the statutory requirements. First, Petitioners have failed to show by a preponderance of the evidence that "persons who are users of a copyrighted work are, or are likely to be in the succeeding three-year period, adversely affected" in their ability to make noninfringing uses of copyrighted works because of the DMCA's prohibition against the circumvention of TPMs.[4] Second, even if Petitioners were found to have met that burden, it is clear that the balance of interests under the statutory factors in 17 U.S.C. § 1201(a)(1)(C) weighs overwhelmingly against granting the exemption because of the likelihood of negative effects on the market for 3D printers and related copyright-protected works.

Indeed, Petitioners concede that the first four factors do not support their case, and instead argue that public policy supports granting the petition to eliminate doubt and uncertainty.[5] The attached report from Dr. Jonathan Baker makes plain that granting the proposed exemption would risk undermining innovation and business models that facilitate increased use of 3D printing.

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[3] Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, Final Rule, 65 Fed. Reg. 64,556 (Oct. 27, 2000) [hereafter, "**2000 Final Rule**"] (emphasis added).

[4] 17 U.S.C. § 1201(a)(1)(B); Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, 79 Fed. Reg. 55,687, 55,689 (Sept. 17, 2014) [hereafter "**2014 Notice of Inquiry**"].

[5] Public Knowledge and LCA Submission at 12-13.

A. The 3D Printing Industry and the Current Marketplace

The first 3D printers were introduced for commercial use in the early 1990s. Over the past decade, 3D printing has developed rapidly in terms of system performance and the range of available materials and applications. The marketplace for 3D printing today includes a variety of different systems used by a diverse array of customers.

Companies in many fields, including aerospace, architecture, automobiles, electronics, entertainment, apparel, and medicine have widely adopted 3D printing for rapid prototyping, which allows prototypes to be developed on-site and speeds up product development cycles.

Increasingly, companies are also using 3D printing technologies for "direct digital manufacturing," or the production of parts incorporated into products sold to end users. Such entities include traditional manufacturing companies, which use 3D printing to make products as varied as parts for airplanes, automobiles, motorcycles, and bicycles, jewelry, shoes, sporting equipment, and dental and orthopedic implants, as well as smaller startups and entrepreneurs who provide niche or custom-made goods and services using 3D printing technologies.

While some individuals purchase 3D printers for personal and home use, the market does not lend itself to neat distinctions between "consumer" and "commercial" users. There is a spectrum of "prosumers" (*i.e.*, "professional consumers") and crowd-sourced communities who commercialize their use of 3D printers to varying degrees. The marketplace also includes users who do not own 3D printers, but who pay to use 3D printers owned by service bureaus. Such users can print their designs at nearby 3D printing "hubs" or send computer-assisted design (CAD) files online to a service bureau that will print and ship the final product.

Innovation in 3D printing and materials science is supported by a large, diverse ecosystem of public and private actors. In the U.S., these include NASA, MIT and other universities, the government-backed "America Makes" initiative, the Oak Ridge, Sandia, and Lawrence Livermore national laboratories, several small and large commercial manufacturers of systems and materials, non-profit research organizations, and crowd-sourced and open source initiatives such as the "RepRap Project."

3D printer users benefit from having a variety of systems in the market so they can choose the system suited to their intended use. Customers of hubs and service bureaus can even select a system optimal for each particular printed product.[6] As described in more detail below, different technological approaches confer different advantages to users, all to the benefit of the overall marketplace.

B. 3D Printing Technologies

All 3D printers use software to translate design files into instructions that cause the printer's hardware to interact with materials to create a 3D printed object. The processes, software programs, and materials that accomplish these functions can, however, vary significantly.

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[6] *See*, *e.g.*, 3D Hubs, http://www.3dhubs.com (last visited Mar. 16, 2015); *About Us*, Shapeways.com, www.shapeways.com/about/ (last visited Mar. 2, 2015); Rakesh Sharma, *3 Companies That Could Become the Kinko's of 3D Printing*, Benzinga, Sept. 30, 2014.

i. Processes

The first 3D printing processes, stereolithography and fused deposition modeling, were pioneered in the late 1980s and early 1990s by 3D Systems and Stratasys, respectively. 3D Systems commercialized stereolithography as "SLA®" systems, while Stratasys offered "FDM®" systems. Since that time, 3D printing technologies have proliferated; now a variety of processes are available in the marketplace. Each process uses different parts, programming, and materials to produce a 3D printed object.

The ASTM International Committee F42 on Additive Manufacturing Technologies has divided 3D printing processes into general classifications, including material extrusion, material jetting, binder jetting, sheet lamination, vat polymerization, powder bed fusion, and directed energy deposition.[7]

Printers that use "material extrusion" processes heat materials and force them through a nozzle or extruder while the extruder head moves on a horizontal plane to deposit one layer of material.[8] The print head moves up, or the build platform down, to deposit each successive layer.[9] The fused deposition modeling process developed by Stratasys (and used in its FDM® 3D printers) is a material extrusion process.

In "material jetting" printers, inkjet print heads deposit droplets of build material, such as photopolymers, across the printer's build area.[10] Some systems use ultraviolet light to cure layers of material after they are deposited.[11] Stratasys PolyJet™ printers use a material jetting process. In "binder jetting" processes, print heads deposit a liquid bonding agent onto powder materials, such as plaster or ceramics, to bind the powder material into the desired object.[12]

"Vat photopolymerization" processes use light-activated polymerization from a laser or other source of UV energy to cure a liquid photopolymer into shape.[13] Stereolithography is a type of vat photopolymerization that uses a laser and mirrors to scan and cure the surface of liquid photopolymer.[14]

"Powder bed fusion" processes use thermal energy from a laser or electron beam to fuse areas of a powder bed into desired form.[15] Such processes are also called laser sintering and selective laser sintering.[16]

In "sheet lamination" printers, sheets of adhesive-coated material are layered and bonded together into the desired shape.[17] "Directed energy deposition" processes use focused thermal energy to melt materials, usually metals, as they are deposited.[18]

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[7] "Standard Terminology for Additive Manufacturing Technologies," ASTM International Committee F42 on Additive Manufacturing, January 2012; *cited in* Wohlers Associates, *Wohlers Report 2014: 3D Printing and Additive Manufacturing State of the Industry*, p. 28 [hereafter "**Wohlers Report 2014**"].
[8] *Id.* at 29.
[9] *Id.*
[10] *Id.* at 30.
[11] *Id.*
[12] *Id.* at 31.
[13] *Id.* at 33.
[14] *Id.*
[15] *Id.* at 35.
[16] *Id.* at 37.
[17] *Id.* at 33.

The above are general descriptions. Each manufacturer may have a different implementation that varies in terms of the pairing of materials to hardware and process. Further, new 3D printing processes are currently in development.[19]

ii. Materials

Petitioners assert that "consumables can be thought of as the 3D printer equivalent of ink or toner in 2D printers,"[20] but the analogy is inapt. The output of a 3D printer is a three-dimensional physical part, generally built entirely from the consumable printing material. Some 3D printed objects must be precision engineered for demanding applications, such as medical implants, aerospace parts, or consumer goods subject to strict safety standards. Materials can be made to be food-safe, colorful, flexible, or durable, and to resist flame, smoke, high-temperatures, fatigue, and mechanical stress. They may be made of thermoplastic, polyamide, polyurethane, nylon, resins, powder, metals, ceramics, or composite materials. Most 3D printing processes use some sort of support material in addition to build material to buttress overhanging structures or otherwise form the object's shape during printing. In contrast, the consumable toner in a 2D printer is bonded to a flat substrate, and therefore has no structural or mechanical properties' requirements.

The engineering of materials is far more intensive than the manufacture of paper and toner. Because a printer's results are determined by an interdependent combination of hardware, programming (firmware and software), and materials, materials' science develops hand-in-hand with other technologies. While a manufacturer's decision to restrict a particular system to specific materials may be based in part on the company's business model, technological and engineering constraints, customer demands, and reliability and maintenance considerations play a significant role. For example, printers that involve more contact between delicate hardware and consumable printing materials, such as Stratasys FDM® printers, benefit from careful calibration of materials' formulations to hardware to minimize wear and ease reloading. Higher end machines designed to print to precise tolerances, in particular, require highly engineered printing materials with precise physical and chemical properties.

Stratasys's materials innovation is extensive. The company produces high-quality proprietary thermoplastics, resins, and materials for Smooth Curvature Printing (SCP), a phase change ink-jetting technology that produces wax-like patterns for casting and mold-making applications. Stratasys believes its portfolio of materials, currently consisting of 38 cartridge-based materials for its FDM® and PolyJet™ systems, five SCP inkjet-based materials, 138 non-color digital materials, and over 1,000 color variations, is the largest available from any manufacturer. Indeed, some of the company's PolyJet™ 3D printers, aided by integrated software, enable users to fabricate parts made of digital materials, which are composite materials produced during the printing process using at least two different resins that are dispensed to produce specific material three-dimensional structures that dictate predetermined visual and mechanical properties. Each new material Stratasys creates undergoes an extensive development cycle, including a long period of testing and tuning with the Stratasys printing system with which it will be used.[21] The

[18] *Id.*

[19] *Id.* at 28.

[20] Public Knowledge and LCA Submission at 4.

[21] For many build materials Stratasys produces, it must also have a corresponding support material with proper adhesive properties. The support material must adhere to the build material during production, but

process can take years, especially when developing materials for direct digital manufacturing.

The formulation and processing of materials impart various valuable properties. For thermoplastics, these may include color, environmental stability, chemical and heat resistance, fatigue resistance, flame and smoke resistance, food safety and bio-compatibility, as well as mechanical properties necessary for functional prototypes and manufactured parts, such as a high strength-to-weight ratio. Resins can be treated to provide strength, accuracy, surface resolution, color, and other properties.

Systems manufacturers and non-manufacturers alike produce materials used in 3D printers. A proliferation of materials' innovations has been reported in the past few years, and a wide variety of new materials are now available. Developers and suppliers of new materials for open systems include Taulman, Proto-Pasta, and MakerJuice, among many others.[22]

Some non-system manufacturers attempt to mimic proprietary formulations to sell knock-off versions of genuine materials for use with closed systems. Petitioners provide one example, that of third-party non-genuine materials for 3D Systems' "Cube" line of printers.[23] As discussed below, such materials can be ill-suited for the uses Petitioners seek to facilitate through this rulemaking.

iii. The Use of Technological Measures to Restrict Materials

3D printing systems cannot be easily classified as either "closed" systems that accept only a manufacturer's own materials or "open" systems that will process any material the user desires. In all printers, technological constraints restrict the type of materials the system can process, as the properties of materials must be suited to the system's hardware and programming.

Some systems have "open source" hardware and software, such that the system can be effectively built and programmed by the user to calibrate it to process a selected material. Other systems use proprietary hardware and software, but tolerate some third-party materials as long as they meet certain specifications. Some systems, including most of those made by Stratasys, are tightly-engineered to meet specific performance demands and use materials with proprietary formulations that are developed in conjunction with the system hardware and software. Each type has benefits and drawbacks, depending on the customer and the intended use.

a. *Open Systems and Partially-Open Systems*

Entirely open source systems allow users to modify hardware and software and share such modifications with the user community.[24] The RepRap Project may be the largest such community.[25] "RepRap" systems reportedly can print 50% of their own parts,

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then separate from the final product without impairing the printed product. Part of the development process for build materials is formulating support materials with the proper adhesion.

[22] *See* http://www.taulman3d.com/news html, http://www.proto-pasta.com/, and http://www makerjuice.com/; *see generally* Wohlers Report 2014 at 49.

[23] Public Knowledge and LCA Submission at 9-10.

[24] Examples include RepRap, PrintrBot, FlashForge Creator, Lulzbot, Ultimaker, and RoBo printers.

[25] Jarkko Moilanen & Tere Vaden, *Manufacturing in Motion: First Survey on the 3D Printing Community*, Statistical Studies of Peer Production, May 31, 2012.

with the remainder consisting of nuts, bolts, and other readily available components.[26] "RepRappers" can print customized print heads and other parts designed to handle innovative materials.[27]

Users of open source systems consist of certain commercial and academic entities, prosumers, hobbyists, and others with the patience and technological expertise to experiment. There is a vibrant and enthusiastic market for open systems, and a growing base of users and publicly available research to support experimentation and innovation.[28]

Other machines contain proprietary closed-source hardware and software, but can process materials, such as filaments of thermoplastic that meet general specifications, that are not specially designed for the machine.[29] Some of these allow the user to change certain parameters, such as the temperature applied to the material at various points throughout the printing process, to adjust the printer to varying formulations. Generally, because they allow for more experimentation and the manufacturer cannot control system inputs, open systems do not offer warranties, or offer short-term, limited warranties.[30]

b. *"Closed" or Fully-Integrated Systems*

Fully-integrated 3D printing systems, such as those made by Stratasys, require manufacturer-approved materials. Stratasys systems offer a number of advantages, including:

- *The ability to consistently produce outputs that match established benchmarks by controlling system inputs*. Many customers shop for 3D printing systems by testing against a "benchmark." A benchmark is a 3D object produced by a printer from a design file provided by the customer. The specifications for the benchmark may include various desired properties. Indeed, prospective customers are more likely to send a CAD file and request that the printed object be sent to them than they are to visit a showroom to see a printer. Stratasys invests significant time and money calibrating materials' formulations to its 3D printing systems so that a customer's results will be repeatable and match the expectations established by the benchmark. Those calibrations range from adapting the material formulation to the FDM® or PolyJet™ printing liquefier or printing head, calibrating size accuracy on various geometries, adjusting heat and temperature within the printing chamber, ensuring build material/support material compatibility, and many more parameters.

- *A closed-loop feedback process that produces real-time quality and performance data to pinpoint performance issues and speed innovation*. Inputs in Stratasys systems are carefully tested, controlled, and monitored, allowing for the development of a substantial knowledge base of performance data that it analyzes to troubleshoot or to identify areas for improvement. Customers also receive

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[26] *See, e.g.*, *About*, RepRap.Org, http://reprap.org/wiki/About (last visited Mar. 2, 2015).
[27] *See, e.g.*, Lucas Mearian, *This 3D Printer Technology Can Print a Game Controller, Electronics and All*, ComputerWorld, Apr. 25, 2014.
[28] Jarkko Moilanen & Tere Vaden, *Manufacturing in Motion: First Survey on the 3D Printing Community*, Statistical Studies of Peer Production, May 31, 2012.
[29] See chart in Section II(B)(iv).
[30] 3D Forged, *The Best 3D Printers for 2015*, Feb. 18, 2015, http://3dforged.com/best-3d-printers/ (last visited Mar. 2, 2015) (noting that a warranty is hard to find on most desktop printers today).

reports with performance data that they can use to pinpoint the source of any production issues and optimize their use of Stratasys systems.

- *The ability to offer a range of solutions at different price points, including lower prices for the initial purchase of the printer and service and maintenance programs*. Stratasys takes into account anticipated revenue from materials' sales when pricing systems, allowing a lower cost for the initial printer purchase. Stratasys also sells maintenance and service programs. It can offer these on a cost-effective basis because the entire system, including materials, has been developed to maximize uptime and lengthen duty cycles. For some applications, packages that contain printing systems, materials, and services are available to meet the needs of the particular application.

- *Steady improvement in reliability and service levels permitting expansion to new classes of customers*. Stratasys collects performance data from its printing systems, contributing to the development of a considerable knowledge base that has allowed it to quickly redress performance issues and target areas of improvement. This has facilitated the development of more reliable systems and end products and increased penetration among new customers for 3D printing technologies and 3D printed products.[31]

- *Revenue to support investment in low volume materials designed for custom and niche applications*. The sale of comprehensive printing solutions provides a revenue stream to support research and development of materials that may initially have limited applications or customers, but which contribute to the overall variety of Stratasys's materials portfolio. Anticipated materials revenue from Stratasys's current installed base incentivizes continued investment in new materials.

Stratasys printing systems include not only its 3D printers and materials, but also its "Insight," "Catalyst," and "Objet Studio" software that convert design files into machine readable instructions, and its motion control software and system control software, which cause the printer's hardware to execute instructions to build a 3D printed object. Stratasys created these proprietary software products in-house and provides them to customers pursuant to a license.

C. The Proposed Exemption

The 2014 Notice of Proposed Rulemaking describes the proposed exemption as a waiver from DMCA liability for the "circumvention of TPMs on firmware or software in 3D printers to allow use of non-manufacturer-approved feedstock in the printer."[32] The Notice, however, also advises that "the proposed classes as described … represent only a

[31] Some fully-enclosed "plug and play" systems are even represented as safe for children. *See* Richard Baguley, *Best 3D Printers 2015*, Jan. 16, 2015, http://www.tomsguide.com/us/best-3d-printers,review-2236.html (last visited Mar. 2, 2015) (review of the Cubify Cube 3 printer).

[32] Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, 79 Fed. Reg. 73,856, 73,871 (Dec. 12, 2014) [hereafter "**2014 Notice of Proposed Rulemaking**"]. The initial petition submitted by Public Knowledge in response to the 2014 Notice of Inquiry proposed an exemption for "users of 3D printers that are protected by control technologies when circumvention is accomplishes [sic] solely for the purpose of using non-manufacturer approved feedstock in the printer." *See* Public Knowledge Petition at 2.

starting point for further consideration in the rulemaking proceeding, and will be subject to further refinement based on the record."[33]

To develop the record, the Notice of Proposed Rulemaking instructed proponents of exemptions to "[d]escribe the TPM(s) that control access to the work and the method(s) of circumvention."[34] Petitioners' submission describes only one form of TPM on one make of 3D printer, supplied by 3D Systems, and does not describe the methods of circumventing it;[35] however, the scope of the proposed exemption is not confined to this one kind of TPM or printer. As drafted in the Notice of Proposed Rulemaking and as further described in Petitioners' submission, the exemption would extend to the circumvention of any TPM in order to use any material with any 3D printer.

i. <u>Types of Circumvention Referenced in the Petition</u>

Petitioners refer generally to two activities that they seek to enable through the exemption: (1) circumvention of chip-based cartridges to allow printers to use third-party versions of a manufacturer's ABS or PLA filament spools,[36] and (2) circumvention to facilitate the use, development, or testing of "innovative" or "exotic" materials on any 3D printer.[37]

a. *Circumventing "Chip-Based Verification Systems" to Allow Use of Third-Party Versions of Manufacturer Materials*

Petitioners describe only one kind of TPM, a "chip verification system," used by 3D Systems in its "Cube" line of printers.[38] Petitioners state that "they believe that there are both hardware- and software-based circumvention methods for these restrictions, but will avoid highlighting either until an exemption protecting them from DMCA liability is granted by the Librarian."[39]

Such methods of circumvention would apply to certain models of 3D printers that use "smart" cartridges (*i.e.*, cartridges with chips that hold data read by the printer's software). The data on a cartridge chip generally consists of nonexecuting code that includes information such as the amount of material in the cartridge, the type of material, and the batch number. A user mechanically installs the cartridge, and the system software embedded on the printer interrogates the chip to verify the material. The printer may keep track of the length or volume of material withdrawn from the cartridge during printing, and write the new count back to the chip to update its information.

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[33] 2014 Notice of Proposed Rulemaking at 73,859.
[34] *Id*. at 73,858.
[35] Only Petitioners provided long form comments in response to the 2014 Notice of Proposed Rulemaking. Other proponents submitted a boilerplate, template comment on a short form generated on the Digital Right to Repair website (hereafter "**Short Form Comments**"). *See* comments posted on the Copyright Office's website at http://copyright.gov/1201/2015/comments-020615/. The Short Form Comments do not provide any additional relevant legal analysis or respond to the request in the NPRM to describe the TPM and methods of circumvention at issue.
[36] After describing the "chip verification system" on 3D Systems' Cube printers, Petitioners argue, without elaboration, that the exemption should "allow owners of 3D printers to *bypass these types of restrictions* without worrying about 1201 liability." Public Knowledge and LCA Submission at 5 (emphasis added).
[37] Public Knowledge and LCA Submission at 9, 13.
[38] *Id*. at 5.
[39] *Id*. at 5-6.

One way that circumvention is accomplished is by copying the information on the manufacturer's chip to a third-party chip that the system software will read as the manufacturer's own. The system software reads the chip, believes the third-party material to be the manufacturer's proprietary material, and instructs the hardware to act as if the material were genuine.[40] Another way to circumvent the process is by reprogramming a used chip with new data that will pass the system interrogation process.

How effectively the printer processes the material depends on how closely the characteristics of the third-party substitute material mimic the characteristics of that for which the system was designed. Even minor variations can affect the interaction between the build material and support material, wear and tear on or clogging of hardware such as print heads and extruders, and the characteristics of the final printed object. The more the non-genuine material deviates from the genuine, the greater the risk of an unsatisfactory end product and system reliability issues.

b. *Circumvention of TPMs to Use, Test, or Develop "Innovative" Materials*

In addition to circumvention to allow use of third-party versions of manufacturer materials, Petitioners also refer to circumvention that would allow a 3D printer to process materials whose properties vary intentionally from those for which a system is calibrated. As explained below, such use requires unauthorized modification of copyright protected software. Petitioners also fail to comprehend that such use is greatly constrained by the inherent limits of the hardware and/or particular 3D manufacturing process, which cannot be overcome by circumventing TPMs.

To modify a 3D printer to process materials that differ significantly from the proprietary materials for which the printer is calibrated, a user must access and modify the system software to change the printer's operating instructions. A number of performance parameters may require modification, such as those relating to print head temperature, build chamber temperature, load parameters, load controls, and dynamic motion controls to synchronize the deposit of materials with the movement of other parts of the printer. For printers that are not open source, such a software modification would likely constitute unauthorized access and result in the creation of an infringing derivative work. To the extent that Petitioners contemplate that the exemption will allow the use, development, or testing of innovative or experimental materials, this modification of software (not just the circumvention of a chipped cartridge) is what is required.

Depending on the printer, multiple hardware- and software-based TPMs control access to system software and firmware. These include panels, ports, and user names and passwords on the user console.[41] A user who gains access to system software and firmware has the ability to modify hundreds of algorithms controlling various performance parameters, creating an unauthorized derivative work. The user would also have access to

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[40] In such systems, the software verifies not only the manufacturer but also the type of material. For example, the printer will return an error message if a user installs ABS thermoplastic filament on a 3D printer calibrated for polycarbonate. The system software also records the amount of material so it can track when the cartridge needs to be changed or alert a user if an insufficient amount of material remains for a particular job.

[41] Circumvention methods include bypassing a user console and the required log-in information by hacking directly into the computer embedded on the printer through the use of customized cables or other vectors of attack.

other intellectual property resident on a 3D printer and protected by the same TPMs, which may include design software, CAD files, proprietary machine-readable files, and reports compiling performance or other data. This intellectual property may belong to the manufacturer or to third parties, such as third-party creators of design files provided pursuant to a license.

Stratasys FDM® printers contain proprietary "CMB" files as well as CAD files. In Stratasys FDM® printers, specialized software converts the CAD files to CMB files, which consist of machine-readable instructions for building a printed part using a format Stratasys developed. The motion control and system control software embedded on the printer translate the instructions in the CMB file to cause the hardware to act on the materials in precise ways. That process informs performance parameters, such as the temperature of the liquefier, oven or chamber, how long the material must stay at that temperature before being extruded, and various load parameters, such as when to feed material to the extruder and at what rate. Stratasys has finely calibrated this process of converting human readable design files into precise actions performed by the hardware on the materials to optimize final results. A user who wanted to change the behavior of the hardware to work with different materials would need to modify each component of this process, the motion control software, the system control software, and the CMB files.

Similarly, some materials used with Stratasys PolyJet™ printers have different machine requirements. Along with each material, there is a parameter file sent to the machine to dictate to the machine operating system how to operate properly. Printing processes like the amount and dose of UV curing, time delays to allow material strain relief, print head maintenance parameters, geometrical scaling, printing algorithms, etc. must be modified and adapted to the materials used with the printer.

Although modifying system software may enable experimentation with some new materials, some examples of innovative materials that Petitioners point to in justifying their proposal cannot be used with most closed systems due to significant engineering constraints, not TPMs. Printers that are designed to extrude, for example, proprietary thermoplastic filaments cannot simply melt and extrude materials such as metals, recycled waste plastic, or human tissue, as Petitioners seem to imagine.[42] Petitioners' claim that initiatives to develop such materials "are successful because they can potentially serve a market consisting of every printer on the planet" reflects a misunderstanding of 3D printing technologies.[43]

Petitioners also miss the important point that some systems are designed to mitigate risks involved in the use of a specific material, such as fire hazards or hazardous fumes. Systems that fuse metal powder, for example, must be used in a controlled environment because the metal powders are highly combustible. The build chamber fills with inert gas (argon or nitrogen) selected for compatibility with the metal powder to prevent the metal from oxidizing during the build process and to manage combustible dust that arises from the printing process.[44] Certain thermoplastic materials may also give off fumes when

[42] Public Knowledge and LCA Submission at 9.
[43] *Id.*
[44] *See, e.g.*, OSHA Final Order, July 11, 2014, https://www.osha.gov/pls/imis/establishment.violation_detail?id=947859.015&citation_id=01001 (last visited Mar. 26, 2015) (citation for an employer's failure to maintain precautions against risks from combustible dust produced by 3D printing equipment processing metal alloy).

heated or heated without proper controls in place. Wohlers Associates warns that, with respect to the "Filabot" extruder that Petitioners mention that is designed to turn recycled plastic into filament, the process can give off harmful chemicals such as styrene and hydrogen cyanide.[45] Petitioners' proposed exemption could compromise the effectiveness of measures designed to manage such risks.

ii. Unknown Types of Circumvention Covered by the Proposed Class

Due to the wide variety of 3D printing technologies, Stratasys is unaware of all of the types of circumvention that are or may be undertaken for the purpose of using a different material than that for which a system is intended. Even printers that use similar processes may have different TPMs that bear on the user's ability to make the printer process the material of the user's choice.

Moreover, the types of TPMs that may emerge within the scope of this class over the next three years are impossible to predict. On the horizon are systems that use increasingly complex processes, such as mixing multiple co-engineered materials and using "intelligent" functionality such as sensors and microprocessors to build increasingly intricate and complicated parts.[46] The distribution mechanisms for the intellectual property used in 3D printing are also developing, as various stakeholders contemplate ways to protect the rights of owners of designs and design software.[47] The nature of the TPMs that may facilitate such innovations defies forecast, and so the impact of the exemption cannot be fully grasped at this time.

II. PETITIONERS HAVE FAILED TO MAKE A *PRIMA FACIE* CASE IN SUPPORT OF THEIR PROPOSED EXEMPTION.

To make a *prima facie* case for an exemption, proponents bear the burden of proving that (1) uses affected by the prohibition on circumvention are or are likely to be noninfringing, and (2) as a result of a technological measure controlling access to a copyrighted work, the prohibition is causing, or in the next three years is likely to cause, an adverse impact on those uses.[48] As detailed below, Petitioners have failed to make either showing.

A. Petitioners Have Not Demonstrated Any Noninfringing Uses Enabled by the Proposed Exemption on Circumvention.

i. Petitioners Cannot Meet Their Burden Without Describing the Circumvention Activities for Which They Seek an Exemption.

"The burden is on proponents to show that *circumvention of TPM* is noninfringing...."[49] An exemption will not issue if proponents do not provide sufficient

[45] Wohlers Report 2014 at 102; Public Knowledge and LCA Submission at 9, fn 9.
[46] *See* PricewaterhouseCoopers, *3D Printing and the New Shape of Industrial Manufacturing*, June 2014, p. 6.
[47] *See, e.g.*, Eli Greenbaum, *Three-Dimensional Printing and Open Source Hardware*, 2 NEW YORK UNIVERSITY JOURNAL OF INTELLECTUAL PROPERTY AND ENTERTAINMENT LAW, 257 (2013); Brian Rideout, *Printing the Impossible Triangle: The Copyright Implications of Three-Dimension Printing*, 1 BUSINESS, ENTREPRENEURSHIP & THE LAW, 161 (2011).
[48] 17 U.S.C. 1201(a)(1)(B); 2014 Notice of Inquiry at 55,689.
[49] *See* Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, Final Rule, 77 Fed. Reg. 65,260, 65,275 (Oct. 26, 2012) (codified at 37 C.F.R. 201.40) [hereafter, "**2012 Final Rule**"] (emphasis added).

information about the circumvention they seek to facilitate through the rulemaking process.[50] Without such information, the Register and the Librarian cannot evaluate whether the act of circumvention creates an infringing copy or derivative work, or whether it falls outside of the scope of the rulemaking because the technological measure circumvented does not control access to a copyright protected work.[51] The Register has emphasized that a class cannot be designated "in a factual vacuum."[52]

Petitioners state that they will not describe the "methods of hardware- and software-based circumvention" until the requested exemption is granted.[53] This puts the cart before the horse, as proponents cannot obtain an exemption from liability for undefined acts of circumvention. Petitioners' comments do not provide a sufficient record on which to base an exemption, and no other party provided comments that could add meaningfully to the record. This alone should cause the Librarian to deny the exemption.

ii. Circumvention to Use Non-Manufacturer Approved Materials Does Not Enable Noninfringing Uses.

To the extent that Petitioners' proposed uses can be evaluated, the proposed uses do not qualify as noninfringing uses within the meaning of Section 1201(a)(1)(A).[54] As the Register stated during the last triennial rulemaking, "[a]n exemption may not be based simply on perceived beneficial or desirable uses,"[55] but must be one of the uses expressly protected by Title 17, such as fair use as described in Section 107, certain educational uses described in Section 11, and certain reverse engineering described in Section 117.[56] Circumvention of a technological measure that does not control access to a copyright-protected work is beyond the scope of the rulemaking and cannot support an exemption.[57] Circumvention that creates an unauthorized derivative work or copy is infringing unless it constitutes a use protected by Title 17.[58]

Petitioners invoke two uses in support of the proposed exemption: (1) the ability to load a 3D printer with third-party versions of a manufacturer's proprietary material, and (2)

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[50] *Id*.
[51] *See, e.g.*, 2012 Final Rule at 65,276; Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, Final Rule, 71 Fed. Reg. 68,472, 68,478 (Nov. 27, 2006) [hereafter, "**2006 Final Rule**"].
[52] 2012 Final Rule at 65,276, *quoting* Recommendation of the Register of Copyrights in RM2011-7, Rulemaking on Exemptions from Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies at 63 (Oct. 12, 2012) [hereafter, "**2012 Recommendation**"].
[53] Public Knowledge and LCA Submission at 6.
[54] 2012 Recommendation at 7; *accord* Recommendation of the Register of Copyrights in RM2008-8, Rulemaking on Exemptions from Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, at 12 (June 11, 2010) [hereafter, "**2010 Recommendation**"] (A proponent "must establish that the proposed use is likely to qualify as noninfringing under relevant law.").
[55] 2012 Recommendation at 158.
[56] *Id*. at 7.
[57] *See* 2012 Final Rule at 65,276 (If a technological measure is not effectively controlling access to the work, an exemption is unnecessary); 2006 Final Rule at 68,475 ("The Register cannot recommend adoption of an exemption for this proposed class ['computer programs and video games distributed in formats that require obsolete operating systems or obsolete hardware as a condition of access'] because it does not involve access controls and, therefore, no exemption is needed.").
[58] *See, e.g.*, 2010 Final Rule at 43,831 (noting that where "substantial changes must be made to the computer program in order to enable use of the mobile phone on another network, those changes might implicate the exclusive right to prepare derivative works" but finding that such use was facilitated by Section 117).

the ability to use, develop, and test experimental new materials. Petitioners do not make any argument for how either use is noninfringing. Petitioners merely assert, without any elaboration or support, that they "do not believe that circumventing a chip-based verification system on a 3D printer in order to use a third party material is a violation of copyright law."[59] They make no argument or comment as to how modifying operating system software or firmware could be a noninfringing use.

Petitioners have not set forth any evidence or persuasive argument that the proposed 3D printing exemption would enable a noninfringing use under Title 17. To the extent that Petitioners argue that certain methods of chip-based circumvention do not violate the DMCA because the chip is not controlling access to a copyright-protected work,[60] then, as discussed above, an exemption for such circumvention is not within the scope of the rulemaking. In the past, the Register and Librarian have declined to grant an exemption for the mere purpose of "clarification" that an activity is not a DMCA violation.[61]

On the other hand, circumvention to facilitate the use, testing, and development of innovative materials likely would involve unauthorized modification of system software and firmware to change how the 3D printer interacts with materials, and thus would likely constitute the creation of an unauthorized derivative work. Petitioners have not offered any argument that fair use or another statutory exception operates to render such activity non-infringing. Therefore, Petitioners have not shown that any non-infringing use would be facilitated by the exemption and have failed to meet their burden.

B. Petitioners Have Not Demonstrated That Technological Protection Measures Cause Any *Substantial Adverse Impacts* Within the Meaning of Section 1201(a)(1).

A proponent of an exemption must show that the TPMs at issue are causing, or are likely to cause within the next three years, adverse impacts on noninfringing uses that are substantial.[62]

To show "substantial" adverse effects, "it is necessary to demonstrate 'distinct, verifiable, and measurable impacts' occurring in the marketplace."[63] Because "*de minimis* impacts" cannot support an exemption, the Copyright Office has advised that "'mere inconveniences' or 'individual cases' do not satisfy the rulemaking standard,"[64] and "isolated or anecdotal problems will be insufficient to justify an exemption."[65]

Further, a causal nexus is required. "The proponent must also demonstrate that the technological protection measure is the *cause* of the claimed adverse impact."[66] "Adverse

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[59] Public Knowledge and LCA Submission at 6.
[60] *See Id*.
[61] 2012 Final Rule at 65,271.
[62] 2014 Notice of Inquiry at 55, 69.
[63] 2014 Notice of Inquiry at 55,690, quoting Tom Bliley, REPORT OF THE HOUSE COMMITTEE ON COMMERCE ON THE DIGITAL MILLENNIUM COPYRIGHT ACT OF 1998, H.R. REP. NO. 105-551, pt. 2, at 37 (1998) [hereafter, "**Commerce Comm. Report**"].
[64] 2014 Notice of Inquiry at 55,690; *quoting* STAFF OF HOUSE COMM. ON THE JUDICIARY, 105TH CONG., SECTION-BY-SECTION ANALYSIS OF H.R. 2281 AS PASSED BY THE UNITED STATES HOUSE OF REPRESENTATIVES ON AUG. 4, 1988, at 6 (Comm. Print 1998) [hereafter, "**House Manager's Report**"]
[65] 2012 Recommendation at 8.
[66] 2014 Notice of Proposed Rulemaking at 73,858.

impacts that flow from other sources – including marketplace trends, other technological developments…or that are not clearly attributable to such a prohibition, are outside the scope of the rulemaking."[67]

Lastly, while a proponent may meet the standard by showing that a substantial adverse impact is *likely* within the next three years, the Copyright Office has made clear that "predicted adverse effects are only cognizable 'in extraordinary circumstances in which the evidence of likelihood of future adverse impact is highly specific, strong and persuasive.'"[68] "It is not sufficient to demonstrate…that the absence of an exemption *could* result in an adverse impact."[69] "Likely," when "used in Section 1201 to describe the showing of future harm that must be made—means 'probable,' 'in all probability,' or 'having a better chance of existing or occurring than not.'"[70] Rampant speculation, which is all that Petitioners offer, is hardly sufficient.

The only alleged adverse effects described by Petitioners are: "undermine[d] expectations of ownership around 3D printers," "uncertainty," "anxiety about the proper role of copyright," "costs for consumers," and "a significant negative impact on innovation in the 3D printing field."[71] Such allegations fall far short of the rulemaking standard.

i. Alleged Adverse Effects of "Undermined Expectations," "Uncertainty," and "Anxiety" Are Speculative and Insubstantial.

"Undermined expectations of ownership," "uncertainty," and "anxiety about the proper role of copyright" do not constitute the "distinct, verifiable, and measurable impacts" required to meet the rulemaking standard.[72] Further, Petitioners offer no evidence that any such impacts are occurring or are likely to occur in the future as a result of these alleged feelings.

While Petitioners claim that uncertainty and anxiety can have "a chilling effect on perfectly lawful activity," they do not provide any supporting evidence or documentation. The only alleged evidence of any person experiencing uncertainty consists of a single quote from a comment on a web forum noting that the DMCA may prohibit circumvention of a chip-based verification system.[73] Petitioners do not show that the DMCA has chilled any activity by this author or others. At minimum, this comment is merely conclusory or anecdotal evidence that is insufficient to meet the substantial adverse impact standard required by the statute.

The only possible evidence of undermined expectations of ownership on record is found in the Short Form Comments, which express dissatisfaction at the prospect of not being able to use the material of one's choice in a 3D printer. The comments, however, are of minimal probative value because they do not link such dissatisfaction regarding this

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[67] House Managers' Report at 6

[68] 2012 Recommendation at 62 (quoting House Manager's Report at 6).

[69] 2012 Recommendation at 6; *accord* Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, Final Rule, 65 Fed. Reg. 64,556 (Oct. 27, 2000) [hereafter, "**2000 Final Rule**"], *citing* House Manager's Report at 8; Commerce Comm. Report at 37.

[70] 2000 Final Rule at 64,562 *quoting* Black's Law Dictionary 638 (Abridged 6th ed. 1991)

[71] Public Knowledge and LCA Submission at 8-10.

[72] *See, e.g.*, 2010 Final Rule at 45,833 (assertions by an expert in the relevant field that "uncertainty" caused by the DMCA was exerting a chilling effect on the non-infringing activity at issue, without further support, amounted to "highly speculative" evidence).

[73] Public Knowledge and LCA Submission at 8 (emphasis added).

constraint to TPMs. As such, the Short Form Comments do not provide enough information to assess whether such impacts are substantial or merely speculative.

ii. TPMs Are Not Causing and Are Not Likely to Cause Any Adverse Impact on Innovation in 3D Printing.

Petitioners admit that there are no adverse effects on innovation in 3D printing presently occurring.[74] Instead, Petitioners premise this argument on future, hypothetical harm, asserting that "allowing…copyright law and the DMCA…[to] restrict the use of third party materials in 3D printers…*would have* a significant negative impact on innovation in the 3D printing field…."[75]

Petitioners do not put forth any evidence, let alone evidence that is "highly specific, strong and persuasive," that negative effects on innovation are more likely than not to occur. Rather, Petitioners suggest that various innovations in materials have come about because independent developers have been able to use "printers they already own" for testing and developing new materials, and that an exemption is necessary to avoid stalling such innovation.[76]

The argument is not grounded in reality. First, companies like Stratasys and 3D Systems developed many of the very innovative materials that Petitioners highlight. The business model used by these companies relies on anticipated revenue from materials sales to support investment in R&D needed to develop new materials, and closed systems provide the performance and testing data needed to rapidly improve formulations and speed innovation.

Second, independent developers are not hampered in their contributions of new materials, but use alternative open systems appropriate for experimentation. In doing so, they have built on the innovations pioneered by Stratasys and other printer manufacturers. There is no doubt that independent developers will be able to continue their activities due to the ready availability of open 3D printers.[77]

Third, even if some independent developers of materials might be inconvenienced by being unable to use "printers they already own" to test and develop new materials, this inconvenience is not caused by TPMs or the DMCA. Petitioners' insistence that innovators benefit from being able to create materials that "can potentially serve a market consisting of every printer on the planet"[78] plainly demonstrates Petitioners' failure to comprehend that engineering or other constraints, not TPMs, restrict such innovation. Engineering constraints prevent systems designed to process a particular material from processing very different materials. Oven temperatures must be adjusted to different melt points, nozzles or print heads can only process filament of a particular diameter or heated to a particular temperature, and extruders lack the mechanical properties to tolerate materials that are more abrasive or otherwise differ physically or chemically different from a manufacturer's materials. Further, for precision-engineered platforms such as those built by Stratasys, developing and fine-tuning materials involves considerable R&D investments and resources as well as extensive periods of testing and recalibration,

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[74] *Id*. at 9 ("3D printing is in the middle of an innovative explosion").
[75] *Id*. at 8 (emphasis added).
[76] *Id*. at 8- 9.
[77] For examples of such printers, see table in Section II.B.iv.
[78] Public Knowledge and LCA Submission at 9.

informed by accumulated testing and performance data and trade secret information about Stratasys's proprietary materials' formulations. Technological constraints, a lack of access to a manufacturer's proprietary IP, and a lack of revenue to support long, expensive R&D cycles are not effects flowing from the DMCA's prohibition on circumvention and are not redressable by this rulemaking.

Tellingly, Petitioners do not point to one instance of an independent materials producer hampered by TPMs. In fact, Petitioners' two examples of new materials pioneered by independent developers[79] were developed on a RepRap open source system[80] and on specially-designed proprietary systems,[81] respectively. The availability of open printers and the technology to develop purpose-built systems makes it highly unlikely that innovation would be hampered by the DMCA.

iii. Paying for Genuine Materials is Not an Adverse Impact.

Costs imposed by TPMs are not the type of adverse impact that the Register and Librarian have found to merit an exemption, especially when alternative products without TPMs are available.[82]

For example, the Librarian has repeatedly declined to grant exemptions for circumvention of access controls on DVDs and streaming video to enable them to operate on the computer or operating system of a user's choice on the rationalization of cost savings to the consumer.[83] The Register has emphasized that such costs "are simply a matter of convenience or preference that is unrelated to the types of uses to which Congress instructed the Librarian to pay particular attention, such as criticism, comment, news reporting, teaching, scholarship, and research as well as the availability for use of works for nonprofit archival, preservation, and educational purposes,"[84] and that "it is not the

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[79] *Id*.
[80] *See Recyclebot*, http://reprap.org/wiki/Recyclebot (last visited Mar. 2, 2015).
[81] Specially-designed "bioprinters" were developed to print human tissues, because heating material to process it, as other 3D printers do, would kill human cells. *See* Juliana Reyes, *Researchers are using these Philly-made 'bioprinters' to make hearts, stomachs*," Technically Philly, http://technical.ly/philly/2015/02/27/biobots-3d-printer-dreamit-health/ (last visited Mar. 4, 2015); *see also Gartner Says Uses of 3D Printing Will Ignite Major Debate on Ethics and Regulation,* http://www.gartner.com/newsroom/id/2658315 (last visited Mar. 4, 2015).
[82] 2012 Recommendation at 47 ("the record shows that alternative computing resources for such projects are available in the marketplace. The fact that the alternatives are (or at one time were) more expensive …is simply an economic reality that does not provide the basis for an exemption"); 2010 Recommendation at 224 ("the fact that a consumer may not be able to play a particular work on the…platform of the consumer's choice is not sufficient to justify an exemption when there are other platforms and alternatives available to view purchased material); *c.f.* Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, Final Rule, 68 Fed. Reg. 62011, 62017 (Oct. 31, 2003) (the inability to play the desired material "on a particular device or with a particular operating system is simply a matter of preference and inconvenience").
[83] 2006 Final Rule at 68,478. "Region coding [of DVDs] imposes, at most, an inconvenience rather than an actual or likely harm, because there are numerous options available to individuals seeking access to content from other regions." 2010 Recommendation at 224 ("With respect to the Linux proposal, the fact that a consumer may not be able to play a particular work on the Linux platform of the consumer's choice is not sufficient to justify an exemption when there are other platforms and alternatives available to view purchased material.").
[84] 2006 Final Rule at 68,478.

purpose of this rulemaking to provide consumers with the most cost-effective manner to obtain" the copyright protected content at issue.[85]

It follows that the cost savings that Petitioners claim the exemption would facilitate are not the type of adverse impacts the rulemaking is intended to address. Rather, the ability to use third-party materials on a closed 3D printing system because a user does not want to pay for a manufacturer's genuine materials or to purchase an open system that can process such materials without circumvention is a matter of convenience and preference.

Even if such costs were the type of adverse impact contemplated by this proceeding, Petitioners would still have failed to establish that the net effect of such costs is adverse to users. As described in more detail in Section III.D and the attached report of Dr. Baker, the business model enabled by restricting materials has facilitated lower prices for many users. Moreover, such third-party formulations may offer less value than proprietary formulations, which are calibrated for use with a particular printing system, resulting in more reliable results and other benefits.[86] The use of third-party formulations can also void valuable warranties and service contracts and drive up repair and maintenance costs. Thus, Petitioners' bare bones evidence of such costs, consisting of a comparison of a manufacturer's and non-manufacturer's prices for an ABS filament spool,[87] is insufficient to show any adverse effects.

iv. Available Alternatives Obviate Any Need for an Exemption.

The 2014 Notice of Proposed Rulemaking instructed commenters to "address potential alternatives that permit users to engage in the asserted noninfringing use(s) without the need for circumvention"[88] and specifically requested that parties commenting on the proposed class of 3D printers identify specific 3D printers that use and do not use such TPMs.[89] Rather than provide the requested information, Petitioners insist that "[t]he existence of printers that do not contain these restrictions does nothing to diminish the importance of this exemption."[90] To the contrary, however, the Librarian and Register have consistently emphasized that the availability of alternatives to circumvention mitigates any claim of adverse effects.[91]

For example, during the fifth triennial rulemaking, the Librarian, acting on the recommendation of the Register, declined to renew an exemption for circumvention of locks that control access to wireless phone networks based primarily on the presence of alternatives in the marketplace:

> "The Register…concluded that the record before her supported a finding that, with respect to new wireless handsets, there [we]re ample alternatives to circumvention.

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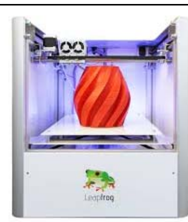
[85] 2010 Recommendation at 223-224.
[86] *See* Section III.D.
[87] Public Knowledge and LCA Submission at 10.
[88] 2014 Notice of Proposed Rulemaking at 73,858.
[89] *Id.* at 73,871.
[90] Public Knowledge and LCA Submission at 11.
[91] *See, e.g.*, 2012 Final Rule at 65,265 ("ample alternatives to circumvention" in the marketplace eliminated the adverse impacts that had justified an exemption in the prior triennial rulemaking); 2006 Final Rule at 68,478 ("An exemption is not warranted simply because some uses are unavailable in the particular manner that a user seeks to make the use, when other options are available.").

That is, the marketplace ha[d] evolved such that there is now a wide array of unlocked phone options available to consumers."[92]

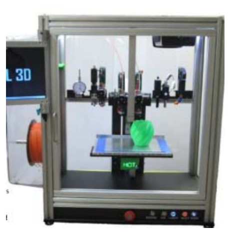
On this basis, the Register found that "with respect to newly purchased phones, proponents had not satisfied their burden of showing adverse effects related to a technological protection measure."[93]

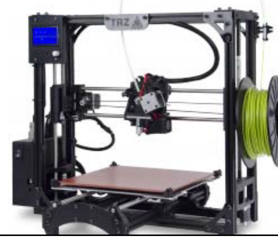
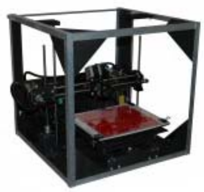
Also during the last rulemaking, the Register found that, with respect to video game consoles, "the record show[ed] that alternative computing resources for [proponents' research] projects are available in the marketplace. The fact that the alternatives are…more expensive than [using circumvented consoles] is simply an economic reality that does not provide a basis for an exemption."[94]

The marketplace for 3D printers, too, offers ample alternatives to circumvention of access controls designed to restrict non-manufacturer printing materials. The non-exhaustive list below of printing systems provided by other suppliers that do not have such TPMs underscores the extent to which the proposed exemption lacks any rational justification in the current market.

Make	Model	Image	Price	Materials	Country of Origin
Beeverycreative	**BEETHEFIRST**		$ 1,467	PLA	Portugal
Leapfrog	**Creatr**		$ 2,144	PLA, ABS, Nylon, PVA	Netherlands
PP3DP	**UP! mini**		$ 899	PLA, ABS	China

92 2012 Final Rule at 65,265.
93 *Id*.
94 2012 Recommendation at 47.

RepRap Printers (Example only)	**Prusa i3 Kit**		$ 749	PLA, ABS	User's Country
Solidoodle	**Solidoodle 4**		$ 599	PLA, ABS	US
Ultimaker	**Ultimaker Original**		$ 1,123	PLA	Netherlands
Zortrax	**Zortrax M200**		$ 1,595	ABS, Z-Ultrat	Poland
Hyrel	**System 30**		$ 3,995	Clay, Plasticine, Sugru, Silicone, Porcelain, ABS, PLA, Nylon	US
mUVe	**mUVe 1**		$ 1,699	Resin	US

ROBO 3D	**R2 Mini**		$499	PLA, ABS, Composite	US
Aleph Objects	**Lulzbot TAZ 5**		$2,200	PLA, ABS, Nylon, Polycarbonate, Composite, Others	US
Astrid	**Model 2000**		$569	ABS recommended	US
Printrbot	**Assembled Metal Plus**		$999	PLA	US

III. THE BALANCE OF STATUTORY FACTORS WEIGHS AGAINST GRANTING AN EXEMPTION.

If the above threshold showings were met, the Register and Librarian would next examine the proposed exemption in relation to the statutory factors set forth in 17 U.S.C. § 1201(a)(1)(C). These factors include: (1) the availability for use of copyrighted works; (2) the availability for use of works for nonprofit archival, preservation, and educational purposes; (3) the impact that the prohibition on circumvention of technological measures applied to copyrighted works has on criticism, comment, news reporting, teaching, scholarship, or research; (4) the effect on the market for copyrighted works; and (5) such other factors as the Librarian considers appropriate.

Petitioners, in fact, concede that the first three statutory factors do not favor their proposed exemption, asserting, "as the circumvention of technological measures designed to prevent the use of third party materials in 3D printers is not the type of harm that Congress was considering when it passed the DMCA, it is not surprising that the first three factors do not directly apply to this exemption."[95] As detailed below, however, the first factor weighs heavily against granting the exemption. The fourth factor also weighs strongly against the exemption, as do public policy considerations the Librarian may weigh under the fifth factor.

[95] Public Knowledge and LCA Submission at 11-12.

A. Availability for Use of Copyrighted Works.

The Register has interpreted the relevant inquiry under this first factor to include: "(1) whether the availability of the work in protected format enhances and/or inhibits public use of particular works, (2) whether the work protected is also available in other formats (and whether those formats are protected by access controls), and (3) if alternative formats are available, whether such formats are sufficient to accommodate noninfringing uses."[96]

The works included within the scope of this inquiry include not only the subject class, but also any other works protected by the TPMs at issue. For example, during the last triennial rulemaking, the Register found that, with respect to video game consoles:

> "[C]onsole access controls encourage the development and dissemination of highly creative copyrighted works by facilitating secure platforms for the development and distribution of video games and other applications…On balance, it appears that console access controls, because they encourage the creation and distribution of valuable expressive works and do not foreclose independent channels of creative development, have the effect increasing, rather than decreasing, the availability of copyrighted works."[97]

The 3D printer class is similar to video game consoles in this respect. The TPMs that control access to proprietary system software and firmware embedded on the machine also protect valuable design software, design files, and proprietary data collected during the printing process, such as customer-accessible performance data that may contain a customers' proprietary or other confidential information. Over the next three years, the increasing availability of such works will depend on the integrity of the TPMs that provide system security.

The use of TPMs also increases the availability in the marketplace of particular kinds of 3D printing systems, such as those offered by Stratasys, and the various performance, maintenance, and pricing benefits they offer over other systems.[98] There is no evidence that the presence of such systems in the market diminishes the availability of others that do not use TPMs to restrict materials; if anything, producers of the latter have stood on the shoulders of the former when coming up with their designs.

Second, as explained in Section II.B.iv, there are many 3D printers on the market that do not use TPMs to restrict the use of non-manufacturer materials. A range of 3D printers that process various kinds of materials are available not only for purchase, but also for temporary or one-time use through hubs and online service bureaus. Available options include 3D printers that are entirely "open source" and can be rebuilt and reprogrammed to maximize flexibility, as well as models that use proprietary software and designs but accept third-party materials. These open alternatives to 3D printers that use TPMs to restrict materials are sufficient to accommodate Petitioners' purported noninfringing uses of using third-party feedstock and the development and testing of innovative materials. Thus, a DMCA exemption is not required or warranted.

[96] 2010 Recommendation at 56.
[97] 2012 Recommendation at 48.
[98] See Section III.D.

B. Availability for Use of Works for Nonprofit Archival, Preservation, and Educational Purposes and the Impact of the Prohibition on Circumvention on Criticism, Comment, News Reporting, Teaching, Scholarship, or Research.

These factors appear to be of limited applicability with respect to this proposed class; Petitioners do not rely upon such purposes and therefore these comments do not address them. Petitioners, in fact, take the position that "the existence or nonexistence of this exemption will likely have no impact on the availability of the work itself, its availability for use by nonprofit archival, preservation, and educational purposes, or on the ability of others to criticize, comment on, report on, teach, study, or research."[99]

C. The Effect of Circumvention of Technological Measures on the Market for or Value of Copyrighted Works.

This factor instructs the rulemaking proceeding to assess "the effect of the circumvention of technological measures on the market for or value of copyrighted works."[100]

The proposed exemption, if granted, would negatively affect the market in at least three ways: (1) it would threaten the value of a manufacturer's 3D printers; (2) it would undermine security protections for intellectual property and confidential information embedded on printers; and (3) it would undermine growth in the overall market for 3D printers and 3D printed objects by placing at risk technological advances enabled by secure, fully-integrated 3D printing systems.

i. <u>The Proposed Exemption Threatens the Value of a Manufacturer's 3D Printers.</u>

Petitioners argue that circumventing TPMs that protect a 3D printer's operating system software does not affect the value of that software because the software is not sold independently from the printer. They also assert that circumvention does not affect the value of the printer itself.[101]

However, the Register and Librarian have established, with respect to embedded software, that circumvention of TPMs can "ha[ve] the effect of diminishing the value of, and impairing the market for, the affected code, because the compromised code [can] no longer serve as a secure distribution platform."[102] 3D printers provide secure platforms for the distribution of proprietary design and modeling software and design files. They also may protect confidential information about a user's business, personal information, or other confidential data used by the user and the manufacturer to improve system performance. The value for 3D printers is reduced if the TPMs that protect such property are circumvented.

Further, circumvention in order to use non-genuine materials can negatively affect a manufacturer's reputation and the image of the manufacturer's systems in the marketplace. The use of non-genuine materials can cause system damage, leading to downtime or other maintenance problems. It can also result in 3D printed objects that fail

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[99] Public Knowledge and LCA Submission at 12.
[100] 17 U.S.C. § 1201(a)(1)(C)(iv).
[101] *Id.* at 12.
[102] 2012 Final Rule at 65,274.

to match established benchmarks or that negatively affect an end user. It is well recognized in the economic literature that the marketplace may not attribute such effects to the use of non-genuine materials.[103] This is especially likely to be true for affected customers who do not realize any non-genuine materials were used, such as customers of end products, customers of service bureaus, or individual users who share network-enabled printers with other users.

ii. The Proposed Exemption Puts Other Intellectual Property Embedded in the 3D Printer at Risk.

The Register and Librarian have established that the market considered under the fourth statutory factor includes not only the class of works that is the subject of the proposed exemption, but any other copyright-protected works protected by the TPMs at issue.[104] In the fifth triennial rulemaking, the Register and Librarian found that TPMs on video game consoles "protect not only the integrity of the console code, but the copyrighted works that run on consoles. In so doing they provide important incentives to create video games and other content for consoles, and thus play a critical role in the development and dissemination of highly innovative materials."[105] The effect on the market for other works protected by console TPMs, and not only the console code, was a significant consideration under this factor.

Like video game consoles, 3D printers occupy the center of a growing intellectual property universe. Because the TPMs that protect access to the operating system and firmware also protect design and modeling software and files, the proposed exemption puts at risk the security and integrity of systems that protect these important rights. The distribution mechanisms and available protections for such IP will develop over the next three years and will likely depend on secure technological protection measures.

The development of such protections is critical to continued innovation and expansion of 3D printing. An exemption to liability under the DMCA for circumventing TPMs that protect intellectual property embedded on the printer would place such property at risk and would handicap systems manufacturers in their efforts to find ways to protect the rights of intellectual property owners.

iii. The Proposed Exemption Threatens Technological Gains Critical to Robust Expansion and Adoption of 3D Printers and 3D Printed Products.

The proposed exemption would negatively affect the market for 3D printers by undermining the various benefits that secure, fully-integrated systems offer. By controlling all system inputs, manufacturers like Stratasys are able to collect data that allows them to pinpoint any service or performance issues and quickly improve products. Customers also use performance data collected by the printing system to track issues in printed products and improve results. Circumvention and the use of non-genuine materials impair Stratasys's and its customers' ability to interpret and act on this data and to translate it into better, more reliable products.

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[103] Ex. A, Expert Report of Jonathan B. Baker, p. 7-8 (Mar. 27, 2015) (citing economic literature for the proposition that "when buyers are uniformed about the source of quality problems, the manufacturer's goodwill or reputation can suffer.") [hereafter "**Baker Report**"].
[104] *See* 2012 Recommendation at 49-50.
[105] *See* 2012 Final Rule at 65,274.

Improving the reliability of both 3D printing systems and 3D printed products is critical to robust expansion and adoption. According to Wohlers Associates, the gap between buyer expectations of the reliability and user-friendliness of 3D printing systems and printers' actual performance capabilities "presents significant risk" to continued growth in the sub-$5,000 printer range.[106] In a recent survey of U.S. businesses by PricewaterhouseCoopers, the reliability of printed products was identified as the top barrier to wider adoption of 3D printing technologies.[107]

Stratasys and other companies are developing systems to match the demands of new classes of customers for dependable performance and ease of use, including affordable, user-friendly "plug and play" systems with longer duty cycles and service contracts, and systems for new direct manufacturing applications that produce repeatable 3D printed objects with precision. The proposed exemption would threaten the integrity of the knowledge base that is facilitating these important innovations.

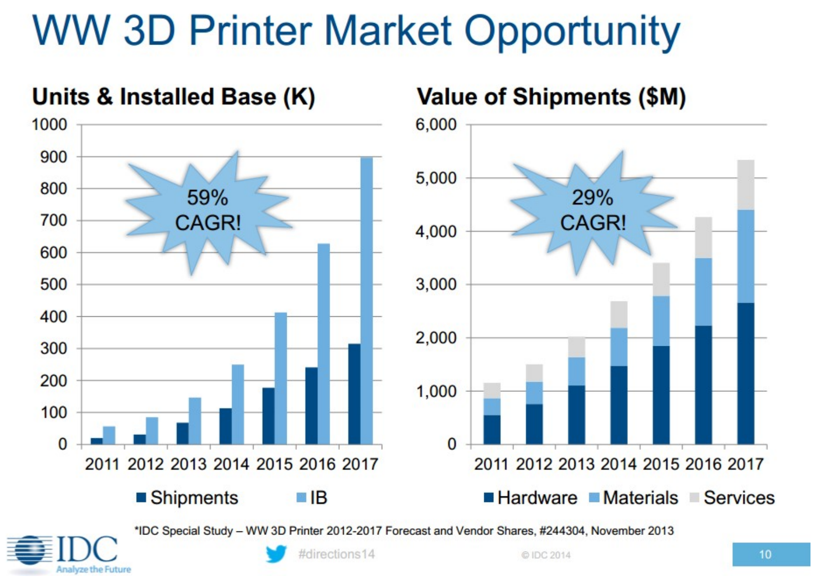
D. Public Policy Supports Denying the Petition.

3D printing is a dynamic and growing industry in its infancy.[108] 3D printing is changing the way companies do business, with new applications for 3D printing reported daily. Companies, which once used 3D printers only to print architectural models and prototypes, are increasingly using 3D printers for tooling and direct digital manufacturing to print dental crowns and bridges, orthopedic implants, custom hearing aids, jewelry, and parts for airplanes and helicopters.[109] In fact, Nike printed 2014 Super Bowl cleats using a 3D printer.[110]

These exciting innovative opportunities are driving substantial growth among 3D printer manufacturers. Those watching the industry estimate that the 3D printing industry has been growing at more than a 30% Compound Annual Growth Rate (CAGR) in recent years and that 3D printer sales will double in 2015.[111] Indeed, IDC estimates that worldwide 3D printer unit sales and installed base will grow at a combined compound annual growth rate of 59% through 2017, with the value of shipments attaining a 27%

[106] Wohlers Report 2014 at 100. ("As the glare of the media spotlight begins to diminish, operational prowess, true R&D, software, real ease of use and maintenance, and high-quality manufacturing will begin to play greater roles in success.")
[107] *Id*. at 17.
[108] *See* Louis Columbus, *Roundup of 3D Printing Market Forecasts and Estimates, 2014*, Forbes.com, Aug. 9, 2014, http://www.forbes.com/sites/louiscolumbus/2014/08/09/roundup-of-3d-printing-market-forecasts-and-estimates-2014/ (last visited Feb. 28, 2015).
[109] *See* Lyndsey Gilpin, *3D printing: 10 companies using it in ground-breaking ways*, TechRepublic, Mar. 26, 2014, http://www.techrepublic.com/article/3d-printing-10-companies-using-it-in-ground-breaking-ways/ (last visited Feb. 28, 2015).
[110] *Id.*; *see also* Stratasys Ltd., Form 20-F, p. 6 (Mar. 3, 2014) ("The markets in which we operate are subject to rapid and substantial innovation and technological change, mainly driven by technological advances and end-user requirements and preferences, as well as the emergence of new standards and practices.").
[111] Brian Krassenstein, *Why Experts Are Likely Underestimating the 2015 3D Printing Markets*, 3dprint.com, Jan. 2015, http://3dprint.com/34560/2015-3d-printing-gartner/ (last visited Feb. 28, 2015) ("Gartner has also estimated that 2015 would be a year in which worldwide 3D printer sales will double, to approximately 217,350 units. On the surface, these seem like very bullish numbers, and in fact they are when you consider the rate of growth. I, however, believe that Gartner, as well as other research firms, is underestimating the potential market in this upcoming year.").

CAGR.[112] The market worldwide, estimated at $1.5 billion in systems and material sales in 2013, is projected to grow to $7 billion by 2016 and $21 billion by 2020.[113]



This meteoric growth has inured to the substantial benefit of customers, who are enjoying cheaper printers in part due to recent technological advancements.[114]

The growth is also attracting significant investments from both established manufacturers and start-ups.[115] Stratasys alone invested $82.3 million in research and development in 2014.[116] Other printer manufacturers are also investing substantial sums in research and development, with 3D Systems reporting investments of $75.4 million in 2014.[117]

Intellectual property protection, including protection afforded by measures that control access to protected works, is critical to encourage companies to invest in such research and development.[118] That intellectual property protection also benefits the

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[112] Robert Parker and Keith Kmetz, *3D Printing – A Transformative Opportunity for Print and Manufacturing*, IDC, Mar. 2014, http://webobjects.cdw.com/webobjects/media/pdf/3dprinting/IDC-report.pdf (last visited Feb. 28, 2015).
[113] Wohlers Report 2014 at 110, 116.
[114] Agam Shah, *3D printer price drops could lure home users*, PCWorld, Apr. 4, 2014, http://www.pcworld.com/article/2140360/3d-printer-price-drops-could-lure-home-users html (last visited Feb. 28, 2015) ("Prices of 3D printers are falling at a fast clip, helped by technological advancements, the expiration of certain patents and increasing competition… .").
[115] Jonathan Shieber, *Innovation and Investment In 3D Printing Surges*, techcrunch.com, Dec. 17, 2014, http://techcrunch.com/2014/12/17/innovation-and-investment-in-3d-printing-surges/ (last visited Feb. 28, 2015.
[116] Stratasys Ltd., Form 20-F, p. 5 (Mar. 3, 2015).
[117] 3D Systems Corporation, Form 10-K, p. 11 (Feb. 26, 2015).
[118] As Dr. Baker explains in his report, the risk of reputational damage from using materials over which the manufacturer does not have control "may discourage manufacturer investment in the development of new and better products and production processes, and discourage the entry of new sellers." Baker Report at 8-9; *see also* Section II.D.iii.

economy as a whole is now well established. As the White House has explained, "IP-intensive industries support at least 40 million jobs and contribute more than $5 trillion to our gross domestic product (GDP). Moreover, IP-driven jobs are good jobs, providing wages that are 42 percent higher on average than wages in other industries, contributing to economic security for America's middle class."[119]

The exemption that Petitioners seek threatens to disrupt the nascent 3D printing industry, chilling investment and slowing the pace of innovation. Petitioners engage in rampant, unsupported when they argue the proposed exemption "would encourage innovation by protecting and growing the market for innovation in materials."[120] Indeed, Petitioners admit that, without a DMCA exemption, "3D printing is in the middle of an innovative explosion"[121] and "development in this space is moving quickly".[122] Rather than "incentivize[] innovation" as Petitioners contend,[123] granting an exemption would put that innovation at serious risk.

i. Controls Permit More Users to Enjoy 3D Printing Technology.

Printer manufacturers rely on anticipated revenue streams from the sale of materials in order to make printers available at attractive prices. Stratasys, for example, is able to price its printers lower than it would otherwise due to this expectation of materials revenue, making 3D printing available to new users and infrequent users.[124] Manufacturers also rely on this anticipated revenue to support R&D in materials optimized for particular systems and applications.

The appended report prepared by Professor Jonathan Baker, former Director of the Federal Trade Commission Bureau of Economics and Chief Economist at the Federal Communications Commission, explains the consumer welfare benefits of allowing manufacturers to price 3D printers so that more customers can buy machines, while earning greater profits on materials sold to heavy users. These benefits to customers are not merely theoretical. As described in Professor Baker's report, based upon well-documented economic theory and research, ensuring revenues from future materials sales can allow printer manufacturers to reduce the initial selling price of 3D printers.[125] Reducing the price of 3D printers means that more customers can enjoy 3D printing, creating substantial customer benefits. Thus, contrary to what Petitioners advocate, restricting manufacturers' flexibility may well drive up the price of 3D printing, rather than "increase[] consumer welfare by driving down costs."[126]

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[119] Quentin Palfrey, *Intellectual Property Helps Fuel an Economy Built to Last*, White House Office of Science and Technology Policy Blog, Apr. 16, 2012, https://www.whitehouse.gov/blog/2012/04/16/intellectual-property-helps-fuel-economy-built-last (last visited Mar. 26, 2015).
[120] Public Knowledge and LCA Submission at 13.
[121] *Id.* at 9.
[122] *Id.* at 13.
[123] *Id.* at 14.
[124] Baker Report at 11 (Mar. 27, 2015) ("in the 3D printing industry, manufacturers using metering can set the price of the printer lower than they would otherwise, in order to sell more printers and increase their profits from selling materials").
[125] Baker Report at 10-12 (Mar. 27, 2015).
[126] Public Knowledge and LCA Submission at 14.

ii. Access Controls Have Technological Benefits for Customers.

Petitioners fail to acknowledge the many benefits that 3D printer customers enjoy from the technological measures printer manufacturers employ.

For example, chipped or "smart" cartridges permit printers to measure the amount of material remaining in a cartridge and to notify the printer operator when replacement or service is required. For systems that use resin or other time-sensitive materials, the mechanism tracks when the materials expire. The mechanism also enables the system to maintain an accurate record of the specific lot or batch of material used to build each printed object, so that users can certify end-use parts and diagnose the source of faulty printed objects.

Circumvention bypasses such technology. It allows operators to reset counters on equipment, which may delay service, and to mis-record the material used, potentially leading to misdiagnosis of part failures. Maintaining an accurate record of the material used for each printed part is important for effective rapid prototyping, but is critical in direct digital manufacturing, especially for sensitive applications such as medical implants and aerospace parts.

Petitioners also fail to acknowledge that the development and use of innovative or experimental materials involves circumventing TPMs that protect the intellectual property embedded on a printer. This threatens the value of that property, especially software, and diminishes the value of the 3D printer as a secure console.

The software used in a 3D printer represents a significant component of the value of the printing system as a whole. It functions to convert a CAD file into a set of precise instructions for the particular machine, optimizing the printing process for both the hardware and the material to be used. The software is also a key differentiator among printer manufacturers. It allows for many of the new features that customers enjoy, such as permitting access to the 3D printer from mobile devices.

Given the important role software plays, some companies are starting to offer stand-alone 3D printing software. Autodesk, "a world leading design software and services company,"[127] recently entered 3D printing with an open source software platform and printer.[128] It claims that the open system will "enable 3D applications and services to better prepare, optimize and deliver 3D models for any 3D printer or service bureau."[129]

iii. Printer Manufacturers Must Be Able to Control the Inputs to Their Printers to Ensure a Quality Product.

3D printing customers expect their printers to work and work well. 3D printer manufacturers like Stratasys therefore go to great lengths to ensure that when a customer hits "print," the output is a reliable, high-quality printed parts because that is how the customer will judge the printer.

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[127] Autodesk, Inc., Form 10-K, p.4 (Mar. 10, 2014).
[128] Rakesh Sharma, *The Autodesk 3D Printer: A Calculated Bet*, Forbes.com, Mar. 23, 2014, http://www forbes.com/sites/rakeshsharma/2014/05/23/the-autodesk-3d-printer-a-calculated-bet/ (last visited Feb. 28, 2015).
[129] http://spark.autodesk.com/about.

Not surprisingly, an essential element of the final printed product is the material or materials used to create it. To control the final printed product, and thus their reputations, printer manufacturers control the inputs. Use of materials that are not optimized for the system or are not properly calibrated may result in poorer quality printed objects or damage to the printer, both of which adversely affect the printer manufacturer's reputation.

The importance of the material to the printing system cannot be overstated. Printer manufacturers spend substantial time and effort in developing materials for use with their printers that will meet the tight tolerances of the equipment. Indeed, Stratasys has patents on several aspects of its materials, including the chemical composition as well as the shape of some of its filaments.[130]

Examples from two of Stratasys's printer lines illustrate just how sensitive the printers are to material properties. The extruder on Stratasys's FDM® printers receives filament, melts the filament in a liquefier to a specific temperature, which varies by filament, and dispenses that material through a nozzle in precise coordination with movement of the nozzle along tool paths that define the part. Because the extruder has no positive cut-off value, the printer must know how the material will respond to the liquefier and at what viscosity the material will exit the nozzle in order to dispense the material in appropriate patterns. Material properties are also critical to maintaining functionality of the hardware. For example, filament materials that are too abrasive can greatly reduce the useful life of filament drive wheels and of the nozzle.

Stratasys PolyJet™ printers provide another example. PolyJet™ printers have a jetting head that receives and dispenses a photocurable (*i.e.*, UV-light sensitive) liquid resin material in precisely controlled liquid droplets through very small nozzles. Unless the resin meets a tight set of requirements, including viscosity and sensitivity to UV light, the nozzles will become clogged and dysfunctional. Clogged nozzles at a minimum will impact the quality of the printed part and can often require professional servicing or replacement, which is generally the most expensive maintenance performed on PolyJet™ printers.

These examples demonstrate the significant potential impact of using materials that have not been calibrated for a particular printer. Indeed, Petitioners' assertion that if an exemption were granted customers would benefit from innovation in composite filaments that integrate metals such as bronze, copper and stainless steel illustrates a fundamental misunderstanding of the technology. Stratasys's printers are designed and optimized for use with specific materials. Composite materials have been demonstrated to damage the extruder, and require professional servicing or replacement.

Use of non-genuine materials in 3D printers also may cause unexpected health issues. To avoid potential health issues, 3D printer manufacturers, such as Stratasys, engage in extensive testing to develop materials with specific chemical and mechanical properties optimized for use in its printers.[131] For example, because Stratasys's FDM® printing systems use a process in which specially designed materials are printed at high temperatures, Stratasys's materials undergo demanding trials in a wide variety of possible machine configurations to ensure, among other requirements, that the printing process does

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[130] *See, e.g.*, US Patent Nos. 8,246,888; 7,754,807; 7,534,386; and 7,122,246.
[131] *See, e.g.*, Stratasys Material Safety Data Sheets (MSDS), http://www.stratasys.com/materials/material-safety-data-sheets.

not create adverse health effects or environmental hazards or result in parts that are unstable or dangerous to handle. Indeed, Stratasys provides Occupational Exposure Air Quality Datasheets based on extensive testing with Stratasys materials to customers to help them manage any occupational exposure risks.[132]

iv. <u>Granting an Exemption Would Encourage Others to Misuse the DMCA Exemption Process.</u>

Finally, opening the door to Petitioner's proposed exemption risks encouraging illegitimate attempts at using the DMCA exemption for purposes other than that for which it was intended. The DMCA exemption process was designed to provide relief for those "adversely affected by the prohibition [against circumventing TPMs] in their ability to make noninfringing uses under this title of a particular class of copyrighted works."[133] The legislative record shows that the purpose of the exemption process is to protect fair use in circumstances where the anti-circumvention norm might threaten access to the copyrighted work.[134]

Petitioners are attempting to hijack this process. Far from seeking noninfringing access to a copyrighted work, Petitioners seek to open certain 3D printing systems to third-party materials. While there are several reasons that this would be bad for both manufacturers and 3D printing customers as described above, even if there were good reasons to open closed 3D printers to third-party materials, this is not the appropriate forum for that debate.

IV. CONCLUSION.

For the foregoing reasons, Stratasys respectfully requests that the Librarian deny Petitioners' proposal to exempt from DMCA liability the circumvention of TPMs controlling access to firmware and software in 3D printers in order to allow for the use of non-manufacturer-approved materials.

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[132] *See* Stratasys, Occupational Exposure Air Quality Datasheet, available from Stratasys upon request.
[133] 17 U.S.C. §1201(a)(1)(C).
[134] WIPO Copyright Treaties Implementation Act and Online Copyright Liability Limitation Act: Hearing on H.R. 2281 and H.R. 2280 Before the Subcomm. on Courts and Intell. Prop. of the House Comm. on the Judiciary, 105th Cong. (1997).

EXHIBIT A

3D PRINTING TECHNOLOGICAL PROTECTION MEASURES: CONSEQUENCES FOR INNOVATION AND CONSUMER WELFARE

JONATHAN B. BAKER

COMPASS LEXECON™

MARCH 27, 2015

This study was commissioned by Stratasys, Ltd. as an independent economic assessment of the consequences for innovation and consumer welfare of technological protection measures in 3D printing. The views and opinions expressed in this study are solely those of the author and do not necessarily reflect the views and opinions of any of the organizations with which the author is or has previously been associated.

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The author thanks Yair Eilat for his insightful and helpful comments.

ASSIGNMENT AND SUMMARY OF CONCLUSIONS

Petitioners have asked the Librarian of Congress to grant an exemption from DMCA liability to allow the circumvention of technological protection measures controlling access to software (including firmware[1]) in 3D printers in order to facilitate the use of feedstocks not approved by the manufacturer.[2] The Long Comment filed by Public Knowledge and the Library Copyright Alliance asserts, among other things, that such measures "have a significant negative impact on innovation in the 3D printing field" and "d[r]ive up costs for consumers."[3] It further contends that granting an exemption "would encourage innovation by protecting and growing the market for innovation in consumables" and that "removing barriers to the development of an independent third party market increases consumer welfare by driving down costs."[4] I understand that the Petitioners claim that these issues are relevant to the fifth statutory factor – "such other factors as the Librarian considers appropriate" – which the Librarian may examine along with other factors, if the Librarian first determines that the petition meets the prima facie requirements of 17 U.S.C. 1201(a)(1)(B).[5]

Stratasys, Ltd. ("Stratasys"), a manufacturer of 3D printing systems, asked me to provide an economic analysis of this assertion. More specifically, I was asked to analyze the consequences for innovation and consumer welfare of technological measures adopted by 3D printing system manufacturers that control the use of consumable materials by protecting access to software.

For the reasons set forth below, I conclude that technological protection measures adopted by 3D printing system manufacturers may in fact result in consumer benefits, including

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[1] Firmware is permanent software programmed into a read-only memory.

[2] Petition for a Proposed Exemption Under 17 U.S.C. § 1201 of Public Knowledge, *In the Matter of Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies*, Docket No. RM 2014-07 (Nov. 3, 2014).

[3] Long Comment Regarding a Proposed Exemption Under 17 U.S.C. 1201 of Public Knowledge and the Library Copyright Alliance at 8, *In the Matter of Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies*, Docket No. RM 2014-07 (Feb. 6, 2015).

[4] *Id.* at 13-14.

[5] *Id. at 12-13;* 17 U.S.C. §1201(a)(1)(C)(v).

reduced prices and expanded output, and enhanced innovation in 3D printing. Contrary to what petitioners claim, therefore, a decision in this proceeding to permit circumvention of these technological protection measures would risk undermining these economic benefits, and, in consequence, threaten to raise consumer prices, and reduce the pace of innovation in the rapidly-developing 3D printing industry.

Two well-established economic mechanisms would lead to these outcomes. First, technological protection measures may enhance the ability of manufactures of 3D printing systems to protect the reputation of their firms and brands for reliability and quality. Doing so will help ensure that printing system manufacturers have strong incentives to invest in the development of new and better products and production processes. Second, such measures facilitate the ability of printing system manufacturers to meter their customers' use of materials. Metering can, and often does, lead to lower consumer prices, greater output, and the development of products to serve classes of consumers that would not otherwise be served, rather than lead to higher prices and reduced output, as petitioners suggest.

This report is based on my economic expertise, past work in the 3D printing industry, a visit to a 3D printing service bureau, review of public materials, and interviews of Stratasys business officials, as well as my review of the Petition and Comments submitted in this matter.

BACKGROUND[6]

Numerous firms manufacture 3D printers. Wohlers Associates identified 33 companies manufacturing and selling professional-grade additive manufacturing systems, and more than 250 companies making personal 3D printers, as of April 2014.[7] 3D printers employ a variety of technologies, including material extrusion, material jetting, binder jetting, sheet lamination, vat polymerization, powder bed fusion, and directed energy deposition.[8]

[6] For a more detailed description of the factual background, see Comments of Stratasys Ltd. in Opposition to Proposed Class 26: Software or Firmware in 3D printers to Allow Use of Non-Manufacturer-Approved Feedstock ("Stratasys Opposition").

[7] Wohlers Associates, Wohlers Report 2014: 3D Printing and Additive Manufacturing State of the Industry ("Wohlers Report") at 59, 99.

[8] These are the technological categories identified by the ASTM International Committee F42 on Additive Manufacturing Technologies in 2012. ASTM Int'l, Standard Terminology for Additive Manufacturing Technologies (No. F28792, 2012). *See also* Wohlers Report, *supra* note 7, at 28.

The 3D printers available today utilize a variety of materials. These include thermoplastics such as ABS, polycarbonate and PLA; thermoset plastics such as proprietary acrylics, acrylates and epoxies; polyamides and photopolymer resins; metals including stainless steel, titanium, titanium alloys, aluminum alloys, nickel-based alloys, cobalt-chromium alloys, copper-based alloys, gold, and silver; as well as ceramics, ceramic-metal hybrids, and composites.[9]

Wohlers Associates estimate that the global 3D printing industry has been growing rapidly, at a compound annual growth rate of 27% over the past 25 years and 32.3% during the years 2011-2013.[10] Worldwide industry revenues exceeded $3 billion in 2013, the most recent year for which data is available, including more than $500 million from materials.[11]

Stratasys, a leading 3D printer manufacturer, develops 3D printing systems in concert with the consumable materials they use. Its hardware innovation is generally accompanied by innovation in materials. New materials are typically developed in-house, as they require tuning the system parameters (controlled by software) to the material's properties, developing compatible modeling and support materials, and, in some cases, modifying hardware designs.[12] Through co-development of printers and materials, Stratasys seeks to optimize the quality of the parts and models printed. It can take years to develop a new printing system, materials included, and even developing new materials for existing printing systems alone can be a lengthy process. During 2014, Stratasys spent over $80 million, or 11% of net sales, on research and development.[13]

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[9] Wohlers Report, *supra* note 7, at 48-58. Other 3D printing systems, not discussed in the Wohlers Report, use biological materials.

[10] Wohlers Report, *supra* note 7, at 109.

[11] Wohlers Report, *supra* note 7, at 109, 112. Consumable materials include modeling materials and support materials. Support materials are deposited during the printing process, and removed after printing to create the printed product.

[12] Stratasys also tests new materials to avoid health or safety hazards from particle emissions during printer operation or from handling printed parts.

[13] Stratasys, Annual Report for Foreign Private Issuers (SEC Form 20-F) (March 3, 2015), at 40, 57.

Stratasys presently employs software verification of compatibility between consumable materials and 3D printers, a technological practice at issue in this proceeding, in all of its commercial printing systems sold under the Fortus, Connex, Objet, Dimension, Mojo and uPrint brands. Industry-wide, high-end 3D printing systems more commonly employ software verification than desktop (entry-level) printing systems, and (as with Statasys' high-end systems) customers of high-end printing systems typically purchase material from the printer manufacturer. In contrast, many entry-level systems do not have access controls, and customers of those systems can purchase materials from hundreds of firms.[14]

Consumable materials are typically sold separately from the printing system (even when both are sold by the same firm).[15] 3D printing system customers vary in the intensity with which they use printers, and thus in the amount of consumable materials they purchase. For heavy users, consumable materials could account for a substantial portion of the overall cost of acquiring and using a 3D printer system, while the opposite is true for light users.

The quality of printed parts or models (the end products) and the reliability of the printing system are crucial product attributes. For example, Stratasys' industrial customers, seeking to use 3D printing to create tools or parts, typically ask to see and test benchmarks (examples) before purchasing a printing system, in order to ensure that the quality and the specifications of the printed model meet their needs. End users also care about printing system reliability, in order to avoid manufacturing delays and costly service calls. Manufacturers of 3D printing systems compete by offering more reliable printers that print higher quality and more consistent parts or models (as well as by offering lower quality-adjusted prices, more desirable features and higher quality customer service). For example, Stratasys' securities filings identify "superior model quality," "material properties of printed objects," and the "quality of printed objects measured by, among other things, resolution, accuracy and surface quality" as "competitive strengths."[16]

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[14] Stratasys Opposition, *supra* note 6, at 20-24.

[15] Materials and service are sometimes bundled, and in some cases also bundled with the printer itself.

[16] Stratasys 20-F, *supra* note 13, at 31, 41. For example, Stratasys promotes its high-temperature PolyJet photopolymer as useful for applications including "High-definition parts requiring excellent surface quality" (http://www.stratasys.com/materials/polyjet/high-temperature); advertises its FDM thermoplastic technology as allowing users "to build tough, durable parts that are accurate, repeatable and stable over time (http://www.stratasys.com/materials); and promotes a study demonstrating the "high degree of repeatability across machines, builds and platform locations" of two of its Fortus printing systems

By limiting the variation in the quality of consumable materials, a manufacturer can improve the quality and consistency of printed models and parts, and protect printer reliability. For example, some Stratasys printers employ extruders that dispense a melted plastic filament through a nozzle or orifice in precise coordination with nozzle or platform movement. This technology requires that the material respond predictably to the liquefier, and have predictable viscosity when exiting the nozzle, in order to print high quality models and avoid shortening the useful lifetime of the extruder. Other Stratasys printers employ inkjet printing heads to dispense a liquid resin to deposit droplets precisely. Unless the resin meets a tight set of physical requirements, including for viscosity and sensitivity to ultraviolet light (used in curing), the multi-nozzle print heads will clog and require professional servicing or replacement to function.

PROTECTING MANUFACTURER CORPORATE AND BRAND REPUTATIONS

Part or model quality problems and system reliability problems arising from the use of inappropriate or suboptimal consumable materials could harm the reputation of Stratasys and its brands with customers. When customers using unauthorized materials evaluate model quality or experience printer reliability problems, those customers would have no basis from which to determine whether adverse experiences are due to the printer or the material. In addition, customers who use shared 3D printers (*e.g.*, in a service bureau) may not know whether the materials used are genuine. In such cases, the disappointed customers may blame the printer and its manufacturer, even when the problem derives from the use of unauthorized materials. More generally, it is recognized in the economic literature that when buyers are uninformed about the source of quality problems, the manufacturer's goodwill or reputation can suffer.[17]

(http://www.stratasys.com/resources/~/media/748AD69721184448AF46F0C37BBD205B.pdf). Other 3D printing manufacturers also compete on quality dimensions (*e.g.* http://www hyrel3d.com/).Moreover, third parties gather information on the quality of the output of 3D printers to assist consumers in choosing a printer. *See* Shane Taylor, Comparison of Quality Output: 3D Hubs' 3D Printer Quality Chart (June 19, 2014), *available at* http://3dprintingindustry.com/2014/06/19/3d-hubs-3d-printer-quality-chart/ ("3D printer network 3D Hubs has unveilled [*sic*] the latest information on the ratings that printer owners — from their broad and increasingly popular network — have given their devices for print output. The quality ratings provide an insight into user satisfaction by a range of 3D printer owners regarding the actual output of their printers.").

[17] *See* F. M. SCHERER & DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 565 (3d. ed. 1990) ("the producer of a technically complex machine" may tie its sale with the sale of consumable materials "to control the quality … so that its reputation is not sullied by breakdowns caused through the use of faulty supplies"); GUNNAR NIELS, HELEN JENKINS & JAMES KAVANAUGH, ECONOMICS FOR COMPETITION LAWYERS 254 (2011) (by selling two products together, the seller "doesn't have to worry that a complementary good outside its control … will damage customers' perceptions of the quality of its main product"); Barry Nalebuff, *Bundling, Tying, and*

When buyers wrongly attribute quality problems to the manufacturer, the manufacturer may have to bear the direct costs of repairs that fall under its warranties and service contracts (which may be magnified if, without software verification, it is more difficult for the manufacturer to diagnose problems). The 3D printing manufacturer may also suffer harm to its corporate and brand reputations, making it more difficult to sell its products in the future or requiring it to discount those products in order to do so.[18] These risks would be present even if users chose rationally between authorized and unauthorized materials.[19]

The emerging nature of 3D printing may amplify these risks. In a developing and rapidly growing industry, customers may have limited information about sellers and products, and acceptance and approval by early adopters can help firms or brands attract more customers as the market grows.[20] Under such circumstances, harm to firm or brand reputation can have a sustained effect on a firm's ability to compete. Moreover, the risk of reputational damage may

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Portfolio Effects 70 (DTI Economics Paper No. 1, Feb. 2003), *available at* http://faculty.som.yale.edu/barrynalebuff/bundlingtyingportfolio_conceptual_dti2003.pdf ("Firms may be motivated to tie for reasons related to quality and/or safety. For example, if the machine breaks down or the end result fails, the seller will suffer a loss of reputation. Thus, the firm needs to specify other inputs in order to ensure proper results"); *cf.* MASSIMO MOTTA, COMPETITION POLICY: THEORY AND PRACTICE 461 (2004) (firms may wish to incorporate the right components into their final products "to overcome possible reputation problems that would arise" if consumers did not combine them properly).

[18] *See* DSM Desotech, Inc. v. 3D Systems Corp., No. 1:08-cv-01531 (ND.Il. Jan. 31, 2013) (relying on testimony from an executive of 3D Systems Corp., a 3D printing system manufacturer, that "one reason 3D tests resins for use on its machines is to protect 3D's reputation since customers will blame 3D if a party does not turn out"). *Cf.* Deloitte, *2014 Global Survey on Reputation Risk: Reputation @Risk* 2 (Oct. 2014) *available at* http://www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl_Reputation_Risk_survey_EN.pdf (today, "in a highly connected world where customers, operations, supply chains, and internal and external stakeholders are scattered across the planet — and where reputations can be globally attacked with just a few keystrokes" — it is likely that on average, more than 25 percent of a company's market value is directly attributable to its reputation); *id.* at 12 (consequences of reputational harms include lost customers and reduced revenues).

[19] Consumers that use unauthorized materials create negative externalities borne initially by the manufacturer and ultimately by the user community as a whole. For example, intermediate customers such as service bureaus or printing departments within large firms externalize reputational losses resulting from printing system downtime or problems with model or part quality when the ultimate customer blames the printing system and its manufacturer for those problems.

[20] *See* R. PRESTON MCAFFEE, COMPETITIVE SOLUTIONS: THE STRATEGIST'S TOOLKIT 95 (2002) (at the beginning of a market, "potential customers often need a great deal of education on the reasons for purchase and on the use of the product"); *id.* at 96 (in the introductory phase of product life cycles, the leading firms "are early entrants who establish a reputation for very high quality" and other desirable characteristics); *id.* at 97 (during the growth phase, market leaders "are usually the firms that began with a solid reputation" or "developed one during the introductory phase"); *id.* at 98 (during the growth phase, "the cultivation of a brand name is a major focus for firm strategy" and is often aided "by the perception, based on reality, of offering the highest quality product and service").

discourage manufacturer investment in the development of new and better products and production processes, and discourage the entry of new sellers.

Software verification can help prevent harms to brand and firm reputations, and the resulting costs to firms and harms to industry competition. Software verification that is not circumvented assures that the user employs genuine materials that have not expired, that the materials used are appropriate for the print job, and that the printer will operate properly and make optimal use of the materials. Software verification also helps the manufacturer protect its firm and brand reputations by creating records of what its 3D printers produce. Those records can be used to diagnose the source of printing problems if they arise, allowing the manufacturer to improve service quality and to develop improved printers and materials.[21]

Overall innovation in the development of consumable materials is unlikely to be harmed when printing system manufacturers are allowed to employ software verification, for at least two reasons. First, printing system manufacturers have strong incentives to encourage the development of new materials and the improvement of existing materials for their printers. If an individual manufacturer chooses policies that impede materials development for its printers, customers that value new and better materials would shift their business to the printing systems developed by other manufacturers, making those policies costly to the manufacturer that adopts them and discouraging manufacturers from doing so. Second, regardless of verification software, independent developers of materials with new ideas have the ability and incentive to pursue them, as they can test their materials on the large number of systems without access controls available in the market and sold by manufacturers that permit or encourage such experimentation[22] or receive permission to test their materials from manufacturers that employ verification software.

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[21] There may be no practical alternatives to software verification for achieving the benefits described in this paragraph. For example, conditioning the warranty on the use of genuine materials may be impractical because without software verification, the manufacturer may not know whether the customer actually used genuine materials. It would also not solve the manufacturer's reputation problem for customers without a warranty or service contract. Conditioning the warranty on the use of authorized materials or materials that meet specifications would present similar difficulties, as well as requiring substantial expenditures by the manufacturer to test and certify materials or develop specifications.

[22] Stratasys Opposition, *supra* note 6, at 20-24.

METERING

Many 3D printing system manufacturers, including Stratasys, sell both printers and consumable materials. More intensive use of a printer requires purchasing more materials and increases the customer's cost of using the printer. So long as materials are sold at prices above marginal costs, more intensive users will contribute more than less intensive users toward the development costs of printer systems.[23] In the economics literature, this business practice is termed metering. The sale of materials "serves as a substitute for placing a meter on the [printer] itself and billing the customer … on the basis of metered usage."[24]

Metering is a common business practice when firms sell a primary product and complementary aftermarket materials. Well known historical examples include IBM (tabulating machines and punch cards), Kodak (cameras and film), and Gillette (razors and blades).[25] Software verification facilitates metering by allowing the printer manufacturer to guarantee that it can sell consumable materials to its printer customers.

Metering facilitates economic price discrimination;[26] that is, it allows sellers to sort buyers based on their responsiveness to price, prevent arbitrage between buyers, and charge lower prices when selling similar products to some buyers.[27] Price discrimination is common in

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[23] To remain viable, 3D printing system manufacturers must recover their fixed costs of developing printers and materials over the printing system's lifecycle.

[24] Scherer & Ross, *supra* note 17 at 566. *See also* Motta, *supra* note 17 at 463.

[25] For other examples, see Erwin A. Blackstone, *Restrictive Practices in the Marketing of Electrofax Copying Machines and Supplies: The SCM Corporation Case*, 23 J. INDUS. ECON. 189, 191-93 (1975) (electrofax copying machines and coated paper); Ricard Gil & Wesley R. Hartmann, *Empirical Analysis of Metering Price Discrimination: Evidence from Concession Sales at Movie Theaters*, 28 MARKETING SCI. 1046 (2009) (movie theater admissions and concessions).

[26] Benjamin Klein, *Price Discrimination and Market Power, in* II ABA SECTION OF ANTITRUST LAW, ISSUES IN COMPETITION LAW AND POLICY 977, 981 (2008) ("The use of an aftermarket input to meter demand for a durable good is a particular form of modern second-degree (consumer self-selection) economic price discrimination."); Dennis W. Carlton & Michael Waldman, *Tying, in* II ABA SECTION OF ANTITRUST LAW, ISSUES IN COMPETITION LAW AND POLICY 1859, 1866 (2008).

[27] Klein, *supra* note 26 at 980 (defining economic price discrimination). Firms that discriminate in price charge higher prices (relative to cost) to customers with higher valuations (or less responsiveness to price), and lower prices to customers with lower valuations (or greater responsiveness to price). With printing systems, more intensive users would be expected to have higher valuations than less intensive users.

competitive markets, as with restaurants that bring in new business by charging pre-theater customers less for dinner than peak-period customers.[28]

Similarly in the 3D printing industry, manufacturers using metering can set the price of the printer lower than they would otherwise, in order to sell more printers and increase their profits from selling materials.[29] By doing so, the firm will attract customers who anticipate fewer benefits or expect to use the printer less and so have a lower intensity of demand. For these customers, the lower price of the printer more than offsets the higher materials costs, thus decreasing their anticipated total cost of ownership. In this way, metering makes it profitable for the manufacturer to serve a group of customers that would otherwise be priced out of their market, namely customers expecting to use the printing system less intensively. As a result, total printing system sales (output) and overall economic welfare are greater than without metering.[30]

In the 3D printing industry in particular, customers that expect to use 3D printers less intensively are valuable to the manufacturer.[31] They will typically be new customers that have limited experience with 3D printing or with the particular advantages of the manufacturer's product, and do not anticipate using the product intensively in the short run. With the low printer prices made possible by metering, these customers may be induced to try the printing system.[32] Some may find they like the product and, with experience, expand their use. The opportunity to sell products to prospective users that are uncertain how much value they will find in their

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[28] *See id.* at 990 ("[P]rice discrimination is a common business practice used by firms in virtually all markets lacking the textbook criteria of perfect competition, including some markets that are highly competitive….[A]ll that is necessary is that the firm face a negatively sloped demand for its products, a condition present in highly competitive markets so long as firms are selling less than perfectly substitutable products.")

[29] Gil & Hartman, *supra* note 25 at 1046 ("[M]etering has the ability to increase efficiency because it can open access of a good to customers that would otherwise be priced out of the market."). *See also* Motta, *supra* note 17 at 463. The comparison is with the prices the manufacturer would set if it had no other way to discriminate in price.

[30] *See* Klein, *supra* note 26 at 985. The overall ownership price may be higher than otherwise for some intensive users, but these users would still value the product at or greater than what they are paying for it.

[31] These customers are also valuable to the industry as a whole, because they may increase awareness of the product category among potential customers and thereby speed industry growth.

[32] Customers base purchase decisions on multiple dimensions of the product, not just price, but all else equal, a lower price would be expected to encourage more customers to purchase the product. From this perspective, metering can be understood as a form of targeted penetration pricing that focuses on a group of customers likely to benefit from trying the product, thereby enhancing firm profitability and overall economic welfare. Without the ability to target low-use customers, it may not be profitable for the manufacturer to engage in penetration pricing.

purchase is likely important to producers and customers in a developing industry with rapidly improving technology such as 3D printing.[33] For example, Stratasys undertakes systematic marketing efforts to highlight the advantages of its printing systems for new users.[34]

Metering is not only beneficial to customers that would not otherwise purchase the equipment; it also increases profits to the manufacturer because it allows the firm to sell to customers that would use the printer less intensively and earn more from customers that would use it more intensively. For this reason, metering gives the manufacturer a greater incentive to develop new products, including printing systems and materials that would attract a wide range of buyers, including those that expect to use printers relatively less intensively.[35] Technological innovation by a 3D printer manufacturer benefits that firm and its customers, and it could generate positive spillovers for the industry as a whole.

For all these reasons, metering is likely to increase seller output and overall economic welfare. It can also lead to lower prices for many customers, and increase manufacturer efforts to develop new products.

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[33] *Cf.* Scherer & Ross, *supra* note 17 at 492-93 (firms may offer new customers lower prices in the hope of developing permanent brand loyalty). The manufacturer could attempt to promote its products to these customers in other ways, but alternative approaches are likely to be less cost-effective, in part because of the difficulty distinguishing customers that expect to use the printing system less frequently from those who would use it more intensively. (If asked, every customer would claim to belong to the former group in an effort to negotiate a lower price).

[34] Stratasys does so in part through case studies illustrating the advantages of its printing systems to specific customers. *E.g.* Kelly Manufacturing (http://www.stratasys.com/resources/case-studies/aerospace/kelly-manufacturing); Champion Motorsport (http://www.stratasys.com/~/media/Main/Secure/Application_Customer_Stories-ACS/SSYS-ACS-ChampionMtrSport-09-14-Web.pdf).

[35] The manufacturer could still seek to serve some customers that are relatively responsive to price by developing new models with features that would appeal to such customer groups, but it would not be able to capture the business of customers that value the same features as other customers but expect to use their printing systems less intensively. Hence product differentiation (or versioning) is unlikely to substitute fully for metering as a means of discriminating in price. In some industries, metering can be achieved by leasing equipment at rates based on usage, but this business practice is not routinely employed in 3D printing, in part because manufacturers would not be able efficiently to monitor printing system usage for some types of customers, such as those that prefer to keep printers offline for confidentiality reasons.

CONCLUSION

As demonstrated above, software verification can increase consumer welfare and industry innovation in at least two ways. First, it can help manufacturers protect firm and brand reputations, enhancing competition among sellers to the benefit of customers and overall economic welfare without harming incentives to innovate. Second, software verification facilitates metering, which likely leads to higher seller output and overall economic welfare. Metering may also lower prices for many customers and enhance manufacturer efforts to develop new products. If this common business practice in the 3D printing industry is disrupted by a regulatory decision that allows other firms to bypass technological protection measures to sell materials, printer prices would increase to many customers and overall economic welfare may be reduced.