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WHO'S AFRAID OF 3D PRINTING?

BEN DEPOORTER* **& BREGT RAUS†**

ABSTRACT

Heralded for ushering in a new era of personalized manufacturing, there is a growing fear that consumer 3D printing is the next frontier of massive intellectual property infringements. Described as the Napster of patents, illegal 3D printing is foretold to disrupt manufacturing in the same manner as digital piracy unsettled the music industry.

This Article shows that the negative forecast of rampant 3D printing piracy is overstated. We explain how the purported analogies between P2P file sharing and consumer 3D printing overlook essential differences between piracy of media content and physical property. We caution against aggressive enforcement against unauthorized consumer 3D printing that would impede innovation and the development of 3D printing technologies.

*Max Radin Distinguished Professor - University of California, Hastings Law School; Visiting Professor, U.C. Berkeley Law (PLLM); Affiliate Scholar, Stanford Law School. Center for Internet & Society, and EMLE Coordinator, Ugent.

†LL.M. Candidate, University of Chicago Law School (BAEF & Fulbright Fellow), 2019; Master of Laws, Ghent University Belgium, 2015.

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INTRODUCTION

Additive manufacturing is predicted to change the world as we know it.[1] By enabling a do-it-yourself manufacturing model for small companies and consumers, 3D printing is expected to set about an "industrial counter-revolution" of sorts, in which manufacturing is no longer synonymous with assembly lines and processing plants.[2] As 3D technologies become more widespread, the average consumer will, from the comfort of his or her own home, be able to use affordable 3D printers to design and manufacture most products currently available in retail markets.[3]

Consumer 3D printing has experienced a tremendous boost in recent years. The industry's global market value exceeded $7.3 billion in 2018 and is expected to multiply in coming years.[4] A growing group of users — taking advantage of price reductions in 3D printing hardware — are already engaging with this new technology on home computers, manufacturing physical items such as small sculptures, toys, and decorative or useful items.[5]

However, as new applications of 3D printing emerge and 3D technologies and markets mature, the 3D printing revolution is causing deep anxiety among some intellectual property owners and commentators.[6] There is a fear that Internet

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[1] *See* Deven R. Desai & Gerard N. Magliocca, *Patents, Meet Napster: 3D Printing and the Digitization of Things*, 102 GEO. L.J. 1691, 1697 (2014) ("3D printing will unleash the power of digitized things on manufacturers.").

[2] *See, e.g.*, AARON COUNCIL WITH MICHAEL PETCH, 3D PRINTING: THE RISE OF THE THIRD INDUSTRIAL REVOLUTION loc. 74 (2014) (ebook); Marshal Burns & James Howison, *Digital Manufacturing - Napster Fabbing: Internet Delivery of Physical Products*, 7 RAPID PROTOTYPING J. 194, 194-96 (2001); *The Printed World*, ECONOMIST (Feb. 10, 2011), http://www.economist.com/node/18114221/print [https://perma.cc/4X9K-7Q7V].

[3] *See* CHRIS ANDERSON, MAKERS: THE NEW INDUSTRIAL REVOLUTION 58-59, 90-95 (2012); Simon Bradshaw et al., *The Intellectual Property Implications of Low-Cost 3D Printing*, 7 SCRIPTED 5, 8-12 (2010).

[4] T.J. McCue, *Wohlers Report 2018: 3D Printer Industry Tops $7 Billion*, FORBES (June 4, 2018, 4:03 AM), https://www.forbes.com/sites/tjmccue/2018/06/04/wohlers-report-2018-3d-printer-industry-rises-21-percent-to-over-7-billion/#6430b91b2d1a [https://perma.cc/B58D-6YER] (reporting findings set out in WOHLERS REPORT 2018: 3D PRINTING AND ADDITIVE MANUFACTURING STATE OF THE INDUSTRY, WOHLERS ASSOC. (2018)).

[5] *See, e.g.*, Scott J. Grunewald, *Weekly Roundup: Ten 3D Printable Doll & Action Figure Playsets*, 3DPRINT.COM (Sept. 11, 2016), https://3dprint.com/148866/ten-3d-printable-playsets/ [https://perma.cc/H8NL-6SBH]. *See also 3d Printed Objects*, ETSY, https://www.etsy.com/market/3d_printed_objects (last visited Feb. 17, 2019) (offering 3D printed objects for sale); THINGIVERSE, www.thingiverse.com/ [http://perma.cc/AXR3-H5P7] (last visited Oct. 8, 2018) (offering free 3D models); *infra* Part I.D.

[6] Daniel Harris Brean, *Asserting Patents to Combat Infringement via 3D Printing: It's No "Use"*, 23 FORDHAM INTELL. PROP., MEDIA & ENT. L.J. 771, 780-781 (2013) (advocating legislative solutions to consumer printing infringements); Stephen Graves, *3D Printing Will Do to the Manufacturing Industry What Napster Did to the Music Industry*, PC & TECH

users will scan, upload, and distribute unauthorized 3D models of objects over which they have intellectual property rights.[7] There is growing alarm is that in a world with 3D printing, physical consumer goods will be subject to the same fate as HBO's *Game of Thrones*: massive online piracy.[8]

Historically, reproduction and distribution costs have limited the scope of illegal markets for patented and trademarked materials.[9] However, by drastically reducing the costs of reproducing physical objects, 3D scanners and printers pave the way to decentralized piracy of items of manufacture.[10] By enabling the conversion of physical materials into digital format – much like MP3 files did for copyrighted works – 3D printing technologies empower individuals to scan and post objects on the Internet, free for others to download and print in physical form.[11] As a result, 3D printing threatens the value of intellectual property rights. Commentators proclaim that 3D printing presents an existential challenge to the core bargain that underlies patent law: the grant of a time-limited exclusive legal

AUTHORITY (Sept. 18 2014), https://www.pcauthority.com.au/feature/3d-printing-will-do-to-the-manufacturing-industry-what-napster-did-to-the-music-industry-392228 [https://perma.cc/P8LX-NLCB] ("The disruptive effects of 3D printing are only just starting to make their presence felt, and there will be much more to come."); Timothy Holbrook & Lucas Osborn, *Digital Patent Infringement in an Era of 3D Printing*, 48 U.C.D. L. REV. 1319, 1322 (2015) ("One respected research firm predicts that by 2018, intellectual property theft due to 3D printing alone will create losses of $100 billion per year."); Elif Sonmez, *Cottage Piracy, 3D Printing, and Secondary Trademark Liability: Counterfeit Luxury Trademarks and DIY*, 48 U.S.F. L. REV. 757, 762 (2014) ("The popular emergence of 3D printing will only make counterfeiting marks easier."); John Paul Titlow, *Why 3D Printing Will Be The Next Big Copyright Fight*, READWRITE (Feb. 20, 2013), https://readwrite.com/2013/02/20/3d-printing-will-be-the-next-big-copyright-fight/ [https://perma.cc/SRN7-2RYR] ("[J]ust as the Internet made trading MP3 music files and ripped movies a breeze, downloading 3D images to print on your shiny new MakerBot printer will be as easy as torrenting 'The Hurt Locker.'"); Frank Ward, *Patents & 3D Printing: Protecting the Democratization of Manufacturing by Combining Existing Intellectual Property Protections*, 25 DEPAUL J. ART. TECH. & INTELL. PROP. L. 91, 91-92, 105-18 (2014) ("[T]he technology raises serious concerns about the potential for infringement of copyrights and patents.").

[7] For instance, market actors are concerned that instead of ordering a Cuisinart toaster on Amazon, would-be consumers might download an illegal file that contains the 3D model of that toaster, and print the toaster themselves at a fraction of the cost. *See* Titlow, *supra* note 6.

[8] *See id*.; Melissa Locker, *Game of Thrones Tops the Most Illegally Downloaded Shows of 2016*, TIME MAGAZINE (Dec. 28, 2016), http://time.com/4618954/game-of-thrones-pirated-2016/ [https://perma.cc/TD6Y-LSA2].

[9] Desai & Magliocca, *supra* note 1, at 1691,1693, 1697, 1704.

[10] *Id*. at 1691, 1697.

[11] *Id*. at 1697.

right in an invention in exchange for the inventor's disclosure of the invention.[12] This bargain "may be meaningless in a world of digitized things."[13]

Some assert that the digitization of physical objects threatens to disrupt manufacturing industries in a similar, if not wholly parallel, manner as experienced by the music industry in the late 1990s.[14] The dogged enforcement campaign by music record labels during that era vividly illustrates the daunting challenge of enforcing intellectual property rights in a setting of mass, decentralized online infringement.[15] In the file-sharing and torrent era, copyright holders face a mass of individual infringers, each of whom are difficult to identify and costly to pursue.[16] Infringement occurs inside the home, creating a perception of security and anonymity among infringers.[17] Stakeholders and observers fear that consumer 3D printing might bring a similar Napster doomsday scenario to intellectual property rights-holders more generally.[18]

This Article argues that concerns as to a future of rampant consumer 3D printing piracy are exaggerated. Analogies connecting P2P file sharing[19] and 3D printing are flawed, as they neglect essential differences between the piracy of audiovisual content and physical goods. The anxiety about 3D printing vastly overestimates the future magnitude of 3D piracy markets. Digitization and printing of physical goods involve substantial costs and efforts that were absent in the Napster-MP3 revolution. 3D printing technologies currently impose considerable burdens on users — including expertise, out-of-pocket costs, and an ever-present risk of defective printouts — and will continue to impose burdens for the foreseeable future. These complications will continue to suppress the supply and demand of 3D pirated materials.

Furthermore, even if advancements in 3D printing technologies were to eliminate all practical limitations, it is unlikely that manufacturing industries will face a Napster scenario as a result of 3D printing piracy. The demand for

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[12] *See* Brean, *supra* note 6, at 782 (predicting that 3D printing is likely to "shake the foundation of our patent system").

[13] Desai & Magliocca, *supra* note 1, at 1691.

[14] *Id*. at 1691, 1693, 1697, 1704 ("3D printing . . . will do for physical objects what MP3 files did for music.").

[15] Ben Depoorter, *Intellectual Property Infringements & 3D Printing Decentralized Piracy*, 65 HASTINGS L.J. 1483, 1486, 1494-1495 (2014) (pointing out difficulties of enforcing intellectual property rights in the context of decentralized infringements).

[16] *Id*. at 1494-95.

[17] *Id*.

[18] *See id*.

[19] P2P, or peer-to-peer, file sharing refers to the direct transmission of files between computers, without the aid of a centralized server, and formed much of the focus of the Napster-era digital copyright infringement discussed below. *See* Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd., 545 U.S. 913, 919–21, (2005). File-sharing services necessarily require that users have some degree of access to other users' private computers — in many instances limiting that access to a shared folder — and differ in part in terms of the means by which the service identifies the location of a given file. *Id.*

physical materials is less concentrated than for music, the social dimension is less strong, warehousing is expensive, and the manufacturing industry can avoid the social backlash that fueled the fires of digital music piracy. As a result, it is highly doubtful that illegal 3D scanning and printing will confront jewellers, fashion designers, and manufacturers of consumer goods such as toys, games, home furnishings, and sports equipment, with the type of industry-wide disruption that the music and movie industries experienced.

We caution against aggressive enforcement and preemptive regulatory policies. Alarmist overreactions tend to induce regulatory action that is premature, ill-advised and may harm innovation. To counter these adverse effects, we provide insight to the proper scope and timing of regulatory action in relation to 3D printing.

This Article is organized as follows: Part I describes the basics of 3D printing, explains how it differs from traditional manufacturing, and evaluates the commercial prospects of consumer 3D printing. Part II describes the rising anxiety about 3D printing piracy and establishes the context for that fear, namely, the digital music piracy era associated with Napster. Part III describes various complications of 3D printing that suppress the public supply and demand of pirated 3D materials. Part IV explains essential differences between music piracy and 3D printing. Part V provides policy recommendations. Part VI concludes.

I. 3D PRINTING EXPLAINED

This Part describes the basic mechanics of 3D printing. We first explain some basic technical aspects of additive printing (Section A) and go on to describe the major differences between additive and traditional manufacturing (Section B). Next, we briefly explain the commercial advantages of consumer 3D printing (Section C) and the advent of consumer 3D printing (Section D). This Part sets the ground for our arguments in Parts III and IV below.

A. Roadmap to 3D Printing

The term "3D printing" is commonly used as a synonym for the term "additive manufacturing,"[20] describing the various processes that build "physical objects by successive addition of material."[21] The basic process of 3D printing can be summarized as follows. A 3D printer reads a digital file containing a 3D model and produces a physical object based on that model.[22] The 3D printer accomplishes this by "adding" small layers — each consisting of a flat cross section of

[20] BEN REDWOOD, FILEMON SCHÖFFER & BRIAN GARRET, THE 3D PRINTING HANDBOOK: TECHNOLOGIES, DESIGN AND APPLICATIONS 9 (2017).

[21] For an overview of general terminology related to additive manufacturing and 3D printing, see ADDITIVE MANUFACTURING — GENERAL PRINCIPLES — TERMINOLOGY, ISO/ASTM 52900:2015 (INT'L ORG. FOR STANDARDIZATION [ISO] 2015) [hereinafter ISO/ASTM 52900:2015].

[22] REDWOOD ET AL., *supra* note 20, at 10.

the final product — together in a successive manner, hence the name additive manufacturing.[23]

To be more precise, 3D printing consists of three major steps.[24] The first step involves the creation of a digital 3D model of an object which is used as a blueprint for printing.[25] There are two principal ways to create 3D models: through the use of CAD (computer-aided design) software, or by scanning an existing object with a 3D scanner.[26] The digital 3D model must be converted into an appropriate format that enables 3D printing.[27] The most popular format is STL, though STL files are somewhat limited as they capture only the surface geometry of the object and cannot reach characteristics such as color and texture.[28] Newer file formats such as additive manufacturing file format (AMF)[29] and objective file (OBJ) do not share these limitations, but have not achieved the same degree of popularity.[30] Overall, creating the digital 3D model is an essential part of the manufacturing process which requires attention to numerous design considerations — including material, wall thickness, the need for support structures, object infill, printer layer height, etc. — all of which determine whether the object will print properly.[31]

In the second step, the user prepares the 3D model and printer for production. The user enters various commands into so-called slicing software, which divides the digital model into layers and translates the file into specific instructions (G-code).[32] These instructions drive the 3D printer.[33]

The final step involves the actual printing. The 3D printer generates the object, layer-per-layer in an additive manner.[34] Depending on the technique, the complexity of the design and overall expectations, the printed item will often require some degree of manual modification upon processing, which may

[23] *Id*. at 9.

[24] *Id*. at 10.

[25] *Id*.

[26] *Id*.

[27] *Id*.

[28] ISO/ASTM 52900:2015 § 2.4.16 (explaining that STL may stand for "STereoLithography", "Standard Tesselation Language" or "Standard Triangulation Language"); JOAN HORVATH, MASTERING 3D PRINTING 33-34 (2014).

[29] HOD LIPSON & MELBA KURMAN, FABRICATED: THE NEW WORLD OF 3D PRINTING, 101-02 (2013).

[30] *See* JOAN HORVATH, MASTERING 3D PRINTING 33-34 (2014); Dibya Chakravorty, *4 Most Common 3D Printer File Formats of* 2018, ALL3DP (June 16, 2018), https://all3dp.com/3d-printing-file-formats/ [https://perma.cc/JT74-43B5].

[31] *See* REDWOOD ET AL., *supra* note 20, at 147-175; *see also* Aura, *Preparing Files for 3D Printing: File-Fixing Terminology Explanation and Checklist*, MATERIALISE (May 29, 2018), https://i.materialise.com/blog/preparing-files-for-3d-printing/ [https://perma.cc/MVG7-EZJB].

[32] REDWOOD ET AL., *supra* note 20, at 10.

[33] HORVATH, *supra* note 28, at 47-70.

[34] LIPSON & KURMAN, *supra* note 29, at 79-81.

encompass removal of support structures, surface finishing, connecting separate parts, and aesthetic processing, such as polishing or painting.[35]

Pragmatically, 3D printing includes a variety of different additive techniques.[36] Printing techniques differ vastly with regards to material and hardware.[37] Even when applying the same process, 3D printers from different manufacturers may include hardware variations.[38] The most widely-used, and often the cheapest, technique for consumer 3D printers is fused filament fabrication (FFF), an additive manufacturing process in which the printer extrudes material to form the physical object in question.[39] The FFF process involves heating thermoplastic materials ("filaments") in the print-head until they form a liquid mass.[40] The heated liquid is then sprayed over the print-bed in the form of a cross section of the digital 3D model.[41] Once the first layer is finished, the printer sprays the second layer and so forth.[42] The material hardens and binds with existing layers after each round of extrusion.[43] Due to the heating and extrusion involved, users employing consumer-grade FFF generally can only print using thermoplastic materials such as nylon, acrylonitrile butadiene styrene (ABS), and polylactic acid (PLA).[44] Users wishing to print objects comprised of other materials, such as thermosets and/or metals, must generally do so via techniques such as Vat Polymerization,[45] Powder Bed Fusion,[46] Material Jetting, Binder Jetting, Direct Energy Deposition and Sheet Lamination.[47]

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[35] *Id*. at 81; *see also* HORVATH, *supra* note 28, at 129, 132-135; REDWOOD ET AL., *supra* note 20, at 37-38.

[36] REDWOOD ET AL., *supra* note 20, at 9.

[37] *Id*.

[38] For instance, FFF printers can make use of one or several extruders. *See* REDWOOD ET AL., *supra* note 20, at 28, 32.

[39] *Id*. at 28, 38.

[40] Elizabeth Palermo, *Fused Deposition Modeling: Most Common 3D Printing Method*, LIVE SCIENCE (Sept. 19, 2013, 06:28 PM), https://www.livescience.com/39810-fused-deposition-modeling.html [https://perma.cc/7424-ZY5N].

[41] *Id*.

[42] *Id*.

[43] *Id*.

[44] *See* Horvath, *supra* note 28, at 79; REDWOOD ET AL., *supra* note 20, at 21-22, 35.

[45] Elizabeth Palermo, *What is Stereolithography?*, LIVE SCIENCE (July 16, 2013, 2:39 AM), www.livescience.com/38190-stereolithography.html [https://perma.cc/KZV5-MKS9] (explaining that SLA, which uses a laser to solidify a liquid resin, is one means of conducting Vat Polymerization).

[46] Elizabeth Palermo, *What is Selective Laser Sintering?* LIVE SCIENCE (Aug. 13, 2013, 5:18 PM), https://www.livescience.com/38862-selective-laser-sintering.html [https://perma.cc/7W46-E2U4] (noting that a means of accomplishing Powder Bed Fusion is SLS, by which the user employs a laser to sinter a powder).

[47] *See* ISO/ASTM 52900:2015; REDWOOD ET AL., *supra* note 20 , at 20-22.

B. Divergence with Traditional Manufacturing

3D printing employs a production method that is very different from traditional manufacturing, in that it enables the production of small, unique objects in a simple and cost-effective manner.

Traditional manufacturing involves various possible methods of industrial production, ranging from subtractive methods, such as drilling and cutting objects from a block of materials, to formative methods, such as using heat and pressure to melt a material which the manufacturer then forms into the desired shape.[48] In the 1950s, the idea to automate these various manufacturing techniques — controlling them with a computerized process known as "computer numerical control", or CNC — surfaced, effectively enabling the manufacturing of products which had formerly been too complex to be within the capacity of available processes.[49] Today, the manufacturing of almost all commercial products either directly or indirectly involves CNC.[50] These processes are subtractive as they involve whittling crude materials into their final forms.[51] Subtractive machines have important limitations, however. First, programming the cutting machine's path is extremely complex.[52] Second, subtractive CNC machines do not create internal structures.[53]

In contrast, 3D printing is based on automated additive processes.[54] Additive manufacturing offers several advantages over traditional computer-controlled manufacturing. Programing the hardware for 3D printing is much simpler than programming the hardware for traditional, CNC manufacturing.[55] Moreover, by working with layers, 3D printing constantly provides for a flat surface that the print-heads have unlimited access to, allowing for the construction of internal structures.[56] These two advantages allow for the formation of complex objects in one motion.[57]

The additive, 3D, production method further provides for two additional benefits. First, the printer always starts from scratch and adds layer on top of layer.[58]

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[48] *See* ISO/ASTM 52900:2015; Bradshaw et al., *supra* note 3, at 6; REDWOOD ET AL., *supra* note 20, at 8-9.

[49] Neil Gershenfeld, *How to Make Almost Anything: The Digital Fabrication Revolution*, FOREIGN AFF., Nov.–Dec. 2012, at 43.

[50] *Id.* at 43-44.

[51] *See* REDWOOD ET AL., *supra* note 20, at 8.

[52] Bradshaw et al., *supra* note 3, at 7.

[53] *See* Gershenfeld, *supra* note 49, at 44.

[54] *See* ISO/ASTM 52900:2015.

[55] Bradshaw et al., *supra* note 3, at 8.

[56] *Id.*

[57] *See* Michael Weinberg, *It Will be Awesome if They Don't Screw it Up: 3D Printing, Intellectual Property, and the Fight Over the Next Great Disruptive Technology,* PUB. KNOWLEDGE (2010), www.publicknowledge.org/files/docs/3DPrintingPaper-PublicKnowledge.pdf [https://perma.cc/8AEH-GW3K].

[58] Bradshaw et al., *supra* note 3, at 8.

This means that 3D printing requires less manual, tool intensive work and little to no assembly[59] — enabling both a reduction in costs as well as a more flexible production process.[60] Second, because 3D printing does not involve trimming and waste of materials during the production process, additive methods present significant savings on the costs of materials.[61] Ideally, the printer uses no more material than is strictly necessary.[62] The flexibility of the production process also ensures that it is possible to tailor a product to specific preferences and make custom parts in small batches or even as standalone pieces.[63]

Overall, 3D printing has the potential to make production in small product sets drastically simpler and more affordable.New printing technologies open the door to increased creativity, innovation, and consumer involvement.[64] It becomes possible to produce whatever comes to mind more freely and creatively.[65] In this regard, 3D printing stands in sharp contrast to traditional manufacturing, the latter relying on production output and economies of scale.[66]

C. Commercial Advantages of 3D Printing

3D printing enables manufacturers to produce locally and save on transport costs.[67] 3D printing also facilitates on-demand production.[68] A designer can design and market products without a need to warehouse excess items.[69] In other words, manufacturers can produce products as orders come in. In addition, producers can more easily test and fix products based on consumer feedback.[70] Further, the flexibility of the production process enables manufacturers to tailor

[59] LIPSON & KURMAN, *supra*, note 29, at 20-23.

[60] *See* Daniel L. Cohen, *Fostering Mainstream Adoption of Industrial 3D Printing: Understanding the Benefits and Promoting Organizational*, 1 3D PRTG. & ADDITIVE MFG. 62, 63-65 (2014); LIPSON & KURMAN, *supra*, note 29, at 20-23, 30-33; Anthony Vicari, *Efficiencies of Improved 3D Printing Inspire Innovation* (Jan. 2, 2014, 12:00 am), https://www.epmag.com/efficiencies-improved-3-d-printing-inspire-innovation-709866#p=full [https://perma.cc/JQ5B-Z364].

[61] John F. Hornick, *3D Printing and the Future (or Demise) of Intellectual Property*, 1 3D PRTG. & ADDITIVE MFG. 34, 35 (2014); Dinusha Mendis, *"The Clone Wars" – Episode 1: The Rise of 3D Printing and its Implications for Intellectual Property Law – Learning Lessons from the Past?*, 35 EUR. INTELL. PROP. REV. 155, 158 (2013).

[62] *See* Thomas Birtchnell & John Urry, *3D, SF and the Future*, 50 FUTURES 25, 27 (2013).

[63] *See id*. at 10. *See also* LIPSON & KURMAN, *supra*, note 29, at 33.

[64] *See* MICHAEL WEINBERG, WHAT'S THE DEAL WITH COPYRIGHT AND 3D PRINTING? PUB. KNOWLEDGE 1 (2013); Depoorter, *supra* note 15, at 1484-85.

[65] *See* ANDERSON, *supra* note 3, at 87-89.

[66] *See* Irene Petrick & Timothy Simpson, *3D Printing Disrupts Manufacturing: How Economies of One Create New Rules of Competition*, RES.-TECH. MGMT. 1, 15-16 (2013).

[67] *Id*. at 15.

[68] *Id*. at 16.

[69] *See id*. at 15.

[70] *See* Birtchnell & Urry, *supra* note 62, at 27, 30; Bradshaw et al., *supra* note 3, at 10-11.

products to individual customer preferences.[71] All told, this flexibility enables the production of personalized products based on each customer's preferences.[72] Finally, as additive manufacturing can occur locally and without waste, it might have a smaller environmental footprint.[73]

D. The Rise of Home 3D Printing

As more consumers have become involved with 3D printing applications, mainstream interest in 3D printing has skyrocketed.[74] An increasing number of websites provide downloads of 3D model files, which users can then employ as the blueprints for 3D-printed physical objects.[75] Consumers can also use commercially-available 3D scanners to create a 3D model of an existing object.[76] In this regard, 3D printing allows the consumer to step into the shoes of the producer.[77] Using a desktop 3D printer, the consumer can convert digital 3D models from files into physical objects[78] or employ a third-party 3D printing service[79]

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[71] Birtchnell & Urry, *supra* note 62, at 26-27. For example, BMW-Mini Cooper offers its customers custom, 3D-printed, trim options. *See* Sarah Saunders, *Customize Your MINI in 2018 with 3D Printed and Laser Lettered Trim*, 3DPRINT.COM (Dec. 27 2017), https://3dprint.com/198469/mini-yours-customised-products/ [https://perma.cc/C5JS-WZ93].

[72] *See* Birtchnell & Urry, *supra* note 62, at 27-28.

[73] *See* ANDERSON, *supra* note 3, at 86.

[74] Although 3D printing has received heightened media attention in recent years, the technology has existed for decades. The first U.S. patent on 3D printing technology was issued in 1977. Bradshaw et al., *supra* note 3, at 7-8. The first industrial and commercial installations date from the late 1980's. Terry Wohlers & Tim Gornet, *History of Additive Manufacturing*, WOHLERS REP. 1, 1 (2012); *see* also Swanson, *infra* note 78, at 485.

[75] *See, e.g.*, CGTRADER, https://www.cgtrader.com/ [http://perma.cc/5H3S-QD3A] (last visited Oct. 8, 2018) (offering downloadable 3D model files for payment); THINGIVERSE, www.thingiverse.com/ [http://perma.cc/AXR3-H5P7] (last visited Oct. 8, 2018) (offering free 3D models). *See also*, Eddie Krassenstein, *MakerBot Launches Thingiverse Groups, Bringing the Community of 3D Designers Together*, 3DPRINT.COM (Jan. 20, 2015), https://3dprint.com/38680/makerbot-thingiverse-groups/ [https://perma.cc/T66V-THLQ] (last visited Oct. 8, 2018) ("When it comes to 3D designs, MakerBot's Thingiverse stands alone atop the 3D printable file repositories on the net.").

[76] *E.g.* "*Sense*" *3D Scanner*, 3D SYSTEMS, https://www.3dsystems.com/shop/sense [https://perma.cc/2XLL-AEN6] (last visited Nov. 5, 2017) (advertising a 3D scanner available to consumers).

[77] *See* Desai & Magliocca *supra* note 1, at 1693, 1695.

[78] *See* Charles W. Finnochiaro, *Personal Factory or Catalyst for Piracy: The Hype, Hysteria, and Hard Realities of Consumer 3-D Printing*, 31 CARDOZO ARTS & ENT. L.J. 473, 474 (2013); Sarah Swanson, *3D Printing: A Lesson in History: How to Mold the World of Copyright*, 43 SW. L. REV. 483, 484-85 (2014).

[79] For example, consumers might turn to a website such as, Shapeways, which offers both 3D Printing services and a range of 3D models. *See* SHAPEWAYS, https://www.shapeways.com/marketplace [http://perma.cc/27X8-ZHAZ] (last visited Oct. 8, 2018).

to print on their behalf. Many customers rely on the latter option,[80] as consumer-model desktop 3D printers are relatively expensive and often have limited capabilities.[81]

While these developments may seem positive from a consumer perspective, not all appreciate 3D printing's newfound accessibility and ease-of-use. As is discussed below, the continued evolution of 3D printing technologies has stoked anxiety in some that 3D printing will lead to potential widespread infringement of intellectual property rights, with some likening it to online music piracy.

II. FEAR OF 3D NAPSTER

A. The Prospect of 3D Napster

Each leap in technological capacity presents novel legal challenges.[82] 3D printing is no exception. It introduces a host of legal issues across various doctrines[83] — especially in the area of intellectual property law.[84]

Although 3D printers have ample lawful uses, 3D printers can be employed to illicitly reproduce items without authorization from intellectual property right

[80] TJ McCue, *3D Printing Service Bureaus on Growth Path With Almost $3 Billion in Revenue,* FORBES (Aug. 30, 2018, 11:50 PM), https://www.forbes.com/sites/tjmccue/2018/08/30/3d-printing-service-bureaus-on-growth-path-with-almost-3-billion-in-revenue/#52659f222d8d [https://perma.cc/762N-FMEU].

[81] Lyndsey Gilpin, *3D Printing: 10 Factors Still Holding It Back*, TECHREPUBLIC (Feb. 19, 2014), https://www.techrepublic.com/article/3d-printing-10-factors-still-holding-it-back/ [https://perma.cc/SJW2-B2M3].

[82] On the legal challenges presented by technological advances, *see, e.g.*, Ben Depoorter, *Technology and Uncertainty: The Shaping Effect on Copyright Law*, 157 U. PA. L. REV. 1831, 1834 (2009) (discussing legal challenges under copyright law associated with such technological advances); Mark Grady, *Why Are People Negligent? Technology, Nondurable Precautions, and the Medical Malpractice Explosion*, 82 NW. U. L. REV. 293, 334 (1988) (discussing technological advances and related challenges under tort law); James Krier & Clayton Gillette, *The Un-Easy Case for Technological Optimism*, 84 MICH. L. REV. 405, 429 (1985) (dispelling mythology of technological optimism).

[83] 3D printing might give rise to potential claims relating to, for example, products liability and gun-regulation. *See*, *e.g.*, Nora Freeman Engstrom, *3D Printing and Product Liability: Identifying the Obstacles*, 162 U. PA. L. REV. ONLINE 35, 40-41 (2013) (discussing potential claims relating to products liability); Peter Jensen-Haxel, *3D Printers, Obsolete Firearm Supply Controls, and the Right to Build Self-Defense Weapons Under Heller*, 42 GOLDEN GATE U. L. REV. 447, 495-96 (2012) (discussing potential claims involving gun regulation); Chris Brandrick, *3D Printer Lets You Print Your Own Prescription*, PCWORLD (Apr. 19, 2012, 3:59 PM), https://www.pcworld.com/article/254118/3d_printer_lets_you_print_your_own_prescription.html [http://perma.cc/H5ST-D9MJ] (discussing a project to 3D print medicine).

[84] *See*, *e.g.*, Bradshaw et al., *supra* note 3, at 6.

holders.[85] A 3D-printing-pirate merely needs to purchase print materials[86] and obtain blueprints of existing objects, which, as discussed above, are available for purchase online, or can be custom created with the use of products and materials available for purchase in retail stores.[87] For instance, users of 3D printers may download (potentially unlawful) blueprints of patented items for the purpose of fabricating unauthorized reproductions.[88] Similarly, users might scan and adapt items to create derivative works that violate the exclusive right of copyright holders,[89] or use 3D printers to make and sell in commerce counterfeit copies of trademarked materials.[90]

As several commentators have pointed out, 3D printing may give rise to massive, decentralized, non-commercial, piracy,[91] and as such shares common ground with copyright infringement on P2P file-sharing networks. Accordingly, some predict that 3D printing may present a Napster-like scenario to manufacturing industries.[92] They argue that the blurred boundaries between physical and digital objects opens the door to a potential explosion of intellectual property infringements.[93] That is to say, there is a fear that individuals will be able to create blueprints of counterfeit goods, share them online, and print physical

[85] *See id*.

[86] *See*, *e.g*., *Printing Material Suppliers*, REPRAP, http://reprap.org/wiki/Printing_Material_Suppliers [http://perma.cc/VKQ6-RTR7] (last visited on Oct. 8, 2018) (RepRap lists suppliers of filament).

[87] *See* NEIL GERSHENFELD, FAB: THE COMING REVOLUTION ON YOUR DESKTOP-FROM PERSONAL COMPUTERS TO PERSONAL FABRICATION, 103 (2005). *See also* text accompanying *supra* notes 74-76.

[88] *See, e.g*., Colin B. Harris & David Nguyen, Oblon, *BMW Group Files Suit Against TurboSquid*, LEXOLOGY (May 9, 2016), https://www.lexology.com/library/detail.aspx?g=efb0f954-657c-44c2-9491-e8c754a11f99 [https://perma.cc/45F3-XH3Q] (reporting on a lawsuit in which BMW group alleged that a website infringed, inter alia, its design patents "by selling unauthorized virtual 3D models of BMW Group vehicle designs on the TurboSquid website.").

[89] Kyle Dolinsky, *CAD's Cradle: Untangling Copyrightability, Derivative Works, and Fair Use in 3D Printing*, 71 WASH. & LEE L. REV. 591, 664-65 (2014).

[90] Harris & Nguyen, *supra* note 88.

[91] *See* Depoorter, *supra* note 15, at 1486.

[92] *See* Brean, *supra* note 5, at 780-81; Holbrook & Osborn, *supra* note 6, at 1321-24; Sonmez, *supra* note 6, at 782-83; Ward, *supra* note 6, at 91-92 & 105-18 (2014); Graves, *supra* note 6; John Paul Titlow, *Why 3D Printing Will Be The Next Big Copyright Fight*, READWRITE (Feb. 20, 2013), https://readwrite.com/2013/02/20/3d-printing-will-be-the-next-big-copyright-fight/ [https://perma.cc/SRN7-2RYR].

[93] *See* Desai & Magliocca *supra* note 1, at 1692, 1697; Joseph Storch, *3-D Printing Your Way Down the Garden Path: 3-D Printers, the Copyrightization of Patents, and a Method for Manufacturers to Avoid the Entertainment Industry's Fate*, 3 NYU J. INTELL. PROP. & ENT. L. 249, 300 (2014).

objects from the comfort of their homes.[94] All of this would occur on a global scale, at low-cost, and without requiring assistance from commercial counterfeiters.[95]

While the manufacturing and retail industries have always faced commercial counterfeiters, 3D printing's digital revolution presents an unfamiliar, potential challenge to them: mainstream, decentralized piracy of items of manufacture. As with P2P music and video file sharing, the decentralized nature of infringement severely complicates the effort to enforce intellectual property rights online. Traditional IP enforcement avenues are unavailable as commercial intermediaries, cash transactions, postal addresses and store fronts are largely absent.

Concerns with the unauthorized consumer 3D printing follow in part from the problems experienced by the music industry in the wake of Napster, the history of which, along with the constituent elements of decentralized piracy, is the subject of the next section. Parts III and IV analyze whether that analogy holds for 3D printing.

B. Napster and the Difficulty of Combatting Decentralized Infringements

When Napster was introduced to the world in 1999, it was the start of an exceptionally tumultuous period for the music industry.[96] The conversion of audio files from analog to digital format,[97] opened the Pandora's box of piracy in the digital age — allowing individuals to effortlessly digitize and share music files.[98] This seamless media reproduction enhanced consumers' portability of music, which likewise made unauthorized copying and distribution an attractive prospect to potential infringers.[99] As individuals started collecting music on their own personal computers, they also started exchanging those files with others.[100] Napster supercharged this process, enabling the general public to use the Internet

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[94] *Id*.; Swanson, *supra* note 78, at 484-85.

[95] Swanson, *supra* note 78, at 484-85.

[96] Storch, *supra* note 93, at 258.

[97] Including, first and foremost, the now ubiquitous MP3 file. *See* Mona Lalwani, *How a file format brought an industry to its knees*, ENGADGET (June 26, 2015), https://www.engadget.com/2015/06/26/mp3-digital-music-piracy/ [https://perma.cc/5PJM-ZLAK] ("When the MP3 format became accessible . . . it eventually led to the rise of music piracy and simultaneous demise of CDs.").

[98] Storch, *supra* note 93, at 258.

[99] *Id*.

[100] *See* Paul Lamere, *What's On Your iPod?*, DUKE LISTENS! (May 22, 2006), http://static.echonest.com/DukeListens/what_s_on_your_ipod.html [https://perma.cc/3Z9F-HGYL] (reporting an average of 3,500 songs). *See also* Dan Sabbagh, *Average Teenager's iPod Has 800 Illegal Music Tracks*, TIMES (June 16, 2008, 1:10 AM), https://www.thetimes.co.uk/article/average-teenagers-ipod-has-800-illegal-music-tracks-l57572s20dc [https://perma.cc/N4NN-SW95].

to exchange their personal music libraries and leading to costless, worldwide, unauthorized end-user distribution of music files.[101]

Thus, the development of Napster's P2P technology was a watershed moment. It brought rampant unauthorized copying and distribution to mainstream audiences. Young individuals especially embraced the new technology and adapted mantras such as "sharing is caring," and "the Internet wants to be free," to accommodate their use of it.[102] Although Napster itself did not have a long shelf-life, a stream of subsequent file sharing technologies continued to test the boundaries of copyright law.[103] File sharing technologies continued to evolve, becoming increasingly more decentralized and difficult to cabin within existing copyright infringement doctrines.[104]

In response, copyright industries mounted a vigorous enforcement campaign against creators and users of file-sharing technologies.[105] Record labels took to court to apply and expand copyright intermediary liability,[106] gained eye-opening verdicts against file-sharing services,[107] and obtained settlements from a reported twenty thousand individuals that it had alleged to have shared files on P2P networks.[108] After a failed attempt to work with Internet service providers to provide copyright infringement notices to individual infringers,[109] the

[101] *See* Peter S. Menell, *This American Copyright Life*: *Reflections on Re-Calibrating Copyright Law for the Internet Age*, 61 J. COPYRIGHT SOC'Y U.S.A. 235, 291-98 (2014) (detailing Napster's facilitation of illegal file sharing).

[102] David Opderbeck, *Peer-to-Peer Networks, Technological Evolution, and Intellectual Property Reverse Private Attorney General Litigation*, 20 BERKELEY TECH. L.J. 1685, 1700-01 (2005) ("File sharers were not simply enamored of the Napster application: instead, they had internalized sharing norms that transcended any particular application or network. As a result, after Napster shut down, end users migrated to other networks.").

[103] Ben Depoorter, Alain Van Hiel & Sven Vanneste, *Copyright Backlash*, 84 S. CAL. L. REV. 1251, 1258-59 (2011).

[104] *See* Kristina Groennings, *Costs and Benefits of the Recording Industry's Litigation Against Individuals*, 20 BERKELEY TECH. L.J. 571, 573 (2005); *see also* AERNOUT SCHMIDT, WILFRED DOLFSMA & WIM KEUVELAAR, FIGHTING THE WAR ON FILE SHARING 4 (2007); Depoorter et. al., *supra* note 103, at 1258-59.

[105] For a description and discussion, see *infra* Part IV.B.

[106] *See, e.g.,* Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd., 545 U.S. 913, 936–37 (*2005*) (imposing intermediary liability for inducing users of file sharing services to infringe entertainment industry copyrights).

[107] *See, e.g.*, Aaron O. Patrick & Sarah McBride, *Four Guilty in Web Piracy Case*, WALL ST. J. (Apr. 18, 2009), https://www.wsj.com/articles/SB123996047873328827 (operators of file-sharing website fined and sentenced to jail).

[108] *See RIAA v. The People: Five Years Later*, ELEC. FRONTIER FOUND. (Sept. 30, 2008), https://www.eff.org/wp/riaa-v-people-five-years-later [https://perma.cc/XS7U-PBRF].

[109] *See* Ben Depoorter & Alain Van Hiel, *Copyright Alert Enforcement: Six Strikes and Privacy Harms*, 39 COLUM. J.L. & ARTS 233, 246 (2015); Greg Sandoval, *RIAA Gives Thumbs Up to France's Three-Strike Law*, CNET (Apr. 8, 2009, 2:28 PM), https://www.cnet.com/news/riaa-gives-thumbs-up-to-frances-three-strike-law/ [https://perma.cc/BBM2-AH2Y]; Kerry Sheehan, *It's the End of the Copyright Alert System*

entertainment industry continues to pursue new legislation which it hopes will curb the ongoing[110] digital copyright infringements in the wake of Napster.[111]

Why have measures to suppress copyright infringement in the post-Napster era proven so ineffective? As we describe below, law enforcement in a digital setting is an uphill battle due to a lethal combination of factors — low piracy production costs increase the ease of infringement, and high enforcement costs make enforcement thereof comparably difficult.

1. Low Piracy Production Costs

Digital technologies and the Internet made pirating music nearly effortless. *Creating* unauthorized copies of copyrighted content is as simple as clicking a button on a keyboard.[112] Likewise, *distributing* pirated content has become an everyday affair. Whereas piracy in the pre-Internet era was the province of purposeful, commercial, planning by intermediaries, the unauthorized distribution of entertainment products online has been something that many individuals have engaged in without even knowing it.[113] Notably, P2P piracy does not rely on the

(As We Know It), ELEC. FRONTIER FOUND. (Feb. 6, 2017), https://www.eff.org/deeplinks/2017/02/its-end-copyright-alert-system-we-know-it [https://perma.cc/4L5S-4PPR].

[110] File sharing — now on BitTorrent applications and illegal streaming websites — continues to be an issue for the entertainment industry. James Titcomb, *The New War on Internet Piracy: How Illegal Streaming and Kodi Boxes Have Reignited the Fight*, TELEGRAPH: TECH. INTELL., (July 15, 2017, 1:15 PM), https://www.telegraph.co.uk/technology/2017/07/15/new-war-internet-piracy-illegal-streaming-kodi-boxes-have-reignited/; Ed Treleven, *Paid Services Don't Keep Pace with Piracy*, WIS. ST. J., Feb. 4, 2007, at A4, 2007 WLNR 2249047.

[111] Such legislation proposes, *inter alia*, disabling access to virtual private networks and removing infringing sites from the Internet and web browser search results. Kieren McCarthy, *Your Internet History on Sale to Highest Bidder: US Congress Votes to Shred ISP Privacy Rules*, REGISTER (Mar. 28, 2017, 7:42 PM), https://www.theregister.co.uk/2017/03/28/congress_approves_sale_of_internet_histories [https://perma.cc/PMU6-Y8WT]; *see also Internet Society Perspectives on Internet Content Blocking: An Overview*, INTERNET SOC'Y 1, 5–21 (Mar. 2017), https://www.internetsociety.org/wp-content/uploads/2017/03/ContentBlocking-Overview.pdf [https://perma.cc/ERR6-DLUR].

[112] Jelle Janssens, Stijn Vandaele & Tom Vander Beken, *The Music Industry on (the) Line? Surviving Music Piracy in a Digital Era*, 17 EUR. J. CRIME, CRIM. L. & CRIM. JUST. 77, 77–78 (2009). Even more so, with the widespread industry adoption of digital methods for music distribution, pirates need not even undertake the minimal effort formerly associated with actually copying physical media formats such as CDs and records. *See* Derek Thompson, *The Death of Music Sales*, ATLANTIC (Jan. 25, 2015), https://www.theatlantic.com/business/archive/2015/01/buying-music-is-so-over/384790/ [https://perma.cc/N6AS-V8T8] ("CDs *are dead*."). *See also* J. D. Biersdorfer, *Digitize Your CDs and Reclaim Your Closet*, N.Y. TIMES (Feb. 9, 2017), https://www.nytimes.com/2017/02/09/technology/personaltech/digitize-cds.html [https://perma.cc/ASQ5-85UB] (discussing the process for digitizing CDs).

[113] Tim Wu, *When Code Isn't Law*, 89 VA. L. REV. 679, 735–36 (2003) (explaining that on most P2P networks, one's files were available to others on most networks unless a user had removed them from the download folder).

involvement of intermediaries, in fact, file sharing software is traditionally freely available online and its functionality by definition relies, to some degree, on its user base.[114]

P2P technologies also tend to reduce infringers perception of the risks associated with piracy.[115] Many users of a file sharing services might distinguish file-sharing from other unlawful behavior, as, in a paradigmatic case, file-sharing occurs inside the home, with the perceived anonymity of the Internet,[116] and presumably without tangible evidence of unlawful behavior such as an exchange of money, the use of credit cards or the involvement of postal addresses.[117]

As online piracy is both easy and accessible, the resulting magnitude of infringing activity renders piracy less risky, with each additional infringer increasing the cost of enforcement reducing the risk of enforcement for all other such infringers. Through a phenomenon that criminologists term the "snowball effect,"[118] the overall probability that any one given offender will be caught reduces as the number of infringers increases. In this process, the strain on rights-holders' limited enforcement budget continues to increase.

2. High Piracy Enforcement Costs

Digital piracy's decentralized structure makes enforcement particularly costly. Prior to Napster, rights-holders had the luxury of focusing their enforcement efforts on a few major offenders — primarily intermediaries engaged in

[114] *See, e.g.*, Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd., 545 U.S. 913, 920, 940 (*2005*) (explaining the user centric nature of file sharing services, including their decentralized transmission of files and reliance advertising revenue associated with large user bases); Jon Healey, *BitTorrent Adds Another Wrinkle to Its File-Sharing Platform*, L.A. TIMES (June 23, 2016, 8:00 AM), http://www.latimes.com/business/technology/la-fi-tn-bittorrent-now-ads-20160619-snap-story.html [https://perma.cc/4EB2-XB5B] (discussing how most streaming sites rely on the activities of the site operators, but this is less so for BitTorrent and most other user-seeded platforms.).

[115] *See* Depoorter & Hiel, *supra* note 109, at 263; Robert LaRose, et. al, *Sharing or Piracy? An Exploration of Downloading Behavior*, J. COMPUTER MEDIATED COMM. Nov. 2005, at 1, 15 ("[C]oping with the risk of detection [encouraged downloading]. The expectation of punishment, however, was related to intentions to discontinue. . . . In multivariate analyses, only the expectation of punishment remained as a factor supporting discontinuance").

[116] While many using file-sharing services were unaware that they could be identified via their IP address, many others ensured that their IP address remained hidden behind Virtual Private Networks (VPN). Depoorter & Hiel, *supra* note 109, at 270.

[117] *See* Amanda Lenhart & Mary Madden, *Teen Content Creators and Consumers: Part 2. Teens as Content Consumers*, PEW RES. CTR. (Nov. 2, 2005), http://www.pewinternet.org/2005/11/02/part-2-teens-as-content-consumers/ [https://perma.cc/J3BP-T6KJ] (noting the prevalence of file sharing, particularly for the purpose of downloading music, amongst teenagers).

[118] Lydia Pallas Loren, *Digitization, Commodification, Criminalization: The Evolution of Criminal Copyright Infringement and the Importance of the Willfulness Requirement*, 77 WASH. U. L. Q. 835, 842 (1999).

repeated infringements for commercial gain.[119] By contrast, if piracy is decentralized — as is the case in contemporary file-sharing systems such as BitTorrent — rights-holders have no means of curbing supply of infringing content, and therefore must target individual, small-scale, offenders.[120]

Moreover, while enforcing copyright law against commercial pirates is relatively straightforward, matters are more complicated for decentralized, non-commercial infringements. Commercial infringers necessarily must operate from physical locations, which present convenient targets for enforcement authorities.[121] Further, commercial transactions with customers increase the overall traceability of infringing activities.[122] However, such traditional means of investigating piracy are conspicuously unavailable in instances of non-commercial digital infringement.[123] Copyright holders must resort to attempting to attribute infringement to the individual Internet subscribers associated with the IP addresses from which the instances of infringement occurred, despite the fact that the mere association with a given IP address is not truly probative of whether the subscriber in question is responsible.[124] Efforts to reduce these enforcement costs — be those efforts through litigation strategy or through use of automated enforcement technologies — have faced some hostility in both the courts of law and public opinion.[125]

Third, attempts to increase the risks associated with file-sharing generated substantial public backlash.[126] Record labels secured hundreds of thousands of

[119] Wu, *supra* note 113, at 713–14.

[120] *See infra* notes 134-138 and accompanying text.

[121] Such operational requirements include space to produce, warehouse, and distribute the pirated material. *See, e.g.*, Aaron Falk, *Police seize 29,000 pirated CDs and DVDs*, SALT LAKE TRIB. (Feb. 15, 2011, 8:33 AM) http://archive.sltrib.com/article.php?id=51248055&itype=CMSID [https://perma.cc/FBT6-X7PZ] (reporting that Utah police had seized 29,000 pirated CDs and DVDs — all in two individual "busts").

[122] *Id*. (explaining that the police discovered the pirated material through "[a] nine-month investigation that started with purchasing music and movies outside Mexican food markets"). While some pirated goods are exchanged through online transactions which provide some anonymity, such as transactions on the dark web, those forums are typically not accessible to many consumers of pirated materials. *See* John Denley, *We Can't Let the Dark Web Give Online Anonymity a Bad Name*, WIRED MAG. (Sept. 28, 2017), https://www.wired.co.uk/article/dark-web-drugs-porn-internet-freedom [https://perma.cc/6JJJ-C4HY] ("It's a tiny enclave where the real promises of the internet - freedom, anonymity, privacy - are, for the most part, still intact.").

[123] *See, e.g.*, Malibu v. Doe, 325 F.R.D. 504, 504-07 (D.D.C. 2018) (deeming the use of an IP address to determine defendant's property as the location from which online infringement of a copyrighted work occurred to be insufficiently probative of defendant's role as the infringer).

[124] *Id*.

[125] *See* Ben Depoorter & Robert Walker, *Copyright False Positives*, 89 NOTRE DAME L. REV. 319, 319-322 (2013).

[126] *Id*. at 326-27, 333, 358.

dollars in statutory damage awards from a few individual offenders. The industry hoped to raise public awareness about their determination to enforce their IP rights,[127] but instead secured the public's outrage about what many believed was a grossly disproportionate and inappropriate enforcement campaign.[128] As a result, rights-holders faced a "Hobson's choice . . . either aggressively ramp up enforcement against all infringers — despite widespread public condemnation of the practice — or [relax enforcement and] face potentially devastating losses in revenue."[129]

At the end of the day, the music industry's enforcement campaign was unsuccessful in that it did not halt copyright infringement associated with digital piracy.[130] Instead the music industry survived by revising its business model.[131] Apple's iTunes was the first step in this direction, allowing consumers to purchase individual songs for one dollar.[132] More recently, online content subscription models, such as Spotify and Netflix, have successfully monetized file-sharing-esque, buffet-style online consumption of entertainment in the post-Napster era,[133] which has helped to offset some of the losses it sustains through piracy.[134]

Commentators believe that manufacturing may face the same fate as the music industry did when consumer 3D printing reaches a mainstream audience.[135] If so, manufacturers might seek to preempt piracy by either adapting their business model to contemporary technology or secure new legislation that might help stem the tide of piracy. Although the latter scenario is already unfolding, in

[127] *See, e.g.*, Capitol Records, Inc. v. Thomas-Rasset, 692 F.3d 899, 907 (8th Cir. 2012) (upholding the United States District Court for the District of Minnesota's grant of 9,250 per sound recording, amounting to $222,000 damages over 24 songs).

[128] Depoorter & Walker, *supra* note 125, at 333.

[129] *Id.* at 325-26.

[130] *See* Simon Crerar, *Illegal File Sharing As Popular As Ever,* THE TIMES ONLINE (Jan. 19, 2006, 12:00 AM), https://www.thetimes.co.uk/article/illegal-file-sharing-as-popular-as-ever-6z9xnfn0cp2 [https://perma.cc/B4UH-U44P]; *see also* James Titcomb, *Rise of Illegal Kodi Streaming Threatens Piracy Crackdown, Says Government Report*, THE TELEGRAPH (Jul 7, 2017), http://www.telegraph.co.uk/technology/2017/07/07/rise-illegal-kodi-streaming-threatens-piracy-crackdown-says/ [https://perma.cc/VK4J-562A].

[131] Brandon Griggs & Todd Leopold, *How iTunes Changed Music, and the World*, CNN (Apr. 26, 2013, 4:40 PM), https://www.cnn.com/2013/04/26/tech/web/itunes-10th-anniversary/index.html [https://perma.cc/VB8L-PV7W].

[132] *See* Ed Nash, Opinion, *How Steve Jobs Saved the Music Industry*, WALL ST. J., Oct. 21, 2011, at A15.

[133] *See* Ben Sisario, *Streaming Drives U.S. Music Sales Up 11% in 2016*, N.Y. TIMES (Mar. 30, 2017), https://www.nytimes.com/2017/03/30/business/media/digital-music-spotify-apple-record-labels.html [https://perma.cc/9GKL-YYB8].

[134] *Id.*; *see also* Mark Sweeney, *Film and TV Streaming and Downloads Overtake DVD Sales for the First Time*, THE GUARDIAN (Jan. 4, 2017), https://www.theguardian.com/media/2017/jan/05/film-and-tv-streaming-and-downloads-overtake-dvd-sales-for-first-time-netflix-amazon-uk [https://perma.cc/2MTX-3578].

[135] *See supra* Part II.A.

the next two Parts we argue that protective legislation may be unnecessary, as it is unlikely that manufacturing industries will face a "Napster scenario." We first focus on persistent technical complications that will continue to reduce the demand for and supply of 3D piracy (Part III). Next, we explain that the ways in which items of manufacture are consumed limit the potential scope of piracy thereof (Part IV). Overall, these insights provide caution against aggressive enforcement or regulation of consumer 3D technologies.

III. DON'T BE AFRAID OF 3D NAPSTER: THE SHORT RUN

In this Part, we argue that the music industry's losing-battle against Internet piracy does not foreshadow a similar tension with consumer uses of additive printing technologies. Several fundamental, but overlooked, differences between the supply and demand of items of manufacture and that of media make it unlikely that manufacturers will face a Napster-like scenario as a result of 3D printing.[136] Although 3D printing piracy, analogous to digital media piracy, will likely face infringement from numerous, decentralized, actors,[137] there are a number of important obstacles that will limit the overall scale and scope of 3D printing piracy.

As described above, 3D printing involves two steps: converting a physical object to a digital file, and subsequently using that digital file to create a physical embodiment thereof.[138] Unlike the process for digital media piracy, which arguably flourished because it is easy, both of 3D printing's steps are burdensome, decreasing the supply of, and thus the mainstream demand for, 3D pirated materials, especially where those materials are illicit.[139] Consequently, 3D piracy markets will never scale to levels that will present an existential crisis to manufacturers' operations.

A. Supply Side: Who Will Upload Blueprints?

Much of the difficulty plaguing the music industry in the file-sharing era has been a direct result of digital media piracy's decentralized nature.[140] Decentralized piracy, however, necessarily requires a substantial number of participating parties. In the absence of a widespread supply of pirated materials, the system breaks down.[141]

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[136] *See infra* Parts III.A-B.

[137] Depoorter, *supra* note 15, at 1496.

[138] *See supra* Part I.A.

[139] *See* Nick Allen, *Why 3D Printing Is Overhyped (I Should Know, I Do it for a Living)*, GIZMODO (May 17, 2013, 9:11 AM), http://gizmodo.com/why-3d-printing-is-overhyped-i-should-know-i-do-it-fo-508176750 [https://perma.cc/V4S7-TFJJ].

[140] *See supra* Part II.B.2.

[141] *See, e.g.*, Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd., 545 U.S. 913, 920 (*2005*) ("Since copies of a file . . . are available on many users' computers, file requests and retrievals may be faster than on other types of networks").

Given the significant legal risks involved, commentators have sought to explain why individuals shared infringing content through P2P networks.[142] One straightforward reason is that the copying and distribution of content was so seamless that many users simply forgot to remove the files that they had downloaded to their computer's publicly accessible folder.[143] Hence, much of the content available on P2P networks was merely a product of user oversight, rather than of a desire to "share" these works with the rest of the world.[144] This sort of oversight is possible in the media context since converting media content into a perfect digital copy is both simple and virtually free of cost.[145] This simplicity is in striking contrast to 3D printing piracy. Uploading any given 3D printable object's source file to the Internet requires a number of technical and time-intensive steps.

First, a user must create a digital model of the physical item to serve as a blueprint for printing.[146] This is no small task and requires substantial expertise and time, as 3D model makers must consider the physical characteristics of the object — such as weight, odor, and texture — as well as the chemical properties of that object's constituent materials.[147]

Moreover, the two primary methods of making such a model, reverse engineering and 3D scanning, are complex and costly.[148] Reverse engineering, for example, requires expertise in and use of complex, time intensive, CAD software.[149] Further, if the user hopes to do more than create a visual imitation of the object, they will need an understanding of each of the object's constituent parts as well as each of those parts' respective functionalities.[150] The 3D drawing must enable printing in three dimensions. More consumer-friendly 3D printing programs, such as Tinkercad, still require a certain level of expertise, yet do not

[142] *See, e.g.*, Yuval Feldman & Janice Nadler, *The Law and Norms of File Sharing*, 43 SAN DIEGO L. REV. 577, 605–12 (2006) (providing survey evidence on sharing norms in the context of P2P file-sharing); *see also* Daniel J. Gervais, *The Price of Social Norms: Towards a Liability Regime for File-Sharing*, 12 J. INTELL. PROP. L. 39, 51 (2004) (discussing social norms about online music sharing); Lior Jacob Strahilevitz, *Charismatic Code, Social Norms, and the Emergence of Cooperation on the File-Swapping Networks*, 89 VA. L. REV. 505, 549 (2003) (explaining how computer code fosters sharing norms).

[143] Lior, *supra* note 142, at 584-85.

[144] *Id.*

[145] *See id.* at 525, 542-43, 556, 584-85.

[146] *See supra* Part I.A.

[147] Allen, *supra* note 139.

[148] LIPSON & KURMAN, *supra* note 29, at 93, 95-96.

[149] *Id.* at 98-100.

[150] *See generally* Matej Paulic et al., *Reverse Engineering of Parts with Optical Scanning and Additive Manufacturing*, 69 PROCEDIA ENGINEERING 795 (2014) (discussing the process of reverse engineering an object for additive manufacturing purposes); *see also* Hod Lipson, *Is CAD Keeping up?*, 3D PRTG. & ADDITIVE MFG., 177 (2014) (discussing how additive manufacturing cannot yet address the complexity of a hip joint).

operate at a level of detail that produces realistic copies of existing, desirable commodities.[151]

3D scanning, on the other hand, does not require the same degree of design expertise.[152] That said, consumer-model 3D scanners produce less than perfect results.[153] Note that scanning, *i.e.* digitally representing an object, does not automatically equate to creating a 3D model that one can 3D print. While 3D scanners intended for consumer use are generally affordable,[154] it seems unlikely that would-be infringers would assume legal risk in order to produce a model that does not capture the exact essence of an intended object. While more precise professional models exist, they can cost tens of thousands of dollars and thus are not within the reach of many in the general public.[155]

A further bar to widespread consumer 3D scanning is its inability to captures anything beyond the surface of an object.[156] This limitation means that in essence, a pirate using 3D scanning technology is unable to produce working replicas of mechanical items without first tediously disassembling an item — which in its own right is not always possible — and scanning its components one-by-one.[157] Thus, even were a consumer to have access to a 3D scanner which would allow them to consistently make detailed 3D models of products' exteriors, the simple truth is that despite these advancements it remains impossible to conveniently scan objects consisting of multiple components so as to render them immediately ready to print.[158]

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[151] *See* LIPSON & KURMAN, *supra* note 29, at 98, 102-03.

[152] 3D-scanning works by capturing information from a number of data points, which when combined form a "point cloud" of the object. HORVATH, *supra* note 28, at 34. The scanner then digitally renders and converts the "point cloud" into a surface model or "surface mesh" of the object. *Id*.

[153] Bill Loguidice, *The pitfalls and potential of inexpensive 3D scanning solutions*, ARS TECHNICA (June 17, 2017,10:00 AM), https://arstechnica.com/gadgets/2017/06/reality-check-personal-3d-scanning-has-come-far-but-its-no-copy-machine-yet/ [https://perma.cc/4H2X-LQ9H] ("Generally, current consumer versions of 3D scanners produce decidedly modest results.").

[154] *Top 10 Best Low Cost 3D Scanners (2018 Update)*, 3D NATIVES (Nov. 30, 2017), https://www.3dnatives.com/en/top-10-low-cost-3d-scanners280320174/ [https://perma.cc/T6Y2-5BC7] (last visited Nov. 5, 2018) (listing a number of 3D scanners available for consumer purchase, which cost between $200 and $1,400).

[155] *See, e.g.*, Loguidice, *supra* note 153.

[156] REDWOOD ET AL., *supra* note 20, at 236; Allen, *supra* note 139.

[157] *See* Finnochiaro, *supra* note 78, at 492-93.

[158] For instance, the Einscan-SE, which is accurate down to less than 0.1 mm and costs around $1200-$1400, is an example of one such product that has reached the market. Frederik Bedrich, *EinScan-SE Review – Best Value 3D Scanner in 2018*, ALL3DP (Sept. 19, 2018), https://all3dp.com/1/einscan-se-3d-scanner-review/ [https://perma.cc/96WJ-WNE9]; *EinScan-SE*, SHINING 3D, https://www.einscan.com/ [http://perma.cc/2CRW-XNR6] (last visited Oct. 16, 2018).

It is thus highly questionable that we will see a steady flow of unauthorized 3D models on torrent sites and other Internet platforms. Where digital media piracy likewise relied upon a decentralized supply of illegal content, it flourished because of a number of factors — ranging from user's unwitting participation,[159] to ease of use and resentment toward "repressive" music industry responses to file-sharing[160] — all of which are notably absent 3D printing context.

In summary, the hurdles associated with creating a supply of infringing 3D printed content — significant investments of time, money, effort, and expertise — make it unlikely that like the music industry before it, manufacturers will face an endless, sheer unlimited inflow of illegal materials online.

B. Demand Side: Who Will Print Pirated Materials?

Once a music or movie file is available on file sharing networks, users can download and access the content therein with only the click of a mouse.[161] The consumption of physical objects, however, requires a second step: after obtaining the digital file, the user must also reverse the process and render a physical item from the digital file.

In the idealized version of the 3D printing popular-fantasy, this second step is flawless and easy. Consumers will print 3D objects as if they were printing a paper document on a standard home printer and thus their homes will be transformed into factories.[162] Given the enthusiastic narrative in media reports, one would be almost forgiven for expecting as much.[163] Nothing could be further from the truth, however. Even many of the most idealistic forecasts for 3D printing present a future with industrial applications involving expensive machines that are operated by trained professionals.[164] These spectacular industrial developments stand in strong contrast to the actual reality of consumer 3D printing today. The Napster analogy — whereby the general public, acting from the comfort of the home, engages in massive unaided, low-cost, and decentralized piracy — thus does not hold up in light of 3D printing's realities.

As Part II illustrates, 3D printing is by no means seamless from a technical perspective. For instance, in order to print a detailed object, a user must navigate

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[159] *See generally* Peter Yu, *P2P and the Future of Private Copying*, 76 U. COLO. L. REV. 653, 743 (2005) (P2P platform developers combated the problem by designing their software so that sharing was encouraged or even required in order to be able to download).

[160] *See supra* Parts II.A-B.

[161] If the user hopes to access the content on a mobile device, they need only take limited additional steps. *See, e.g.*, *Transfer music from a computer to your phone or tablet*, GOOGLE PLAY MUSIC, https://support.google.com/googleplaymusic/answer/1101500?hl=en [https://perma.cc/8WZG-4TQD] (last visited Jan. 16, 2019).

[162] *See* Weinberg, *supra* note 57.

[163] *See e.g.*, Pascal-Emmanuel Gobry, *THE NEXT TRILLION DOLLAR INDUSTRY: 3D Printing* (Feb. 25, 2011, 12:30 PM), https://www.businessinsider.com/3d-printing-2011-2 [https://perma.cc/5K4J-QWNL].

[164] Allen, *supra* note 139.

and calibrate the slicer software settings; understanding and considering technical matters such as retraction, build speed, layer height, infill, and filament.[165] When done correctly, these settings often yield products which still require some form of manual processing. Importantly, as 3D printing combines multiple inputs, including mechanics, electronics, software, filament, and 3D models, its output is only as strong as the weakest such input — making failed printouts a real possibility.[166]

Even the more expensive consumer-friendly 3D printers[167] remain limited in their potential, in large part as a result of their use of FFF technology.[168] The FFF printing process operates by extruding molten material in a manner not dissimilar to a glue gun.[169] As a result, FFF only supports printing in thermoplastic materials,[170] which comes with associated disadvantages such a heightened susceptibility to warping or distortion.[171] Moreover, this "glue gun" method entails pressing layer upon layer to create adhesion of the material.[172] This in turn implies two things. First, as extruded filament needs to bond with previously printed layers, the strength of a printed object is premised on a user's having accurately calibrated the printer's settings so as to ensure adhesion.[173] Second, it is not possible to print freely in height and width; if an existing layer cannot support the subsequent one, the use of support structures is required.[174] Two

[165] HORVATH, *supra* note 28, at 63, 183-88. See LIPSON & KURMAN, *supra* note 29, at 81.

[166] *See e.g.*, Jessica Leber, *What Yoda Taught Me About 3-D Printing*, MIT TECH. REV.: BUS. REPORT (Jan. 7, 2013), www.technologyreview.com/news/509286/what-yoda-taught-me-about-3-d-printing/ [https://perma.cc/QG6D-VJD5]; *see also* HORVATH, *supra* note 28, at 137-47.

[167] *See, e.g.*, ULTIMAKER 3, https://ultimaker.com/en/products/ultimaker-3 [https://perma.cc/5XJM-9WSK] (advertising the Ultimaker 3 printer as "[p]rofessional 3D printing made accessible" and listing it at a price of $3495).

[168] *See supra* text accompanying notes 39-44. An exception in the high-end consumer range is the Form 2 printer by Formlabs which prints using Vat Polymerization (SLA), FORMLABS, https://formlabs.com/3d-printers/form-2/ [https://perma.cc/MW35-9FGY] (last visited Feb. 18, 2019).

[169] *See* Leber *supra* note, 166.

[170] HORVATH, *supra* note 28, at 79-84. Consumer 3D printers tend to use durable plastics such as PLA and ABS, with some permitting plastic hybrids or variations so as to accomplish different aesthetic results. *See* Ken Giang, *PLA vs. ABS: What's the difference?, https://www.3dhubs.com/knowledge-base/pla-vs-abs-whats-difference* [https://perma.cc/Y2N5-SG29] (last visited Nov. 9, 2018); *How to Print With woodFill Filament,* COLORFABB (Nov. 29, 2013), https://learn.colorfabb.com/how-to-print-with-woodfill/ [https://perma.cc/DW3U-VMMP] (describing the use of "woodFill filament," which combines PLA and wood fiber to create 3D printed products with some of the visual characteristics of wood).

[171] REDWOOD ET AL., *supra* note 20, at 29-30.

[172] *Id*. at 30.

[173] *Id*. at 165-67.

[174] *Id*. at 30-33, 158-65.

additional limitations relate to building volume and speed. The process limits the size of the objects an FFF 3D printer can produce,[175] rendering contemporary consumer 3D printers unable to print even small items such as cabinet planks and shoes, as well as the speed at which they can produce those objects.[176]

Finally, FFF relies on print heads to extrude filament onto the print bed.[177] Thus the number of print heads — some employing one, with others using two — determines the amount of material[178] and, in many instances, the variety of colors that the printer can print.[179] As most, if not all, objects that we use on a daily basis consist of a combination of materials and moving parts,[180] FFF's inability to simultaneously utilize various materials means that in order to print even the most basic of everyday objects,[181] a user would have to print in multiple stages and assemble all spare parts into one object afterwards.[182]

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[175] HORVATH, *supra* note 28, at 131. *See also* Leber, *supra* note 166 ("The big drawback for consumers is that 3-D printers are still tricky to use and very limited in what they can make. The objects they produce are not just fairly crude but quite small, since the thermoplastic will warp at larger sizes."). Even if they could print at a rate sufficient to make printing large items feasible, consumer 3D printers offer, on average, a mere 200mm by 200mm by 200mm of building volume. REDWOOD ET AL., *supra* note 20, at 29.

[176] Additionally, most consumer printers are rather slow.Speeds vary greatly across printers.Note that advertised print speeds should be taken with a grain of salt. The actual speed will depend on the resolution selected by the user. Printing thinner layers increases the resolution, but slows down the print process. Failed printouts also increase the time to print of course. As discussed in Part II, when a 3D model file is faulty, this will result in failed prints. *See e.g.*, HORVATH, *supra* note 28, at 45-46; Allen, *supra* note 139; Petrick & Simpson, *supra* note 66, at 1, 2.

[177] *See, e.g.*, Perry Cain, *Supports in 3D Printing: A technology overview,* 3D HUBS, https://www.3dhubs.com/knowledge-base/supports-3d-printing-technology-overview [https://perma.cc/36L6-V7GH] (last visited Nov. 11, 2018).

[178] As the second print head is often used to print an object's support structure, a printer can often only handle a single material. *See id.* ("on finely tuned printers with two print heads, the support material can be printed with a dissolvable material that . . . does not affect the main material of the printed model.").

[179] Progress might be lurking around the corner. *See* Lav Radis, *The Palette Filament Feeding System*, 3DPRINTING.COM (Apr. 24, 2015), http://3dprinting.com/news/the-palette-filament-feeding-system/ [https://perma.cc/KV56-3A96].

[180] *See* Melba Kurman & Hod Lipson, *Why You Shouldn't Worry About 3D-Printed Piracy*, POPULAR MECHANICS (May 30, 2014), www.popularmechanics.com/technology/gadgets/a10687/why-you-shouldnt-worry-about-3d-printed-piracy-16841445/ [https://perma.cc/8K92-P8BU]; Michael Copeland, *Why 3-D Printing Won't Turn Your Home Into a Factory*, WIRED (Mar. 21, 2013, 9:30 AM), www.wired.com/2013/03/ideas-not-dinner-plates-are-the-future-of-3-d-printing/ [https://perma.cc/Y9XV-X2T9].

[181] Dave Johnson, *3D Printing: Don't Believe the Hype*, CBS NEWS: MONEYWATCH (June 21, 2013, 3:28 PM), www.cbsnews.com/news/3d-printing-don't-believe-the-hype/ [https://perma.cc/S8T4-KUCT].

[182] *Id.*

Of course, consumers might want to avoid these complications and rely on professional 3D printing services instead. As is the case with 3D scanning services, this increases the costs of 3D printing and undermines the decentralized structure that makes piracy so difficulty to combat.[183]

In sum, the 3D printing process is not seamless. Incidental to the process employed by most contemporary consumer 3D printers, printing involves plastic materials that are susceptible to warping, require support structures and carefully calibrated layer adhesion, and can generally only print relatively small items at slow speeds. Moreover, even if different types of plastic are available, the printer can usually use only one type of plastic per object, meaning that users must print objects consisting of different materials in multiple stages, and thereafter assemble those objects manually.[184] Undertaking such a process will not be appealing to many, especially given that the finished products are likely to be of lower quality than the original.[185]

C. The Limited Potential for 3D Scan and Print Services

Concerns that would-be infringers will obviate the limitations of consumer 3D printing equipment by resorting to commercial intermediaries is likewise misplaced.[186] While 3D scanning and printing services often employ high-quality equipment, and thus can produce high-quality 3D outputs,[187] individuals will find that persuading intermediaries to assume the precarious legal position of engaging in, or assisting with, potential intellectual property infringement is no easy task. The intermediary likewise faces liability for reproducing the object without permission.[188] Intermediaries that produce and distribute physical items from static locations are a more convenient target for enforcement actions than individual online infringers — rendering them especially vulnerable to becoming the scapegoat for 3D printing piracy writ-large. This level of vulnerability, along with the risk it brings to the significant capital investments in equipment and distribution that the intermediary will have necessarily made, will deter 3D service providers from either engaging in or ignoring intellectual right

[183] *See supra* note 35 and accompanying text.

[184] Additionally, users must manually remove the support structures required for printing objects with overhanging shapes. *See supra* notes 31, 35 and accompanying text.

[185] *See* Part II.B.

[186] Finnochiaro, *supra* note 78, at 499.

[187] *See supra* notes 118, 126 and accompanying text.

[188] Where the intermediary actually undertook the act of scanning or printing the item, rights-holders might claim, for example, that in duplicating the item without authorization, the intermediary infringed their copyright, patent, and/or trademark rights in the item. Tabrez Y. Ebrahim, *3D Printing: Digital Infringement & Digital Regulation*, 14 NW. J. TECH. & INTELL. PROP. 37, 49 (2016). Were the consumer to merely use the intermediary's equipment, intellectual property right holders can turn to doctrines of intermediary liability, specifically contributory and vicarious liability, to enforce their intellectual property rights against 3D printing shops. *See id.* at 57.

violations.[189] Thus, commercial 3D services can be expected to take care not to provide services where so doing would involve unauthorized 3D scanning or printing.

Indeed, the policies of existing 3D printing service providers reflect an acute awareness of the risk of intellectual property infringement.[190] For instance, i.materialise, an online 3D printing platform, stipulates in its terms and conditions that (1) anyone placing an order must ensure the order does not infringe third-party intellectual property rights; (2) it may refuse orders which infringe third-party intellectual property rights; and (3) the user is liable for any damage resulting from infringing orders.[191] i.materialise also encourages rights-holders to contact the service when they believe someone has used the service to violate their rights.[192]

Even if available, the use of intermediaries will be an unattractive proposition for most would-be pirates. First, when consumers place an order with a 3D service provider, they to some degree forfeit the anonymity and safety associated with infringement from the home.[193] Second, in the case of intermediaries providing 3D print services, the intermediary merely produces the object, not the 3D model that the object embodies. As a result, the service provider will produce a finished product with any flaws that might accompany the model in question, regardless of whether the intermediary employs high-quality equipment.[194] Unlike source-files in the context of digital media piracy, which likewise faced similar unreliability,[195] 3D printing requires a substantial investment

[189] *See, e.g.,* Marcus Thymian, *Evaluating IP Infringement Risks for Designers and Consumers of 3D Printing Services*, TECHCRUNCH (Nov. 15, 2016), https://techcrunch.com/2016/11/15/evaluating-ip-infringement-risks-for-designers-and-consumers-of-3d-printing-services/ [https://perma.cc/2ECE-YKB8].

[190] *See, e.g.*, *Terms and Conditions*, I.MATERIALISE, http://i.materialise.com/legal/terms#intellectual [https://perma.cc/8MP6-XTB5] (last visited Oct. 8, 2018).

[191] *Id.* ("If the design you submit to Materialise risks infringing the intellectual property rights of third parties, Materialise reserves the right to either not produce the design or produce the design without the part that risks infringing the rights of third parties. Should your user generated content nevertheless be found to be infringing and/or in violation of any law, you will defend i.materialise against third party claims, and be held liable for all [direct and indirect] damages and costs incurred by i.materialise with respect to such claims.").

[192] *Id.* ("i.materialise encourages intellectual property rights owners to contact i.materialise if they believe that a user of the i.materialise service has infringed their rights.").

[193] *See* Finocchiaro, *supra* note 78, at 501-02.

[194] *See* LIPSON & KURMAN, *supra* note 29, at 77-79. Professional intermediaries can be employed to check and correct CAD design at a service charge. Of course, such services increase the costs of piracy to the consumer and the intermediary subject itself to potential intellectual property violations.

[195] Mindi McDowell, Brent Wrisley, & Will Dormann, U.S. Comput. Emergency Readiness Team, Security Tip (ST05-007), *Risks of File-Sharing Technology*, DEP'T HOMELAND SEC'Y (Oct. 1, 2016), https://www.us-cert.gov/ncas/tips/ST05-007 [https://perma.cc/A93F-Y43J].

in time and money. As a result, the potential unreliability of 3D printed products embodying unauthorized CAD files is likely to reduce demand for intermediary services employing such files.

That negative incentive is even more acute given that 3D printing services may be more expensive and time consuming than would a user's buying the actual product from the official distributor. Due to the large scale of production, traditional manufacturers are able to sell at low prices[196] — which might even be lower than the cost of employing at 3D printing service. A simple example: printing a vase. Using a traditional manufacturing process, the manufacturer incurs a fixed cost of $100 and a variable cost of $4 per unit. Thus, the cost of producing a single vase is $104. The consumer can also purchase the vase from a 3D printing service. This requires a fee of $15 for each vase. At first sight, the vase from the 3D printing service seems cheaper: it costs $15 and the manufacturer's vase costs $104. However, as soon as the manufacturer makes 10 vases, the price drops to $14 per vase.[197] Due to the increased production, the vase from the 3D print service is no cheaper. The manufacturer can benefit from the economies of scale in ways that are not available to the 3D printing service.[198]

To conclude, although 3D printers will become more affordable and increasingly user-friendly, 3D printing for the masses is far on the horizon. Even more so, the *piracy* of physical objects is not an appealing proposition to mainstream consumers today given 3D printing's significant technological limitations. In the next Part, we consider a future world in which technological progress has enabled effortless consumer 3D printing.

IV. DON'T BE AFRAID OF 3D NAPSTER: THE LONG RUN

The 3D printing market seems to be developing via 3D printing services, as opposed to home 3D printers.[199] Parts II and III above show that 3D printing technologies — from the modeling through printing processes — are sufficiently complicated to cast doubt on the notion that consumers will ever be able to print physical items from home, at no cost, with just a push of a button.[200] This might pose an insurmountable bar to a "3D Napster" scenario.[201] Even if individuals

[196] *See* Ian Whadcock, *A Third Industrial Revolution*, THE ECONOMIST (Apr. 21, 2012), www.economist.com/node/21552901 [https://perma.cc/YP88-RRDQ]; Irene J. Petrick & Timothy W. Simpson, *3D Printing Disrupts Manufacturing: How Economies of One Create New Rules of Competition*, 56 RES.-TECH. MGMT. 12, 12 (2013).

[197] This calculation is as follows: adding the fixed cost — $100 — to the variable cost — $40 — and dividing the total by 10 units yields a per-unit cost of $14.

[198] *See generally* ANDERSON, *supra* note 3, at 87 (describing the economies of scale).

[199] *See* Leber, *supra* note 166.

[200] *See* Finnochiaro, *supra* note 78, at 507; *see also* Copeland, *supra* note 180.

[201] *See* Gilpin, *supra* note 81. The CEO of Shapeways, one of the world's largest online marketplaces and 3D print service providers, foresees future use of consumer 3D printers as limited to small, last minute projects, in contrast to industrial 3D printers, which will serve to facilitate larger projects. *See* Signe Brewster, *The future of consumer 3D printing: What's*

are able to resort to intermediaries in order to print an item, they will only be able to do so if 3D models are available, but those models will only become available once there is a sufficient market for them — *i.e.*, once 3D printing gains general consumer acceptance. As such, in order for 3D printing to proliferate on the Internet, all elements of 3D technologies must evolve, not merely the printers.[202]

Due to the complexity of 3D technologies and the required degree of user-friendliness, consumer 3D printing may never fully come to replace all segments of traditional manufacturing. By way of analogy, professional photography printing services continue to offer a qualitatively superior alternative to most high-quality home printing.[203] While many good quality home photo printers are commercially available,[204] few affordable versions of such printers produce high-quality printouts, and technological advances over the past few decades have done little to accommodate large-format photography printing.[205] This might be telling for the future of 3D printing of physical objects. Three-dimensional objects are far more complex than two-dimensional photographs. As a result, they are more likely to face these limitations. If 3D printing ever becomes a mainstream home application, this evolution will likely be gradual and may never reach the seamless nature that facilitated the massive piracy of digital music since Napster.[206]

Yet, even if technical advances eventually bring about seamless 3D digitization and printing for the public, various other obstacles stand in the way of the emergence of a 3D-Napster scenario for manufacturing. Napster's creative destruction of the music industry was the product of a number of surrounding

real, what's coming, and what's hype, GIGAOM (Oct. 2, 2013, 5:00 AM), https://gigaom.com/2013/10/02/the-future-of-consumer-3d-printing-whats-real-whats-coming-and-whats-hype/ [https://perma.cc/KG2F-BV49]. Carl Bass, the former CEO of the largest manufacturer of 3D modeling software, claims that it is very unlikely that the mainstream public will own 3D printers. Lyndsey Gilpin, *Autodesk CEO "Debunks the Hype" on 3D Printing, Says Industrial 3D Printing is the Real Revolution*, TECHREPUBLIC (Apr. 4, 2014, 7:37 AM), https://www.techrepublic.com/article/autodesk-ceo-debunks-the-hype-on-3d-printing-says-industrial-3d-p-autodesk-the-largest-producer-of-3d-modeling-software-says-improvements-in-software-machinery-and-material-science-are-driving-an-exci/ [https://perma.cc/E4XM-3XSG].

[202] *See* Finnochiaro, *supra* note 78, at 490.

[203] *See* Storch, *supra* note 93, at 307-08 ("[T]he photos printed on a home photo printer were never quite the quality of those published at commercial facilities.").

[204] *See, e.g.*, Tony Hoffman, *The Best Photo Printers for 2019*, PC MAG (Dec. 21, 2018, 2:37PM), https://www.pcmag.com/article2/0,2817,1872566,00.asp [https://perma.cc/FL7C-QJRQ].

[205] *See* Storch, *supra* note 93, at 307-08.

[206] *See* Bradshaw et al., *supra* note 3, at 31; Storch, *supra* note 93, at 305. *See also* Copeland, *supra* note 180 (statement of Mark Hatch, CEO of Techshop: "It's been a gradual improvement over the last 20 years, and will continue to be gradual.").

circumstances that are absent with regard to 3D printing.[207] First, music and film are different from physical objects in ways that impact the demand for and supply of pirated goods. Second, the response from the music industry was a catalyst that helped fuel the fire of piracy online. The circumstances surrounding 3D printing today are completely different. The manufacturing industry may be able to learn from the mistakes of the music industry and avert many of the most harmful effects of piracy.

A. Physical Objects are Different

Physical objects, on the one hand, and information goods, on the other hand, are different in ways that influence piracy. First, music and audiovisual content have strong social network effects.[208] People enjoy the shared experience of watching the same movies and listening to the same music. As a result, the demand for entertainment content is rather concentrated. Markets for entertainment content are often described as having "winner takes all" characteristics.[209] This concentrated demand for entertainment content enables digital pirate markets to focus more narrowly and effectively on providing widespread access to the most desirable content. For example, in 2014 HBO's highly-popular program, *Game of Thrones*, was the most illegally downloaded television series for a third year in a row.[210] In contrast, markets for physical goods are, as a whole, less concentrated. Although trends may emerge that create some concentration in physical goods, the intensity of demand is structurally different from the concentration in entertainment content markets. Digital media piracy involves a fixed number of industries — audiovisual and audio content – whereas 3D printing piracy theoretically reaches into nearly all other consumer industries (*e.g.*, clothing, shoes, jewelry, decoration, arts & crafts, collectibles, household & kitchen items, tools, sports & outdoor equipment, travel equipment, general

[207] *See infra* Part IV.

[208] *See* Rajiv K. Sinha, Fernando S. Machado & Collin Sellman, *Don't Think Twice, It's All Right: Music Piracy and Pricing in a DRM-Free Environment*, 74 J. MKTG. 40, 42 (2010) (describing "social network effects" on consumer demand, *i.e.*, "the [non-utilitarian] value of possessing products resides . . . in their importance in forming social relationships and their role in expressing the sense of self.").

[209] *See*, *e.g.*, WILLIAM LANDES & RICHARD POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY 61-62, 62 n.36 (2003); DEREK THOMPSON, HIT MAKERS: HOW TO SUCCEED IN AN AGE OF DISTRACTION 233-35 (2017).

[210] Sam Frizell, *Game of Thrones Was the Most Pirated TV Show of 2014*, TIME (Dec. 26, 2014), http://time.com/3647612/game-of-thrones-downloads/ [https://perma.cc/2M5L-Q5E6]; Joanna Robinson, Game of Thrones *Is Even More Insanely Popular than You Think*, VANITY FAIR (July 19, 2016, 5:57 PM), https://www.vanityfair.com/hollywood/2016/07/game-of-thrones-most-popular-show-ratings [https://perma.cc/X7NW-A2AG] ("Deadline reports that when accounting for repeat airings, DVR, HBO Go, HBO Now, and HBO on Demand together, Game of Thrones averaged an insane 25.1 million viewers for its sixth season. And that's not even counting the record-breaking number of people who watched the season illegally through online torrents.").

accessories, toys, etc.).[211] Quantitatively, compared to the vast landscape of physical goods, demand for entertainment content is more concentrated also due to the fewer amount of industries and products.[212] Additionally, despite the wide diversity of entertainment content, consumer demand is condensed within a limited set of segments (for instance, Top 50 most played pop music). By contrast, the demand for physical goods is spread across a vast amount of categories and subcategories of physical goods — even within, for instance, clothing or jewelry industries. Given the further categorization and subcategorization required to make any meaningful claims about popularity of certain individual items, it is less likely that consumers will as easily find a blueprint for each and every product they are looking for; at least not in the way that the Napster file-sharing system contained almost every song released on major record labels. In the absence of such concentrated demand, downloaders may face high search costs or simply will not be able to find online pirated versions of the 3D models they are looking for.

A second important difference is that media files are digital, and as such, only take up as much physical space as the machines they are stored on;[213] regardless of whether users watch, copy, or store 5 media files or 500 media files. Material objects, on the other hand, are different. They take up space as a result of their three-dimensional, physical nature. Housing large quantities of physical items, therefore, is not a viable option for most individuals. Given the limits on an

[211] *See supra* note 5 and accompanying text.

[212] As an illustration, consider the following: as of January 10th, 2018, Amazon carried 562,382,292 products. *How Many Products Does Amazon Sell? – January 2018*, SCRAPEHERO (Jan. 11, 2018), https://www.scrapehero.com/many-products-amazon-sell-january-2018/ [https://perma.cc/DB6G-AD38]. In contrast, Apple Music and Spotify have catalogs which include approximately 40,000,000 and 30,000,000 songs, respectively. Parker Hall, *Apple Music vs. Spotify*, DIGITAL TRENDS (Feb. 5, 2019, 11:19 AM), https://www.digitaltrends.com/music/apple-music-vs-spotify/ [https://perma.cc/EL8K-J97G]. Likewise, Netflix carries less than 6,000 individual titles. Travis Clark, *New data shows Netflix's number of movies has gone down by thousands of titles since 2010 — but its TV catalog size has soared*, BUS. INSIDER (Feb. 20, 2018, 3:03 PM), https://www.businessinsider.com/netflix-movie-catalog-size-has-gone-down-since-2010-2018-2 [https://perma.cc/MHP3-FZX7].

[213] Even then, each file is only a portion of the total utility of that space. Moreover, some digital media piracy take the form of online streaming, meaning that at least one party to some piracy never needs to permanently store the pirated media at all. *See* Shigenori Matsui, *Does It Have to Be a Copyright Infringement: Live Game Streaming and Copyright*, 24 TEX. INTELL. PROP. L.J. 215, 219 (2016) (discussing media streaming and its role in digital media piracy); PC Plus, *How internet video streaming works*, TECHRADAR (Sept. 16, 2012), https://www.techradar.com/news/internet/how-internet-video-streaming-works-1095211 [https://perma.cc/SS9H-L98M] (explaining that online streaming primarily takes two forms: "pseudo-streaming" by which the user views the contents of a file as it is downloading, after which the file automatically deletes and "real streaming," by which the user consumes the media via a "data-buffering viewer (all data is kept in memory), with no file being saved on disk.").

individual's ability to store physical items, more is not always better. This further reduces both the supply of, and demand for, pirated 3D objects.

Third, while the digital nature of music and movie content reduces the degree to which piracy is perceived as "stealing,"[214] research suggest that moral reservations about physical piracy are stronger. For instance, experiments show that individuals are willing to pay more for printed materials than their digital counterparts; even if both options are available at no cost.[215]

Fourth, 3D printing pirates will always at least incur the cost of the constituent materials of the object that is being printed,[216] which is particularly problematic given the potential imprecision attendant to use of unlawful CAD files.[217] In this regard, consumer quality assurances and customer services provide licensed 3D printing services an advantage over pirating.

These differences cast doubt on the 3D Napster prophesy, even in the advent of continued technological advances.

B. Napster Was Fueled by Enforcement Backlash

Confronted with the vast amount of copyright infringement on P2P networks, copyright holders started an aggressive enforcement campaign in 2003. The Recording Industry Association of America (RIAA) began sending subpoenas to Internet service providers, demanding the names of individuals who were allegedly sharing music on P2P networks[218] which they would then use to file over 3,400 lawsuits — primarily targeting those who stored large amounts of music

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[214] *See* Amanda Lenhart & Susannah Fox, *Downloading Free Music: Internet Music Lovers Don't Think It's Stealing*, PEW RES. CTR. (Sept. 28, 2000), http://www.pewinternet.org/2000/09/28/downloading-free-music/ [https://perma.cc/4BBD-RC7S] ("[O]f those in the general Internet population . . . 53% say downloading music is not stealing, compared to 31% who believe it is stealing."); Twila Wingrove, Angela L. Korpas & Victoria Weisz, *Why were millions of people not obeying the law? Motivational influences on non-compliance with the law in the case of music piracy*, 17 PSYCHOL., CRIME & L. 261, 271-72 (reporting that study participants were less apt to feel compelled to follow the law in light of four factors — deterrence, social influence, personal morality, and legal obligation — in relation to downloading and sharing music than they were in relation to shoplifting a CD).

[215] *See* Luuk Koelman, *Piraterij uitdaging voor de boekenbranche* [Piracy challenge for the book industry], WEBWERELD (Feb. 9, 2012) (Neth.), https://webwereld.nl/security/868-piraterij-uitdaging-voor-de-boekenbranche-column [https://perma.cc/F53T-BRPX] (reporting that where individuals were given the opportunity to purchase an e-book and the corresponding print version thereof on a voluntary basis, substantially less individuals paid for the e-book than did for the physical book).

[216] Mendis, *supra* note 61, at 168.

[217] *See supra* notes 194-195 and accompanying text.

[218] Paul Roberts, *RIAA Sues 532 'John Does'*, PC WORLD (Jan. 21, 2004), http://www.pcworld.com/article/114387/article.html [https://perma.cc/QD66-MATG].

files in publicly accessible folders.[219] The movie industry joined the fray[220] and initiated five rounds of lawsuits against individual file sharers.[221] At least 18,000 individuals received threatening letters from the music and movie industries,[222] with some facing hundreds of thousands of dollars in statutory damages.[223]

This enforcement campaign also involved a number of awkward public relations incidents. For instance, media outlets once reported that content industries had accused a twelve-year-old girl in New York of copyright infringement, despite the fact that her mother lived in low-income housing run by the New York City Housing Authority.[224] On another occasion, an eighty-three-year-old woman, who had died over a month earlier, also faced accusations of copyright infringement.[225]

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[219] *RIAA v. The People: Five Years Later*, ELECTRONIC FRONTIER FOUND. (Sept. 30, 2008), https://www.eff.org/wp/riaa-v-people-five-years-later [https://perma.cc/94UH-EGFL].

[220] The movie industry decided to no longer sit back in 2004 as a result of an increase in the number of motion pictures exchanged over P2P networks. Grant Gross, *MPAA to Sue Movie File Swappers*, PCWORLD (Nov. 4, 2004), https://www.pcworld.com/article/118485/article.html [https://perma.cc/4FAX-MCMD]. The spike in piracy was mainly due to increased broadband width and improved compression technologies. *Id*. For a further report of this moment in history, *see* Bary Alyssa Johnson, *MPAA Anti-Piracy Lawsuits Target Individuals*, PCMAG (Aug. 29, 2005, 4:32 EST), https://www.pcmag.com/article2/0,2817,1853573,00.asp.

[221] *See* Thomas Mennecke, *MPAA Launches New Round of Lawsuits*, SLYCK (June 3, 2005), http://www.slyck.com/story816_MPAA_Launches_New_Round_of_Lawsuits [https://perma.cc/49U3-J68K].

[222] Nate Anderson, *Has the RIAA sued 18,000 people… or 35,000?*, ARS TECHNICA (Jul. 8, 2009), https://arstechnica.com/tech-policy/2009/07/has-the-riaa-sued-18000-people-or-35000/ [https://perma.cc/DAY8-SQGS].

[223] *See* Capitol Records, Inc. et al v. Thomas-Rasset, 692 F.3d 899, 902 (8th Cir. 2012) (reinstating an order mandating that defendant who shared twenty-four songs online pay $222,000 in statutory damages after two prior jury trials had set willful statutory damages at $1.92 million and $1.5 million, respectively); Sony BMG Music Entm't v. Tenenbaum, 660 F.3d 487, 490 (1st Cir. 2011) (levying $675,000 in statutory damages against a defendant who had shared thirty songs). For further discussions of both cases, see Dave Itzkoff, *Student Fined $675,000 in Downloading Case*, N.Y. TIMES (July 31, 2009), https://www.nytimes.com/2009/08/01/arts/music/01arts-GRADUATESTUD_BRF.html [https://perma.cc/MUF2-5UCV]; David Kravetz, *Jury in RIAA Trial Slaps $2 Million Fine on Jammie Thomas*, WIRED (June 18, 2009), http://www.wired.com/2009/06/riaa-jury-slaps-2-million-fine-on-jammie-thomas/ [http://perma.cc/XE8F-RU4E].

[224] *See* John Borland, *RIAA Settles with 12-Year-Old Girl*, CNET (Sept. 9, 2003), https://www.cnet.com/news/riaa-settles-with-12-year-old-girl/ [http://perma.cc/N88M-SDEV].

[225] Andrew Orlowski, *RIAA Sues the Dead*, THE REGISTER (Feb. 5, 2005), http://www.theregister.co.uk/2005/02/05/riaa_sues_the_dead/ [http://perma.cc/KL9Z-BTY4].

Critics condemned content industry's having sought grossly excessive statutory damage awards[226] and decried the extortionary nature of the RIAA settlement letters.[227] Along the way, the music industry lost public support and the public lost respect for copyright law.[228] This is all to say that the aggressive approach to copyright enforcement helped to fuel a backlash against the music industry and copyright ownership in digital media more generally.[229] The negative reaction to aggressive enforcement, especially among young individuals, may have increased resistance to copyright law and encouraged file-sharing and countermeasures to prevent detection, including the use of VPNs.

The music and movie industries have since abandoned these aggressive approaches to copyright enforcement and instead embracing the novel technologies and business models that iTunes, Netflix, Spotify, Amazon Prime, and the like embody, which has proven to be effective.[230] If manufacturing industries avoid the mistakes made by the music industry, they should be able to prevent a 3D Napster revolution.

V. HOW TO PREVENT POLICY OVERREACH

As new applications of 3D printing continue to evolve, stakeholders have become increasingly nervous about emerging applications of 3D printing. Regulatory action is on the horizon. In the United States, focus is on 3D applications that involve the manufacture of guns and counterfeit pharmaceutical products.[231]

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[226] *See* Cam Barker, *Grossly Excessive Penalties in the Battle Against Illegal File-Sharing*, 83 TEX. L. REV. 525, 526-27 (2004); Kate Cross, *David v. Goliath: How the Record Industry is Winning Substantial Judgments Against Individuals for Illegally Downloading Music*, 42 TEX. TECH L. REV. 1031, 1038 (2010) ("If one song on iTunes costs ninety-nine cents to purchase, then a judgment awarding $80,000 for one song is not only grossly disproportionate but 'obviously unreasonable by any measure.'"); Pamela Samuelson & Ben Sheffner, *Unconstitutionally Excessive Statutory Damages Awards in Copyright Cases*, 158 U. PA. L. REV. PENNUMBRA 53, 56-67 (2009).

[227] *See, e.g.*, Nash *supra* note 132. *See also* Daniel Reynolds, *The RIAA Litigation War on File Sharing and Alternatives More Compatible with Public Morality*, 9 MINN. J. L. & TECH. 977 (2008) ("One of the RIAA's essential problems is that its business model is stuck in the past: the recording industry is trying to force a potentially inconvenient purchase of products that can be conveniently obtained for free online.").

[228] *See, e.g.*, Menell, *supra* note 101, at 241-69 (examining how to improve copyright's "public approval rating").

[229] Depoorter et. al., *supra* note 103, at 1284-87.

[230] *See supra* note 130 and accompanying text.

[231] Undetectable Firearms Modernization Act of 2015, H.R. 2699, 114th Cong. (2015); Andy Greenberg, *Feds Tighten Restrictions on 3-D Printed Gun Files Online*, WIRED (Jun. 11, 2015, 11:05 AM), https://www.wired.com/2015/06/feds-restrict-3d-printed-gun-files/ [https://perma.cc/5F2B-TEPJ]; Kelsey Wilbanks & Armani Vadiee, *Beyond Prototyping: 3d Printing in Government Contracts*, THE PROCUREMENT LAW., Winter 2017, at 1, 15; Cyrus Farivar, *Court: With 3d Printer Gun Files, National Security Interest Trumps Free Speech*,

In the European Union, concerns about intellectual property rights have prompted several impending 3D printing policies.[232] Proposals include restricting the scope of protections against liability for private and non-commercial use, the addition of indirect third party design infringements, the imposition of additional remedies for intermediary liability resulting from the sanctioning or authorizing of design infringements, and the expansion of the definition of infringement to include the unauthorized creation of a design document.[233] These proposals for additional liabilities seek to limit 3D printing's potential impact on manufacturers' abilities to exploit their designs.[234] Some in the United States manufacturing industry are expressing similar concerns regarding intellectual property infringement.[235] As Parts III and IV describe, concerns with massive decentralized intellectual property infringements are likely misplaced.

Intellectual property rights-holders have a long history of overreacting to new technologies, with rights-holders repeatedly claiming that innovation presents an imminent threat to their existence.[236] Historic examples include painters concerns regarding photography,[237] performance artists concerns regarding gramophone records,[238] the gramophone record industry's concern regarding radio,[239]

ARS TECHNICA (Sept. 21 2016, 2:52 PM), https://arstechnica.com/tech-policy/2016/09/court-groups-3d-printer-gun-files-must-stay-offline-for-now/ [https://perma.cc/93QZ-DK8A].

[232] *See generally*, Vincent Duchêne et al., Exec. Agency for Small & Medium-sized Enter., European Comm'n, *Report on 3D-printing: Current and Future Application Areas, Existing Industrial Value Chains and Missing Competences in the EU* (July 15, 2016), http://ec.europa.eu/growth/content/report-3d-printing-current-and-future-application-areas-existing-industrial-value-chains-0_en [https://perma.cc/M43C-25QL].

[233] Jos Dumortier et al., Exec. Agency for Small & Medium-sized Enter., European Comm'n, *Legal Review on Industrial Design Protection in Europe*, 128-34 MARKT2014/083/D (Apr. 15, 2016), http://ec.europa.eu/growth/content/legal-review-industrial-design-protection-europe-0_en [https://perma.cc/MFM2-U27P].

[234] *Id*.

[235] *See generally*, PWC, 3D PRINTING COMES OF AGE IN US INDUSTRIAL MANUFACTURING (2016), https://www.pwc.com/us/en/industrial-products/publications/assets/pwc-next-manufacturing-3d-printing-comes-of-age.pdf [https://perma.cc/JC7J-YTB8].

[236] *See* Mark Lemley, *Is the Sky Falling on the Content Industries?*, 9 J. ON TELECOMM. & HIGH TECH. L. 125, 125-32 (2011).

[237] *Id* at 125-26; STEPHEN BANN, PAUL DELAROCHE: HISTORY PAINTED 9 (1997) (reporting that upon seeing a work of photography for the first time, Painter Paul Delaroche reportedly exclaimed "from today painting is dead.").

[238] John Philip Sousa, *The Menace of Mechanical Music*, 8 APPLETON'S MAG. 278, 278 (1906).

[239] Lemley, *supra* note 236, at 127.

broadcast stations' concern regarding cable television,[240] and television's concern regarding the advent of VCR and DVD players.[241]

Although new technologies upset prevailing business models, they often create new business opportunities and generate additional revenue for right holders. For instance, movie industry representatives analogized the threat that the VCR recorder posed to the American film producer and the American public to the threat posed by "the Boston strangler [] to the woman home alone".[242] After the Supreme Court found VCRs non-infringing, the technology generated substantial revenues for the movie and TV companies, amounting to $30 billion in 2002 alone.[243]

The lack of foresight among right holders is highly unfortunate. Alarmist overreactions tend to induce regulatory action that is both premature and ill advised. This Part provides insight on the proper timing and scope of regulatory action in relation to 3D printing technologies which impact intellectual property right holders more generally.

A. Wait-and-See

Overreactions to potential intellectual property violations involving emerging technologies tend to induce untimely regulation. This is problematic, as regulatory action predating knowledge of the social and economic implications of an emerging technology are tends to be misplaced and poorly aligned with the ends that action hopes to achieve.[244] Although attempting to proactively prevent harm to rights-holders is commendable, addressing developing technologies is notoriously difficult as the social and economic ramifications of those technologies — including the precise nature and scope of any associated intellectual property infringement — are difficult to predict.[245] In this context, imposing technical

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[240] *Id*.

[241] Nate Anderson, *100 Years of Big Content Fearing Technology – In Its Own Words*, ARS TECHNICA, (Oct. 11, 2009, 11:00 PM), https://arstechnica.com/tech-policy/2009/10/100-years-of-big-content-fearing-technologyin-its-own-words/ [https://perma.cc/3BFJ-Y3VL].

[242] *Home Recording of Copyrighted Works*: *Hearings on H.R. 4783, H.R. 4794, H.R. 4808, H.R. 5250, H.R. 5488, and H.R. 5705 Before the Subcomm. on Courts, Civil Liberties, and the Admin. of Justice of the H. Comm. on the Judiciary*, 97th Cong. 8 (1982) (testimony of Jack Valenti, President, Motion Picture Association of America, Inc.) ("We are going to bleed and bleed and hemorrhage, unless this Congress at least protects one industry that is able to retrieve a surplus balance of trade and whose total future depends on its protection from the savagery and the ravages of this machine").

[243] Lemley, *supra* note 236, at 128-29.

[244] *See infra* notes 246-253 and accompanying text.

[245] One famous example of the unpredictable path of innovation is IBM's underestimation of the future market for home computer. NATHAN ROSENBERG, EXPLORING THE BLACK BOX: TECHNOLOGY, ECONOMICS AND HISTORY 220-230 (1994) ("The computer was regarded by its inventors as a purely scientific device") (quoting Barbara G. Katz & Almarin Phillips, *The Computer Industry, in* GOVERNMENT AND TECHNICAL PROGRESS 162, 171 (Richard R. Nelson ed., 1982)). *See also* JON ELSTER, EXPLAINING TECHNICAL CHANGE: A CASE STUDY IN THE

restrictions and liability on developers threatens to hamper the natural, technical, and commercial growth of a technology.

Moreover, as history informs us, imposing legal limitations on the design of a technology might have the inadvertent effect of wiping out positive commercial outcomes for intellectual property right holders resulting from those technologies.[246] For example, had the Supreme Court found that VCR manufacturers were liable for copyright infringement as a result of the VCR's record button, as some in the content industries had requested, it is possible that video rental and sale markets — to say nothing of markets for the VCRs themselves — might never have developed.[247] Such a scenario is not merely hypothetical, Congressional action has actually killed the market for innovative technologies. The digital audio recorder, for instance, never gained mainstream market acceptance after, at the behest of the music industry, Congress prematurely regulated the technology via the Audio Home Recording Act.[248] The legislation was a waste of resources and time, as it merely had the effect of limiting innovation.[249] Congress's entrenchment of legal protections for digital rights management, or DRM, technologies via the Digital Millennium Copyright Act of 1998 represents a third example of negative and premature legislation.[250] Worse still, it represents misplaced expectations about what DRM would do, a misunderstanding DRM's technological capabilities, and an underestimation of the adverse social reactions to DRM technology[251] — all with the result of imposing legal restrictions that were out of line with the needs of DRM developers and impinging on public rights and the freedom of consumers.[252]

These and other vivid examples from the past illustrate the potential consequences of hastily regulating developing technologies in anticipation of

PHILOSOPHY OF SCIENCE 91 (Jon Elster & Gudmund Hernes eds., 1983); JOEL MOKYR, THE LEVER OF RICHES: TECHNOLOGICAL CREATIVITY AND ECONOMIC PROGRESS 3-4, 7 (1990); CHRISTOPHER FREEMAN, THE ECONOMICS OF INDUSTRIAL INNOVATION 82-89 (2d ed. 1982).

[246] Lemley, *supra* note 236, at 128-29 and accompanying text (explaining that despite its opposition to the introduction of VCRs, the television industry made a windfall following the Supreme Court's refusal to declare such devices illegal because their ubiquity led to the creation of the video sales and rental markets).

[247] *See id.*

[248] Audio Home Recording Act of 1992, 17 U.S.C. §§ 1001-1010; MELVILLE B. NIMMER & DAVID NIMMER, 2 NIMMER ON COPYRIGHT § 8B.01[A] (Matthew Bender rev. ed.); Lemley, *supra* note 236, at 129-30.

[249] *Id.*

[250] DRM refers to technology which permits content providers and manufacturers to limit the types of technology on which users can consume certain content. EC-COUNCIL, COMPUTER FORENSICS: INVESTIGATING NETWORK INTRUSIONS AND CYBER CRIME, 9-26 (2010).

[251] *See* Sinha, *supra* note 208, at 40-41, 51 (arguing against digital rights management legislation); *DRM*, ELEC. FRONTIER FOUND. https://www.eff.org/issues/drm [https://perma.cc/R5QK-VX2T] (last visited Jan. 18, 2018).

[252] *Id.*

intellectual property infringement.[253] Such regulation, which latches onto technology while in the early stages of its development, risks becoming obsolete in the face of technological evolution, or, even worse, may stump the technologies natural development and prevent it from realizing its full potential.

B. The Case for General Rules

Another issue with overreaction to new technologies is that such regulatory responses tend to consist of narrowly-tailored rules so as to effectuate a very narrow scope. While detailed rules are suitable to address specific technological issues, they are less appropriate for technologies that are still evolving. Instead, the unpredictable nature of evolving technologies compels open-ended standards.[254]

Regulation via narrowly-tailored rules is likely to increase errors. In an unpredictable, rapidly-changing technological landscape, new innovation often does not fit within existing concepts and definitions.[255] Moreover, specific, narrow rules are easy for developers to circumvent.[256] Innovators have, and will

[253] For an overview of content industries misapprehensions regarding innovation, see Lemley, *supra* note 236, at 125-32.

[254] Copyright law is mostly governed by open-ended standards rather than rules. For instance, fair use, arguably the most important such standard, exempts users from infringement as follows:

> [T]he fair use of a copyrighted work, including such use by reproduction in copies or phonorecords or by any other means specified by that section, for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright. In determining whether the use made of a work in any particular case is a fair use the factors to be considered shall include:
>
> (1) the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes;
>
> (2) the nature of the copyrighted work;
>
> (3) the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and
>
> (4) the effect of the use upon the potential market for or value of the copyrighted work.

Copyright Act of 1976, 17 U. S. C. § 107 (2012).

[255] The literature on fair use especially emphasizes the benefits of flexible rules. *See, e.g.*, Matthew Sag, *God in the Machine: A New Structural Analysis of Copyright's Fair Use Doctrine*, 11 MICH. TELECOMM. & TECH. L. REV. 381, 396 (2005) (noting how open rules, such as the fair use standard, enables courts to adjust copyright protection in relation to new technologies); Dan L. Burk, *Muddy Rules for Cyberspace*, 21 CARDOZO L. REV. 121, 140 (1999) ("The 'muddy' four-part balancing standard for fair use allows courts to reallocate what the market cannot."); Michael W. Carroll, *Fixing Fair Use*, 85 N.C. L. REV. 1087, 1138-39 (2007) (pointing out that fair use requires context-sensitive analysis).

[256] Dan L. Burk, *Inventing Around Copyright*, 109 NW. L. REV. 64, 64 (2014) (asserting that the "language of the copyright statute, and judicial readings of the statute, create boundaries around which potential infringers may technologically navigate.").

continue to, continuously seek to exploit the gaps between technological possibilities and the self-described boundaries of the law.[257]

For example, when, in holding developers contributorily liable for file-sharing related copyright infringement in *A&M Records, Inc., v. Napster Inc.*, the 9th Circuit relied upon the fact that developers of file sharing technology could utilize centralized servers to remove infringing material from search indexes,[258] developers responded by decentralizing P2P file-sharing programs; obviating the need for file-indexing servers while performing the same function as the programs that the *Napster* court had deemed infringing.[259] *ABC v. Aereo, Inc.* — wherein a company attempted to skirt the Copyright Act's definition of "public performance" by transmitting broadcast programming through tiny antennae that it had assigned to each of its customers — represents another example of developer avoision.[260]

Where narrow rules provide boundaries and gaps ripe for easy exploitation, general standards[261] leave room for adaptive judicial interpretation, and are thus

[257] Developers notoriously engage in what Leon Katz has termed legal "avoision," the creation of technological applications that defeat the purpose of existing regulations but do not violate those regulations *sensu stricto*. *See* LEO KATZ, ILL-GOTTEN GAINS: EVASION, BLACKMAIL, FRAUD AND KINDRED PUZZLES OF THE LAW 17-30 (1996) (contrasting "avoision" of ethical and legal rules); Wu, *supra* note 113, at 682 ("The programmer is not unlike the tax lawyer, exploiting differences between stated goals of the law, and its legal or practical limits. He targets specific weaknesses in legal regimes.").

[258] 239 F.3d 1004, 1019-27 (9th Cir. 2001).

[259] Groennings, *supra* note 104, at 573.

[260] 134 S. Ct. 2498, 2500 (2014). The company publicly admitted it had designed its system in light of definitions set out in prior copyright case law. Brian Fung, *Aereo: Yes, We're a Rube Goldberg Device. And We're Proud of It.*, WASH. POST (March 27, 2014), https://www.washingtonpost.com/news/the-switch/wp/2014/03/27/aereo-yes-were-a-rube-goldberg-device-and-were-proud-of-it/?utm_term=.31f5c4dcbc49 [https://perma.cc/H6CA-KFRH]. The Supreme court disagreed with Aero's rigid textual interpretation, referring instead Congressional intent, concluding:

> [I]n light of the purpose and text of the Clause . . . when an entity communicates the same contemporaneously perceptible images and sounds to multiple people, it transmits a performance to them regardless of the number of discrete communications it makes.

Aero, 134 S. Ct. at 2511. For a further discussion of the *Aero* case see Adam Liptak & Emily Steel, *Aereo loses at Supreme Court, in victory for TV broadcasters*, N.Y. TIMES, (June 15, 2014), https://www.nytimes.com/2014/06/26/business/media/supreme-court-rules-against-aereo-in-broadcasters-challenge.html [https://perma.cc/BL4E-KFVB].

[261] Law and economics scholars distinguish between rules and standards:

> [l]egal norms can be precise rules, which are blueprints for action and allow for mechanical decisions by judges and civil servants. Alternatively, they can be vague, mission-oriented standards, which delegate decisions from the maker of the law to the judiciary and the administration. Rules economize on the costs of adjudication and administration. Standards economize on the costs of norm specification.

Hans-Bernd Schäfer, *Rules Versus Standards in Rich and Poor Countries: Precise Legal Norms as Substitutes for Human Capital in Low-Income Countries*, 14 SUP. CT. ECON. REV. 113, 113 (2006). There is not a binary distinction between the two categories. Rather, "[t]he

more difficult to circumvent.[262] Open-ended standards provide judges flexibility to condemn behavior that might otherwise be outside the scope of a narrower definition. For instance, in copyright law the open-ended nature of the fair use standard provides for judicial discretion — enabling courts to look to a technology's true effect when resolving ambiguities, rather than merely considering whether the technology falls outside of the exact terminology of a legal command.[263]

To conclude, the history of law and technology suggests that it is wise to hold off on specific regulations regarding 3D printing — at least until the technology has matured and the economic effects of regulating it are clear. Until that time, disputes between intellectual property rights-holders, developers and users of 3D printers should be resolved by courts on the basis of common law principles.

CONCLUSION

The fear that consumer 3D printing will bring about a Napster doomsday event for manufacturing industries is misplaced. The supply of, and demand for, 3D-printed pirated materials will likely be more modest than currently portrayed by most commentators. Moreover, the manufacturing industry can draw lessons from the mistakes made by the content industries to avoid the backlash that fueled the fires of digital music piracy.

As unauthorized consumer 3D printing is unlikely to present an existential threat to manufacturing, we urge caution against alarmist overreaction and policy initiatives that may slow technological progress. As a matter of public policy, emerging technologies deserve a legislative wait-and-see approach. Until the social and economic impact of a new technology becomes apparent, including the ability of traditional manufacturers to integrate consumer 3D printing into their business model, intellectual property rights- holders should instead be compelled to turn to courts and rely on general common law principles to address actual, rather than hypothetical, predicted harm.

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difference between a rule and a standard is a matter of degree-the degree of precision." Isaac Ehrlich & Richard A. Posner, *An Economic Analysis of Legal Rulemaking,* 3 J. LEGAL STUD. 257, 258 (1974). For further discussions on this subject, see generally Louis Kaplow, *Rules Versus Standards: An Economic Analysis*, 42 DUKE L.J. 557, 561-62, 565, 586, 593-94 (1992); Pierre J. Schlag, *Rules and Standards*, 33 UCLA L. REV. 379, 383, 426-30 (1985).

[262] *See, e.g.*, Burk *supra* note 256, at 64-65 (discussing the Supreme Court's finding of secondary liability on Grokster's "inventing around").

[263] R. Terry Parker, *Sold Downstream: Free Speech, Fair Use, and Anti-Circumvention Law*, 6 PIERCE L. REV. 299, 300-05 (2007) (describing fair use as a "safety valve" for free speech); s*ee, e.g.*, Wendy J. Gordon, *Fair Use as Market Failure: A Structural and Economic Analysis of the* Betamax *Case and Its Predecessors*, 82 Colum. L. Rev. 253, 270-71 (1982) ("Fair use is one label courts use when they approve a user's departure from the market.").