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3D Printing in the Aerospace Industry: Emerging Legal Issues for Counsel and Insurers

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3D PRINTING IN THE AEROSPACE INDUSTRY: EMERGING LEGAL ISSUES FOR COUNSEL AND INSURERS

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ABSTRACT

This Article covers the fast-growing use of additive manufacturing, also known as 3D printing, in the aerospace industry for critical and noncritical parts. The use of this technology raises regulatory and liability issues in the United States and Europe. Insurers of aerospace-related companies must also consider how to plan for the risks involved with the technology and the new entrants in the market who are designing, selling, and distributing additive manufacturing printers. Neither the regulatory bodies in the United States nor Europe have issued regulations aimed at additive manufacturing, as the law is even further behind. This Article informs lawyers and others in aerospace to raise awareness of this transformative technology.

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I. INTRODUCTION

ADDITIVE MANUFACTURING (AM), also referred to as 3D printing, involves building physical objects layer by layer that can produce certain objects faster—and with fewer design restrictions and waste—than certain traditional manufacturing processes.[1] In 3D printing, the adding is done pursuant to instructions from a computer-aided design program (CAD).[2] Unlike traditional methods such as cutting, milling, and grinding—which involve the removal of material—the product grows from a CAD file instructing the machine to layer material.[3]

Many aerospace companies have long been using AM techniques, but it is anticipated that new and expanded uses will have significant, disruptive impacts in the industry.[4] The National Aeronautics and Space Administration (NASA) was one of the early users, emailing a wrench to a 3D printer on the International Space Station in 2014.[5] In 2017, GKN Aerospace signed

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1 Rebecca Linke, *Additive Manufacturing, Explained*, MIT Sloan (Dec. 7, 2017), https://mitsloan.mit.edu/ideas-made-to-matter/additive-manufacturing-explained [https://perma.cc/3HDX-8TY9].

2 *Id.*

3 *Id.*

4 *See* Morgan Schwartz, *How 3D Printing Is Transforming the Aerospace Industry*, TriMech Blog (Nov. 7, 2017), https://blog.trimech.com/how-3d-printing-in-transforming-the-aerospace-industry [https://perma.cc/FXJ3-GJTG].

5 James Temperton, *NASA Just E-Mailed a Wrench to Space*, Ars Technica (Dec. 19, 2014, 10:40 AM), https://arstechnica.com/science/2014/12/nasa-just-e-mailed-a-wrench-to-space/ [https://perma.cc/HV4S-8U78].

an agreement with Oak Ridge National Laboratory to work on ways to use titanium to print large structural parts for aircraft to reduce waste material and shorten assembly time by half.[6] NASA's Orion spacecraft will be made of over 100 AM parts, many made by Lockheed Martin using state-of-the-art material.[7] AM is also being used to print fuel-nozzle tips for jet engines,[8] manufacture parts for military satellites,[9] and even make turbine-blade nozzles.[10]

Maintenance, repair, and overhaul organizations (MROs) are exploring AM for use in refurbishing, retrofitting, and repairing aircraft.[11] AM provides a cost-effective way for MROs to produce parts and reduce inventories.[12] Etihad Airways Engineering began using AM in 2015 after gaining European Union Aviation Safety Agency (EASA) approval to design and certify AM cabin parts.[13] Lufthansa Technik has a center in Hamburg to learn about AM.[14] This research includes the development of AM repair processes.[15] Indeed, Lufthansa Technik has the capability to perform a powder bed fusion hybrid batch repair in which an

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6 *GKN Aerospace and Oak Ridge National Laboratory Join Forces on Additive Manufacturing*, GKN AEROSPACE (June 19, 2017), https://www.gknaerospace.com/en/newsroom/news-releases/2017/gkn-aerospace-and-oak-ridge-national-laboratory-join-forces-on-additive-manufacturing/ [https://perma.cc/CGL4-ALA3].

7 Charles Goulding, *Lockheed Martin's Contributions to 3D Printing*, 3DPRINT.COM (June 20, 2018), https://3dprint.com/217176/lockheed-martin-3d-printing [https://perma.cc/9GDB-MZZ5].

8 *5 Ways GE Is Changing the World with 3D Printing*, GE NEWS (Aug. 26, 2017), https://www.ge.com/news/reports/5-ways-ge-changing-world-3d-printing [https://perma.cc/52AS-3WTA].

9 David Szondy, *Lockheed Martin Using 3D-Printed Parts in Military Satellites*, NEW ATLAS (Apr. 5, 2017), https://newatlas.com/lockheed-martin-3d-printed-military-satellite/48776/ [https://perma.cc/Q2GS-TAZT].

10 Tomas Kellner, *An Epiphany of Disruption: GE Additive Chief Explains How 3D Printing Will Upend Manufacturing*, GE NEWS (Nov. 13, 2017), https://www.ge.com/news/reports/epiphany-disruption-ge-additive-chief-explains-3d-printing-will-upend-manufacturing [https://perma.cc/34CA-DKHG].

11 *See* Laura Griffiths, *How 3D Printing Is Shaping the Future of Aircraft Maintenance, Repair & Overhaul*, TCT MAG. (June 18, 2018, 2:00 PM), https://www.tctmagazine.com/additive-manufacturing-3d-printing-news/additive-manufacturing-aerospace-maintenance-repair/ [https://perma.cc/Q79F-927C].

12 *Id.*

13 *See Why Additive Manufacturing Could Be Addictive for MROs*, TIMES AEROSPACE, https://www.timesaerospace.aero/features/maintenance/why-additive-manufacturing-could-be-addictive-for-mros [https://perma.cc/5H8R-2EUT].

14 *Id.*

15 *Id.*

AM process is used for repairing a damaged part—such as a blade—by replacing lost material.[16]

As is common with innovative technologies, AM is pushing the boundaries of the legal and regulatory systems, which often struggle to keep pace with fast-moving changes. This Article addresses the regulatory and liability frameworks in the United States and Europe for aerospace products using 3D printing. It also provides guidance to manufacturers and the maintenance community, others in the aerospace industry, and their legal representatives and insurers on navigating the shifting liability landscape, including product liability[17] and how to anticipate and control risk included in contractual agreements by using terms and conditions.

II. THE REGULATORY LANDSCAPE

A. In the United States

In the United States, the Federal Aviation Administration (FAA) regulates aviation safety, including setting the safety standards for the design and manufacturing of aviation products and certifying that products meet them.[18] The FAA regulations require federal certification or "type certification" of aviation product designs to ensure the safety and integrity of aviation products.[19] The FAA approves the design of an aviation product and issues a type certificate if the agency determines that the product satisfies its certification basis—which consists of all of the regulatory requirements and any special conditions that must be met to achieve approval—and has no unsafe feature or characteristic.[20] The FAA issues type certificates for aircraft, en-

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16 *Id.*

17 There is little case law on product liability issues with 3D printing. Most of the case law to date involving 3D printing focus on intellectual property and copyright-related issues or deals with non-aerospace products. *See* Nora Freeman Engstrom, Essay, *3-D Printing and Product Liability: Identifying the Obstacles*, 162 U. Pa. L. Rev. Online 35, 38–40 (2013).

18 *What We Do: Summary of Activities*, Fed. Aviation Admin., https://www.faa.gov/about/mission/activities [https://perma.cc/43E7-3S90].

19 *Id.*

20 14 C.F.R. § 21.21(b) (2022); U.S. Dep't of Transp., FAA Order No. 8110.4C Changes 1 thru 6 Incorporated 17 (2017), https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8110_4C_Chg_6.pdf [https://perma.cc/8USZ-RLJ7].

gines, and propellers.[21] Components may be certified as part of a type-certificated product or as a replacement or modification part for a type-certificated product under a Parts Manufacturing Approval (PMA).[22] A PMA is an FAA joint design and production approval for replacement parts or modification articles.[23] To obtain a PMA, an applicant must show either that the proposed article is identical to the design covered under a type certificate or that the article independently meets the applicable regulatory requirements.[24]

FAA regulations also require a manufacturer to obtain an FAA production certificate to duplicate an approved design, the requirements for which include—in pertinent part—a quality system and written procedures for supplier control.[25] Additionally, the FAA issues airworthiness certificates to individual aircraft upon finding that an aircraft conforms to its type certificate and "is in condition for safe operation."[26]

Because of the complexity of aviation products and the regulatory system governing them, designing aviation products is often onerous, time-consuming, and costly. Depending on the size of a project, type certification can take multiple years and many thousands of hours of testing and analyses.[27] AM can be

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[21] *Design Approvals*, FED. AVIATION ADMIN., https://www.faa.gov/aircraft/air_cert/design_approvals/ [https://perma.cc/5AFM-ZUEF] (Oct. 14, 2020, 4:03 PM).

[22] *Parts Manufacturer Approval (PMA) Design Approval*, FED. AVIATION ADMIN., https://www.faa.gov/aircraft/air_cert/design_approvals/pma/pma_des/ [https://perma.cc/96R4-5L8H] (July 3, 2012, 12:49 PM).

[23] *See generally* 14 C.F.R. pt. 21, subpt. K.

[24] *Id.* § 21.303(a)(4).

[25] *See id.* §§ 21.131–21.150.

[26] *Id.* § 21.183; *see also id.* § 91.203 (prohibiting anyone from operating a civil aircraft in the United States without a valid airworthiness certificate). The FAA also issues special airworthiness certificates in the experimental category to operate, among other things, amateur-built aircraft (assembled by a person for recreational/educational purposes) and kit-built aircraft (assembled from a kit manufactured by the holder of a production certificate, without the supervision of the production certificate holder) that do not conform to a type certificate, but are found to be in a condition for safe operation. *Experimental Category*, FED. AVIATION ADMIN., https://www.faa.gov/aircraft/air_cert/airworthiness_certification/sp_awcert/experiment/ [https://perma.cc/WS4D-V8D5] (June 7, 2011, 1:52 PM). Experimental aircraft are subject to regulatory limitations to mitigate potential risk, including a prohibition against operating over densely populated areas. *See* 14 C.F.R. § 91.313.

[27] *See, e.g.*, *Airworthiness Certification*, FED. AVIATION ADMIN., https://www.faa.gov/aircraft/air_cert/airworthiness_certification/ [https://perma.cc/33MY-HED2] (Mar. 5, 2021, 1:42 PM).

used to make certain parts faster and cheaper, facilitating more efficient testing and redesign opportunities.[28] AM also can allow for the production of certain complex parts without the increased costs typically associated with complexity in traditional manufacturing.[29] Further, AM can reduce part weight while maintaining or improving strength properties.[30] Accordingly, AM is an attractive tool for many aviation manufacturers.

At the same time, AM presents challenges, including certification under current FAA regulations, which were written largely for traditional manufacturing processes.[31] Some AM processes' complexity and lack of maturity may require new approaches. Issues include limited understanding of the acceptable ranges of variation across certain manufacturing parameters, limited understanding of key failures and anomalies, and a lack of industry specifications and standards for materials and processes.[32] Significantly, AM is not a single process; different AM processes have different quality and control considerations.[33] The FAA has explicitly identified process variation and issues regarding the characterization of process-related defects and anomalies and their impacts on parts durability as challenges for AM processes.[34] Repeatable characteristics and consistent quality are needed to ensure airworthiness.

The FAA is working with the aerospace industry to address the limitations of the current regulatory framework to accommodate AM. In January 2015, the FAA chartered an Additive Manufacturing National Team to develop a roadmap—including requirements, guidelines, and education materials—for certification, production, and maintenance of AM for safety-critical

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28 Linke, *supra* note 1.

29 *Id.*

30 *Id.*

31 *See* AIA ADDITIVE MFG. WORKING GRP., AIA AERO. INDUS. ASS'N, RECOMMENDED GUIDANCE FOR CERTIFICATION OF AM COMPONENT 5 (2020), https://www.aia-aerospace.org/wp-content/uploads/2020/02/AIA-Additive-Manufacturing-Best-Practices-Report-Final-Feb2020.pdf [https://perma.cc/E33Q-A2ZT].

32 Linke, *supra* note 1.

33 *Id.*

34 *See, e.g.*, FAA Materials and Processes Rule, 14 C.F.R. § 23.2260(a)–(b) (2022) ("The applicant must determine the suitability and durability of materials used for parts, articles, and assemblies, accounting for the effects of likely environmental conditions expected in service, the failure of which could prevent continued safe flight and landing. The methods and processes of fabrication and assembly used must produce consistently sound structures. If a fabrication process requires close control to reach this objective, the applicant must perform the process under an approved process specification.").

parts.[35] About two years later, in September 2017, the FAA released a draft Additive Manufacturing Strategic Roadmap for review.[36] This roadmap is not only intended to assist the FAA in regulating the certification and maintenance of AM parts and processes, but also sets forth goals for research and development, education, and training related to AM.[37] At the FAA's request, the Aerospace Industries Association (AIA) has chartered a working group to support the FAA in developing effective and consistent certification guidelines for AM parts.[38] This working group has been tasked with identifying and prioritizing the main risk factors associated with the design, manufacture, and maintenance/repair of AM parts from the manufacturer's perspective.[39] AIA published AM best practices early in 2020.[40] Additionally, two leading industry-standards bodies, the International Organization for Standardization and ASTM International, have banded together under a Partner Standards Developing Organization to leverage their joint expertise and facilitate the development of AM standards for worldwide recognition, including standards for aerospace.[41]

Aside from the challenges associated with regulating the technology itself, AM is expected to bring new players into the manufacturing space by lowering some of the barriers to entry.[42] New entrants into aerospace manufacturing that lack experience with aviation products and the FAA regulatory scheme present another set of challenges. Commitment to a risk-based regulatory approach and the ability to leverage industry exper-

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35 Ken Hutcherson, Aviation Safety Inspector, Fed. Aviation Admin., Gorham Conference: FAA Update on Additive Manufacturing (Mar. 21, 2017), http://gorham-tech.com/yahoo_site_admin/assets/docs/Gorham_AM_Presentation_2017_Final_3917.8051458.pdf [https://perma.cc/M8PU-57CX].

36 Debra Werner, *FAA Prepares Guidance for Wave of 3D-Printed Aerospace Parts*, SPACE NEWS (Oct. 20, 2017), https://spacenews.com/faa-prepares-guidance-for-wave-of-3d-printed-aerospace-parts/ [https://perma.cc/G3FZ-LWA7].

37 *Id.*

38 AIA ADDITIVE MFG. WORKING GRP., *supra* note 31, at 1.

39 *See id.*

40 *Id.*

41 Katie Armstrong, *ISO and ASTM Develop AM Standards Development Structure*, 3D PRINTING INDUSTRY (Oct. 12, 2016, 12:30 PM), https://3dprintingindustry.com/news/iso-astm-develop-standards-development-structure-96761/ [https://perma.cc/R4WS-NK6K].

42 Michael Petch, *2022 Trends in 3D Printing, Forecasts from Additive Manufacturing Experts and Leaders*, 3D PRINTING INDUSTRY (Jan. 17, 2022, 11:45 AM), https://3dprintingindustry.com/news/2022-trends-in-3d-printing-forecasts-from-additive-manufacturing-experts-and-leaders-202426/ [https://perma.cc/E72A-F3TS].

tise will be important to help the FAA keep pace as the use of AM in aerospace continues to grow.

The FAA's aviation-product safety mandate also extends to monitoring approved products' safety and security, including detecting and monitoring counterfeit or improperly manufactured parts, called "Suspected Unapproved Parts" (SUPs).[43] SUPs can take many forms, including parts rejected during production for defects or counterfeit parts deliberately misrepresented as having been designed and manufactured under regulatory approval.[44]

SUPs can pose a serious threat to aviation safety.[45] The FAA detects SUPs through reports from the aviation community, FAA accident and incident investigation, and surveillance activities.[46] In the 1990s, the FAA established a SUP program office to identify, investigate, and remove SUPs from stocks and aircraft.[47] The office was subsequently disbanded in 2007, and its functions were delegated to the FAA offices at the regional, directorate, and local levels.[48] The agency's success in monitoring and removing SUPs from use has repeatedly come under scrutiny,[49] and AM has the potential to exacerbate the problem of SUPs in the aviation industry. AM potentially introduces new risks into the design, manufacturing, and supply chain of AM products, including the potential to increase counterfeiting and fraudulent parts.[50] There are real challenges to mitigating piracy, both on an individual and mass-production level.[51] How the FAA intends to effectively manage this risk will be an impor-

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[43] MATTHEW E. HAMPTON, FED. AVIATION ADMIN. OFFICE OF INSPECTOR GENERAL, AUDIT REPORT: ENHANCEMENTS ARE NEEDED TO FAA'S OVERSIGHT OF THE SUSPECTED UNAPPROVED PARTS PROGRAM 1 (2017).

[44] *Id.*

[45] *Id.* at 3.

[46] *Id.*

[47] *Id.* at 3–4.

[48] *Id.* at 1.

[49] *Id.* at 1–2.

[50] *See, e.g.*, Michael Stehn, Ian Wing, Joe Dichairo & Joe Mariani, *3D Opportunity for Adversaries: Additive Manufacturing Considerations for National Security*, DELOITTE (Aug. 22, 2017), https://www2.deloitte.com/us/en/insights/focus/3d-opportunity/national-security-implications-of-additive-manufacturing.html [https://perma.cc/S8SV-Z4SL].

[51] *See, e.g.*, HADEN QUINLAN & A. JOHN HART, ADDITIVE MANUFACTURING: IMPLICATIONS FOR TECHNOLOGICAL CHANGE, WORKFORCE DEVELOPMENT, AND THE PRODUCT LIFECYCLE 34–36 (2020), https://workofthefuture.mit.edu/wp-content/uploads/2020/11/2020-Research-Brief-Quinlan-Hart4.pdf [https://perma.cc/YE3N-3WNL].

tant consideration for the agency as it develops mechanisms to enforce AM regulation.

B. In the European Union

Several European Union (EU) Regulations govern the design, production, and maintenance of aircraft and related products, such as their engines, propellers, parts, equipment, and appliances (aircraft and aeronautical products) and their operations.[52] Effective September 11, 2018, the EU Basic Regulation applies to the design, production, maintenance, and operation of aircraft and aeronautical products, registered or operated in the EU, as well as to personnel and organizations involved in the design, production, maintenance, and operation of such aircraft and products.[53] Its principal objective "is to establish and maintain a high uniform level of civil aviation safety" in the EU, under the supervision of an independent entity, the EASA.[54] To accomplish this safety goal, the EU Regulations require that all aircraft, including any installed products or parts, that are designed, produced, registered, operated, or used (or any combination thereof) in a Member State[55] must "comply with the essential requirements for airworthiness set out in Annex II" of that regulation.[56] Compliance of such aircraft and its products and parts is established through a type certificate.[57]

Applications for an aircraft type certificate must have "a three-view drawing of that aircraft and preliminary basic data, includ-

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[52] *See, e.g.*, Regulation 2018/1139, of the European Parliament and of the Council, 2018 O.J. (L 212) 1, 14.

[53] *Id.* at 14–16. Regulation 2018/1139, of the European Parliament and of the Council of 4 July 2018 promulgates "common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency . . ." *Id.* at 1.

[54] *Id.* at 13.

[55] *Id.* at 14.

[56] *Id.* at 22 (emphasis added).

[57] *Id.* at 22–23. Conditions of certification of aircraft, aeronautical products, and aeronautical parts as well as of approval of design and production organizations are defined in Commission Regulation 748/2012 of 3 August 2012, as amended, "laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations." Commission Regulation 748/2012, 2012 O.J. (L 224) 1, 1–3. In the EU, type certificates are generally issued by the EASA. *See* Fed. Aviation Admin., Frequently Asked Questions: European Aviation Safety Agency (EASA) 3 (2012), https://www.faa.gov/aircraft/air_cert/international/easa/media/easa_faq.pdf [https://perma.cc/3S67-PUP6].

ing the proposed operating characteristics and limitations."[58] Such operating characteristics and limitations must comply with the essential requirements for airworthiness outlined in Annex II to Regulation 2018/1139.[59] Upon issuance of the type certificate, the holder has numerous obligations.[60] The type certificate holder shall also collaborate with the production organization to ensure satisfactory coordination of design and production and proper support of the continued airworthiness of the aircraft and aeronautical products.[61]

Changes to an aircraft or aeronautical-product type certificate are subject to approval.[62] Organizations involved at each stage of the development and maintenance of the aircraft and its parts must adhere to the type certificate requirements and must meet rigorous approval standards.[63] EASA has provided guidance regarding regulatory expectations relating to the introduction and use of AM technologies in aircraft and aeronautical products, subject to EASA type certification.[64]

EASA is not required to approve AM materials or processes but must approve the change in the relevant type certificate, whether classified as minor or major, arising from the change in manufacturing materials or processes.[65] Such approval is subject to the type certificate holder demonstrating:

- by test or experience, that the material is suitable for the intended use of the aeronautical product being manufactured and that the material is being purchased per an approved material specification and controlled by approved inspection methods;
- that the derived AM design values are based upon representative statistically-significant test data;

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[58] Commission Regulation 748/2012, *supra* note 57, at 16.

[59] Regulation 2018/1139 *supra* note 52, at 22.

[60] Commission Regulation 748/2012, *supra* note 57, at 16.

[61] *Id.* at 15.

[62] Type-certificate changes are approved in accordance with sections 21.A.95 or 21.A.97 of Annex I to the EU Regulation 748/2012. *Id.* at 22.

[63] *See* Aerospace Indus. Ass'n, Aircraft Elecs. Ass'n, Gen. Aviation Mfrs. Ass'n & The FAA Aircraft Certification Serv. & Flight Standards Serv., The FAA and Industry Guide to Product Certification, at ii (3d ed. 2017), https://www.faa.gov/aircraft/air_cert/design_approvals/media/CPI_guide.pdf [https://perma.cc/3G7Z-TV36].

[64] *See* Eur. Union Aviation Safety Agency [EASA], *Certification Memorandum: Additive Manufacturing*, at 1, 4–5, EASA Doc. CM S-008 Issue 1 (Apr. 4, 2017).

[65] Commission Regulation 748/2012, *supra* note 57, at 22.

- that values obtained from tests conducted on simple specimens accurately represent the mechanical properties of the aeronautical product; and
- that design values used in the evaluation of any parts produced using AM are applicable to the material and process specifications used to fabricate the parts and to the facilities at which the parts are fabricated.[66]

Implementation of AM processes may also impact the Design Organization Approval and Product Organization Approval holders' processes as well as aircraft and aeronautical products maintenance, repair, and overhaul (MRO), and may require EASA's oversight.

Aviation is one of the most heavily regulated industries.[67] There can be no doubt that AM presents certain regulatory challenges. The FAA and EASA have held joint workshops on AM to find common ground for the aviation industry on the qualification and certification of AM parts, including an annual aviation AM event hosted by FAA and EASA.[68] Many questions face the FAA and EASA as these regulatory authorities attempt to keep up with this fast-paced and changing technology.[69]

III. LIABILITY CONSIDERATIONS

A. The United States

Although aviation products are among the most heavily regulated products in the world, stringent regulation and federal certification in the United States have not consistently resulted in courts finding preemption in product liability cases[70]—de-

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66 *See* EASA, supra note 64, at 5–6.

67 Milton Ezrati, *Airlines Face More Regulation, Even From This Administration*, Forbes (Jan. 29, 2018, 9:07 AM), https://www.forbes.com/sites/miltonezrati/2018/01/29/airlines-face-more-regulation-even-from-this-administration/?sh=95b6b0f56b3b [https://perma.cc/4XJP-QLDE].

68 *2020 Joint FAA-EASA Additive Manufacturing Workshop*, Fed. Aviation Admin., https://www.faa.gov/aircraft/air_cert/step/events/2020_additive_mfg_workshop/ [https://perma.cc/D8L5-5BPY] (Oct. 27, 2021, 9:31 AM); *2019 EASA-FAA Workshop on Additive Manufacturing*, EASA, https://www.easa.europa.eu/newsroom-and-events/events/2019-easa-faa-workshop-additive-manufacturing [https://perma.cc/94Q4-E84D].

69 *2019 EASA-FAA Workshop on Additive Manufacturing,* EASA, https://www.easa.europa.eu/newsroom-and-events/events/2019-easa-faa-workshop-addi tive-manufacturing [https://perma.cc/94Q4-E84D].

70 *See, e.g.*, Jones Day, Deciphering Sikkelee: Implications for Aviation Claims and Product Manufacturers 3 (2016), https://www.jonesday.com/-/media/files/publications/2016/05/deciphering-isikkeleei-implications-for-avia-

spite the FAA maintaining that its regulations preempt state design and manufacturing standards for over twenty-five years.[71] As such, AM aviation cases may be governed by traditional state tort law.

Currently, there is no well-formed body of case law addressing issues relating to AM (other than intellectual property) in aerospace or other industries. Several articles discuss product liability and AM in general terms, but many focus on consumer products and medical devices.[72] In 2013, Stanford Law Professor Nora Freeman Engstrom wrote one of the first and often-cited legal articles to start looking at 3D printing and product liability.[73] Her article focuses on home 3D printers and possible injury by a consumer.[74] Examining the definition of strict liability for defective products, Professor Engstrom cited the Third Restatement of Torts, which states, "[o]ne engaged in the business of selling or otherwise distributing products who sells or distributes a defective product is subject to liability for harm to persons or property caused by the defect."[75] Looking at the anticipated prevalence of 3D printers in homes, Professor Engstrom examined who might be the potential defendants.[76] The three potential defendants she considered were the hobbyist inventor and seller of the 3D printer, the manufacturer of the 3D printer, and the digital designer who wrote the code for the printer.[77]

Professor Engstrom dispatched claims against all of these potential defendants.[78] First, the hobbyist is not a commercial seller and, therefore, does not fall under the Restatement (this argument carried many caveats).[79] To hold the printer manufacturer responsible, the plaintiff would have to prove that there

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tion-c/files/deciphering-sikkeleepdf/fileattachment/deciphering_sikkelee.pdf [https://perma.cc/NVS3-RUGQ].

71 *See, e.g.*, Letter Brief for the Dep't of Transp. & the Fed. Aviation Admin. as Amici Curiae, Sikkelee v. Precision Airmotive Corp., 822 F.3d 680 (3d Cir. 2016).

72 *See generally* Patrick J. Comerford & Erik P. Belt, *3DP, AM, 3DS and Product Liability*, 55 SANTA CLARA L. REV. 821 (2015); James M. Beck & Matthew D. Jacobson, *3D Printing: What Could Happen to Products Liability When Users (and Everyone Else in Between) Become Manufacturers*, 18 MINN. J.L. SCI. & TECH. 143 (2017).

73 Engstrom, *supra* note 17, at 36.

74 *Id.*

75 *Id.* at 36 (quoting RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 1 (AM. L. INST. 1998)).

76 *Id.* at 37.

77 *Id.* at 36–37.

78 *Id.* at 37.

79 *Id.* at 37–38. This Article does not discuss the hobbyist scenario but instead focuses on a commercial seller.

was a defect in the printer and that the defect existed when the printer was manufactured.[80] Finally, as discussed further below, it has been difficult in most jurisdictions to bring a product liability claim involving digital code because computer code may not be considered a product.[81]

Professor Engstrom's article establishes a foundation for how to analyze product liability claims involving AM products.[82] How might the analysis work in the context of the use of an AM product in the aerospace industry, which is much more complex than the hobbyist scenario? This Article addresses possible approaches to this question below.

1. Product Liability Risks for AM in the Aerospace Industry

No product is without risk. If there is some incident in which AM is used in the production chain, what do claimants and those in the production line need to consider when searching for potentially liable parties? In many ways, the causes of action and potential parties may parallel product liability actions for traditionally manufactured products, but the introduction of AM literally and figuratively adds additional layers to the manufacturing process that may complicate the analysis. What are the potential causes of action, and who are the possible parties? There can be multiple problems: a problem with the design of the product that will cause an unreasonable risk of harm, a problem with the printing process whereby the manufactured product does not conform to the design specifications, and a problem with whether there was a warning about safely using the product. So, what has to be looked at in determining a potential cause of action where AM is involved somewhere in the chain?

How do you determine a design or manufacturing defect using traditional strict product liability analysis? Where are the specifications, and who wrote the specifications? Where is the manufacturing performed? Is there a problem with the material used? Who did the testing and how? Was the product defective at the time of sale or distribution? The standard analysis may work but assessing legal fault might be more difficult.

Another complicating issue raised by AM is what is the product? Is it the digital CAD file? Or is it the result of the CAD—the

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[80] *Id.* at 38.
[81] *Id.*
[82] *See id.* at 36.

finished product? Electronic data, such as code, is not a product under the Restatement Third of Torts, which defines a product as tangible property.[83] But some non-tangible items, such as electricity, have been considered products.[84] In aviation, aeronautical navigational charts have been considered products and held to a strict liability analysis.[85]

In an article addressing 3D printing of medical devices, Eric Lindenfeld expresses concerns about problems that can occur because of the use of code, such as syntax errors, unit changes, geometry formation, and inaccurate geometric alignment.[86] Mr. Lindenfeld's article also notes:

> Another limitation is the possibility of failure of the object created. When printing in layers, each layer has the potential to fail manufacturing standards. Considering that products are made up of multiple layers, the potential for flaws is multiplied by the number of layers needed to complete the product. This is in contrast to conventional manufacturing which does not require multiple layers.[87]

Although it did not directly implicate AM, a case out of Louisiana involving a customized medical device that featured electronic files and patient-matched imaging data may be illustrative.[88] In that case, the device was a disposable cutting guide designed and manufactured from 3D imaging data from magnetic resonance imaging, or MRI, or computerized tomography, or CT, scans, which was created by a software program from a 3D model of the patient's anatomy.[89] The U.S. District Court for the Western District of Louisiana allowed a design-

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83 *See* Beck & Jacobson, *supra* note 72, at 163 (quoting RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 19 (AM. L. INST. 1998)).

84 RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 19 cmt. d.

85 Robert B. Schultz, *Application of Strict Product Liability to Aeronautical Chart Publishers*, 64 J. AIR L. & COM. 431, 431–32 (1998).

86 Eric Lindenfeld, *3D Printing of Medical Devices: CAD Designers as the Most Realistic Target for Strict, Product Liability Lawsuits*, 85 UMKC L. REV. 79, 85 (2016) (citing Michael H. Park, Note, *For a New Heart, Just Click Print: The Effect on Medical and Products Liability from 3-D Printed Organs*, 2015 U. ILL. J.L. TECH. & POL'Y 187, 191 (2015)).

87 *Id.* at 85 n.30 ((quoting Park, *supra* note 86, at 191) (citing David H. Freedman, *Layer by Layer: With 3-D Printing, Manufacturers Can Make Existing Products More Efficiently—and Create Ones That Weren't Possible Before*, MIT TECH. REV. (Dec. 19, 2011), https://www.technologyreview.com/2011/12/19/20869/layer-by-layer/ [https://perma.cc/5P99-8FSH])).

88 *See* Corley v. Stryker Corp., No. 6:13-CV-02571, 2014 U.S. Dist. LEXIS 92002, at *1–2 (W.D. La. May 27, 2014).

89 *Id.*

defect products liability cause of action to survive a motion to dismiss, finding that the cutting guide was unreasonably dangerous in design due to alleged software defects.[90] In that case, the manufacturer of the device and the software were the same.[91] It is unclear whether the court would have considered the software a product if it had been separate from the end product.

With AM, there may be a blending of design and manufacturing-type claims. There could also be claims that the choice of using AM is itself negligent or defective. Even if the CAD is not a product, a plaintiff still may be able to bring a negligence or breach of warranty claim. What is the duty of care, and who owes it? The plaintiff will have to show the existence of a duty, breach of the duty, and proximate cause for the plaintiff's injuries.[92] Negligence always looks at reasonable care.[93] In a new technology, what are the standards for reasonable care?

With so many unanswered questions regarding AM, checklists may be a useful tool to develop. Below are two sample checklists that can be adapted in the context of product liability litigation where AM products are involved:

CLAIMS CHECKLIST:

- ☐ What product was defective and how it might be defective? – CONFIRM.
- ☐ Was the original product defective? – CHECK.
- ☐ Was the original digital design defective? – CHECK.
- ☐ Was the digital CAD file defective? – CHECK.
- ☐ Was the digital CAD file the subject of corruption through malware or other cyber event? – AS RQRD.
- ☐ Was the 3D printer itself defective? – CHECK.
- ☐ Were the materials used with the 3D printer defective? – CHECK.
- ☐ Was there an error in the manufacturing? – CHECK.
- ☐ Was there human error somewhere in the process – from design through manufacturing?[1] – AS RQRD

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[90] *Id.* at *12.

[91] *Id.* at *2 n.1.

[92] Legal Information Institute, *Negligence*, CORNELL L. SCH., https://www.law.cornell.edu/wex/negligence [https://perma.cc/2NNB-JBP4].

[93] *E.g.*, *id.*

CHECKLIST OF POTENTIAL DEFENDANTS:

- ☐ Printer manufacturer
- ☐ Printer seller
- ☐ User of the printer (product manufacturer)
- ☐ CAD designer
- ☐ Product designer
- ☐ Materials supplier
- ☐ Seller of the AM product
- ☐ Seller of the end product

All this can be further complicated when trying to obtain jurisdiction over any potential entities in the chain of creating and selling a 3D product. Aerospace, in particular, is a global industry, and finding out who is in the supply chain and defining who is the manufacturer of the alleged defective part presents an even greater challenge.[94]

2. *How Can Potential Defendants Prepare for 3D Printing Litigation?*

Defenses in a case involving AM likely will follow the traditional product liability defenses, such as the lack of a defect and the plaintiff's failure to exercise reasonable care.[95] The state-of-the-art defense becomes vital. Be ready to show that there was no defect, but query as to who is responsible for the chain in the manufacture of the end product. Showing reasonable care when dealing with new technology will also likely be an issue. Were specifications followed? This will open a whole new market for experts to make a substantial sum of money.

3. *Risk Allocation Using Contractual Agreements*

All entities in the chain of potential defendants should review contractual provisions being used by their company or client(s) to see whether changes need to be made as to such provisions as choice of law, hold harmless and indemnification, confidential-

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94 *See Industry Profile*, AEROSPACE INDUS. ASS'N, https://www.aia-aerospace.org/research-center/industry-profile/ [https://perma.cc/5SZ9-F8Q9].

95 *See* MARK SCHULTZ, COZEN O'CONNOR, DEFENSES IN A PRODUCT LIABILITY CLAIM 2–4 (2002), https://www.cozen.com/subrogation/resources/publications/defenses-in-a-product-liability-claim-subrogation-and-recovery—articles-and-papers [https://perma.cc/GK8F-G6J4].

ity, representations, warranties, and insurance provisions—whether in terms and conditions, maintenance services agreements, or on the back of a sales document. Who has the leverage in this chain to force contractual provisions that shift or apportion liability? Typically, the original equipment manufacturer (OEM) has the leverage to dictate apportionment of liability, choice of law and venue, indemnification, and limitations of liability. Where the chain is now longer, with multiple terms and conditions up and down the chain, the battle of the forms will be ripe for a law exam topic. What are the CAD designers, printer manufacturers, and sellers doing to limit their liability through disclaimers? Also, keep in mind the possibility of product recall or what might happen if there is a cyberattack or malware. Finally, it is important to ensure that regulations are being followed and that companies are aware of trade association task forces and regulatory bodies considering enacting guidelines and obligations to allow for timely response to new requirements.

4. Other Considerations

There are other considerations to keep in mind if your company or client is using 3D printers. Are employees adequately trained to use the printers? What is the backup plan if the 3D printer breaks down? What about considerations of business interruption? Is there an environmental risk? Does your company own the software, or does it partner with another company in the development of the software? It is best to be prepared for all eventualities in using this technology, particularly because it is not known what the long-term durability of 3D printed products might be.

Overall, AM is an exciting technology whose benefits generally outweigh the liability risks. However, companies using AM do have to be prepared for the risk, and a thorough understanding of the particular use of AM or a product manufactured with AM is necessary.

B. French and EU Grounds for Liability

As this Article goes to print, French courts have not yet had the opportunity to address liability issues involving AM litigation. Assuming litigation arises from an in-flight incident involving an aircraft with AM products, in practice, the plaintiff would most likely file a claim against the air carrier and its insurer, which would exercise a recourse claim against the aircraft manufacturer and its insurer, which would in turn exercise a recourse claim against its subcontractors, suppliers, maintenance organizations, and the OEMs of the aircraft and aeronautical products, which may have caused or contributed to the incident. In that event, if some of the supplies and products were manufactured with an AM process, relevant subcontractors, suppliers, and OEMs would in turn exercise a recourse claim against the seller of the 3D printer, the 3D printer manufacturer, the 3D raw material supplier, the designer of the CAD, etc. The claim, at this point, is not too different from what a lawsuit in the United States may look like when AM is involved.

In France, as well as in most EU Member States, several legal grounds for civil liability may exist, such as liability for a defective product,[96] contractual liability, and tort liability, which could all be applicable within litigation involving AM, depending on the cause of action, which is likely to lie in multiple concurrent faults.[97] These faults could be a design or manufacturing default, misuse, negligence, security breach, or information breach, depending on the author of the claim (victim, operator, seller of the AM product, or seller of the end product) and the party against whom the claim is asserted.[98]

1. *The Action for Liability of Defective Products, Based on Articles 1245 Through 1245-17 of the French Civil Code*

Articles 1245 through 1245-17 of the French Civil Code[99] establish the basis for a claim for strict liability.[100] The action for damages based on liability for defective products is subject to a three-year statute of limitation, from the date when the plaintiff knew or should have known of the damage, the defect, and the identity of the producer,[101] and is time-barred after ten years following the product's circulation.[102]

Any victim, whether the victim is a professional, consumer, direct victim, or victim by ricochet, can obtain "réparation du dommage qui résulte d'une atteinte à la personne" [compensa-

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[96] Council Directive 85/374/EEC, art. 1, 1985 O.J. (L 210) 29, 30.

[97] *See, e.g.*, Edward A. Tomlinson, *Tort Liability in France for the Act of Things: A Study of Judicial Lawmaking*, 48 LA. L. REV. 1299, 1299–1300 (1988).

[98] *See, e.g.*, *id.*

[99] Formerly Articles 1386-1 to 1386-18 of the French civil code. CODE CIVIL [C. CIV.] [CIVIL CODE] arts. 1386-1–1386-18 (2016) (Fr.).

[100] *Id.* art. 1245.

[101] *Id.* arts. 1245-15–1246-16.

[102] *Id.* art. 1245-15.

tion for damage resulting from personal injury] or "à un bien autre que le produit défectueux lui-même" [to property other than the defective product itself].[103] The question arose whether liability for defective products applied to products for professional use.[104] On a preliminary ruling from the French *Cour de Cassation*, the Court of Justice of the European Union, in a judgment of June 4, 2009, stated that "compensation for damage to an item of property intended for professional use and employed for that use is not covered by the scope of application of Directive 85/374."[105] The court further stated that Directive 85/374 "does not preclude the interpretation of domestic law or the application of settled domestic case-law according to which an injured person can seek compensation for damage to an item of property intended for professional use and employed for that purpose," provided that the "injured person simply proves the damage, the defect in the product and the causal link between that defect and the damage."[106] French case law nevertheless applies the provisions of Articles 1245 through 1245-17 of the French Civil Code to compensation for damage caused by a defective product to professional property—as opposed to private property—only expressly covered by the directive (i.e., a product ordinarily intended for private use or consumption—such as a defective wine bottle).[107] Thus, subject to future developments in case law, liability for defective products may be invoked in the presence of damage to professional property.

A product is deemed defective when it does not offer the security that one can legitimately expect. A claimant may establish that a defect resulted from "serious, precise and concordant presumptions."[108] However, the simple implication of a product in the occurrence of damage is not, in itself, sufficient to establish the product's defect.[109] Every producer, defined as the manufac-

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[103] *Id.* art. 1245-1.

[104] *See* Vonnick Le Guillou, Camille Lallemand, Audrey Lemniaï & Laura Debizet, *Product Liability in France*, DLA PIPER (Nov. 9, 2018), https://www.lexology.com/library/detail.aspx?g=6ef46767-1ce2-4625-9bf1-1f3899c2fb05 [https://perma.cc/C82A-PPXU].

[105] Case C-285/08, Moteurs Leroy Somer v. Dalkia France, 2009 ECR I-4733.

[106] *Id.*

[107] *See, e.g.*, Cour de cassation [Cass.] [supreme court for judicial matters] 1e civ., July 1, 2015, Bull. civ., No. 834 (Fr.).

[108] Cass. 1e civ., Sept. 26, 2012, Bull. civ. I, No. 187 (Fr.).

[109] Cass. 1e civ., Oct. 22, 2009 (Fr.) (unpublished decision) (appeal number 08-15171).

turer of a finished product, raw material, or component,[110] is liable for the damage caused by a defect of that producer's product.[111] French jurisprudence considers a product a component if it becomes inseparable from the finished product.[112] In such a case, if a default occurs, the producer of the component and the producer of the finished product are jointly liable.[113]

While a court on the merits considers whether the final contribution to damages could fall on the manufacturer of an incorporated component if only this component is affected by a safety defect,[114] the French *Cour de Cassation* considers that should several parties be liable for the same damage, their liability is joint and several pursuant to Article 1245-7 of the French Civil Code, and their contribution to awarded damages should be divided equally among the co-obligors in the absence of an actual fault attributable to one of them.[115] The grounds for exemption from the liability of the producer of a defective product are restrictive[116] and must be strictly interpreted.[117] In addition, if an inci-

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110 C. CIV. art. 1245-5 (Fr.).

111 *Id.* art. 1245.

112 *See* Guillou et al., *supra* note 104.

113 *See* C. CIV. art. 1245-7 (Fr.).

114 Cour d'appel [CA] [regional court of appeal] Nîmes, 1e ch., Mar. 17, 2009, 06/00889; CA Aix-en-Provence, 8e ch., June 25, 2010, 08/11963.

115 Cass. 1e civ., Nov. 26, 2014, Bull. civ. I, No. 198 (Fr.).

116 C. CIV. art. 1245-10 (Fr.). This Article of the French Civil Code provides that a *"producteur est responsable de plein droit à moins qu'il ne prouve:*
1. Qu'il n'avait pas mis le produit en circulation;
2. Que, compte tenu des circonstances, il y a lieu d'estimer que le défaut ayant causé le dommage n'existait pas au moment où le produit a été mis en circulation par lui ou que ce défaut est né postérieurement;
3. Que le produit n'a pas été destiné à la vente ou à toute autre forme de distribution;
4. Que l'état des connaissances scientifiques et techniques, au moment où il a mis le produit en circulation, n'a pas permis de déceler l'existence du défaut;
5. Ou que le défaut est dû à la conformité du produit avec des règles impératives d'ordre législatif ou réglementaire.
Le producteur de la partie composante n'est pas non plus responsable s'il établit que le défaut est imputable à la conception du produit dans lequel cette partie a été incorporée ou aux instructions données par le producteur de ce produit."
[producer is fully liable unless he proves:
1. That he had not put the product into circulation;
2. That, taking into account the circumstances, it is necessary to consider that the defect having caused the damage did not exist at the time when the product was put into circulation by him or
that this defect arose subsequently;
3. That the product was not intended for sale or any other form of distribution;
4. That the state of scientific and technical knowledge, at the time when he put the product into circulation, did not allow the existence of the defect to be detected;

dent is caused jointly by the defect of a product and the fault of the victim (arising, for example, from improper use of the product) or a person for whom the victim is responsible, the producer's liability may, depending on circumstances, be reduced or eliminated.[118]

2. *Recourse Actions Between the Parties, Based on Contractual Liability Depending on the Possible Causes of the Incident*

Whatever the genesis of the recourse actions between the manufacturers (aircraft manufacturer, subcontractors, OEMs, 3D printer manufacturer, etc.) and the suppliers (spare parts suppliers, 3D raw material supplier, designer of the CAD, etc.), their respective contractual liability towards one another and the extent thereof would depend on the causes of the incident (manufacturing defect, design or engineering defect, latent defect, unsuitable spare parts or components, improper use, lack of maintenance, breach of security duty, breach of duty to inform, etc.) and the terms of their contractual obligations and warranty towards one another, as well as contractual limitations of liability. A party invoking liability of its co-contractor must prove the latter's fault/default, cause for liability, the actual suffered loss and damage, and the causal link between the two.[119]

Before ruling on the merits of a claim arising from an incident and involving technical issues and determinations, French courts usually appoint an expert in charge of determining the technical causes of the incident, in compliance with the adversarial principle and within the procedural framework of court-ordered expertise outlined in the French Code of Civil Procedure.[120] Court-ordered technical investigations are very strategic because they lead to a report on technical findings and conclusions,[121] on which, in most cases, French courts entirely rely when ruling on incurred liabilities.

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5. Or that the defect is due to the conformity of the product with mandatory rules of a legislative or regulatory nature.

The producer of the component part is also not liable if he establishes that the defect is attributable to the design of the product in which this part has been incorporated or to the instructions given by the producer of this product.] *Id.*

[117] Case C-203/99, Veedfald v. Amtskommune, 2001 E.C.R. I-03569, ¶ 15.

[118] C. CIV. art. 1245-12 (Fr.).

[119] *See id.* arts. 1231-1–1231-4.

[120] *See* Guillou et al., *supra* note 104.

[121] *Id.*

In case of liability, damages granted by French courts may include economic loss, such as cost for repair or replacement of the damaged equipment, products, property, and related costs (i.e., logistics and transport), loss of margin, costs and expenses incurred as a result the default, loss of opportunity, and moral damages (i.e., damage to the image of an entity).[122] If a technical incident proceeded from several causes, French courts may either determine the contributory part of each liable party,[123] or award damages which would be jointly borne by all the parties having contributed to the damage.[124]

Under French law, liability limitations outlined in general terms of sale/service or contracts are valid[125] to the extent they do not void the contractual obligations they pertain to.[126] In other words, liability limitations clauses may not expressly or implicitly undermine the substance of a party's contractual obligations towards its co-contractors.

3. Tort Liability

Tort liability is exclusive from contractual liability.[127] In other words, a party to a contract that suffers loss and damage arising from a contractual default may not base judicial action on tort liability provisions.[128] If a contractual default causes loss and damage to third parties, the latter may seek compensation based on tort liability provisions,[129] provided they prove the default, actual loss and damage, and the causal link between the two. Overall, the liability considerations in the United States and the EU do not change when applied to AM products, but certainly, the involvement of an AM product in litigation adds complexity both factually and legally.[130]

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122 *Id.*

123 *E.g.*, CA Dijon, 1e ch., July 10, 2014, 09/01456.

124 *E.g.*, CA Versailles, 13e ch., Sept. 4, 2014, 12/08470.

125 C. CIV. art. 1231-5 (Fr.).

126 *Id.* art. 1170.

127 *See id.* art. 1245-17.

128 Fabrice Fages & Myria Saarinen, *France*, LATHAM & WATKINS 16 (2018), https://fr.lw.com/thoughtLeadership/complex-commercial-litigation-law-review-France-2018 [https://perma.cc/52U8-JA9H].

129 *See* C. CIV. arts. 1240–42, 1245, 1245-8 (Fr.).

130 *See* Schwartz, *supra* note 4.

IV. CONSIDERATIONS FOR INSURERS

AM is here to stay, and its use will continue to increase in the aerospace industry, both for critical and noncritical parts. Insurers should contemplate how various policies deal with any potential risk, including commercial general liability policies, professional liability or error, omissions policies, and cyber insurance policies. Insurers should also be mindful of indemnification and additional insureds provisions in contracts that the insured has entered into with others in the supply chain.

Many of the same questions arise for insurers as aerospace companies: What are other potential risks of additional manufacturing? Is there a longer-term pollutant risk? Are there safety issues surrounding the use of industrial 3D printers? What health risk might be presented to those using 3D printers and various materials?

It is important for insurers to educate themselves about this technology and its impact on the aerospace industry.

V. CONCLUSION

AM is being used in all aspects of the aerospace industry. Economically, AM makes sense—it will be less expensive to print an engine fan blade that fractures on-premises than to buy a new one and wait for the supplier to ship it (assuming there are no spare parts on-site) or have it repaired. It remains to be seen if AM lengthens the supply chain or whether AM, in fact, contracts the supply chain as manufacturers gain the ability to manufacture their own parts. Will regulations and prospective liability negate this possibility? Like the technology itself, the landscape for AM is likely to grow, layer-by-layer, as its use grows and develops in the aerospace industry. Some of the challenges presented by AM are the same kind of issues raised by any new technology. Whether the law will change or adapt to accommodate remains to be seen.