

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN TUOZHU TECHNOLOGY CO., LTD.,
Petitioner,

v.

STRATASYS, INC.,
Patent Owner.

IPR2025-00532
Patent 10,556,381 B2

Before HYUN J. JUNG, CHRISTOPHER L. OGDEN, and LILAN REN,
Administrative Patent Judges.

JUNG, *Administrative Patent Judge.*

JUDGMENT
Final Written Decision
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

We have jurisdiction under 35 U.S.C. § 6 (2024). This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73 (2025). For the reasons that follow, we determine that Shenzhen Tuozhu Technology Co., Ltd. (“Petitioner”) has shown by a preponderance of the evidence that claims 1–16 of U.S. Patent No. 10,556,381 B2 (Ex. 1001, “the ’381 patent”) are unpatentable.

A. Background and Summary

Petitioner filed a Petition (Paper 2, “Pet.”) requesting institution of an *inter partes* review of claims 1–16 of the ’381 patent. Discretionary denial of institution was determined to be not appropriate in this proceeding, and the proceeding was referred to the Board. Paper 10. Pursuant to 35 U.S.C. § 314, we instituted an *inter partes* review of claims 1–16 of the ’381 patent on all presented challenges. Paper 11 (“Inst. Dec.”), 15.

After institution, Patent Owner filed a Response (Paper 18, “PO Resp.”), to which Petitioner filed a Reply (Paper 25, “Pet. Reply”), and Patent Owner, thereafter, filed a Sur-reply (Paper 33, “PO Sur-reply”). An oral hearing in this proceeding was held on July 14, 2026; a transcript of the hearing is included in the record. Paper 37 (“Tr.”).

B. Real Parties in Interest

Petitioner identifies Shenzhen Tuozhu Technology Co., Ltd., Bambulab Limited, Shanghai Lunkuo Technology Co. Ltd., Tuozhu Technology Limited, and Bambulab USA Inc. as the real parties in interest. Pet. 79. Patent Owner identifies Stratasys, Inc. and Stratasys Ltd. as real parties in interest. Paper 3 (Patent Owner’s Mandatory Notices), 2.

C. Related Matters

The parties identify *Stratasys, Inc. v. Shenzhen Tuo Zhu Technology Co. Ltd.*, 2-24-cv-00644 (E.D. Tex.) and *BambuLab USA, Inc. v. Stratasys, Inc.*, 1-24-cv-01511 (W.D. Tex.) as related matters. Pet. 79; Paper 3, 2. Patent Owner also identifies IPR2025-00257, IPR2025-00311, IPR2025-00321, IPR2025-00354, IPR2025-00438, IPR2025-00531, IPR2025-00585, and IPR2025-00611 as related matters.

The parties jointly filed a “Verdict Form” (Ex. 2030) and “Defendants’ Disclosure of Final Invalidity Theories, Final Prior Art References/Combinations, and Final Equitable Defenses” (Ex. 2029) from *Stratasys, Inc. v. Shenzhen Tuo Zhu Technology Co. Ltd.*, 2-24-cv-00644 (E.D. Tex.). The “Verdict Form” indicates that claims 1 and 11 of the ’381 patent were not proven to be invalid by the Defendants. Ex. 2030, 5; *see also id.* at 2 (“The ‘’381 Patent’ refers to U.S. Patent No. 10,556,381.”); Ex. 2029, 1–2 (Defendants’ “final invalidity theories” including “[t]he combination of MakerBot Replicator and Bukkapatnam render[ing] Claims 1 and 11 obvious under 35 U.S.C. § 103.”).

For the reasons explained below, in this proceeding, Petitioner shows by a preponderance of the evidence that Warren would have rendered obvious claims 1 and 11 and that Calderon and RepRap20208 would have also rendered obvious claims 1 and 11. Petitioner also filed a stipulation that

they will not pursue in the 2:24-cv-00644 case or the 2:25-cv-00465 case, against the ’381 Patent, (i) the specific grounds asserted in IPR2025-00532, (ii) any other ground that was raised or could have been reasonably raised in an IPR (i.e., any ground that could be raised under §§ 102 or 103 on the basis of prior art patent or printed publications), (iii) any ground based on a combination of system prior art (i.e., prior art that is neither a

patent or printed publication) and the references that form the basis of any ground raised in IPR2025-00532, or (iv) any ground that could be raised under §§ 102 or 103 on the basis of system art corresponding to the references that form the basis of any ground raised in IPR2025-00532.

Ex. 1027. The Decision Referring Petitions to the Board found that “Petitioner has also filed a broad stipulation” in reaching its determination that “Petitioner’s arguments . . . against discretionary denial are persuasive.” Paper 10, 3.

In view of the above and the facts and circumstances of this proceeding (particularly the different combination of prior art references presented to us), we do not consider our determination for claims 1 and 11 of the ’381 patent in this proceeding to be inconsistent with the determination from related litigation.

D. The ’381 Patent (Ex. 1001)

The ’381 patent issued on February 11, 2020 from an application filed on October 16, 2015 that is a continuation of an application filed on October 29, 2013 and claims priority to a provisional application filed on October 29, 2012. Ex. 1001, codes (22), (45), (60), (63).

The ’381 patent explains that “components of the three-dimensional printer may degrade with time” and “become dented, warped, misaligned, etc.,” leading to “errors [that] may disadvantageously affect the ability of the three-dimensional printer to accurately fabricate objects.” Ex. 1001, 1:16–20. Thus, according to the ’381 patent, there is “a need for pressure-sensing extruders.” *Id.* at 1:20–21.

Figure 1 of the '381 patent is reproduced below.

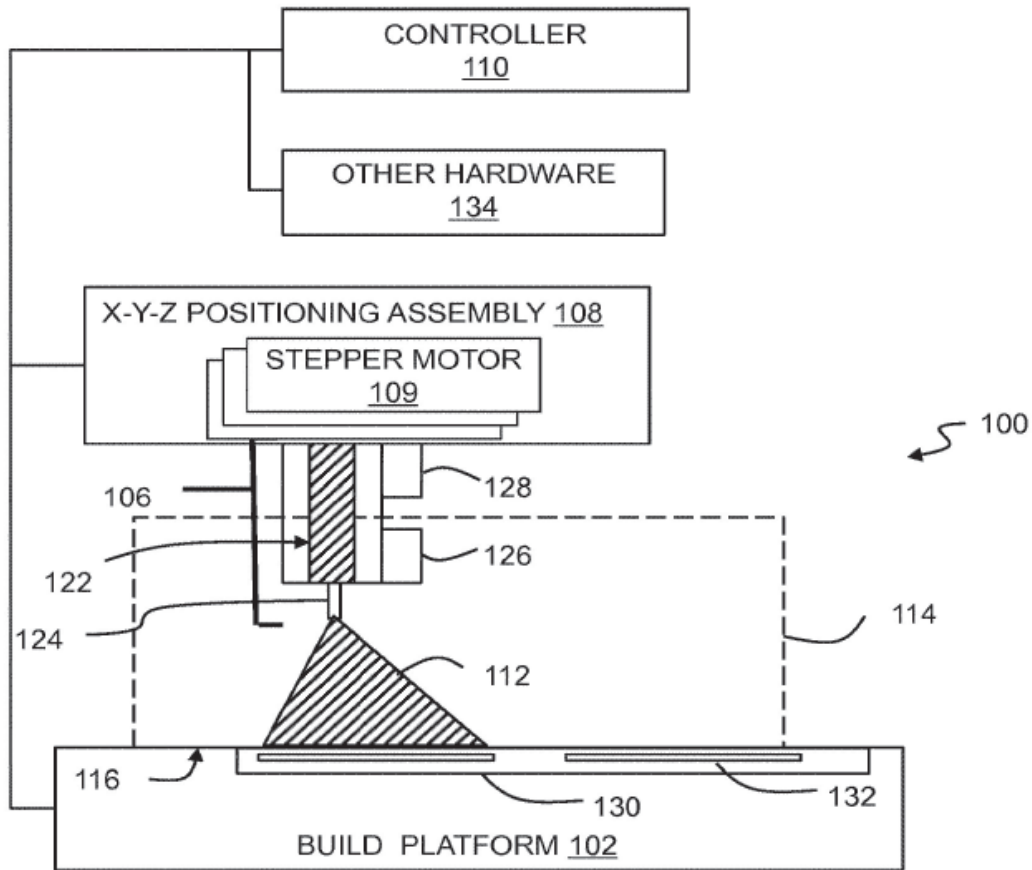


Fig. 1

Figure 1 shows “a block diagram of a three-dimensional printer.” Ex. 1001, 1:39, 2:9. “In general, the printer 100 may include a build platform 102, an extruder 106, an x-y-z positioning assembly 108, and a controller 110 that cooperate[s] to fabricate an object 112 within a working volume 114 of the printer 100.” *Id.* at 2:10–13.

Figure 3 of the '381 patent is reproduced below.

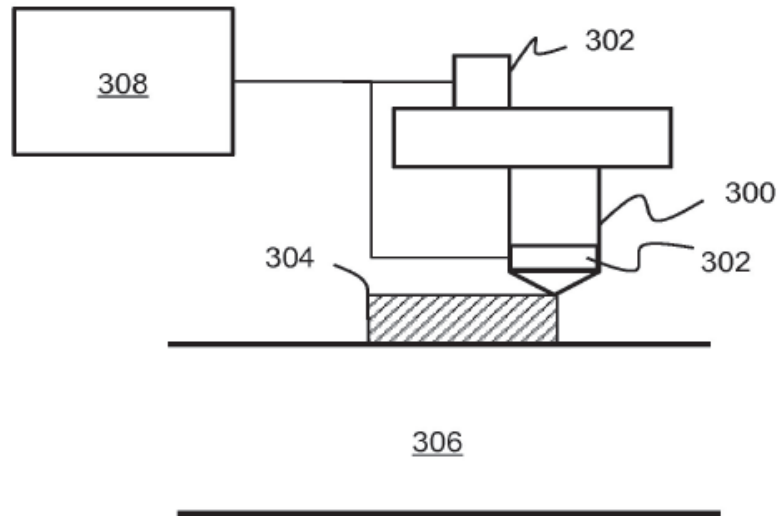


Fig. 3

Figure 3 shows “a block diagram of a fabrication tool for use in a three-dimensional printer.” Ex. 1001, 1:41–42, 8:55–56. “The tool 300 may include, for example, an extruder or other tool operable to add build material to an object 304,” and “[o]ne or more sensors 302 may be mechanically coupled or otherwise included in the fabrication tool 300.” *Id.* at 8:56–61. “Each sensor 302 may be operable to sense a contact force between the fabrication tool 300 and a separate structure, such as the object 304, the build platform 306, or some other structure.” *Id.* at 8:61–64. “[T]he controller 308 may include circuitry for determining and transmitting, based at least in part on the sensor signals, a control signal to various actuators or other components of the three-dimensional printer to control the three-dimensional printer in a manner responsive to the detected forces.” *Id.* at 9:35–40.

E. Illustrative Claim

The '381 patent includes 16 claims, all of which Petitioner challenges. Reproduced below is claim 1, the only independent claim.

1. A three-dimensional printer comprising:
a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

Ex. 1001, 12:59–13:4.

F. Asserted Prior Art and Proffered Testimonial Evidence

Petitioner identifies the following references as prior art in the asserted grounds of unpatentability:

Name	Reference	Exhibit
Calderon	US 6,629,011 B1, issued Sept. 30, 2003	1009
Warren	US 2003/0100824 A1, published May 29, 2003	1004
Dunn	US 2007/0228592 A1, published Oct. 4, 2007	1007
RepRap20208	Discussion Thread “Genetic Algorithms” (available at https://reprap.org/forum/read.php?1,20208,page=1)	1010

Petitioner contends that “[t]he references are prior art under §§ 102(a), 102(b), and/or 102(e).”¹ Pet. 1–2. Petitioner also provides a Declaration of

¹ The relevant sections of the Leahy-Smith America Invents Act (“AIA”), Pub. L. No. 112–29, 125 Stat. 284 (Sept. 16, 2011), took effect on March 16, 2013. Because the '359 patent issued from an application filed before that date, our citations to 35 U.S.C. §§ 102 and 103 in this Decision are to their

Andrew Wolfe, Ph.D. (Ex. 1003). Petitioner further provides a Declaration of Dr. Adrian Bowyer (Ex. 1014) to support that RepRap20208 is a printed publication, a Declaration of June Munford (Ex. 1015) to support that Exhibit 1013 is a true and correct copy, and a Declaration of Lynn Berthusen (Ex. 1022) to support that RepRap20208 was visited and printed out on December 31, 2024.

Patent Owner provides a Declaration of Dr. Tim A. Osswald. Ex. 2027. Deposition transcripts for Dr. Wolfe (Ex. 2020) and Dr. Osswald (Ex. 1042) were filed.

G. Asserted Grounds

Petitioner asserts that claims 1–16 are unpatentable on the following grounds:

Claims Challenged	35 U.S.C. §	Reference(s)/Basis
1–6, 9–16	103	Warren
3, 7, 8	103	Warren, Dunn
1–6, 9–16	103	Calderon, RepRap20208
3, 7, 8	103	Calderon, RepRap20208, Dunn

Pet. 1.

II. ANALYSIS

A. Legal Standards

“In an [*inter partes* review], the petitioner has the burden from the onset to show with particularity why the patent [claim] it challenges is unpatentable.” *Harmonic Inc. v. Avid Tech., Inc.*, 815 F.3d 1356, 1363 (Fed.

pre-AIA versions. *See also* Pet. 1 (stating that “[t]he ’359 patent claims priority to several provisional applications as early as 1/28/2009 (‘Critical Date’)”).

Cir. 2016). This burden of persuasion never shifts to Patent Owner. *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1378 (Fed. Cir. 2015). To prevail in an *inter partes* review, the petitioner must support its challenges by a preponderance of the evidence. 35 U.S.C. § 316(e); 37 C.F.R. § 42.1(d).

Petitioner contends that the challenged claims of the '381 patent are unpatentable under § 103. Pet. 1. A claim is unpatentable under § 103 if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations, including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of skill in the art; and (4) where in evidence, so-called secondary considerations. *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). When evaluating a combination of teachings, we must also “determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue.” *KSR*, 550 U.S. at 418 (citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006)).

B. Level of Ordinary Skill in the Art

Petitioner proposes that one of ordinary skill in the art would have had “a bachelor’s degree in Mechanical Engineering, Computer Engineering, Electrical Engineering, or a comparable field and at least two years of experience working with 3D printers,” and that “[a]dditional years of

experience could substitute for a formal degree or formal training (and vice versa).” Pet. 4 (citing Ex. 1003 ¶¶ 20–23).

Patent Owner proposes for the purpose of its Response that one of ordinary skill in the art “would have had a bachelor’s degree in Mechanical Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, Materials Science, or a comparable field and at least two years of experience related to 3D printing, with additional experience potentially being a substitute for a formal degree or training (and vice versa).” PO Resp. 8–9 (citing Ex. 2027 ¶¶ 22–26). Patent Owner also argues that “the Petition has failed to show that the claims of the ’381 Patent are unpatentable irrespective of the level of skill of a skilled artisan.” *Id.* at 9.

Based on the full record, we adopt Petitioner’s proposed level of ordinary skill in the art. We find that Petitioner’s proposal is consistent with the ’381 patent and the asserted prior art. Our analysis below would not change if we had adopted Patent Owner’s proposal.

C. Claim Construction

In an *inter partes* review, the claims are construed

using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. [§] 282(b), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

37 C.F.R. § 42.100(b); *see Phillips v. AWH Corp.*, 415 F.3d 1303, 1312–13 (Fed. Cir. 2005) (en banc).

According to Petitioner, “the Challenged Claims are obvious under any reasonable *Phillips* interpretation,” and “Petitioner submits that the Board need not resolve any express constructions.” Pet. 5. “For the

purposes of [its] Response, Patent Owner submits that the Board does not need to construe any claim terms in any particular way to conclude that the challenged claims are not unpatentable.” PO Resp. 8.

We agree with the parties that we do not need to interpret expressly any claim term to resolve the parties’ dispute. *Realtime Data, LLC v. Iancu*, 912 F.3d 1368, 1375 (Fed. Cir. 2019) (“The Board is required to construe ‘only those terms that . . . are in controversy, and only to the extent necessary to resolve the controversy.’”) (quoting *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999)).

D. Asserted Obviousness Based on Warren

1. Warren (Ex. 1004)

Warren “relates generally to tools and methods for depositing materials accurately on a selected substrate.” Ex. 1004 ¶ 3. Warren describes 3D printing called “direct-write deposition technology” (“DWDT”), which can be used “for dispensing uniform lines of viscous solutions, suspensions, sols, or pastes to create exact replicas of stored patterns.” *Id.* ¶¶ 10, 11. When a DWDT 3D printing apparatus is employed for “biological, medical, bioengineering, and tissue-engineering,” Warren uses the label “human architecture tool” (“HAT”). *Id.* ¶ 14. “The DWDT/HAT technology has a plurality of aspects that, in some embodiments, combine to make a tool capable of producing a modeled structure through 3D direct construction of various materials into complex shapes.” *Id.* ¶ 93.

Warren describes “a system and method for controlling the position of one or more elements of a dispensing system to maintain a desired contact force between the elements.” Ex. 1004 ¶ 288. According to Warren,

“vibration of particular amplitude (A) is imparted to one or more of the elements of the dispensing system,” such as “the dispenser, the substrate, or both the dispenser and the substrate.” *Id.* ¶ 289.

“A change in the amplitude of vibration (ΔA) of the dispenser, the substrate, or both the dispenser and the substrate upon contact with each other, is detected by the system.” Ex. 1004 ¶ 289. “The position of one or more of the elements is varied, based on the detected ΔA , to maintain a desired force of contact between the dispenser and the substrate.” *Id.* According to Warren, “the system is sensitive enough to maintain a desired contact force between the dispenser and the substrate.” *Id.* ¶ 290.

Figure 18 of Warren is reproduced below.

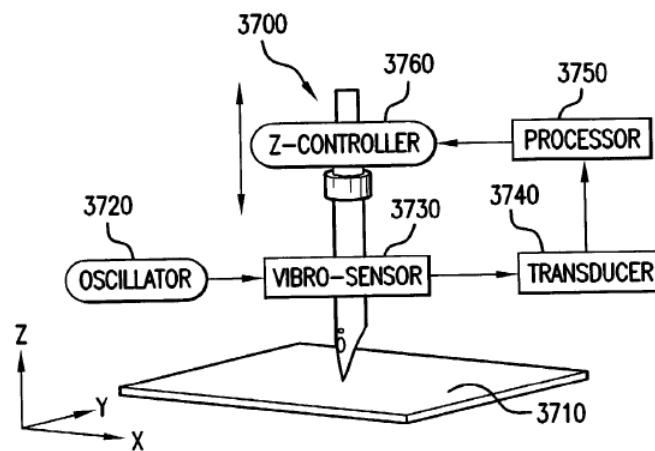


FIG. 18

Figure 18 “is a schematic illustration of an exemplary system for dispensing materials using feedback to control the position of a dispenser according to one embodiment.” Ex. 1004 ¶ 35. Warren’s “vibration oscillator 3720 is attached to the dispenser 3700 for imparting vibration to the dispenser 3700,” and “[a] vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700 for sensing the A and f of vibration of the dispenser 3700.” *Id.* ¶ 300.

“The vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 dispenser with the substrate 3710.” Ex. 1004 ¶ 302. “The transducer 3740 senses and transfers the changed vibration signal to an amplifier (not shown), which then creates a feedback signal that is generally proportional to the intensity of the physical contact of the dispenser 3700 with the substrate 3710.” *Id.* “The feedback signal is used to control the position of the dispenser 3700 to maintain a desired force of contact between the dispenser 3700 and the substrate 3710.” *Id.*

Figure 22A of Warren is reproduced below.

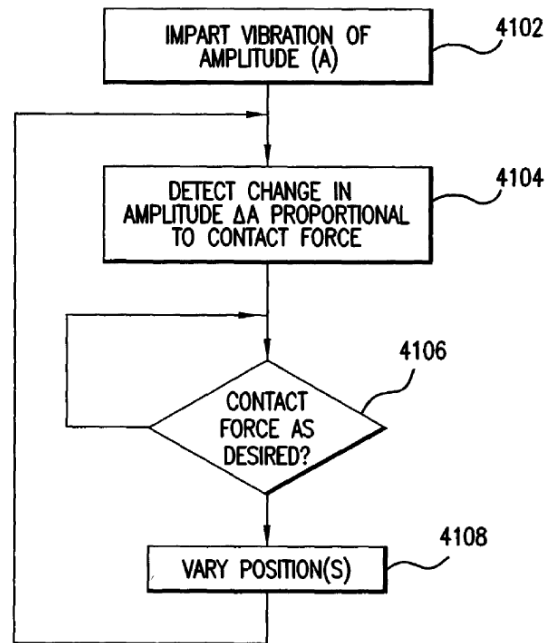


FIG. 22A

Figure 22A “is a flow chart of an exemplary method of controlling the position of the elements of a dispensing system.” Ex. 1004 ¶ 39. Warren states that “[a]t step 4104, a change in the amplitude of vibration of the dispenser and/or the substrate is detected,” and that “[t]his change in

amplitude is proportional to the force of contact between the dispenser and the substrate.” *Id.* ¶ 313.

2. *Claim 1*

a) *“A three-dimensional printer comprising:”*

Petitioner argues that Warren teaches “[a] three-dimensional printer.” Pet. 15 (citing Ex. 1003 ¶¶ 75, 76; Ex. 1004 ¶¶ 63, 93, 226–229, 288–290, 293–321, Fig. 18).

We find that a portion of Warren cited by Petitioner discloses “a plurality of aspects that, in some embodiments, combine to make a tool capable of producing a modeled structure through 3D direct construction of various materials into complex shapes.” Ex. 1004 ¶ 93. We credit Petitioner’s testimonial evidence regarding the preamble, because the cited portions of Warren support it. Ex. 1003 ¶ 75; Ex. 1004 ¶¶ 63, 93, 288–290, 293–321, Fig. 18. Patent Owner does not present a response for the preamble of claim 1. *See* PO Resp. 16–34.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the preamble of claim 1. In view of our finding, we do not need to determine if the preamble is limiting.

b) *“a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process”*

Petitioner argues that Warren’s apparatus 10 with capillary vibro-sensor dispenser 100 and through-nozzle dispenser 100 discloses the recited fabrication tool with an extruder. Pet. 15–18 (citing Ex. 1003 ¶¶ 77–81, 83, 84; Ex. 1004 ¶¶ 7, 63, 230–252, 295, 299, 321, 324, 446, Figs. 11A–11D, 12A, 12B, 18, 19, 23A–23C). Petitioner also proposes, with citations to the record, combining different aspects of Warren’s disclosure. *Id.* at 11–14.

Petitioner further argues that Warren’s teachings parallel the preferred embodiment of the ’381 patent. *Id.* at 18 (citing Ex. 1001, 2:28–52; Ex. 1003 ¶ 82).

We find that cited Figures 23A–23C show “a fabrication tool.” *See also* Ex. 1004 ¶ 278 (stating that “[o]ne specific embodiment of the tabletop in vitro tool design is . . . illustrated in FIGS. 23A-23C” and that “this embodiment includes four material dispensers, one through-nozzle dispenser and three capillary-based dispensers”). We also find that Petitioner cites portions of Warren that disclose that its capillary vibro-dispensing unit forces “fluid or paste . . . through the tip 3840” and that its through-nozzle dispenser “appl[ies] positive pressure to a material in a reservoir 149, and the flow of material is controlled by adjusting the open position P1 and closed position P2 of the valve 130.” Ex. 1004 ¶¶ 232, 295, Figs. 11A–11D, 12A, 12B, 18, 20A, 20B.

We credit Petitioner’s testimonial evidence regarding “a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process,” because the cited portions of Warren support it. Ex. 1003 ¶¶ 77–81, 83; Ex. 1004 ¶¶ 7, 63, 230–252, 295, 299, 321, 324, 446, Figs. 11A–11D, 12A, 12B, 18–20B, 23A–23C. We agree with Petitioner’s declarant that Warren’s teachings parallel an embodiment of the ’381 patent. Ex. 1001, 2:28–52; Ex. 1003 ¶ 82.

Patent Owner does not dispute the teachings above but responds with citations to the record that there would have been no motivation to combine different embodiments of Warren’s dispensers. PO Resp. 16–25. The parties also provide reply arguments. Pet. Reply 1–3; PO Sur-reply 1–4. We analyze below the parties’ dispute regarding the proposed modification.

See also Tr. 40:24–41:10 (Petitioner’s counsel indicating that the proposed modification is not necessary for the challenge to claim 1),

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests “a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process.”

- c) *“one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool”*

Petitioner argues that vibration sensor 3730 and transducer 3740 attached to dispenser 3700 teach the above-quoted limitations. Pet. 19–21 (citing Ex. 1003 ¶¶ 85, 86; Ex. 1004 ¶¶ 300, 302, 313, 315, Figs. 18, 22A). Petitioner also argues that one of ordinary skill in the art would have understood that “**contact force** can be readily calculated from the detected ‘change in the amplitude.’” *Id.* at 21 (citing Ex. 1003 ¶¶ 86–90; Ex. 1004 ¶¶ 301–307, 313). Petitioner further argues that Warren’s vibration sensor and transducer align with the ’381 patent’s description of its sensors. *Id.* (citing Ex. 1001, 8:49–61; Ex. 1003 ¶¶ 90, 91).

(1) Patent Owner’s Response

Patent Owner also responds that Warren does not teach “one or more sensors . . . collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool.” PO Resp. 25. According to Patent Owner, “Petitioner concedes that Warren senses a change in amplitude of vibration and does not sense a contact force.” *Id.* at 25–26 (citing Pet. 21; Ex. 1004 ¶ 313).

Patent Owner argues that Petitioner “resorts to impermissible hindsight.” PO Resp. 26. Patent Owner also argues that “Warren repeatedly refers to detecting a change in amplitude of a vibration, not detecting or calculating a contact force.” *Id.* at 26–27 (citing Ex. 1004 ¶¶ 289, 313, 315). Patent Owner, thus, argues that “[t]here is no teaching or suggestion to calculate a contact force.” *Id.* at 27 (citing Ex. 2025, 62, Fig. 3.16; Ex. 2026, 47–56, Fig. 2.32; Ex. 2027 ¶¶ 163–170).

(2) Reply Arguments

The parties provide reply arguments that are directed to calculating contact force. *See* Pet. Reply 1–9; PO Sur-reply 4–9. We address those arguments below in our analysis of “a controller configured to . . . to calculate the contact force between the extruder and the separate structure.”

(3) Petitioner Persuades us that Warren Teaches or Suggests the Limitation

We find that the cited portions of Warren disclose vibration sensor 3730 and transducer 3740 are attached to dispenser 3700. Ex. 1004 ¶¶ 300, 315, Fig. 18. Another cited portion of Warren discloses that “a change in the amplitude of vibration of the dispenser and/or the substrate is detected,” and that “this change in amplitude is proportional to the force of contact between the dispenser and the substrate.” *Id.* ¶ 313, Fig. 22A (showing “detect change in amplitude ΔA proportional to contact force” at block 4104).

We also credit Petitioner’s testimonial evidence, because the citations to Warren support it. Ex. 1003 ¶¶ 85, 86, 89; Ex. 1004 ¶¶ 300, 302, 313, 315, Fig. 18. We agree with Petitioner’s declarant that Warren’s vibration sensor and transducer would be “sensors that are collectively operable to

sense any force . . . of the fabrication tool and separate structure” and so “may be used as sensors 302,” as described by the ’381 patent. Ex. 1001, 8:49–61; Ex. 1003 ¶ 90.

Turning to Patent Owner’s responsive arguments, Patent Owner does not dispute that Warren discloses detecting a change in amplitude of vibration and that Warren discloses a “determination of whether there is a desired contact force . . . ‘based on the detected change in amplitude.’” PO Resp. 26–27 (quoting Ex. 1004 ¶ 289) (citing Ex. 1004 ¶¶ 313, 315). Because Warren also discloses that the “change in amplitude is proportional to the force of contact between the dispenser and the substrate,” we find that one of ordinary skill in the art would have understood that Warren teaches or suggests “sens[ing] a contact force between the extruder and a separate structure distinct from the fabrication tool” by detecting “a change in the amplitude of vibration of the dispenser and/or the substrate.” Ex. 1004 ¶ 313.

Thus, even if Warren does not directly detect current contact force, as argued by Patent Owner, Warren discloses detecting the change in amplitude to sense the current contact force “based on the detected change in amplitude.” Ex. 1004 ¶ 313, Fig. 22A. Warren teaches or suggests using the change in amplitude as an indirect way to sense the contact force, because Warren expressly teaches that the two are proportional. *Id.* ¶ 313, Fig. 22A. Because Warren further discloses that the “position of one or more of the elements is varied, based on the detected ΔA , to maintain a desired force of contact between the dispenser and the substrate,” Warren teaches or suggests that the “detected ΔA ” represents the current contact force. *Id.* ¶ 289.

In view of our findings, we determine that these teachings are within the scope of the claim language “one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool.” Patent Owner’s arguments appear to limit the claim language to direct detection of current contact force, but such a claim interpretation was not presented and finds no support in the record. *See* PO Resp. 8 (“Patent Owner submits that the Board does not need to construe any claim terms in any particular way to conclude that the challenged claims are not unpatentable.”). Also, in view of our findings, we do not agree with Patent Owner that Petitioner is resorting to impermissible hindsight. *Id.* at 26.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests “one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool.”

d) “a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure”

Petitioner argues that Warren’s microprocessor or personal computer is configured to receive a feedback signal from vibration sensor 3730 and transducer 3740 to calculate a contact force between the capillary vibro-sensor dispenser or the through-nozzle dispenser and substrate 3710.

Pet. 21–23 (citing Ex. 1003 ¶ 92; Ex. 1004 ¶¶ 302, 303, 313, Fig. 18).

Petitioner also argues that “determin[ing] the intensity of contact force between elements” would have “further[ed] Warren’s objective ‘to maintain a desired contact force between the dispenser and the substrate’” so as to

“prevent their ‘destruction.’” *Id.* at 23 (citing Ex. 1004 ¶¶ 286, 287, 313–316, Fig. 22A).

According to Petitioner, one of ordinary skill in the art “would have known, or found it obvious, that Warren’s controller calculates the contact force based on the feedback signal using the proportionality.” Pet. 23 (citing Ex. 1003 ¶ 94; Ex. 1012 ¶¶ 120, 121; Ex. 1017, Fig. 4). Petitioner argues that “[c]alculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012” and “was also obvious because of its many advantages in a control system designed to ‘maintain a desired contact force.’” *Id.* (citing Ex. 1003 ¶ 95).

Petitioner also argues that one of ordinary skill in the art “would have been motivated knowing that the comparison between the sensor signal and a ‘desired contact force’ requires a conversion of the values to the same domain (and it was obvious to try either of the two domains), and that it is advantageous to use a force domain, rather than sensor signal domain.” Pet. 23 (citing Ex. 1003 ¶ 95). Petitioner, thus, argues that Warren would have rendered obvious claim 1. *Id.* at 24 (citing Ex. 1003 ¶¶ 73–96).

(1) Patent Owner’s Response

Patent Owner responds that Warren does not teach “a controller configured . . . to calculate the contact force between the extruder and the separate structure.” PO Resp. 25. Patent Owner also argues that “it would not have been obvious for a controller to be configured to calculate the contact force from the detected change in amplitude.” *Id.* at 27 (citing Pet. 21–24).

Patent Owner contends that “Warren does not explain how to calculate the contact force from a change in amplitude” and states that the “amplitude of the modulation in the signal is proportional to the force applied between the dispenser and the substrate.” PO Resp. 27 (citing Ex. 1004 ¶ 315; Ex. 2027 ¶¶ 171–192). Patent Owner also contends that Figure 21 of Warren does not describe which frequency or frequencies to select for detecting a change in amplitude. *Id.* at 27–29 (citing Ex. 1004 ¶ 306, Fig. 21; Ex. 2020, 77:5–20, 79:13–80:20; Ex. 2027 ¶¶ 169–174, 176, 184).

In Patent Owner’s view, “[r]ecognizing that Warren fails to provide a motivation or teaching for its desired result, Petitioner resorts to hindsight bias, asserting that converting Warren’s feedback detecting a change in amplitude to a contact force is well-known.” PO Resp. 29 (citing Pet. 23–24; Ex. 1017, Fig. 4). Patent Owner argues that Petitioner’s cited evidence fails to support that such conversion was well-known and does not explain how the conversion could be done. *Id.* at 29–30 (citing Ex. 1012 ¶¶ 120, 121, 128, 129; Ex. 1014, Fig. 21; Ex. 1017, Figs. 3, 4; Ex. 2027 ¶¶ 177, 178). Patent Owner argues that “calculating a contact force from Warren’s change in amplitude was not ‘rudimentary engineering and commonplace long before 2012.’” *Id.* at 31 (citing Ex. 1003 ¶ 95; Ex. 2024, Fig. 4.1; Ex. 2025, Fig. 3.16; Ex. 2026, Fig. 2.32; Ex. 2027 ¶¶ 179–191).

Patent Owner also argues that, besides selecting an appropriate frequency for detecting the change in amplitude, the various compositions in the substrate, dispensed materials, substrate shapes, Young’s moduli, and material stiffness would impact the ability to calculate a contact force. PO Resp. 31–33 (citing Ex. 1004 ¶¶ 293, 295, 316; Ex. 2024, Fig. 4.1; Ex. 2020,

72:13–73:16, 89:2–21; Ex. 2027 ¶¶ 167, 182–186, 188–191). Patent Owner, thus, argues that “converting Warren’s change in amplitude to a calculated contact force is vastly different than the examples that Petitioner identified for other applications and vastly more complicated without any reasonable expectation of success.” *Id.* at 33.

Patent Owner also responds that “there is no motivation to calculate the contact force from the change in amplitude that is used in Warren’s solution.” PO Resp. 33. Patent Owner argues that Warren does not compare its sensor signal to any desired contact force, as argued by Petitioner, because Warren determines whether desired contact force is achieved by detecting a change in amplitude of vibration. *Id.* (citing Pet. 23; Ex. 1004 ¶¶ 302, 306, 311, 313, Figs. 21, 22A; Ex. 2027 ¶ 192).

Patent Owner also argues that, although the ’381 patent describes that different sensors may be used, the ’381 patent does not describe contact force may be calculated from Warren’s change in amplitude. PO Resp. 34 (citing Ex. 1001, 9:5–10; Ex. 1004 ¶ 306, Fig. 21; Ex. 2027 ¶ 193). Patent Owner further argues that “there is no teaching in Warren of using a desired contact force setpoint in units of force” and, thus, “there is no motivation to convert Warren’s change in amplitude to a contact force.” *Id.* (citing Ex. 1003 ¶ 95; Ex. 2027 ¶ 194). Patent Owner additionally argues that “the user is responsible for selecting the appropriate frequency / frequencies that correspond to the desired change in amplitude.” *Id.* (citing Ex. 1004 ¶ 306; Ex. 2020, 79:13–80:20). Patent Owner, thus, argues that Warren would not have rendered claim 1 unpatentable. *Id.* (citing Ex. 2027 ¶¶ 158–195).

(2) Petitioner's Reply

Petitioner replies that Patent Owner is “invent[ing] technical hurdles to calculating force from vibration amplitude, flatly ignoring Warren’s express teaching that the two are proportional.” Pet. Reply 1. According to Petitioner, Patent Owner admits that “the ’381 patent describes its sensors broadly to sense anything, ‘so long as the contact force(s) . . . may be calculated from the sensed physical characteristics.’” *Id.* at 3 (quoting Ex. 1001, 8:49–61) (citing also Pet. 21; PO Resp. 34; Ex. 1003 ¶¶ 90, 91). Petitioner argues that Warren’s vibration sensors satisfy the claim, because they sense a change in amplitude of vibration, from which contact force can be calculated, because the two are proportional to each other. *Id.* (citing Pet. 20–21; Ex. 1003 ¶¶ 90, 91; Ex. 1004 ¶¶ 302, 313).

Petitioner also argues that Warren teaches calculating contact force from the change in amplitude. Pet. Reply 3 (citing Ex. 1004 ¶¶ 287, 313–316). Petitioner, thus, argues that one of ordinary skill in the art “would have immediately recognized that Warren teaches a sensor from which ‘the contact force . . . may be calculated from sensed physical characteristics’ consistent with the ’381 patent and claims.” *Id.* (citing Ex. 1003 ¶¶ 90, 91).

Petitioner argues that, as pointed out by Patent Owner, Warren teaches varying elements of its dispenser to maintain a desired contact force between the dispenser and the substrate based on a comparison of detected contact force and a desired contact force. Pet. Reply 4 (citing PO Resp. 26; Ex. 1004 ¶¶ 283, 313–316, Fig. 22A, claims 54–56, 61, 65–67, 72). According to Petitioner, Warren explains that it determines contact force intensity down to micronewtons of force or smaller. *Id.* at 4–5 (citing Pet. 23, 25–27, 33; Ex. 1004 ¶¶ 287, 316). Petitioner also argues that

Warren describes force feedback control. *Id.* at 5 (citing Pet. 23, 25–27, 33; Ex. 1004 ¶ 316).

Petitioner further argues that “[t]he necessity of calculating contact force from the vibrating sensor output is built directly into Warren’s operating principles.” Pet. Reply 5. In order to maintain a desired contact force, Petitioner contends that “Warren must compare the vibrating force sensor’s reading against the desired force” and “must either convert the desired force into vibration amplitude units or convert the sensor’s amplitude output into units of force.” *Id.* (citing Ex. 1004 ¶ 289). Petitioner argues that Warren teaches calculating the contact force and controlling its dispenser by comparing calculated contact force to desired contact force. *Id.* at 5–6 (citing Ex. 1004 ¶¶ 301–316, 322, 324).

Petitioner also replies that calculating the contact force would have been obvious, because one of ordinary skill in the art “would have understood that to control to a desired force intensity, one would need to know the difference between the desired force and a detected force” and Warren provides express motivation. Pet. Reply 6 (citing Pet. 19–24; Ex. 1003 ¶¶ 89–91; Ex. 1004 ¶¶ 285, 301–307, 313–316). Petitioner argues that Warren states that knowledge of contact force intensity is required and identifies a need to determine accurately contact force intensity between a dispensing tip and a substrate surface. *Id.* at 6–7 (citing Pet. 19–21; Ex. 1003 ¶ 89; Ex. 1004 ¶¶ 285, 287, 302).

According to Petitioner, one of ordinary skill in the art would have compared calculated contact force and desired contact force using units of force to obtain an accurate result. Pet. Reply 7 (citing Pet. 23–24; Ex. 1003 ¶ 93; Ex. 1004 ¶¶ 313–316). Petitioner argues that Warren expresses a

desire to sense force with a high precision, thereby suggesting Warren does not rely solely on measuring a change in amplitude. *Id.* (citing Ex. 1004 ¶ 316). Petitioner also argues that the proportionality between change in amplitude and contact force means that contact force can be readily calculated. *Id.* at 7–8 (citing Pet. 20–21, 23; Ex. 1003 ¶¶ 86–90, 95; Ex. 1004 ¶ 313).

Regarding Patent Owner’s arguments about Young’s moduli and frequency selection, Petitioner replies that Warren teaches that the contact force is proportional to the change in amplitude and teaches a desire to compare the measured contact force to a desired contact force. Pet. Reply 8. Petitioner argues that Patent Owner has the burden to show undue experimentation was necessary to practice Warren. *Id.*

Petitioner also argues that Patent Owner’s infeasibility arguments support that calculating contact force could be done, because Patent Owner argues that properties relevant to calculating contact force were known for a variety of materials and could be looked up. Pet. Reply 8–9 (citing Pet. 23; PO Resp. 32; Ex. 1003 ¶ 95; Ex. 1042, 80:2–81:6; Ex. 2024, 6–8; Ex. 2027 ¶ 185). Petitioner further argues that Patent Owner’s contentions ignore that proportionality can be established by measurement and calibration. *Id.* at 9 (citing Ex. 1042, 100:13–104:14). Petitioner additionally argues that the evidence shows that calculating contact force from change in amplitude was common. *Id.* (citing Pet. 23; Ex. 1012 ¶¶ 34, 78; Ex. 1017 ¶¶ 6–7).

(3) Patent Owner’s Sur-Reply

Patent Owner replies that Petitioner does not address its argument that contact force is not detectable from a change in amplitude. PO Sur-reply 4 (citing PO Resp. 25–34; Pet. Reply 3–9). Patent Owner argues that

Petitioner misreads Warren's precision in micronewtons with a calculated contact force that is not taught in Warren. *Id.* at 4 (citing Pet. Reply 4–9; Ex. 1004 ¶ 316). Patent Owner also argues that the described precision includes many components in Warren. *Id.* at 4–5 (citing PO Resp. 15–16, 18–19, 21–22, 24–25; Ex. 1004 ¶¶ 278–279, 295, 361, Figs. 23A–C; Ex. 2027 ¶¶ 128–135).

Patent Owner argues again that detecting a change in amplitude is not detecting or calculating a contact force, and that Petitioner misreads Warren as comparing vibrating force to desired force. PO Sur-reply 5 (citing PO Resp. 26–27; Pet. Reply 5; Ex. 1004 ¶¶ 289, 313, 315–317; Ex. 2027 ¶¶ 163–170). Patent Owner further replies that Petitioner presents an improper, new theory about the necessity of detecting contact force. *Id.* at 5–6 (citing Pet. Reply 5–6). Patent Owner reiterates that Warren detects substrate contact by change in amplitude and contact is maintained if the feedback signal based on the amplitude change is at a constant level. *Id.* at 6 (citing PO Resp. 26–27; Ex. 1004 ¶¶ 289, 312, 313, Fig. 22A).

Patent Owner argues that the alternative obviousness theory is based on the flawed necessity argument, that Petitioner presents attorney argument about force intensity being a component of a force vector, and that obviousness requires more than just the ability to be determined. PO Sur-reply 6–7 (citing Pet. Reply 6–8). According to Patent Owner, it would not have been obvious to calculate a contact force from Warren's amplitude change with a reasonable expectation of success. *Id.* at 8 (citing PO Resp. 26–34; Ex. 2027 ¶¶ 163–195).

Patent Owner also argues that its declarant explained that calculating contact force from amplitude changes is more than looking up material

properties, and that there is no support that the calculation was commonplace. PO Sur-reply 7–8 (citing Pet. Reply 7–9; Ex. 1004 ¶¶ 168, 181, 191, Fig. 21; Ex. 2027 ¶¶ 181–184). Patent Owner further argues that Petitioner cannot presume enablement and, because Warren does not discuss calculating contact force, enablement is irrelevant. *Id.* at 8 (citing Pet. Reply 8).

Patent Owner also replies that Petitioner no longer relies on what was presented in the Petition and injects a new theory in reply that calculating contact force was common. PO Sur-reply 8 (citing Pet. 23; Pet. Reply 9). According to Patent Owner, Petitioner fails to rebut its declarant’s testimony. *Id.* at 9 (citing Ex. 1004, Fig. 21; Ex. 1017, Fig. 3; Ex. 2027 ¶ 178).

Patent Owner also argues that its declarant concluded that Petitioner’s additionally cited evidence fails to address how to convert Warren’s change in amplitude from a vibration to a contact force and, instead, do not calculate a contact force or differs from Warren’s frequency-dependent, varying amplitude change. PO Sur-reply 9 (citing PO Resp. 29–30; Ex. 1004, Fig. 21; Ex. 1012 ¶¶ 34, 77, 78, Figs. 2, 3; Ex. 1017, Fig. 3; Ex. 2027 ¶ 177). Patent Owner concludes that Petitioner fails to cure the deficiency that it was not common to calculate contact force from Warren’s amplitude change. *Id.*

(4) Petitioner Shows the Limitations

We find that a portion of Warren cited by Petitioner discloses that “[t]he transducer 3740 senses and transfers the changed vibration signal to an amplifier (not shown), which then creates a feedback signal that is generally proportional to the intensity of the physical contact of the dispenser 3700 with the substrate 3710” and “[t]he feedback signal is used to

control the position of the dispenser 3700 to maintain a desired force of contact between the dispenser 3700 and the substrate 3710.” Ex. 1004 ¶ 302; *see also id.* ¶ 313 (describing that “a change in the amplitude of vibration of the dispenser and/or the substrate” is sensed, the “change in amplitude is proportional to the force of contact between the dispenser and the substrate,” “a determination is made whether the contact force is that which is desired, based on the detected change in amplitude,” and, if it is not, then the position of the dispenser or the substrate is varied), Fig. 22A. Another cited portion discloses that “z-controller 3750 may be implemented with, e.g., a microprocessor.” *Id.* ¶ 303. Figure 18 of Warren shows a processor.

Petitioner’s arguments indicate, correctly, that “to calculate the contact force” requires more than merely “to sense a contact force” as discussed above for the previous limitation. Pet. 23–24. Also, as we discussed above, we find that Warren discloses sensing a contact force indirectly through measuring a change in amplitude, which according to Warren is proportional to the contact force. Ex. 1004 ¶¶ 300, 313, 315, Figs. 18, 22A.

Patent Owner does not dispute that Warren teaches or suggests “a controller configured to receive a signal from the one or more sensors on the extruder,” but argues that Warren does not disclose a controller configured to “to calculate the contact force.” *See* PO Resp. 16–34. We agree with Patent Owner that Warren does not teach a controller configured to perform that calculation, but Petitioner persuades us, and we determine, that Warren would have motivated calculating the contact force from the change in amplitude.

Having considered the evidence of record and the expert testimony on both sides, we find Petitioner’s argument credible and persuasive that a person of ordinary skill in the art would have had the motivation and capability to modify Warren by explicitly calculating the contact force between a dispensing tip and a substrate surface. Pet. 23–24; Ex. 1003 ¶¶ 94, 95. Warren itself calls out the contact force as a quantity of interest in controlling a three-dimensional printer. According to Warren, “a need exists for a system and method for controlling the position of one or more elements of a depositing system that *accurately determines the intensity of the contact force* between a dispensing rip and a substrate surface to maintain a desired contact force between the dispenser and the substrate.” Ex. 1004 ¶ 287 (emphasis added). We, thus, find factual support for Petitioner’s asserted motivation. *Id.*

We also find credible and persuasive the testimony of Petitioner’s declarant that “calculating the contact force would [have] facilitate[d] programming Warren’s controller to a desired contact force setpoint because the setpoint used by the controller and the desired contact force would be in the same units (force)” and would have allowed a user to set, adjust, or view the contact force in values of force, thereby facilitating user interaction. Ex. 1003 ¶ 95.

Also, in view of Warren’s “need . . . for controlling the position of one or more elements of a depositing system that accurately determines the intensity of the contact force” (Ex. 1004 ¶ 287) and because Petitioner’s proposed motivation to modify Warren is based, in part, on Warren’s own teachings, we do not agree with Patent Owner that Petitioner is resorting to impermissible hindsight. PO Resp. 29, 33.

We also disagree with Patent Owner that there would have been no reasonable expectation of success in calculating the contact force or that performing such a calculation would have been outside the ordinary level of skill in the art. PO Resp. 27–33. The record does not support Patent Owner’s argument.

Warren describes that a change in amplitude of vibration is proportional to the force of contact between the dispenser and the substrate. Ex. 1004 ¶¶ 302, 313, 315, Fig. 22A. Patent Owner does not address Warren’s express disclosures of the proportionality between change in amplitude and force of contact. *See* PO Resp. 29–33; Pet. Reply 1. We find credible the testimony of Petitioner’s declarant that determining the proportionality constant would have been within the level of ordinary skill in the art. Ex. 1003 ¶ 95 (citing Ex. 1004 ¶¶ 286, 287).

We have considered the testimony of Patent Owner’s declarant that there would be challenges in determining the proportionality constant based on material and mechanical properties (Ex. 2027 ¶¶ 179–195), but in light of the evidentiary record as a whole, this testimony does not lead us to the view that there would have been no motivation to determine the proportionality constant or that this would have been outside the level of ordinary skill in the art. *See, e.g.*, Ex. 1042, 100:13–104:13 (Patent Owner’s declarant explaining how one could establish the relationship between a sensor frequency and a force experimentally). We also agree with Petitioner that Patent Owner’s infeasibility arguments indicate that it was possible to calculate contact force, because Patent Owner shows that properties relevant to calculating contact force were known for a variety of materials, beyond those disclosed in Warren. PO Resp. 31–33; Pet. Reply 8–9.

Based on the full record and for the reasons above, Petitioner persuades us, and we find, that Warren teaches or suggests “a controller configured to receive a signal from the one or more sensors on the extruder” and that it would have been obvious that Warren’s controller is configured “to calculate the contact force between the extruder and the separate structure.”

e) Reason to Modify

Petitioner argues that Warren suggests combining aspects of its disclosure. Pet. 11 (citing Ex. 1003 ¶ 66; Ex. 1004 ¶¶ 93, 230–252, 283–318). Petitioner proposes applying Warren’s through-nozzle dispenser as dispenser 3700 in the vibrating force sensor configuration. *Id.* at 12 (citing Ex. 1003 ¶ 67; Ex. 1004 ¶¶ 226–252, 283–318).

Petitioner argues that one of ordinary skill in the art would have been motivated to do so, because Warren states that “dispenser 3700 may be implemented differently” and is not limited to the implementation described. Pet. 12 (citing Ex. 1004 ¶¶ 294, 299). According to Petitioner, the proposed combination would be combining known elements using known techniques to achieve predictable results. *Id.* (citing Ex. 1003 ¶ 68).

Another motivation, Petitioner argues, would be that, because of its more precise flow control capability via its linear actuator 144, the through-nozzle design would be used in dispenser 3700. Pet. 12–13 (citing Ex. 1003 ¶ 69; Ex. 1004 ¶ 243). Petitioner also argues that linear actuator 144 is conventional and its inclusion in dispenser 3700 would be a predictable combination suggested by Warren’s statement that aspects in some embodiments can be combined. *Id.* at 13 (citing Ex. 1003 ¶ 70; Ex. 1004 ¶¶ 93, 243).

Petitioner further argues that applying vibration force sensing to the through-nozzle dispenser would avoid damage to the nozzle or substrate, facilitate control over the deposition geometry, and overcome issues with agglomeration or sticking. Pet. 13–14 (citing Ex. 1003 ¶ 71; Ex. 1004 ¶ 286). Petitioner additionally argues that the proposed combination is nothing more than integrating complementary teachings from the same reference related to the same technology. *Id.* at 14 (citing Ex. 1003 ¶ 72).

(1) Patent Owner's Response

Patent Owner responds that Petitioner's reasons to combine are insufficient. PO Resp. 16–17 (citing Pet. 11–14), 25 (citing Ex. 2027 ¶¶ 119–157). In particular, Patent Owner responds that Warren does not invite using vibration sensing with its through-nozzle design. *Id.* at 17 (citing Pet. 12). Patent Owner argues that Warren merely states that dispenser 3700 is not limited to the implementations shown in Figures 19, 20A, and 20B, and there is no motivation to implement dispenser 3700 as a through-nozzle design. *Id.* at 17–18 (citing Ex. 1004 ¶¶ 278, 295, 298–300, Figs. 18, 19, 20A, 20B, 23A–23C; Ex. 2027 ¶¶ 118–127).

Patent Owner also responds that Warren's capillary dispenser already provides high-precision, Warren teaches switching from the through-nozzle dispenser to the capillary dispenser for higher detail and precision, and Warren teaches using a through-nozzle design for less detailed dispensing. PO Resp. 18–19 (citing Pet. 12–13; Ex. 1004 ¶¶ 260, 278), 19–20 (citing Ex. 1004 ¶¶ 243, 260, 279, 298; Ex. 2027 ¶¶ 128–136, 147, 148, 154, 156). Patent Owner, thus, argues there would have been no motivation to use the less-precise through-nozzle dispenser for high precision. *Id.* at 19 (Ex. 2027 ¶¶ 128–136).

Patent Owner further responds that there is no motivation to include a linear actuator in the capillary dispensers or quill-pen designs, because the suggestion to combine aspects applies only to combining tools, not adding features from one design to another. PO Resp. 20–21 (citing Pet. 13; Ex. 1004 ¶¶ 93, Figs. 2A–2F; Ex. 2027 ¶¶ 137–146). Patent Owner argues that Petitioner relies on impermissible hindsight, because there would have been no need for a linear actuator to open and close capillary dispensers. *Id.* at 21–22 (citing Ex. 1004 ¶¶ 231, 234, 260, 279, 298; Ex. 2027 ¶¶ 147–149).

Patent Owner also argues that there was no motivation to provide Warren’s through-nozzle dispenser with vibrating force sensor capabilities, because the through-nozzle dispenser is controlled through the xyz motion of the dispenser to enable precise control of deposition geometry. PO Resp. 22–24 (citing Pet. 13–14; Ex. 1004 ¶¶ 227, 228, 234, 243, Fig. 36; Ex. 2027 ¶¶ 149–154). Patent Owner notes that the proposed combination is to apply the through-nozzle to dispenser 3700, not the other way around, as implicated by Petitioner’s assertion to add vibrating force sensor capabilities to the through-nozzle dispenser. *Id.* at 22 (citing Pet. 11–12).

Patent Owner further responds that Warren teaches that other dispensers have a specific need for vibration control. PO Resp. 24 (citing Ex. 1004 ¶¶ 234, 260, 278, 279, 295, 298). Patent Owner argues that the agglomeration issue is related to the quill-pen dispenser. *Id.* at 24–25 (citing Pet. 14; Ex. 1004 ¶¶ 298, 331, 332). Patent Owner, thus, argues that there would be no reason to apply a solution for dispensing inks to the through-nozzle dispenser. *Id.* at 25 (citing Ex. 2027 ¶¶ 155, 156).

(2) Reply Arguments

Petitioner replies that both Warren's through-nozzle and capillary dispensers are relied upon, and that Warren's capillary dispenser is the fabrication tool and uses vibration force sensing. Pet. Reply 1 (citing Pet. 15–17). According to Petitioner, Patent Owner does not dispute that Warren's capillary dispenser uses vibrating force sensing. *Id.* (citing PO Resp. 24).

Petitioner points to Warren's claims 54–59 and 65–70 to support that vibration sensing is used with the through-nozzle. Pet. Reply 2. Petitioner, thus, argues that Warren supports that vibrating force sensor concepts are used with other configurations. *Id.* (citing Pet. 12–14; Ex. 1003 ¶¶ 68–72). Petitioner also argues that Warren expressly teaches that its through-nozzle design has precise rate and speed control. *Id.* at 2–3 (citing Ex. 1003 ¶ 69; Ex. 1004 ¶¶ 234, 243).

Patent Owner replies that Petitioner does not contest its responsive arguments and, instead, presents a new theory. PO Sur-reply 1–2 (citing Pet. 11–14; PO Resp. 17–25; Pet. Reply 1–3). Patent Owner argues that Petitioner cites new portions of Warren and the cited claims of Warren do not support the proposed combination, because they are directed to dispensers with multiple tools. *Id.* at 2–3 (citing PO Resp. 11–25; Ex. 1004 ¶¶ 278, 318, Figs. 23A–23C). Patent Owner also argues that Warren teaches that its through-nozzle is less precise, thus undermining Petitioner's motivation to combine. *Id.* at 3–4 (citing PO Resp. 15–16, 18, 24–25; Pet. Reply 2; Ex. 1004 ¶ 278, Figs. 23A–23C; Ex. 2027 ¶¶ 128–136, 155, 156).

(3) Petitioner Shows a Reason to Combine Embodiments

We find that Petitioner cites portions of Warren that disclose “dispenser 3700 may be implemented differently, depending upon the application” (Ex. 1004 ¶ 294), “[f]or example, capillary vibro-sensor dispensing units, such as that depicted in FIG. 19” (*id.* ¶ 295) and “[a]s another example, a quill-pen may be used . . . [as] shown in detail in FIGS. 20A and 20B” (*id.* ¶ 298). *See also* Pet. 12 (citing Ex. 1004 ¶¶ 226–252, 283–318). Warren describes both capillary and quill-pen dispensers as “exemplary.” Ex. 1004 ¶¶ 295, 296, 298. Warren reiterates that “[t]he material dispensers illustrated in FIGS. 19, 20A and 20B are shown by way of example only” and immediately follows that statement with the disclosure that “dispenser 3700 need not be limited to these implementations.” *Id.* ¶ 299. In view of the disclosures above, we find that Warren expressly does not limit dispenser 3700 to any particular implementation. *Id.* ¶¶ 294–296, 298, 299.

We also find that Petitioner cites portions of Warren that disclose “material dispenser 100 may include a through-nozzle design” that can include “linear actuator 144 to control valve opening and closing” and “valve 130 near the point of dispensing.” Ex. 1004 ¶ 231. We further find that another cited portion discloses that “[t]he rate and degree of valve opening and closing may be dynamically controlled by using a conventional linear actuator 144 to control the valve 130, which provides a means to control precisely the rate (speed) and the degree of valve opening and closing” and that “the valving mechanism may be synchronized with the xyz motion of the dispenser.” *Id.* ¶ 234. Warren also discloses that the valve’s

“position is not changed until near the end of the motion or at certain ‘trouble spots’ in the middle of a path.” *Id.* ¶ 238.

Based on our findings above, Petitioner persuades us that one of ordinary skill in the art would have applied Warren’s through-nozzle dispenser as dispenser 3700 in the vibrating force sensor configuration. We credit Petitioner’s testimonial evidence because its citations to Warren support the testimony. Ex. 1003 ¶¶ 66–70; Ex. 1004, 93, 226–252, 283–318.

We agree with Petitioner’s declarant that Warren provides express motivation and suggestion for the proposed modification (Ex. 1003 ¶¶ 69, 70), and that the proposed modification would have represented combining known elements using known techniques to achieve predictable results and would have been nothing more than integrating complementary teachings from the same reference related to the same technology (*id.* ¶¶ 68, 72). Because the proposed modification involves integrating complementary teachings from the same reference, we also determine that there would have been a reasonable expectation of success. *Id.* ¶ 72.

Turning to Patent Owner’s responsive arguments, we find that Warren motivates or suggests using the through-nozzle design in dispenser 3700. Ex. 1003 ¶¶ 69, 70; Ex. 1004 ¶¶ 294–296, 298, 299. We, thus, disagree that there is no invitation or motivation for Petitioner’s proposed modification. PO Resp. 17–18.

Regarding Warren’s capillary dispenser already providing high-precision and, therefore, failing to provide a motivation or reason to use the through-nozzle dispenser for high-precision (PO Resp. 18–19), we find that Warren does provide a motivation or suggestion to use the through-nozzle dispenser, because “dispenser 3700 may be implemented differently,

depending upon the application.” Ex. 1004 ¶¶ 294–296, 298, 299. We also determine that the proposed modification would have represented combining known elements using known techniques to achieve predictable results and would have been nothing more than integrating complementary teachings from the same reference related to the same technology. Ex. 1003 ¶¶ 68, 72. Also, because we find that Warren motivates or suggests Petitioner’s proposed modification, we do not agree that Petitioner relies on impermissible hindsight or hindsight bias. PO Resp. 21–22.

Based on the full record and for the reasons above, we determine that one of ordinary skill in the art would have made the proposed combination with a reasonable expectation of success.

f) Objective Evidence of Nonobviousness

Patent Owner does not present any objective evidence of nonobviousness in connection with any claim of the ’381 patent. See PO Resp.

g) Petitioner Shows that Claim 1 is Unpatentable over Warren

“Once all relevant facts are found, the ultimate legal determination [of obviousness] involves weighing of the fact findings to conclude whether the claimed combination would have been obvious to an ordinary artisan.”

Arctic Cat Inc. v. Bombardier Recreational Prods. Inc., 876 F.3d 1350, 1361 (Fed. Cir. 2017) (quoting *In re Cyclobenzaprine Hydrochloride Extended-Release Capsule Patent Litig.*, 676 F.3d 1063, 1068–69 (Fed. Cir. 2012)).

Above, based on the full record before us, we provide our factual findings regarding (1) the level of ordinary skill in the art, (2) the scope and content

of the prior art, (3) any differences between the claimed subject matter and the prior art, and (4) objective evidence of nonobviousness.

In particular, we find that (1) Petitioner's proposed level of ordinary skill in the art is consistent with the prior art of record, (2) Warren teaches or suggests all the limitations of claim 1, and (3) one of ordinary skill in the art would have combined embodiments of Warren in the manner asserted by Petitioner with a reasonable expectation of success, and (4) no objective evidence of nonobviousness has been asserted in connection with any claim.

Weighing these underlying factual determinations, a preponderance of the evidence persuades us that claim 1 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

3. Claim 2

Claim 2 depends from claim 1 and recites "wherein the contact force is a force along an extrusion axis of the extruder." Ex. 1001, 13:5–7.

According to Petitioner, a contact force would be along the z-axis of the capillary vibro-sensor dispenser and through-nozzle dispenser design. Pet. 24 (citing Ex. 1003 ¶¶ 97, 98). Petitioner argues that "Warren's dispenser is oriented along the z-axis, which serves as the extrusion axis in this configuration" and, when the substrate is aligned to the x-y plane, "the contact force exerted at the tip of dispenser is directed along the extrusion axis." *Id.* (citing Ex. 1003 ¶ 99; Ex. 1004 ¶¶ 293, 294, Fig. 18). Petitioner also argues that Warren teaches "controlling the z-height of the substrate and/or dispenser in response to the contact force" and "even if the dispenser were not precisely oriented along the z-axis, there is a force component directed along the dispenser/extrusion axis and this force component is a contact force." *Id.* at 25 (citing Ex. 1003 ¶¶ 99, 100; Ex. 1004 ¶ 316).

a) Patent Owner's Response

Patent Owner responds that, if the contact force is along the extrusion axis that is normal to the substrate, then it cannot include a deflection force. PO Resp. 35 (citing Pet. 24–25, 28–29). Patent Owner also argues that, if it does include deflection force, then the contact force is not along the extrusion axis. *Id.*

Patent Owner further argues that the challenged patent uses a pair of sensors to isolate deflection forces from normal force and that Petitioner is resorting to hindsight. PO Resp. 35–36 (citing Ex. 1001, 9:34–24; Ex. 1003 ¶¶ 99, 114). Patent Owner contends that there is no support from Warren that, when the dispenser is not oriented along the z-axis, there is still a component that is the contact force. *Id.* at 36 (Ex. 1003 ¶¶ 99, 114). Patent Owner also contends that there is no teaching of calculating a contact force component. *Id.* Patent Owner, thus, argues that claim 2, along with claims 3 and 6, have not been shown to be unpatentable. *Id.* (citing Ex. 2027 ¶¶ 197–203).

b) Reply Arguments

Petitioner replies that its declarant opined that contact force would be a force component and that claims 2 and 6 are not mutually exclusive, because force can have components in orthogonal directions. Pet. Reply 10 (citing Pet. 25, 28–29; Ex. 1003 ¶¶ 99, 100, 114). Petitioner argues that Warren's nozzle might not be normal to the substrate, such as for conformal or curved surfaces. *Id.* (citing Ex. 1003 ¶¶ 101–103; Ex. 1004 ¶ 316, Fig. 22). Petitioner also argues that its declarant opined that friction from contact with a curved surface causes a deflection force. *Id.* at 10–11 (citing Pet. 25; Ex. 1003 ¶¶ 101–103; Ex. 1004 ¶¶ 316, 322).

Patent Owner replies that Petitioner introduces a new argument about force having orthogonal components. PO Sur-reply 10 (citing Pet. 25; Pet. Reply 10–11; Ex. 1003 ¶¶ 101–103). Patent Owner also argues that Petitioner ignores that claims 2 and 6 require that the contact force is a force along an extrusion axis or normal to a surface, and that claim 3 requires including a deflection force. *Id.* Patent Owner, thus, argues that, even if a force has components, it cannot be both a force along the extrusion axis and normal to a surface and further include another force. *Id.* (citing PO Resp. 35–36; Ex. 2027 ¶¶ 197–203).

c) Petitioner Persuades us that Claim 2 is Unpatentable

We find that Petitioner cites portions of Warren that disclose and show that its dispenser is oriented along a z-axis, its substrate is in the x-y plane, and, when the dispenser contacts the substrate, a contact force would be exerted at the tip of the dispenser and, thus, along the axis of the extruder. Ex. 1004 ¶¶ 293 (“the substrate 3710 in FIG. 18 is shown as being flat”), 316 (“the force feedback control continuously corrects the dispensing structure’s z-height position as the z height of the substrate surface changes, either by modifying the dispenser’s position, the substrate’s position, or both”), Fig. 18. We credit Petitioner’s testimonial evidence for claim 2, because the cited portions of Warren support it. Ex. 1003 ¶ 99; Ex. 1004 ¶¶ 293, 294, 316, Fig. 18.

Patent Owner’s responsive argument does not address why the contact force in the embodiment shown in Warren’s Figure 18 would not be along the extrusion axis, as argued by Petitioner. PO Resp. 35–36; PO Sur-reply 10. Patent Owner, instead, focuses on Petitioner’s contact force

further including or not including a deflection force. Claim 2, however, does not require a deflection force.

Because Petitioner points us to disclosures in Warren with credible testimonial support, we do not agree with Patent Owner that Petitioner is resorting to impermissible hindsight. Ex. 1003 ¶ 99; Ex. 1004 ¶¶ 293, 316, Fig. 18. Also, for the reasons given above for claim 1, we determine that it would have been obvious to calculate the contact force. PO Resp. 36.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 2. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 2 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

4. Claim 3

Claim 3 depends from claim 1 and recites “wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.” Ex. 1001, 13:8–10.

Petitioner argues that “[t]he '381 patent distinguishes a ‘deflection force’ from a ‘normal force’” and that Warren’s contact force “includes a deflection force due to friction from contact of the moving dispenser against the surface the material is being dispensed on as the dispenser traverses its build path.” Pet. 25 (citing Ex. 1001, 9:23–24; Ex. 1003 ¶¶ 101–103; Ex. 1004 ¶¶ 316, 322).

We find that Petitioner cites portions of Warren that disclose “[c]ontrol applied in this manner allows for dispensing to be accomplished onto conformal surfaces” by “continuously correct[ing] the dispensing structure’s z-height position as the z-height of the substrate surface changes”

and that “[c]apillary vibro-sensoric dispensers as illustrated in this embodiment possess tactile properties that enable them to follow and to cover curved surfaces.” Ex. 1004 ¶¶ 316, 322.

We credit Petitioner’s testimonial evidence for claim 3, because the cited portions of Warren support it. Ex. 1003 ¶ 102; Ex. 1004 ¶¶ 316, 322. We agree that “[t]he contact force in Warren . . . includes a deflection force due to friction from contact of the dispenser against the surface the material is being dispensed on as the dispenser traverses its build path.” Ex. 1003 ¶ 102.

Patent Owner provides its response for claim 3 together with claim 2. PO Resp. 35–36. The parties also provide reply arguments for claim 3 together with claim 2. Pet. Reply 10–11; PO Sur-reply 10. Patent Owner’s responsive argument does not address why the friction from contact of the dispenser against a build surface as the dispenser travels would not teach or suggest the “deflection force exerted by the separate structure on a tip of the extruder,” required by claim 3. PO Resp. 35–36; PO Sur-reply 10.

Patent Owner, instead, contends that a contact force along the extrusion axis that is normal to the substrate cannot include a deflection force. PO Resp. 35. While Warren’s dispenser is stationary, contacting the substrate, and aligned with the z-axis (as shown in Warren’s Figure 18), we find that there would be a contact force along the extrusion axis that is normal to the substrate, but, when the dispenser is moving to dispense build material, we find that the force at the tip of the contact would include a friction force, as pointed out by Petitioner’s declarant. Ex. 1003 ¶ 102.

We do not agree with Patent Owner that a contact force that is normal to the substrate and includes a deflection force would be mutually exclusive

in view of the claim language that does not limit the circumstances under which a contact force can include the recited deflection force. Claims 2 and 3 both depend from claim 1, and even if the two forces were mutually exclusive, claims 2 and 3 by their dependency would cover different, and maybe mutually exclusive, circumstances of contact force.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 3. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 3 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

5. *Claim 4*

Claim 4 depends from claim 1 and recites “wherein the separate structure includes an object being fabricated by the three-dimensional printer.” Ex. 1001, 13:11–13.

Petitioner argues that the structure being built on substrate 3710 would be the “separate structure [that] includes an object being fabricated. Pet. 25–26 (citing Ex. 1003 ¶¶ 104–106; Ex. 1004 ¶¶ 88, 93, 295, 316, 324, 427, Fig. 18). Petitioner also argues that Warren’s vibration force sensing enables finding contact with a surface. *Id.* at 26 (citing Ex. 1004 ¶¶ 301–316, 375). Petitioner, thus, argues that one of ordinary skill in the art would have understood that Warren meets or would have rendered obvious the limitations of claim 4. *Id.* at 26–27 (citing Ex. 1003 ¶¶ 106, 107; Ex. 1004 ¶¶ 316, 324).

a) *Patent Owner’s Response*

Patent Owner responds that Petitioner is resorting to hindsight, because Warren repeatedly teaches that its sensor is intended for contact

between the dispenser and the substrate. PO Resp. 36–37 (citing Pet. 25–27; Ex. 1004 ¶¶ 287, 289, 302, 313–316). Patent Owner argues that Warren never teaches sensing contact between the dispenser and the object being fabricated, and that there is no teaching that the “separate structure” includes the object being fabricated. *Id.* at 37 (citing Ex. 2027 ¶¶ 206–208). Patent Owner also argues that contact with such an object would vary with material stiffness and deformation. *Id.* (citing Ex. 2024, Fig. 4.1; Ex. 2027 ¶ 208). Patent Owner, thus, argues that there is no teaching that a “separate structure” includes “an object being fabricated by the three-dimensional printer.” *Id.* (citing Ex. 2027 ¶¶ 204–209).

b) Reply Arguments

Petitioner replies that Warren does not restrict the surface to a substrate surface and expressly teaches control based on contact force so that dispensing can be accomplished on conformal surfaces by correcting z-height. Pet. Reply 11 (citing Pet. 26–27; Ex. 1003 ¶ 106; Ex. 1004 ¶ 316). Petitioner argues that Warren teaches sensing a force between the surface and the material being extruded, and that it would have been obvious that the surface included the object being fabricated. *Id.* (citing Ex. 1003 ¶¶ 106, 107; Ex. 1004 ¶¶ 295, 316).

Patent Owner replies that Petitioner fails to cure its deficiencies, merely repeats prior arguments, and fails to respond to the hindsight argument. PO Sur-reply 11. Patent Owner argues that Warren does not teach contact between the dispenser and the object being fabricated. *Id.* (citing PO Resp. 36–37; Ex. 2027 ¶¶ 204–209).

c) Petitioner Persuades Us that Claim 4 is Unpatentable

We find that Petitioner cites a portion of Warren that discloses Warren’s manner of control “allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects the dispensing structure’s z-height position as the z height of the substrate surface changes,” “enables . . . writing on curved surfaces,” and “enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity.” Ex. 1004 ¶ 316. We credit Petitioner’s testimonial evidence for claim 4, because the cited portions of Warren support it. Ex. 1003 ¶ 106; Ex. 1004 ¶¶ 88, 93, 295, 301–316, 324, 375, 427.

Based on our findings from Warren, we agree with Petitioner’s declarant that one of ordinary skill in the art would have understood “Warren’s description of using a dispenser with the vibrating force sensor to ‘maintain contact’ and to deposit material on ‘a layered surface’ built on the substrate to be, or render obvious, sensing contact force with a *separate structure* that *includes an object being fabricated*.” Ex. 1006 ¶ 106 (citing Ex. 1004 ¶¶ 316, 324). We, therefore, disagree with Patent Owner that Warren fails to teach or suggest sensing contact between the dispenser the object being fabricated. PO Resp. 36–37; PO Sur-reply 11. Because we find Warren teaches or suggests the limitations of claim 4, we also disagree that Petitioner is resorting to impermissible hindsight. PO Resp. 36.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 4. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 4 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

6. *Claim 5*

Claim 5 depends from claim 1 and recites “wherein the separate structure includes a build platform of the three-dimensional printer.”

Ex. 1001, 13:14–16.

Petitioner argues that Warren’s substrate 3710 is a build platform. Petitioner also argues that Warren teaches measuring contact force between its dispenser and a surface such as the surface of the substrate in a manner consistent with the description of the ’381 patent. Pet. 27–28 (citing Ex. 1001, 8:55–64; Ex. 1003 ¶¶ 108–111; Ex. 1004 ¶ 311, Figs. 18, 22).

We find that the cited portions disclose substrate 3710 on which a modeled structure is built. Ex. 1004 ¶ 311, Figs. 18, 22. We also credit Petitioner’s testimonial evidence because the citations to Warren support it. Ex. 1003 ¶ 110; Ex. 1004 Ex. 1004 ¶ 311, Figs. 18, 22. We agree that Warren teaches measuring contact force between its dispenser and a surface such as the surface of the substrate in a manner consistent with the description of the ’381 patent. Ex. 1001, 8:55–64; Ex. 1003 ¶ 110. Patent Owner responds that claim 5 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 5. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 5 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

7. *Claim 6*

Claim 6 depends from claim 1 and recites “wherein the contact force is a force normal to a surface of the separate structure.” Ex. 1001, 13:17–19.

Petitioner argues that the contact force of claim 1 would be a force normal to the surface of the substrate, because contact force at the tip of dispenser 3700 acts along the z-axis. Pet. 28–29 (citing Ex. 1003 ¶¶ 112–114; Ex. 1004 ¶¶ 293, 294, 301–303, Fig. 18). Petitioner also argues that Warren’s description comports with the description in the ’381 patent of its normal force between fabrication tool 300 and build platform 306. *Id.* at 29 (citing Ex. 1001, 8:65–9:10). Petitioner further argues that, if dispenser 3700 is not precisely normal to the surface of the substrate, it would have been understood that “there was a force component directed normal to the substrate and that this force component is a contact force.” *Id.* (citing Ex. 1003 ¶¶ 114, 115).

We find that the cited portions of Warren disclose that “the substrate may have irregular surfaces” instead of “being flat” and that “vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 dispenser with the substrate 3710.” Ex. 1004 ¶¶ 293, 302, Fig. 18. We credit Petitioner’s testimonial evidence for claim 6, because the cited portions of Warren support it. Ex. 1003 ¶ 114; Ex. 1004 ¶¶ 293, 294, 301–303, Fig. 18.

Based on our findings from Warren, we agree that one of ordinary skill in the art “would have understood that there was a force component directed normal to the substrate and that this force component was a contact force.” Ex. 1003 ¶ 114. Patent Owner provides its response for claim 6 together with claim 2. PO Resp. 35–36. The parties also provide reply

arguments for claim 6 together with claim 2. Pet. Reply 10–11; PO Sur-reply 10. For the reasons discussed above for claims 2 and 3, Patent Owner’s responsive arguments do not show a deficiency for claim 6. PO Resp. 35–36; PO Sur-reply 10.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 6. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 6 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

8. *Claim 9*

Claim 9 depends from claim 1 and recites “wherein each of the one or more sensors are selected from the group consisting of: capacitive sensors, electromagnetic sensors, optical sensors, potentiometric sensors, and piezoelectric sensors.” Ex. 1001, 13:27–31.

Petitioner argues that Warren teaches piezoelements, piezomembranes, and piezotransducers for measuring contact forces and a fiber optic sensor for monitoring vibration. Pet. 31 (citing Ex. 1003 ¶¶ 116–118; Ex. 1004 ¶¶ 283–306).

We find that the cited portions of Warren disclose a “piezomembrane” implemented with an electroceramic sensor, transducer, or oscillator” (Ex. 1004 ¶¶ 295, 296, 300), a “piezoelement” of the dispenser (*id.* ¶¶ 304, 306), and “piezotransducer” (*id.* ¶ 305). We credit Petitioner’s cited testimonial evidence, because Warren supports it. Ex. 1003 ¶ 117; Ex. 1004 ¶¶ 283–306. Patent Owner responds that claim 9 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 9. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 9 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

9. *Claim 10*

Claim 10 depends from claim 1 and recites “wherein the one or more sensors include one or more strain gauges.” Ex. 1001, 14:1–2.

Petitioner argues that Warren teaches piezoelectric devices that would have been understood to convert strain into an electrical output and, thus, understood to be strain gauges. Pet. 30 (citing Ex. 1003 ¶¶ 119–121; Ex. 1004 ¶¶ 300–302). Petitioner also argues that it would have been obvious to configure vibration sensor 3730 as a strain gauge. *Id.* (citing Ex. 1003 ¶¶ 120, 121).

We find that the portions of Warren cited by Petitioner describe that oscillator 3720 and transducer 3740 may be a “piezoceramic plate” or a “piezoelectric bimorph ceramic element.” Ex. 1004 ¶ 300. We also credit Petitioner’s cited testimonial evidence that such devices were commonly configured to convert mechanical strain to an electrical output and, thus, it would have been obvious to configure vibration sensor 3700 to sense strain of dispenser 3700, because the citations to the record support the testimony. Ex. 1003 ¶ 120; Ex. 1004 ¶¶ 300, 302; Ex. 1006 ¶¶ 44, 45, Fig. 7; Ex. 1012 ¶ 34. Patent Owner responds that claim 10 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 10. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 10 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

10. Claim 11

Claim 11 depends from claim 1 and recites

further comprising: one or more actuators mechanically coupled to the fabrication tool, and a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.

Ex. 1001, 14:3–11.

Petitioner relies on Warren's z-controller step motor for the "actuator mechanically coupled to the apparatus" and z-controller processor 3750 in communication with the z-controller step motor for the "control circuit."

Pet. 31–32 (citing Ex. 1003 ¶¶ 122–125; Ex. 1004 ¶ 302, Figs. 1, 18).

Petitioner argues that z-controller processor 3750 maintains a desired contact force between dispenser 3700 and substrate 3710 by using a feedback signal.

Id. at 32 (citing Ex. 1003 ¶ 126; Ex. 1004 ¶ 302). Petitioner also argues that dispenser 3700 would have been understood to be part of the "sensor." *Id.*

(citing Ex. 1003 ¶ 127). Petitioner further argues that, if a specified contact

force is not required between sensors and separate structure, then Warren

achieves a specified contact force in the same manner as the '381 patent. *Id.*

at 32–33 (citing Ex. 1003 ¶¶ 127, 128; Ex. 1004 ¶ 302).

a) Patent Owner's Response

Patent Owner responds that Warren does not teach a specified contact force and merely states that it desires a contact force based on amplitude change. PO Resp. 37 (citing Pet. 32; Ex. 1003 ¶ 127; Ex. 1004 ¶ 313), 38 (citing Ex. 2027 ¶¶ 210–214). Patent Owner also argues that the '381 patent expressly describes “a target for the contact force.” *Id.* at 38 (citing Ex. 1001, 11:45–48).

b) Reply Arguments

Petitioner replies that Warren compares the calculated force to desired force to determine whether to reposition the dispenser or substrate. Pet. Reply 11 (citing Ex. 1004 ¶¶ 313–316). Petitioner also argues that Warren teaches determining whether the contact force is the desired force and, if so, the process may stop. *Id.* at 12 (citing Ex. 1003 ¶¶ 122–128; Ex. 1004 ¶ 313). If not, Petitioner argues that Warren teaches that the position of the dispenser or substrate is changed. *Id.* (citing Ex. 1003 ¶¶ 122–128; Ex. 1004 ¶ 313). Petitioner, thus, argues that Warren controls the dispenser or substrate to achieve the desired contact force. *Id.* (citing Ex. 1003 ¶¶ 122–128).

Patent Owner replies that Petitioner fails to cure the deficiencies, fails to address its responsive arguments and adds improper new theories citing new portions of Warren. PO Sur-reply 11 (citing Pet. 30–33; Pet. Reply 11–12; Ex. 1003 ¶¶ 122–128). Patent Owner argues that Warren does not teach achieving a specified contact force and teaches detecting a change in vibration amplitude to determine desired contact force. *Id.* (citing PO Resp. 26–34, 37–38; Ex. 2027 ¶¶ 159–195). Patent Owner also argues that the '381 patent discloses build instructions with specified contact force. *Id.*

(citing Ex. 1001, 11:45–48). In response to the asserted new arguments, Patent Owner contends that Warren does not want a change in vibration amplitude and teaches targeting a constant amplitude which corresponds to absence of a specified contact force. *Id.* at 12 (citing Ex. 1004 ¶ 312).

c) Petitioner Persuades us that Claim 11 is Unpatentable

We find that Petitioner cites portions of Warren that disclose z-controller step motor 3760 and z-controller processor 3750. Ex. 1004 ¶ 302, Fig. 18. We credit Petitioner’s testimonial evidence for claim 11, because the cited portions of Warren support it. Ex. 1003 ¶¶ 124–127; Ex. 1004 ¶ 302, Figs. 18, 23A.

Patent Owner does not dispute that Warren teaches or suggests “one or more actuators mechanically coupled to the fabrication tool, and a control circuit in data communication with the one or more actuators and the one or more sensors,” as recited by claim 11. PO Resp. 37–38. Patent Owner’s responsive argument that Warren fails to teach “a specified contact force” because it merely describes a desired contact force based on amplitude change (*id.* at 37 (citing Ex. 1004 ¶ 313)) does not overcome Petitioner’s showing.

We find that Warren’s disclosure of “desired force of contact” (Ex. 1004 ¶ 302) or “desired contact force” (*id.* ¶ 313) teaches or suggests the required “specified contact force,” even if Warren’s desired force is based on an amplitude change, as argued by Patent Owner. Patent Owner’s argument implies that claim 11’s requirement “to achieve a specified contact force” must be by direct contact force determination and would exclude Warren’s determination through an amplitude change. That argument is not supported by the language of claim 11 or a proposed interpretation. *See* PO

Resp. 8 (“Patent Owner submits that the Board does not need to construe any claim terms in any particular way to conclude that the challenged claims are not unpatentable.”). Further, for the reasons given above for claim 1, Petitioner persuades us that one of ordinary skill in the art would have been motivated to modify Warren to calculate contact force, because “calculating the contact force would [have] facilitate[d] programming Warren’s controller to a desired contact force setpoint because the setpoint used by the controller and the desired contact force would be in the same units (force).” Ex. 1003 ¶ 95.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 11. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 11 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

11. Claim 12

Claim 12 depends from claim 1 and recites “wherein the controller is further configured to adjust operation of the three-dimensional printer according to one or more of the signal from the one or more sensors and the calculated contact force.” Ex. 1001, 14:12–16.

Petitioner argues that Warren’s controller uses calculated contact force, or it would have been obvious to do so, to compare to desired contact force. Pet. 33–34 (citing Ex. 1003 ¶¶ 129–131; Ex. 1004 ¶¶ 312–316, Figs. 18, 22A). Petitioner then argues that z-positioning of dispenser 3700 is controlled to maintain desired force of contact. *Id.* at 34–35 (citing Ex. 1003 ¶¶ 132, 133; Ex. 1003 ¶¶ 302, 303, 313).

Petitioner also argues that Warren teaches valve 130 of the through-nozzle dispenser controls flow of material and that the valve operates in conjunction with dispenser motion. Pet. 35–37 (citing Ex. 1003 ¶¶ 134, 135; Ex. 1004 ¶¶ 230–252, Figs. 11A–11D, 12A, 12B). Petitioner further argues that it would, thus, have been understood that opening the valve controls material feed rate. *Id.* at 36 (citing Ex. 1003 ¶ 136).

Petitioner also points to Warren’s teaching that temperature is controlled to adjust viscosity of the material and that, in turn, affects the flow characteristics of the material inside the nozzle. Pet. 37 (citing Ex. 1004 ¶¶ 212, 247, 248). Petitioner, thus, argues that it would have been obvious to have the feedback control scheme also control temperature on the dispenser. *Id.* at 37–38 (citing Ex. 1003 ¶¶ 137, 138; Ex. 1004 ¶ 93).

We find that the portions of Warren cited by Petitioner teach or suggest the additional limitations of claim 12. Ex. 1004 ¶¶ 230–252, 302, 303, 312–316, Figs. 11A–11D, 12A, 12B, 18, 22A. We credit Petitioner’s testimonial evidence because the citations to Warren support it. Ex. 1003 ¶¶ 131, 133–136; Ex. 1004 ¶¶ 302, 303, 309, 313, 316, Figs. 18, 22A. Patent Owner responds that claim 12 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 12. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 12 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

12. Claim 13

Claim 13 depends from claim 12 and recites “wherein the controller is configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.” Ex. 1001, 14:17–21. Petitioner refers to its arguments for claim 12. Pet. 38 (citing Ex. 1003 ¶¶ 139, 140).

Patent Owner responds that Petitioner fails to explain how material feed rate, speed of the dispenser, and temperature are controlled in response to calculated contact force. PO Resp. 38–39 (citing Pet. 35–39; Ex. 1003 ¶¶ 134–138). Patent Owner argues that change in vibration amplitude is used to control the position of the dispenser and that Warren does not teach that calculated contact force controls feed rate, speed of movement, or temperature. *Id.* at 39 (citing Ex. 2027 ¶ 219). Patent Owner also argues that Petitioner fails to point to any teaching. *Id.* (citing Ex. 2027 ¶¶ 215–219).

Petitioner replies that Warren teaches synchronizing the valve with dispenser motion, extruder temperature can control flow rate, and extruder speed controls the amount of material deposited. Pet. Reply 12 (citing Pet. 35–38; Ex. 1004 ¶¶ 212, 234, 316). Petitioner argues that it would have been understood that Warren is adjusting feed rate based on calculated contact force. *Id.* at 12–13 (citing Pet. 33–38).

Patent Owner replies that Petitioner does not explain how there is modulation in response to the calculated contact force and Warren does not teach changing feed rate, speed, or temperature in response to calculated contact force. PO Sur-reply 12 (citing Pet. 33–37; PO Resp. 38–39; Ex. 2027 ¶¶ 215–219). Patent Owner also argues that Petitioner presents a new argument. *Id.* (citing Pet. Reply 12–13).

We find that the portions of Warren cited by Petitioner disclose that “material dispenser 100 may include a through-nozzle design” that can include “linear actuator 144 to control valve opening and closing” and “valve 130 near the point of dispensing.” Ex. 1004 ¶ 231. We also find that another cited portion discloses that “[t]he rate and degree of valve opening and closing may be dynamically controlled by using a conventional linear actuator 144 to control the valve 130, which provides a means to control precisely the rate (speed) and the degree of valve opening and closing” and that “the valving mechanism may be synchronized with the xyz motion of the dispenser.” *Id.* ¶ 234. We credit Petitioner’s testimonial evidence, because the citations to Warren support it. Ex 1003 ¶ 134; Ex. 1004 ¶¶ 230–252, Figs. 11A–11D, 12A, 12B.

Patent Owner’s argument that the feed rate is not responsive to calculated contact force does not address the proposed modification. PO Resp. 38–39. In Petitioner’s proposed modification, “Warren’s controller controls (i) z-controller step motor for adjusting the z-position of the dispenser, (ii) the valve to provide synchronous adjustments to the flow of material from the dispenser, and (iii) the xyz speed of the dispenser in tandem with valve on the dispenser using the through-nozzle design.” Pet. 37 (citing Ex. 1003 ¶ 136). Petitioner, thus, proposes controlling feed rate “in tandem” with z-position adjustment so that both are ultimately based on the contact force. *See id.*; Ex. 1003 ¶ 136.

Based on the full record and for the reasons above, Petitioner persuades us, and we determine, that the proposed modification of Warren would have had the additional limitations of claim 13. Weighing our underlying factual determinations, a preponderance of the evidence

persuades us that claim 13 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

13. Claim 14

Claim 14 depends from claim 12 and recites “wherein the controller is configured to adjust a z-axis position of the extruder in response to the calculated contact force.” Ex. 1001, 14:22–24. Petitioner refers to its arguments for claim 12. Pet. 38 (citing Ex. 1003 ¶¶ 141, 142).

We find that the portions of Warren cited by Petitioner for claim 12 teach or suggest the additional limitations of claim 14. Ex. 1004 ¶¶ 230–252, 302, 303, 312–316, Figs. 11A–11D, 12A, 12B, 18, 22A. We credit Petitioner’s testimonial evidence because the citations to Warren support it. Ex. 1003 ¶¶ 131, 133–136, 142; Ex. 1004 ¶¶ 302, 303, 309, 313, 316, Figs. 18, 22A. Patent Owner responds that claim 14 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 14. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 14 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

14. Claim 15

Claim 15 depends from claim 12 and recites “wherein the controller is configured to adjust a speed of movement of the extruder in response to the calculated contact force.” Ex. 1001, 14:25–27. Petitioner refers to its arguments for claim 12. Pet. 38–39 (citing Ex. 1003 ¶¶ 143, 144).

We find that the portions of Warren cited by Petitioner for claim 12 teach or suggest the additional limitations of claim 15. Ex. 1004 ¶¶ 230–252, 302, 303, 312–316, Figs. 11A–11D, 12A, 12B, 18, 22A. We credit Petitioner’s testimonial evidence because the citations to Warren support it. Ex. 1003 ¶¶ 131, 133–136, 144; Ex. 1004 ¶¶ 302, 303, 309, 313, 316, Figs. 18, 22A.

Patent Owner provides its response for claim 15 together with claim 13. PO Resp. 38–39. The parties also provide reply arguments for claim 15 together with claim 13. Pet. Reply 12–13; PO Sur-reply 12.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 15. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 15 of the ’381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

15. Claim 16

Claim 16 depends from claim 12 and recites “wherein the controller is configured to adjust a temperature of the extruder in response to the calculated contact force.” Ex. 1001, 14:28–30. Petitioner refers to its arguments for claim 12. Pet. 39 (citing Ex. 1003 ¶¶ 145, 146).

We find that the portions of Warren cited by Petitioner for claim 12 teach or suggest the additional limitations of claim 16. Ex. 1004 ¶¶ 230–252, 302, 303, 312–316, Figs. 11A–11D, 12A, 12B, 18, 22A. We also find that Petitioner’s cited portions of Warren teach providing temperature control to adjust viscosity of materials and the viscosity impacts flow characteristics in the nozzle. *Id.* ¶¶ 212, 247, 248. We credit Petitioner’s testimonial evidence because the citations to Warren support it. Ex. 1003

¶¶ 131, 133–138, 142; Ex. 1004 ¶¶ 93, 212, 247, 248, 302, 303, 309, 313, 316, Figs. 18, 22A.

Patent Owner provides its response for claim 16 together with claim 13. PO Resp. 38–39. The parties also provide reply arguments for claim 16 together with claim 13. Pet. Reply 12–13; PO Sur-reply 12.

Based on the full record, Petitioner persuades us, and we find, that Warren teaches or suggests the additional limitations of claim 16. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 16 of the '381 patent is unpatentable over Warren. *Arctic Cat*, 876 F.3d at 1361.

E. Asserted Obviousness Based on Warren and Dunn

1. Dunn (Ex. 1007)

Dunn is directed to “a deposition device in a three-dimensional modeling machine.” Ex. 1007, Abstract. Dunn discloses a “multi-axis sensor assembly” with “the capability of sensing surfaces in the X and Y directions” in addition to “sensing surfaces in the Z-direction.” *Id.* ¶ 69.

2. Claim 3

Claim 3 depends from claim 1 and recites “wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.” Ex. 1001, 13:8–10.

Petitioner argues that “Warren experiences a deflection force due to friction from contact of the dispenser against the surface the material is being deposited on” and that the proposed combination with Dunn would have sensed force in the x, y, and z directions, thereby sensing the deflection due to friction. Pet. 41 (citing Ex. 1003 ¶¶ 149–151).

a) Reason to Combine

Petitioner argues that “Warren discloses a 3D printing system incorporating force feedback control to maintain consistent contact force for successive layer-by-layer fabrication” but only a single-axis sensor configuration, and also discloses “xyz motion of the dispenser.” Pet. 40 (citing Ex. 1004 ¶ 234, Fig. 18). Petitioner further argues that Warren is not limited to its specific embodiments. *Id.* (citing Ex. 1004 ¶ 572).

According to Petitioner, Warren would have been combined with Dunn “to expand Warren’s single-axis example into a multi-axis configuration for contact force sensing along two or more non-parallel axes (e.g., the x, y and/or z axes) to improve the situational awareness of the resulting dispensing system during the xyz motion.” Pet. 41 (citing Ex. 1003 ¶¶ 147, 148). Petitioner also argues that there would have been a reasonable expectation of success “to achieve predictable improvements (i.e., multi-axis) without impacting the operating principle of Warren’s dispenser system.” *Id.* (citing Ex. 1003 ¶ 148).

(1) Patent Owner’s Response

Patent Owner responds that there would have been no motivation to combine, because (1) Dunn’s multi-axis sensor design is for offset calibrations, not for force sensing; (2) Dunn’s multi-axis sensor design is used for a dedicated assembly that uses a plunger, spring, and separate tip to sense a material pad, not contact with an extruder or its tip; (3) Dunn’s assembly would impede Warren’s described precise control; and (4) adding multiple vibration oscillators and sensors to Warren’s dispenser would frustrate the sensing capabilities of Warren’s vibration sensing teachings. PO Resp. 42–43 (citing Pet. 40–41; Ex. 1004 ¶¶ 227, 257, 278, 279, Fig. 18;

Ex. 1007 ¶¶ 69–73, Figs. 9, 10; Ex. 2027 ¶¶ 224–227). Patent Owner also argues that there would have been no reasonable expectation of success because vibrations from one oscillator would impede other sensors. *Id.* at 43 (citing Ex. 2027 ¶¶ 221–228), 44 (citing Ex. 1004, Fig. 18; Ex. 2027 ¶¶ 230–232).

Patent Owner also responds that the proposed “combination does not include multi-axis sensing to sense any force exerted by the separate structure on the tip of the extruder, much less to sense a deflection force.” PO Resp. 44 (citing Pet. 41; Ex. 2027 ¶ 231). Patent Owner argues that Dunn discloses a separate assembly with a plunger to sense material pad, not sensing a force exerted on an extruder tip. *Id.* (citing Ex. 1004, Fig. 18; Ex. 1007 ¶¶ 69–73; Ex. 2027 ¶¶ 230–232).

(2) Reply Arguments

Petitioner replies that Warren already teaches calculating force from a vibrating sensor and it would have been obvious to expand its single-axis sensing into a multi-axis configuration, as taught by Dunn. Pet. Reply 13 (citing Pet. 40; Ex. 1003 ¶ 148). Petitioner also argues that Warren would have benefited from a multi-axis configuration, and Dunn evidences that multi-axis configurations were known. *Id.* (citing Pet. 40–41; Ex. 1003 ¶¶ 147, 148; Ex. 1004 ¶ 316; Ex. 1007 ¶ 96). Petitioner also argues that making the combination would have achieved predictable improvements without detracting from Warren’s operation. *Id.* at 13–14 (citing Pet. 41; Ex. 1003 ¶ 148). Petitioner also replies that the combination senses force, as required by claim 3. *Id.* at 14 (citing Pet. 41; Ex. 1003 ¶¶ 149–151).

Patent Owner replies that Petitioner fails to rebut its responsive arguments. PO Sur-reply 13 (citing PO Resp. 42–43). Patent Owner argues

that it is not arguing bodily incorporation but a deficient combination. *Id.* (citing Ex. 2027 ¶ 228). Patent Owner also argues that Petitioner presents an improper new theory based on Dunn’s other multi-axis configuration that was not previously cited in the Petition. *Id.* at 13–14 (citing Pet. 39–41; Pet. Reply 13; Ex. 1003 ¶¶ 52, 53, 147, 148; Ex. 1007 ¶¶ 69, 70, Fig. 9).

b) Petitioner Persuades us that Claim 3 is Unpatentable

For the reasons given above for the challenge to claim 3 based on Warren alone, Petitioner persuades us that the claim is unpatentable. For the following reasons, Petitioner also persuades us that claim 3 is unpatentable over Warren and Dunn.

We find that Petitioner’s proposed combination of Warren and Dunn teach or suggest the additional limitations of claim 3 and that one of ordinary skill in the art would have made the combination in the manner asserted with a reasonable expectation of success. Ex. 1003 ¶¶ 147–151. In particular, we agree that Warren shows a single-axis sensor and xyz motion of its dispenser (Ex. 1004 ¶ 234, Fig. 18) and that Warren does not limit itself to specific embodiments (*id.* ¶ 572). We also agree that Warren suggests a desire for multi-axis sensing and that Dunn provides an example of a multi-axis sensor. Ex. 1003 ¶ 148.

We further agree that Warren would have been combined with Dunn “to expand Warren’s single-axis example into a multi-axis configuration for contact force sensing along two or more non-parallel axes (e.g., the X and Y axes in addition to the Z axes) to improve the situational awareness of the resulting dispensing system during the xyz motion.” Ex. 1003 ¶ 148. We additionally agree that there would have been a reasonable expectation of success. *Id.*

Patent Owner's argument that one of ordinary skill in the art would not have applied Dunn, because Dunn's multi-axis sensor design is for offset calibrations, not for force sensing, and uses a different sensor design, does not address the proposed combination. Petitioner proposes using the multi-axis configuration of Dunn in Warren. Pet. 41. Petitioner does not further propose using multi-axis configuration of Dunn for the same purpose with the same sensors. *See id.*

Also, Patent Owner's arguments that combining with Dunn would impede Warren's precise control and frustrate Warren's vibration sensing capabilities do not have supporting evidence that the proposed combination would have required a large assembly or would have had interfering vibrations from several oscillators. PO Resp. 43; Ex. 2027 ¶¶ 226, 227. These arguments appear to relate more to reasonable expectation of success, rather than whether or not the combination would have been made. PO Resp. 43. To the extent they are related to reasonable expectation of success, there is no evidence that the proposed modification was beyond either party's proposed level of ordinary skill in the art. Pet. 4; PO Resp. 8–9.

Based on the full record and for the reasons above, Petitioner persuades us, and we determine, that Warren and Dunn teach or suggest the additional limitations of claim 3 and that one of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 3 of the '381 patent is unpatentable over Warren and Dunn. *Arctic Cat*, 876 F.3d at 1361.

3. *Claim 7*

Claim 7 depends from claim 1 and recites “wherein the one or more sensors are collectively operable to sense a force between the fabrication tool and the separate structure along two or more non-parallel axes.”

Ex. 1001, 13:19–22.

Petitioner argues that its proposed combination would have been “operable to sense a force ***along two or more non-parallel axes*** (e.g., the x, y or z axes).” Pet. 42 (citing Ex. 1003 ¶¶ 152, 153). Patent Owner responds that claim 7 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record and for the reasons given above for claims 1 and 3, Petitioner persuades us, and we determine, that Warren and Dunn teach or suggest the additional limitations of claim 7 and that one of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 7 of the ’381 patent is unpatentable over Warren and Dunn. *Arctic Cat*, 876 F.3d at 1361.

4. *Claim 8*

Claim 8 depends from claim 7 and recites “wherein the one or more sensors are collectively operable to sense a force between the fabrication tool and the separate structure along three or more non-parallel axes.”

Ex. 1001, 13:23–26.

Petitioner argues that its proposed combination would have been “operable to sense a force ***along three or more non-parallel axes*** (e.g., the x, y or z axes).” Pet. 42 (citing Ex. 1003 ¶¶ 154, 155). Patent Owner

responds that claim 8 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 35 (citing Ex. 2027 ¶ 196).

Based on the full record and for the reasons given above for claims 1 and 3, Petitioner persuades us, and we determine, that Warren and Dunn teach or suggest the additional limitations of claim 8 and that one of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 8 of the ’381 patent is unpatentable over Warren and Dunn. *Arctic Cat*, 876 F.3d at 1361.

F. Asserted Obviousness Based on Calderon and RepRap20208

1. Calderon (Ex. 1009)

Calderon discloses “modeling machines which form three-dimensional objects by depositing modeling material onto a substrate mounted to a modeling platform.” Ex. 1009, 1:5–10, Abstract. Figure 1 of Calderon is reproduced below.

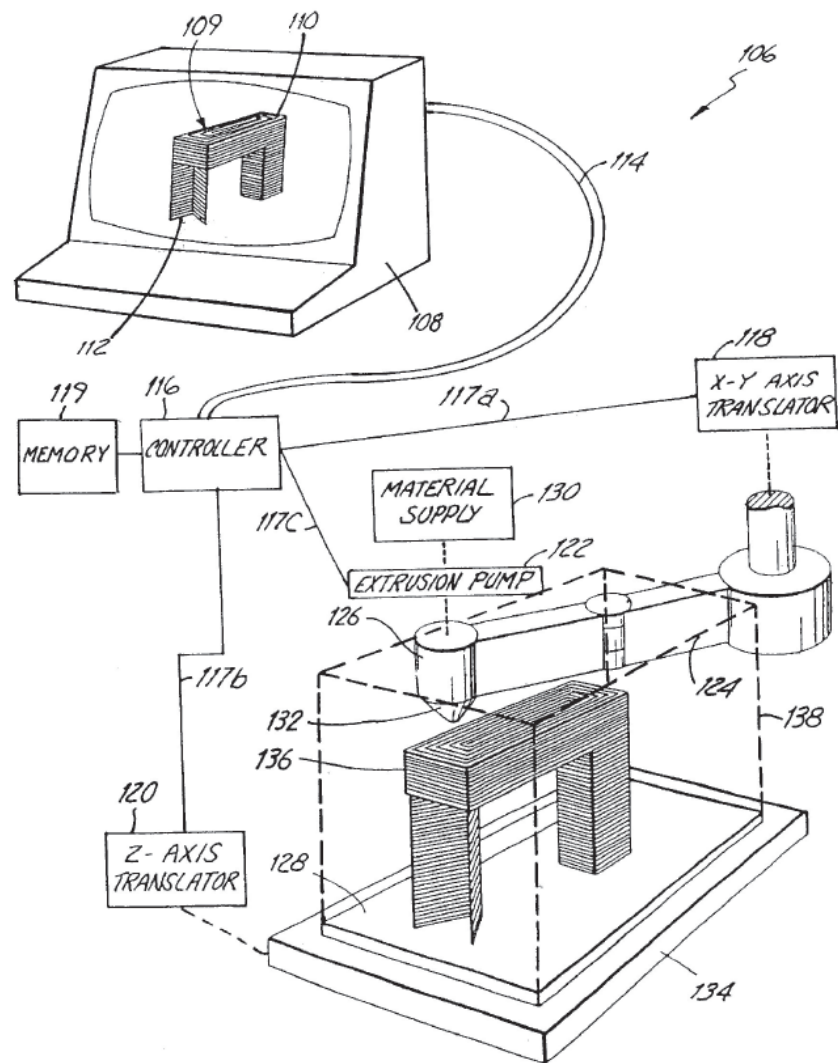


FIG. 1

Figure 1 shows “a schematic of a representative generic extrusion-based, layered modeling system.” Ex. 1009, 3:66–67. “A computer aided design (CAD) program resident in a processor 108 generates a file describing the geometry of a part 109 to be created,” and “[a] slicing program (shown as resident in processor 108 but which may alternatively be resident in a separate processor) algorithmically subdivides the file into volume elements 110 corresponding to shapes that can be extruded from a nozzle.” *Id.* at 4:21–28, Fig. 1. “[E]xtrusion-based layered modeling system

106” includes “electronic controller 116 [that], in response to receiving three-dimensional shape data from processor 108 over line 114, controls the extrusion of modeling material in an xyz-coordinate reference frame” and “sends control signals to an xy axis translator 118, a z-axis translator 120 and an extrusion pump 122, over output signal lines 117 a, 117b and 117c, respectively.” *Id.* at 4:19–21, 4:34–37, 4:41–44, Fig. 1.

“Extrusion pump 122 synchronously provides modeling material from a material supply 130 to extrusion head 126,” and “[t]he extrusion head 126 terminates in a nozzle 132 through which the modeling material is extruded.” Ex. 1009, 4:47–52, Fig. 1. “A sensor assembly 140” is “mounted to an extrusion head 142,” and the sensor of sensor assembly 140 “may be interchanged with any sensing means which can detect and signal contact between the plunger and the substrate.” *Id.* at 5:10–11, 6:41–43.

2. *RepRap20208*

RepRap20208 is a discussion thread from an online public forum for developing low-cost 3D printers. A user named “Wade” states that “an accelerometer on the write head” “might be able to detect . . . [a] series of head collisions due to a bad programming job” and that a “strain gauge on the extruder mount would do that as well.” Ex. 1010, 13.

User “Wade” also states in other posts that “[c]ollision detection is a nice side [e]ffect” and strain gauges would provide “a constant measurement of the force on the head (including it[’s] weight).” Ex. 1010, 19, 20. He acknowledges that “a certain amount of backlash to take up before the sensor registers, which would prevent . . . knowing exactly when the head touches” but goes on to state that “a constant measurement of the force on

the head (including it[']s weight) would be useful” and “[t]hat points more towards strain gauges.” *Id.* at 20.

a) Whether RepRap20208 is a Printed Publication

Patent Owner argued that RepRap20208 is not a printed publication in its Preliminary Response, and the Institution Decision determined that, on the record at institution, Petitioner sufficiently showed that RepRap20208 is a printed publication but invited further development of the issue. Paper 8, 27–31; Inst. Dec. 11–13.

Petitioner argues that RepRap20208 was from a forum that was keyword searchable. Pet. Reply 27–29 (citing Ex. 1010, 1, 13–21; Ex. 1014 ¶¶ 2, 4, 6). Petitioner also argues that no evidence contradicts the Bowyer declaration (Ex. 1014). *Id.* at 29.

Patent Owner responds that RepRap20208 is not a printed publication and was not publicly accessible, because Petitioner does not explain how one would reach the “Generic Algorithms” thread in a general forum. PO Sur-reply 14–16 (citing Pet. Reply 27–29; Ex. 1010, 1; Ex. 1014 ¶¶ 6, 8–10, Ex. B-1). Patent Owner also faults Petitioner for raising in the reply for the first time the use of keywords and for failing to provide evidence of any search being performed and of any query before the critical date that would have led to the thread. *Id.* at 16 (citing Pet. Reply 27–28; Ex. 1014 ¶ 6). Patent Owner argues only technical accessibility has been shown, not accessibility to the particular thread. *Id.* at 16–17. Patent Owner also argues that the thread had different titles that did not evolve as Petitioner argued. *Id.* at 17–19 (citing Pet. Reply 28–29; Ex. 1010, 1, 15–18, 20–23).

b) Petitioner Shows that RepRap20208 is a Printed Publication

The determination of whether a reference is a “printed publication” “involves a case-by-case inquiry into the facts and circumstances surrounding the reference’s disclosure to members of the public.” *In re Klopfenstein*, 380 F.3d 1345, 1350 (Fed. Cir. 2004). Whether a document qualifies as a printed publication is a legal conclusion based on underlying factual determinations. *Medtronic, Inc. v. Barry*, 891 F.3d 1368, 1380 (Fed. Cir. 2018).

“Because there are many ways in which a reference may be disseminated to the interested public, ‘public accessibility’ has been called the touchstone in determining whether a reference constitutes a ‘printed publication.’” *Jazz Pharmaceuticals, Inc. v. Amneal Pharmaceuticals, LLC*, 895 F.3d 1347, 1355 (Fed. Cir. 2018) (quoting *In re Hall*, 781 F.2d 897, 898–99 (Fed. Cir. 1986)). A reference is considered publicly accessible if it was “disseminated or otherwise made available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising reasonable diligence, can locate it.” *Id.* at 1355–56 (quoting *In re Wyer*, 655 F.2d 221, 226 (CCPA 1981)).

Petitioner provides testimonial evidence from an administrator of the website that hosted the forum that includes RepRap20208. Ex. 1014 ¶¶ 3, 7. The administrator and declarant, Mr. Bowyer, avers that the forum with RepRap20208 was publicly available. *Id.* ¶ 5. The declarant also avers that people interested in 3D printing and rapid prototyping accessed the forum. *Id.* ¶ 4 (explaining that the RepRap forum directly relates to three-dimensional printing and was frequented by “around 1,000 regular monthly users” who were “interested in 3D printing [as] both professionals and

hobbyists” and was “often discussed in various print and web media and on social media” from the inception of the forum through today). Patent Owner does not dispute that RepRap20208 came from a forum that was publicly accessible and that persons interested and ordinarily skilled in the art visited the forum. PO Sur-reply 14–19.

Mr. Bowyer further avers that the website was organized by forums and threads and could be searched by keyword or author during December 2008. Ex. 1014 ¶¶ 6–12. In particular, he states that “[i]nterested members of the public would have been able to locate the discussion thread [(RepRap20208)] by clicking through to the relevant forum or through keyword searching based on the relevant terms that appear in this thread.” *Id.* ¶ 7. Patent Owner does not dispute this testimony. PO Sur-reply 14–19.

Because we asked the parties to further develop the record on this issue during trial, Petitioner did so in its first available brief thereafter, and Patent Owner had an opportunity to respond and did so, Patent Owner does not show a fault in raising in the reply for the first time the use of keywords. PO Sur-reply 16. We also disagree with Patent Owner that Petitioner fails to provide evidence of any search being performed and of any query before the critical date that would have led to the thread. *Id.*

Mr. Bowyer states “[i]nterested members of the public would have been able to locate [RepRap20208] by clicking through to the relevant forum or through keyword searching based on the relevant terms that appear in this thread.” Ex. 1014 ¶ 7. Mr. Bowyer also states that “[p]ersons interested in 3D printing and rapid prototyping, both professionals and hobbyists, would have been aware of RepRap.org” and “RepRap.org had around 1,000 regular monthly users with many more users occasionally visiting or interacting

with the website and public forums.” *Id.* ¶ 4. Taking these statements together, they indicate that interested people were able to (and possibly did) search for and access RepRap20208 before the critical date. RepRap20208 itself shows that posts were made by several users over a twenty-day period in January 2009, indicating that the thread was accessed before the critical date despite the changing titles. *See* Ex. 1010.

Based on the “the facts and circumstances surrounding [RepRap20208]’s disclosure to members of the public,” Petitioner persuades us, and we determine, that RepRap20208 is a printed publication.

We have considered whether our determination based on the facts and circumstances of this proceeding is inconsistent with the determination in another Board proceeding involving the same parties that a video from the same forum and an article linked to the video were not sufficiently shown to be publicly accessible. *Shenzhen Touzhu Technology Co., Ltd. v. Stratasys, Inc.*, IPR2025-00321, Paper 36, 13–17 (PTAB June 9, 2026) (Final Written Decision). The issue was discussed during the oral hearing, and we agree with the parties that the evidence and issue in this proceeding are different and, therefore, can lead to a different outcome. *See* Tr. 11:2–18 (discussing with Petitioner’s counsel possible inconsistencies among proceedings between the same parties), 84:8–22 (discussing with Patent Owner’s counsel that different evidence and issues may result in a different outcome). Based on the different and more persuasive evidence presented in this proceeding, our decision is not inconsistent with that in the other proceeding.

3. *Claim 1*

a) *“A three-dimensional printer comprising:”*

Petitioner argues that Calderon discloses the preamble. Pet. 58 (citing Ex. 1003 ¶ 177; Ex. 1009, 4:20–5:10, Fig. 1).

We find that the cited portions of Calderon disclose “extrusion-based layered modeling system 106.” Ex. 1009, 4:20–5:10, Fig. 1. We also credit Petitioner’s testimonial evidence regarding the preamble, because the cited portions of Calderon support it. Ex. 1003 ¶ 177; Ex. 1009, 4:20–5:10, Fig. 1. Patent Owner does not present a response for the preamble of claim 1. *See* PO Resp. 46–53.

Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests the preamble of claim 1. In view of our finding, we do not need to determine if the preamble is limiting.

b) *“a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process”*

Petitioner argues that Calderon’s pump 122 and extrusion head 126 disclose the above-quoted limitations. Pet. 58–59 (citing Ex. 1003 ¶¶ 178, 179; Ex. 1009, 4:34–65, Fig. 1).

We find that the cited portions of Calderon discloses xy axis translator 118, z-axis translator 120, extrusion pump 122, and extrusion head 116. Ex. 1009, 4:34–65, Fig. 1. We agree with Petitioner’s declarant that these features provide an extruder as described in the ’381 patent. Ex. 1001, 2:28–52; Ex. 1003 ¶ 178.

Patent Owner does not present a response for the above-quoted limitations of claim 1. *See* PO Resp. 46–53. Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests “a

fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process.”

- c) *“one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool”*

Petitioner argues that RepRap20208 describes strain gauges on an extruder mount, thereby teaching “one or more sensors mechanically coupled to the extruder.” Pet. 59 (citing Ex. 1010, 13). Petitioner also argues that such strain gauges would sense displacement or strain at the extrusion head mount; would sense the contact force between the extruder and modeling platform 134, substrate 128, or model 136; would be mounted as described by the ’381 patent; and would, thus, “sense a contact force between the extruder and a separate structure.” *Id.* at 59–61 (citing Ex. 1001, 9:17–23; Ex. 1003 ¶¶ 180, 181; Ex. 1009, Fig. 1).

Petitioner argues that Calderon describes auto-initialization of the z-axis by using the tip of nozzle 132 to find the z-axis positions of a platform. Pet. 48 (citing Ex. 1009, 9:63–10:23). Petitioner also argues that RepRap20208 complements Calderon’s disclosure by incorporating a strain gauge on an extrusion mount so that the strain gauge calibrates the z-axis and enables collision detection. *Id.* (citing Ex. 1010, 13–14, 19).

Because of the asserted complementary disclosures, Petitioner argues that there would have been motivation to use strain gauges as a “‘sensing means,’ to monitor ‘contact between the tip of the nozzle 132 and the substrate 128,’ rather than Calderon’s servo drive current monitoring. Pet. 48–49 (citing Ex. 1003 ¶¶ 156–158; Ex. 1009, 9:63–10:23; Ex. 1010, 13–14), 54 (citing Ex. 1003 ¶¶ 160–168; Ex. 1009, 10:1–8). Petitioner also

argues that the proposed combination “would have been nothing more than applying proven elements to a system ready for improvement.” *Id.* at 49 (citing Ex. 1003 ¶ 159).

According to Petitioner, the combination would have been made to (1) avoid the “slop/backlash” from Calderon’s use of servo drive motor currents, (2) overcome inaccuracies in servo drive motor currents due to dirt, wear, friction, or damage, (3) compensate better for softer or harder substrates, and (4) use known strain gauges (“predictable inclusion of a strain gauge follows the familiar pattern of merely substituting one element (a strain gauge) for another known in the field (Calderon’s teaching of monitoring servo drive current) to obtain predictable results.”). Pet. 49–54 (citing Ex. 1003 ¶¶ 161, 164–172; Ex. 1009, 2:15–53; Ex. 1010, 19, 20).

Petitioner argues that there would have been a reasonable expectation of success. Pet. 49 (citing Ex. 1003 ¶ 159), 54 (citing Ex. 1003 ¶ 168). In support, Petitioner argues that strain gauges were commonly used to sense force, and that the proposed combination would have been predictable and expected to work. *Id.* at 54 (citing Ex. 1018, 302–304).

(1) Patent Owner’s Response

Patent Owner responds that “Calderon already has his own technique for auto-initialization and collision detection to determine contact between a nozzle and the substrate by ‘monitoring a change in the servo drive current’” and discourages use of “special purpose sensing means.” PO Resp. 46–47 (citing Pet. 48–57; Ex. 1009, 9:63–10:8, 10:26–47, 10:57–64), 56–57. Patent Owner argues that Petitioner fails to address these teachings, misrepresents and ignores the teachings of the references, and relies on

impermissible hindsight. *Id.* at 47–48 (citing Pet. 50–54; Ex. 1009, 9:63–10:5, 10:26–47; Ex. 2027 ¶ 241).

Patent Owner also argues that the proposed combination goes against Calderon’s express avoidance of special purpose sensing means. PO Resp. 47–48 (citing Pet. 48, 50, 53–54; Ex. 1009, 9:63–10:5, 10:26–47; Ex. 2027 ¶ 241). Patent Owner further argues that the mentions of backlash and slop are not related to Calderon’s monitoring of its servo drive motors and, instead, related to a sensor unrelated to Calderon’s solution. *Id.* at 48 (citing Pet. 50–52; Ex. 1009, 10:5–8; Ex. 1010, 19, 20; Ex. 2027 ¶ 242).

Patent Owner also argues that Petitioner fails to address how a strain gauge would be closer to the point of contact with platform 134 than Calderon’s z-axis translator that drives platform 134. PO Resp. 49 (citing Pet. 51; Ex. 1009, Fig. 1; Ex. 2027 ¶ 243). Patent Owner further argues that the rationale regarding accuracy and consistency is based on impermissible hindsight, because the only support comes from Petitioner’s declarant and there is no supporting disclosure. *Id.* (citing Pet. 52; Ex. 1003 ¶ 164; Ex. 2027 ¶ 244).

The rationale about supporting different substrates, Patent Owner argues, is flawed because the references do not mention it, and there is no teaching that strain gauges provide a benefit over Calderon’s monitoring of its servo drive motors. PO Resp. 49 (citing Pet. 53, 55–56; Ex. 1009; Ex. 1010; Ex. 2027 ¶ 245). Patent Owner additionally argues that Calderon teaches damaging a foam substrate to extrude layers buried in the foam. *Id.* at 49–50 (citing Ex. 1009, 2:44–50; Ex. 2027 ¶ 245). Patent Owner, thus, argues that Petitioner has failed to show a motivation to combine. *Id.* at 51 (citing Ex. 2027 ¶¶ 235–248), 53 (citing Ex. 2027 ¶¶ 235–248, 258, 259).

(2) Reply Arguments

Petitioner replies that Calderon only monitors servo drive currents when servo drive motors are used and predominantly teaches embodiments that do not use servos, such as the one relied on for the proposed combination. Pet. Reply 14 (citing Pet. 42–46, 49–57; PO Resp. 46; Ex. 1009, 4:34–5:24, 6:16–18, 10:5–8). Petitioner argues that, in the relied-on embodiment, Calderon teaches z-height determination. *Id.* at 14–15 (citing Ex. 1009, 4:66–5:3, Fig. 1). Petitioner also argues that Calderon teaches monitoring for contact between nozzle and substrate and does not restrict the type of sensors used. *Id.* at 15 (citing Pet. 54; Ex. 1003 ¶¶ 54–60; Ex. 1009, 6:38–7:5, 9:63–10:23; Ex. 1010, 20). Petitioner further argues that Calderon also teaches nozzles tip depth at zero and above the substrate surface. *Id.* at 16–17 (citing PO Resp. 55; Ex. 1009, 8:45–52).

Turning to RepRap20208, Petitioner argues that it links the strain gauge to z-height determination and relates it to avoiding collision problems. Pet. Reply 16 (citing Pet. 51–53, 62; Ex. 1003 ¶ 165; Ex. 1009, 2:36–53, 9:63–10:23; Ex. 1010, 13, 14, 18–20). Petitioner also argues that strain gauges were commonly used for force sensing, as stated by the '381 patent, and that RepRap20208 recognized strain gauges had advantages over other sensors. *Id.* at 17–18 (citing Pet. 53–54; PO Resp. 57; Ex. 1001, 9:17–23; Ex. 1003 ¶¶ 165–168; Ex. 1009, 2:36–53; Ex. 1010, 14, 16, 19), 24. Petitioner, thus, argues that strain gauges would have been used in implementations without servos. *Id.* at 18 (citing Pet. 53; Ex. 1001, 9:17–23; Ex. 1003 ¶ 165).

Even in implementations with servos, Petitioner argues that, in the Petition, it contends that it would have been obvious to use strain gauges for

detecting extrusion head collisions and for z-axis calibration. Pet. Reply 18 (citing Pet. 46–54). Petitioner points to RepRap20208 and its declaration for support that backlash was a problem in monitoring servo currents. *Id.* at 18–19 (citing Pet. 50–51; PO Resp. 48, 49; Ex. 1003 ¶¶ 169–171; Ex. 1010, 20). Petitioner also argues that strain gauges would have improved Calderon by performing z-height calibration while performing collision detection. *Id.* at 19–20 (citing Pet. 46, 70–71; Ex. 1010, 13, 18–19).

Patent Owner replies that Petitioner is abandoning its proposal to apply a strain gauge on the extruder mount and, instead, argues that Calderon discloses monitoring more generally, not just in servo implementations. PO Sur-reply 19 (citing Pet. 48–49; Pet. Reply 14, 15, 18). Patent Owner argues that “Petitioner cannot cure its failure to show a motivation to combine in the Petition by changing its motivation theory in the Reply—specifically, from applying RepRap20208’s strain gauges rather than Calderon’s servo drive monitoring to merely ‘using a strain gauge with Calderon.’” *Id.* (citing Pet. 48–49; Pet. Reply 14).

Patent Owner also argues that Calderon does not limit its current monitoring to servo implementations. PO Sur-reply 20 (citing Pet. Reply 14; Ex. 1009, 9:63–10:22). Patent Owner further argues that Petitioner does not address that Calderon teaches away from special purpose sensors and so that teaching remains undisputed. *Id.* (citing PO Resp. 46–48; Pet. Reply 15–16; Ex. 1009, 9:63–10:5, 10:7–8, 10:26–47). Patent Owner contends that Petitioner’s proposed combination ignores that teaching and introduces a special-purpose sensor. *Id.* at 20–21 (citing PO Resp. 45–46, 50; Ex. 1009, 10:1–8; Ex. 1018, 302–304; Ex. 2027 ¶¶ 111, 112, 241).

Patent Owner also replies that Petitioner introduces a new theory that Calderon and RepRap20208 have the same problem, whereas the Petition argued the RepRap20208 solved a problem that Calderon had. PO Sur-reply 21 (citing Pet. 51, 52). According to Patent Owner, Calderon already has a collision detection solution. *Id.* (citing PO Resp. 46–48; Pet. Reply 16–17, 20; Ex. 1009, 9:63–10:5, 10:26–47, 10:57–64).

Patent Owner further replies that Petitioner attempts to shift the burden to Patent Owner by asserting that Patent Owner did not address printing at the surface. PO Sur-reply 21–22 (citing Pet. Reply 16–17, 21). Patent Owner argues that Calderon prints below the surface of some substrates and already has a solution for preventing damage to the substrate and nozzle. *Id.* at 22 (citing PO Resp. 46–47, 49–50; Ex. 1009, 2:44–50, 9:63–10:8, 10:26–47; Ex. 2027 ¶¶ 238, 245).

Patent Owner also argues that Petitioner provides a new analysis of RepRap20208, not presented in the Petition. PO Sur-reply 22 (citing Pet. 48–57; Pet. Reply 17; Ex. 1010, 16). Patent Owner also identifies the argument that strain gauges would work over long periods of time as new analysis and unsupported attorney argument. *Id.* at 22–23 (citing Pet. Reply 17; Ex. 1010, 17). Patent Owner contends that Petitioner fails to rebut that Calderon teaches not to use special-purpose sensors, that RepRap20208 only mentions backlash, that a strain gauge is not closer to the contact than z-axis drive motor monitoring, that RepRap20208 refers to a sensor different than Calderon’s current monitoring, and that RepRap20208’s context indicates reference to another sensor, not Calderon’s solution. *Id.* at 23–24 (citing PO Resp. 47–49; Pet. Reply 19–20; Ex. 1009, 9:63–10:8, 10:26–47, Fig. 1; Ex. 1010, 19–20; Ex. 2027 ¶¶ 241–243, 272).

(3) Petitioner Shows the Limitations

We find that Petitioner cites portions of RepRap20208 that describe that a “strain gauge on the extruder mount” could detect a “series of head collisions.” Ex. 1010, 13. We credit Petitioner’s testimonial evidence that RepRap20208’s strain gauge would have been used to “measure upwards pressure from a calibration touch” and to provide a “measurement of the force on the head” during calibration,” because the cited portions of RepRap20208 support the testimony. Ex. 1003 ¶ 181; Ex. 1010, 13, 19–20.

We also find that Petitioner cites a portion of Calderon that describes an “initialization routine” that “records the z-axis position of platform 134” by positioning nozzle 132 over locations of the substrate and raising platform 134 “until the nozzle tip contacts the substrate.” Ex. 1009, 9:63–10:5.

Based on our findings above, we credit Petitioner’s testimonial evidence that strain gauges would have been implemented in Calderon for sensing contact between nozzle 132 and substrate 128. Ex. 1003 ¶¶ 156–158. We agree with Petitioner’s declarant that “combining the strain gauge example of RepRap20208 with Calderon’s three-dimensional printer would have been nothing more than applying proven elements to a system ready for improvement.” Ex. 1003 ¶ 159.

We also agree that “[t]he predictable inclusion of a strain gauge amounts to nothing more than supplementing Calderon with a strain gauge on the extrusion head mount, which would not have disturbed the other aspects of the system, and would have produced substantially similar functionality to what Calderon described.” Ex. 1003 ¶ 166. The record supports that there would have been a reasonable expectation of success in

making the proposed combination. Ex. 1003 ¶ 167; Ex. 1018, 284–290, 302–304.

Regarding Patent Owner’s teaching away argument, Calderon states that “[i]n an apparatus that uses servo drive motors, contact with the substrate 128 can be detected by simply monitoring a change in the servo drive current without need for any special purpose sensing means.” Ex. 1009, 10:5–8. We find that this statement “merely expresses a general preference for [simply monitoring a change in the servo drive current without need for any special purpose sensing means] but does not ‘criticize, discredit, or otherwise discourage’ investigation into [strain gauges for collision detection].” *See DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1327 (Fed. Cir. 2009) (quoting *In re Fulton*, 391 F.3d 1195, 1201 (Fed. Cir. 2004)). Supporting our determination, Calderon elsewhere states that the sensor of sensor assembly 140 “may be interchanged with any sensing means which can detect and signal contact between the plunger and the substrate.” Ex. 1009, 6:41–43.

Based on the full record and for the reasons above, Petitioner persuades us, and we determine, that Calderon and RepRap20208 teach or suggest the limitations and that one of ordinary skill in the art would have made the proposed combination with a reasonable expectation of success.

d) *“a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure”*

Petitioner argues that Calderon’s controller 116 teaches the recited controller. Pet. 61 (citing Ex. 1003 ¶ 185; Ex. 1009, 9:63–10:8). Petitioner also argues that one of ordinary skill in the art would have found it obvious that controller 116 “receive[s] a signal from the one or more sensors on the

extruder” so that controller 116 can “electrically record[] the z-axis position of platform 134.” *Id.* at 61–62 (citing Ex. 1003 ¶ 186; Ex. 1009, 2:54–3:3, 9:63–10:8, Fig. 1; Ex. 1010, 13). Petitioner further argues that it would have been obvious for controller 116 “to calculate the contact force between the extruder and the separate structure” so that controller 116 can monitor “[c]ontact between tip of nozzle 132 and the substrate 128,” as taught by Calderon. *Id.* at 62 (citing Ex. 1003 ¶ 187; Ex. 1009, 10:1–8; Ex. 1010, 13).

Because of the asserted complementary disclosures, Petitioner argues that there would have been motivation to calculate contact force based on measurements from the strain gauge using Calderon’s controller 116 or another controller in the proposed combination. Pet. 48–49 (citing Ex. 1003 ¶¶ 156–158; Ex. 1009, 9:63–10:23; Ex. 1010, 13–14), 54–55 (citing Ex. 1003 ¶ 169). According to Petitioner, the reasons include that RepRap20208 invites using strain gauges to calculate contact force because RepRap20208 seeks a measurement of force and weight; the proposed combination would have been understood, or found obvious, to include a maximum contact pressure to control contact force to prevent damage to substrate 128 or nozzle 132; and having the set maximum for contact pressure and substrate strength in the same force-based units would facilitate programming the controller and the user’s interaction with the controller. *Id.* at 54–56 (citing Ex. 1003 ¶¶ 170–172; Ex. 1010, 17, 19, 20).

Petitioner argues that there would have been a reasonable expectation of success in calculating contact force from strain gauges with the controller. Pet. 57 (citing Ex. 1003 ¶ 173). In support, Petitioner argues that the calculating contact force and then contact pressure was commonplace and rudimentary. *Id.* (citing Ex. 1018, 302–304). Petitioner also argues that the

'381 patent describes using sensors operable to sense strain “so long as the contact force(s) . . . may be calculated from the sensed physical characteristics.” *Id.* (quoting Ex. 1001, 8:65–9:10).

Petitioner, thus, argues that one of ordinary skill in the art “would have understood RepRap20208 to disclose calculating, or found it obvious to calculate, contact force with a controller using the strain gauge output” of the proposed combination. Pet. 57 (citing Ex. 1003 ¶¶ 169–174). Petitioner also argues that Calderon and RepRap20208 would have rendered obvious claim 1. *Id.* at 62 (citing Ex. 1003 ¶¶ 175–188).

(1) Patent Owner’s Response

Patent Owner responds that “there is no teaching of calculating a contact force.” PO Resp. 52 (citing Pet. 59–62), 53 (citing Ex. 2027 ¶¶ 254–256). Patent Owner argues that RepRap20208 “merely discloses using a strain gauge on the extruder mount” and teaches away from using a “force sensor” because it does not work well over long periods of time under force, backlash, and uncertainty as to when the head touches. *Id.* at 52–53 (citing Ex. 1010, 13, 19, 20). Patent Owner also argues that constant measurement of force on the head is described, but not calculating a contact force. *Id.* at 53 (citing Ex. 1010, 20).

Patent Owner also responds that there is no motivation to calculate a contact force using controller 116. PO Resp. 50 (citing Pet. 54–57; Ex. 2027 ¶ 246). Patent Owner argues that RepRap20208 does not disclose it and discourages doing so. *Id.* (citing Pet. 55; Ex. 1010, 20). Patent Owner also argues that Petitioner’s comparison of calculated force to a maximum setpoint lacks supporting evidence and is guided by impermissible hindsight, because the references do not teach it. *Id.* at 51 (citing Pet. 56–57; Ex. 1003

¶¶ 170–172; Ex. 1009; Ex. 1010, 19–20; Ex. 2027 ¶ 247). In Patent Owner’s view, Petitioner is merely arguing that contact force *could* have been calculated, not *would* have been calculated. *Id.* (citing Pet. 57).

Patent Owner, thus, argues that Petitioner has failed to show a motivation to combine Calderon and RepRap 20208. PO Resp. 51 (citing Ex. 2027 ¶¶ 235–248), 53 (citing Ex. 2027 ¶¶ 235–248, 258, 259). Patent Owner also argues that claim 1 is not unpatentable. *Id.* at 53 (citing Ex. 2027 ¶¶ 249–259).

(2) Reply Arguments

Petitioner replies that contact force would have been calculated from the strain gauge, because RepRap20208 expressly discloses “constant measurement of the force” and doing so was commonplace and typical. Pet. Reply 20–21 (citing Pet. 54–57; Ex. 1003 ¶¶ 170–173; Ex. 1009, 8:14–20; Ex. 1010, 20; Ex. 1042, 60:1–63:7, 67:24–68:20). Petitioner also replies that the combination would prevent damage to the nozzle caused by collisions, a motivation to combine not addressed by Patent Owner. *Id.* at 21 (citing Pet. 55, 70–71; Ex. 1003 ¶ 216; Ex. 1010, 18–19).

Petitioner argues that Calderon teaches z-start positions that are not below the surface of the substrate and, even when below the surface, determining the force would have been beneficial so as to determine the optimal z-axis starting position. Pet. Reply 22–23 (citing Pet. 55–56; Ex. 1009, 2:27–34). Petitioner also argues that, in both cases, a z-axis calibration is performed that would benefit from calculating the contact force. *Id.* at 23 (citing Pet. 55–56; Ex. 1009, 8:10–37). Petitioner reiterates that the advantages include “the ability to directly compare the strain gauge data to the compression strength of the substrate or nozzle.” *Id.* (citing

Pet. 55–56). Petitioner points to RepRap20208’s teaching of “measur[ing] upwards pressure from a calibrated touchdown” for support. *Id.* (citing Pet. 56). Petitioner further argues that RepRap20208 links using a strain gauge to Z-height calibration, collision detection, and force sensing, thereby being directly applicable to Calderon. *Id.* (citing Pet. 46–51; Ex. 1010, 18–20).

Patent Owner replies that Petitioner does not identify any teaching of calculating the contact force, does not address its arguments for claim 1, and tacitly admits that RepRap20208 does not teach calculating contact force, only a “constant measurement of the force” that includes the weight of the head. PO Sur-reply 24–25 (citing PO Resp. 50–51, 52–53; Pet. Reply 14–21; Ex. 1010, 19–20). Patent Owner argues that Petitioner did not account for that weight and “could” is not the standard for obviousness. *Id.* at 24–25 (citing Pet. 57)

Regarding damage providing a motivation, Patent Owner replies that “Calderon already protects his nozzle by monitoring drive-current changes and providing collision detection, including after initialization.” PO Sur-reply 25 (citing PO Resp. 46; Ex. 1009, 9:63–10:8, 10:26–47, 10:57–64; Ex. 2027 ¶ 238). Patent Owner argues that teaching undermines Petitioner’s rationale no matter the type of substrate used. *Id.* (citing Pet. 53; PO Resp. 49–50)

Patent Owner further argues that Petitioner introduces a new argument that calculating force would be beneficial, but the Petition does not describe such benefits when printing below the surface of the substrate. PO Sur-reply 25–26 (citing Pet. 62; PO Resp. 49–50; Pet. Reply 22–23; Ex. 2027 ¶ 245). Patent Owner also identifies the reply argument about Calderon’s z-axis

starting point as new, unsupported by evidence, and merely arguing that contact force could have been calculated, not would have been. *Id.* at 26 (citing Pet. 55–56; PO Resp. 51; Pet. Reply 23; Ex. 2027 ¶ 247).

(3) Petitioner Shows the Limitations

We find that the portion of Calderon cited by Petitioner discloses that “[c]ontact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means and the controller 116 electrically records the z-axis position of platform 134 at the time contact is detected.” Ex. 1009, 10:1–5. We credit Petitioner’s testimonial evidence that controller 116 receives a signal from the sensors on the extruder, because the citations to Calderon support it. Ex. 1003 ¶ 186; Ex. 1009, 2:54–3:3, 9:63–10:8, Fig. 1.

We also determine that one of ordinary skill in the art would have looked to RepRap20208 for implementing a specific “sensing means” for use in Calderon’s three-dimensional printer and would have been motivated to follow RepRap20208’s suggestion of using a strain gauge for that purpose. Ex. 1010, 13, 19–20. Supporting our determination is that RepRap20208 states strain gauges can provide “a constant measurement of the force on the head (including it[]s weight)” and that this measurement “would be useful.” Ex. 1010, 20.

Because the record supports it, we credit the testimony of Petitioner’s declarant that it would have been obvious for controller 116 of the proposed combination to calculate the contact force between an extruder and a separate structure based on signals received from strain gauges on an extruder mount. Ex. 1003 ¶ 187; Ex. 1009, 10:1–8; Ex. 1010, 13, 20. We find credible Petitioner’s testimonial evidence that “calculating the contact force, and then the contact pressure, would facilitate programming the

controller to a maximum contact pressure setpoint related to the compression strength of the substrate and nozzle because the setpoint and the compression strength would be in the same units.” Ex. 1003 ¶ 172. We also find credible that, “if the controller were configured to allow a user to change the setpoint, such as to allow the printer to be adapted to different substrate materials, calculating contact force and contact pressure would facilitate a user’s interaction with the controller,” because “[t]he controller’s settings values could more readily be set, adjusted or displayed in meaningful (to a user) force-based units rather than in values of strain at the extrusion head mounting.” *Id.*

The record also supports that there would have been a reasonable expectation of success in making the proposed combination. Ex. 1003 ¶ 173; Ex. 1018, 284–290, 302–304. Petitioner’s proposed combination does not rely on impermissible hindsight, because RepRap20208 focuses on contact force between the extruder and the substrate as an important variable to ascertain in controlling a three-dimensional printer. Ex. 1010, 13, 19–20.

Patent Owner does not meaningfully address Petitioner’s argument that the proposed combination would have been made to facilitate programming the controller and user interaction with the controller. *See* PO Resp. 50–53. We also find that Patent Owner’s asserted teaching away in RepRap20208 relates to issues that the strain gauge would overcome. *See* Ex. 1010, 13, 19, 20 (stating that “you’ve got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I’m really interested in,” “so I was thinking a constant measurement of the force on the head

(including it[]s weight) would be useful,” and “[t]hat points more towards strain gauges”).

We disagree with Patent Owner that RepRap20208 does not refer to a contact force. PO Resp. 52–53. According to Patent Owner, although RepRap20208 “describes a constant measurement of the force on the head, including its weight,” it “does not mention a contact force.” *Id.* at 53 (citing Ex. 1010, 20; Ex. 2027 ¶¶ 254–256). However, the context of this forum discussion shows that the commenters were discussing the “upward pressure” of a contact force. *See* Ex. 1010, 19–20. We credit the testimony of Petitioner’s declarant that one of ordinary skill in the art would have understood RepRap20208’s “suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate.” Ex. 1003 ¶ 163. That difference (subtracting out the weight) would be a measurement of the contact force by the strain gauge.

Based on the full record and for the reasons above, Petitioner persuades us, and we determine, that Calderon and RepRap20208 teach or suggest the limitations and that one of ordinary skill in the art would have made the proposed combination with a reasonable expectation of success.

e) Objective Evidence of Nonobviousness

Patent Owner does not present any objective evidence of nonobviousness in connection with any claim of the ’381 patent. *See* PO Resp.

f) Petitioner Shows that Claim 1 is Unpatentable over Calderon and RepRap20208

Based on the full record before us, we find that (1) Petitioner’s proposed level of ordinary skill in the art is consistent with the prior art of record, (2) Calderon and RepRap20208 teach or suggest all the limitations of claim 1, (3) one of ordinary skill in the art would have combined Calderon and RepRap20208 in the manner asserted by Petitioner with a reasonable expectation of success, and (4) no objective evidence of nonobviousness has been asserted in connection with any claim.

Weighing these underlying factual determinations, a preponderance of the evidence persuades us that claim 1 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

4. Claim 2

Claim 2 depends from claim 1 and recites “wherein the contact force is a force along an extrusion axis of the extruder.” Ex. 1001, 13:5–7.

Petitioner argues that “***the contact force is a force*** that acts on the tip of nozzle 132 of extruder 126” and “[w]hen the top surface of substrate is generally orthogonal to the tip (the desired orientation), the contact force is ***along*** the vertical axis (i.e., ***the extrusion axis***) ***of the extruder 126.***”

Pet. 63 (citing Ex. 1003 ¶¶ 189, 190; Ex. 1009, 9:63–10:15, Fig. 1).

Petitioner also argues that, “even if the substrate 128 were not precisely orthogonal to the tip of nozzle 132, a [person of ordinary skill in the art] would have understood that there to be a force component from the contact directed along the extrusion axis and that this force component is a contact force.” *Id.* (citing Ex. 1009, 9:63–10:15).

We find that the portions of Calderon cited by Petitioner teach or suggest the additional limitations of claim 2. Ex. 1009, 9:63–10:15, Fig. 1. We credit Petitioner’s testimonial evidence because the citations to Calderon support it. Ex. 1003 ¶ 190; Ex. 1009, 10:1–5, Fig. 1. Patent Owner responds that claim 2 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests the additional limitations of claim 2. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 2 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

5. Claim 3

Claim 3 depends from claim 1 and recites “wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.” Ex. 1001, 13:8–10.

Petitioner argues that, as argued previously, the proposed combination implements collision detection whenever the extrusion head is moving, and that, when a collision occurs, “the resulting force includes a deflection force” measured by the strain gauge on the extrusion head mount. Pet. 71–72 (citing Ex. 1003 ¶¶ 217–219; Ex. 1009, 4:45–48).

We credit the Petitioner’s testimonial evidence, because the citation to Calderon supports it. Ex. 1003 ¶ 218; Ex. 1009, 4:45–48. Patent Owner responds that claim 3 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests the additional limitations of claim 3. Weighing

our underlying factual determinations, a preponderance of the evidence persuades us that claim 3 of the '381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

6. *Claim 4*

Claim 4 depends from claim 1 and recites “wherein the separate structure includes an object being fabricated by the three-dimensional printer.” Ex. 1001, 13:11–13.

Petitioner argues that the proposed combination would have rendered obvious claim 4. Pet. 72 (citing Ex. 1003 ¶¶ 220–222; Ex. 1005, 18:5–18; Ex. 1009, 4:62–63, Fig. 1; Ex. 1010, 13).

We determine that the proposed combination of Calderon and RepRap20208 would have deposited modeling material to build model 136 on substrate 128 and the strain gauge on the extruder mount sensing contact force between nozzle 132 and model 136. Ex. 1009, 4:62–63, Fig. 1; Ex. 1010, 13. We credit Petitioner’s testimonial evidence, because the citations to the record support it. 1003 ¶ 221; Ex. 1009, 4:62–63, Fig. 1; Ex. 1010, 13. We also agree with Petitioner’s declarant that the proposed combination aligns with the '381 patent. Ex. 1001, 8:55–64; Ex. 1003 ¶ 221. Patent Owner responds that claim 4 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 4. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 4 of

the '381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

7. *Claim 5*

Claim 5 depends from claim 1 and recites “wherein the separate structure includes a build platform of the three-dimensional printer.” Ex. 1001, 13:14–16.

Petitioner argues that a strain gauge on the extruder mount would have sensed a contact force between the tip of nozzle 132 and substrate 128 on modeling platform 134. Pet. 63 (citing Ex. 1003 ¶¶ 191, 192; Ex. 1009, 4:53–65, 10:1–5, Fig. 1; Ex. 1010, 13). Petitioner also argues that the proposed combination would have been recognized as being similar to what is described in the '381 patent. *Id.* at 63–64 (citing Ex. 1001, 8:55–64; Ex. 1003 ¶ 192). Petitioner, thus, argues that the combination would have rendered obvious that “*the separate structure includes* the substrate 128 (i.e., *a build platform*) or the substrate 128 together with the and modeling platform 134 (i.e., collectively *a build platform*).” *Id.* at 64 (citing Ex. 1003 ¶¶ 192, 193; Ex. 1009, 4:62–63, Fig. 1).

We determine that the proposed combination of Calderon and RepRap20208 would have had the strain gauge on the extruder mount sensing contact force between nozzle 132 and substrate 128. Ex. 1009, 4:53–65, 10:1–5, Fig. 1; Ex. 1010, 13. We credit Petitioner’s testimonial evidence, because the citations to the record support it. 1003 ¶ 192; Ex. 1009, 4:62–63, 10:1–5, Fig. 1; Ex. 1010, 13. We also agree with Petitioner’s declarant that the proposed combination aligns with the '381 patent. Ex. 1001, 8:55–64; Ex. 1003 ¶ 192. Patent Owner responds that

claim 5 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 5. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 5 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

8. *Claim 6*

Claim 6 depends from claim 1 and recites “wherein the contact force is a force normal to a surface of the separate structure.” Ex. 1001, 13:17–19.

Petitioner argues that “***the contact force is a force*** that acts on the tip of nozzle 132 of extruder 126” and “[w]hen the top surface of substrate is generally orthogonal to the tip of nozzle 132, the contact force is ***normal to the surface of the separate structure.***” Pet. 64 (citing Ex. 1003 ¶¶ 194–196; Ex. 1009, 9:63–10:15, Fig. 1). According to Petitioner, Calderon confirms this. *Id.* (citing Ex. 1009, 9:63–10:15). Petitioner also argues that, “even if the substrate 128 were not precisely orthogonal to the tip of nozzle 132, a [person of ordinary skill in the art] would have understood that there were a force component from the contact directed normal to the substrate and that this force component would have been a contact force.” *Id.* (citing Ex. 1003 ¶¶ 195, 196).

We find that the portions of Calderon cited by Petitioner teach or suggest the additional limitations of claim 6. Ex. 1009, 9:63–10:15, Fig. 1. We credit Petitioner’s testimonial evidence because the citations to Calderon support it. Ex. 1003 ¶ 195; Ex. 1009, 10:1–5, Fig. 1. Patent Owner

responds that claim 6 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests the additional limitations of claim 6. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 6 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

9. Claim 9

Claim 9 depends from claim 1 and recites “wherein each of the one or more sensors are selected from the group consisting of: capacitive sensors, electromagnetic sensors, optical sensors, potentiometric sensors, and piezoelectric sensors.” Ex. 1001, 13:27–31.

Petitioner argues that a strain gauge is, or would have been obvious to configure as, a potentiometric sensor. Pet. 65 (citing Ex. 1003 ¶¶ 197, 198). Petitioner also argues that it would have been obvious to use piezoelectric or capacitive strain sensors on the extruder mount to measure strain, because such sensors were commonly used and Calderon advocates using a capacitive sensor. *Id.* (citing Ex. 1003 ¶ 199; Ex. 1009, 6:38–47).

Petitioner, thus, argues that one of ordinary skill in the art would have been motivated to use piezoelectric or capacitive sensors because they were readily available, well understood, and designed to measure strain and force. Pet. 65–66 (citing Ex. 1003 ¶ 199). According to Petitioner, the use of such sensors would have been a mere substitution of one known sensor for another to obtain predictable results, would not have disturbed other aspects of the system, and would have produced substantially the same functionality described in RepRap20208. *Id.* at 66 (citing Ex. 1003 ¶ 199). Petitioner

also argues that the recited list “encompasses nearly all common types of strain sensors.” *Id.* (citing Ex. 1003 ¶ 200).

We credit Petitioner’s testimonial evidence because the citations to the record support it. Ex. 1003 ¶¶ 197, 198, 200; Ex. 1009, 6:38–47; Ex. 1018, 284–290, 302–304; Ex. 1019, Abstract; Ex. 1020. Patent Owner responds that claim 9 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination would have had the additional limitations of claim 9. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 9 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

10. Claim 10

Claim 10 depends from claim 1 and recites “wherein the one or more sensors include one or more strain gauges.” Ex. 1001, 14:1–2.

Petitioner argues that its proposed combination includes strain gauges. Pet. 66–67 (citing Ex. 1003 ¶¶ 201–203; Ex. 1010, 13).

We credit Petitioner’s testimonial evidence because the citations to the record support it. Ex. 1003 ¶ 202; Ex. 1010, 13. Patent Owner responds that claim 10 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination would have had the additional limitations of claim 10. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 10 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

11. Claim 11

Claim 11 depends from claim 1 and recites

further comprising: one or more actuators mechanically coupled to the fabrication tool, and a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.

Ex. 1001, 14:3–11.

Petitioner maps Calderon’s x-y translator 118 and z-axis translator 120 to the “actuators,” extrusion head 126 on robotic arm 124 to the “fabrication tool,” and controller 116 and associated memory 119 to the “control circuit.” Pet. 67 (citing Ex. 1003 ¶¶ 204–207; Ex. 1009, 4:41–52, 11:6–11, Fig. 1). Petitioner argues that RepRap20208’s strain gauge would teach the “one or more sensors.” *Id.* at (citing Ex. 1009, Fig. 1; Ex. 1010, 13). Petitioner refers to previous arguments that controller 116 sends control signals to achieve a specified contact force that “does not exceed a force limit” between the strain gauge and the modeling platform to prevent damage. *Id.* at 68 (citing Ex. 1003 ¶¶ 204–207).

a) Patent Owner’s Response

Patent Owner responds that “force limit” only appears in the Petition and declaration, not the references. PO Resp. 54 (citing Pet. 67–68; Ex. 1003 ¶ 206). Patent Owner argues that the cited portions of the references describe sending control signals responsive to receiving data, running a program to record Z-positions, monitoring a change in servo drive current, and monitoring vibration the head experiences with an accelerometer. *Id.* at 54–55 (citing Ex. 1009, 4:34–52, 11:6–15; Ex. 2027 ¶ 263).

Patent Owner also argues that the assertion based on preventing damage lacks support. PO Resp. 55 (citing Pet. 68). Patent Owner relies on previous arguments that a strain gauge would not support different substrates without damage, because Calderon damages the substrate when its extrusion nozzle is below the surface of a foam substrate. *Id.* (citing Ex. 1009, 2:44–50). Patent Owner, thus, argues that Petitioner’s proposed combination does not have a contact force sufficient for measurement that “does not exceed a force limit to be damaging between the strain gauge and modeling platform / substrate” and that “Petitioner fails to show that one or more actuators are controlled to achieve a specified contact force.” *Id.* (citing Ex. 2027 ¶¶ 261–265).

b) Reply Arguments

Petitioner replies that its declarant supports that the controller sends a signal to achieve a contact force that maps to the claimed “specified contact force,” Calderon’s z-axis starting position depends on the substrate so there would have been an advantage to calculating contact force, Calderon is not limited to z-start positions below the surface of the substrate, and Calderon is not limited to servo implementations. Pet. Reply 24–25 (citing Pet. 55–56, 68; Ex. 1003 ¶¶ 204–207; Ex. 1009, 2:27–53, 8:43–52, 10:5–8).

Petitioner additionally argues that, in servo implementations, “[p]lacing the strain gauge near the dispensing head at a position close to the nozzle tip permits accurate force sensing without having to address the backlash/slop exhibited by the other parts of the system.” *Id.* at 25 (citing Pet. 50–51; Ex. 1003 ¶¶ 161–163; Ex. 1010, 20).

Patent Owner replies that there is no teaching of a force limit and Petitioner concedes that some substrates are damaged. PO Sur-reply 26–27

(citing PO Resp. 51, 54–55; Pet. Reply 24–25). Patent Owner also argues that the “starting position” argument is an improper new argument supported by attorney arguments about what would have been recognized or understood. *Id.* at 27 (citing Pet. Reply 25–26). Patent Owner further argues that Petitioner does not address its arguments that “a strain gauge is not closer to the contact than Calderon’s z-axis drive motor monitoring, which would not need to address backlash/slop in ‘other parts of the system.’” *Id.* (citing PO Resp. 48–49; Ex. 1009, Fig. 1; Ex. 1010, 20; Ex. 2027 ¶¶ 242–243).

c) Petitioner Persuades us that Claim 11 is Unpatentable

We find that Petitioner cites portions of Calderon that disclose x-y translator 118, z-axis translator 120, extrusion head 126 on robotic arm 124, controller 116, and memory 119. Ex. 1009, 4:41–52, 11:6–11, Fig. 1. We also find that RepRap20208 discloses strain gauges. Ex. 1010, 13. We credit Petitioner’s testimonial evidence for claim 11, because the cited portions of the record support it. Ex. 1003 ¶ 205; Ex. 1009, 4:41–52, Fig. 1; Ex. 1010, 13.

Patent Owner does not dispute that Calderon and RepRap20208 teach or suggest “one or more actuators mechanically coupled to the fabrication tool, and a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators.” PO Resp. 54–55. Patent Owner’s responsive argument that the references fail to mention “a specified contact force” does not overcome Petitioner’s showing. *Id.* at 55.

Petitioner refers to its arguments for claim 1. Pet. 68 (citing Ex. 1003 ¶¶ 204–207). As discussed above for claim 1, Petitioner persuades us that

Calderon and RepRap20208 would have been combined so that controller 116 receives a signal from the sensors on the extruder. Ex. 1003; Ex. 1009, 2:54–3:3, 9:63–10:8, Fig. 1. Petitioner also persuades us that the proposed combination would have been made to facilitate programming the controller to a maximum setpoint and to facilitate a user setting or adjusting the controller. Ex. 1003 ¶ 172. We, therefore, determine that Petitioner’s proposed combination would have had a “control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.”

Based on the full record, Petitioner persuades us, and we find, that Calderon and RepRap20208 teach or suggest the additional limitations of claim 11. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 11 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

12. Claim 12

Claim 12 depends from claim 1 and recites “wherein the controller is further configured to adjust operation of the three-dimensional printer according to one or more of the signal from the one or more sensors and the calculated contact force.” Ex. 1001, 14:12–16.

Petitioner argues that Calderon teaches using software in its controller to record z-positions by monitoring contact between nozzle 132 and substrate 128, calculate a z-start position, and then automatically position its platform to the calculated z-start position. Pet. 68–69 (citing Ex. 1009, 3:27–30, 7:63, 8:11–37, 10:1–5, 10:9–15). According to Petitioner, one of ordinary skill in the art would have recognized that those teachings meet the

limitations of claim 12. *Id.* at 69 (citing Ex. 1003 ¶¶ 209, 210; Ex. 1009, 3:27–30).

We find that the portions of Calderon cited by Petitioner teach or suggest the additional limitations of claim 12. Ex. 1009, 3:27–30, 7:63, 8:11–37, 10:1–5, 10:9–15. We credit Petitioner’s testimonial evidence because the citations to Calderon support it. Ex. 1003 ¶ 190; Ex. 1009, 3:27–30, 7:63, 8:11–37, 10:1–5, 10:9–15. Patent Owner responds that claim 12 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we find, that Calderon teaches or suggests the additional limitations of claim 12. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 12 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

13. Claim 13

Claim 13 depends from claim 12 and recites “wherein the controller is configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.” Ex. 1001, 14:17–21.

Petitioner argues that one of ordinary skill in the art would have known that shutting down the machine upon detecting a collision would have stopped the feed of build material, thereby “adjust[ing] a feed rate of build material from the extruder.” Pet. 73 (citing Ex. 1003 ¶¶ 223–226).

We credit Petitioner’s testimonial evidence because the citations to the record support it. Ex. 1003 ¶¶ 224, 225; Ex. 1008 ¶ 180; Ex. 1010, 13, 19, 20. Patent Owner responds that claim 13 has not been shown to be

unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 13. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 13 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

14. Claim 14

Claim 14 depends from claim 12 and recites “wherein the controller is configured to adjust a z-axis position of the extruder in response to the calculated contact force.” Ex. 1001, 14:22–24.

Petitioner argues that Calderon teaches adjusting the z-axis of its extruder. Pet. 69–70 (citing Ex. 1003 ¶¶ 212, 213; Ex. 1009, 3:27–30, 11:6–11). Petitioner also argues that, in its proposed combination, the strain gauges would have been used for collision detection and would have shut down the machine upon detecting a collision. *Id.* at 70 (citing Ex. 1003 ¶ 214; Ex. 1010, 19). Petitioner reiterates arguments for why the combination would have been made. *Id.* at 70–71 (citing Ex. 1003 ¶¶ 215, 216; Ex. 1005, 18:5–18; Ex. 1010, 19, 20).

We find that the portions of Calderon cited by Petitioner teach or suggest the additional limitations of claim 14. Ex. 1009, 3:27–30, 11:6–11. We credit Petitioner’s testimonial evidence because the citations to Calderon support it. Ex. 1003 ¶¶ 213, 214; Ex. 1009, 11:6–11. Patent Owner responds that claim 14 has not been shown to be unpatentable “for at least

the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 14. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 14 of the ’381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

15. Claim 15

Claim 15 depends from claim 12 and recites “wherein the controller is configured to adjust a speed of movement of the extruder in response to the calculated contact force.” Ex. 1001, 14:25–27.

Petitioner argues that one of ordinary skill in the art would have known that shutting down the machine upon detecting a collision would have stopped the movement of the extruder, thereby meeting claim 15. Pet. 73–74 (citing Ex. 1003 ¶¶ 227–229; Ex. 1010, 20).

We find that the portion of RepRap20208 cited by Petitioner teaches or suggests the additional limitations of claim 15. Ex. 1010, 20. We credit Petitioner’s testimonial evidence because the citations to the record support it. Ex. 1003 ¶¶ 228, 229; Ex. 1008 ¶ 180; Ex. 1010, 20. Patent Owner responds that claim 15 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 15. Weighing our underlying factual

determinations, a preponderance of the evidence persuades us that claim 15 of the '381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

16. Claim 16

Claim 16 depends from claim 12 and recites “wherein the controller is configured to adjust a temperature of the extruder in response to the calculated contact force.” Ex. 1001, 14:28–30.

Petitioner argues that one of ordinary skill in the art would have known that shutting down the machine upon detecting a collision would have shut down the heater on the extruder. Pet. 74 (citing Ex. 1003 ¶¶ 230, 231; Ex. 1010, 20). Petitioner also argues that it would have been obvious to turn off the heater in response to a collision “to save the machine and conserve energy.” *Id.* (citing Ex. 1003 ¶ 232).

We find that the portion of RepRap20208 cited by Petitioner teaches or suggests the additional limitations of claim 16. Ex. 1010, 20. We credit Petitioner’s testimonial evidence because the citations to the record support it. Ex. 1003 ¶¶ 231, 232; Ex. 1008 ¶ 180; Ex. 1010, 20. Patent Owner responds that claim 16 has not been shown to be unpatentable “for at least the reasons provided above for claim 1.” PO Resp. 54 (citing Ex. 2027 ¶ 260).

Based on the full record, Petitioner persuades us, and we determine, that the proposed combination of Calderon and RepRap20208 would have had the additional limitations of claim 16. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 16 of the '381 patent is unpatentable over Calderon and RepRap20208. *Arctic Cat*, 876 F.3d at 1361.

G. Asserted Obviousness Based on Calderon, RepRap20208, and Dunn

1. Claim 3

Claim 3 depends from claim 1 and recites “wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.” Ex. 1001, 13:8–10.

Petitioner argues that Dunn discloses a sensor assembly that senses surfaces in the x, y, and z directions. Pet. 75 (citing Ex. 1007 ¶¶ 69, 70, Fig. 9). Petitioner also argues that, in a z-axis initialization, Calderon describes moving its extrusion head 141 between stationary blocks 190, 192 in the x-direction to locate the outside of its modeling envelope 138. *Id.* (citing Ex. 1009, 7:16–23, 7:53–61, Figs. 7A, 7B).

Petitioner, thus, argues that Calderon would have been modified to have multiple strain gauges in accordance with the multi-axis sensor assembly of Dunn so that the combination would have Calderon’s z-sensing and sensing in the x and y directions. Pet. 75 (citing Ex. 1003 ¶¶ 233–235; Ex. 1007 ¶¶ 69, 70). Petitioner also argues that modification would have improved the efficiency of Calderon’s z-axis initialization routine because of the predictable improvement of including the x and y directions, and that there would have been a reasonable expectation of success in making the modification. *Id.* (citing Ex. 1003 ¶¶ 235, 236; Ex. 1009, 7:16–23, 7:53–61).

Petitioner argues that Calderon’s extrusion head would have experienced a deflection force due to collision when moving in the x-y plane, and that the sensors of the proposed combination would have sensed that deflection and sensed a force acting in the x-y axes. Pet. 76 (citing Ex. 1003 ¶¶ 237, 238).

a) Patent Owner's Response

Patent Owner responds that there is no motivation to combine because Dunn does not perform force sensing or measuring, only determines offsets in different directions by tilting a plunger of a dedicated assembly to sense the top and sides of a material pad. PO Resp. 56 (citing Pet. 75–76; Ex. 1007 ¶¶ 69–73, Figs. 9, 10; Ex. 2027 ¶ 270). Patent Owner also argues that RepRap20208 teaches away from multiple strain gauges on the extruder head, because it says they are “labor intensive” and “not cheap.” *Id.* (citing Ex. 1010, 16). Patent Owner further argues that strain gauges would be impacted by the heat from the extruder, so there would not have been motivation to use multiple strain gauges in place of Dunn’s tilting plunger. *Id.* at 56–57 (citing Ex. 1010, 16, 19; Ex. 2027 ¶¶ 267–272).

Patent Owner also responds that Dunn teaches a separate assembly with a plunger that is used to sense a material pad and does not teach sensing force as required by claim 3. PO Resp. 57–58 (citing Pet. 76–77; Ex. 1007 ¶¶ 69–73, Figs. 9, 10; Ex. 2027 ¶¶ 273–277).

b) Reply Arguments

Petitioner replies that RepRap20208 teaches force sensing that would have benefitted from Dunn’s teaching of a multi-axis configuration. Pet. Reply 25–26 (citing Pet. 75). Petitioner argues that RepRap20208 does not teach away, because the same poster explains how they can be implemented and the heat concern was for a metal bar implementation, not directed to strain gauges in general. *Id.* at 26 (citing Ex. 1010, 16–17, 19). Petitioner, thus, argues that it would have been obvious to provide multiple strain gauges in the extrusion head mount to measure in multiple axes to sense

surfaces in the x, y, and z directions. *Id.* (citing Ex. 1003 ¶¶ 233–235; Ex. 1007 ¶¶ 69, 70).

Petitioner also replies that it is not asserting a bodily incorporation of Dunn, Dunn teaches multi-axis configurations, and Dunn is not limited to a plunger implementation. Pet. Reply 27 (citing Ex. 1007 ¶ 96). Petitioner argues that its proposed combination senses in the x and y directions in addition to Calderon’s x direction. *Id.* (citing Ex. 1007 ¶ 69).

Patent Owner replies that Petitioner fails to rebut that Dunn does not sense or measure force and, instead, senses a material pad by tilting a plunger. PO Sur-reply 27–28 (citing PO Resp. 42–43, 56–57; Pet. Reply 25–26). Patent Owner also replies that Petitioner fails to respond to RepRap20208 teaching away from multiple strain gauges on the extruder head and that heat is still an issue for plastic strain gauges. *Id.* at 28 (citing Ex. 1010, 16).

Patent Owner also replies that Petitioner presents a new argument that relies on Dunn’s additional configurations beyond its separate-assembly implementations relied on in the Petition. PO Sur-reply 28 (citing Pet. 76–77; PO Resp. 57; Pet. Reply 27; Ex. 1007 ¶ 96). Patent Owner also argues that Petitioner tacitly admits that Dunn “does not teach force sensing but rather sensing the top and sides of a physical pad.” *Id.* (citing PO Resp. 57; Ex. 2027 ¶¶ 273–277).

c) Petitioner Persuades us that Claim 3 is Unpatentable

For the reasons given above for the challenge to claim 3 based on Calderon and RepRap20208, Petitioner persuades us that the claim is unpatentable. For the following reasons, Petitioner also persuades us that claim 3 is unpatentable over Calderon, RepRap20208, and Dunn.

We find that Petitioner’s proposed combination of Calderon, RepRap20208, and Dunn teaches or suggests the additional limitations of claim 3 and that one of ordinary skill in the art would have made the combination in the manner asserted with a reasonable expectation of success. Ex. 1003 ¶¶ 233–238; Ex. 1007 ¶¶ 69, 70, Fig. 9; Ex. 1009, 7:16–23, 7:53–61, Figs. 7A, 7B. In particular, we agree that Calderon moves its extrusion head 142 in the x-direction so as to define the range for its z-axis initialization and that Dunn provides an example of a multi-axis sensor. Ex. 1003 ¶¶ 234, 236; Ex. 1007 ¶¶ 69, 70; Ex. 1009, 7:16–23, 7:53–61, Figs. 7A, 7B, 8A, 8B.

We also agree that Calderon would have been combined with Dunn “to provide multiple strain gauges in the extrusion head mount” of the proposed combination “oriented to measure in multiple ax[e]s,” so that surfaces can be sensed in the x, y, and z directions. Ex. 1003 ¶ 235. We further agree that there would have been a reasonable expectation of success. *Id.* ¶ 236

Patent Owner’s argument that one of ordinary skill in the art would not have applied Dunn, because Dunn’s multi-axis sensor design is for offset calibrations, not for force sensing, and uses a different sensor design, does not address the proposed combination. PO Resp. 56–58. Petitioner proposes using the multi-axis configuration of Dunn, but does not further propose using the multi-axis configuration of Dunn for the same purpose with the same sensors. *See* Pet. 75–76. We also agree with Petitioner that RepRap20208 does not teach away, because it explains how they can be implemented and that the heat concern was for a metal bar implementation,

not directed to strain gauges in general. Pet. Reply 26 (citing Ex. 1010, 16–17, 19).

Based on the full record and for the reasons above, Petitioner persuades us, and we determine, that Calderon, RepRap20208, and Dunn teach or suggest the additional limitations of claim 3 and that one of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 3 of the '381 patent is unpatentable over Calderon, RepRap20208, and Dunn. *Arctic Cat*, 876 F.3d at 1361.

2. Claim 7

Claim 7 depends from claim 1 and recites “wherein the one or more sensors are collectively operable to sense a force between the fabrication tool and the separate structure along two or more non-parallel axes.” Ex. 1001, 13:19–22.

Petitioner argues that the sensors of the proposed combination would have sensed force along two or more non-parallel axes. Pet. 76–77 (citing Ex. 1003 ¶¶ 239, 240). Patent Owner responds that Dunn teaches a separate assembly with a plunger that is used to sense a material pad and does not teach sensing force as required by claim 7. PO Resp. 57–58 (citing Pet. 76–77; Ex. 1007 ¶¶ 69–73, Figs. 9, 10; Ex. 2027 ¶¶ 273–277). The parties present their replies for claim 7 together with the reply for claim 3. Pet. Reply 27; PO Sur-reply 28.

Based on the full record and for the reasons given above for claim 3, Petitioner persuades us, and we determine, that Calderon, RepRap20208, and Dunn teach or suggest the additional limitations of claim 7 and that one

of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 7 of the '381 patent is unpatentable over Calderon, RepRap20208, and Dunn. *Arctic Cat*, 876 F.3d at 1361.

3. Claim 8

Claim 8 depends from claim 7 and recites “wherein the one or more sensors are collectively operable to sense a force between the fabrication tool and the separate structure along three or more non-parallel axes.” Ex. 1001, 13:23–26.

Petitioner argues that the sensors of the proposed combination would have sensed force along three or more non-parallel axes. Pet. 77 (citing Ex. 1003 ¶¶ 241, 242). Patent Owner responds that Dunn teaches a separate assembly with a plunger that is used to sense a material pad and does not teach sensing force as required by claim 8. PO Resp. 57–58 (citing Pet. 76–77; Ex. 1007 ¶¶ 69–73, Figs. 9, 10; Ex. 2027 ¶¶ 273–277). The parties present their replies for claim 8 together with their replies for claims 3 and 7. Pet. Reply 27; PO Sur-reply 28.

Based on the full record and for the reasons given above for claim 3, Petitioner persuades us, and we determine, that Calderon, RepRap20208, and Dunn teach or suggest the additional limitations of claim 8 and that one of ordinary skill in the art would have made the proposed combination in the manner asserted with a reasonable expectation of success. Weighing our underlying factual determinations, a preponderance of the evidence persuades us that claim 8 of the '381 patent is unpatentable over Calderon, RepRap20208, and Dunn. *Arctic Cat*, 876 F.3d at 1361.

III. CONCLUSION²

In summary:

Claims	35 U.S.C. §	Reference(s)/Basis	Claims Shown Unpatentable	Claims Not Shown Unpatentable
1–6, 9–16	103	Warren	1–6, 9–16	
3, 7, 8	103	Warren, Dunn	3, 7, 8	
1–6, 9–16	103	Calderon, RepRap20208	1–6, 9–16	
3, 7, 8	103	Calderon, RepRap20208, Dunn	3, 7, 8	
Overall Outcome			1–16	

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that claims 1–16 of U.S. Patent No. 10,556,381 B2 have been shown, by a preponderance of the evidence, to be unpatentable; and

FURTHER ORDERED that, because this is a Final Written Decision, the parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

² Should Patent Owner wish to pursue amendment of the challenged claim in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner's attention to the April 2019 *Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding*. See 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. See 37 C.F.R. § 42.8(a)(3), (b)(2).

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