

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Aljosa Kemperle et al.
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Issue Date: February 11, 2020
Appl. Serial No.: 14/922,267
Filing Date: October 26, 2015
Title: THREE-DIMENSIONAL PRINTER WITH FORCE
DETECTION

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**PETITION FOR *INTER PARTES* REVIEW OF UNITED STATES PATENT
NO. 10,556,381 PURSUANT TO 35 U.S.C. §§ 311–319, 37 C.F.R. § 42**

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EXHIBITS

EX1001	U.S. Patent No. 10,556,381 to Kemperle et al. (“the ’381 patent”)
EX1002	Excerpts from the Prosecution History of the ’381 Patent (“the Prosecution History”)
EX1003	Declaration of Dr. Andrew Wolfe (including CV)
EX1004	US20030100824A1 to Warren et al (“Warren”)
EX1005	US9,031,680 to Napadensky (“Napadensky”)
EX1006	US20090273122A1 to Batchelder et al (“Batchelder122”)
EX1007	US20070228592A1 to Dunn et al (“Dunn”)
EX1008	US20070179656A1 to Eshed et al (“Eshed”)
EX1009	US 6,629,011 B1 to Calderon et al (“Calderon”)
EX1010	RepRap Discussion Thread “Genetic Algorithm” (available at https://reprap.org/forum/read.php?1,20208,page=1) (“RepRap20208”)
EX1011	US7552543B2 to Tomelleri (“Tomelleri”)
EX1012	US20070056176A1 to Matsumiya et al (“Matsumiya”)
EX1013	<i>Practical 3D Printers, The Science and Art of 3D Printing</i> by Brian Evans
EX1014	Declaration of Dr. Adrian Bowyer
EX1015	Declaration of June Munford

- EX1016 Exhibit E of Infringement Contentions from Stratasys, Inc., v. Shenzhen Touzhu Technology Co., Ltd., et al., Case Nos. 2:24-cv-00644-JRG and 2:24-cv-00645-JRG (E.D. Tex. Nov. 14, 2024)
- EX1017 US20080195353A1 to Igasaki et al (“Igasaki”)
- EX1018 J.E. Carryer, R.M. Ohline, and T.W. Kenny, *Introduction to Mechatronic Design*, ISBN-13: 978-0-13-143356-4, Pearson Education, Inc., Upper Saddle River, New Jersey 07458 (2011)
- EX1019 J. Srihohi, I. Chopra, *Fundamental Understanding of Piezoelectric Strain Sensors*, Journal of Intelligent Material Systems and Structures, Vol. 11, P. 246-257, April 2000
- EX1020 https://web.archive.org/web/20060615115221/http://www.allegtronics.com/cgi-bin/item/PE-49/466/PIEZO_ELEMENT_.html (piezoelectric element product discussed in <https://reprap.org/forum/read.php?1,8028,8276#msg-8276>)
- EX1021 US5,340,433 to Crump (“Crump”)
- EX1022 Declaration of Lynn Berthusen
- EX1023 Stipulation sent by Petitioner’s counsel to Patent Owner’s counsel
- EX1024 Docket Control Order (Document 34), *Stratasys, Inc. v. Shenzhen Tuozhu Technology Co. Ltd. et al*, 2-24-cv-00644 (EDTX)
- EX1025 U.S. District Court, Eastern District of Texas [Live] Calendar Events Set for 6/1/2026-7/1/2026
- EX1026 Defendant’s Motion to Dismiss for Failure to Join Indispensable Party (Document 38), *Stratasys, Inc. v. Shenzhen Tuozhu Technology Co., Ltd. et al.*, 2:24-cv-00644 (EDTX)

LISTING OF CLAIMS

Claim 1	
[1.pre]	A three-dimensional printer comprising:
[1.a]	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
[1b]	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
[1c]	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.
Claim 2	
[2]	The three-dimensional printer of claim 1, wherein the contact force is a force along an extrusion axis of the extruder.
Claim 3	
[3]	The three-dimensional printer of claim 1, wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.
Claim 4	
[4]	The three-dimensional printer of claim 1, wherein the separate structure includes an object being fabricated by the three-dimensional printer.
Claim 5	
[5]	The three-dimensional printer of claim 1, wherein the separate structure includes a build platform of the three-dimensional printer.
Claim 6	

[6]	The three-dimensional printer of claim 1, wherein the contact force is a force normal to a surface of the separate structure.
Claim 7	
[7]	The three-dimensional printer of claim 1, 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.
Claim 8	
[8]	The three-dimensional printer of claim 7, 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.
Claim 9	
[9]	The three-dimensional printer of claim 1, 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.
Claim 10	
[10]	The three-dimensional printer of claim 1, wherein the one or more sensors include one or more strain gauges.
Claim 11	
[11]	The three-dimensional printer of claim 1, 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.
Claim 12	
[12]	The three-dimensional printer of claim 1, 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.
Claim 13	
[13]	The three-dimensional printer of claim 12, wherein the controller is configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.
Claim 14	
[14]	The three-dimensional printer of claim 12, wherein the controller is configured to adjust a z-axis position of the extruder in response to the calculated contact force.
Claim 15	
[15]	The three-dimensional printer of claim 12, wherein the controller is configured to adjust a speed of movement of the extruder in response to the calculated contact force.
Claim 16	
[16]	The three-dimensional printer of claim 12, wherein the controller is configured to adjust a temperature of the extruder in response to the calculated contact force.

CONVENTIONS OF THE PETITION

- All emphases are added unless noted otherwise;
- Bold-italic emphases correlate to claim language;
- Quotations are generally from exhibits, not claim language; and
- The phrase “as discussed” and equivalent phrases incorporate fully the analysis of the cross-cited portion of the Petition.

Petitioner Shenzhen Tuozhu Technology Co., Ltd. petitions for IPR of claims 1-16 (“the Challenged Claims”) of U.S. Patent No. 10,556,381 (“the ’381 patent”) based on the grounds in this Petition.

I. REQUIREMENTS FOR IPR UNDER 37 C.F.R. § 42.104

A. Grounds for Standing Under 37 C.F.R. § 42.104(a)

Petitioner certifies that the ’381 patent is available for IPR, and that Petitioner is not barred or estopped from requesting IPR.

B. Challenge Under 37 C.F.R. § 42.104(b) and Relief Requested

Petitioner requests IPR of the Challenged Claims on the grounds below. Dr. Andrew Wolfe provides a supporting expert declaration (EX1003) cited throughout this Petition. EX1003, ¶¶1-246.

Ground	Claims	§103 Basis
1A	1-6, 9-16	Warren
1B	3, 7, 8	Warren and Dunn
2A	1-6, 9-16	Calderon and RepRap20208
2B	3, 7, 8	Calderon, RepRap20208, and Dunn

The references predate October 29, 2012, the ’381 Patent’s potential earliest effective date, and thus qualify as prior art, as shown by the table below.¹

¹ Petitioner reserves the right to challenge the patent’s priority.

Reference	Date	Pre-AIA Section	Post-AIA Section
Warren	May 29, 2003 (published)	§102(b)	§§102(a)(1)&(2)
Dunn	Oct. 4, 2007 (published)	§102(b)	§§102(a)(1)&(2)
Calderon	Sep. 30, 2003 (issued)	§102(b)	§§102(a)(1)&(2)
RepRap20208	Jan. 2009 (published)	§102(b)	§§102(a)(1)&(2)

RepRap20208, is an online discussion thread published around January 2009 on RepRap.org, which was the online forum created for the RepRap open source 3D printer development project well-known to developers and users of 3D printers. EX1013, 14-16; EX1014, 1-44. Dr. Adrian Bower, the originator of the RepRap project and co-administrator of the RepRap.org site, explains that this forum was accessible to the public without requiring login since its inception in March 2005. EX1014, ¶¶3-12. A registered user can start and “post” to forum discussion threads. *Id.* The forum was accessible from the front page at RepRap.org, and was ordered by subject matter and keyword searchable. *Id.*, ¶¶5-10. In fact, the inventors of the ’381 patent knew about the RepRap forum, as evidenced by their having disclosed a different thread to the USPTO. EX1001, Front Page.

II. SUMMARY OF THE ’381 PATENT

A. Pertinent Disclosure

The ’381 patent provides “pressure-sensing extruders” for a “three-dimensional printer.” EX1001, 1:14-21. “An extruder or other tool head of a three-

dimensional printer is instrumented to detect contact force against the extruder, such as by a build platform or an object being fabricated.” *Id.*, Abstract, 1:25-33. “The resulting feedback data can be used...to control operation of the three-dimensional printer.” *Id.*

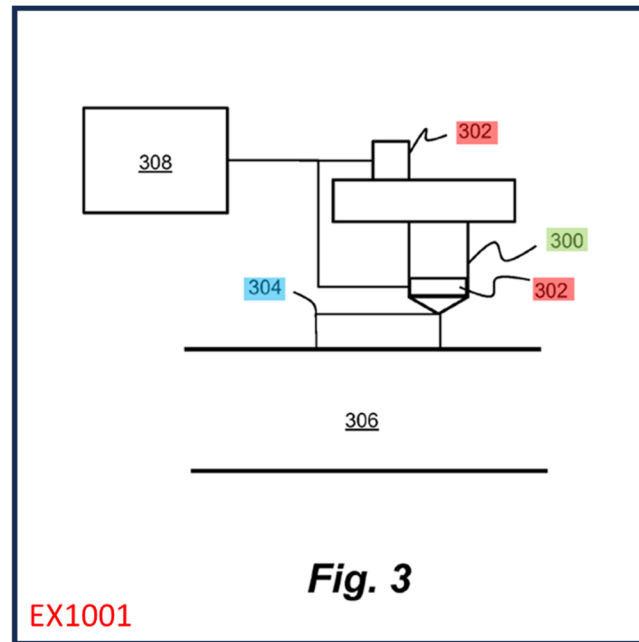


FIG. 3 (annotated above) depicts “a fabrication tool for use in a three-dimensional printer,” including “an extruder or other tool operable to add build material to an object 304 during a build process.” EX1001, 8:55-64. “[S]ensors 302 may be mechanically coupled or otherwise included in the fabrication tool 300...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.* Additionally, a “controller may...control the three-dimensional printer in a manner responsive to the detected forces.” *Id.*, 9:9-23. According to the ’381 patent, “sensors that are

collectively operable to sense any force or displacement of the fabrication tool and separate structure, or any related properties such as compression or strain, may be used as sensors 302, so long as the contact force(s) described above may be calculated from the sensed physical characteristics.” *Id.*, 8:65-9:10; EX1003, ¶¶35-37.

B. Prosecution History

The Examiner allowed the ’381 patent because he believed that “[t]he prior art fails to teach or suggest a three-dimensional printer comprising:...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....” EX1002, 7-23 (Notice of Allowance on 10/9/2019) (emphasis original). But as demonstrated by this Petition, the Challenged Claims are obvious, and this conclusion would have been apparent if the Examiner had the prior art presented here. EX1003, ¶¶ 38-42.

III. LEVEL OF ORDINARY SKILL

The range of qualifications for a POSITA would have included 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. EX1003, ¶¶20-23. Additional years of experience could substitute for a formal degree or formal training (and vice versa). *Id.*

As Dr. Wolfe explains, this POSITA would have possessed background knowledge and understanding of the pertinent technologies employed by the '381 patent, including implementing sensor based systems. EX1003, ¶¶21-23, 7-19, and Appx. A. Sensor based technologies, such as sensors used to determine force, were commonplace and readily commercially available long before 2012. *Id.*, ¶21.

IV. CLAIM CONSTRUCTION—37 C.F.R. §42.104(b)(3)

As detailed below, the Challenged Claims are obvious under any reasonable *Phillips* interpretation. Petitioner submits that the Board need not resolve any express constructions. *Wellman, Inc. v. Eastman Chem. Co.*, 642 F.3d 1355, 1361 (Fed. Cir. 2011). Petitioner reserves the right to address any subsequent issues of claim interpretation that arise here or in the district court.

V. THE CHALLENGED CLAIMS ARE UNPATENTABLE

A. GROUND 1A – Claims 1–6, 9-16 Are Obvious Over Warren

1. Warren (EX1004)

Like the '381 patent, Warren is about 3D printing. EX1003, ¶¶43-51. Specifically, Warren teaches a kind of 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.” EX1004, [0010-0011]. DWDT is broadly applicable to “organic and inorganic applications.” *Id.*, [0013]. When DWDT is employed for “biological, medical, bioengineering, and tissue-engineering,” Warren uses the label “human architecture

tool” (“HAT”). *Id.*, [0014]. Warren describes its DWDT/HAT technology used to construct “3D engineered tissue constructs (ETC).” *Id.*, [0061]. In short, Warren’s “DWDT/HAT technology has a plurality of aspects that...combine to make a tool capable of producing a modeled structure through 3D direct construction of various materials into complex shapes.” *Id.*, [0093].

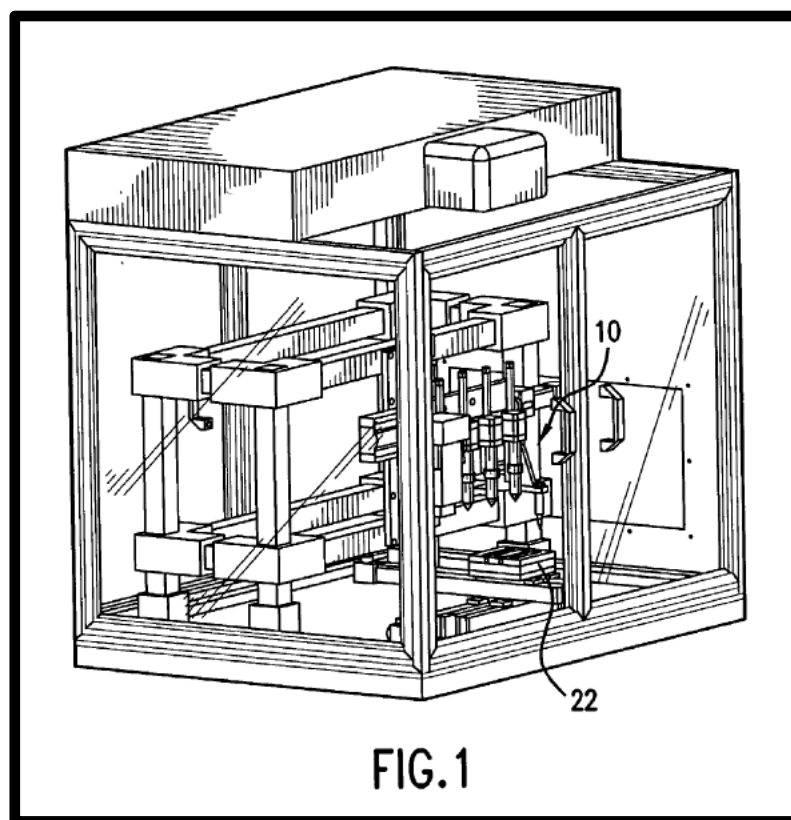


FIG. 1 shows Warren’s DWDT/HAT tool. EX1004, [0058]. In Warren, the “DWDT/HAT may include a material dispenser 100 that facilitates the fabrication and assembly of biocompatible scaffolds, cells, nutrients, growth factors, ECM proteins, therapeutics, and other biological, organic, or inorganic components as desired to form various components, such as 3D engineered tissue constructs

(ETC).” EX1004, [0061]. Warren explains that the ability to construct “supportive 3D matrices, bioactive factors, and cells that differentiate and grow brings about a new-to-the-world advance to the metabolic- and tissue-engineering communities.” *Id.*, [0063], [0007] (“3D requirements”), [0321] (“the bioscaffold can require 3D fabrication processes”), [0324] (3D layered fabrication to deposit cells atop a bio scaffold material), [0446] (“The disclosed apparatuses, tools and methods can also be used to create specific 3D scaffolding out of biologically compatible material”).

Warren discloses “controlling the position of one or more elements of a depositing system that accurately determines the intensity of the contact force between a dispensing tip and a substrate surface to maintain a desired contact force between the dispenser and the substrate.” EX1004, [0287], [0226]-[0229], [0288-290], [0283-84].

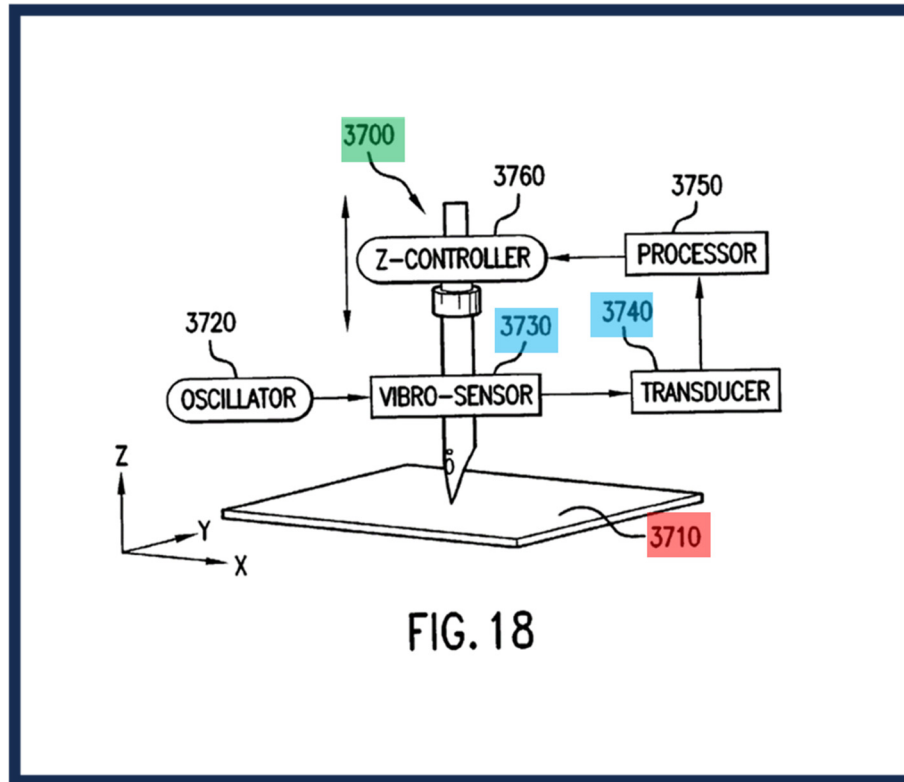
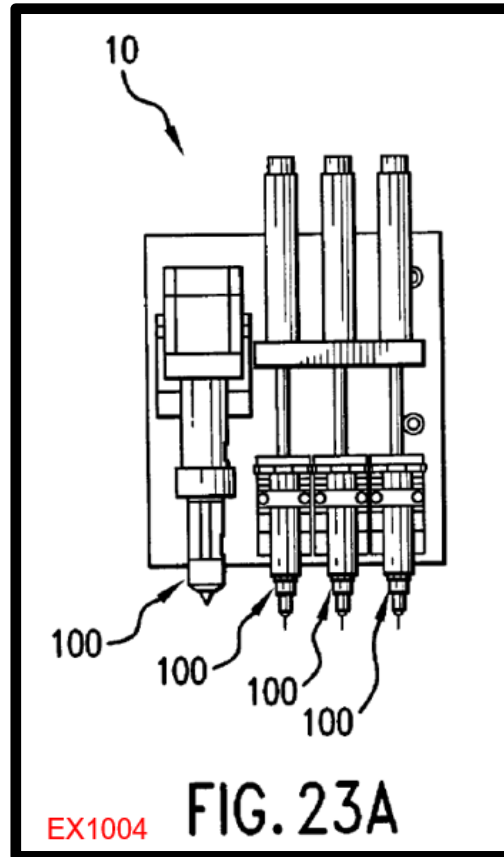


FIG. 18

Referencing FIG. 18 (above), Warren discloses “an exemplary system for controlling the position of a **dispenser 3700** relative to a **substrate 3710** [which] may have irregular surfaces.” *Id.*, [0293]. “A **vibration sensor 3730** and a **transducer 3740** are attached to the dispenser 3700.” *Id.*, [0300], [0315]. Warren teaches vibrating the dispenser 3700, and when “[t]he vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 dispenser with the substrate 3710...[t]he transducer 3740 senses and transfers the changed vibration signal to an amplifier...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.*, [0302], [0283-307] (additional details on force sensing). In one example, “the feedback signal may be used by a z-controller processor 3750 to control the z

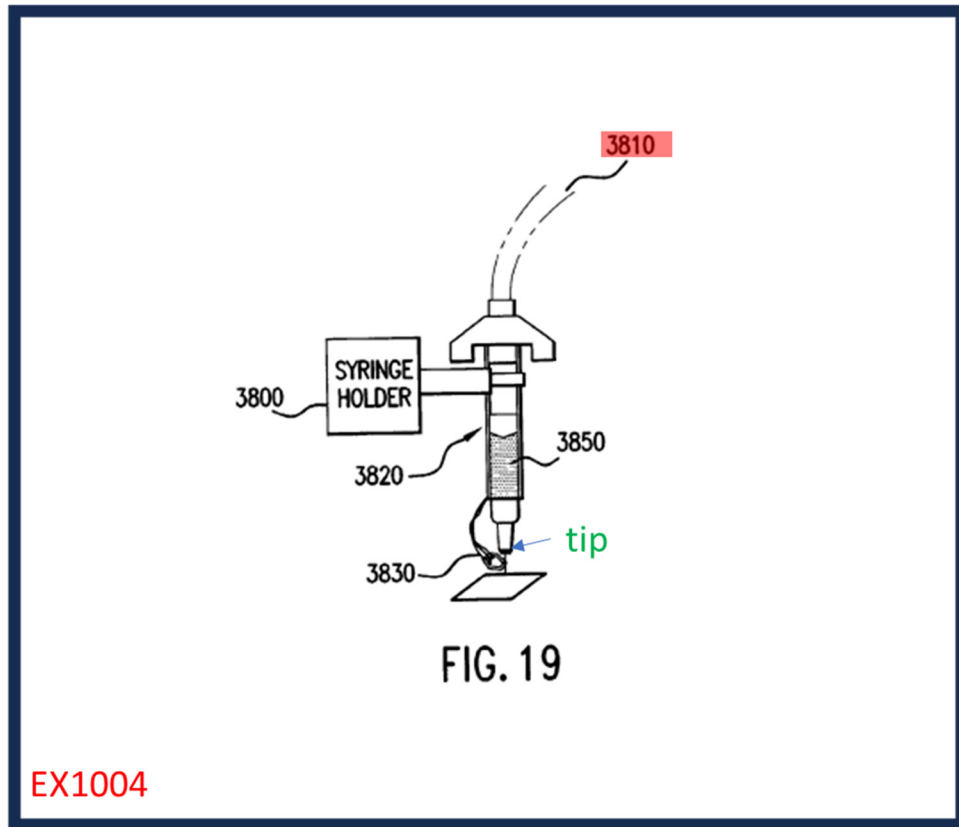
positioning of the dispenser 3700 via a z-controller step motor 3760.” *Id.*, [0313], [0283-0318] (describing FIGS. 18-22A).

Warren further describes that its DWDT/HAT tool (“apparatus 10”) can have one or multiple material dispensers (“dispensers 100”), and provides the example of FIGS. 23A-23C including “four material dispensers, one through-nozzle dispenser and three capillary-based dispensers.” EX1004, [0278] (“apparatus 10”, “dispensers 100”), FIG. 23A-C.

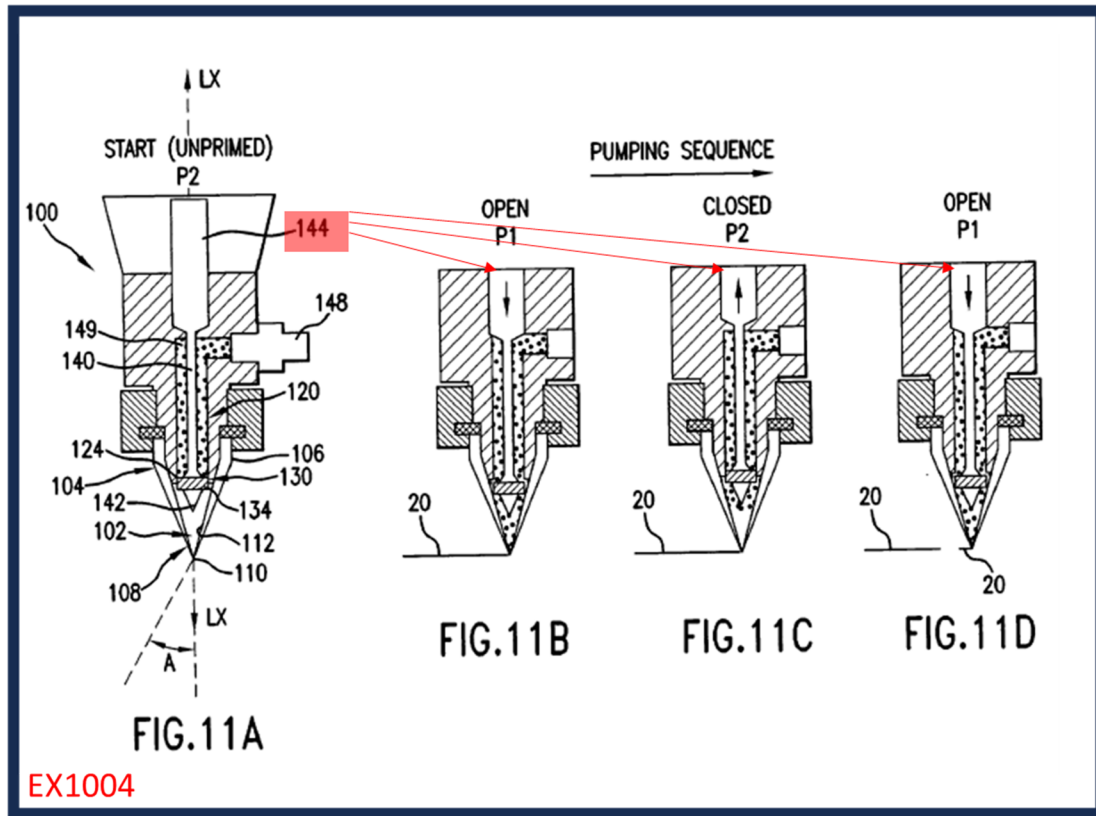


The capillary-based dispensers, referred to as a “capillary vibro-sensor dispensing unit” in “FIGS. 19 [below], 20A and 20B,” can be “implemented in the system shown in FIG. 18” employing vibrating force sensing. EX1004, [0299].

According to Warren, “[t]his type of dispenser forces, e.g., fluid or paste, in a reservoir 3850 through the tip 3840 of a syringe using air pressure applied from a source 3810 to the top side of a plunger 3820.” *Id.*, [0295].



Warren additionally discloses a through-nozzle dispenser capable of precise control of “the amount of material dispensed per second” using, e.g., **linear actuator 144** (as annotated in FIGS. 11A-D (below)) “to control valve opening and closing.” EX1004, [0230-0252].



2. The Combination, Reasons to Combine, & Expectation of Success

Warren suggests combining various aspects of its disclosure to achieve a comprehensive 3D printing tool. EX1004, [0093] (“The DWDT/HAT technology has a plurality of aspects that...combine to make a tool capable of producing a modeled structure through 3D direct construction of various materials into complex shapes.”). Thus, for example, although Warren discloses using vibration force sensing in connection with its capillary vibro-sensor dispenser (EX1004, [0283-0318]), a POSITA would have found it obvious to use the vibrating force sensor concepts with Warren’s through-nozzle dispenser (e.g., *id.*, [0230-0252]). EX1003, ¶66.

A POSITA would have been motivated to apply Warren's through-nozzle dispenser (EX1004, [0230-0252] (describing FIGS. 11A-11D and 12A-12B)) as dispenser 3700 in Warren's vibrating force sensor configuration (*id.*, [0283-0318], [0226-0229]). *Id.*, [0239]; EX1003, ¶67. A POSITA would have been motivated to use Warren's through-nozzle design as Warren's dispenser 3700 for at least the following independent reasons. *Id.*

First, Warren invites the use of the vibrating force sensor concepts with other configurations of dispenser when it explains that the capillary dispenser is shown with the vibrating force sensor "by way of example only," and "[t]he dispenser 3700 need not be limited to [the capillarity dispenser] implementations." EX1004, [0299], [0294] ("dispenser 3700 may be implemented differently"); EX1003, ¶68. Using Warren's through-nozzle dispenser as dispenser 3700 merely involves combining known elements using known techniques to achieve predictable and advantageous results. *Id.*

Second, a POSITA would have been motivated by the precise flow control capability of Warren's through-nozzle design in which "linear actuator 144 controls the material dispensing rate and improves start and stop characteristics by controlling the position of the valve piston 140 and speed of displacement." EX1004, [0243]. "During the initial valve opening, the motion of the piston 140 transfers a momentum to the material and causes the material to flow at a specific flow rate...so

that the material flowing through the valve 130 will have the same flow velocity, thereby leading to a smooth dispensing start.” *Id.* A POSITA would have found it advantageous to employ Warren’s through-nozzle design in dispenser 3700 so that “the initiation of material flow...can be smooth, seamless, and very reproducible.” *Id.*; EX1003, ¶69 (citing “inconsistent volumes and inaccurate start times” in the absence of actuator control (*id.*)).

Third, Warren makes clear that its linear actuator 144 is “conventional,” and the predictable use of such conventional linear actuator in Warren’s dispenser system 3700 to “provide[] a means to control precisely the rate (speed) and the degree of valve opening and closing” (*id.*, [0243]) would have been obvious. Significantly, Warren explains that its “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.*, [0093]. A POSITA would have recognized Warren’s express suggestion to add features from its through-nozzle design (such as linear actuator 144) to Warren’s dispenser system 3700 to pursue a predictable combination. EX1003, ¶70.

Fourth, a POSITA would have recognized the benefits of providing the through-nozzle dispenser with vibrating force sensor capabilities. As Warren explains, “for proper deposition some knowledge is required of the intensity of the

contact force between the dispenser tip and surface where deposition is desired.”

EX1004, [0286]. “Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the tip crashes into the substrate material, or little to no control of the deposition geometry due to a large spacing between the tip and the substrate surface.” *Id.* Thus, a POSITA would have sought to apply Warren’s vibration force sensing to Warren’s through-nozzle dispenser to avoid damage to the substrate or nozzle and to facilitate control over the deposition geometry. EX1003, ¶71. Further, a POSITA would have sought “to overcome issues regarding agglomeration and/or sticking of the constituent material” with the vibrating aspects. EX1004, [0331]-[0332]; EX1003, ¶71.

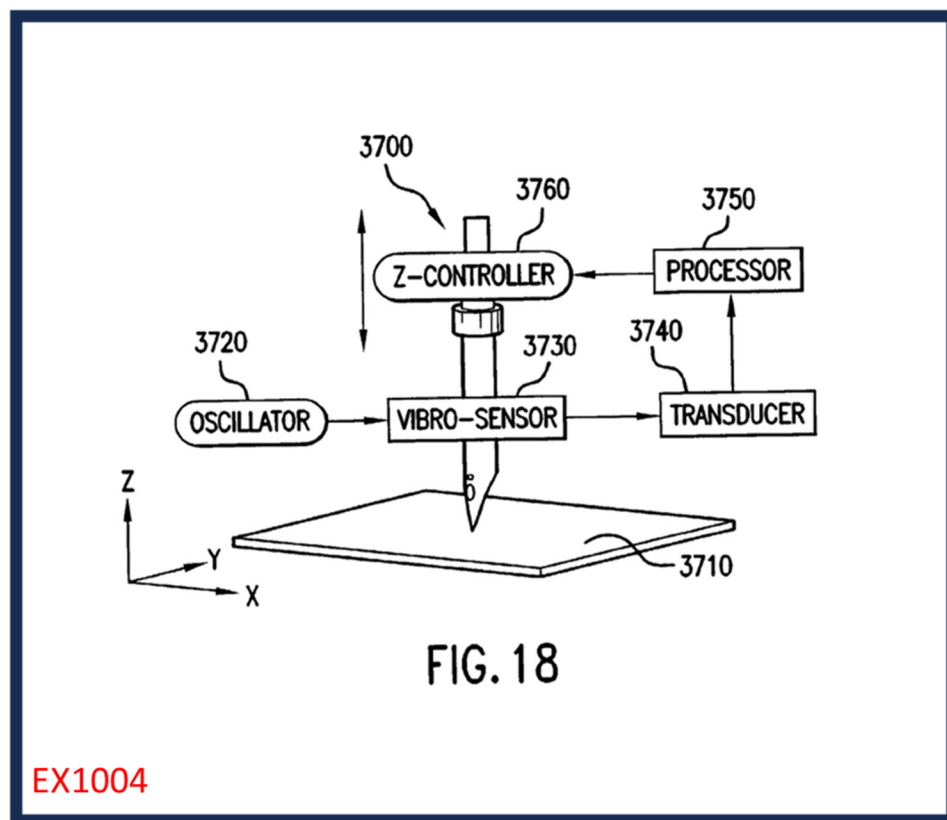
Combining the relevant aspects of Warren would have been nothing more than integrating complementary teachings from within the same reference, all of which relate to the same DWDT/HAT technology. EX1003, ¶72. The fundamental aspects of Warren’s vibrating force sensor configuration using force feedback would remain intact, bolstered by the beneficial aspects of the through-nozzle design with a reasonable expectation of success. *Id.*

3. Claim Element Analysis

[1.pre]: A three-dimensional printer comprising:

To the extent the preamble is limiting, Warren teaches a **three-dimensional printer** for “3D direct construction of various materials into complex shapes.”

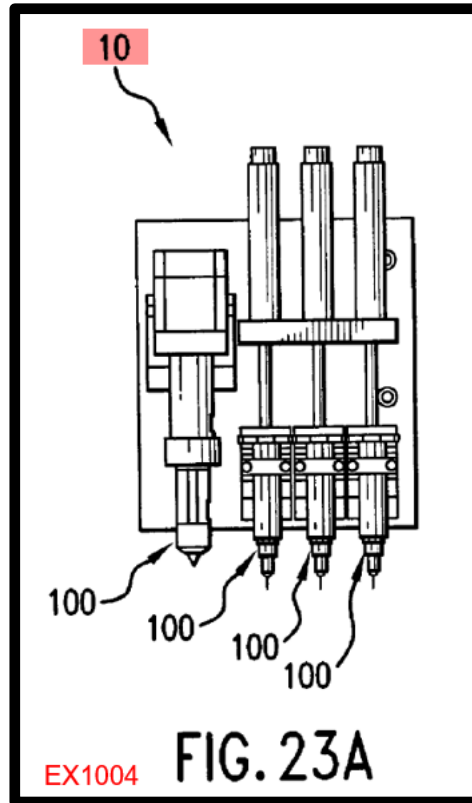
EX1004, [0093], [0063], [0226]-[0229], [0293-0321], [0288-290]; §§V.A.1-2; EX1003, ¶¶75-76.



[1.a] a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;

Warren includes *a fabrication tool*, e.g., the apparatus 10 shown in FIGS.

23A-23C:

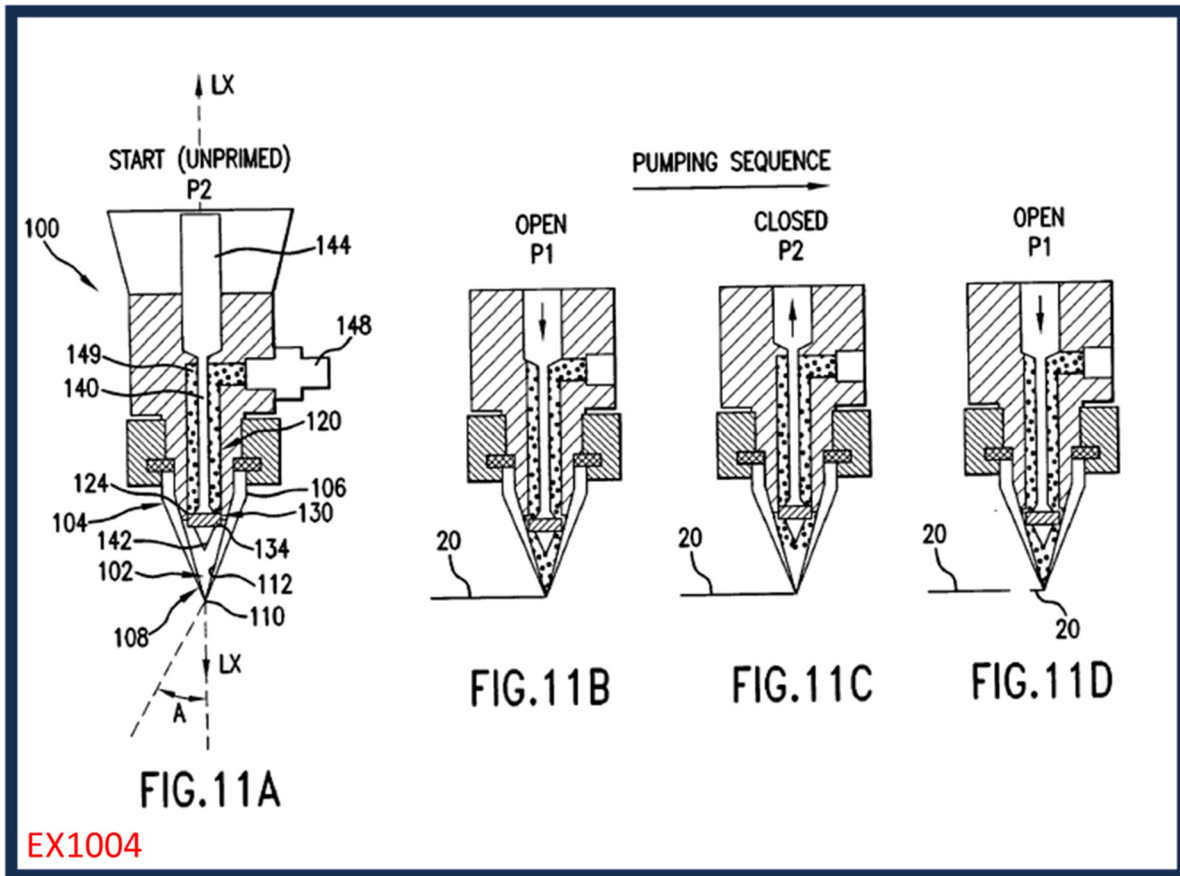


The fabrication tool includes *an extruder* (e.g., the capillary vibro-sensor dispenser and/or the through-nozzle dispenser – both designated as 100 in FIG. 23A) *configured to extrude build material to fabricate an object* (e.g., a modeled structure via the DWDT/HAT technology) *during a build process* (e.g., a 3D direct construction process). EX1003, ¶¶77-78.

As discussed *supra* §§V.A.1-2, the capillary vibro-sensor dispenser is expressly disclosed as used with Warren’s vibrating force sensing and a POSITA would also have been motivated to configure the through-nozzle dispenser with Warren’s vibrating force sensing. Use of either, or both, satisfies claim 1. EX1003, ¶79.

The capillary vibro-sensor dispenser is *an extruder* in that it “forces, e.g., fluid or paste, in a reservoir 3850 through the tip 3840 of a syringe using air pressure applied from a source 3810.” EX1004, [0295], [0299], FIGS 18-19; EX1003, ¶80.

The through-nozzle dispenser is likewise *an extruder* in that it features a “pump 148 [that] powers a simple process of applying 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.” EX1004, [0232], [0230-0252], FIGS. 11A-11D (annotated below), 12A-12B. The “valve 130 includes a linear-actuated piston 140..., the piston being operatively coupled to [the] miniature displacement pump 148.” *Id.*, [0242]. “[T]he linear actuator 144 [operating the valve piston 140] controls the material dispensing rate” through the nozzle tip orifice 110. *Id.*, [0243-0244]; EX1003, ¶81.

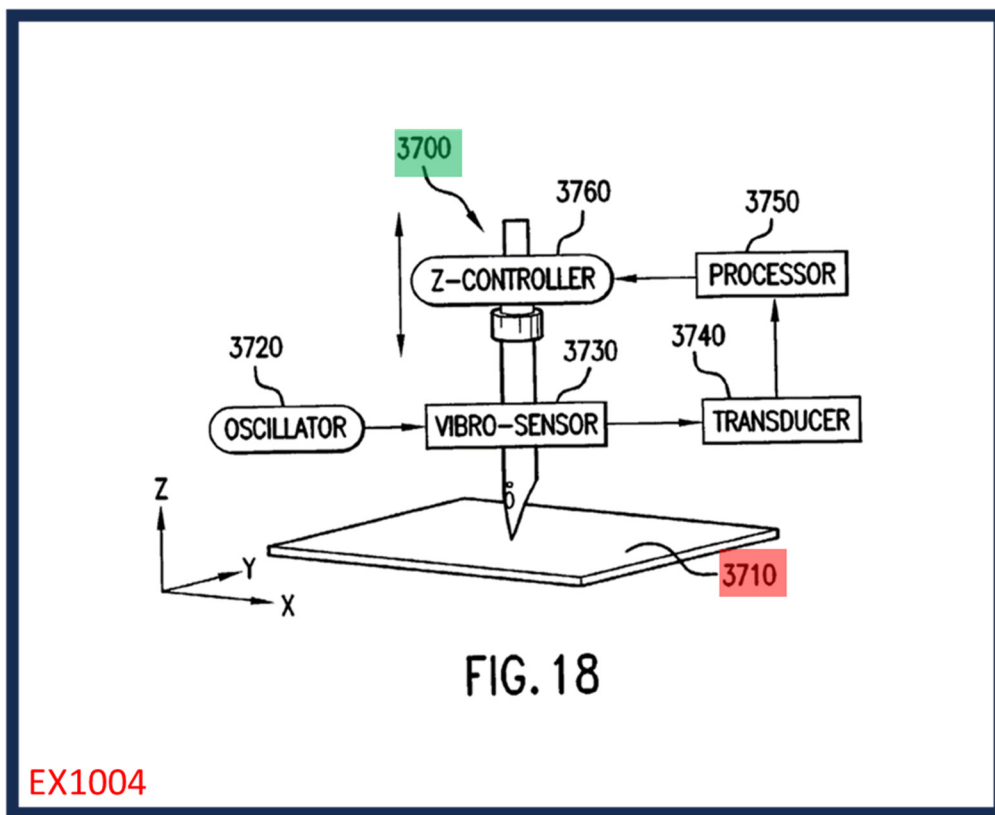


Moreover, Warren's teachings parallel the '381 patent's preferred embodiments, which "push the build material into the chamber 122 and/or through the extrusion tip 124." EX1001, 2:28-52; EX1003, ¶82 (noting extruders in fused deposition modeling, like the '381 patent, have long been referred to as "dispensers" by citing EX1021, 3:14-38).

Both of Warren's dispensers are *configured to extrude build material to fabricate an object during a build process*, including "to precisely and selectively add, in real time, supportive 3D matrices, bioactive factors, and cells." *Id.*, [0063], [0007], [0321], [0324], and [0446]. EX1003, ¶¶83-84.

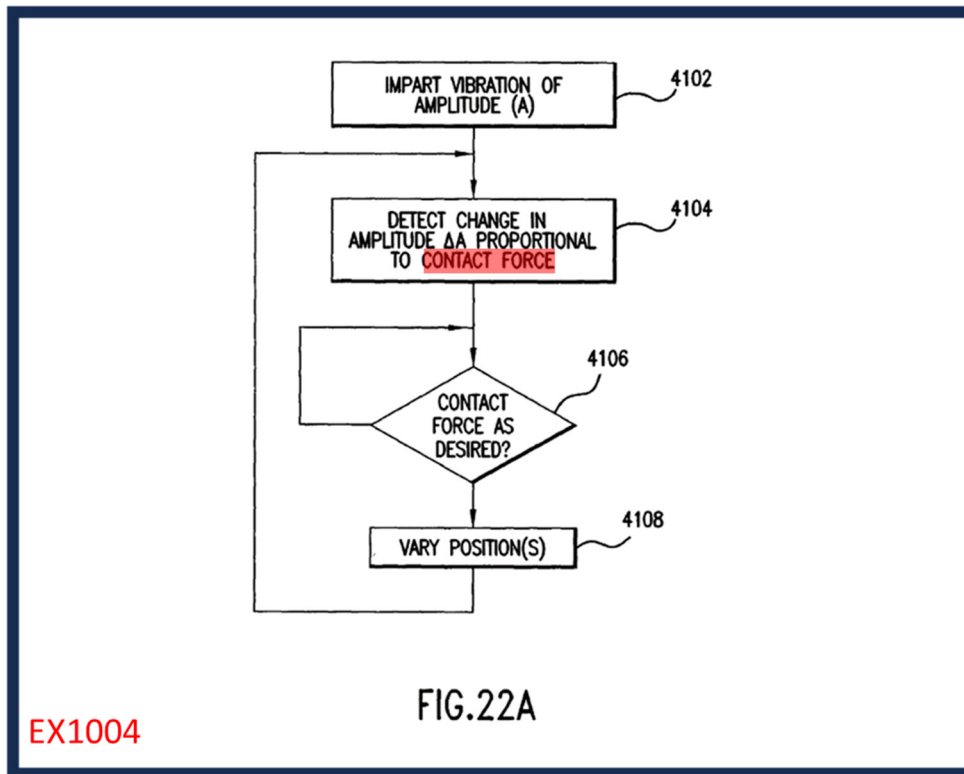
[1.b] one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and

The combined teachings of Warren provide *one or more sensors* (e.g., vibration sensor 3730 and transducer 3740) *mechanically coupled to the extruder* (e.g., capillary vibro-sensor dispenser and/or the through-nozzle dispenser). *E.g.*, EX1004, [0300] (“A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700”), [0315], FIG. 18 (below); EX1003, ¶85.



Warren’s *sensors* are *operable to detect a contact force* (e.g., the force of contact) *between the extruder* (e.g., the capillary vibro-sensor dispenser and/or the through-nozzle dispenser) *and a separate structure* (e.g., substrate 3710). EX1003,

¶86. For example, Warren’s system includes “a vibration oscillator 3720...for imparting vibration to the dispenser 3700” and “[a] vibration sensor 3730 and a transducer 3740...for sensing the A and f of vibration of the dispenser 3700.” EX1002, [0300]. According to Warren, “[t]he vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 [sic] dispenser with the substrate 3710” such that “[t]he transducer 3740 senses and transfers the changed vibration signal to an amplifier...which then creates a feedback signal.” EX1004, [0302]. Warren further explains that “this change in amplitude is proportional to *the force of contact* between the dispenser and the substrate.” *Id.*, [0313] (discussing FIG. 22A (annotated below showing “detect change in amplitude ΔA proportional to contact force”)).

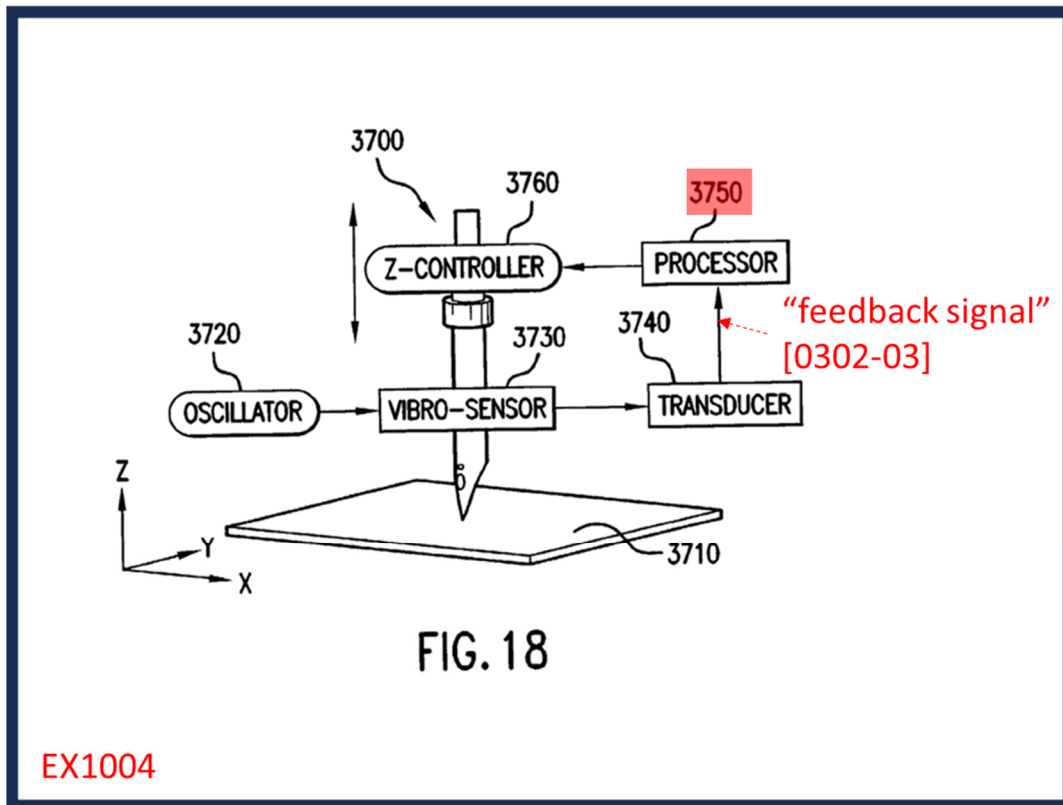


In view of the proportionality, a POSITA would have understood that the *contact force* can be readily calculated from the detected “change in the amplitude.” EX1004, [0313], [0301]-[0307]; EX1003, ¶¶86-90 (explaining additional details of Warren’s sensing operations). Warren’s vibration sensor and transducer thus align with the specification of the ’381 patent, which describes its sensors broadly to sense anything, “so long as the contact force(s)...may be calculated from the sensed physical characteristics,” EX1001, 8:49-61; EX1003, ¶¶90-91.

[1.c] 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.

The combined teachings of Warren provide *a controller* (e.g., a “microprocessor” or “a personal computer”) *configured to receive a signal* (e.g., the

feedback signal) *from the one or more sensors* (e.g., vibration sensor 3730 and transducer 3740) to calculate the contact force *between the extruder* (the capillary vibro-sensor dispenser and/or the through-nozzle design) *and a separate structure* (e.g., substrate 3710). EX1003, ¶92.



Warren discloses: “The transducer 3740 senses and transfers the changed vibration signal to an amplifier...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.” EX1004, [0302]. “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.* In one example, “the feedback signal

may be used by a z-controller processor 3750 to control the z positioning of the dispenser 3700 via a z-controller step motor 3760.” *Id.*, [0313]. “The **z-controller [processor] 3750** may be implemented with, e.g., a microprocessor,” or “personal computer.” *Id.*, [0302-0303]; EX1003, ¶93.

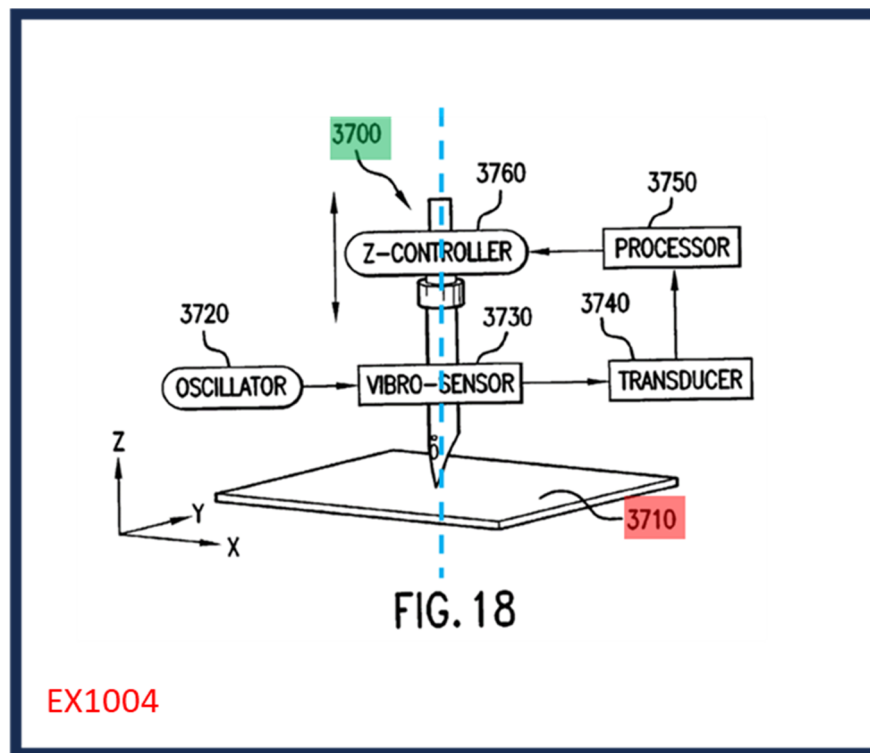
Warren also explains it is significant “to determine the intensity of contact force between elements” to further Warren’s objective “to maintain a desired contact force between the dispenser and the substrate” and prevent their “destruction.” EX1004, [0286-287], [0313-0316], FIG. 22A. A POSITA would have known, or found it obvious, that Warren’s controller calculates the contact force based on the feedback signal using the proportionality. EX1003, ¶94 (noting the well-known conversion); *E.g.*, EX1012, [0120-121] (“scanning measuring force”), [0128-129] (“touch detecting measuring force”), and EX1017, FIG. 4. Calculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012. EX1003, ¶95. Calculating contact force was also obvious because of its many advantages in a control system designed to “maintain a desired contact force.” *Id.* Among other reasons, a POSITA 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. *Id.*

(discussing advantages in programming and user interaction because force is meaningful to a user).

Accordingly, Warren renders obvious all limitations of claim 1. EX1003, ¶¶73-96.

2. The three-dimensional printer of claim 1, wherein the contact force is a force along an extrusion axis of the extruder.

In the context of claim 1, *the contact force is a force along an extrusion axis* (e.g., the z-axis) *of the extruder* (the capillary vibro-sensor dispenser and/or the through-nozzle dispenser design). §§V.A.1-2; EX1003, ¶¶97-98.



Referring to FIG. 18 (annotated above), Warren's dispenser is oriented along the z-axis, which serves as the extrusion axis in this configuration. EX1004, [0293-

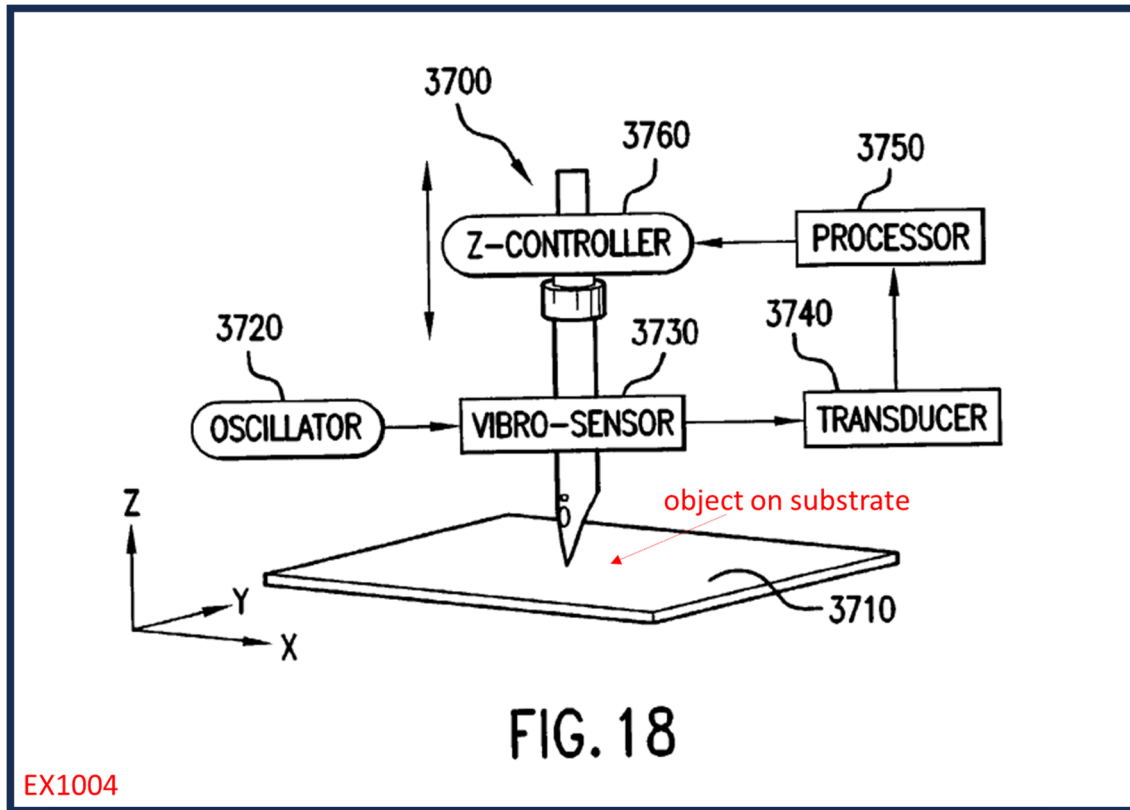
94]. When the substrate is aligned with the x-y plane, as in FIG. 18, the contact force exerted at the tip of dispenser is directed along the extrusion axis. *Id.*, EX1003, ¶¶99. Warren further explains controlling the z-height of the substrate and/or dispenser in response to the contact force. EX1004, [0316]. Moreover, 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. EX1003, ¶¶99-100.

3. The three-dimensional printer of claim 1, wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.

The '381 patent distinguishes a “deflection force” from a “normal force.” EX1001, 9:23-24. The contact force in Warren, however, also 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. EX1003, ¶¶101-103; EX1004, [0316] (describing use of the vibrating force sensor while dispensing material to “continuously correct[] the dispensing structure's Z-height position”), [0322] (“follow” curved surfaces).

4. The three-dimensional printer of claim 1, wherein the separate structure includes an object being fabricated by the three-dimensional printer.

In the context of claim 1, *the separate structure includes an object being fabricated* (e.g., the modeled structure being built on substrate 3710) *by the three-dimensional printer.* §§V.A.1-2; EX1003, ¶¶104-105.

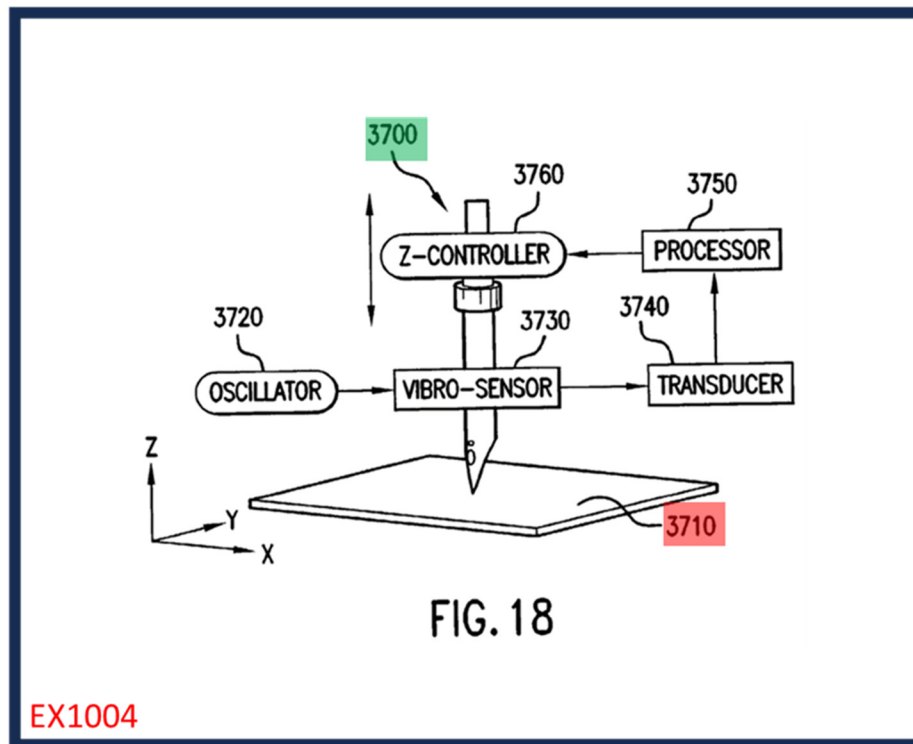


Referring to FIG. 18 (above), a modeled structure (i.e., *an object*) is being built on substrate 3710. EX1003, ¶106; *E.g.*, EX1004, [0295] (“multilayered” structure), [0324] (“four different layers”), [0088], [0093], [0316], [0427]. Warren describes that the vibrating force sensing “enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force.” *Id.*, [0316], [0375], [0301-316]. A POSITA would understand Warren’s description of using a dispenser with the vibrating force sensor to “find contact with” 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*. EX1004, [0316], [0324]; EX1003, ¶¶106-107.

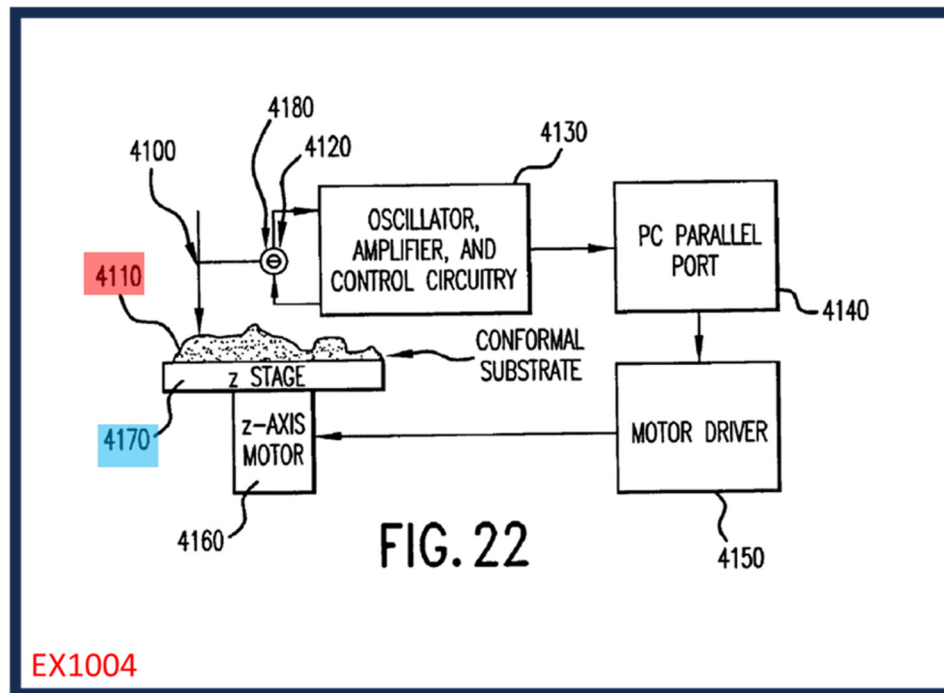
5. The three-dimensional printer of claim 1, wherein the separate structure includes a build platform of the three-dimensional printer.

In the context of claim 1, *the separate structure includes a build platform* (e.g., the substrate and/or underlying z stage on which the modeled structure is being built) *of the three-dimensional printer*. §§V.A.1-2; EX1003, ¶¶108-109.



Referring to FIG. 18 (annotated above), the substrate 3710 is a *build platform*. EX1003, ¶110. The substrate 3710 and underlying structure could also provide the claimed *build platform*. *Id.* As annotated below, FIG. 22 of Warren (“implemented in a manner similar to FIG. 18”) shows “the substrate 4110 rests” upon “z-axis stage

4170.” EX1004, [0311]. As explained *supra* §§V.A.1-2, Warren teaches measuring the contact force between its dispenser and an underlying surface such as the surface of the substrate. This arrangement is consistent with the description of the ’381 patent. EX1001, 8:55-64 (“a separate structure, such as...the build platform 306...”); EX1003, ¶¶110-111.



6. The three-dimensional printer of claim 1, wherein the contact force is a force normal to a surface of the separate structure.

In the context of claim 1, Warren’s combined teachings provide *a contact force is a force normal to a surface of the separate structure* (a substrate). EX1003, ¶¶112-113.

Referring to FIG. 18 (annotated *supra* claim 3), Warren depicts substrate 3710 as positioned on an underlying build platform, which lies in the x-y plane. EX1004,

[0293-294, 0301-303], FIG. 18. The contact force at the tip of dispenser 3700 acts along the z-axis, and therefore *normal* to the surface of the separate structure (positioned in the X-Y plane). EX1003, ¶114. Warren’s description thus comports with the ’381 specification at 8:65-9:10 (“...a normal force (e.g., instantaneous contact force) between the fabrication tool 300 and the build platform 306 may be sensed”). Moreover, even if the dispenser were not precisely normal to the surface of the substrate, a POSITA would have understood that there was a force component directed normal to the substrate and that this force component is a contact force. EX1003, ¶¶114-115.

9. The three-dimensional printer of claim 1, 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.

In the context of claim 1, Warren’s combined teachings provide *sensors* that are *optical sensors* and *piezoelectric sensors*—e.g., piezoelements, piezomembranes, and piezotransducers—to measure contact forces while the modeled structure is being built. EX1004, [0283-0306]; EX1003, ¶¶116-117. Warren explains that “According to one embodiment, a noncontact, high accuracy (submicrometer) fiber optic sensor may be used as the sensor element to monitor vibration.” *Id.*, [0297]. A “fiber optic sensor” is an *optical sensor*. EX1003, ¶117. Warren also explains that oscillator 3720 and the transducer 3740 may be “implemented in a piezoelectric bimorph ceramic element,” which is a piezoelectric

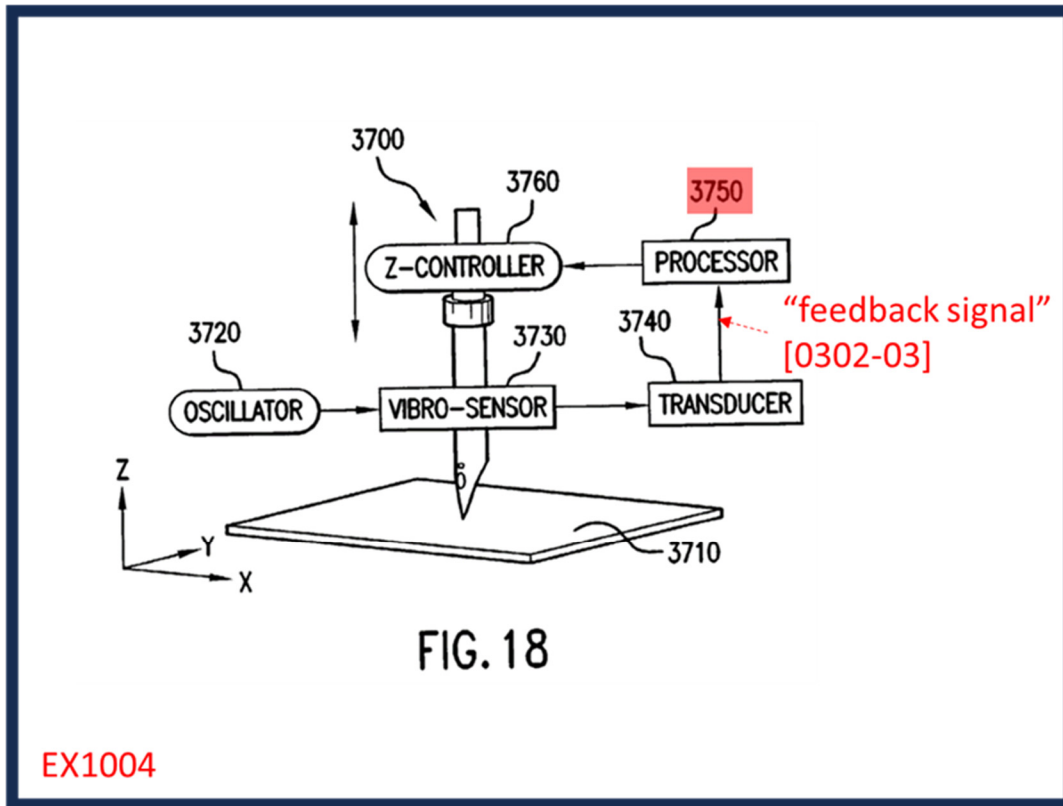
sensor. EX1004, [0300], [0304], [0306-07] (“a dispensing system with a piezoelement attached”); EX1003, ¶¶117-118.

10. The three-dimensional printer of claim 1, wherein the one or more sensors include one or more strain gauges.

As discussed in Claim 9, *supra*, Warren provides several examples of piezoelectric devices as sensors “for sensing ...vibration of the dispenser 3700.” EX1004, [0300-302]. As explained by Dr. Wolfe, it was general knowledge that piezoelectric devices convert input mechanical displacement/strain to a change in electrical output based on the piezoelectric effect. EX1003, ¶¶119-120 (citing, e.g., EX1019). A POSITA would have understood piezoelectric devices to be strain gauges, or at least found it obvious to configure vibration sensor 3730 of Warren as a strain gauge to sense the displacement of the vibrating dispenser 3700 in determining its amplitude and frequency of vibration. EX1003, ¶¶120-121 (citing EX1012, [0034] (discussing force detection based on a vibrating stylus by using “a strain gauge for detecting distortion of the stylus” and EX1006, [0044-45], FIG. 7).

11. The three-dimensional printer of claim 1, 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.

In the context of claim 1, Warren's combined teachings provide *actuators* (e.g., z-controller step motor 3760) *mechanically coupled to the fabrication tool* (e.g., dispensing system 3700). EX1003, ¶¶122-123.



Referring to FIG. 18 (above), Warren teaches using “a z-controller processor 3750 to control the z positioning of the dispenser 3700 via a z-controller step motor 3760,” EX1004, [0302], which a POSITA would have recognized as *mechanically coupled to* the apparatus of FIG. 23A supporting dispensing system 3700. EX1003, ¶124; EX1004, FIG. 1 (also showing mechanical coupling).

Moreover, Warren describes that “the z-controller processor 3750 may be implemented with, e.g., a microprocessor,” which a POSITA would have known to

include a constituent circuit (i.e., *a control circuit*) *in data communication with* z-controller step motor 3760 (i.e., *the actuators*) and vibration sensor 3730 and transducer 3740 (i.e., *the sensors*) so that z-controller processor 3750 can receive signals and assert control over, e.g., z-controller step motor 3760. EX1003, ¶125.

Warren's feedback signal is used by "a z-controller processor 3750 to *control* the z positioning of the dispenser 3700 via a z-controller step motor 3760" (i.e., *the one or more actuators*) so as "to maintain a desire force contact [i.e., *a specified contact force*] between the dispenser 3700 and the substrate 3710 [included by *the separate structure*]." EX1004, [0302]; EX1003, ¶126. The language of the claim 11 "*to achieve a specified contact force between the one or more sensors and the separate structure*" literally requires the specified contact force be between the sensor and the separate structure. A POSITA would have understood Warren's dispenser 3700 could also be considered part of the claimed *sensor* and the contact force to be "*between the //sensors and the separate structure,*" because the dispenser 3700, due to its vibration, is an active component in Warren's the vibrating force sensor. EX1003, ¶127. If it is argued that claim 11 does not require a specified contact force between the sensors and the separate structure, Warren also discloses achieving a specified contact force in a manner that parallels the '381 patent specification by sensing contact force with the vibration sensor 3730 and transducer 3740 (the *one or more sensors*) attached to the dispenser 3700 and the substrate

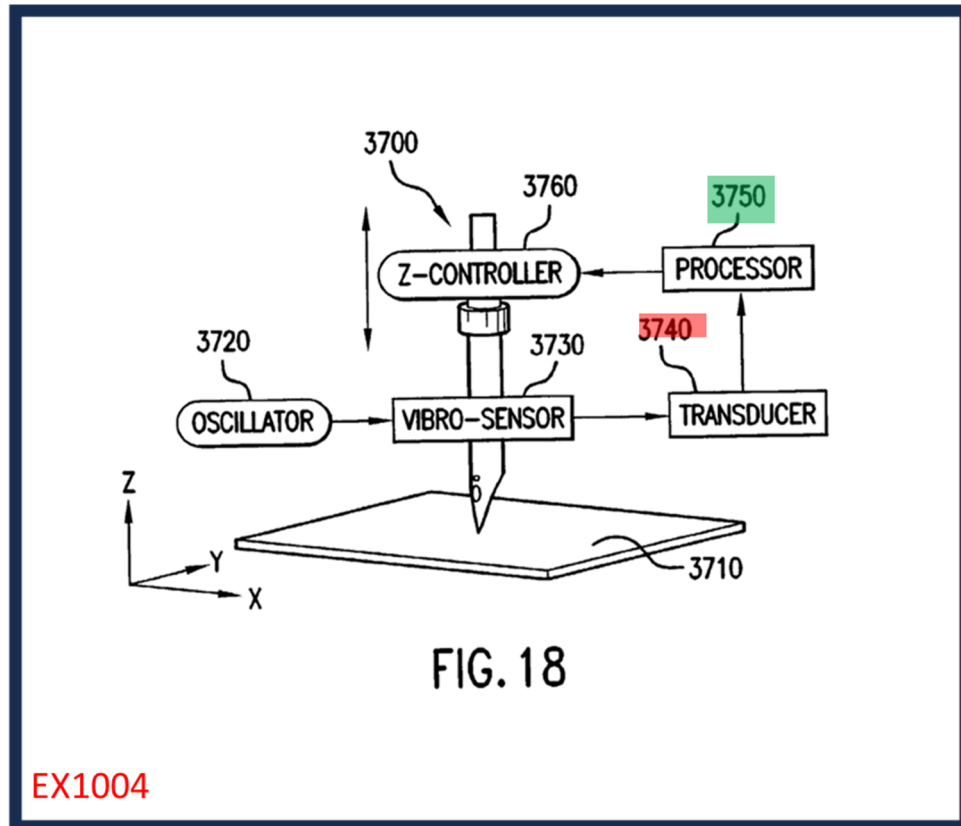
3710 (included by *the separate structure*). EX1004, [0302]. EX1003, ¶127-128 (noting Warren’s disclosure parallels the ’381 patent at 9:25-40).

12. The three-dimensional printer of claim 1, 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.

As explained *supra* §§V.A.1-2 and Elements [1.b]-[1.c], the ***controller*** (e.g., a “microprocessor” or “a personal computer (PC)”) operates responsive to ***one or more of the signal from the one or more sensors*** (e.g., “changed vibration signal” as detected by transducer 3740) ***and the calculated contact force*** (e.g., “the force of contact” calculated per Element [1.c]). EX1003, ¶¶129-130.

Warren explains: “The vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 [sic] dispenser with the substrate 3710” such that “[t]he transducer 3740 senses and transfers the changed vibration signal to an amplifier...which then creates a feedback signal” to drive a controller “to maintain a desired force of contact.” EX1004, [0302-0316], FIG. 22A; EX1003, ¶131 (noting processor 3750 as an example of the controller, which also controls other operations of the dispensing system). To the extent it is argued that the controller does not use the calculated contact force, a POSITA would have found it obvious to use the calculated contact force, for example, to facilitate comparison of the detected contact force to the “desired force of contact,” as well as for other

advantages of the controller operating in a force domain, rather than sensor signal domain. *Id.*



In the above context, Warren’s combined teachings provide the *controller* (e.g., a “microprocessor” or “a personal computer (PC)”) asserts control *to adjust operation of operation of the three-dimensional printer* including, e.g., a z-axis position, a feed rate, a movement speed, and a temperature, as detailed below.

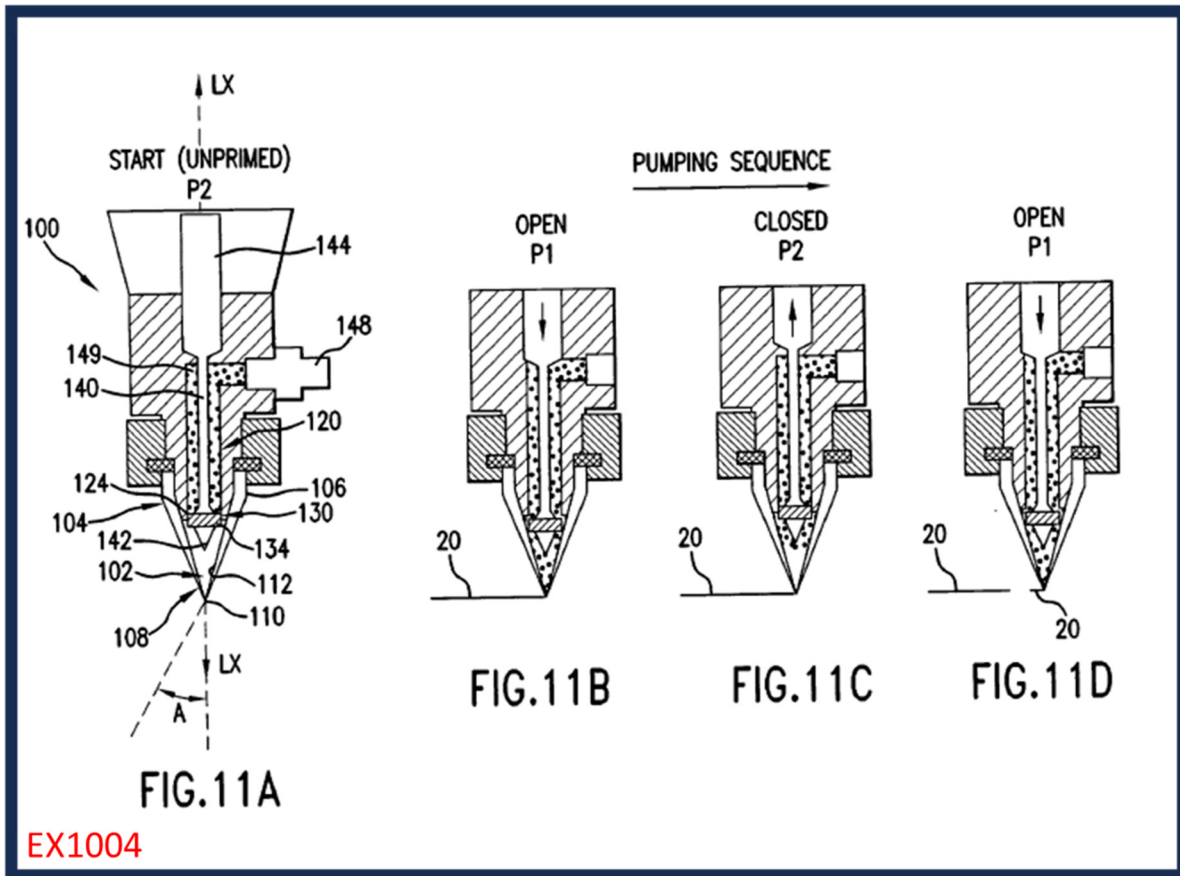
Z-axis Position

Warren discloses: “The feedback signal [created by the amplifier] 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.* In one example, “the

feedback signal may be used by a z-controller processor 3750 to control the z positioning of the dispenser 3700 via a z-controller step motor 3760.” *Id.*, [0313] (varying “the position(s) of the dispenser and/or the substrate” depending on “whether the contact force is that which is desired” at steps 4106 and 4108 of FIG. 22A). “The z-controller [processor] 3750 may be implemented with, e.g., a microprocessor,” and, optionally, “[a] personal computer (PC) may be used in conjunction with z-controller [processor] 3750.” *Id.*, [0302-0303]; EX1003, ¶¶132-133.

Feed Rate and Speed of Movement

In the through-nozzle dispenser design, the flow of material is controlled by valve 130. EX1004, [0232], [0230-0252], FIGS. 11A-11D (annotated below), 12A-12B. Warren teaches that the actuator-controlled “valving mechanism may be synchronized with the xyz motion of the dispenser.” EX1004, [0234]; EX1003, ¶134.



Warren describes different modes of “synchronizing the valve with the substrate motion.” *Id.*, [0234-0252]. In a “distance invariant” mode, Warren teaches to “open the valve independently before any xyz motion begins, then finish opening the valve over a set xyz distance” so that “if xyz motion speed was increased the valve still opens completely at the same xyz location, albeit faster due to the faster xyz speed.” *Id.*, [0235]. A POSITA would, of course, understand that opening and finish opening the valves affect the material feed rate through the dispenser. EX1003, ¶135. Warren also presents “[a] combination approach...to define the

speed at which the dispenser should move, and then adjust with [valve positioning] techniques” in tandem. *Id.*, [0240].

Accordingly, it would have been apparent or obvious to a POSITA that 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. EX1003, ¶136.

Temperature

Warren’s combined teachings also provide “temperature control...to enable the user to adjust viscosity of the constituent materials, to accelerate or decelerate setting of a scaffold material, or otherwise to provide a suitable environment for delicate or temperature-sensitive constituent materials.” EX1004, [0212]. Warren teaches that the viscosity of its constituent material impacts the flow characteristics inside the nozzle of the through-nozzle dispenser. *Id.*, [0247-248] (citing Equation (1) where fluid dynamic viscosity impacts the shear force of the flowing constituent material). A POSITA, would understand this viscosity factor to be temperature-dependent and recognized that providing temperature control abilities would have been advantageous. *Id.* Indeed, a POSITA would have a reasonable expectation of success in the combination given that Warren’s temperature control techniques were

all known techniques, and the predictable use of such known techniques in Warren's dispenser system would have been straightforward. EX1004, [0093]; EX1003, ¶137.

Accordingly, it would have been obvious to a POSITA that, in the context of constructing a modeled structure, Warren's force feedback control scheme also allows the controller to control a temperature on the dispenser. EX1003, ¶138.

13. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.

In the context of claim 12, *supra*, Warren's combined teachings provide ***the controller...configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.*** EX1003, ¶¶139-140.

14. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a z-axis position of the extruder in response to the calculated contact force.

In the context of claim 12, *supra*, Warren's combined teachings provide ***the controller...configured to adjust a z-axis position of the extruder in response to the calculated contact force.*** EX1003, ¶¶141-142.

15. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a speed of movement of the extruder in response to the calculated contact force.

In the context of claim 12, *supra*, Warren’s combined teachings provide *the controller...configured to adjust a speed of movement of the extruder in response to the calculated contact force*. EX1003, ¶¶143-144.

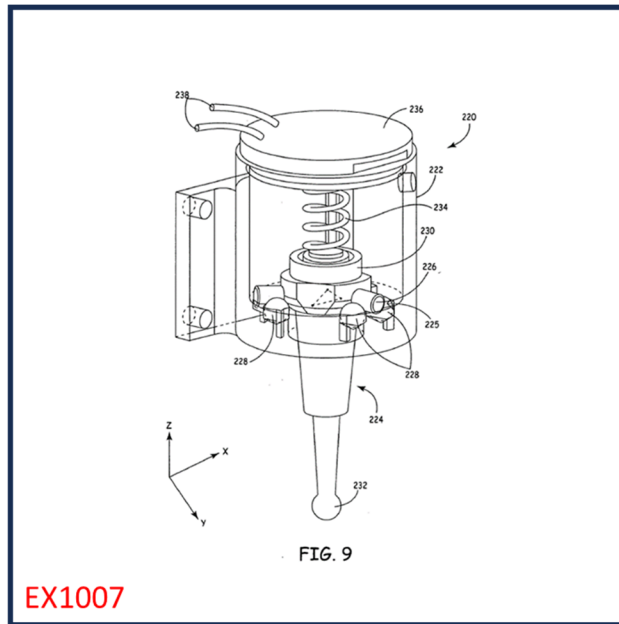
16. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a temperature of the extruder in response to the calculated contact force.

In the context of claim 12, *supra*, Warren’s combined teachings provide *the controller...configured to adjust a temperature of the extruder in response to the calculated contact force*. EX1003, ¶¶145-146.

B. GROUND 1B – Claims 3, 7 and 8 Are Obvious Over Warren and Dunn

1. Dunn (EX1007)

Like the ’381 patent, Dunn is also directed to “a deposition device in a three-dimensional modeling machine.” EX1007, Abstract. Specifically, Dunn discloses “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.*, [0069].



Referring to FIG. 9 (above), Dunn teaches that “[t]he multi-axis sensor assembly 220 [is] used to sense not only a top surface of a material pad, but also the sides of the material pad as well.” EX1007, [0070]; EX1003, ¶¶52-53.

2. The Combination, Reasons to Combine, & Expectation of Success

As explained *supra* §V.A.1, Warren discloses a 3D printing system incorporating force feedback control to maintain consistent contact force for successive layer-by-layer fabrication. While Warren shows a single-axis sensor configuration in its FIG. 18, Warren also states that “the invention is not limited to the specific embodiments, and that many modifications and other embodiments are intended to be included within the scope of the invention.” EX1004, [0572]. Warren also discloses “xyz motion of the dispenser.” *Id.*, [0234].

A POSITA would have recognized that Warren would benefit from multi-axis sensing capability to accommodate the xyz motion of its dispenser. EX1003, ¶¶147-148. In view of Dunn's express example of a multi-axis sensor design, a POSITA would have found it obvious 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. EX1003, ¶148. A POSITA would have a reasonable expectation of success because doing so merely involves adding multi-axis sensing, as taught in Dunn, to Warren's material dispensing system, which already has a single-axis example, to achieve predictable improvements (i.e., multi-axis) without impacting the operating principle of Warren's dispenser system. *Id.*

3. Claim Element Analysis

3. The three-dimensional printer of claim 1, wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.

As discussed above, Warren experiences a deflection force due to friction from contact of the dispenser against the surface the material is being deposited on. §V.B.3, claim 3. The sensors of the Warren-Dunn combination are collectively operable to sense force in the x, y and z axis, and thus sense a deflection due to this friction. EX1003, ¶¶149-151.

7. The three-dimensional printer of claim 1, 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.

The sensors of the Warren-Dunn combination are collectively operable to sense a force *along two or more non-parallel axes* (e.g., the x, y or z axes).

EX1003, ¶¶152-153.

8. The three-dimensional printer of claim 7, 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.

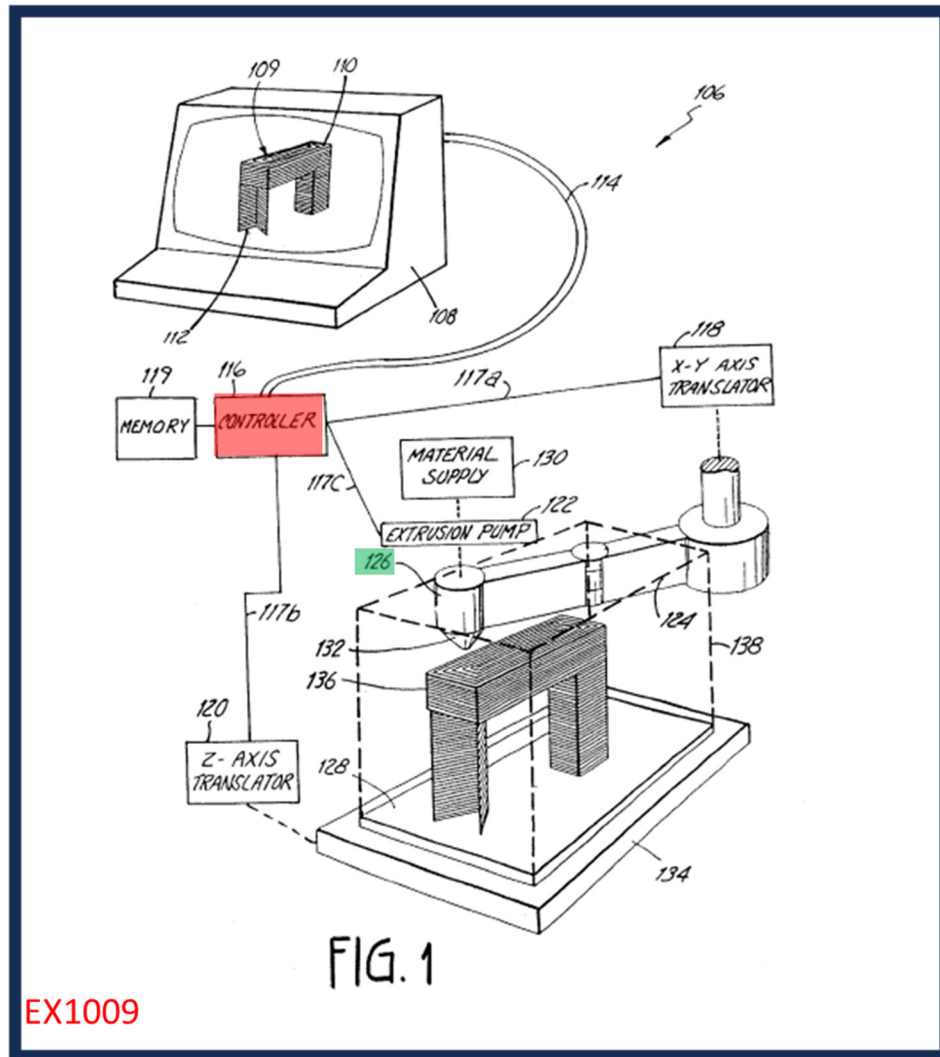
The sensors of the Warren-Dunn combination are collectively operable to sense a force *along three or more non-parallel axes* (e.g., the x, y or z axes).

EX1003, ¶¶154-155.

C. GROUND 2A – Claims 1-6, 9-16 Are Obvious Over Calderon and RepRap20208

1. Calderon (EX1009)

Like the '381 patent, Calderon discloses “machines which form three-dimensional objects by depositing modeling material.” EX1009, 1:5-10, Abstract. FIG. 1 (below) depicts an “extrusion-based layered modeling system 106” where “[a] computer aided design (CAD) program resident in a processor 108 generates a file describing the geometry of a part 109 to be created.” *Id.*, 4:20-33.



“An **electronic controller 116**, in response to receiving three-dimensional shape data from processor 108...controls the extrusion of modeling material in an xyz-coordinate reference frame so that beads of modeling material are extruded layer-by-layer in a pattern defined by the volume elements 110 and 112.” EX1009, 4:34-52. While “sequentially position[ing] an extrusion head 126 carried by the arm 124 within an xy-plane with respect to a modeling substrate 128,” Calderon teaches “[e]xtrusion pump 122 synchronously provides modeling material from a material

supply 130 to **extrusion head 126**” so that “[t]he modeling material is extruded from nozzle 132 onto the substrate 128...to build up a model 136 layer-by-layer on the substrate 128.” *Id.*, 4:34-5:10.

Calderon emphasizes that “[b]efore building up a model...the z-axis position of the platform requires initialization.” EX1009, 2:2:35-53. “An incorrect z-start position can result in failure in forming a model.” *Id.*, 2:63-3:1, 2:54-62 (“if the top surface of the substrate is not in an xy plane, nozzle tip depth will be incorrect at some locations of the substrate. This results in “modeling in air” or in too much ‘plowing’ by the tip”).

Calderon describes “an automated apparatus and method for initialization of a computer-controlled modeling machine that builds up three-dimensional objects.” EX1009, 3:1-10.

Calderon teaches using a “sensor assembly...mounted to an extrusion head,” such as the one depicted in FIG. 1, to sense “the force of contact of the [sensor] tip against the substrate.” EX1009, 5:10-24, 6:16-18 (reference numbers omitted), 6:37-47 (“Sensor [of FIGS. 2-4] may be interchanged with any sensing means which can detect and signal contact between the plunger and the substrate”).

The sensing means of Calderon encompasses “[a]ny manner of sensing a surface at selected coordinates to detect the corresponding Z-axis coordinate.” EX1009, 6:62-7:5. Calderon enumerates a long list of conventional sensors

including “a magnet proximity switch, a Hall sensor, a Wiegand wire, a reed switch, a capacitive sensor or an inductance sensor.” *Id.*, 6:37-47. Calderon also provides a “plunging means” for sensing “force of contact with the substrate such as a cam, pawl, cantilever, screw or membrane, or other mechanical structure” where “the plunging means need not move upward in response to contact with the substrate.” *Id.* 6:47-61. In its Example 3, Calderon describes that “the tip of nozzle 132...can be used as a plunging means to find z-axis positions of the platform.” *Id.*, 9:63-10:23. “The initialization routine is performed by positioning the nozzle 132 above pre-selected locations of the substrate and raising the platform 134 until the nozzle tip contacts the substrate. Contact 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.” *Id.* Calderon provides an example of “using servo drive motors” where “contact with the substrate 128 can be detected [from] the servo drive current without need for any special purpose sensing means.”) *Id.* As explained by Dr. Wolfe, Calderon was suggesting that the mechanism for force measurement can include any known sensing mechanism using a conventional sensor such as a strain gauge, which was known as “a common sensor.” EX1003, ¶¶54-60 (citing EX1001, 9:17-23).

Calderon further teaches applying its Find-Z program that “uses the recorded z-axis positions to calculate a z-start position.” 8:11-37 (further discussing Step (4)

“Add a constant value Z, representing the desired depth of the tip of nozzle 144 below the top surface of substrate 146, to the result of step (3), to arrive at the Z-Start position”), 10:9-15 (“The Find-Z program works much the same in the present example as described with respect to Examples, 1 or 2 above.”); EX1003, ¶61.

2. RepRap20208 (EX1010)

RepRap is a community project to develop low-cost 3D printers with an accompanying online public forum (i.e., reprap.org) accessible to the public. EX1014, 1-44; EX1003, ¶62. RepRap20208 is a discussion thread posted on this forum around January 2009. The thread includes postings from different users that target a common problem, namely, how to improve control of the RepRap 3D printer. Here, the developer community observed “it shouldn’t be too hard to hack together a bunch of open source monitoring devices to record data like temperature, speed, vibration, etc.” EX1010, 13.

Among the different monitoring devices (sensors), the developer community discussed incorporating a strain gauge for detecting extrusion head collisions and Z-axis calibration of the extrusion head relative to print bed position. For example, developer Wade suggested that “[a] strain gauge on the extruder mount would [show head collisions] as well, and it could do a few other things as well, like finding the bed height automatically.” EX1010, 13 (below).

 **Wade**

Re: Genetic Algorithms
January 14, 2009 04:10PM

Registered: 16 years ago
Posts: 536

Hm, I don't look forward to trying to code up a vision system from scratch....

but, an accelerometer on the write head might be useful. Keep an eye on the RMS power of the vibration the head experiences; that might be able to detect the next time I have an all-night long series of head collisions due to a bad programming job.

A strain gauge on the extruder mount would do that as well, and it could do a few other things as well, like finding the bed height automatically. Could take some time though.

Wade

 [Reply](#)  [Quote](#)

Another developer, Mr. Seeker, concurred and observed that “[y]ou could also use it to calibrate the Z-axis.” EX1010, 14. Wade later explains “I’d like to measure the important variable - nozzle to bed height - directly.” *Id.*, 18-19. And, another developer, fred, explains “It could also be used for a calibration cycle where you touch down on the four corners of the bed or the maximum build area to check for alignment or height of Z.” *Id.*, 19-20. Wade then replies “I was thinking a constant measurement of the force on the head (including it’s [sic] weight) would be useful. That points more towards strain gauges. Yeah, the 4 corners calibration was what I was thinking as well.” *Id.*, 20; EX1003, ¶¶63-64.

A POSITA would have understood that these RepRap posters were discussing contacting the print bed and extrusion head, and using strain gauges on the extruder mount to identify that contact to establish a known relative position of the extrusion head and print bed for Z-axis calibration. EX1003, ¶65. This technique for Z-axis

calibration was well known, and similar to the technique described by Calderon years earlier. Given the posts were discussing a common technique, a POSITA would have understood them as a common disclosure, or at least have found it obvious to combine the teachings of the various posts on this topic. *Id.*

3. The Combination, Reasons to Combine & Expectation of Success

Calderon describes auto-initialization of the z-axis of a three-dimensional printer where “the tip of nozzle 132...can be used as a plunging means to find z-axis positions of the platform,” where “[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.” EX1009, 9:63-10:23.

RepRap20208 complements Calderon’s disclosure with developers’ perspective of incorporating a “strain gauge on the extrusion mount,” which can be used “to calibrate the Z-axis.” EX1010, 13-14.

A POSITA would have found it obvious to use one or more strain gauges on the extrusion head mount, as suggested by RepRap20208, to provide Calderon’s “sensing means,” to monitor “contact between the tip of the nozzle 132 and the substrate 128.” EX1010, 13-14; EX1009, 9:63-10:23; EX1003, ¶¶156-158. In view of the synergistic and complementary disclosures, a POSITA would have been

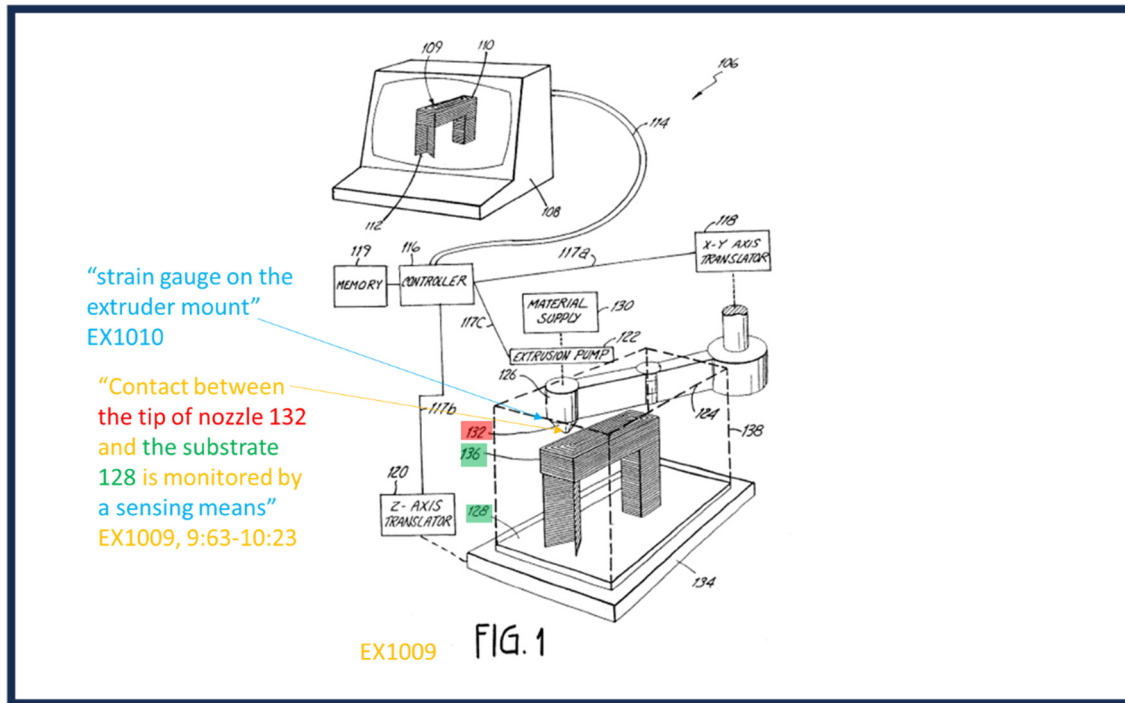
motivated to (i) apply strain gauges as in RepRap20208, rather than relying on Calderon’s suggestion of “monitoring a change in the servo drive current,” and (ii) calculate the contact force based on measurements from the strain gauge. *Id.*, ¶158.

Indeed, combining strain gauges of RepRap20208 with Calderon’s three-dimensional printer would have been nothing more than applying proven elements to a system ready for improvement. EX1003, ¶159. The fundamental operations of Calderon’s three-dimensional printer would remain intact, bolstered by the known advantages of RepRap’s strain gauge with a reasonable expectation of success. *Id.*

a) Apply strain gauges from RepRap20208

A POSITA would have been motivated to provide one or more strain gauge on the extrusion head mount, where Calderon’s extrusion head 126 mounts to the arm 124, to sense a contact force between nozzle 132 and substrate 128. EX1003, ¶160. The visual aid below demonstrates the Calderon-RepRap20208 Combination where the strain gauge example of RepRap20208 is applied as Calderon’s “sensing means.”² *Id.*

² This visual aid includes an adapted drawing from Calderon. To be clear, Petitioner is not proposing a bodily incorporation of Calderon and RepRap20208.



The following independent reasons, taken separately or collectively, support the Calderon-RepRap20208 Combination.

First, a POSITA would know that Calderon’s suggestion of using the current of the “servo drive motors” as force sensors would have had “slop/backlash” that would make it difficult to accurately and precisely identify when the nozzle contacted the substrate as is needed for Calderon’s Find-Z program. EX1010, 20; EX1003, ¶161. Calderon’s arm 124, x-y axis translator 118, z-axis translator 120 and servo drive motors would all introduce slop/backlash. EX1003, ¶161. As Wade described, if “you’ve got a certain amount of backlash to take up before the sensor registers, [it] would prevent [one] from knowing exactly when the head touches.” EX1010, 20. In other words, using the servo drive as a sensing means would have

a dampening effect on the force signal due to this “slop/backlash.” *Id.*; EX1003, ¶161.

In contrast, the RepRap20208 approach of using strain gauge on the extruder mount would not suffer the same degree of “slop/backlash,” in part because strain gauges would measure force from a location closer to the point of contact (the nozzle), i.e., measuring at the extrusion head mount, which would not be subject to the “slop/backlash” in Calderon’s arm, x-y axis translator or its servo drive. EX1003, ¶162.

Furthermore, Wade explains “There’s fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it’s [sic] weight) would be useful.” EX1010, 20. A POSITA would understand Wade’s suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the force supported by the extrusion head mounting is reduced by contact of the nozzle to the substrate. EX1003, ¶163. A POSITA would appreciate that this manner of identifying contact would not be influenced by slop/backlash, because it is not measuring force relative to a reaction force applied through the system that exhibits the slop/backlash. *Id.* Also, a strain gauge on the extrusion mount would allow the weight of the extrusion head to be constantly monitored during initialization. *Id.* Thus, a POSITA would seek to use a

strain gauge on the extrusion head mounting as a “sensing means” in Calderon to more precisely identify when the nozzle 132 has contacted the substrate 128 with less imprecision caused by slop/backlash. *Id.*

Second, a POSITA would have understood that “monitoring a change in the servo drive current” measures the force of resistance to movement of the substrate 128 and platform 134 in the Z-axis, not just the contact force between the substrate 128 and nozzle 132. EX1003, ¶164. The resistance to movement of the substrate 128 and platform 134 can be influenced by other factors like damage, wear or friction (e.g., due to dirt or need of maintenance) in the servo drive motors and drive system, as well as other factors. *Id.* This resistance to movement can change over time, and so measurements made from “the servo drive current” are both inaccurate and, over time, inconsistent. *Id.* Force measured by a strain gauge on the extrusion head mount would not be influenced by these factors, because the extrusion head mount does not experience this type of damage, wear or friction. *Id.* A strain gauge on the extrusion head mount measures the forces acting on the extrusion head, itself, which during Calderon’s initialization is largely the contact force between the nozzle 132 and substrate 128. *Id.* Thus, a POSITA would seek to implement RepRap20208’s strain gauge on the extrusion head as a “sensing means” in Calderon’s system to produce more accurate and consistent force measurements by which to sense contact of the nozzle 132 to the substrate 128. *Id.*

Third, Calderon teaches that different substrates, including “rigid substrates” and “foam substrates,” can be used in its 3D modeling process and that those substrates can have greatly different compression strength. EX1009, 2:15-53 (e.g., a polystyrene foam with a very low “compression strength of 30 psi” versus a metal “magnetic material.” – e.g., compression strength of steel is 25,000 psi or more); EX1003, ¶165. A POSITA would understand or find obvious that the contact force between the nozzle 132 and substrate 128 must be controlled to prevent damaging the substrate 128 during initialization, especially with low compression strength foam substrates, and that there is also a risk of damaging the nozzle 132 on rigid substrates. *Id.* Strain gauges were commonly used for force sensing long before the ’381 patent. *Id.* Thus, a POSITA would be motivated to use a strain gauge as a convenient, well understood manner of measuring force that would allow the contact force, and thus contact pressure of the nozzle 132 on the substrate 128 to be sensed with sufficient precision to prevent damage to the nozzle on the “rigid substrates” and damage to “foam substrates.” EX1009, 2:36-53; EX1003, ¶165.

Fourth, strain gauges were commonly used for force measurement of the type described in Calderon long before the ’381 patent. EX1003, ¶166. In fact, the ’381 patent admits that “[s]train gauges are one common sensor used for such [contact force] measurements.” EX1001, 9:17-23. The 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. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. at 416 (2007); *In re Lackey*, 371 Fed. Appx. at 82 (Fed. Cir. 2010); EX1003, ¶166. Supplementing Calderon with a strain gauge on the extrusion head mount would not have disturbed the other aspects of the system, and it would have produced substantially similar functionality to what Calderon described. *Id.*

A POSITA would have reasonably expected success in the above-discussed combination. EX1003, ¶168. Strain gauges and the use of strain gauges to sense force was commonplace well before the '381 patent. *Id.* (citing EX1018 at 302-304 (strain gauge commonly used in a Wheatstone configuration described at 284-290)). Thus, the result of the Combination would have been predictable to a POSITA, and the POSITA would have expected it to work. *Id.*

Accordingly, for at least these reasons, a POSITA would have found it obvious to apply a "strain gauge on the extruder mount" from RepRap20208 as the "sensing means" of Calderon, rather than following Calderon's suggestion of "monitoring a change in the servo drive current" (EX1009, 10:1-8). EX1003, ¶¶160-168.

b) Calculate the contact force

A POSITA would have been further motivated to calculate the contact force from the strain gauges in the Calderon-RepRap20208 Combination using Calderon's

controller 116 or another controller associated with the system. EX1003, ¶169. The following independent reasons, taken separately or collectively, support the motivation.

A POSITA would have understood RepRap20208 to teach calculating contact force from the strain gauge signals when Wade explains “I was thinking a constant measurement of the force on the head (including it’s [sic] weight) would be useful,” because Wade is indicating he seeks a “measurement of the force” and a “weight,” not simply a sensor signal. EX1010, 17; EX1003, ¶¶170. This disclosure at least invites a POSITA to use the strain gauges to calculate contact force. *Id.*

Furthermore, as discussed above, a POSITA would have configured the Calderon-RepRap20208 Combination to control the contact force to prevent damaging the substrate 128 or the nozzle 132. Thus, a POSITA would have understood, or would have found it obvious, that the controller of the Calderon-RepRap20208 Combination includes a maximum contact pressure, either coded into the software or input by a user, that was related to the compression strengths of the substrate 128 and nozzle 132. EX1003, ¶¶170-171. Compression strength can be expressed as force per unit area, e.g., pounds per square inch (psi) or newtons per square meter (pascals). *Id.* Yet, the output of a strain gauge in the Calderon-RepRap20208 Combination would be a signal indicative of displacement or strain at the extruder mount, not directly the contact pressure. *Id.* A POSITA would have

been motivated to program the controller to calculate the contact force at the nozzle 132/substrate 128 interface from the signal output by the strain gauges so that the contact pressure, in turn, could be calculated and be directly comparable to the compression strength of the substrate or nozzle. *Id.* In fact, RepRap20208 taught to “measure upwards pressure from a calibration touch down.” EX1010, 19.

The controller calculating the contact force, and then the contact pressure, would facilitate programming the controller to a maximum contact pressure setpoint and comparing the current contact pressure to the set maximum, because the setpoint and the compression strength would be in the same units (force per unit area). EX1003, ¶172. 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 as discussed by Calderon, calculating contact force and contact pressure would facilitate a user’s interaction with the controller. The controller’s setpoint values could more readily be set, adjusted or displayed in meaningful (to a user) force-based units rather than sensor values. *Id.* Thus, for example, the Calderon-RepRap20208 Combination would accommodate a variety of substrate materials by enabling a user to input a contact strength setpoint based on a specification sheet for the substrate material. *Id.* Moreover, as evidenced by RepRap20208, POSITA thought of the contact sensing in terms of force. EX1010, 17, 20 (“we’d *like* three forces”; “a constant measurement of force”; “here’s a force sensor”); EX1003, ¶172.

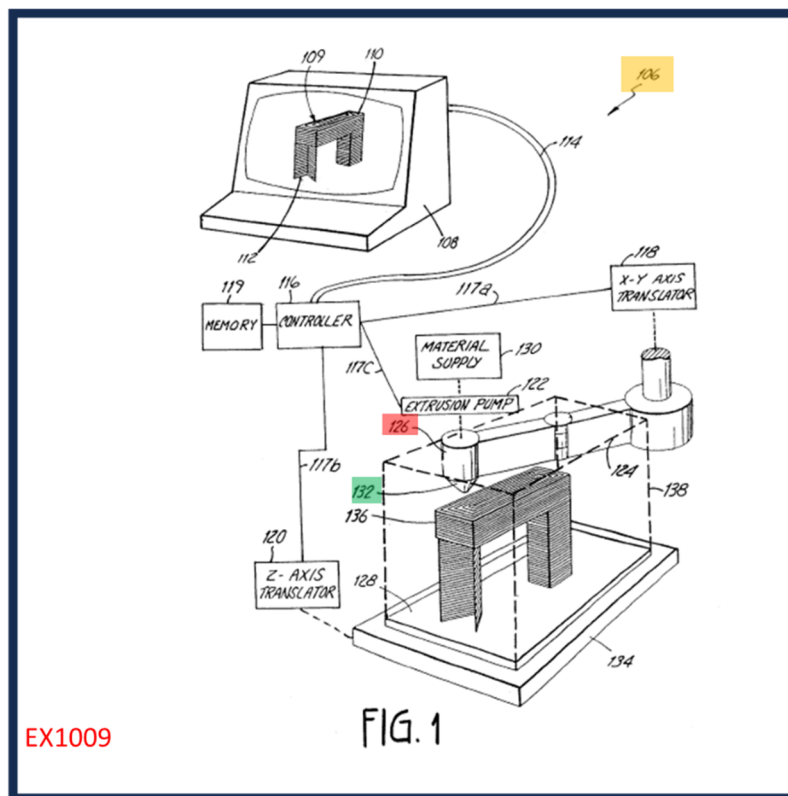
A POSITA would have reasonably expected success in calculating, with a controller, the contact force from the strain gauges of the combination. EX1003, ¶173. Calculating contact force, and then contact pressure, with a controller from a sensor intended to produce a signal related to force, and particularly a strain gauge, was commonplace, rudimentary engineering before the '381 patent. *Id.* (citing EX1018 at 302-304 (strain gauge commonly used in a Wheatstone configuration described at 284-290)). The '381 patent accords, explaining that “sensors that are collectively operable to sense any force or displacement of the fabrication tool and separate structure, or any related properties such as compression or strain, may be used as sensors 302, so long as the contact force(s) described above may be calculated from the sensed physical characteristics.” EX1001, 8:65-9:10. Thus, these calculations would have been predictable to a POSITA, and the POSITA would have expected it to work. *Id.*

Accordingly, a POSITA 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 Calderon-RepRap20208 Combination. EX1003, ¶¶169-174.

4. Claim Element Analysis

[1.pre]: A three-dimensional printer comprising:

As discussed *supra* §§V.C.1-3, the Calderon-RepRap20208 Combination discloses a three-dimensional printer. *E.g.*, EX1009, 4:20-5:10 (discussing “extrusion-based layered modeling system 106” as depicted in FIG. 1); EX1003, ¶177.



[1.a]: a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;

In the Calderon-RepRap20208 Combination, Calderon provides *a fabrication tool* (“pump 122” and “extrusion head 126”) *including an extruder* (“extrusion head 126.”) EX1009, 4:34-65, FIG. 1 (above). Specifically, “extrusion head 126

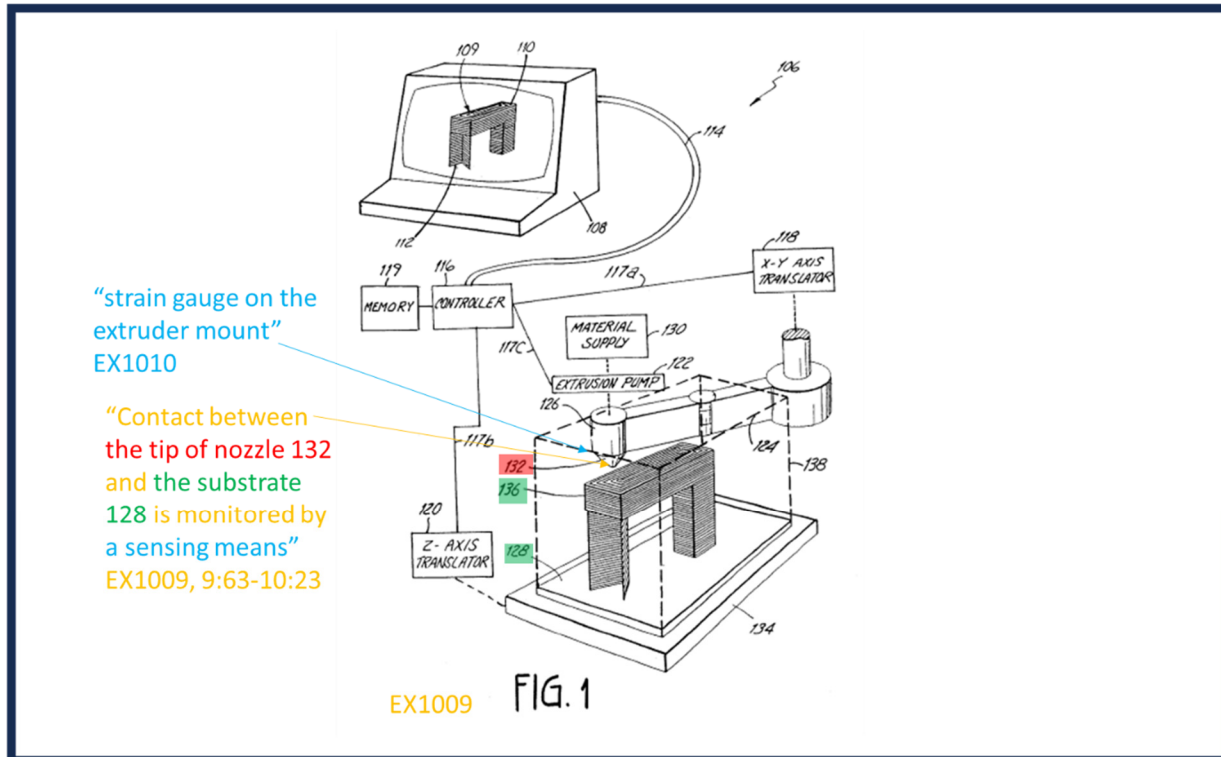
terminates in a nozzle 132 through which the modeling material is extruded...onto the substrate 128...to build up a model 136 layer-by-layer on the substrate 128.” *Id.* These features of Calderon provide *an extruder* like ta in the ’381 patent. EX1001, 2:28-52; EX1003, ¶¶178-179.

[1.b]: 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

The Calderon-RepRap20208 Combination renders obvious the *claimed one or more sensors*. As explained *supra* §V.C.2, RepRap20208 provides one or more strain gauges on the extruder mount, which would be *sensors mechanically coupled to the extruder* consistent with the ’381 specification. EX1010, 13; EX1001, 9:17-23 (“Strain gauges are one common sensor used for such [contact force] measurements, and may be suitably adapted...by affixing one or more strain gauges to an extruder or other location along a mechanical chain that supports an extruder in an intended position during fabrication.”).

As explained *supra* §§V.C.1-3, a POSITA would have found it obvious to use strain gauges in the Calderon-RepRap20208 Combination to “measure upwards pressure from a calibration touch,” “touch down on the four corners of the bed or the maximum build area to check for alignment or height of Z,” and to provide a “measurement of the force on the head” during calibration. EX1010, 13, 19-20; EX1009, FIG. 1 (below). A strain gauge at the extrusion head mount would sense *a*

contact force between the extruder and a separate structure by sensing the displacement/strain at the extrusion head mount and that displacement/strain would be a function of and could be used to calculate the contact force. EX1003, ¶¶180-181.



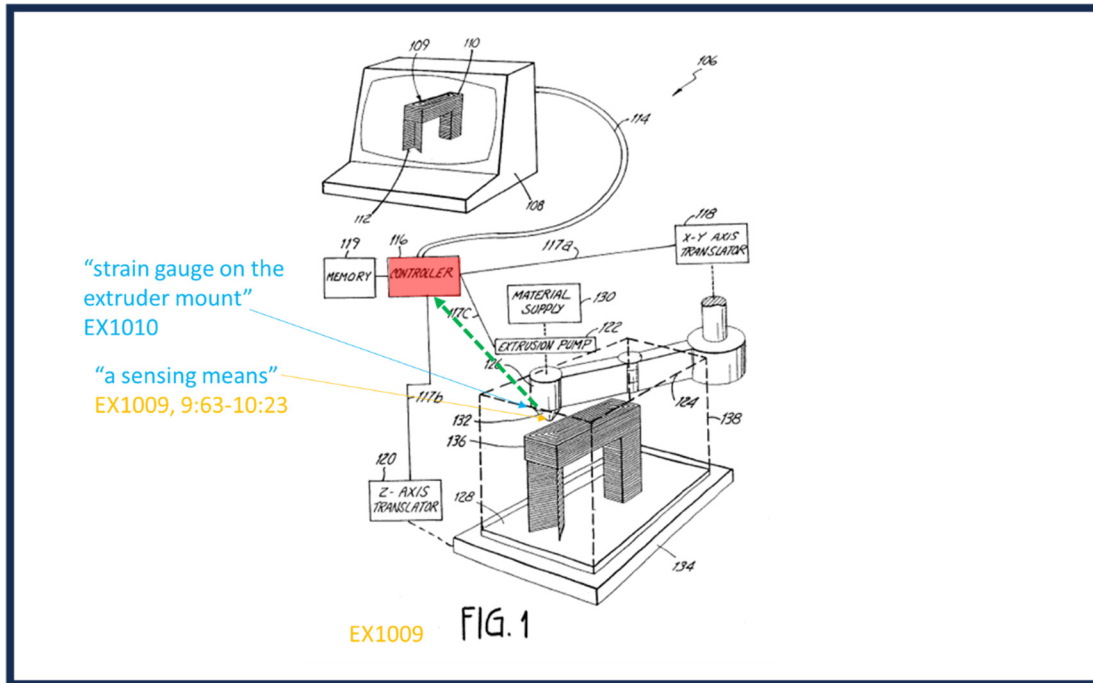
RepRap20208’s “strain gauge on the extruder mount” (EX1010, 14), are “affix[ed] to an extruder or other location along a mechanical chain that supports an extruder in an intended position during fabrication,” as disclosed by the ’381 patent. EX1001, 9:17-23. Thus, the one or more strain gauges of the Calderon-RepRap20208 Combination operate to *sense the contact force between the extruder and a separate structure*, such as the modeling platform 134 where substrate 128 is

mounted, or the model 136 being built in a layer-by-layer manner. EX1003, ¶¶182-184.

[1.c]: 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.

The Calderon-RepRap20208 Combination renders obvious the claimed ***controller***. EX1003, ¶185. In Calderon's Example 3, Calderon describes: "Contact 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." EX1009, 9:63-10:8 ("the tip of nozzle 132 (shown in FIG. 1) can be used as a plunging means to find Z-axis positions of the platform").

In the above context, a POSITA would have found it obvious for the controller 116 in the Calderon-RepRap20208 Combination to ***receive a signal from the one or more sensors on the extruder*** (e.g., one or more strain gauges on the extruder mount) so that the controller 116 can "electrically record[] the z-axis position of platform 134," as intended by Calderon's initialization routine. EX1009, 9:63-10:8, 2:54-3:3 ("incorrect z-start position can result in failure in forming a model" such as "'modeling in air' or...too much 'plowing' by the tip"), FIG. 1 (below); EX1010, 13; EX1003, ¶186.



As further explained *supra* §V.C.3, a POSITA would have found it obvious for the controller 116 in the Calderon-RepRap20208 Combination to ***calculate the contact force between the extruder and the separate structure*** (e.g., based on the signal received from the one or more strain gauges on the extruder mount). EX1010, 20. As discussed above, a POSITA would have been prompted to have the controller of the Calderon-RepRap20208 Combination ***calculate the contact force*** (e.g., based on the signal received from the strain gauges) and monitor the “[c]ontact between tip of nozzle 132 and the substrate 128” accordingly (e.g., so as not to damage a foam substrate or the nozzle), as provided by Calderon. EX1010, 13; EX1009, 10:1-8; EX1003, ¶187.

Accordingly, the Calderon-RepRap20208 Combination renders obvious all limitations of claim 1. EX1003, ¶¶175-188.

2. The three-dimensional printer of claim 1, wherein the contact force is a force along an extrusion axis of the extruder.

In the Calderon-RepRap20208 Combination, *the contact force is a force* that acts on the tip of nozzle 132 of extruder 126. EX1009, 10:1-5 (“Contact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means”). When 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*. *Id.*, FIG. 1; EX1003, ¶¶189-190. Calderon confirms this in explaining use of its nozzle tip “to find z-axis positions of the platform.” EX1002, 9:63-10:15. Moreover, even if the substrate 128 were not precisely orthogonal to the tip of nozzle 132, a POSITA 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.*

5. The three-dimensional printer of claim 1, wherein the separate structure includes a build platform of the three-dimensional printer.

In the context of claim 1, the “strain gauge on the extruder mount” would sense a contact force between the tip of nozzle 132 and “the substrate 128...mounted onto a modeling platform 134.” EX1009, 4:53-65, 10:1-5, FIG. 1; EX1010, 13; EX1003, ¶¶191-192. A POSITA would have recognized that this scenario is similar to the ’381 specification where, as illustrated in FIG. 3, “sensor 302 may be operable

to sense a contact force between the fabrication tool 300 and a separate structure, such as...the build platform 306....” EX1001, 8:55-64; EX1003, ¶192. Accordingly, the Calderon-RepRap20208 combination renders 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*). EX1009, 4:62-63, FIG. 1; EX1003, ¶¶192-193.

6. The three-dimensional printer of claim 1, wherein the contact force is a force normal to a surface of the separate structure.

In the Calderon-RepRap20208 Combination, *the contact force is a force* that acts on the tip of nozzle 132 of extruder 126. EX1009, 10:1-5 (“Contact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means”). When the top surface of the substrate 128 is generally orthogonal to the tip of nozzle 132, the force is *normal to the surface of the separate structure*. *Id.*, FIG. 1; EX1003, ¶¶194-196. Calderon confirms this in explaining use of its nozzle tip “to find z-axis positions of the platform.” EX1002, 9:63-10:15. Moreover, even if the substrate 128 were not precisely orthogonal to the tip of nozzle 132, a POSITA 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. EX1003, ¶¶195-196.

9. The three-dimensional printer of claim 1, 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.

As explained by Dr. Wolfe, a strain gauge is, or would be obvious to be configured as, a potentiometric sensor because it was general knowledge to use a strain gauge in a Wheatstone bridge configuration with a readout voltage (e.g., a differential voltage between two parallel voltage dividers), which renders the configuration a potentiometric sensor. EX1003, ¶¶197-198 (citing EX1018, 302-304, 284-290).

Additionally, a POSITA would have found it obvious to use one or more piezoelectric or capacitive strain sensors on the extruder mount of the Calderon-RepRap20208 Combination to measure strain. As explained by Dr. Wolfe, such types of strain sensors were commonly used to measure mechanical pressure/strain. EX1003, ¶199 (citing, e.g., EX1019, Abstract (“Strain measurements from piezoceramic (PZT) and piezofilm (PVDF) sensors are compared with strains from a conventional foil strain gage and the advantages of each type of sensor are discussed, along with their limitations.”), Conclusions (noting “the performance of piezoelectric sensors surpasses that of conventional foil type strain gages” in some cases)). Calderon, even, advocates a capacitive sensor for sensing displacement. EX1009. 6:38-47. A POSITA would have been motivated to employ a piezoelectric or capacitive strain sensor in the Calderon-RepRap20208 Combination because such

sensors were readily available off-the shelf type devices, well understood, and a convenient sensor designed for the very purpose of measuring strain and force. EX1003, ¶199 (citing, e.g., EX1020). The predictable inclusion of a piezoelectric or capacitive strain sensor follows the familiar pattern of merely substituting one element (a common piezoelectric strain sensor) for another known in the field (RepRap20208's broad teaching of a "strain gauge") to obtain predictable results. *KSR*, 550 U.S. at 416; *Lackey*, 371 Fed. at 82; EX1003, ¶199. Supplementing the Calderon-RepRap20208 Combination with a piezoelectric or capacitive strain sensor would not have disturbed the other aspects of the system, and it would have produced substantially similar functionality to what RepRap20208 described. *Id.* Moreover, the claim's list of "capacitive sensors, electromagnetic sensors, optical sensors, potentiometric sensors, and piezoelectric sensors" encompasses nearly all common types of strain sensors. *Id.*, ¶200. A POSITA would have found it obvious to incorporate any of these common types of strain sensor based on RepRap20208's general teaching of a "strain gauge." *Id.* (noting the specification reveals nothing more than commonly known).

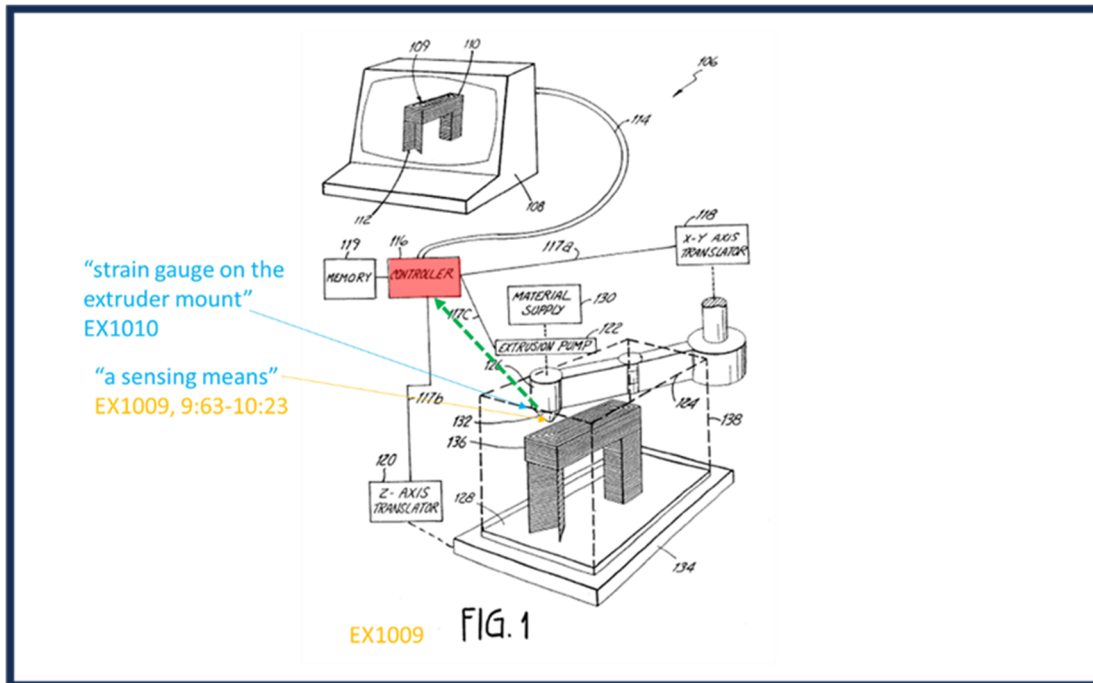
10. The three-dimensional printer of claim 1, wherein the one or more sensors include one or more strain gauges.

As explained *supra* §§V.C.1-3 and claim 1, the one or more sensors on the three-dimensional printer of the Calderon-RepRap20208 Combination include ***one***

or more strain gauges (e.g., “strain gauge on extruder mount”). EX1010, 13; EX1003, ¶¶201-203.

11. The three-dimensional printer of claim 1, 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.

The Calderon-RepRap20208 Combination provides x-y axis translator 118 and z-axis translator 120 (i.e., *the one or more actuators*) *mechanically coupled to the fabrication tool* (e.g., extrusion head 126 carried by robotic arm 124). EX1009, 4:41-52, FIG. 1. A POSITA would understand, or find obvious, that Calderon’s extrusion head 126, arm 124 and z-axis translator 120 are mechanically coupled, as they are all parts of the same system 106 and/or because they sit on a common surface (e.g., the floor or table). EX1003, ¶¶204-207. Further, Calderon discloses, or renders obvious, the z-axis translator being part of, and move, the extrusion head and arm. EX1009, 11:6-11. The Calderon-RepRap20208 Combination also provides controller 116 and associated memory 119 (i.e., *a control circuit*) *in data communication with* x-y axis translator 118 and z-axis translator 120 and “strain gauge on extruder mount” (i.e., *the one or more sensors*). *Id.*, 4:41-52, FIG. 1 (below); EX1010, 13.



As explained *supra* §§V.C.1-3 and claim 1, controller 116 sends control signals to the z-axis translator (i.e., *controls the one or more actuators*) to achieve a contact force sufficient for measurement but does not exceed a force limit to be damaging (i.e., *a specified contact force*) *between* the “strain gauge on extruder mount” (i.e., *one or more sensors*) and the modeling platform 134 (i.e., *separate structure*). EX1003, ¶¶204-207.

12. The three-dimensional printer of claim 1, 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.

Calderon teaches “using the plurality of recorded z-axis positions to calculate a z-start position of the platform” and “then automatically position the platform at the calculated z-start position, without operator intervention.” EX1009, 3:27-30.

Calderon further teaches “a ‘Find-Z’ software program loaded into controller 116,” which “uses the recorded z-axis positions to calculate a z-start position.” *Id.*, 7:63-63, 8:11-37, 10:9-15. As explained *supra* §V.C.1, Calderon teaches: “Contact 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.” *Id.*, 10:1-5. A POSITA, when reading the above, would have readily recognized that the controller of the Calderon-RepRap20208 Combination would “automatically position the platform” (i.e., *adjust operation of the three-dimensional printer*) “at the calculated z-start position” calculated using the recorded z-axis position, which was recorded at the time instant of a sufficient contact (i.e., according to *one or more of the signal from the one or more sensors and the calculated contact force* that indicate the time of each recorded contact). EX1009, 3:27-30; EX1003, ¶¶208-211.

14. The three-dimensional printer of claim 12 , wherein the controller is configured to adjust a z-axis position of the extruder in response to the calculated contact force.

In the context of claim 12, a POSITA would have found it obvious that the controller of the Calderon-RepRap20208 Combination *adjusts a z-axis position of the extruder* because Calderon make clear that “in a modeling system having a dispensing head movable along the z-axis,” the same relative distance between the

dispensing head and the platform can be achieved “by lowering the dispensing head instead of raising the modeling platform.” EX1009, 11:6-11. Moreover, adjusting the z-axis position of the extruder is based on the calculated z-start position calculated using the recorded z-axis position, which was recorded at the time instant of a sufficient contact (i.e., in response to the calculated contact force that indicate the sufficient contact). *Id.*, 3:27-30; EX1003, ¶¶212-213.

Implement collision detection after initialization

Further to the explanations *supra* §V.C.3, RepRap20208 discloses that one or more strain gauges on the extruder mount could be used for “[c]ollision detection” to cause “the machine [to] shut down.” EX1010, 19. A POSITA also would have found it obvious to implement collision detection in Calderon’s controller or another controller, as described by RepRap20208, using the “strain gauge on extruder mount” from RepRap20208 whenever the extrusion head or platform is moving. EX1003, ¶214. Upon detecting a collision, the controller in the Calderon-RepRap20208 Combination would shut the three-dimensional printer down. *Id.*

A POSITA would have been prompted by RepRap20208’s express invitation to include collision detection because “[c]ollision detection is a nice side affect [sic]” of the RepRap20208 strain gauge configuration. EX1010, 19. A POSITA would have been inspired to use the suggested strain gauge on extruder mount for real-time collision detection after system initialization, and anytime the extrusion head or

platform were moving (i.e., while there is a risk of collision), because the feature would have used the same sensor configuration without requiring additional hardware. EX1003, ¶215.

A POSITA would have also been prompted by the benefits collision detection. As explained by developer Wade: “I’d have the machine shut down and flag me if it [i.e., collision] happens, as opposed to breaking something.” EX1010, 19. Developer Wade further explains “a tangled plastic filament feed, which has wrecked a few builds of mine...would probably just trigger the head collision detection.” *Id.*, 20. A POSITA would have understood collision may also be “a result of dispensed layers being too thick and/or inconsistent in thickness, and/or because of a mechanical malfunction of the dispensing head,” and that “faulty material dispensing that may occur anywhere in the path” of the extrusion head. EX1005, 18:5-18. Each of these potential collisions occur apart from initialization and when the extrusion head and/or platform are moving. EX1003, ¶216. A POSITA would have further been motivated to shut down the three-dimensional printer upon detecting a collision to minimize damage, conserve energy, and avoid material waste. *Id.*

3. The three-dimensional printer of claim 1, wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.

As discussed above, in the Calderon-RepRap20208 Combination implementing collision detection, the collision detection operates whenever the extrusion head is moving. Calderon's extrusion head 126 moves in the x-y plane. EX1009, 4:45-48. When a collision nozzle tip to a separate structure occurs while the extrusion head is moving the x-y plane, the resulting contact force includes a deflection force. EX1003, ¶¶217-218. The strain gauge on the extrusion head mount would measure that deflection force, because the force would impart a deflection moment to the strain gauge on extrusion head mount. EX1003, ¶¶218-219.

4. The three-dimensional printer of claim 1, wherein the separate structure includes an object being fabricated by the three-dimensional printer.

In the Calderon-RepRap20208 Combination implementing collision detection, when the three-dimensional printer is depositing modeling material “to build up a model 136 layer-by-layer on the substrate 128,” the “strain gauge on the extruder mount” would sense a contact force between the tip of nozzle 132 and the top surface of model 136 if the two collided. EX1009, 4:62-63, FIG. 1; EX1010, 13; EX1005, 18:5-18 (examples of collisions); EX1003, ¶220-221. Accordingly, the Calderon-RepRap20208 combination renders obvious that *the separate structure includes* the model 136 (i.e., *an object being fabricated by the three-dimensional printer*). EX1009, 4:62-63, FIG. 1; EX1003, ¶222.

13. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a feed rate of build material from the extruder in response to the calculated contact force.

As discussed above, a POSITA would have found it obvious to shut the three-dimensional printer down upon detecting a collision. Shutting the printer down would *adjust the feed rate of build material* by ceasing material feed. EX1003, ¶¶223-225. As observed by Dr. Wolfe, it was general knowledge in the field of 3D printing to “stop[] production of an object” when “a collision has occurred.” EX1003, ¶225 (citing EX1008, [0180]). To save the machine and avoid material waste, a POSITA would have known to stop feeding of additional build material, and hence *adjust a feed rate of build material from the extruder*. EX1003, ¶¶225-226.

15. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a speed of movement of the extruder in response to the calculated contact force.

Like the feed rate of claim 13, a POSITA would have recognized that shutting the three-dimensional printer down would also stop the movement of the extruder (i.e., *adjusting a speed of movement of the extruder*) *in response to the calculated contact force*. EX1010, 20; *supra* §V.C.3; EX1003, ¶¶227-228. Because it was general knowledge in the field of 3D printing to “stop[] production of an object” when “a collision has occurred,” a POSITA would have known to stop the movement

of the extruder, and hence *adjust a speed of movement of the extruder* to save the machine and conserve energy. EX1003, ¶229 (citing EX1008, [0180]).

16. The three-dimensional printer of claim 12, wherein the controller is configured to adjust a temperature of the extruder in response to the calculated contact force.

Like the feed rate of claim 13 and extruder movement of claim 15, a POSITA would have recognized that RepRap20208's statement on shutting down the machine suggested shutting down the heater on the extruder (i.e., *adjusting a temperature of the extruder*) in response to the calculated force contact force (e.g., when "the upward force on the extruder" indicates a collision has occurred). EX1010, 20; *supra* §V.C.3; EX1003, ¶¶230-231. At a minimum, a POSITA would have found it obvious to turn off the heater of the extruder (i.e., *adjust a temperature of the extruder*) in response to the calculated contact force indicating that a collision has just occurred. Because it was general knowledge in the field of 3D printing to "stop[] production of an object" when "a collision has occurred," a POSITA would have known to turn off the heater of the extruder, and hence *adjust a temperature of the extruder* to save the machine and conserve energy. EX1003, ¶232 (citing EX1008 at [0180] and noting no reason to keep the heaters going if the print has stopped due to a collision).

D. GROUND 2B – Claims 3, 7 and 8 Are Obvious Over Calderon, RepRap20208, and Dunn

1. The Combination, Reasons to Combine, & Expectation of Success

As explained *supra* §V.B.1, Dunn discloses “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.” EX1007, [0069-70], FIG. 9.

Calderon already describes defining a lateral range for its z-axis initialization routine by, e.g., “moving extrusion head 142 in the x-direction so as to drive actuator 154 against a first stationary block 190 located outside of the modeling envelope 138 to the right of extrusion head 142,” as depicted in FIGS. 7A-7B, and later “moving the extrusion head 142 in the x-direction towards a second stationary block 192 located outside of the modeling envelope 138, to the left of extrusion head 147,” as depicted in FIGS 8A-8B. EX1009, 7:16-23, 53-61.

A POSITA would have found it obvious to provide multiple strain gauges in the extrusion head mount of the Calderon-RepRap20208 Combination oriented to measure in multiple axis, in accordance with the “multi-axis sensor assembly” of Dunn, so that the three-dimensional printer of the Calderon-RepRap20208-Dunn Combination has “the capability of sensing surfaces in the X and Y directions” in addition to “sensing surfaces in the Z-direction.” EX1007, [0069-70]; EX1003, ¶¶233-235. Here, measuring force in multiple axis, like Dunn’s multi-axis sensor

assembly, would have allowed the three-dimensional printer to efficiently identify the surfaces of first and second stationary blocks in the x-direction, thereby improving the efficiency of Calderon's z-axis initialization routine. *Id.* EX1009, 7:16-23, 53-61; EX1003, ¶235. Moreover, a POSITA would have recognized the predictable improvement of the Calderon-RepRap20208-Dunn Combination is not limited to the x-direction, but rather includes the y-direction. *Id.*, ¶236. Indeed, a POSITA would have enjoyed a reasonable expectation of success by combining known elements to arrive at the predictable improvement. *Id.*

2. Claim Element Analysis

3. The three-dimensional printer of claim 1, wherein the contact force includes a deflection force exerted by the separate structure on a tip of the extruder.

As discussed above, Calderon's extrusion head would experience a deflection force due to collision while moving in the x-y plane. *Supra*, §V.C.4 & claim 3. The sensors of the Calderon-RepRap20208-Dunn combination are collectively operable to sense a deflection force acting in the x-y axes. EX1003, ¶¶237-238.

7. The three-dimensional printer of claim 1, 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.

The sensors of the Calderon-RepRap20208-Dunn combination are collectively operable to sense a force *along two or more non-parallel axes* (e.g., the x, y or z axes). EX1003, ¶¶239-240.

8. The three-dimensional printer of claim 7, 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.

The sensors of the Calderon-RepRap20208-Dunn combination are collectively operable to sense a force *along three or more non-parallel axes* (e.g., the x, y or z axes). EX1003, ¶¶241-242.

VI. ANALYSIS ON DISCRETION

A. 35 U.S.C. §325(d)—Advanced Bionics

Although Calderon (EX1009) was cited by the '381 patent (EX1002, Front Page), it was never applied. RepRap20208, which was never considered, discloses a sensor configuration, recited by claim 1 that and the examiner believed to be missing from the prior art. *Supra*, §II.B. As demonstrated above, when the strain gauge of RepRap20208 is applied as the sensing means of Calderon, claim 1 would have been obvious. Additionally, the Warren discloses all elements of claim 1 and was never considered during prosecution. Simply put, both the Calderon-RepRap20208 combination and the Warren ground provide exactly what the examiner mistakenly believed to be missing from the prior art. *Id.* Such a material error during original

examination gives rise to the need for this review.

B. 35 U.S.C. §314(a)—*Fintiv*

The *Fintiv* precedent should not be followed here because it exceeds the Director's authority, is arbitrary and capricious, and was adopted without notice-and-comment rulemaking. Even if considered, the factors favor institution.

The Petition is being filed before an answer has been filed in either parallel District Court action and there is a pending Motion to Dismiss in EDTX. EX1026. ***Factor 1*** is neutral since there is no evidence that, if the action is maintained and a stay is requested, the EDTX will deny a stay. ***Factor 2*** is neutral because six different trials are scheduled for June 2026 in EDTX, and no one knows which will be delayed/rescheduled. EX1025. Further, if the motion to dismiss is successful, the EDTX trial will not happen. Based on the Federal Courts Statistics, trial is not expected in the WDTX until mid-2027. Finally, Petitioner's diligence in preparing this petition in less than six months from service of the EDTX complaint also weighs against discretionary denial, especially in light of the stipulation (see Factor 4) that avoids overlap with invalidity at the theoretical EDTX trial. EX1024. ***Factor 3*** favors institution because there has been little investment by the courts and the EDTX Markman hearing is scheduled for December 3, 2025, well after institution. EX1024. ***Factor 4*** favors institution as Petitioner has stipulated not to pursue the IPR grounds in district court. EX1023. Petitioner's Motion to Dismiss further favors

institution under **Factors 5** and **6** because, if granted, there will be no overlap of issues between the IPR and EDTX action.

VII. PAYMENT OF FEES – 37 C.F.R. § 42.103

Petitioner authorizes the Patent and Trademark Office to charge any fees to Deposit Account No. 06-1050.

VIII. CONCLUSION

Accordingly, Petitioner respectfully requests institution of an IPR for the '381 patent for each of the grounds presented herein.

IX. MANDATORY NOTICES UNDER 37 C.F.R § 42.8(a)(1)

A. Real Party-In-Interest Under 37 C.F.R. § 42.8(b)(1)

In addition to Petitioner, Bambulab Limited, Shanghai Lunkuo Technology Co. Ltd., Tuoazhu Technology Limited, and Bambulab USA Inc. are listed as potential real parties-in-interest.

B. Related Matters Under 37 C.F.R. § 42.8(b)(2)

Petitioner is not aware of any disclaimers, reexamination certificates or petitions for inter partes review for the '381 Patent. The '381 patent is the subject of civil action: *Stratasys, Inc. v. Shenzhen Tuoazhu Technology Co. Ltd. et al*, 2-24-cv-00644 (EDTX), filed August 8, 2024, and *BambuLab USA, Inc. et al v. Stratasys, Inc.*, 1-24-cv-01511 (WDTX), filed December 9, 2024.

C. Lead And Back-Up Counsel Under 37 C.F.R. § 42.8(b)(3)

Petitioner provides the following designation of counsel.

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D. Service Information

Please address all correspondence and service to the address listed above.

Petitioner consents to electronic service by email at IPR56224-0009IP1@fr.com
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Respectfully submitted,

Dated February 5, 2025

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CERTIFICATION UNDER 37 CFR § 42.24

Under the provisions of 37 CFR § 42.24(d), the undersigned hereby certifies that the word count for the foregoing Petition for *Inter partes* Review totals 13,999 words, which is less than the 14,000 allowed under 37 CFR § 42.24.

Dated February 5, 2025

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CERTIFICATE OF SERVICE

Pursuant to 37 CFR §§ 42.6(e)(4)(i) *et seq.* and 42.105(b), the undersigned certifies that on February 5, 2025, a complete and entire copy of this Petition for *Inter partes* Review, Power of Attorney, and all supporting exhibits were provided via Federal Express, to the Patent Owner by serving the correspondence address of record as follows:

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