**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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| In re Patent of: | Aljosa Kemperle et al. | | |
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| Title: | THREE-DIMENSIONAL PRINTER WITH FORCE DETECTION | | |

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# PETITION FOR *INTER PARTES* REVIEW OF UNITED STATES PATENT NO. 9,168,698 PURSUANT TO 35 U.S.C. §§ 311–319, 37 C.F.R. § 42

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**EXHIBITS**

| | |
|---|---|
| EX1001 | U.S. Patent No. 9,168,698 to Kemperle et al. ("the '698 patent") |
| EX1002 | Excerpts from the Prosecution History of the '698 Patent ("the Prosecution History") |
| EX1003 | Declaration of Dr. Andrew Wolfe (including CV) |
| EX1004 | US6,986,739B2 (US20030100824A1) to Warren et al ("Warren") |
| EX1005 | US9,031,680B2 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 | US6,629,011B1 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 | US7,552,543B2 to Tomelleri ("Tomelleri") |
| EX1012 | US20070056176A1 to Matsumiya et al ("Matsumiya") |
| EX1013 | *Practical 3D Printers, The Science and Art of 3D Printing* by Brian Evans |
| EX1014 | Declaration of Dr. Adrian Bowyer |
| EX1015 | Declaration of June Munford |

| | |
|---|---|
| EX1016 | Exhibit D 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.allelectronics.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** | |
|---|---|
| [1pre] | A method comprising: |
| [1a] | identifying build instructions for fabricating an object; |
| [1b] | initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure; |
| [1c] | detecting the current contact force based on a sensor signal from the one or more sensors; and |
| [1d] | creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build. |
| **Claim 2** | |
| [2] | The method of claim 1, wherein the fabrication tool includes an extruder. |
| **Claim 3** | |
| [3] | The method of claim 2, wherein the at least one component of the three-dimensional printer controls a feed rate for a build material used in the build. |
| **Claim 4** | |
| [4] | The method of claim 2, wherein the at least one component of the three-dimensional printer controls a z-distance between the extruder and a build platform of the three-dimensional printer. |
| **Claim 5** | |
| [5] | The method of claim 2 further comprising comparing the current contact force to an expected contact force. |

| **Claim 6** | |
|---|---|
| [6] | The method of claim 5 further comprising adjusting at least one parameter of the three-dimensional printer to reduce a difference between the current contact force and the expected contact force. |
| **Claim 7** | |
| [7] | The method of claim 5 further comprising terminating the build when a difference between the current contact force and the expected contact force indicates a fabrication error. |
| **Claim 8** | |
| [8] | The method of claim 1 wherein the control signal includes a signal to the three-dimensional printer to change a distance between the fabrication tool and the separate structure. |
| **Claim 9** | |
| [9] | The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder. |
| **Claim 10** | |
| [10] | The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure. |
| **Claim 11** | |
| [11] | The method of claim 10 further comprising fabricating a layer on the surface of the separate structure that decreases one or more irregularities in the surface of the separate structure. |
| **Claim 12** | |
| [12a] | The method of claim 1, wherein the build instructions include at least one instruction for achieving a specified contact force between the fabrication tool and a separate structure, and |

| | |
|---|---|
| [12b] | wherein the control signal controls the at least one component of the three-dimensional printer to achieve the specified contact force. |
| **Claim 13** | |
| [13] | The method of claim 1 wherein the one or more sensors include a strain gauge. |
| **Claim 14** | |
| [14] | The method of claim 1 wherein the one or more sensors include a piezoelectric sensor. |
| **Claim 15** | |
| [15] | The method of claim 1 wherein the one or more sensors include at least one of a capacitive sensor, an optical sensor, an electromechanical sensor, an electromagnetic sensor, and an acoustical sensor. |

## 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 1-15 ("the Challenged Claims") of U.S. Patent No. 9,168,698 ("the '698 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 '698 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 supporting explanations in an expert declaration (EX1003) cited throughout this Petition. EX1003, ¶¶1-244.

| Ground | Claims | §103 Basis |
| --- | --- | --- |
| **1A** | 1-6, 8-15 | Warren |
| **1B** | 3, 7, 9 | Warren and Eshed |
| **2A** | 1-5, 7-10, 12-15 | Calderon and RepRap20208 |
| **2B** | 11 | Calderon, RepRap20208, and Napadensky |

Each reference predates October 29, 2012, the '698 Patent's earliest effective date, and thus qualifies 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) |
| Eshed | Aug. 10, 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) |
| Napadensky | Jan. 25, 2010 (filed) | §§102(e) | §§102(a)(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 the public without requiring login, since its inception in March 2005. EX1014, ¶¶3-12. A registered user can start, or "post," forum discussion threads. *Id*. The threads were accessible from the front page at RepRap.org, ordered by subject matter and keyword searchable. *Id*., ¶¶5-10. In fact, the inventors of the '698 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 '698 PATENT

### A. Pertinent Disclosure

The '698 patent provides "pressure-sensing extruders" for a "three-dimensional printer." EX1001, 1:13-20. "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, 1:23-30. "The resulting feedback data can be used…to control operation of the three-dimensional printer." *Id.*

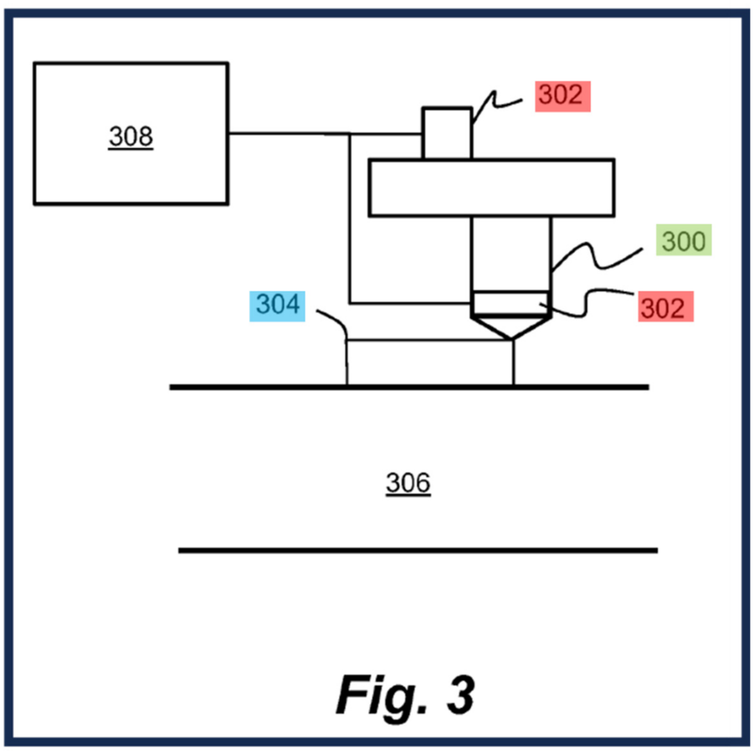



FIG. 3 (annotated above) depicts "a fabrication tool for use in a three-dimensional printer," includes "an extruder or other tool operable to add build material to an object 304 during a build process." EX1001, 8:39-48. "[S]ensors 302 may be mechanically coupled or otherwise included in the fabrication 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 '698 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.*, 8:49-61; EX1003, ¶¶35-37.

### B. Prosecution History

The Examiner who allowed the '698 patent did so because he believed: "The prior art fails to teach or suggest an [sic] method comprising…creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build."). EX1002, 16-27 (Notice of Allowance 07/22/2015). But as demonstrated by this Petition, the Challenged Claims are obvious, and this conclusion would have been apparent had the Examiner more thoroughly searched the prior art and vetted the Challenged Claims. 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 (and vice versa). *Id*.

As Dr. Wolfe explains, this POSITA would have possessed background knowledge and understanding of the pertinent technologies employed by the '698 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 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 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, 8-15 Are Obvious Over Warren

### 1. Warren (EX1004)

Like the '698 patent, Warren is about 3D printing. EX1003, ¶¶43-50. 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 a DWDT 3D printing apparatus 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].

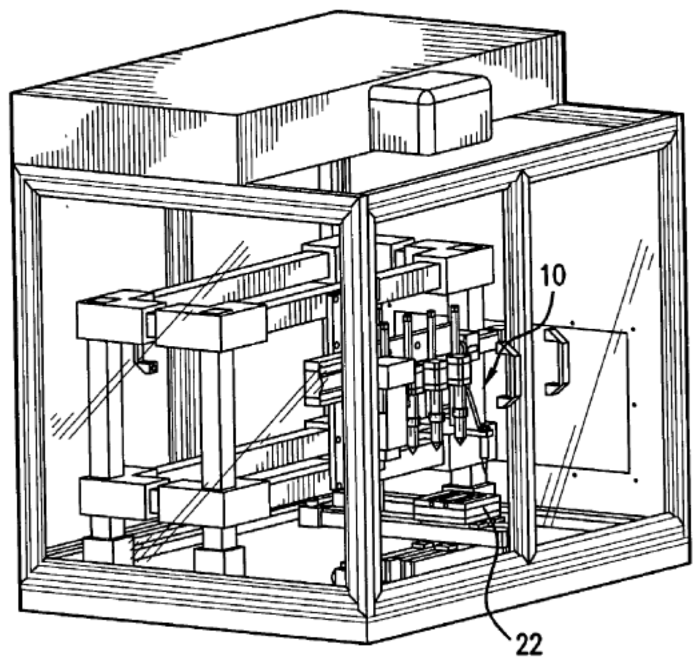



FIG. 1

FIG. 1 shows Warren's DWDT/HAT tool. EX1004, [0058]. In Warren, the "DWDT/HAT may include a material dispenser 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] (reference number omitted). Warren explains that the "ability to precisely and selectively add, in real time, 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" so as "to fabricate scaffold microstructure with controlled spatial gradients of cells, growth factors, and other desired ingredients"), [0324] (3D layered fabrication to deposit cells atop a layer of polyurethane and bio scaffold material "using the vibro-sensoric capillary dispensing system"), "), [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], [0288-0290], [0283-0284].

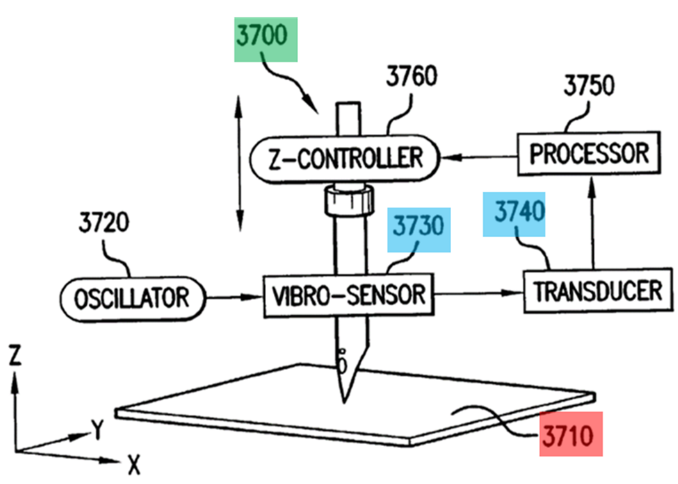
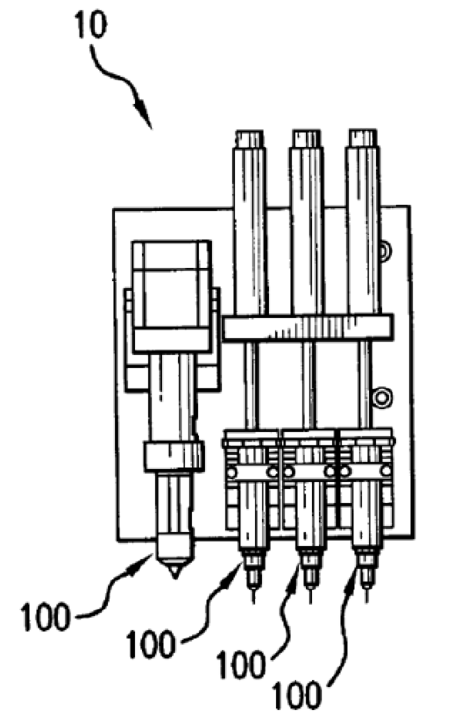



FIG. 18

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], [0303-307] (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].




EX1004 FIG. 23A

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].

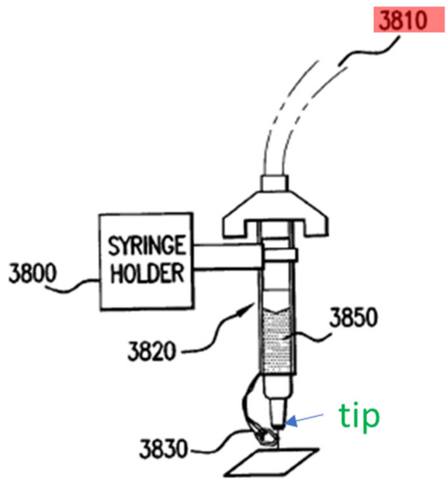
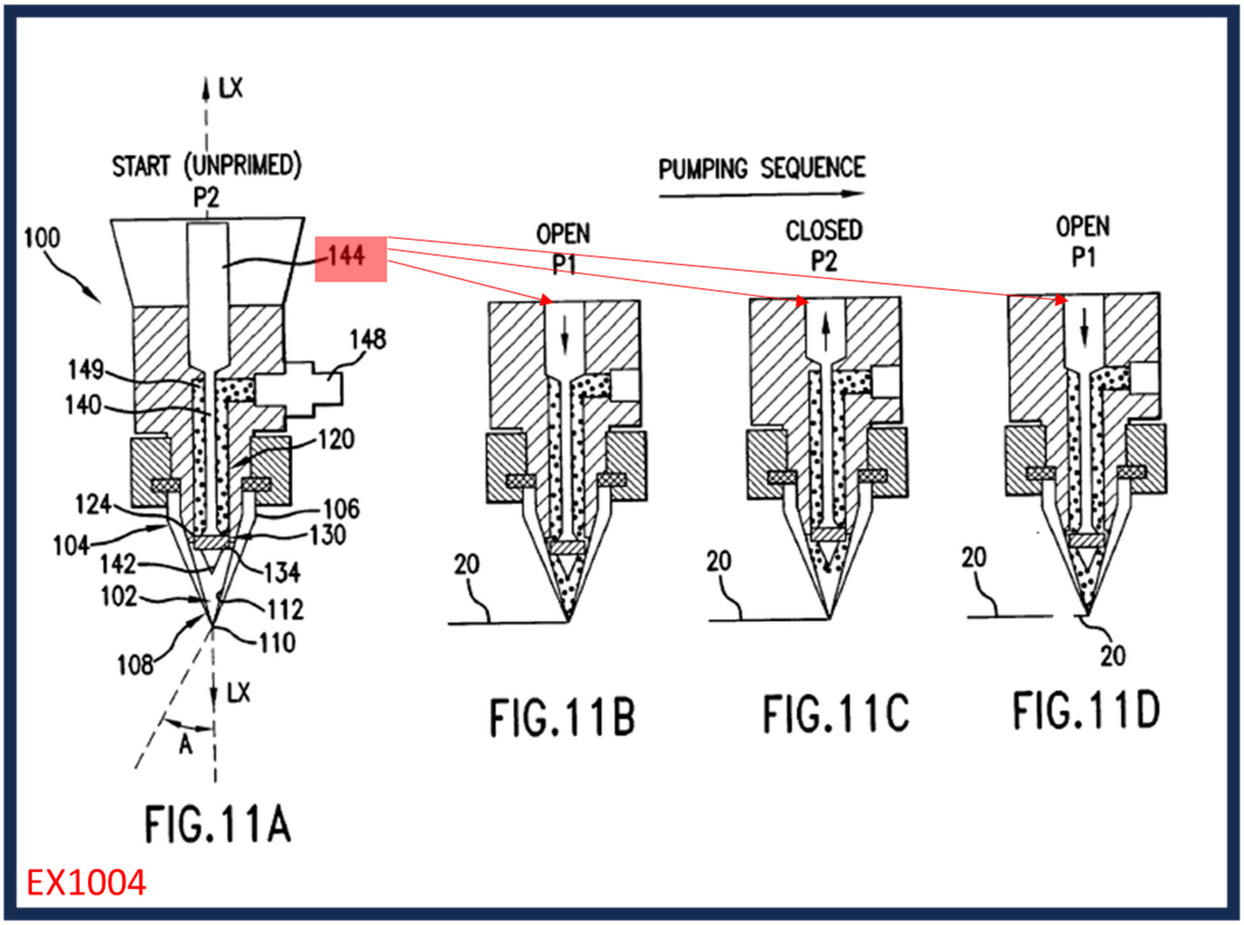



FIG. 19

Warren additionally teaches 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].




Warren teaches "acquiring various kinds of detailed information about the tissue to be regenerated and/or constructed," and then "create virtual images" of "the engineered tissue construct (ETC)" as "computer-aided design and manufacturing (CAD/CAM) program data." EX1004, [0402], [0403], [0392]. "This transformation of images into machine language allows the images to be constructed by the HAT computer automation." *Id.*, [0403], [0393], [0397]. After setting "parameters specific to the act of deposition," Warren teaches "[i]nitiating CAD/CAM layer-by-layer depositions" to construct the ETC. *Id.*, [0406], [0408], [0412], [0427], [0391]-[0434]; EX1003, ¶¶43-50.

#### 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 (*id.*, [0283-0318]), a POSITA would have found it obvious to use the vibrating force sensor concepts with Warren's through-nozzle dispenser (*id.*, [0230-0252]). EX1003, ¶65.

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 using the vibrating force sensor concepts with other dispenser configurations 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 dispensing unit] implementations." EX1004, [0299], [0294] ("dispenser 3700 may be implemented differently"). Using Warren's through-nozzle dispenser as dispenser 3700 merely involves combining known elements using known techniques to achieve predictable and advantageous results. EX1003, ¶68.

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 features from 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 <u>a plurality of aspects</u> that, in some embodiments, <u>combine</u> 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.

<u>Fourth</u>, a POSITA would have recognized the benefits of providing Warren's 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. EX1003, ¶71. A POSITA would have also found motivation for the combination to facilitate control over the deposition geometry. *Id.* 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, ¶66. 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 dispenser with a reasonable expectation of success. *Id.*

### 3. Claim Element Analysis

***[1.pre]: A method comprising:***

To the extent the preamble is limiting, Warren teaches a ***method*** "of producing a modeled structure through 3D direct construction of various materials into complex shapes." EX1004, [0093], [0007-0014], [0058]-[0063], [0230]-[0324], [0390]-[0446]; §§V.A.1-2; EX1003, ¶¶74-75.

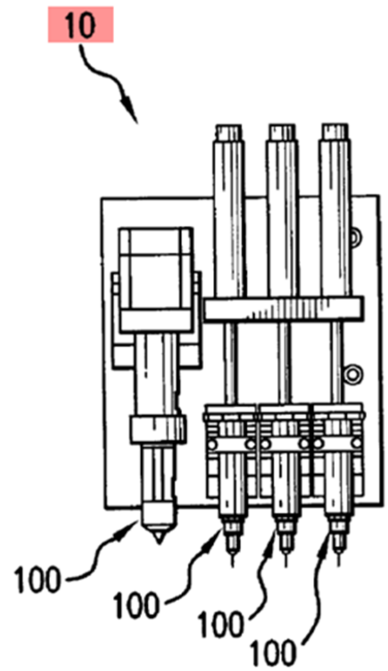
***[1.a]: identifying build instructions for fabricating an object;***

Warren teaches ***identifying build instructions*** (e.g., generating CAD/CAM program data as machine language) for ***fabricating an object*** (e.g., preparing engineered tissue constructs (ETC)). EX1003, ¶76; §§V.A.1-2. For example, Warren teaches creating "virtual images of…the engineered tissue construct (ETC)" and "transform[ing] the image information obtained in the previous step into computer-aided design and manufacturing (CAD/CAM) program data [to provide] machine language [that] allows the images to be constructed by the HAT computer automation." *Id.*, [0402], [0403], [0392], [0393]. Warren's reference to CAD/CAM data corresponds to the 3D model of the engineered tissue construct (ETC) and the corresponding machine language (***build instructions***) for the material dispenser to ***fabricate*** the ETC. EX1003, ¶¶76-77. Thus, Warren's teaching to generate CAD/CAM data provides or renders obvious the '698 patent's claimed step of ***identifying build instructions for fabricating an object***. *Id.* According to the '698 patent's specification, this claim language "is intended to be construed broadly" to include "generating machine-ready code from a three-dimensional model," just as Warren teaches. EX1001, 10:28-37; EX1003, ¶¶77-78.

***[1.b]: initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;***

Warren's combined teachings provide the step of ***initiating a build*** (e.g., "executing the tool operation parameters and the material dispensing and deposition parameters, thereby preparing the engineered tissue construct," (EX1004, [0397], [0404-0415])) ***using a three-dimensional printer*** for "producing a modeled structure through 3D direct construction of various materials into complex shapes," (*id.*, [0093], [0063], [0293-0321], [0288-290]). EX1003, ¶79.

As explained *supra* §§V.A.1-2, Warren includes ***a fabrication tool***, e.g., the apparatus 10 shown in FIGS. 23A-23C:



EX1004 FIG. 23A

Warren's apparatus 10 can include either or both the capillary vibro-sensor dispenser or the through-nozzle dispenser – both designated as 100 in FIG. 23A. Warren also provides ***one or more sensors*** (e.g., vibration sensor 3730 and transducer 3740) ***mechanically coupled to the fabrication tool*** (e.g., apparatus 10). *E.g.*, EX1004, [0300] ("A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700"), [0315] ("vibration sensor…attached to the dispenser"), FIG. 18 (below); EX1003, ¶¶80-81.

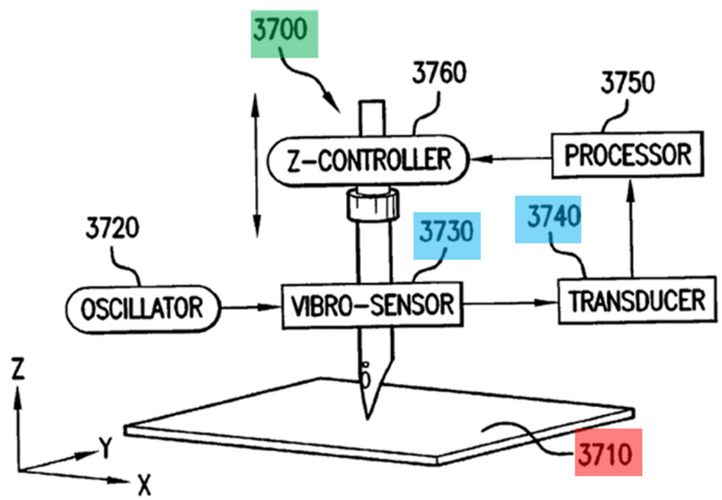



FIG. 18

Warren's ***sensors*** are ***configured to detect a current contact force*** (e.g., the force of contact) ***between the fabrication tool*** (the capillary vibro-sensor dispenser and/or the through-nozzle dispenser) ***and a separate structure*** (e.g., substrate 3710). EX1003, ¶¶82-85. 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." EX1004, [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." *Id.*, [0302]. Warren further explains that "a change in the amplitude of vibration of the dispenser and/or the substrate is ***detected***," where "this change in amplitude is proportional to ***the force of contact*** between the dispenser and the substrate." *Id.*, [0313] (describing FIG. 22A (below)).

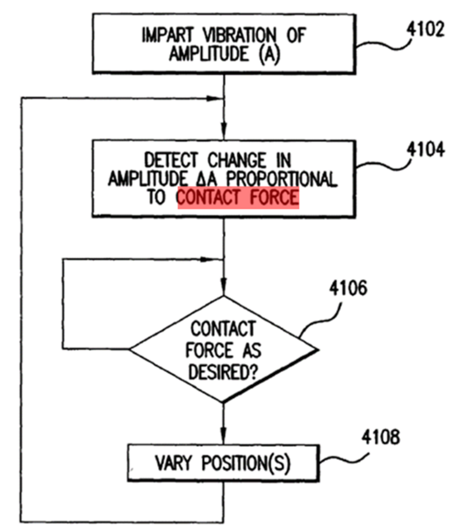



FIG.22A

EX1004

In view of the proportionality, a POSITA would have understood or found it obvious that the ***contact force*** can be readily calculated from the detected "change in the amplitude." EX1004, [0313], [0301]-[0307]; EX1003, ¶86 (explaining additional details of Warren's sensing operations). Warren's vibration sensor and transducer thus align with the specification of the '698 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, ¶86-87.

***[1.c]: detecting the current contact force based on a sensor signal from the one or more sensors; and***

Warren's combined teachings provide ***detecting the current contact*** (e.g., "the force of contact between the dispenser and the substrate") ***based on a sensor signal*** (e.g., "a change in the amplitude of vibration of the dispenser") ***from the one or more sensors*** (e.g., vibration sensor 3730 and transducer 3740). *E.g.*, EX1004, [0313] ("At step 4104, a change in the amplitude of vibration of the dispenser and/or the substrate is detected," where "[t]his change in amplitude is proportional to the force of contact between the dispenser and the substrate."), [0302] (transducer 3740 senses and transfers the changed vibration signal to an amplifier); EX1003, ¶¶88-89; *supra* Element [1.b].

***[1.d]: creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.***

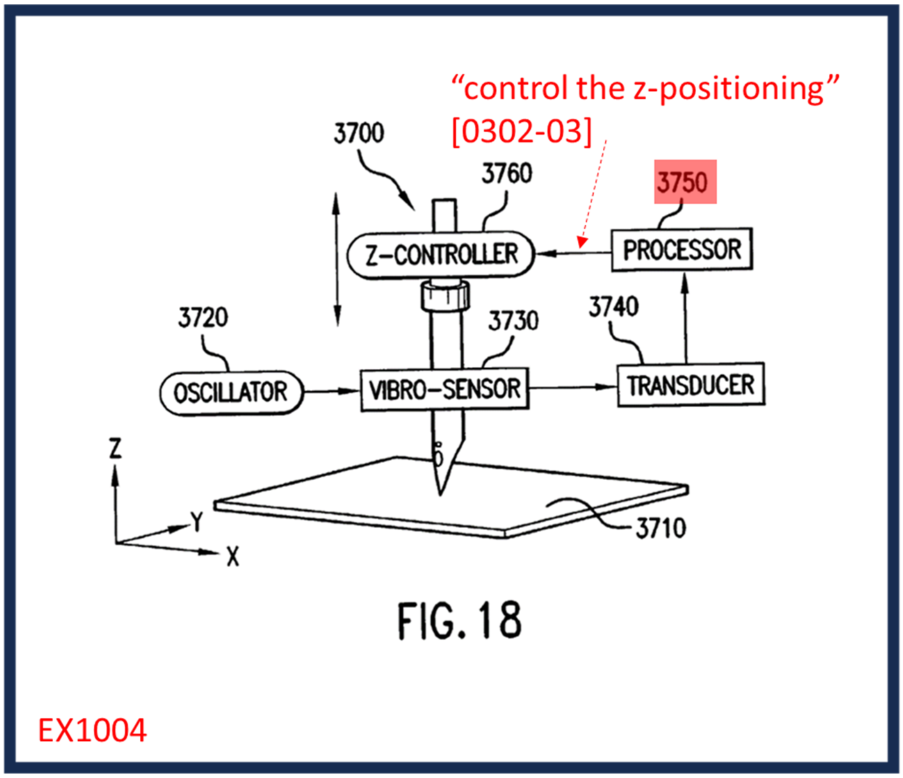
Warren's combined teachings provide ***creating a control signal*** (e.g., the signal provided by a "microprocessor" or "personal computer (PC)") ***to control at***

***least one component*[2] *of the three-dimensional printer*** (e.g., at least one of a "z-controller step motor" and a "linear actuator" of the material dispensing system) ***in response to the current contact force*** (e.g., "force of contact") ***while depositing material during the build*** ("even as the material protruding from a nozzle on a dispenser contacts the substrate surface"). EX1004, [0302], [0309], [0313], [0316]; EX1003, ¶90.

In the context of FIG. 18 (below), Warren discloses: "The feedback signal [from vibration sensor 3730 and transducer 3740] 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." EX1004, [0302], [0286-287]. 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," or "personal computer (PC)." *Id.*, [0302-0303]. Warren also

[2] The '698 patent describes the at least one component includes "a drive system…that controls a feed rate," and "a component that controls a Z-axis position of an extruder." EX1001, 10:62-11:16; §II.A.

discloses continuously detecting contact force for dispensing "onto conformal surfaces as the force feedback control continuously corrects for dispensing structure's z-height position as the height of the substrate surfaces changes." *Id.*, [0316], [0293], [0301-0304], FIG. 22A; EX1003, ¶91.




Accordingly, Warren renders obvious all elements of claim 1. EX1003, ¶¶72-92.

***2. The method of claim 1, wherein the fabrication tool includes an extruder.***

Warren's ***fabrication tool*** (e.g., the apparatus 10 shown in FIGS. 23A-23C) ***includes an extruder*** (the capillary vibro-sensor dispenser and/or the through-nozzle dispenser – both designated as 100 in FIG. 23A). EX1003, ¶¶93-94. As discussed *supra* §§V.A.1-2, the capillary vibro-sensor dispenser expressly utilizes 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, provides the claimed ***extruder***.

The capillary vibro-sensor dispenser is ***an extruder*** because 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 18-20A, 20B.

The through-nozzle dispenser is likewise ***an extruder*** because it features a "positive-displacement/suck-back pump system," where "the pump 148 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-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, ¶¶95-96.

Moreover, Warren's teachings parallel the '698 patent's preferred embodiments, which "employ a "motor 128 or the like to push the build material into the chamber 122 and/or through the extrusion tip 124." EX1001, 2:45-47; EX1003, ¶¶97-98. And extruders in fused deposition modeling, like the '698 patent, have long been referred to as "dispensers." EX1021, 3:14-38 (30-year-old fused deposition patent with a "dispenser").

***3. The method of claim 2, wherein the at least one component of the three-dimensional printer controls a feed rate for a build material used in the build.***

In the through-nozzle dispenser, "the flow of material is controlled by adjusting…the valve 130." EX1004, [0232],[0230-0252], FIGS. 11A-11D, 12A-12B. The "valve 130 includes a linear-actuated piston 140…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], [0239]; EX1003, ¶¶99-100.

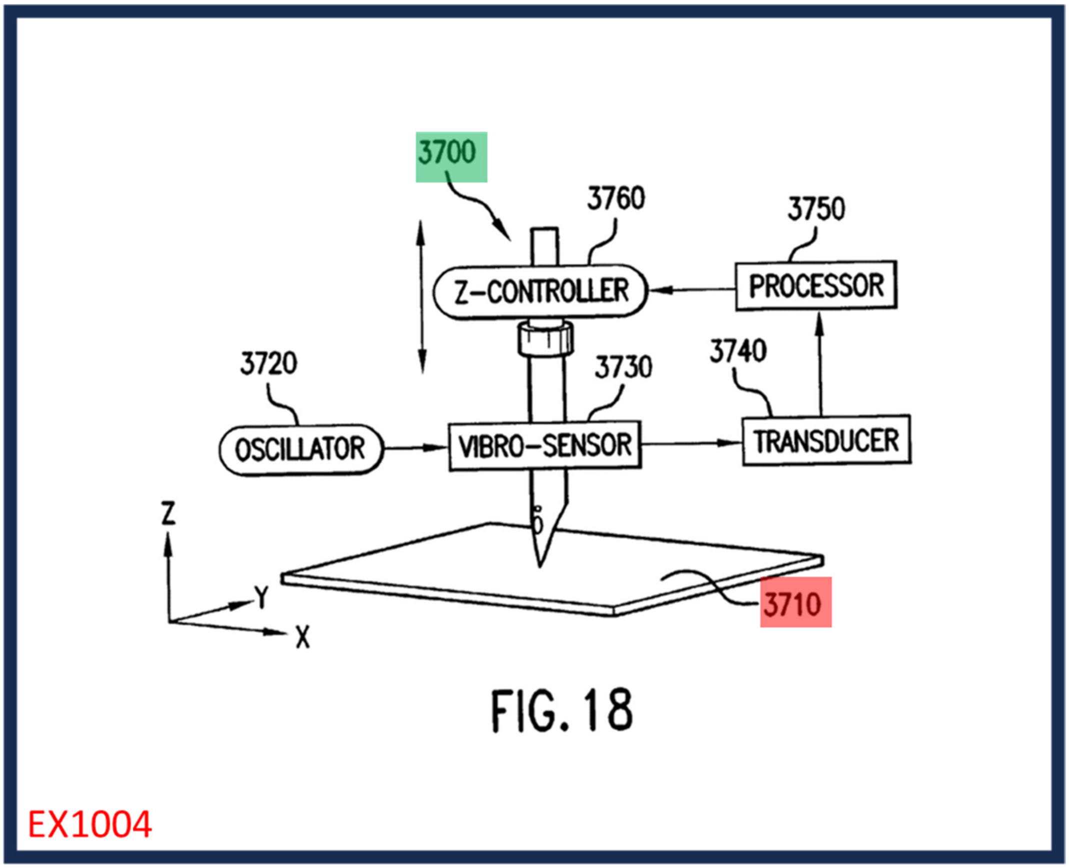
Warren further teaches that the actuator-controlled "valving mechanism may be synchronized with the xyz motion of the dispenser." EX1004, [0234], [0235-0240]. In view of Warren's teaching that the z-height be controlled based on contact force, it would have been apparent or obvious to a POSITA that control signals to the <u>z-controller step motor</u> for adjusting the z-position of the dispenser based on contact force result in corresponding control signals to <u>the linear actuator</u> to provide synchronous adjustments to the flow of material from the dispenser. EX1003, ¶101.

Further, Warren describes the position of the valve is changed at certain "'trouble spots' in the middle of a path (such as at a corner where there is too much material being deposited, the valve position can be slightly closed." EX1004, [0238]. A POSITA would have known, or found it obvious that, the same contact force sensing enabling dispensing onto conformal surfaces would identify these trouble spots "where there is too much material being deposited" and, in response, Warren teaches "the valve position can be slightly closed." EX1003, ¶102; EX1004, [0238]; *supra*, Element [1.d].

Thus, the through-nozzle dispenser includes a linear actuator (i.e., one of the claimed "***at least one component***") to adjust dispensing rate (i.e., ***feed rate for build material used in the build***). EX1004, [0243] ("flow characteristic upon leaving the tip orifice 110"), [0239], [0243]; EX1003, ¶103. Further, feed rate is controlled synchronously with the "xyz motion of the dispenser" and in response to identified " 'trouble spots'…where there is too much material being deposited" – both of which are controlled based on contact force. *Id.*, EX1004, [0234], [0236], [0238]; EX1003, ¶¶103-104.

***4. The method of claim 2, wherein the at least one component of the three-dimensional printer controls a z-distance between the extruder and a build platform of the three-dimensional printer.***

As explained *supra* §§V.A.1-2 and further discussed *supra* [1d], Warren discloses creating a control signal "to control the position of the dispenser 3700." EX1004, [0302]. FIG. 18 (below) illustrates an example of using "<u>a z-controller processor 3750 to control the z positioning of the dispenser 3700 via a z-controller step motor 3760</u>." *Id.*




A POSITA would have found it apparent or obvious that "substrate 3710" of FIG. 18 can be mounted on a z stage (i.e., ***build platform***), as depicted in FIG. 22, and hence, a "z-controller step motor" of the material dispensing system (i.e. one of the claimed "***at least one component***") ***controls a z-distance between the extruder*** (e.g., tip of the extruder) ***and a build platform***. EX1003, ¶¶105-108.

***5. The method of claim 2 further comprising comparing the current contact force to an expected contact force.***

In the context of claims 1 and 2, Warren's combined teachings further provide ***comparing the current contact force*** (e.g., measured contact force) ***to an expected***

***contact force*** (e.g., desired contact force). EX1004, [0313] ("a determination is made whether the contact force is that which is desired, based on the detected change in amplitude."), FIG. 22A (below); EX1003, ¶¶109-111.

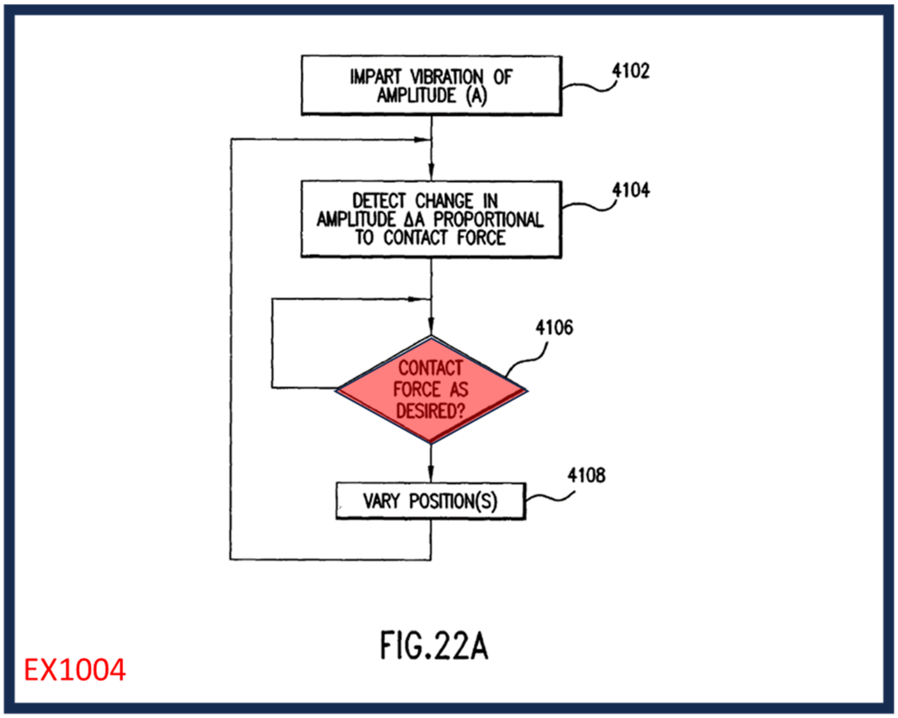



FIG.22A

***6. The method of claim 5 further comprising adjusting at least one parameter of the three-dimensional printer to reduce a difference between the current contact force and the expected contact force.***

In the context of claims 1, 2, and 5, Warren's combined teachings further provide ***adjusting at least one parameter of the three-dimensional printer*** (e.g., the z-position of integrated dispenser) to ***reduce a difference between the current contact force and the expected contact force*** (e.g., maintain a desired force of contact). EX1003, ¶¶112-113.

Specifically, Warren teaches that "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." EX1004, [0302], [0313] ("Steps 4104, 4106 and 4108 are repeated as necessary to obtain a desired contact force between the substrate and the dispenser, e.g., to maintain contact of a desired force between the substrate and the dispenser."). "If at step 4108 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or substrate are varied at step 4108, causing a change in the amplitude of vibration." *Id*., [0313]; EX1003, ¶114-115.

***8. The method of claim 1 wherein the control signal includes a signal to the three-dimensional printer to change a distance between the fabrication tool and the separate structure.***

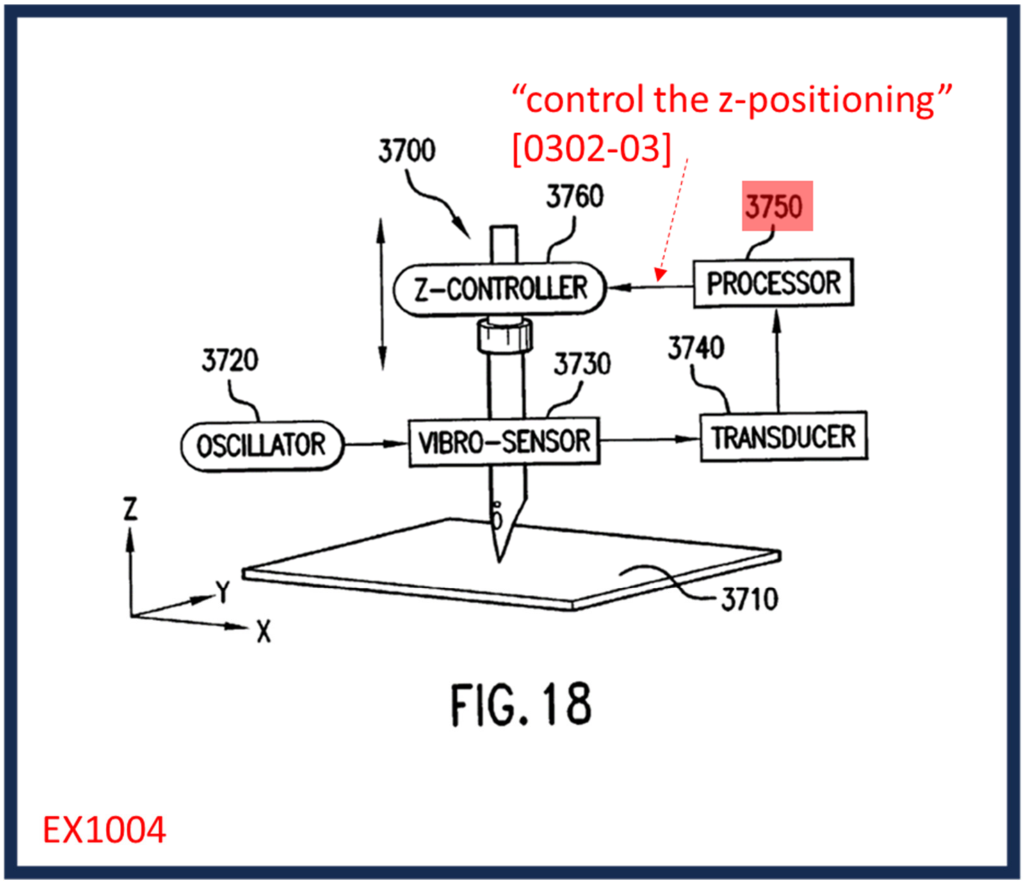



FIG. 18

As annotated above and explained *supra* [1.d], Warren teaches that "a z-controller processor 3750 [asserts an instance of a control signal] to control the z positioning of the dispenser 3700 via a z-controller step motor 3760" so that "the position(s) of the dispenser and/or the substrate are varied." EX1004, [0302], [0313], FIGS. 18, 22A. Hence, the ***distance between*** the tip of the extruder (on ***the fabrication tool***) ***and*** the substrate (i.e., ***the separate structure***) is changed. EX1003, ¶¶116-118.

***9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.***

As explained *supra* claim 3, Warren's processor provides instances of control signal to drive components of the material dispensing system including a linear actuator, which "controls the material dispensing rate." EX1004, [0243], [0239], [0234], [0255], FIGS. 11A-11C, and 12A-12B. In the context of Warren's "force feedback control" that "enables the dispenser to seek and find contact with a surface," dispense on "conformal surfaces," and identify "trouble spots" having "too much material," a POSITA would have known that the linear actuator regulates the dispensing rate of material from the dispenser to control the amount of material fed to the nozzle tip per second (i.e., ***feed rate of build material extruded by the extruder***) so that Warren's dispenser "maintains contact of a desirable intensity." *Id.* [0316], [0238], [0234] ("flow characteristic upon leaving the tip orifice 110"); EX1003, ¶¶119-121; *supra*, claim [3].

***10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.***

In the context of claims 1 and 2, Warren's combined teachings further provide ***detecting a planarity of the separate structure*** (e.g., flatness of the substrate positioned on the build platform) ***based upon a number of contact force measurements*** (e.g., by measuring ΔA (changed amplitude) of a vibration signal imposed on the dispenser) ***across a surface of the separate structure*** (e.g., a surface of the substrate positioned on the build platform). EX1003, ¶¶122-124.

As Warren explains, control based on continuously detecting contact force "allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects for dispensing structure's z-height position as the height of the substrate surfaces changes." EX1004, [0316], [0293]; *supra* [1b] (citing e.g., [0301-0304] and FIG. 22A).

**Detecting Planarity During Printing**

Warren's dispensing system, "by varying the position of the dispenser relative to the substrate, enables the dispenser to follow irregular or curved surfaces." EX1004, [0293] (reference number omitted). A POSITA would have recognized that, when printing on a non-flat (e.g., irregular or conformal) surface, Warren's dispensing system is detecting that the substrate is not flat (i.e., ***detecting a planarity of the separate structure***) by "continuously" measuring "a change in the amplitude of vibration signal [which] is proportional to the force of contact" (i.e., ***a number of contact force measurements across a surface)*** with the substrate, and correcting for it "as the force feedback control continuously corrects the dispensing structure's z-height position as the z height of the substrate surface changes." EX1004, FIG. 22, [0313], [0316]; EX1003, ¶125.

**Detecting Planarity Before Printing**

A POSITA would have found it obvious to apply Warren's force sensing to determine surface planarity as part of a calibration procedure before printing an object. EX1003, ¶¶126-127. As explained Dr. Wolfe, a POSITA would have been motivated by known benefits and advantages of the calibration procedure including, e.g., obtaining "spatial relationship between the extrusion tip and the substrate prior to building" in order to "build accurate error-free models." *Id.* (citing EX1007, [0006], [0052-54]); EX1004, [0285] (discussing risk of crash and control of deposition geometry).

***11. The method of claim 10 further comprising fabricating a layer on the surface of the separate structure that decreases one or more irregularities in the surface of the separate structure.***

Warren discloses its HAT process "begins with a biocompatible scaffold that acts as a framework for the subsequent cell growth and proliferation." EX1004, [0320]. "The porosity and the surface area…are important characteristics of the scaffold material" so as "to allow cell attachment" and "so that cells penetrate the pores." *Id.*, [0074], [0068] ("cells seeded into a porous, biodegradable polymer scaffold"), [0069] (scaffold material requirements including "pore volume"), [0320] ("seeding preformed porous scaffolds with host cells"). A POSITA would understand that such porosity is an ***irregularity in the surface*** of the scaffold. EX1003, ¶129. Warren's "dispensers may all be used for cellular deposition," and when they are used to deposit cells as ***a layer on the surface of the separate***

***structure*** (the scaffold), a POSITA would understand that the deposited cells are ***a layer on the separate structure*** and that ***decreases one or more irregularities*** by attaching and penetrating the pores. EX1004, [0323], [0324]; EX1003, ¶¶128-129.

Warren also teaches "the force feedback control continuously corrects the dispensing structure's z-height position as the z height of the substrate surface changes." EX1004, FIG. 22, [0316], [0313], [0293], [0010], [0015].

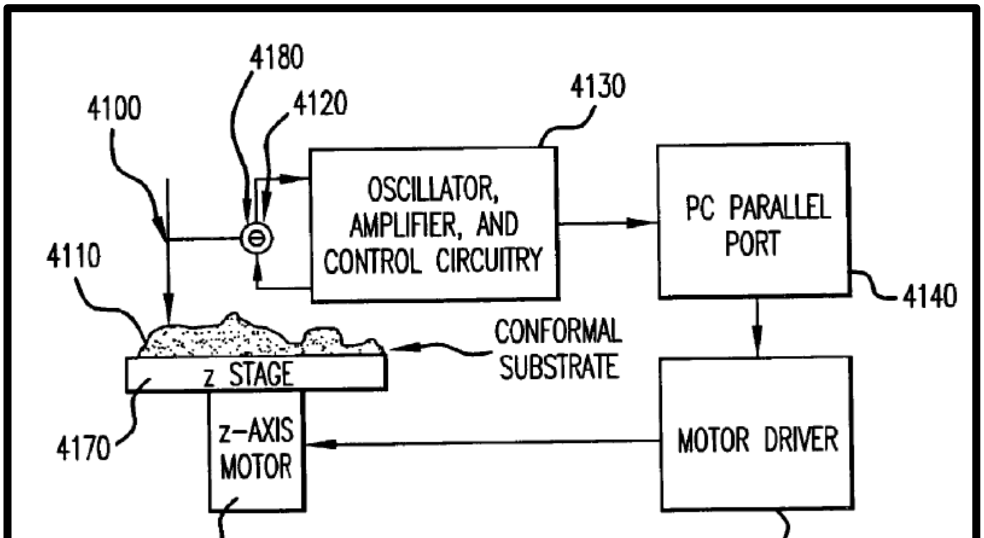


FIG. 22

In its "layer-by-layer deposition process," Warren discloses depositing ***a layer on the surface*** of the varying z height surface. EX1004, [0088], [0010], [0015], [0295], [0316], [0324] ("four different layers"); EX1003, ¶¶130-131. As explained by Dr. Wolfe, as the "viscous materials" exit the through-nozzle dispenser or the capillary dispenser, the extruded fluids would ***decrease irregularities***, and certainly any smaller irregularities, ***in the surface of the separate structure*** when the viscous materials accumulate and fill irregularities on the surface. EX1004, [0278]; EX1003, ¶¶131-132 (citing EX1007, [0030] ("The bottom of the extrusion tip typically includes an 'iron' that physically contacts and flattens out the bead of material making up the build path for that layer as it is deposited"); EX1005, 17:56-18:4, 18:5-18, 18:25-47)).

***[12.a] The method of claim 1, wherein the build instructions include at least one instruction for achieving a specified contact force between the fabrication tool and a separate structure, and***

In the context of claim 1, Warren's combined teachings provide that the computer-aided design and manufacturing (CAD/CAM) data, capable of being executed on the integrated printing system, include ***at least one instruction*** "to maintain a desired force of contact between the dispenser 3700 and the substrate 3710" (i.e., ***for achieving a specified contact force between the fabrication tool and a separate structure***). EX1004, [0302], [0313] ("maintain contact of a desired force between the substrate and the dispenser"), [0285] (discussing risk of crash and control of deposition geometry), [0290], [0397], [0404-415];§§V.A.1-2; EX1003, ¶¶133-134.

***[12.b] wherein the control signal controls the at least one component of the three-dimensional printer to achieve the specified contact force.***

As explained *supra* §§V.A.1-2 and further discussed *supra* under Elements [1c] and [1d], the control signal (e.g., from the processor) ***controls the at least one component of the three-dimensional printer*** (including, e.g., z-controller step motor and linear actuator) ***to achieve the specified contact force***. EX1004, [0302], [0288-289], [0304-0305]; EX1003, ¶¶135-136.

***13. The method of claim 1 wherein the one or more sensors include a strain gauge.***

Warren provides piezotransducers as sensors "for sensing …vibration of the dispenser 3700." EX1004, [0300-302]. As explained by Dr. Wolfe, it was general knowledge that piezotransducers were commonly configured to convert input mechanical pressure/strain to an electrical output based on the piezoelectric effect. EX1003, ¶137-139 (citing, e.g., EX1019). Because the vibrating dispenser 3700 of Warren experiences mechanical distortion, a POSITA would have found it obvious to configure, e.g., vibration sensor 3730 of Warren, to sense mechanical properties, such as strain, of the vibrating dispenser 3700. *Id.* (citing EX1012,[0034] (force sensing using "a strain gauge for detecting distortion of the [vibrating] stylus"), and EX1006, [0044-45], FIG. 7).

***14. The method of claim 1 wherein the one or more sensors include a piezoelectric sensor.***

In the context of claim 1, the one or more sensors include a ***piezoelectric sensor*** (e.g., a piezoelement). EX1003, ¶¶140-141. For example, Warren describes "piezoelement" when explaining its sensor operation to detect changed amplitude, known as ΔA, which "brings additional flexibility and sensitivity to the system." EX1004, [0304], [0306-07] (examples of "a dispensing system with <u>a piezoelement</u> attached"). A POSITA would have recognized that the piezolement refers to a piezo electric sensor. EX1003, ¶141 (noting the terms are used interchangeably as seen in EX1004, [0305] ("piezotransducer"), [0300] ("transducer"), [0295-96] ("piezomembrane")).

***15. The method of claim 1 wherein the one or more sensors include at least one of a capacitive sensor, an optical sensor, an electromechanical sensor, an electromagnetic sensor, and an acoustical sensor.***

In the context of claim 1, the one or more sensors include an ***electromechanical sensor*** and/or ***an acoustical sensor*** (e.g., transducer 3740). EX1003, ¶¶142-143. In the combination, Warren provides "[a] vibration sensor 3730 and a transducer 3740…for sensing the A and f of vibration of the dispenser 3700." EX1004, [0300], [0301] (100 kHz range), FIG. 18; *supra* claim 14. The transducer 3740 is electromechanical in that it converts mechanical vibration into an electrical signal, and acoustic in that it converts vibration into an electrical signal. EX1003, ¶143.

### B. GROUND 1B – Claims 3, 7 and 9 Rendered Obvious Over Warren and Eshed

#### 1. Eshed (EX1008)

Similar to Warren's disclosure, Eshed teaches "rapid production apparatus", abbreviated as RPA, "for producing a 3-dimensional object by sequentially forming thin layers of material one on top of the other, responsive to data defining the object." EX1008, [0002], Abstract. Eshed notes a known collision problem in which shuttle (including print head) may collide with "unwanted protuberances," when, "during construction of an object, construction material debris may fall on a construction layer." *Id.*, [0171]. In fact, the potential for collision of the print head was a well-established concern to a POSITA. EX1003, ¶63 (noting other common collision sources by citing EX1005, 18:5-18 ("for example, as a result of dispensed layers being too thick and/or inconsistent in thickness, and/or because of a mechanical malfunction of the dispensing head.")). Eshed's RPA includes "an obstacle detection system" that "[u]pon occurrence of a collision, controller…stops production of the object and generates an alarm indicating that user intervention is required." *Id.*, [0180], EX1003, ¶63.

#### 2. The Combination, Reasons to Combine, and Reasonable Expectation of Success

As described *supra* §§V.A.1-2 and claims 5, Warren teaches comparing the current contact force to the expected contact force. EX1004, [0313] ("a determination is made whether the contact force is that which is desired, based on the detected change in amplitude [of vibration]," which change is "proportional to the force of contact between the dispenser and the substrate"), [0288-290], [0302]. Warren also acknowledges that an "improper prediction" of contact force "may result in either destruction of the dispenser or the substrate as the tip crashes into the substrate material." *Id.*, [0285]. A POSITA would understand, or find obvious, that a contact force above the desired contact force resulting in "destruction of the dispenser or the substrate" to be a fabrication error. EX1003, ¶¶144-145.

A POSITA would have been motivated to safeguard operation of the three-dimensional printer by comparing the current contact force and the expected contact force, as taught in Warren, and stopping production when the difference indicates a fabrication error, such as a collision with unwanted protuberances, terminating the build, as suggested by Eshed. EX1008, [0171] ("… as shuttle [including printing head] moves over the construction layer it may collide with the protuberance and be damaged"); §§V.A.1-2, V.B.1; EX1003, ¶146.

<u>First</u>, a POSITA would have known the desirability of preventing further damage to the extruder tip and the build structure being constructed. Here, once a collision has occurred, continuing the build can cause further damage to both. EX1003, ¶147. <u>Second</u>, a POSITA would have been prompted by operational efficiency—once a collision has occurred, the build structure can be damaged beyond repair. Hence, there is no point to continue the build as it may not result in a usable ETC. *Id*. <u>Third</u>, Warren already suggests "destruction of the dispenser or the substrate as the tip crashes into the substrate material," (EX1004, [0285]), which would have prompted a POSITA to look for complementary teachings from references like Eshed that explain what to do in those scenarios, i.e., shut the system down and output an error message. *Id*.

As a POSITA would have known, the scenario of "unwanted protuberances" described by Eshed is just an example for causing collision -- an obstacle in the path of the extruder of the integrated printing system during fabrication. EX1008, [0171-0172]; §§V.A.1-2; EX1003, ¶148. Eshed further teaches that "[t]he detection system generates signals responsive to unwanted protuberances that may be formed on a construction layer." EX1008, [0172]. In the Warren-Eshed Combination, Warren's acknowledging potential "destruction of the dispenser or the substrate" due to a fabrication error and teaching of "comparing the current contact force and the expected contact force" provides a known technique for a POSITA to apply to the detection system of Eshed to achieve predictable results (i.e., when the difference indicates a fabrication error (e.g., blockage by unwanted protuberances), the fabrication is terminated). EX1003, ¶148. Hence, a POSITA would have a reasonable expectation of success.

### 3. Claim Element Analysis

***3. The method of claim 2, wherein the at least one component of the three-dimensional printer controls a feed rate for a build material used in the build.***

In the context of claim 2, in the Warren-Eshed Combination, a POSITA would have understood or found it obvious that when "[u]pon occurrence of a collision, controller…stops production of the object" the controller would stop the feed of material as part of stopping production. EX1003, ¶¶149-150. Thus, creating a control signal to stop production based on the measured contact force indicating a fabrication error, e.g., collision, provides the claimed ***creating a control signal to control at least one component*** where the ***component…controls a feed rate for a build material used in the build***. EX1003, ¶150-151.

***7. The method of claim 5 further comprising terminating the build when a difference between the current contact force and the expected contact force indicates a fabrication error.***

As described *supra* §§V.B.1-2, the Warren-Eshed combination provides ***terminating the build*** (e.g., stop the fabrication, as taught in Eshed) ***when a difference between the current contact force and the expected contact force*** (e.g., based on comparing the current contact force and the expected contact force, as taught in Warren) ***indicates a fabrication error*** (e.g., blockage by unwanted protuberances, as taught in Eshed). EX1003, ¶¶152-154.

***9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.***

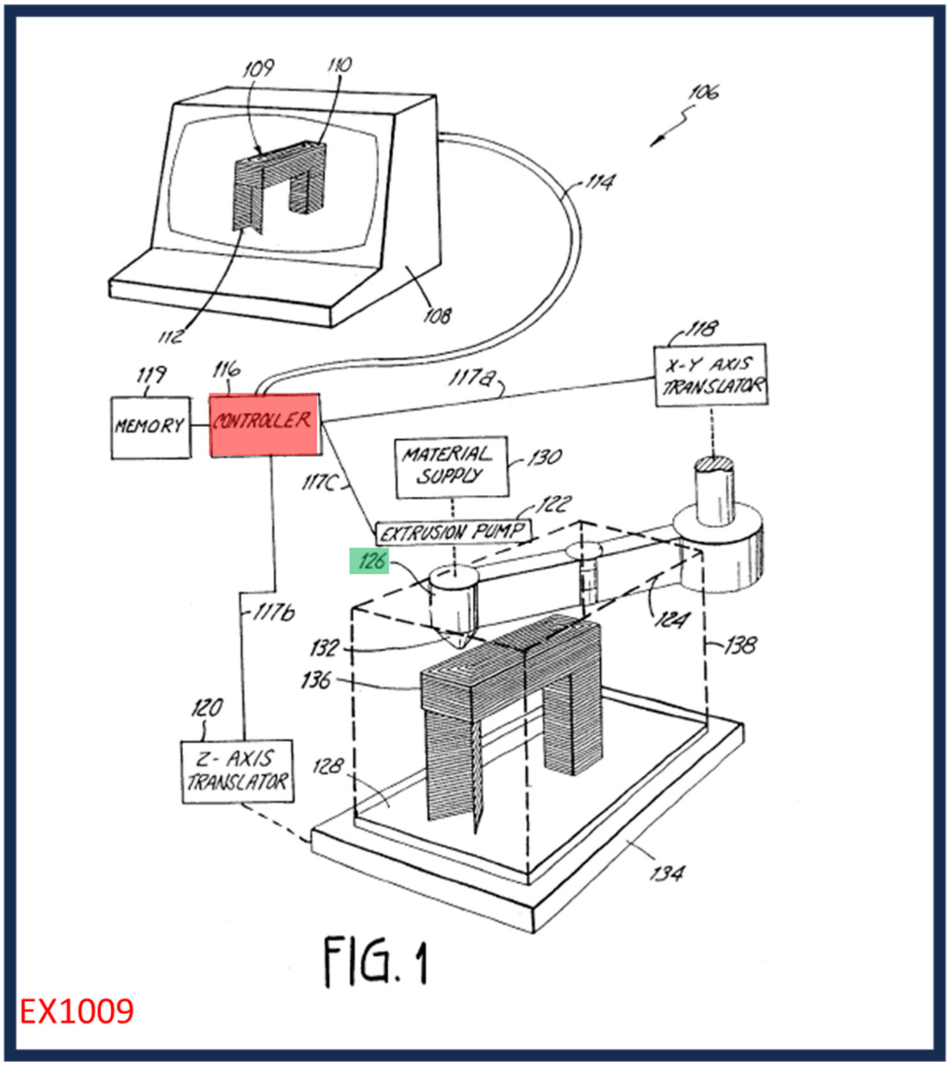
In the context of claim 2, in the Warren-Eshed Combination, a POSITA would have understood or found it obvious that when "[u]pon occurrence of a collision, controller…stops production of the object" the controller would stop the feed of material as part of stopping production. EX1003, ¶¶155-156. Thus, creating a control signal to stop production based on the measured contact force indicating a fabrication error, e.g., collision, provides the claimed ***control signal*** that ***includes a***

***signal…to change a feed rate of build material extruded by the extruder***. *Id.*, ¶¶156-157.

### C. GROUND 2A – Claims 1-5, 7-10, and 12-15 Rendered Obvious by Calderon and RepRap20208

#### 1. Calderon (EX1009)

Like the ’698 patent, Calderon discloses “modeling machines which form three-dimensional objects by depositing modeling material onto a substrate mounted to a modeling platform.” 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 on a substrate supported by a modeling platform." EX1009, 3:1-10.

Calderon teaches using a "sensor assembly…mounted to an extrusion head of an extrusion-based layered modeling system," 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."

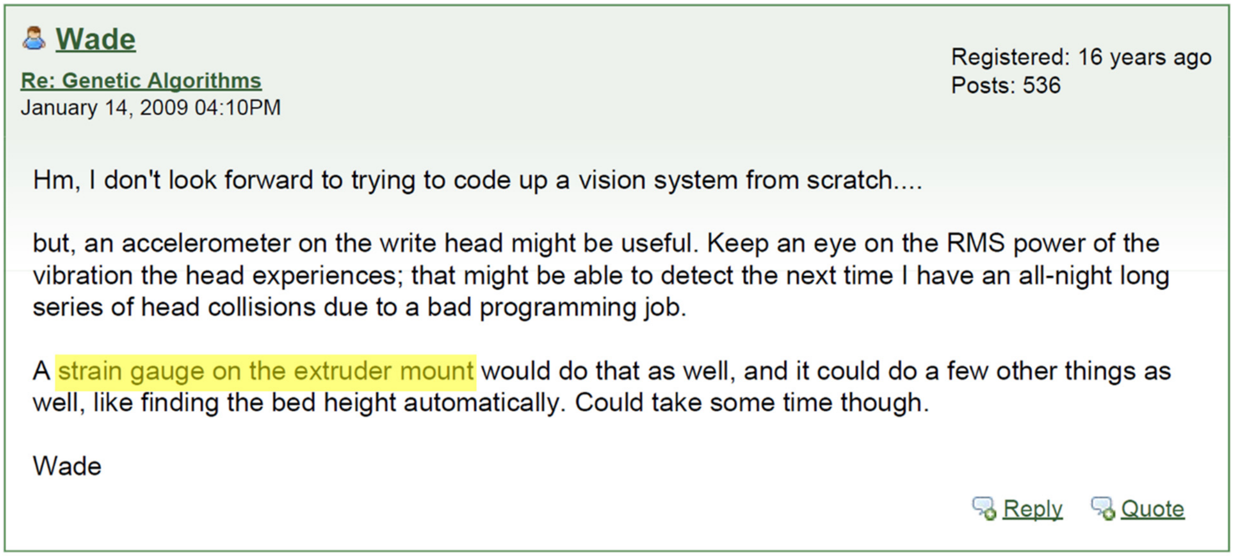
EX1009, 6:62-7:5. Calderon enumerates a long list of conventional sensors including "a magnet proximity switch, a Hall sensor, a Wiegand wire, a reed switch, a capacitive sensor or an inductance sensor." *Id.*, 6:37-47. Calderon also provides a "plunging means" for sensing "force of contact with the 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, ¶¶55-61 (citing EX1001, 9:1-2).

Calderon further teaches applying its Find-Z program that "uses the recorded z-axis positions to calculate a z-start position." EX1009, 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, ¶62.

#### 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, ¶51. RepRap20208 is a discussion thread posted on this on-line public 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." EX1013, 14. Wade later explains "I'd like to measure the important variable - nozzle to bed height - directly." *Id.*, 18-19. And, another developer, freds, 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, ¶¶52-53.

A POSITA would have understood that these RepRap posters were discussing both collision detection and purposefully 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, ¶54. This technique for Z-axis calibration was well known, and similar to the technique described by Calderon years earlier, but reinforced using developers' perspective revealing it is similarly relevant to collision detection during printing. Given the posts were discussing common techniques, 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; & Reasonable Expectation of Success

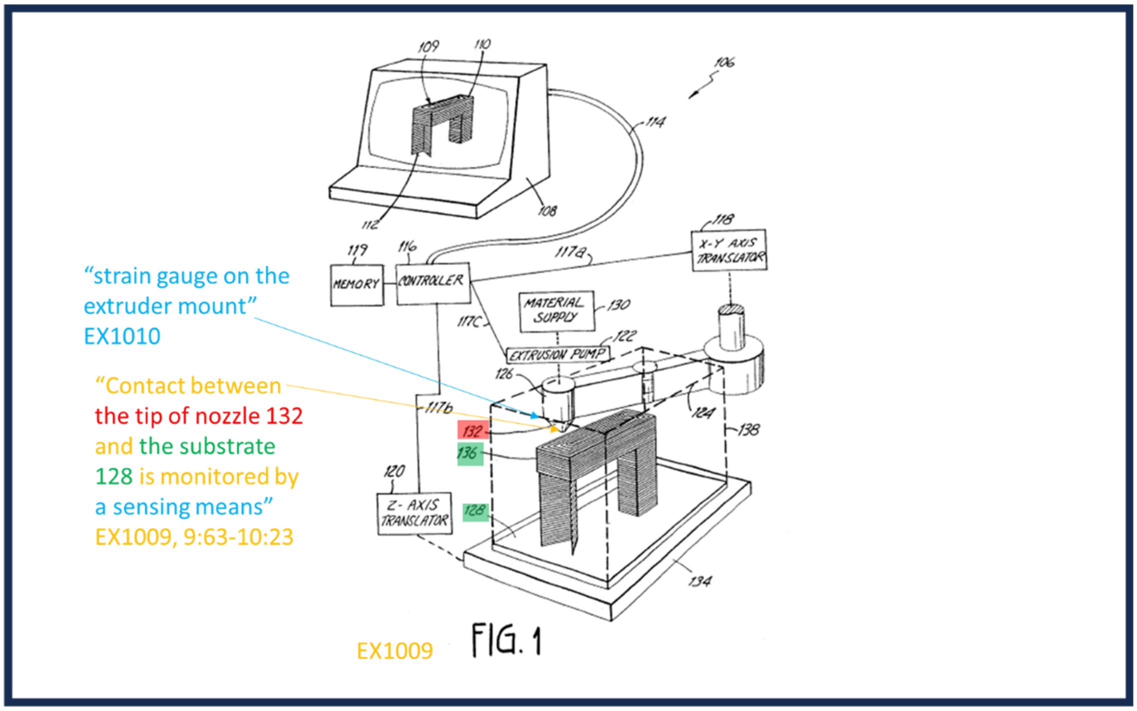
As discussed, Calderon describes auto-initialization of the z-axis of a three-dimensional printer where "the tip of nozzle 132…can be used as a plunging means to find z-axis positions of the platform," where "<u>[c]ontact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means</u> 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, e.g., "[a] <u>strain gauge on the extrusion mount</u>," which can be used "<u>to calibrate the Z-axis</u>" and enable "collision detection." EX1010, 13-14, 19. According to developer Wade on RepRap20208: "I'd <u>have the</u>

machine shut down and flag me if it [a collision] happens, as opposed to breaking something." *Id.*, 19.

In view of the synergistic and complementary disclosures, a POSITA would have been motivated to implement collision detection after initialization, for example, using one or more strain gauges on the extrusion head mount, as suggested by RepRap20208, rather than Calderon's suggestion of "monitoring a change in the servo drive current" to enable collision detection as well as to provide "a sensing means," as called for by Calderon to monitor "contact between the tip of the nozzle 132 and the substrate 128." EX1010, 13-14; EX1009, 9:63-10:23; EX1003, ¶¶158-160. The collision detection in the Calderon-RepRap20208 Combination would follow RepRap20208's suggestion to "have the machine shut down" upon collision to avoid damage to the machine. EX1010, 19; EX1003, ¶160.

A POSITA would have been motivated to apply one or more strain gauges from RepRap20208 to Calderon's three-dimensional printer so that the printer of the Calderon-RepRap20208 Combination is equipped with one or more strain gauges located on the extruder mount, where Calderon's extrusion head 126 mounts to the arm 124, to sense a contact force between nozzle 132, and substrate 128. EX1003, ¶161. The visual aid below demonstrates an exemplary three-dimensional printer embraced by the Calderon-RepRap20208 Combination where the strain gauge example of RepRap20208 is applied to Calderon's "sensing means."[3] *Id.*




Indeed, adding collision detection using strain gauges as described in RepRap20208 to Calderon's three-dimensional printer would have been nothing more than applying proven elements to a system ready for improvement. EX1003, ¶162. The fundamental operations of Calderon's three-dimensional printer would remain intact, bolstered by the known advantages of RepRap's strain gauge based collision detection with a reasonable expectation of success. *Id.*

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

A POSITA also would have found it obvious to implement collision detection using strain gauges on the extruder mount to shut down the 3D printer upon collision detection, as advocated by RepRap20208, to improve operation of the three-dimensional printer of the Calderon-RepRap20208 Combination. EX1003, ¶163.

The following independent reasons, taken separately or collectively, support the Calderon-RepRap20208 Combination. EX1003, ¶164.

First, a POSITA would have been reminded of the benefits collision detection. As explained by developer Wade: "I'd have the machine shut down and flag me if it [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 that "a collision may be, for example, as a result of dispensed layers being too thick and/or inconsistent in thickness, and/or because of a mechanical malfunction of the dispensing head," or "faulty material dispensing that may occur anywhere in the path" of the extrusion head. EX1003, ¶165 (citing EX1005, 18:5-18). A POSITA would have been motivated to shut down the three-dimensional printer upon collision detection to conserve energy, minimize damage, and avoid material waste. EX1003, ¶165.

Second, a POSITA would have been prompted by the express indication that "[c]ollision detection is a nice side affect [sic]" for its strain gauge configuration.

EX1010, 19. A POSITA would have been inspired to use the suggested strain gauges on extruder mount for real-time collision detection after system initialization because the feature would have used the same sensor configuration as initialization without requiring more. EX1003, ¶166.

Third, 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." *Id*. 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, ¶167.

In contrast, the RepRap's approach of using strain gauge on the extruder mount would not suffer the same degree of "slop/backlash," in part because the strain gauges would measure force from a location closer to the nozzle – at the extrusion head mounting – which would alleviate the issue of "slop/backlash" in Calderon's arm, x-y axis translator or its servo drive. EX1003, ¶168.

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 weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate. EX1003, ¶169. A POSITA would appreciate that this manner of identifying contact would not be influenced by slop/backlash, because it is not measuring in force relative to a reaction force affected by slop/backlash. *Id*. A strain gauge on the extrusion mount would allow the weight of the extrusion head to be constantly monitored. *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 without the imprecision caused by slop/backlash. *Id*.

Fourth, 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, ¶170. 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 can measure 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.*

Fifth, 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, ¶171. 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, 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 ’698 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 control the contact force or contact pressure to an amount that would not damage the nozzle on the “rigid substrates” and not to damage “foam substrates.” EX1009, 2:36-53; EX1003, ¶171.

Sixth, strain gauges were commonly used for force measurement of the type described in Calderon long before the ’698 patent. EX1003, ¶172. In fact, the ’698 patent admits that “[s]train gauges are one common sensor used for such [contact force] measurements.” EX1001, 9:1-7. 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, ¶172. 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, ¶173. Strain gauges and the use of strain gauges to sense force were commonplace at the time of the '698 patent in 2012, and had been successfully demonstrated in the real-world by then. *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) and implement collision detection using that same strain gauge. EX1003, ¶¶164-174.

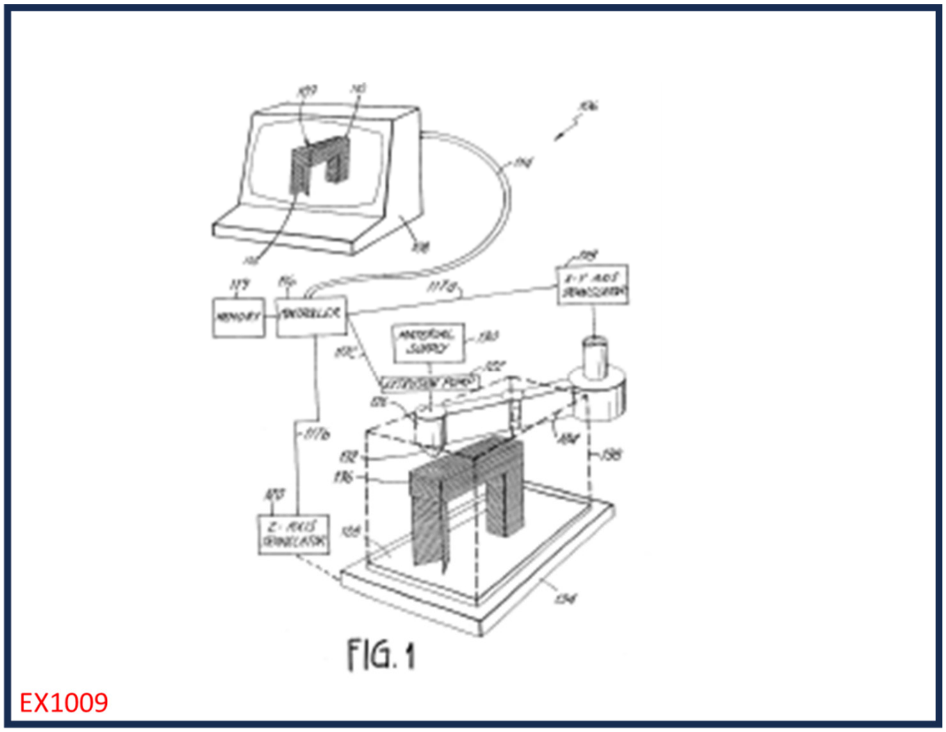
### 4. Claim Element Analysis

***[1.pre]: A method comprising:***

As discussed *supra* §§V.C.1-3, the Calderon-RepRap20208 Combination provides a method for fabricating three-dimensional objects. Calderon teaches "a method" to operate "an additive process computer-controlled three-dimensional modeling machine," (Abstract), in which a "sensor assembly mounted to an extrusion head" is used to sense "the force of contact," EX1009, 5:10-24, 6:16-18 (reference numbers omitted), FIG. 1. RepRap20208 states: "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, 19 ("Collision detection is a nice side affect [sic]" in addition to "extruder height control"). As explained *supra* §V.C.3, the combination method provides "a constant measurement of the force on the head," i.e., both during initialization and during printing. EX1010, 20; EX1003, ¶177.

***[1.a]: identifying build instructions for fabricating an object;***

In the Calderon-RepRap20208 Combination, Calderon teaches ***identifying build instructions*** (e.g., "*a file* describing the geometry of a part 109 to be created," where the file includes "volume elements 110 corresponding to shapes that can be extruded from a nozzle," (EX1009, 4:19-33)) ***for fabricating an object*** (e.g., "build up model 136 layer-by-layer on the substrate 128." *Id.*, 4:53-65, claim 5 ("building an object in the coordinate system of the substrate"), FIG. 1 (below).




Calderon also refers to the file as "*design data* provided from a computer aided design (CAD) system," where "[a] mathematical description of a physical part to be created is split into (usually) planar layers." *Id.*, 1:12-23 ("layered manufacturing"), 1:33-47 ("The extruded material is deposited layer-by-layer in areas *defined from the CAD model*."); §§V.C.1-3; EX1003, ¶¶178-180.

***[1.b]: initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;***

In the Calderon-RepRap20028 Combination, Calderon teaches ***initiating a build*** using "extrusion-based layered modeling system 106," (i.e., ***a three-dimensional printer***), when "[a]n electronic controller 116, in response to receiving three-dimensional shape data …, 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." EX1009, 4:19-21, 34-39.

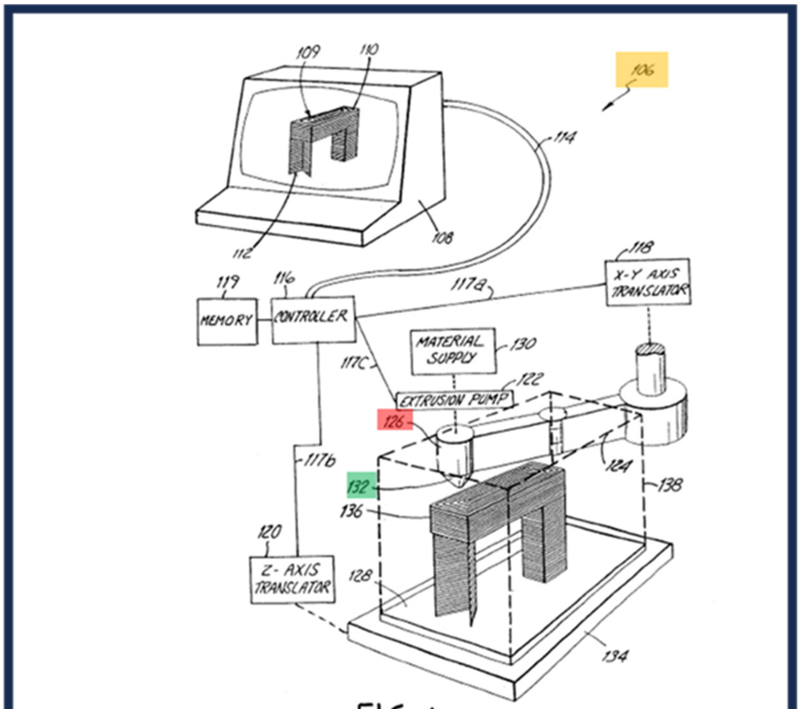


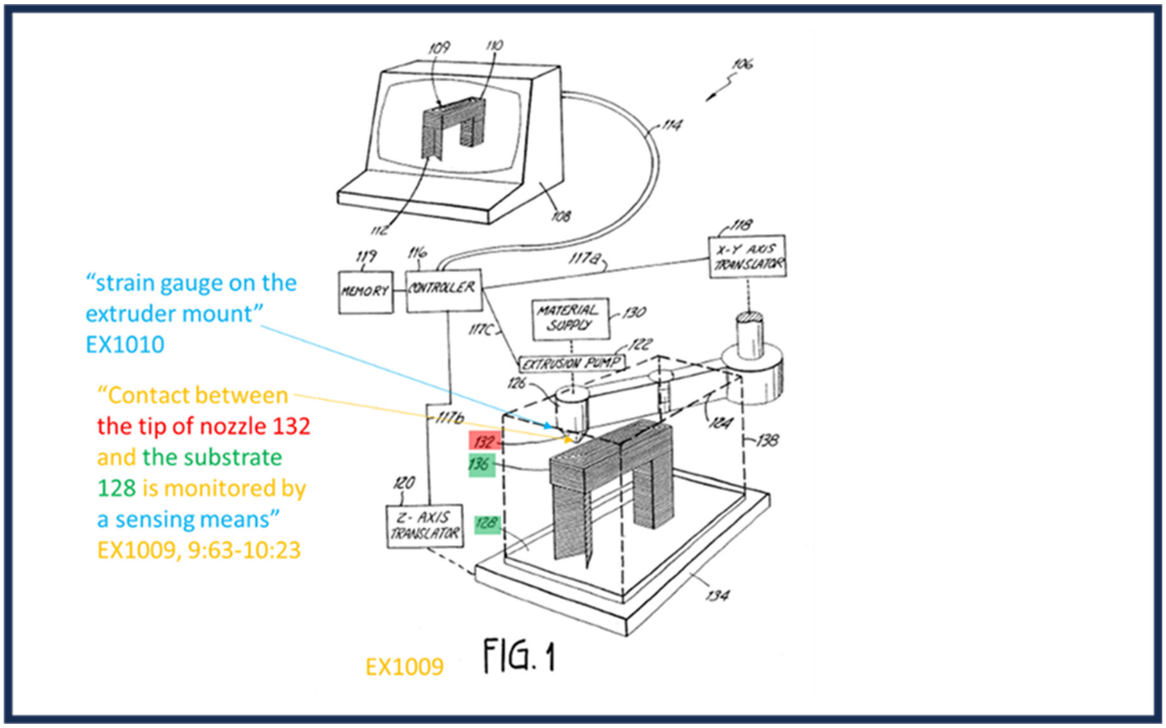
FIG. 1

As depicted in FIG. 1 (above), the "extrusion-based layered modeling system 106" includes ***a fabrication tool***, e.g., "pump 122" and "an extrusion head 126." EX1009, 4:34-5:10 ("The extrusion head 126 terminates in a nozzle 132 through which the modeling material is extruded…onto substrate 128…to build up a model 136 layer-by-layer"). Calderon further teaches a "sensor assembly…mounted to an extrusion head," which can sense "the force of contact of the tip [i.e., part of the

***fabrication tool***] against the substrate." EX1009, 5:10-24, 6:16-18 (reference numbers omitted), 6:37-7:5 (sensor "may be interchanged with any sensing means").

As explained *supra* §V.C.2, RepRap20208 provides one or more strain gauges on the extruder mount which would be ***mechanically coupled to the fabrication tool***, and "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 '698 patent. EX1001, 9:1-7; EX1003, ¶¶181-183.

As explained *supra* §V.C.3, a POSITA would have found it obvious to use the strain gauge example from RepRap20208 (e.g., "strain gauge on the extruder mount" (EX1010, 13)), as Calderon's "sensing means," (EX1009, 6:37-7:5, 9:63-10:23), which corresponds to the ***claimed one or more sensors***. EX1010, 13, 19-20; EX1009, FIG. 1 (below).




As depicted at FIG. 1 (above), the one or more strain gauges of the Calderon-RepRap20208 Combination operate to ***detect the contact force between the fabrication tool and a separate structure***, e.g., the substrate 128 (mounted on modeling platform 134) or the model 136 being built in a layer-by-layer manner. EX1003, ¶¶184-186.

***[1.c]: detecting the current contact force based on a sensor signal from the one or more sensors; and***

As explained *supra* §§V.C.1-3, a POSITA would have found it obvious to use the strain gauge from RepRap20208 in the Calderon-RepRap20208 Combination to "provide a constant measurement of the force on the head," thereby ***detecting the current contact force***. EX1010, 20. Here, a sensor signal from one or more strain gauges of the Calderon-RepRap20208 Combination is provided to not only "measure upwards pressure from a calibration touch," but also to implement collision detection during printing. *Id.*, 13, 19-20; EX1009, FIG. 1; EX1003, ¶¶186-188 (explaining no need to stop force sensing after initialization).

***[1.d]: creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.***

In the Calderon-RepRap20208 Combination, Calderon teaches ***creating a control signal*** (e.g., control signal from controller 116) ***to control at least one component of the three-dimensional printer*** (such as an xy axis translator 118, a z-axis translator 120 and an extrusion pump 122 on the extrusion-based layered modeling system 106). EX1009, 4:34-52, FIG. 1; *supra* §V.C.1.

As explained *supra* §§V.C.1-3, a POSITA would have found it obvious to create the control signal ***in response to the current contact force*** (e.g., detected by the strain gauges on the extruder mount, as taught in RepRap20208) ***while depositing material during the build*** (e.g., to implement real-time collision detection, as suggested by RepRap20208). EX1003, ¶¶189-190.

As explained *supra* §V.C.3, a POSITA would have known that collision detection matters whenever the extrusion head is being moved, including when build material is being deposited during printing. EX1003, ¶¶189-191. In other words, there would be no reason to turn off the strain gauge based collision detection while depositing material. *Id.* Tellingly, the prosecution history makes clear that the Applicant equated "during a build" with "while material is being extruded to fabricate an object." *E.g.*, EX1002, 28-37 (When distinguishing prior art to obtain allowance, Applicant represented that "the presently claimed use of a force sensor, which provides feedback to control print parameters <u>during a build, i.e., while material is being extruded to fabricate an object</u>."); EX1003, ¶¶177-193.

***2. The method of claim 1, wherein the fabrication tool includes an extruder.***

In the Calderon-RepRap20208 Combination, Calderon teaches "[t]he extrusion head 126 terminates in a nozzle 132 through which the modeling material is extruded," which aligns with the claimed "***extruder***." *Compare* EX1009, 4:48-56 *with* EX1001, 2:25-47 ("The extruder 106 may include an extrusion tip 124 or other opening that includes an exit port"); *supra* §V.C.2; EX1003, ¶¶194-195.

***3. The method of claim 2, wherein the at least one component of the three-dimensional printer controls a feed rate for a build material used in the build.***

As explained *supra* §§V.C.1-3, the Calderon-RepRap20208 Combination would "have the machine shut down" upon a collision detection. As stated by developer Wade on RepRap20208: "I'd <u>have the machine shut down</u> and flag me if it [a collision] happens, as opposed to breaking something." EX1010, 19. A POSITA would have recognized or found obvious that shutting the 3D printer down includes stopping the feed of additional build material (i.e., ***controlling a feed rate***

***of build material used in the build***). EX1003, ¶¶196-198. In fact, it was general knowledge in the field of 3D printing to "stop[] production of an object" when "a collision has occurred." *Id.* (citing EX1008, [0180]). To save the machine and avoid material waste, a POSITA would have known, or at least found it obvious, to stop feeding of additional build material by controlling, e.g., "[e]xtrusion pump 122…that provides modeling material from a material supply 130 to extrusion head 126," (EX1009, 4:48-50), and hence ***controlling a feed rate of build material used in the build***. EX1003, ¶¶198-199.

***4. The method of claim 2, wherein the at least one component of the three-dimensional printer controls a z-distance between the extruder and a build platform of the three-dimensional printer.***

The Calderon-RepRap20208 Combination meets claim 4 during printing when a collision is detected. Similar to the analysis under claim 3, the Calderon-RepRap20208 Combination would "have the machine shut down" upon a collision detection. A POSITA would have recognized, or found obvious, that shutting the 3D printer down includes stopping any change the relative z-distance between the dispensing head and the platform to prevent damage. EX1003, ¶¶200-201. Moreover, it was general knowledge in 3D printing to "stop[] production of an object" when "a collision has occurred." *Id.* (citing EX1008, [0180]). Thus, a POSITA would have known, or at least found it obvious, to stop changing any relative distance between the dispensing head and the platform by controlling, e.g., "z-axis translator 120," (EX1009, 4:56-57), and hence ***controlling a z-distance between the extruder and a build platform of the three-dimensional printer*** to save the machine, as suggested by RepRap20208. EX1010, 19; EX1003, ¶¶201-202.

***5. The method of claim 2 further comprising comparing the current contact force to an expected contact force.***

In the Calderon-RepRap20208 Combination, a POSITA would have known, or found it obvious, to introduce a threshold force (***an expected contact force***) that, when exceeded, indicates collision and ***compare the current contact force*** (e.g., obtained based on sensor signals from the strain gauges on the extruder mount, as taught in RepRap20208) to the threshold so a collision event (i.e., "when you run into something") can be detected. *Id.*; EX1003, ¶¶203-205 (explaining ubiquitous use of a trigger condition).

***7. The method of claim 5 further comprising terminating the build when a difference between the current contact force and the expected contact force indicates a fabrication error.***

The Calderon-RepRap20208 Combination meets claim 7 because the three-dimensional printer (e.g., modelling system) of claim 1 would have been shut down (i.e., ***the build is terminated***) ***when a difference between the current contact force and the expected contact force indicates*** (by exceeding the threshold as compared under claim 5) that a collision is occurring (i.e., ***a fabrication error***). EX1003, ¶¶206-208. As stated by developer Wade on RepRap20208: "I'd <u>have the machine</u>

shut down and flag me if it [i.e., a collision] happens, as opposed to breaking something." EX1010, 19. As explained 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, ¶¶207-208 (citing EX1008, [0180]). Thus, a POSITA would have known, or at least found it obvious, to terminate the build once a collision is detected so that energy and material can be saved while additional damages may be prevented. *Id.*

***8. The method of claim 1 wherein the control signal includes a signal to the three-dimensional printer to change a distance between the fabrication tool and the separate structure.***

In the Calderon-RepRap20208 Combination, a POSITA would have known, or found it obvious, to have a threshold force indicative of collision, and compare the current contact force to this threshold to detect a collision event (i.e., "when you run into something"). *Id.*; EX1003, ¶¶209-210 (explaining ubiquitous use of a trigger condition). Such a threshold force in the Calderon-RepRap20208 combination would prevent mistakenly identifying a collision and shutting down the 3D printer in response to things that are not a problematic collision event, such as forces resulting from the extrusion of material, the 3D printer being bumped, and light contact between the extrusion head 126 and separate structure that would not damage the extrusion head, print bed or 3D object. *Id*. When the current contact force is not exceeding the threshold, a POSITA would understand, or find obvious, for the 3D printer to continue to print the 3D object and for such printing to involve ***a signal to the three-dimensional printer to*** continue to ***change a distance between the fabrication tool and the separate structure***. EX1003, ¶210.

Also, the Calderon-RepRap20208 Combination provides a control signal to, e.g., z-axis translator 120, to ***change a z-distance between the fabrication tool*** (including, e.g., extrusion head 126) ***and the separate structure*** (e.g., modeling platform 134 where substrate 128 is mounted) in performing z-axis initialization, after the nozzle has contacted the substrate as taught in Calderon. Or, a POSITA would have found it obvious to ***change a distance between the fabrication tool and the separate structure*** in disengaging the nozzle from the separate structure once a collision is detected during printing, as suggested by RepRap20208. EX1009, 3:1-10, 27-30, 4:56-57, 11:6-11; EX1010, 13, 19-20; *supra* §§V.C.1-3, Element [1.b]; EX1003, ¶¶211-212.

***9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.***

The Calderon-RepRap20208 Combination provides claim 9. As explained under claim 3, Calderon-RepRap20208 Combination shuts the 3D printer down upon collision, and with it the feed of additional build material (i.e., ***controlling a feed rate of build material used in the build***). EX1010, 13, 19-20. Thus, a POSITA would have known, or at least found it obvious, to stop feeding additional build material by sending ***a control signal to***, e.g., "[e]xtrusion pump 126 that provides modeling material from a material supply 130 to extrusion head 126," (EX1009, 4:48-50), and hence ***changing a feed rate of build material extruded by the extruder*** from supplying to not supplying material. EX1003, ¶¶213-215.

***10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.***

As explained *supra* §V.C.1, Calderon teaches z-axis initialization "to determine whether the top surface of substrate is approximately parallel to a horizontal, xy-plane." EX1009. 7:65-8:5 (noting if "substrate top surface does not closely enough approximate a horizontal plane, that result indicates either that the substrate was not mounted flush to platform, or that the substrate has a deformity") (reference numbers omitted). In Calderon's Example 3, Calderon describes "positioning the nozzle above pre-selected location**s** of the substrate" so that "[c]ontact between the tip of nozzle and the substrate is monitored" with a "sensing means" at these "pre-selected location**s**." *Id.*, 9:65-67 (reference numbers omitted). The method of the Calderon-RepRap20208 Combination, thus further includes a multi-point calibration (i.e., ***detecting a planarity of the separate structure*** (such as the substrate) ***based upon a number of contact force measurements across a***

***surface of the separate structure***) that precedes printing as part of the z-axis initialization routine provided by Calderon. EX1003, ¶¶216-219.

***[12.a] The method of claim 1, wherein the build instructions include at least one instruction for achieving a specified contact force between the fabrication tool and a separate structure, and***

As explained *supra* §V.C.1, Calderon provides build instructions for electronic controller 116 to "control[] the extrusion of modeling material in an xyz-coordinate reference frame so that beads of modeling material are extruded layer-by-layer." EX1009, 4:19-52. A POSITA would have known, or found it obvious, to compare the current contact force (e.g., obtained based on sensor signals from the strain gauges on the extruder mount, as taught in RepRap20208) to a threshold indicative of, e.g., "when you run into something." EX1010, 13-14; EX1003, ¶¶220-222 (explaining ubiquitous use of a trigger condition for comparison, as discussed under claims 5, 7, 8).

In this context, a POSTIA would have recognized that the Calderon-RepRap20208 Combination provides ***at least one build instruction for achieving a specified contact force*** (e.g., one that does not exceed the threshold) ***between the fabrication tool and the separate structure***, as already discussed under claim 1. EX1003, ¶223.

***[12.b] wherein the control signal controls the at least one component of the three-dimensional printer to achieve the specified contact force.***

In the context of Element [12.a], a POSITA would have understood that the control signal, as discussed under claim 1, is sent to control ***at least one component of the three-dimensional printer*** (such as "an xy axis translator 118, a z-axis translator 120 and an extrusion pump 122," EX1009, 4:33-52) so that "[c]ontact between the tip of nozzle 132 and the substrate 128" (EX1009, 9:63-10:8) is monitored by "strain gauge on the extruder mount" (EX1010, 13) to achieve the specified contact force that does not exceed the threshold, as explained *supra* §V.C.3 and under claims 5 and 7. EX1003, ¶¶224-225.

***13. The method of claim 1 wherein the one or more sensors include a strain gauge.***

As explained *supra* §§V.C.1-3, the Calderon-RepRap20208 combination applies the "strain gauge on the extruder mount," as suggested by RepRap20208, to Calderon's "sensing means." EX1010, 19-20; EX1009, 9:63-10:23; EX1003, ¶¶226-228.

***14. The method of claim 1 wherein the one or more sensors include a piezoelectric sensor.***

A POSITA would have found it obvious to use one or more piezoelectric strain sensors on the extruder mount of the Calderon-RepRap20208 Combination. As explained by Dr. Wolfe, piezoelectric strain sensors were commonly used to measure mechanical pressure/strain. EX1003, ¶¶229-231 (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 [sic]" in some cases)). A POSITA would have been motivated to employ a piezoelectric strain sensor in the Calderon-RepRap20208 Combination because such sensors were well understood, convenient, and readily available off-the shelf type devices designed for the very purpose of measuring strain and force. EX1003, ¶230 (citing, e.g., EX1020). The predictable inclusion of a piezoelectric 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, ¶230. Supplementing the Calderon-RepRap20208 Combination with a piezoelectric 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.*

***15. The method of claim 1 wherein the one or more sensors include at least one of a capacitive sensor, an optical sensor, an electromechanical sensor, an electromagnetic sensor, and an acoustical sensor.***

As explained by Dr. Wolfe, a strain gauge is an ***electromechanical sensor*** because it was general knowledge to use a strain gauge to convert a mechanical input (e.g., strain) to an electrical readout (e.g., a differential voltage between two parallel voltage dividers on a Wheatstone bridge configuration). EX1003, ¶¶232-233 (citing EX1018 at 302-304, 284-290).

Moreover, the claim's list of "a capacitive sensor, an optical sensor, an electromechanical sensor, an electromagnetic sensor, optical sensors, and an acoustic sensor" encompasses nearly all common types of strain sensors. EX1003, ¶¶234-235. 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).

### D. GROUND 2B – Claim 11 Rendered Obvious by Calderon, RepRap20208, and Napadensky

#### 1. Napadensky (EX1005)

Like the '698 patent, Napadensky teaches three-dimensional printing, also known as "solid freeform fabrication" (or "SFF"), "a technology enabling fabrication of arbitrarily shaped structures directly from computer data via additive formation steps." EX1005, 1:21-29, Abstract. Napadensky describes potential collision with an object on the surface over which build material is being dispensed, "for example, as a result of dispensed layers being too thick and/or inconsistent in thickness, and/or because of a mechanical malfunction of the dispensing head." *Id.*, 18:5-18 ("Collision may also occur as a result of material spill or faulty material dispensing that may occur anywhere in the path of the dispensing head.") To address the collision issue, Napadensky teaches that "the layer thus formed may be straightened by leveling device 32." *Id.*, 18:25-47, 17:56-18:4 ("Leveling device 32 serves to straighten the newly formed layer prior to the formation of the successive layer thereon."). As observed by Dr. Wolfe, Napadensky's leveling process is similar to the description of the '698 patent. EX1003, ¶64 (citing EX1001, FIG. 5, 10:20-27 ("leveling operation [where] dent 502…is filled with build material to form the layer 504")).

#### 2. The Combination; Reasons to Combine; & Reasonable Expectation of Success

In the Calderon-RepRap20208-Napadensky Combination, a POSITA would further incorporate a leveling operation, as suggested by Napadensky, to "straighten the newly formed layer prior to the formation of the successive layer thereon." EX1005, 18:25-47.

A POSITA would have been motivated to pursue the Calderon-RepRap20208-Napadensky Combination because the leveling reduces surface irregularities that could cause collisions (e.g., "dispensed layers being too thick and/or inconsistent in thickness," "material spill or faulty material dispensing"). EX1005, 18:5-18. As explained *supra* (e.g., §V.C.1-3, claim 10), "if the substrate is deformed [and] lacks a horizontal planar surface, the model quality will be adversely affected." EX1009, 2:63-3:1; EX1003, ¶¶236-237.

A POSITA would have a reasonable expectation at the Calderon-RepRap20208-Napadensky Combination because doing so merely involves applying known elements to achieve predictable improvements, namely, reduced surface irregularities to facilitate formation of successive layers. EX1003, ¶238.

### 3. Claim Element Analysis

***11. The method of claim 10 further comprising fabricating a layer on the surface of the separate structure that decreases one or more irregularities in the surface of the separate structure.***

In the context of claims 1, 2, and 10, the Calderon-RepRap20208-Napadensky Combination provides ***fabricating a layer*** (e.g., newly formed layer subject to the leveling operation, as taught in Napadensky) ***on the surface of the separate structure*** (e.g., surface of the platform as provided by Calderon) ***that decreases one or more irregularities in the surface of the separate structure*** (e.g., reduces surface irregularities, as taught in Napadensky). *Supra* §§V.C.1-3 & V.D.1-2; EX1005, 18:25-47, 17:56-18:4; EX1003, ¶¶239-240.

# VI. ANALYSIS ON DISCRETION

## A. 35 U.S.C. §325(d)—*Advanced Bionics*

Although Calderon (EX1009) was cited by the ’698 patent (EX1001, Front Page), it was never discussed on the merits. RepRap20208, which was never considered during prosecution, discloses a sensor configuration, recited by claim 1 that was added during prosecution and believed to be missing from the prior art. *Supra*, §II.B. As demonstrated above, when the strain gauge example of RepRap20208 is combined with the sensing means of Calderon, claim 1 would have been obvious. Additionally, the Warren ground presents additional prior art that 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 a fulsome review here.

## 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 court and the EDTX Markman hearing is scheduled for December 3, 2025, well after institution. EX1024. ***Factor 4*** favors institution as Petitioner has made a stipulation 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 potential overlap of issues between the IPR and parallel 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

’698 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., Tuozhu 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 ’698 Patent. The ’698 patent is the subject of civil action: *Stratasys, Inc. v. Shenzhen Tuozhu 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.

| Lead Counsel | Backup 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 IPR56224-0008IP1@fr.com (referencing No. 56224-0008IP1).

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 13,895 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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