

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN TUOZHU TECHNOLOGY CO., LTD.,

Petitioner

v.

STRATASYS, INC.

Patent Owner.

PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 8,562,324

Case No. IPR2025-00311

DECLARATION OF DR. DENIS R. CORMIER

TABLE OF CONTENTS

I.	Introduction.....	1
A.	Qualifications and Experience	1
B.	Compensation.....	3
C.	Scope of Work and Materials Considered	4
II.	The Challenged Claims of the '324 Patent	5
III.	Level of Ordinary Skill in the Art.....	7
IV.	Legal Standards.....	9
A.	Legal Standard for Claim Construction	9
B.	Legal Standard for Prior Art	13
C.	Legal Standard for Patentability.....	14
1.	Anticipation and Inherency.....	15
2.	Obviousness	15
V.	The '324 Patent and the Challenged Claims.....	20
A.	Summary of the '324 Patent (EX1001).....	20
B.	Summary of the Prosecution History of the '324 Patent (EX1002)	30
VI.	Summary of the Prior Art	33
A.	Overview of Mazumder (EX1004)	34
B.	Overview of Mori (EX1005).....	36
C.	Overview of Tian (EX1006)	45
D.	Overview of Hull (EX1007, translated as EX1008)	46
E.	Overview of Seki (EX1009).....	47
F.	Overview of Waehner (EX1010)	48
G.	Overview of Lan (EX1011)	48
H.	Overview of Anderson (EX1012)	49
I.	Overview of Tay (EX1013)	50
J.	Overview of Henke (EX1014)	53
K.	Overview of Kritchman (EX1015).....	57

VII. Ground 1A: Claims 1, 3, 5-7, 9-10, and 19-22 Would Not Have Been Obvious Over Ground 1A (Combination of Mazumder and Mori)	59
A. Field of Invention of Mori and '324 Patent	59
B. Claim 1	64
C. Claim 5	92
D. Claim 6	98
E. Claim 19	99
VIII. Grounds 1B-1G: Challenged Claims Would Not Have Been Obvious	101
IX. Ground 1C: Claim 8 Would Not Have Been Obvious Over Ground 1C (Combination of Mazumder, Mori, and Hull)	102
X. Ground 2A: Claims 1, 3, 5-7, 9-10, 19-22 Would Not Have Been Obvious Over Ground 2A (Combination of Kritchman, Tay, and Henke).....	107
A. Field of Invention of Henke and '324 Patent.....	108
B. Henke is not reasonably pertinent.....	112
C. Claim 1	114
D. Claims 3 and 5	128
E. Claim 6	130
F. Claim 19	131
XI. Grounds 2B-2G: Challenged Claims Would Not Have Been Obvious	132
XII. Ground 2G: Claim 5 Would Not Have Been Obvious Over Ground 2G (Combination of Kritchman, Tay, Henke, and Anderson)	133
XIII. Ground 2C: Claim 8 Would Not Have Been Obvious Over Ground 2C (Combination of Kritchman, Tay, Henke, and Hull).....	135
XIV. Conclusion	136

EXHIBIT LIST

Exhibit No.	Description
2010	Transcript of Deposition of Dr. Andrew Wolfe
2011	Abdul-Ameer, H. et al., Towards Computer Vision Feedback for Enhanced CNC Machining, IEEE (2011)
2012	U.S. Patent No. 7,168,935 to Taminger et al
2013	Uriarte, O., What Type of CNC Coolant Should I Use? (Oct. 2022), https://web.archive.org/web/20221020050138/https://www.cncmasters.com/cool-down-with-the-right-coolant/

I. INTRODUCTION

1. My name is Denis R. Cormier, and I declare as follows:

2. I am a citizen of the United States and am over 18 years of age. I have personal knowledge of the matters stated in this declaration.

3. I have been asked to provide technical assistance in the *inter partes* review of U.S. Patent No. 8,562,324, which I may abbreviate as “the ’324 Patent” or refer to as the “Challenged Patent.” I understand that this patent is owned by Stratasy, Inc. (“Stratasy”). This declaration is a statement of my opinions on issues related to the patentability of claims of the Challenged Patent.

A. Qualifications and Experience

4. I am the Earl W. Brinkman Endowed Professor of Advanced Machine Tools at the Rochester Institute of Technology (RIT), where I have been since 2009.

5. Prior to joining RIT, I was a faculty member at North Carolina State University for 15 years, from 1994 to 2009.

6. Over the past 30 years, my primary teaching, research, and service focus has been additive manufacturing and three-dimensional printing (3D printing). As part of this work, I have operated dozens of different 3D printers.

7. I earned a Bachelor of Science in Systems Engineering from the University of Pennsylvania in 1989, a Master of Science degree in Industrial

Engineering from State University of New York at Buffalo in 1991, and a Ph.D. in Industrial Engineering from North Carolina State University in 1995.

8. I am an inventor on 10 patents and have published well over 100 papers related to aspects of additive manufacturing and 3D printing.

9. Over the course of my career, I have been the principal investigator for over \$30 million in research grants and contracts related to additive manufacturing and 3D printing. My funding has come from dozens of companies, such as Boeing, General Electric, Xerox, Ford, and Intel, as well as from government agencies such as NASA, the Departments of Defense (Air Force, Navy, Army), and the National Science Foundation.

10. I have received numerous awards over the course of my career. I am the 2024 recipient of the International FAME award that recognizes career achievements in additive manufacturing and 3D printing research and development. I understand that only 17 individuals worldwide have received this prestigious award since its inception in 2009. In 2020, I was named by Smart Manufacturing Magazine on its 20 Most Influential Faculty in Smart Manufacturing list.

11. I frequently speak on topics related to additive manufacturing and 3D printing. I have given invited talks at conferences in France, Canada, Portugal, Germany, England, Ireland, China, Japan, and the U.S. Also, I serve on the Editorial

Advisory Board for two of the most prominent additive manufacturing / 3D printing research journals – *Additive Manufacturing*, and the *Rapid Prototyping Journal*.

12. I have also taught classes in additive manufacturing / 3D printing. Approximately 25 years ago, I was among the first faculty members worldwide to develop and teach a course dedicated to additive manufacturing / 3D printing. Since then, I have developed numerous additional additive manufacturing / 3D printing courses pertaining to topics such as 3D printing of metallic components, and 3D printed medical devices.

13. In addition to teaching additive manufacturing / 3D printing classes, I have taught computer-aided design (CAD) and computer-aided manufacturing (CAM) classes over the past 30 years. My teaching experience with machining processes, including computer numerically controlled (CNC) machining dates to the early 1990s.

14. My academic and professional background and qualifications are further elaborated in my curriculum vitae (Appendix A).

B. Compensation

15. I am being compensated at my normal rate of \$300 per hour for my analysis, plus reimbursement for expenses. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

C. Scope of Work and Materials Considered

16. This declaration is based on my education, personal knowledge, and professional and academic experience in the area of three-dimensional printing.

17. I have been asked to review the Challenged Patent and its prosecution history, to provide an understanding of the technology relevant to the Challenged Patent, to review certain prior-art references, and to analyze whether or not those references disclose or teach limitations of claims from the Challenged Patent.

18. The opinions stated in this declaration are from the perspective of a Person of Skill in the Art (POSITA) as of August 18, 2010, whose qualifications and abilities are described below. I understand that Petitioner and Patent Owner may have a dispute as to whether the claims of the Challenged Patent are entitled to a priority date of at least August 18, 2010. Unless otherwise noted, my opinions expressed in this report remain unchanged regardless of the date used.

19. In forming my opinions, I have reviewed the Challenged Patent, its prosecution history, the materials cited in the List of Exhibits, and the materials cited throughout my declaration. I have also relied on my academic and professional experience in reaching the opinions expressed in this declaration.

II. THE CHALLENGED CLAIMS OF THE '324 PATENT

20. I understand that Petitioner has challenged claims 1, 3-11, and 17-22 of the '324 Patent (the "Challenged Claims"). The Challenged Claims are set forth below, with some claim elements further sub-divided for ease of reference:

Claim Element	Claim Language from '324 Patent
1.pre (preamble)	A device comprising:
1.a	a three-dimensional printer including a build volume;
1.b	a network interface coupled to a data network;
1.c	a video camera positioned to capture video of the build volume from a point of view; and
1.d	a processor configured to receive a three-dimensional model through the network interface, and to control operation of the three-dimensional printer to fabricate the three-dimensional model as an object within the build volume of the three-dimensional printer, the processor further configured to provide a user interface to a remote user accessing the device through the network interface, and to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.
3	The device of claim 1 wherein the two-dimensional projection is simulated based upon operation of the three-dimensional printer.
4	The device of claim 3 wherein the processor is configured to monitor operation of the three-dimensional printer based upon a comparison of the two-dimensional projection with the image of the build volume.

Claim Element	Claim Language from '324 Patent
5	The device of claim 1 wherein the two-dimensional projection is dynamically updated to correspond to a state of physical completion of the object.
6	The device of claim 1 wherein the two-dimensional projection is a video image from the video camera.
7	The device of claim 1 wherein the user interface provides at least one control for manual operation of the three-dimensional printer by the remote user.
8	The device of claim 1 wherein the processor is configured to provide credential-based access to the user interface.
9	The device of claim 1 wherein the user interface provides status information for the three-dimensional printer.
10	The device of claim 1 wherein the user interface provides status information for a build process executing on the three-dimensional printer.
11	The device of claim 1 wherein the user interface displays a two-dimensional tool path for the three-dimensional printer, the two-dimensional tool path corresponding to a current layer of the object during a fabrication of the object by the three-dimensional printer.
17	The device of claim 1 wherein the user interface includes at least one control to capture a stop-motion animation of a fabrication of the object using the video camera.
18	The device of claim 1 wherein the processor is configured to couple the three-dimensional printer in a communicating relationship with a remote print server through the data network.
19.pre (preamble)	19. A method comprising:
19.a	providing a three-dimensional printer including a build volume, a network interface coupled to a data network, and a video camera positioned to capture video of the build volume from a point of view;
19.b	receiving a three-dimensional model through the network interface;

Claim Element	Claim Language from '324 Patent
19.c	fabricating the three-dimensional model as an object within the build volume of the three-dimensional printer; and
19.d	providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.
20	The method of claim 19 further comprising transmitting status information over the data network upon completion of the object.
21	The method of claim 20 wherein the status information includes data presented through the user interface.
22	The method of claim 20 wherein the status information includes a digital image from the video camera.

III. LEVEL OF ORDINARY SKILL IN THE ART

21. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to the Challenged Patent as well as the level of ordinary skill in that art at the time of the claimed invention. The “art” is the field of technology to which the patent is related.

22. I have been instructed by counsel that the person of ordinary skill in the art (“**POSITA**”) is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. I further understand that a person of ordinary skill in the art is determined by looking at (1) the type of problems encountered in the art; (2) the

prior-art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

23. In my opinion, a person of ordinary skill in the art with respect to the '324 Patent is someone with bachelor's degree in Mechanical Engineering, Chemical Engineering, Materials Science, or a comparable field and at least two years of experience related to 3D printing, with additional experience potentially being a substitute for a formal degree or training (and vice versa).

24. I understand that Petitioner and Petitioner's expert, Dr. Wolfe, have proposed a somewhat different level of ordinary skill in the art. Specifically, they assert that a person of ordinary skill in the art "would have had a bachelor's degree in Mechanical Engineering, Computer Engineering, Electrical Engineering, Materials Science, or a comparable field and at least two years of experience related to 3D printers including remote control of rapid fabrication systems." EX1003 (Declaration of Dr. Wolfe), at ¶¶40-42; Petition, at 6. My opinions in this declaration would not change under this proposed level of ordinary skill in the art.

25. As I mentioned, I have degrees in Systems Engineering and Industrial Engineering, which are in a comparable field to Mechanical Engineering, Chemical Engineering, and Materials Science. Among other things, I had been developing

courses for additive manufacturing and 3D printing for many years prior to 2010, and I was listed as an inventor on patents related to 3D printing well before 2010.

26. In rendering my opinions in this declaration, I have viewed the '324 Patent from the perspective of a POSITA under either my definition or Dr. Wolfe's definition. As I discussed above, my education, experience and knowledge, and technical expertise show that I meet the qualifications of a POSITA under either my definition or Dr. Wolfe's definition.

IV. LEGAL STANDARDS

27. I am not a legal expert. In presenting my opinions, I have applied the legal standards provided to me by counsel in arriving at the opinions set forth in this declaration.

28. I understand that in this *inter partes* review proceeding, the Petitioner has the burden of proving that the claims of a Challenged Patent are unpatentable in light of the prior art by a preponderance of the evidence. I understand that a preponderance of the evidence is evidence sufficient to show that a fact is more likely true than not true.

A. Legal Standard for Claim Construction

29. I understand that the first step in determining whether a patent claim would have been anticipated or obvious is to ascertain how a POSITA would have understood the claim terms.

30. I have been instructed by counsel on the law regarding claim construction and patent claims. I understand that a patent may include two types of claims: independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim, or it can further depend from another dependent claim. I understand that a dependent claim includes all the limitations that it recites, as well as all the limitations recited in the claim(s) from which it depends.

31. It is my understanding that in proceedings before the PTAB, the claims of a patent are to be construed under what is referred to as the “*Phillips* standard.” I understand that this means that claim terms of a patent are given the meaning the terms would have to a POSITA, in view of the description provided in the patent itself and the patent’s file history.

32. I understand that to determine how a person of ordinary skill would understand a claim term, one should look to those sources available that show what a person of skill in the art would have understood the disputed claim language to mean. These sources include the words of the claims themselves, the rest of the patent’s description, the prosecution history of the patent (all of which considered “intrinsic” evidence), and “extrinsic” evidence concerning relevant scientific principles, the meaning of technical terms, the technical literature on established and emerging relevant technologies, and the state of the art at the time of the invention.

33. I understand that, in construing a claim term, one looks primarily to the intrinsic evidence, including the words of the claims themselves, the remainder of the patent, and the patent's prosecution history.

34. I understand that extrinsic evidence, which is evidence external to the patent and the prosecution history, may also be useful in interpreting patent claims when the intrinsic evidence itself is insufficient.

35. I understand that words or terms should be given their ordinary and accepted meaning unless it appears that the inventors were using them to mean something else. In making this determination, the claims, the remainder of the patent, and the prosecution history are of principal importance. Additionally, the patent and its prosecution history must be consulted to confirm whether the patentee has acted as its own lexicographer (i.e., provided its own special meaning to any disputed terms), or intentionally disclaimed, disavowed, or surrendered any claim scope.

36. I understand that the claims of a patent define the scope of the rights conferred by the patent. The claims particularly point out and distinctly claim the subject matter which the patentee regards as his invention. Because the patentee is required to define precisely what he claims his invention to be, it is not proper to construe claims in a manner different from the plain import of the terms as used in the patent. Accordingly, a claim construction analysis must begin and remain centered on the claim language itself. Additionally, the context in which a term is

used in the asserted claim can be highly instructive. Likewise, other claims of the patent in question, both challenged and un-challenged, can inform the meaning of a claim term. For example, because claim terms are normally used consistently throughout the patent, the usage of a term in one claim can often illuminate the meaning of the same term in other claims. Differences among claims can also be a useful guide in understanding the meaning of particular claim terms.

37. I understand that a person of ordinary skill in the art is deemed to read a claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the remaining text and figures. For this reason, the words of the claim must be interpreted in view of the entirety of the patent specification (i.e., the claims, remaining text, and figures). The written description (figures and remaining text) is the primary basis for construing the claims and provides a safeguard such that correct constructions closely align with the patent.

38. In addition to consulting the patent itself, I understand that one should also consider the patent's prosecution history. The prosecution history provides evidence of how both the Patent Office and the inventors understood the terms of the patent, particularly in light of what was known in the prior art.

39. I understand that while intrinsic evidence is of primary importance, extrinsic evidence, e.g., all evidence external to the patent and prosecution history,

including expert and inventor testimony, dictionaries, and learned treatises, can also be considered. Extrinsic evidence should not be considered, however, divorced from the context of the intrinsic evidence. Furthermore, while extrinsic evidence can shed useful light on the relevant art, it is less significant than the intrinsic record in determining the legally operative meaning of claim language.

B. Legal Standard for Prior Art

40. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim.

41. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims of the Challenged Patent without undue experimentation. I understand that a patent issued by the United States Patent and Trademark Office is presumed to provide an enabling disclosure. Factors to consider in determining whether undue experimentation is needed are: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims.

42. I understand that for a prior-art reference to be considered for obviousness, the reference must be “analogous.” I understand that the comparison

for purposes of determining “analogous” is between the asserted prior-art reference and the Challenged Patent. I have been further informed that for a prior-art reference to be considered “analogous” to the Challenged Patent and thus available as prior art for obviousness, if (1) the reference is from the same field of endeavor as the Challenged Patent, even if it addresses a different problem; or (2) the reference is reasonably pertinent to the particular problem the Challenged Patent is concerned with, even if it is not within the same field of endeavor.

C. Legal Standard for Patentability

43. I understand that for an invention claimed in a patent to be found patentable, it must be (among other things) new and not obvious based on what was known before the invention was made.

44. I understand that, once the claims of a patent have been properly construed, the second step in determining patentability of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

45. I understand that for purposes of this declaration, there are two ways to demonstrate that a patent claim is not patentable. A patent claim can be anticipated, or a patent claim can be obvious. I address each of these below.

1. Anticipation and Inherency

46. I understand that prior art can “anticipate” the claims of an asserted patent. It is my understanding that in order for a claim to be anticipated by the prior art, every element of that claim must be found, explicitly or inherently, in a single prior art reference. In other words, to determine whether a single prior art reference anticipates a patent claim, one should consider not only what is expressly disclosed in that reference, but also what inherently occurred as a natural result of the practice of the system or method disclosed in that prior art reference.

47. It is further my understanding that to establish such inherency, the missing descriptive matter must be necessarily present in the item of prior art and that it would be so recognized by persons of ordinary skill in the art. It is also my understanding that such inherency may be shown through extrinsic evidence.

2. Obviousness

48. I understand that the prior art may render a patent claim “obvious.” I understand that two or more prior art references (e.g., prior art articles, patents, or publications) that each disclose fewer than all elements of a patent claim may nevertheless be combined to render a patent claim obvious if the combination of the prior art collectively discloses all elements of the claim and one of ordinary skill in the art at the time would have been motivated to combine the prior art in such a way with a reasonable expectation of success.

49. I understand that this motivation to combine need not be explicit in any of the prior art, but it may be inferred from the knowledge of one of ordinary skill in the art at the time the patent was filed. I also understand that one of ordinary skill in the art is not an automaton but is a person having ordinary creativity. I further understand that an obviousness analysis recognizes that market demand often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace. I further understand that one or more prior art references, articles, patents or publications that disclose fewer than all of the elements of a patent claim may render a patent claim obvious if including the missing element would have been obvious to one of skill in the art (e.g., the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system).

50. I understand that a person of ordinary skill in the art provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents a person of ordinary skill from using hindsight in deciding whether a claim is obvious.

51. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the challenged claims, (3) the level of ordinary skill in the pertinent art, and (4) when in evidence, the existence of

secondary considerations (such as commercial success, long-felt but unresolved needs, failure of others, etc.) to the extent they exist and have a nexus to the claimed invention.

52. I am informed that secondary indicia of non-obviousness (also known as secondary considerations) may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success or lack of commercial success of processes covered by the patent; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art; (5) taking of licenses under the patent by others; and (6) deliberate copying of the invention. I also understand that there must be a relationship between any such secondary indicia and the invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination. I also understand that secondary considerations are given less weight when the alleged invention represents a relatively small advance in a crowded field with predictable results. I further understand that the patentee has the burden of coming forward with evidence of the relationship between any secondary consideration of non-obviousness and the claimed invention (also known as the “nexus”).

53. It is also my understanding that there are additional considerations that may be used as further guidance as to when the above factors will result in a finding that a claim is obvious, including the following:

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;
- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;
- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims; and
- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

54. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

55. I further understand that a claim may be deemed invalid for obviousness in light of a single prior art reference, without the need to combine references, if the elements of the claim that are not found in the reference can be supplied by the knowledge or common sense of one of ordinary skill in the relevant art.

56. I also understand that practical and common-sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I further understand that a person of ordinary skill in the art looking to overcome a problem will often be able to fit the teachings of multiple publications together like pieces of a puzzle, although the prior art need not be like two puzzle pieces that must fit perfectly together. I understand that an obviousness analysis therefore considers the inferences and creative steps that a person of ordinary skill in the art would employ under the circumstances.

57. I understand that a person of ordinary skill could have combined two pieces of prior art or substituted one prior art element for another if the substitution can be made with predictable results, even if the swapped-in element is different from the swapped-out element. I understand that the relevant question is whether prior art techniques are interoperable with respect to one another, such that a person of skill would view them as a design choice, or whether a person of skill could apply prior art techniques into a new combined system.

58. In sum, my understanding is that prior art teachings are properly combined where a person of ordinary skill in the art having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

V. THE '324 PATENT AND THE CHALLENGED CLAIMS

A. Summary of the '324 Patent (EX1001)

59. I have reviewed the '324 Patent, which “relates to three-dimensional fabrication using networked resources.” EX1001 at 1:14-15. As the '324 Patent explains, “a more recent trend has emerged toward low-cost three-dimensional prototyping devices suitable for hobbyists and home users. As these resources become more readily and widely available, a need has emerged for networking capabilities and network management for three-dimensional printers.” *Id.* at 1:20-28. “Web-based servers or the like can provide a single point of access for remote users to manage access to distributed content on one hand, and to manage use of distributed fabrication resources on the other.” *Id.* at Abstract; *see also id.* at 1:35-38.

printer.

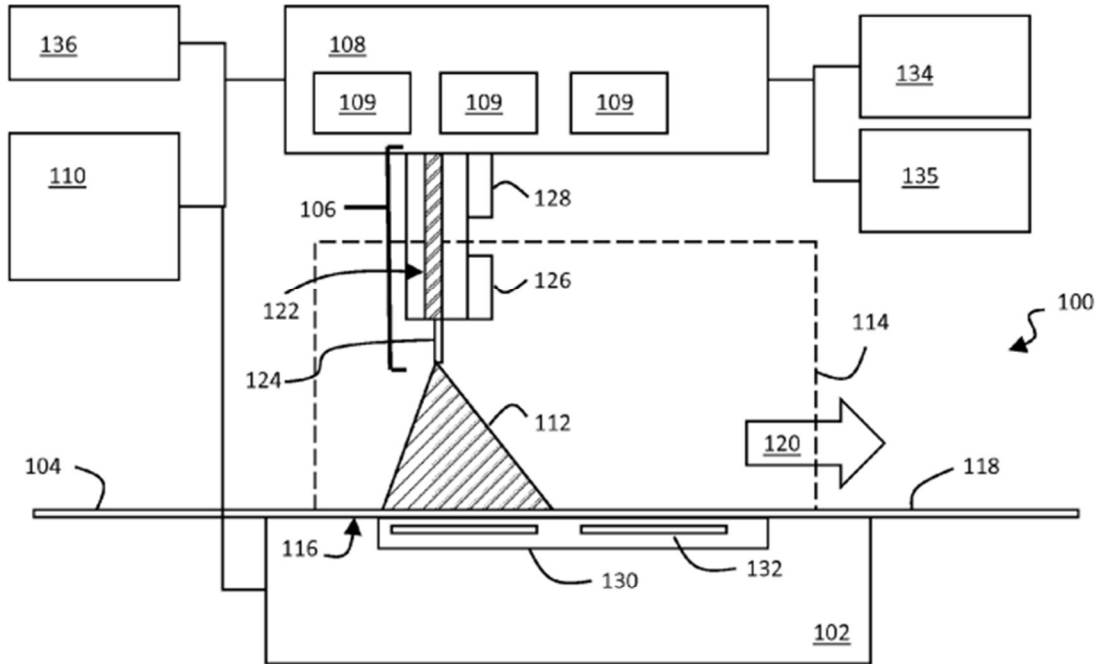


Fig. 1

EX1001, at Fig. 1, 1:48. As shown, the printer (100) includes an extruder (106) that deposits material to form object 112 within the working volume 114. *See id.* at 2:17-21. The printer also includes one or more sensors 134, which can, for example, include a video camera to “capture images” of the working volume 114 and object 112. *Id.* at 6:21-24; *see also id.* at 18:33-36 (The “sensors may include a video camera directed toward a working volume of the three-dimensional printer.”). As the ’324 Patent explains, the “video camera may provide a remote video feed through

the network interface 136.” *Id.* at 6:24-30; *see also id.* at 6:30-33. This enables “video monitoring” by a user of the printer. *Id.* at 14:63-15:5.

61. Figure 3 of the ’324 Patent shows “a networking three-dimensional printing environment.” EX1001 at 1:51-52.

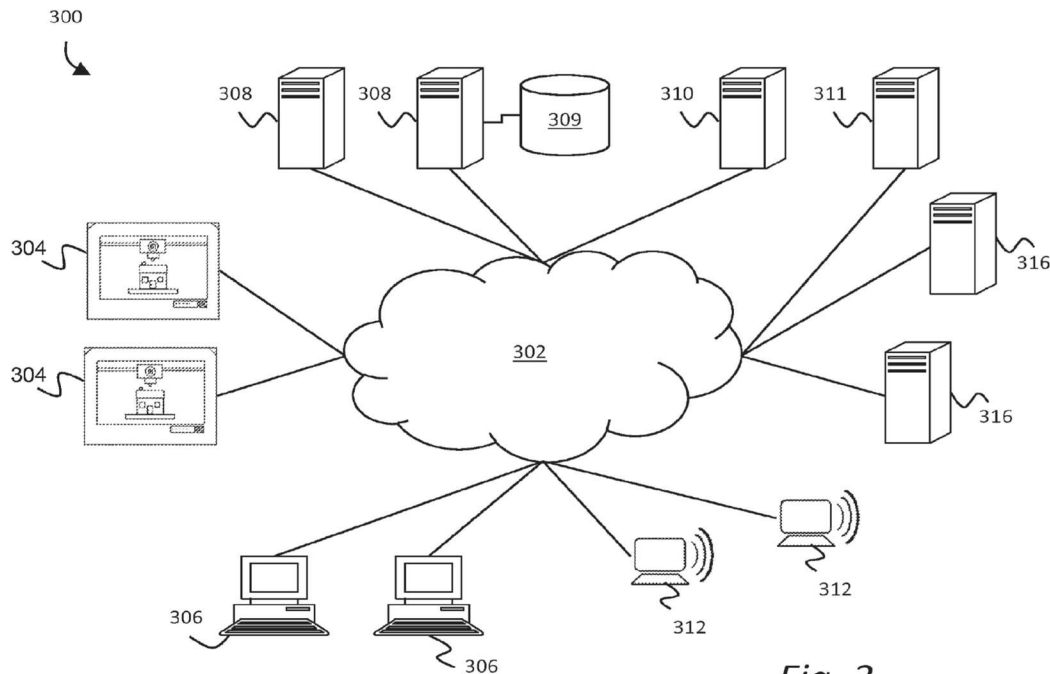


Fig. 3

Id. at Fig. 3. As shown, the environment (300) includes a data network (302) interconnecting multiple devices, including three-dimensional printers (304), client devices (306), print servers (308), content sources (310), mobile devices (312), and other resources (316). *Id.* at 8:12-15, 12:28-39, Fig. 3. According to the ’324 Patent, client devices are “operated by users to initiate and monitor print jobs at the three-dimensional printers 304.” *Id.* at 8:49-51. The ’324 Patent also describes mobile devices in a similar manner, disclosing that mobile devices 312 “may be operated

by users for a variety of user-oriented functions such as . . . to submit objects for printing, to monitor a personally owned printer, and/or to monitor a pending print job.” *Id.* at 12:47-51.

62. Figure 5 of the ’324 shows a user interface for networked three-dimensional printing.

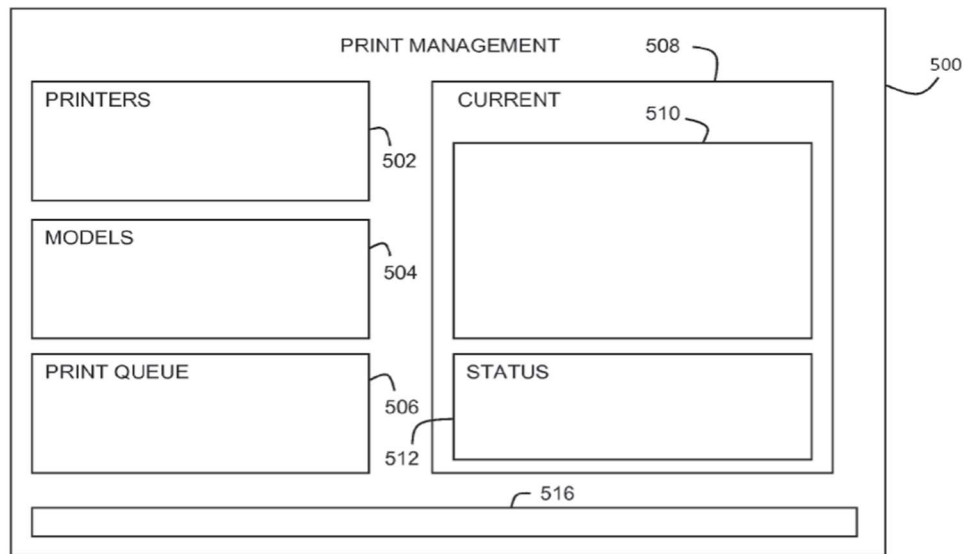


Fig. 5

Id. at Fig. 5, 21:18-19. As shown, the user interface includes four display areas: printers 502, models 504, print queue 506, and display area 508, as well as a menu bar 516.

63. A “first display area 502 that shows a list of available online three-dimensional printers or other fabrication resources.” EX1001, at 21:40-42. “This display area may be interactive, and may permit, e.g., sorting of fabrication resources, searching for new fabrication resources, and the like.” *Id.* at 21:42-45.

“The first display area 502 may also or instead provide status information for each listed fabrication resource, such as information about availability, recent print activity, a current queue of objects for printing at that resource, and so forth.” *Id.* at 21:45-49.

64. A “a second display area 504 that shows a list of available models for fabrication by the fabrication resources.” *Id.* at 21:54-56. “This may include any of a variety of interactive features such as search capabilities for models, and links to information about models such as cost, user reviews, complexity and print time, model renderings, descriptions, notes from a content provider, and so forth.” *Id.* at 21:56-60.

65. A “third display area 506 that shows a print queue.” EX1001, at 22:11-12. “This may include a local print queue for a specific fabrication resource, or this may include a print queue stored at a print server for a user, along with information about where and when each object is scheduled for fabrication.” *Id.* at 22:12-16.

66. A “a fourth display area 508 that displays information for a currently active print job.” EX1001, at 22:30-31. “This area may usefully include any information related to the print job such as status, time to completion, source, current time, etc. Additionally, this area may include a control or group of controls for manual operation of the three-dimensional printer by a remote user. Thus for example a user may remotely stop fabrication, restart fabrication, cancel fabrication,

change fabrication settings, perform a test extrusion, and so forth, as though the user were locally controlling the printer.” *Id.* at 22:32-40.

67. The ’324 Patent also explains that the fourth display area (506) “may include a visualization area 510 that displays a visual representation of the print job.” *Id.* at 22:41-42. “For example, the visualization area 510 may display a current tool path of the printer that is executing the print job, such as a two-dimensional layer of the object showing a path of a print head as it traverses that layer.” *Id.* at 22:43-46. “The visualization area 510 may also or instead show a simulated print object, such as a rendering of a three-dimensional model depicting a current state of the completion of an object being fabricated according to a print job.” *Id.* at 22:46-50. “The visualization area 510 may also or instead show an image of a working volume of a three-dimensional printer or other fabrication resource captured during execution of the print job.” *Id.* at 22:50-53. “This may, for example, include a digital still image (which may be updated periodically) or a video image captured from a video camera at the three-dimensional printer.” *Id.* at 22:53-55. “Thus a user may visually monitor progress or status of a remote print job through the user interface 500.” *Id.* at 22:56-57. Besides visualization area 510, the area can include a status area 512, which “may also be provided that shows current status information (e.g., percentage completion, time until start, time until completion, and so forth) for the active resource.” *Id.* at 22:57-60.

68. Further, “user interface 500 may also include a menu bar 516 or the like for other functions not otherwise accounted for within the other active areas.” *Id.* at 22:61-63.

69. The '324 Patent also explains that, for example, “the user interface may include at least one control to capture a frame of data from the video camera as a video image and to transmit the video image to a remote location through the data network.” *Id.* at 22:66-23:2.

70. Figure 7 of the '324 shows “a flowchart of a method for operating a three-dimensional printer with a video camera and a network interface.”

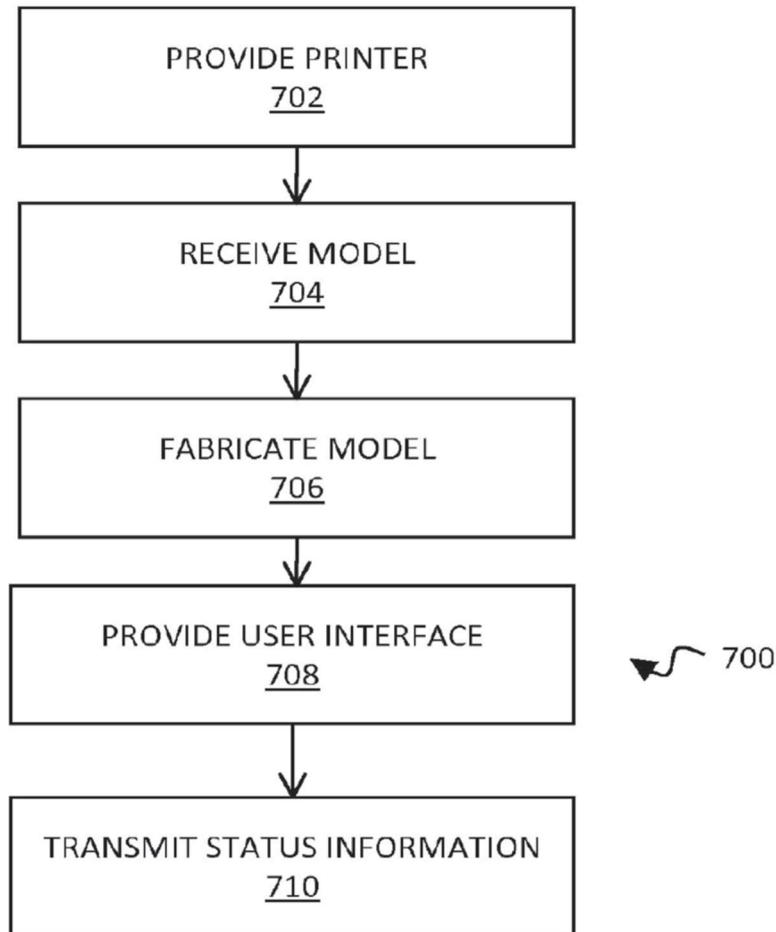


Fig. 7

Id. at Fig. 7, 24:24-26. “In particular, the method 700 of FIG. 7 emphasizes incorporation of data from the video camera into operation and management of the three-dimensional printer.” *Id.* at 24:26-28.

71. “As shown in step 702, the method 700 may begin with providing a three-dimensional printer including a build volume, a network interface coupled to a data network, and a video camera positioned to capture video of the build volume

from a point of view, such as from above or in front a side of the build volume.” *Id.* at 24:29-34. “As shown in step 704, the method 700 may include receiving a three-dimensional model through the network interface using, e.g., any of the techniques for locating and retrieving models as described above.” *Id.* at 24:36-39. “By way of example, this may include direct access to a content source, syndicated access to a feed of content, and/or use of a print server or other remote print management tool.” *Id.* at 24:39-42. “As shown in step 706, the method 700 may include fabricating the three-dimensional model as an object within the build volume of the three-dimensional printer, all as generally contemplated above.” *Id.* at 24:43-46.

72. “As shown in step 708, the method 700 may include providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build volume from the camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* at 24:47-52. The ’324 Patent explains that the “two-dimensional projection may be any suitable rendering, simulation, or other visualization of the model and its current state of completion.” *Id.* at 24:58-61. “Thus for example the two-dimensional projection may be obtained from a three-dimensional scanner or other data acquisition device coupled to a processor of the three-dimensional printer.” *Id.* at 24:61-64. The ’324 Patent also explains that the “two-dimensional projection may be an image of the object as simulated based upon

operation of the three-dimensional printer, using, e.g., a tool path history or a current state of completion.” *Id.* at 24:64-67. In addition, the “two-dimensional projection may be dynamically updated to correspond to a state of physical completion of the object in order to provide real time, or quasi-real time visual status information. In one aspect, the two-dimensional projection may simply be a video image from the video camera.” *Id.* at 24:67-25:5.

73. “As shown in step 710, the method 700 may include transmitting status information over the data network upon completion of the object.” EX1001, at 25:6-8. “This may, for example, include data presented through the user interface, or any other status information or summary thereof. For example, the status information may include a digital image from the video camera, which may be transmitted with an electronic mail communication confirming completion of the object.” *Id.* at 25:8-13.

74. The ’324 Patent also explains that by “comparing actual to expected two-dimensional or three-dimensional results, a fabrication process can be expeditiously aborted and restarted or otherwise addressed without waiting for completion and physical inspection of the constructed object.” *Id.* at 25:45-49. For example, the “processor may be configured to monitor operation of the three-dimensional printer based upon a comparison of the two-dimensional projection with the image of the build volume.” *Id.* at 25:35-38. The ’324 Patent explains that using

“this type of image analysis, it may be possible to track actual progress against predicted progress to identify equipment malfunctions or other interference that might cause the physical object to deviate from the model used to fabricate the physical object.” *Id.* at 25:38-42. “For example, a temperature change in an extruder, an air bubble in a path of melted supply material, or a tool misstep might cause an unrecoverable error in a fabrication process.” *Id.* at 25:42-45. In addition, the ’324 Patent explains that “the processor may be configured to provide credential-based access to a user interface of the three-dimensional printer.” *Id.*, at 25:60-62.

B. Summary of the Prosecution History of the ’324 Patent (EX1002)

75. I reviewed the prosecution history of the ’324 Patent (EX1002). During prosecution, I understand that the examiner rejected pending claims 1-23 as anticipated by or obvious over U.S. Patent No. 7,168,935 to Taminger et al, alone or in combination with additional references. EX1002, 93, 96-97; *see also id.* at 91-100 (Office Action); EX2012 (Taminger).

76. I understand that the applicant filed a response to the office action. In the applicant’s response, the applicant explained that it “has devised a personal manufacturing device, e.g., a three-dimensional printer, configured for use as a remote network resource.” EX1002 at 160. The applicant also explained that in “addition to receiving a model through a network interface and controlling the printer to fabricate a model, a processor provides a user interface that shows both a

video of an object being manufactured and a three-dimensional model of the object.”

Id. “Further, in order for a remote user to monitor progress of fabrication in a meaningful way, the three-dimensional model is rendered in the user interface from the perspective of the video camera that provides the image, thus advantageously permitting side-by-side comparison by a remote user of the model and the resulting object.” *Id.* The applicant concluded the paragraph by saying that this “feature is expressly claimed as a processor configured to ‘present in the user interface an image of the build volume from the camera *and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.*’” *Id.* (emphasis added by the applicant).

77. In the following paragraph, the applicant further asserted that “*Taminger* does not teach or suggest any processor that provides an interface to a remote user that includes both an image from a camera *and a two-dimensional rendering of a model from the point of view of the camera.*” *Id.* According to the applicant, the “outstanding rejection refers generally to col. 11, l. 20 - col. 12, l. 10 of *Taminger* as disclosing this feature, however, this passage of *Taminger* provides no specific teaching of such a user interface, and no suggestion that such a feature is useful, or any more general suggestion that visual rendering of a two-dimensional digital model might improve the disclosed devices.” *Id.*; *see also* EX2012, 11:20-12:10.

78. The applicant expanded on its argument continuing on the next page.

The applicant acknowledged that “*Taminger* discloses various instrumentation subsystems such as lighting systems, networking system, a camera, and a variety of sensors.” *Id.* at 160-61 (citing to *Taminger* (EX2012), at 11:20-27, 11:37-48). The applicant also acknowledged that “*Taminger* appears to further contemplate that such systems and others may in general be interconnected through a network, and that a user interface may be provided for user control.” *See id.* at 161. The applicant also quoted *Taminger* regarding a “computer user interface.” *Id.* (citing *Taminger* (EX2012), 12:3-7). Accordingly, the applicant concluded that, at best, “*Taminger* thus suggests remote control and monitoring of a three-dimensional fabrication process; however, there is nothing in this general suggestion that specifically leads to the applicant’s claimed user interface, which provides both video and model views *from the same point of view* in order to permit side-by-side comparison of model and results by a remote user.” *Id.* On this basis, the applicant concluded that *Taminger* cannot anticipate the invention of claim 1. *Id.*

79. Thereafter, I understand that the examiner allowed the claims. In the Notice of Allowability, the examiner provided its reasons for allowance. *Id.* at 174. First, the examiner stated that “the applicant argued that the closest prior art reference by *Taminger*” does not teach the limitation of “presenting the user interface an image of the build volume from the video camera and a two-dimensional

projection of the three-dimensional model from the point of view of the video camera.” *Id.* Second, the examiner referred to the applicant’s argument on “page 7, lines 7 – 24.” *Id.* I understand that the applicant’s arguments that I discussed earlier started on page 7 and concluded on page 8. *See id.* at 160-61. Those arguments included applicant’s argument that the invention permits “side-by-side comparison by a remote user of the model and the resulting object” by expressly claiming to “present in the user interface an image of the build volume from the camera *and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.*” *Id.* at 160.

VI. SUMMARY OF THE PRIOR ART

80. I have reviewed the references listed below, which I understand Petitioner has cited in support of Grounds 1A-2G of their Petition:

Ground	Claims	References Cited
1A	1, 3, 5-7, 9-10, and 19-22	Mazumder (USP 6,580,959; EX1004) in view of Mori (US 2010/0063615; EX1005)
1B	4	Mazumder and Mori in further view of Tian (US 2009/0015668; EX1006)
1C	8	Mazumder and Mori in further view of Hull (JP2000218708; EX1007, translated in EX1008)
1D	11	Mazumder and Mori in further view of Seki (USP 5,278,479; EX1009)
1E	17	Mazumder and Mori in further view of Waechner (US 2006/0171452; EX1010)
1F	18	Mazumder and Mori in further view of Lan (EX1011)

Ground	Claims	References Cited
1G	20-22	Mazumder and Mori in further view of Anderson (US 2004/0207662; EX2012)
2A	1, 3, 5-7, 9-10, and 19-22	Kritchman (US 2006/0054039; EX1015) in view of Tay (EX1013) and Henke (EX1014)
2B	4	Kritchman, Tay, and Henke in further view of Tian (EX1006)
2C	8	Kritchman, Tay, and Henke in further view of Hull (EX1007, translated in EX1008)
2D	11	Kritchman, Tay, and Henke in further view of Seki (EX1009)
2E	17	Kritchman, Tay, and Henke in further view of Wachner (EX1010)
2F	18	Kritchman, Tay, and Henke in further view of Lan (EX1011)
2G	3, 5, 9-10, 20-22	Kritchman, Tay, and Henke in further view of Anderson (EX1012)

A. Overview of Mazumder (EX1004)

81. Mazumder discloses a “System and Method for Remote Direct Material Deposition Fabrication.” EX1004 at Abstract, Title. Figure 1 of Mazumder is shown below.

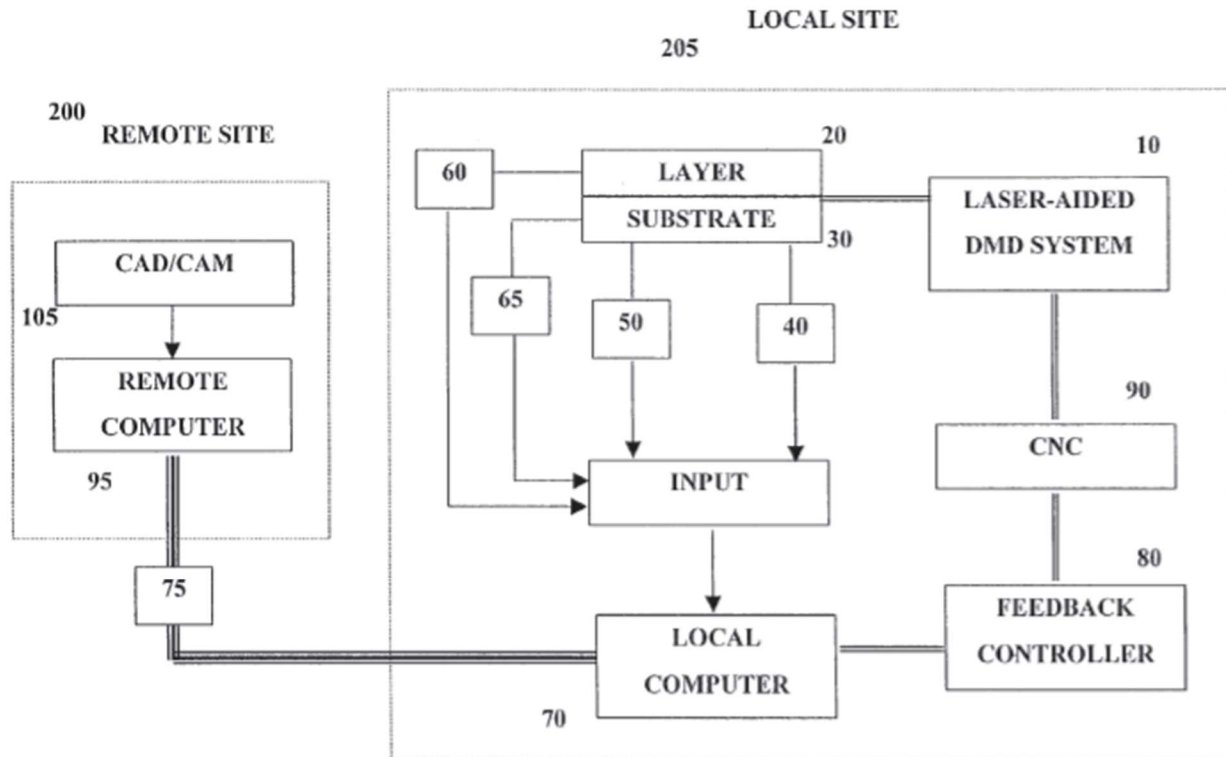
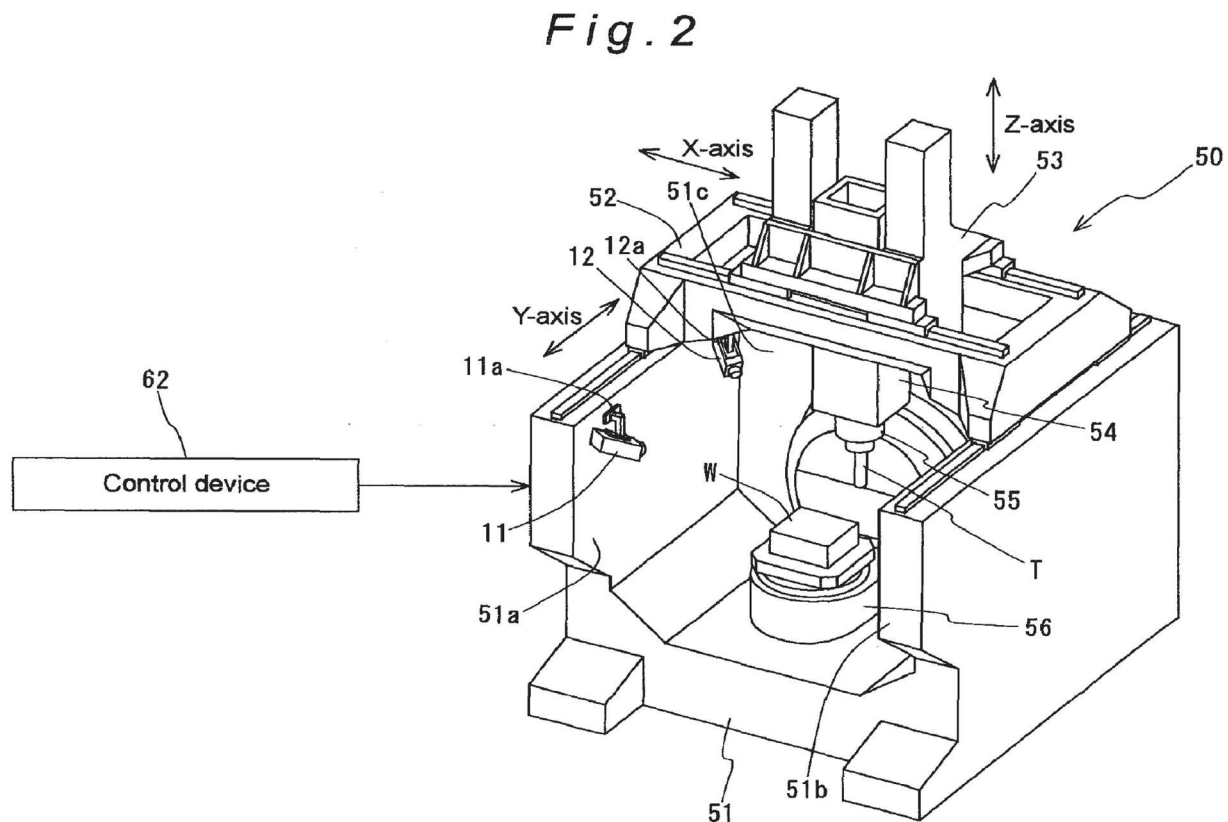


FIG - 1

Id. at Fig. 1. Mazumder’s “fabrication process is recorded by video or television camera and the shown in real-time on a screen display connected to the remote computer.” *Id.* at Abstract. The “video or TV camera 65 records the laser-aided DMD process and transmits the images to the local computer 70” which then sends the images “to the remote computer 95 to be displayed preferably on a TV screen or shown on the remote computer monitor as streaming video.” *Id.* at 6:36-43. The remote computer has “two monitors, one with a graphical user interface and the other for image and video observation of the laser-aided direct material deposition process.” EX1004, 2:27-33.

B. Overview of Mori (EX1005)

82. Mori is entitled “Machining Status Monitoring Method and Machining Status Monitoring Apparatus. EX1005 at Title. Figure 2 of Mori is “a perspective view showing a schematic configuration of a machine tool provided with the machining status monitoring apparatus of the embodiment.” *Id.* at ¶[0031].



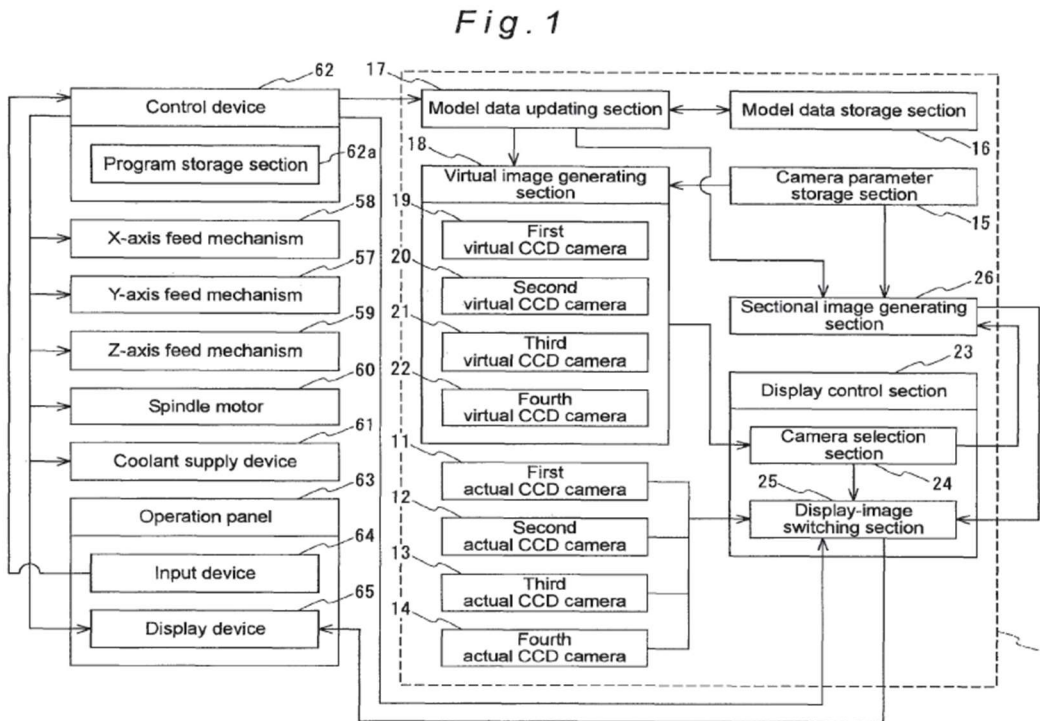
Id. at Fig. 2. The machining tool 50 includes a machining status monitoring apparatus called a machining center. *Id.* at ¶[0043]. As shown, the machining tool (50) includes a tool (T) to machine a workpiece (W) on a table (56). *Id.* at Fig. 2.

83. Mori has two different disclosures of its machine status monitoring apparatus and method. The first apparatus/method is described in Mori's Abstract and Summary of the Invention. In particular, Mori describes selecting virtual cameras using virtual image data where the tool is not hidden from a workpiece and displaying the actual image data from actual CCD cameras corresponding to the selected virtual cameras. *See id.* at Abstract; *see also id.* at [0004]-[0029] (Summary of Invention). Mori explains that if the "tool is hidden by the workpiece in all of the actual" images and "the operator cannot monitor the machining status of a workpiece," Mori's solution will generate and display sectional image data rather than actual image data. *Id.* at [0024]; *see also id.* at [0023] ("displays on the display means the sectional image data . . . when determining that the distal end of the tool is hidden"), [0025]-[0028].

84. The second apparatus/method that Mori describes is disclosed in the section "Description of Embodiment" and the corresponding figures (Figures 1-12). Compared to Mori's first apparatus/method, Mori's second apparatus/method adds the ability to switch to displaying virtual image data when coolant is being supplied. *See, e.g., id.* at [0087] ("Further, since the operator can visually recognize the machining status of the workpiece W through the virtual image when coolant is being supplied to the contact portion of the tool T and the workpiece W, and through

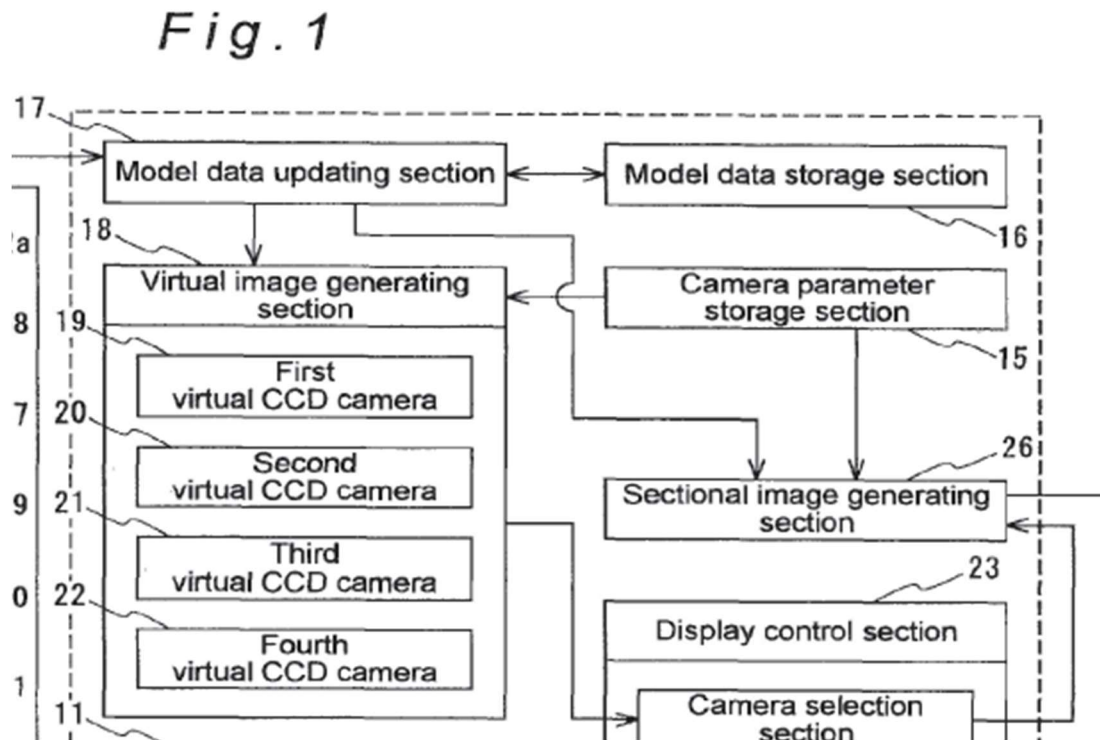
the actual image when coolant is not being supplied, the operator can monitor the machining status of the workpiece W even when coolant is being supplied.”).

85. Figure 1 of Mori provides a block diagram of Mori’s machining status monitoring apparatus (1). *Id.* at [0030].



Id. at Fig. 1. As shown, Mori discloses four actual cameras (11-14) and four virtual cameras (19-22 in virtual image generating section 18) that each correspond to one of the actual cameras arranged at the same position. *Id.* at Fig. 1, [0062]. Mori also discloses several sections: camera parameter storage section (15), model data storage and updating sections (16 and 17), virtual image generating section (18), sectional image generating section (26), and display control section (23). *Id.* at Fig. 1.

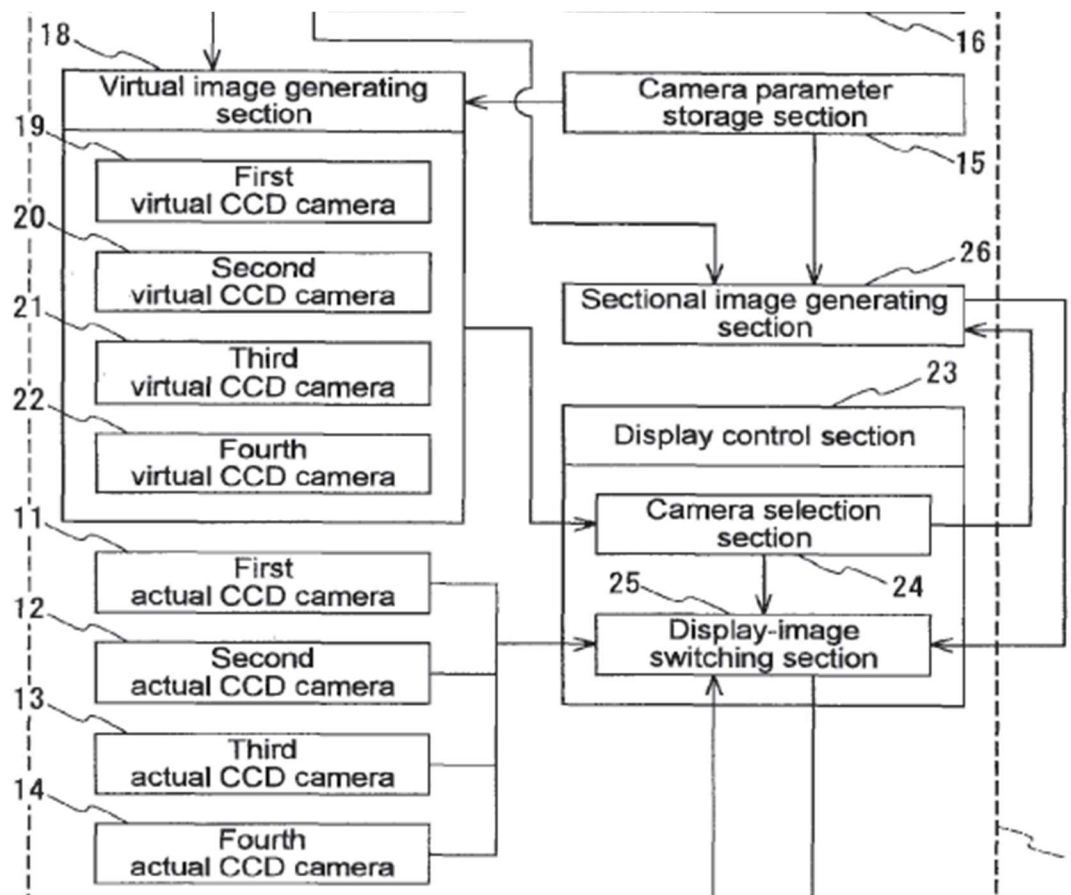
86. As shown by the excerpt to Figure 1 below, both the camera parameter storage section (15) and model data updating section (17) provide inputs to virtual image generating section (18) and sectional image generating section (26).



Id. at Fig. 1 (excerpt). The camera parameter storage section (15) stores parameters of each actual camera, such as “a principal point coordinate, a scale factor, skewness of the two image axes and the like.” *Id.* at [0051]. The model data updating section (17) “updates the model data of the entire machine tool 50 stored in the model data storage section 16” including data for the bed (51), first saddle (52), second saddle (53), spindle head (54), spindle (55), table (56), tool (T), and workpiece (W). *Id.* at [0052]-[0054]; *see also id.* at Fig. 5, [0054]-[0058] (describing Fig. 5).

87. The virtual image generating section (18) generates virtual image data of the tool, workpiece, and part of table 56 based on parameters in camera parameter storage section (15) and model data updating section (17). *Id.* at [0059]; *see also id.* at Figs 6.-7, [0060]-[0064] (discussing Figs. 6-7), [0014], [0018]-[0019] (Summary of the Invention, Solution to Problem) (describing generation of virtual image data).

88. As shown by the excerpt of Figure 1 below, the display control section (23) includes a camera selection section (24) and a display-image switching section (25).

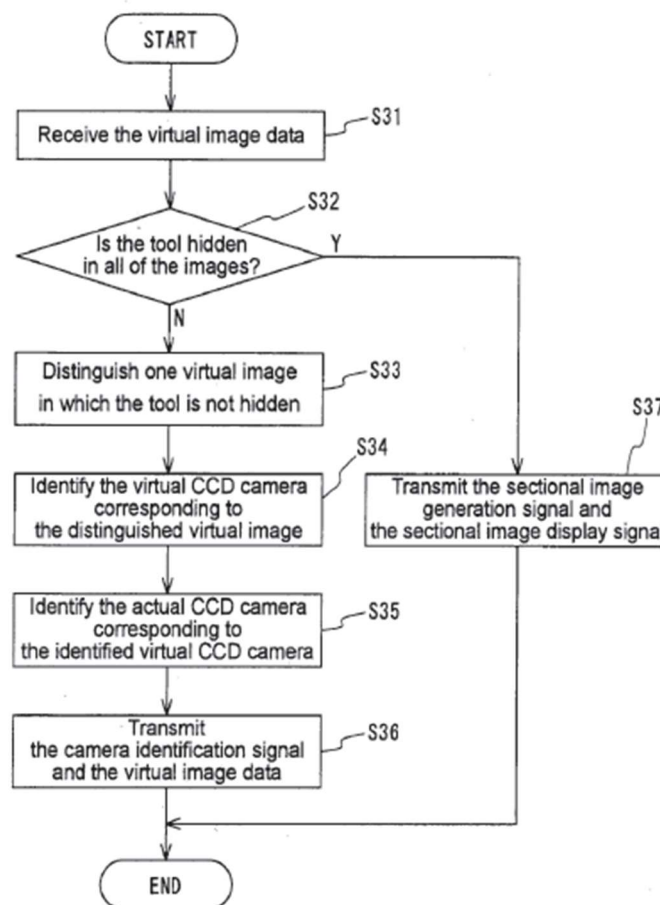


Id. at Fig. 1.

89. The camera selection section (24) selects one actual and one corresponding virtual camera. *Id.* at [0065]. As Mori explains in its Summary of the Invention, the display control means selects “at least one” virtual image “in which the distal end of the tool is not hidden” and the “display means” displays the actual image “corresponding to the selected” virtual image(s). *Id.* at [0020]-[0021] (Summary of the Invention, Solution to Problem).

90. As shown below, Figure 8 of Mori is a flow chart for the operation of camera selection section (24).

Fig. 8

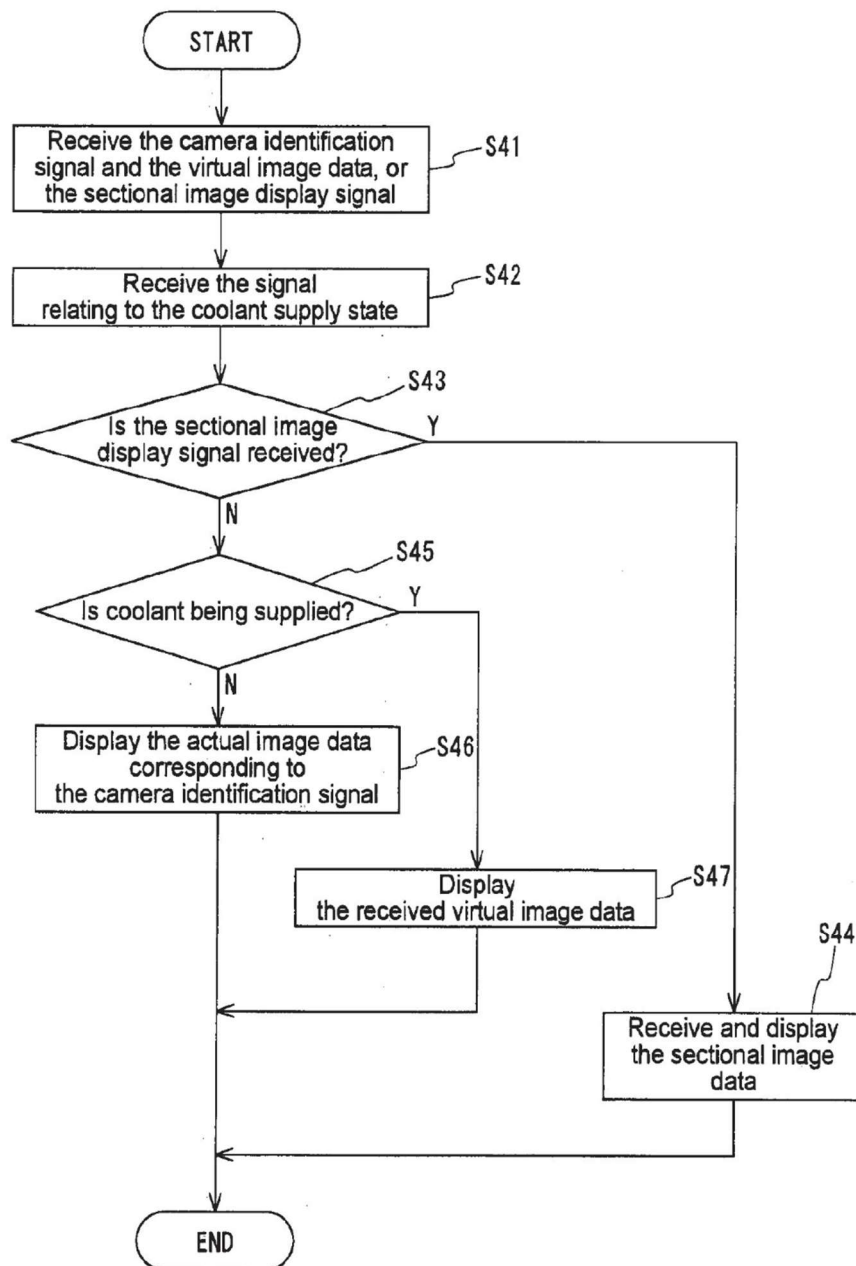


Id. at Fig. 8, [0066]-[0069] (describing Fig. 8), [0015]. More specifically, section 24 receives virtual image data (S31) and checks whether the distal end of the tool is hidden by the workpiece in all virtual images (S32 in Fig. 8). *Id.* at Fig. 8. If the tool is hidden, section 24 transmits a sectional image generation signal and sectional image display signal (S37). *See id.* at Fig. 8, [0069]. Otherwise, section 24 distinguishes at least one virtual image in which the tool is not hidden (S33), identifies the corresponding virtual camera (S34), identifies the actual camera corresponding to the identified virtual camera (S35), and transmits a camera identification signal with the virtual image data (S36). *Id.* Thus, as Mori explains in its Summary of the Invention, at least one of the virtual cameras and corresponding cameras is selected by the display control means (corresponding to display control section 23) and, therefore, “actual images in which the distal end of the tool is not hidden can be always displayed.” *Id.* at [0022]; *see also id.* at [0020] (“the display control means selects at least one from the virtual imaging means” and “displays on the display means the actual two-dimensional image data generated by the actual imaging means corresponding to the selected virtual imaging means”), [0022] (“at least one is selected from the virtual imaging means”).

91. The display-image switching section (25) switches the image displayed between the actual image data from the actual cameras (11-14), virtual image data from camera selection section (24), or sectional image data transmitted from the

sectional image generating section (26). *Id.* at Fig. 1, [0070]; *see also id.* at Fig. 9, [0071]-[0073]. As shown below, Figure 9 of Mori is a flow chart of the display-image switching section (25).

Fig. 9



Id. at Fig. 9, [0071]-[0073]. More specifically, section 25 receives the sectional image display signal, or the camera identification signal and virtual image data, from the camera selection section (24) (S41) and receives a signal for coolant supply state (S42). *Id.* If the sectional display signal is received (S43), section 25 receives and displays the sectional image data (S44). *Id.* Otherwise if the signal for coolant supply indicates coolant is being supplied (S45), section 25 displays the received virtual image data (S47). *Id.* Otherwise, section 25 displays the actual image data corresponding to the camera identification signal from the camera selection section (S46). *Id.* Based on Mori's description of Figure 9 and corresponding description in the Summary of the Invention, a POSITA would have recognized that Mori's first apparatus/method does not include steps S42, S45, and S47, as shown in Figure 9 of Mori, as those steps relate to Mori's second apparatus/method that switches the display to virtual image data if coolant is being supplied.

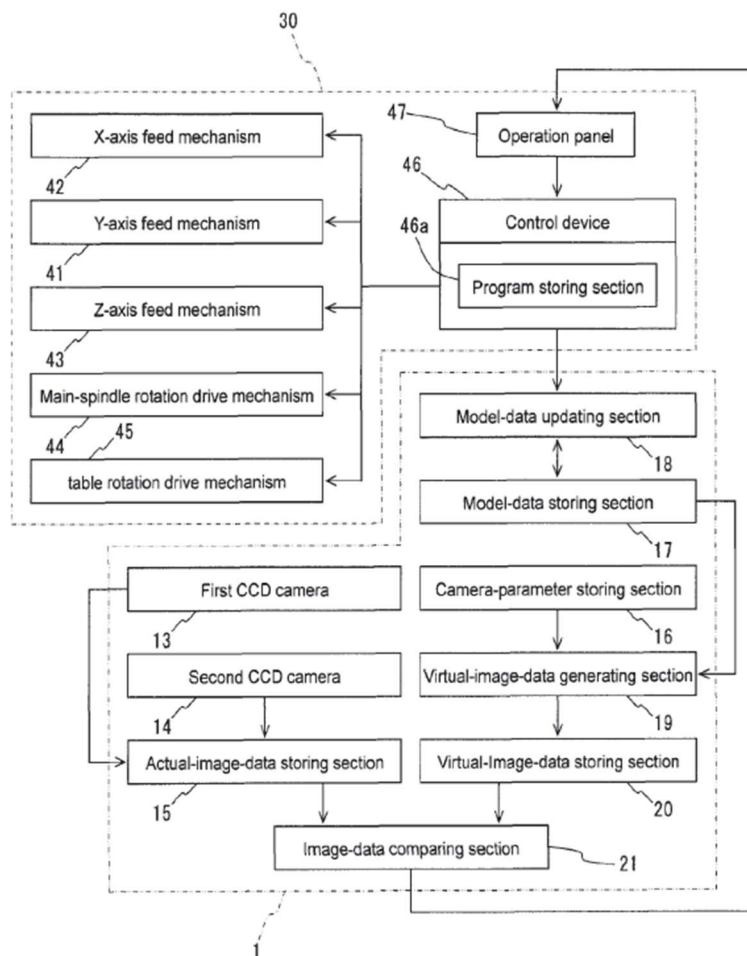
92. The sectional image generating section (26) generates sectional image data if it receives the sectional image generation signal from the camera selection section (24). *Id.* at [0074]. The sectional image is generated based on "a sectional shape appearing when at least the workpiece W is cut along a predetermined cutting plane, and the shape of the workpiece W which is located behind the predetermined cutting plane." *Id.*; *see also id.* at [0075] (when the cutting plane passes through the distal end of the tool), [0076] (when the cutting plane is perpendicular to the optical

axis of an actual camera), [0023]-[0028] (Summary of the Invention, Solution to Problem) (describing sectional image generating means).

C. Overview of Tian (EX1006)

93. Tian is entitled “Three-Dimensional Model Data Confirming Method, and Three-Dimensional Model Data Confirming Apparatus.” EX1006 at Title.

Fig. 1

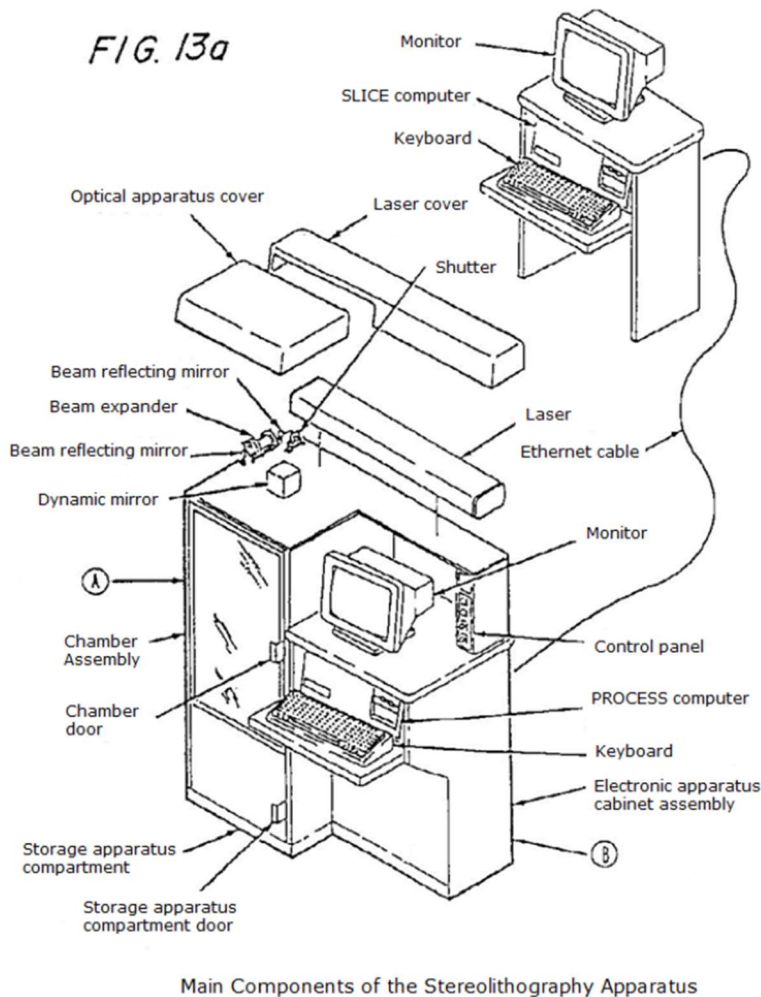


Id. at Fig. 1. I understand that Petitioner is relying on Tian in Grounds 1B and 2B.

See Petition at 1.

D. Overview of Hull (EX1007, translated as EX1008)

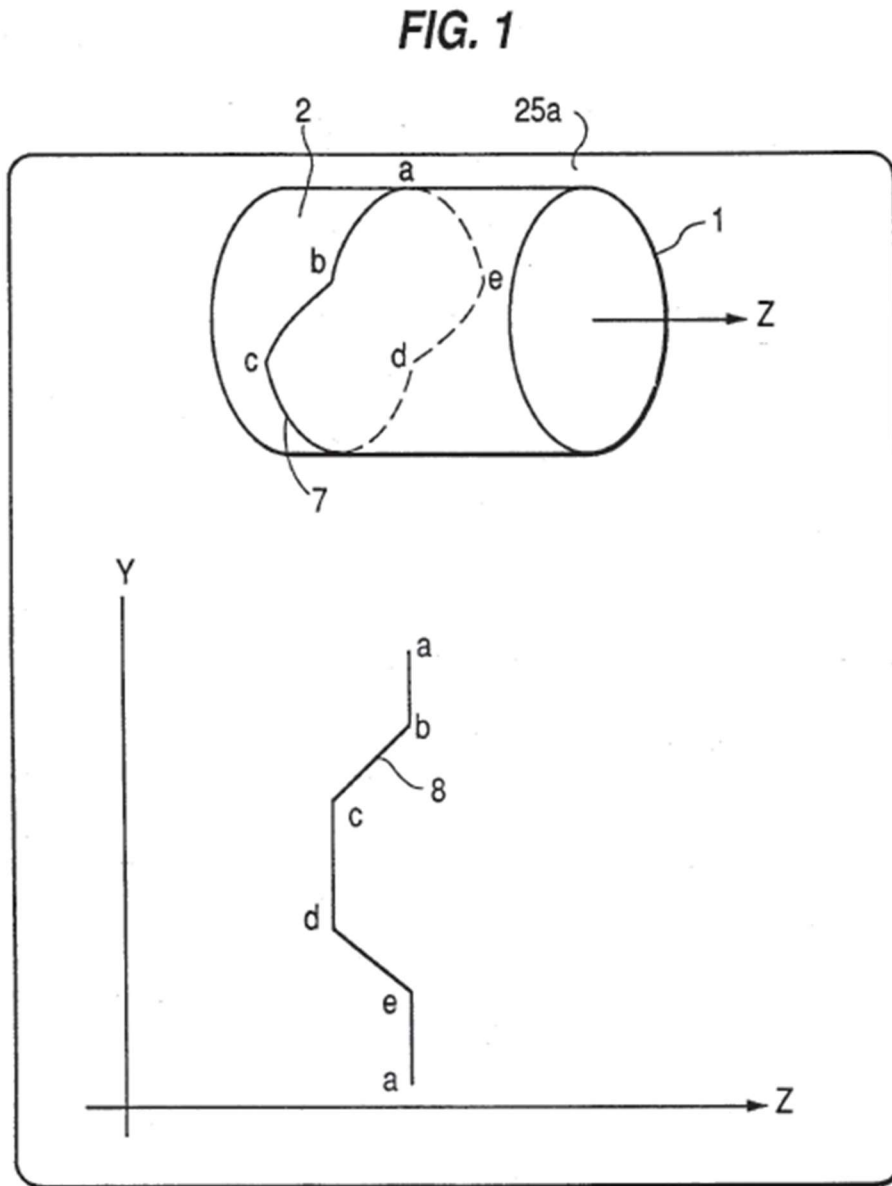
94. Hull is entitled “Stereolithographic Apparatus and Method.” EX1008 at Title. Figure 13a of Hull shows the main components of the stereolithography apparatus (SLA).



Id. at Fig. 13A. As shown, the apparatus includes a slice computer that is remote to a process or control computer in which the slice computer and process/control computer are connected via an Ethernet cable. *Id.* I understand that Petitioner is relying on Hull in Grounds 1C and 2C. *See* Petition at 1.

E. Overview of Seki (EX1009)

95. Seki is entitled “Tool Path Drawing Method.” EX1009 at Title. Figure 1 of Seki shows tool paths.

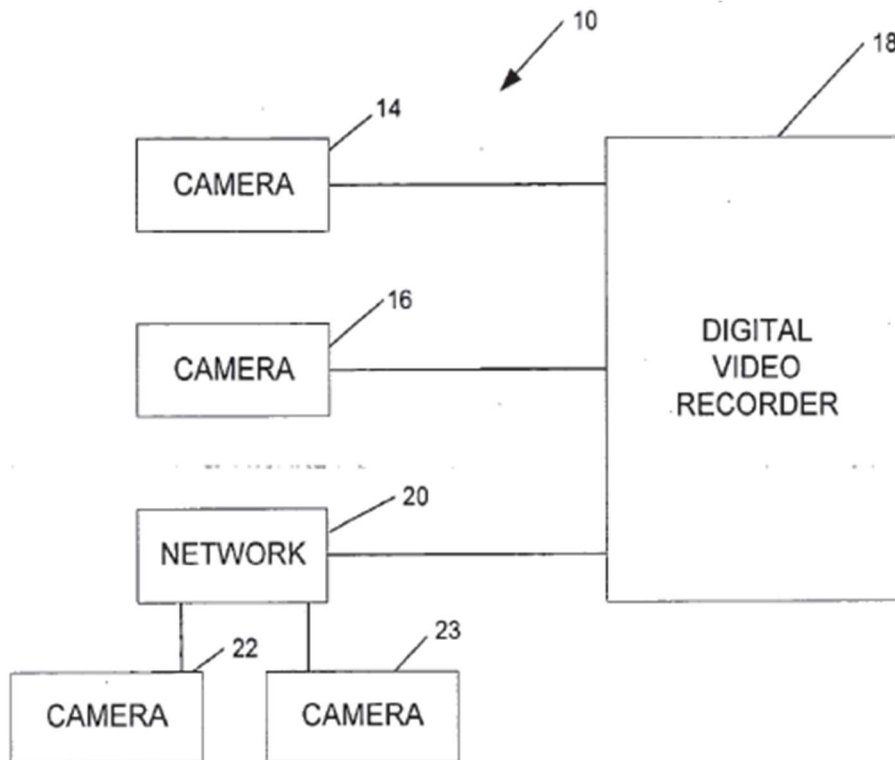


Id. at Fig. 1. I understand that Petitioner is relying on Seki in Grounds 1D and 2D.

See Petition at 1.

F. Overview of Waehner (EX1010)

96. Waehner is entitled “Method and Apparatus for Dual Mode Digital Video Recording.” EX1010 at Title. Figure 1 of Waehner shows its apparatus.



Id. at Fig. 1. I understand that Petitioner is relying on Waehner in Grounds 1E and 2E. *See* Petition at 1.

G. Overview of Lan (EX1011)

97. Lan is entitled “Web-based rapid prototyping and manufacturing systems: A review.” EX1011 at 1. Lan provides a review of literature and “gives an output on possible future development and research direction for Web-based”

systems. *Id.* I understand that Petitioner is relying on Lan in Grounds 1F and 2F. *See* Petition at 1-2.

H. Overview of Anderson (EX1012)

98. Anderson is entitled “User Interface, Method and Apparatus for Providing Three-Dimensional Object Fabrication Status.” EX1012 at Title. Figure 2A of Anderson shows a progressively filled-in wire-frame model.

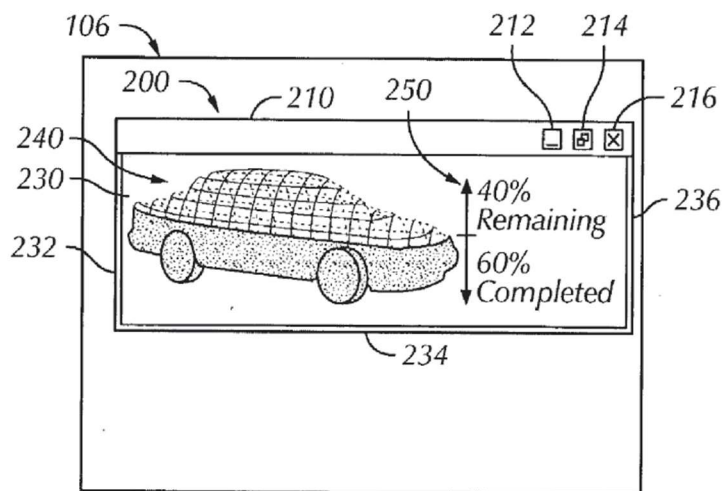


FIG. 2A

Id. at Fig. 2A. Anderson discloses a “status register has a ‘pass number’ which is the number of passes completed by the printhead.” *Id.* at [0018]. A print server “calculates how many passes are required to complete the job.” *Id.* “At a specified interval, the server polls the printer for the pass number. After each polling, the 3D wireframe model representation is re-rendered to show the completed portion as a filled-in (e.g., solid colored) area.” *Id.* I understand that Petitioner is relying on Anderson in Grounds 1G and 2G. *See* Petition at 1-2.

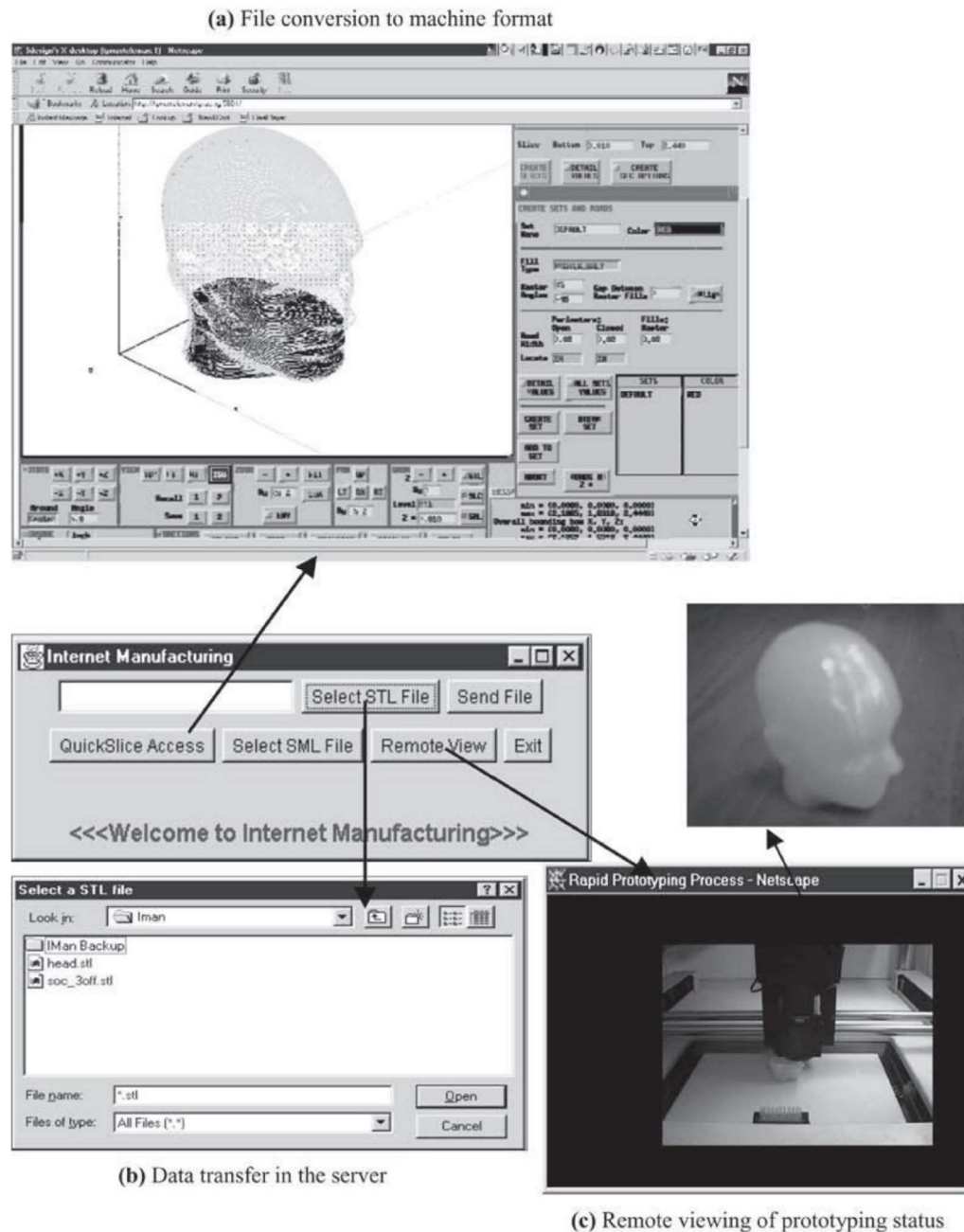
I. Overview of Tay (EX1013)

99. Tay is entitled “Distributed rapid prototyping – a framework for Internet prototyping and manufacturing.” EX1013 at Title. In general, Tay describes distributed rapid prototyping via the Internet (*id.* at 1-2), provides a brief description of an Internet Manufacturing (IMAN) system (*id.* at 2-3), describes an object-oriented architecture of the IMAN system (*id.* at 3-4), and tests and results (*id.* at 4-5).

100. As shown below, Figure 3 of Tay shows the use of a web cam.

Figure 3

(a) File conversion to machine format (b) Data transfer in the server (c) Remote viewing of prototyping status



Id. at Fig. 3, 4 (“use of Web cam and video conferencing (see Figure 3)”). Figure 3 also shows three steps or parts. Step (a) is “File conversion to machine format,” step (b) is “Data transfer in the server,” and step (c) is “Remote viewing of prototyping

status.” *Id.* at 5. More specifically, step (a) converts the file to machine format with QuickSlice. *Id.* at 4 (“front-end terminal intensive tasks such as data conversion to machine format with the QuickSlice.”), 5 (“(a) File conversion to machine format”). Next, step (b) transfers data in the server. *Id.* at 4 (“From the viewpoint of the client application, the socket connection is active only for data transfer and invocation of the rapid prototyping hardware” and “To validate the reliability of data transfer, network performance reliability was monitored in the rapid prototyping laboratory.”); 5 (“(b) Data transfer in the server”). Finally, step (c) concerns remote viewing of the prototyping status. *Id.* at 4 (“a distributed system where the active process needs to be instantaneously viewed by several people at different client stations for concurrency”); 5 (“(c) Remote viewing of prototyping status”).

101. Tay explains that multiple remote individuals can concurrently view the prototyping status. EX1013 at 4 (“These are critical tasks such as data transfer to the front-end terminal via the server and noncritical ones such as video conferencing and concurrently viewing of the rapid prototyping status.”), 1 (“parties involved in product development” can view “the prototyping concurrently”). At the end of the fabrication process, Tay explains that it “is shown that the quality of the prototype fabricated using the IMAN system is not susceptible to varying conditions of the network link, especially the data transfer mode.” *Id.* at 4. As shown above in Figure 3 of Tay, the completed object appears to have been placed on a surface with a wood

grain, which is a different surface than the 3D printer's white build platform as shown in step (c) of Figure 3 for the "Remote viewing of prototyping status." *Id.* at Fig. 3.

J. Overview of Henke (EX1014)

102. Henke is entitled "Rapid Prototyping Modules for Remote Engineering Applications." EX1014 at Title. Henke's solution is designed for students to use simulation tools and existing hardware to "test a designed control algorithm." *Id.* at 2. Henke's "paper starts with an introduction into the design process and describes the tool set, which is provided to the students." *Id.* Henke explains that "*Simulation* and visual prototyping help to find functional errors." *Id.* at 3 (emphasis in original). For instance, the "physical behaviour of the actual model, and its environment as well, will be emulated (e.g., as [a] simulation model)." *Id.*

103. Figure 2 of Henke shows a visual model of the water level control task.

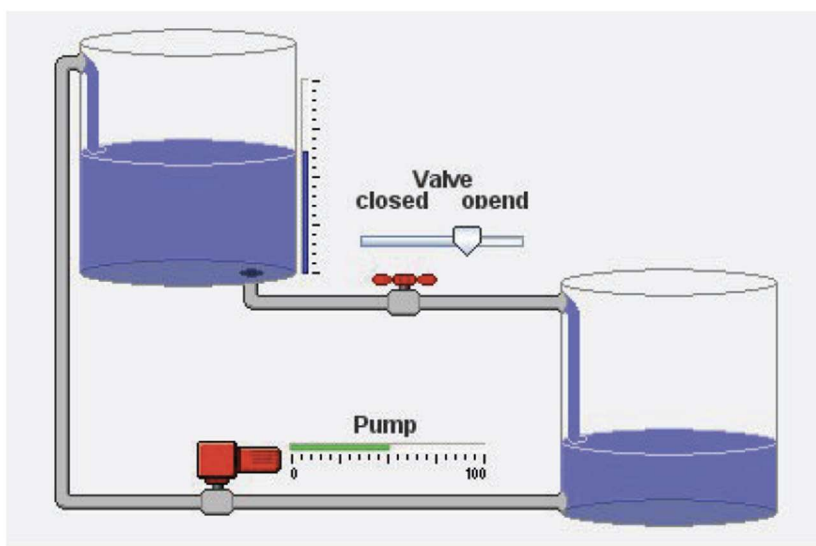


Figure 2. Visual model of the Water level control task

Id. at 3. Henke also explains that “a fault free design algorithm finally should be tested on real electro-mechanical models,” such as the “Water level control unit” in Figure 3.

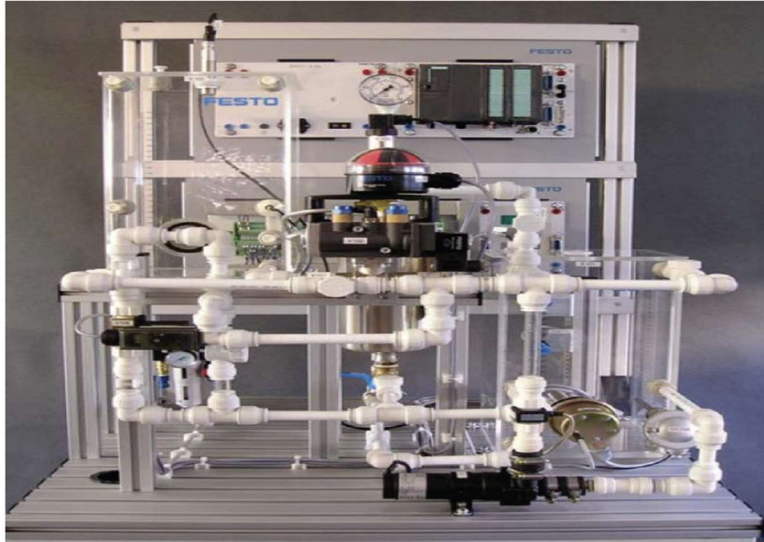


Figure 3. Hardware model of the Water level control unit

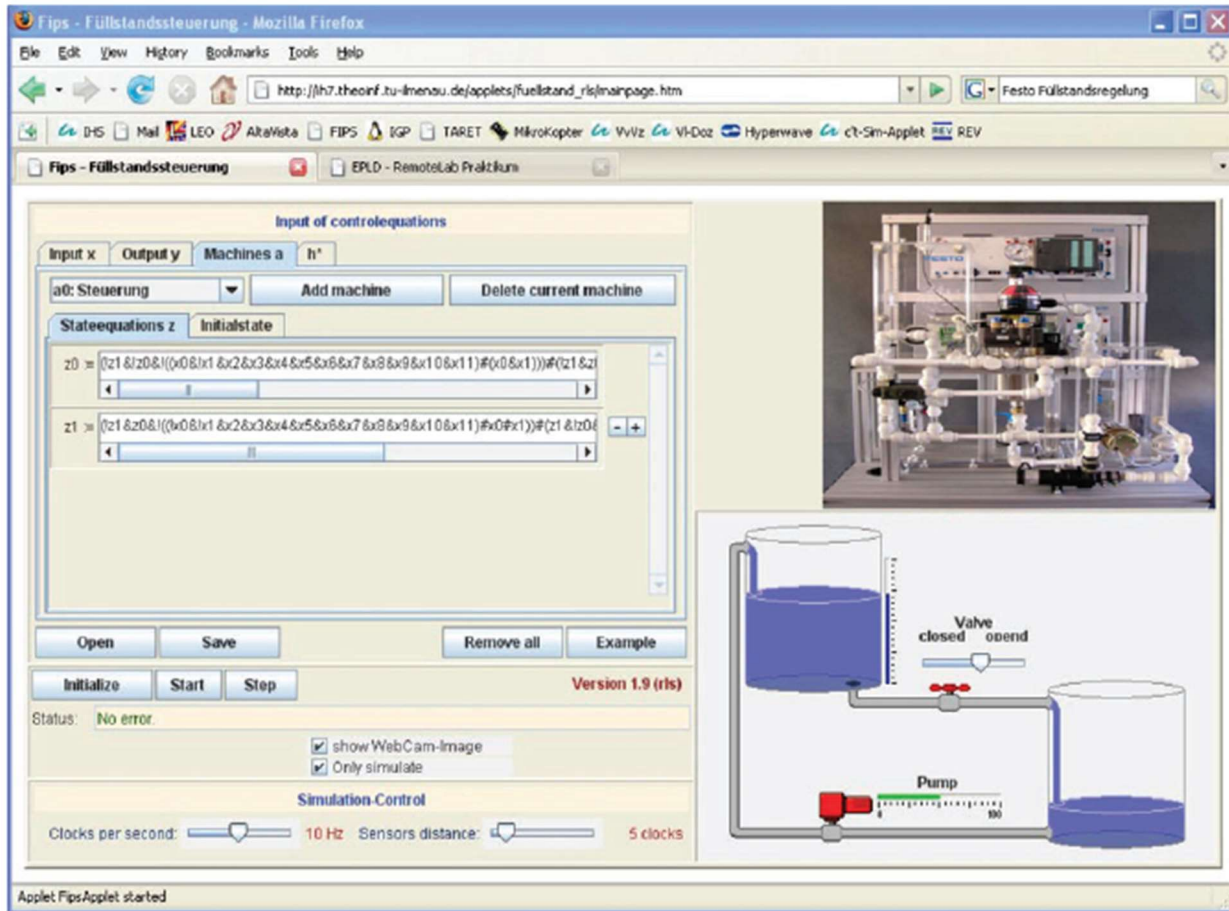
Id. at 3. Using this existing hardware model, Henke’s “implementation enables a Web-based access to control electro-mechanical models.” *Id.* at 1. “The electromechanical models can be controlled by different platforms.” *Id.* “Students have the possibility to test a designed control algorithm directly within a hardware environment by uploading a source file to the Remote Lab server. That way the students can compare architectures of different control-platforms as well as different design approaches to control electro-mechanical models.” *Id.*

104. Henke’s tool set includes the Remote and Applications Laboratory (REAL) system. *Id.* at 5. The REAL system’s features include “Visualization and animation [to] allow observing and testing the properties of the design.” *Id.* REAL

[illegible]

Id. at Fig. 7.

55



Id. at 5, Fig. 8. Specifically, the student downloads their “synthesized hardware and/or software design algorithms,” “handle[s] the laboratory procedure,” “change[s] environmental variables if necessary,” and “watch[es] the laboratory procedure by supervising the model and environmental variables inside an I/O monitor or by observing the hardware model directly via a Web-Cam.” *Id.* Henke explains that “the student has the chance to adjust his algorithm in case of fault” and thus “is able to achieve a fault free solution (a validated control algorithm) step by step.” *Id.*

K. Overview of Kritchman (EX1015)

107. Kritchman is entitled “Process of and Apparatus for Three-Dimensional Printing.” EX1015 at Title. Figure 1 of Kritchman shows a block diagram of its three-dimensional printing system.

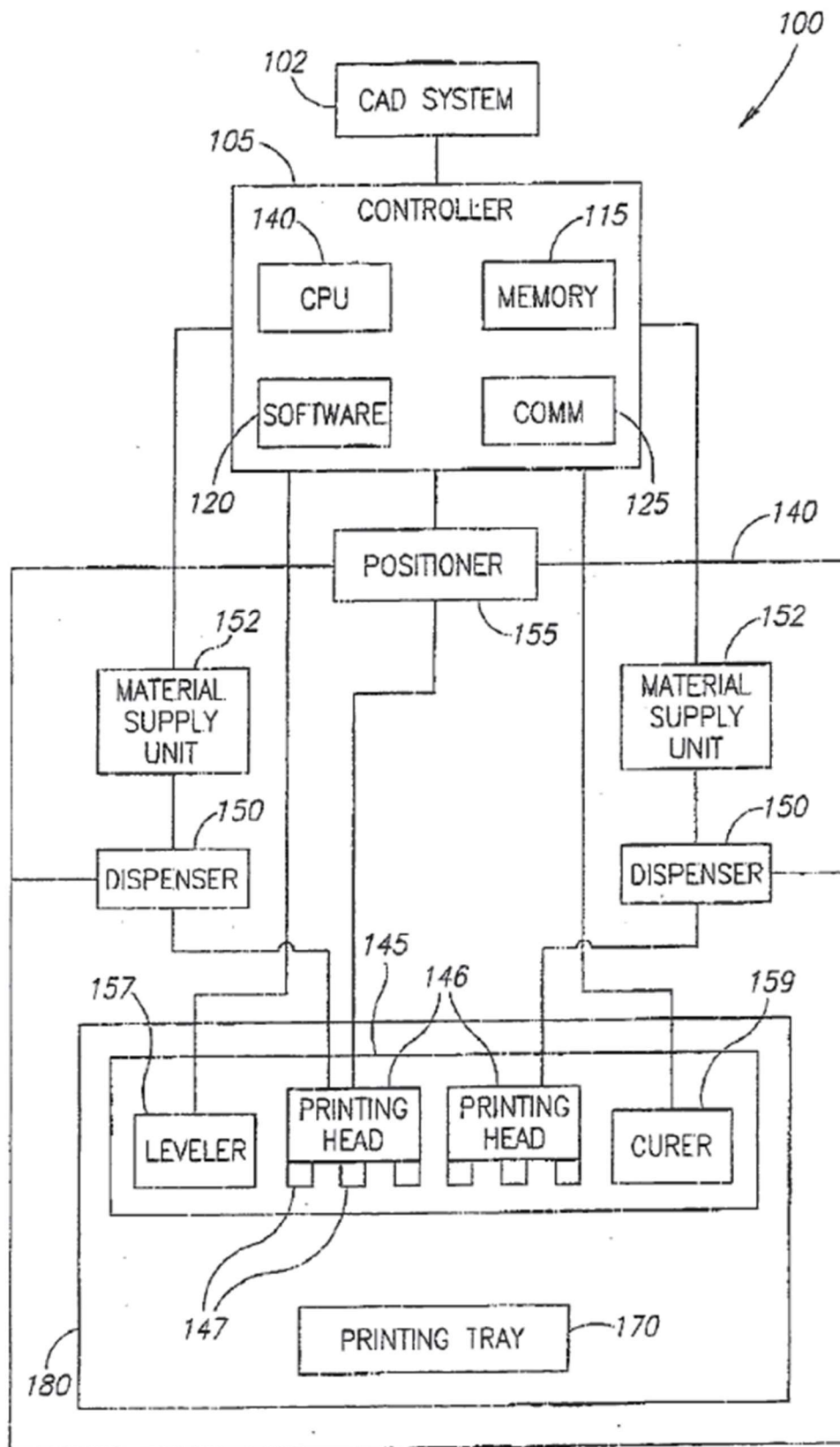


FIG. 1

Id. at Fig. 1.

VII. GROUND 1A: CLAIMS 1, 3, 5-7, 9-10, AND 19-22 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 1A (COMBINATION OF MAZUMDER AND MORI)

108. In Ground 1A of the Petition, Petitioner asserts that claims 1, 3, 5-7, 9-10, and 19-22 are obvious over the combination of Mazumder and Mori. *See* Petition at 6-8 (Overview of Mazumder), 8-10 (Overview of Mori), 10-13 (Mazumder-Mori Combination), 13-14 (1.pre), 14 (1.a), 15-16 (1.b), 16 (1.c), 16-25 (1.d), 25 (claim 3), 25-26 (claim 5), 26 (claim 6), 27 (claim 7), 27-28 (claim 9), 28 (claim 10 and claim element 19.pre), 28-29 (19.a), 29 (19.b, 19.c, 19.d, claim 20), 29-30 (claim 21), 30 (claim 22).

109. I have reviewed Petitioner's challenges in Ground 1A, and it is my opinion that Ground 1A fails to teach or suggest all elements of claims 1, 3, 5-7, 9-10, and 19-22. I explain my opinions below in detail.

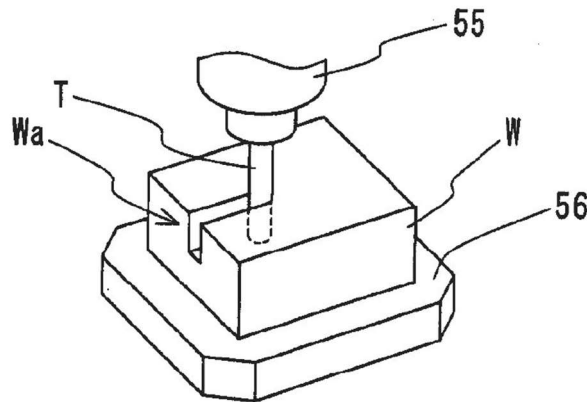
A. Field of Invention of Mori and '324 Patent

110. I understand that Petitioner has asserted that Mori's "three-dimensional fabrication" system is in the same field identified in the '324 Patent. *See* Petition at 12. I also understand that Dr. Wolfe has asserted that Mori and the '324 Patent are about "remote monitoring of a 3D manufacturing process." EX2010, at 67:18-68:6. As Dr. Wolfe recognizes, however, "literally everything in the world is three-dimensional" and thus three-dimensional refers to "something where we have some level of control over all three dimensions." *Id.* at 68:9-69:5. As I discuss below, I

disagree with Petitioner's and Dr. Wolfe's assertions that Mori and the '324 Patent are in the same field.

111. Mori teaches a destructive machining tool with a machining status monitoring status apparatus and method. *Supra* Section VI.B (Overview of Mori). Mori's machining tool (50 in Figure 2) includes a tool (T) and workpiece (W). *See* EX1005, at Fig. 2. As I explained above, Mori has two different disclosures of its machining status monitoring apparatus and method. *Supra* Section VI.B (Overview of Mori). Both of these disclosures consider issues specific to destructive manufacturing tools, including whether the tool is hidden as it cuts into the workpiece and whether coolant is being supplied to cool the contact area between the tool and workpiece. *See* EX1005, Abstract, [0004]-[0029] (describing first apparatus/method), Fig. 9, [0071-0073], [0087] (describing the second apparatus/method). As shown below in Figure 10 of Mori, the tool (T) can cut a groove (Wa) into workpiece (W).

Fig. 10



Id. at Fig. 10, [0069]. When the tool (T) is hidden from view, such as when it is cutting into the workpiece (W), Mori teaches displaying sectional images. *See id.*; *see also* [0085]. And when coolant is being supplied, Mori teaches displaying virtual images in the second apparatus/method. *See id.* at Fig. 9, [0071]-[0073]. Otherwise, Mori teaches displaying actual images. *See id.*; *see also* Abstract, [0022]-[0029]. Thus, Mori is in the field of destructive machining tools and switching display based on whether the tool is visible during machining.

112. In contrast to Mori, the '324 Patent teaches a three-dimensional printer whose operation is controlled by a user interface to a remote user that presents both an image of the build volume and a two-dimensional projection of a three-dimensional model from the same point of view. The hardware implemented in the

'324 Patent is a three-dimensional printer or additive manufacturing/fabrication system.

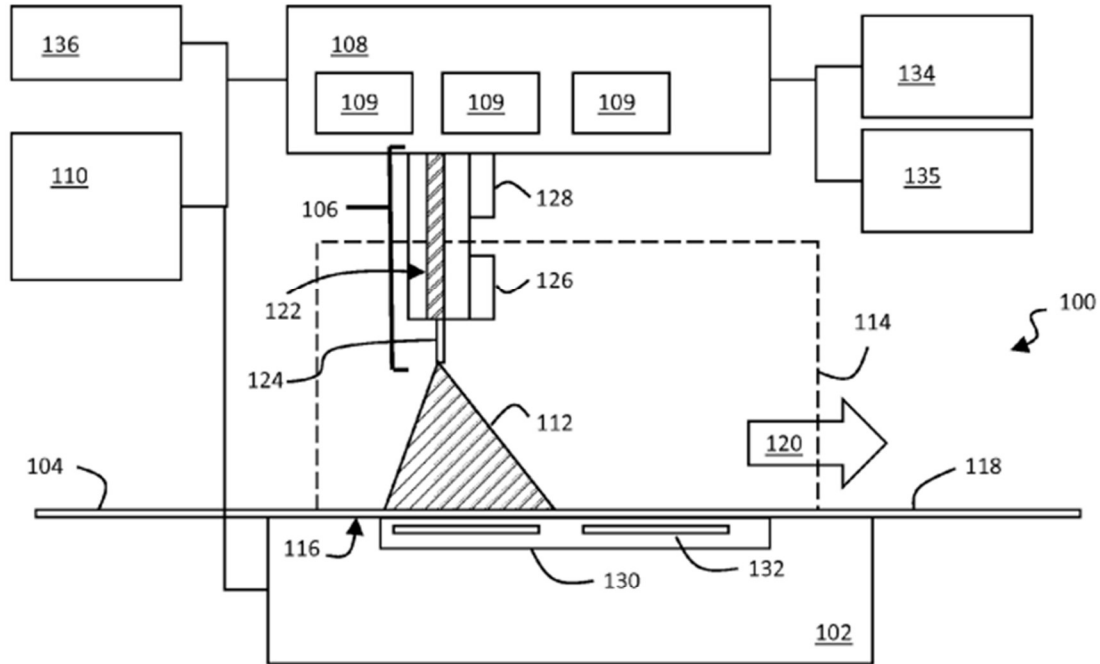


Fig. 1

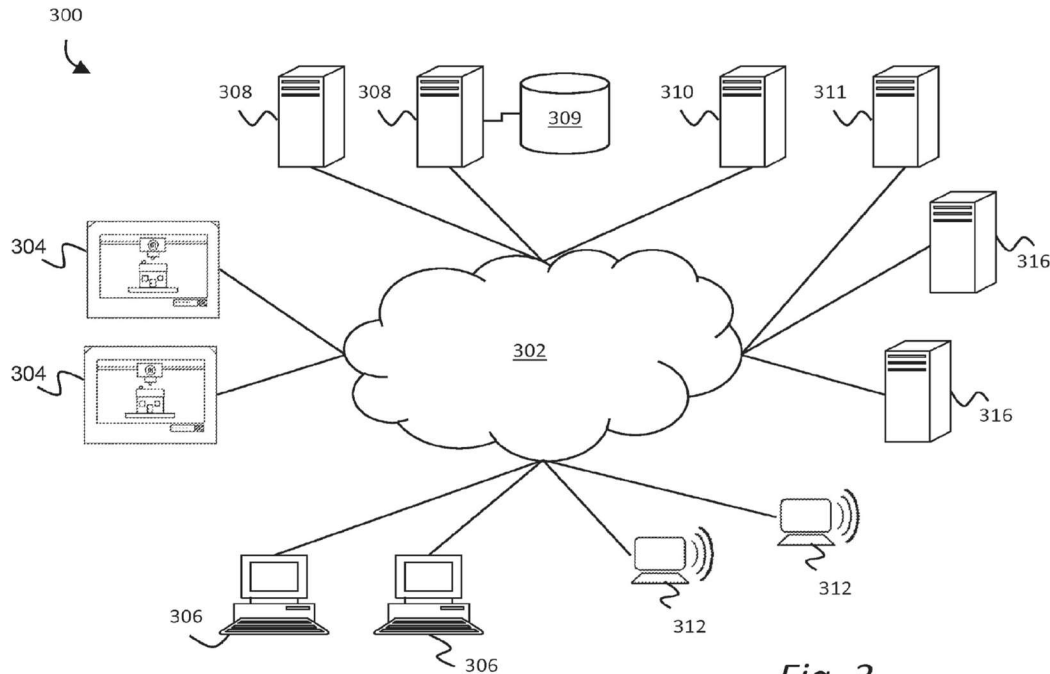


Fig. 3

EX1001, Figs. 1, 3. The claims of the '324 Patent relate to a device or method that comprises “a three-dimensional printer including a build volume” in Claims 1 and 19. *Id.* at 27:20-21, 28:31-33. The Title of the '324 Patent is “Networked Three-Dimensional Printing” and its Abstract refers to tools for “networked use of three-dimensional printers.” *Id.* at Title, Abstract; *see also id.* at 1:34-35. The '324 Patent includes figures that illustrate printing environments, methods, and a user interface. *See id.* at 1:41-61; *see also id.* at 1:65-66 (“Described herein are devices and methods for using networked three-dimensional printers”). As described by the '324 Patent, three-dimensional printing refers to “any and all such additive fabrication process unless a different meaning is explicitly stated or otherwise clear from the context.” *Id.* at 2:8-13. As I discussed above in my Summary of the '324 Patent, it describes

providing a user interface to a remote user that presents an image of the build volume of the three-dimensional printer within which the three-dimensional model is being fabricated as an object and a two-dimensional projection of the three-dimensional model that is from the same point of view as the image. *Supra* Section V.A (Summary of the '324 Patent); *see also* EX1001, 24:43-25:5, Fig. 7. A POSITA would have understood that the '324 Patent does not teach a concern with the three-dimensional printer or object being additively fabricated by the three-dimensional printer being hidden from view during fabrication. Thus, Mori is not in the same field of invention as the '324 Patent.

B. Claim 1

113. Claim 1 of the '324 Patent requires, among other elements, “to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” (part of claim element [1.d]) EX1001 at 27:25-35. Claim 1 also requires, among other elements, “a three-dimensional printer including a build volume” and “a video camera positioned to capture video of the build volume from a point of view.” *Id.* at 27:21, 27:23-24.

114. Regarding the video camera, I understand Petitioner relies on the sensors at Mazumder’s local site. *See* Petition at 16. Petitioner asserts that the local site includes a “video or television camera 65” that “records the laser-aided DMD

process and transmits the images to the local computer 70.” *Id.* Petitioner also asserts that Mazumder’s “local computer transmits the images ‘to the remote computer 95 to be displayed.”” *Id.* at 20. Petitioner states that “the combined video and sensor data is displayed on a ‘TV screen’” which is purportedly “a display device that does not include its own computing capability.” *Id.*

115. Regarding the two-dimensional projection, I understand Petitioner asserts that the Mazumder-Mori combination would have provided the user interface with both the two-dimensional projection and image of the build volume from the video camera. *See* Petition at 21 (citing EX1005 (*Mori*) at ¶¶[0043], [0049]-[0050]). Petitioner also asserts that “Mori describes that the user interface displays the actual image data from the actual CCD cameras, the virtual image data, and the sectional image data showing a virtual cross section of the workpiece.” Petition at 23 (citing EX1005 at ¶¶[0070], [0074]-[0076], FIGS. 4, 7, 10). Petitioner further asserts that Mori suggests that the combination would include “‘virtual image generating section 18’ to provide views of the workpiece and work environment based on the stored model of the workpiece” and the benefits of two types of imaging—video camera images and virtual images. Petition at 22 (citing EX1005, ¶¶[0059]-[0065], [0079]-[0083]).

116. Regarding the user interface that presents the image and projection, I understand that Petitioner has made three separate assertions. First, Petitioner asserts

that Mazumder's video satisfies both types of imaging under Petitioner's interpretation of the infringement contentions. *See* Petition at 22, footnote 3 ("Mazumder's disclosure of video images ("displayed preferably on a TV screen or shown on the remote computer monitor as streaming video") satisfies both of these requirements"). Second, Petitioner asserts that the combination teaches presenting the video camera images and the virtual images at the same positions/orientations, but it appears that Petitioner is interpreting the claims to permit presenting the image and projection at different times. *See* Petition at 22-23. Third, Petitioner asserts that the combination would have been modified so that the video camera images and virtual images are presented at the same time. *See* Petition at 23-24 (asserting that "it would have been obvious to display the actual image and the virtual image of the product simultaneously").

117. With regards to Petitioner's first assertion that Mazumder's video satisfies both types of imaging, a POSITA would have understood that the reference, as used in the combination, does not teach a user interface that presents an image and projection from the same point of view. *See* Petition at 5, 22. I understand that Petitioner is arguing that the infringement contentions indicate the claims encompass the same images satisfying both the image and projection because they are based on video camera captures. *See id.* (claim elements "are fulfilled by merely displaying images captured by a video camera alone"). I have reviewed portions of the

infringement contentions in Exhibit 1016 and with respect to this claim element of claim 1, there is no assertion that the same images satisfy both the image and projection. The contentions point to a "camera view" and a "2-D projection of a 3-D model for [a] cute little dinosaur," as well as a "time lapse." EX1016 at 41-44, 46. There is no indication, for example, that the camera view has the same images as the 2-D projection of a 3-D model for the cute little dinosaur or as the time lapse. *See id.* Therefore, Mazumder's video does not satisfy both the image and projection. *See* EX1004, 6:36-43, 8:14-17.

118. With regards to Petitioner's second assertion that the Mazumder-Mori combination teaches presenting the video camera images and the virtual images, a POSITA would have understood that the combination does not teach a user interface that presents an image and projection from the same point of view at the same time. *See* Petition at 23.

119. In particular, a POSITA would have understood that the plain meaning of the claim terms in claims 1 and 19 is that the image and projection are presented at the same time. Claim 1 of the '324 Patent recites "the processor further configured to provide a user interface to a remote user accessing the device through the network interface, and to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera." EX1001 at 27:29-35. Similarly, claim 19 of

the '324 Patent recites “providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* at 28:41-46. As stated in the claims, the image and projection in the user interface is presented at the same time. Claim 19 recites “providing a user interface to a remote user” wherein “the user interface presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* Similarly, claim 1 recites a processor configured “to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* at 27:30-32. Thus, the claims plainly indicate that the image and projection are presented in the user interface at the same time.

120. A POSITA would have understood that the disclosures in the specification of the '324 Patent are consistent with the plain meaning of the claims in which the image and projection are presented in the user interface at the same time. The Abstract of the '324 Patent contemplates that servers provide remote users access to manage the use of distributed fabrication resources:

Three-dimensional fabrication resources are improved by adding networking capabilities to three-dimensional printers and providing a

variety of tools for networked use of three-dimensional printers. Web-based servers or the like can provide a single point of access for remote users to manage access to distributed content on one hand, and to manage use of distributed fabrication resources on the other.

EX1001 at Abstract. Similarly, the Summary of the '324 patent contemplates the same thing:

Three-dimensional fabrication resources are improved by adding networking capabilities to three-dimensional printers and providing a variety of tools for networked use of three-dimensional printers. Web-based servers or the like can provide a single point of access for remote users to manage access to distributed content on one hand, and to manage use of distributed fabrication resources on the other.

Id. at 1:31-38. Accordingly, the Background of the '324 Patent explains that as the availability of three-dimensional fabrication devices increases, there is a need for network management for three-dimensional printers.

A variety of three-dimensional fabrication techniques have been devised to support rapid prototyping from computer models. These techniques have been refined over the years to increase accuracy, working volume, and the variety of build materials available in a rapid prototyping environment. While these increasingly sophisticated and expensive machines appear regularly in commercial design and engineering settings, a more recent trend has emerged toward low-cost three-dimensional prototyping devices suitable for hobbyists and home users. As these resources become more readily and widely available, a need has emerged for networking capabilities and network management for three-dimensional printers.

Id. at 1:16-28. As shown in Figure 3 of the '324 Patent below, such management can be performed using remote client devices (306).

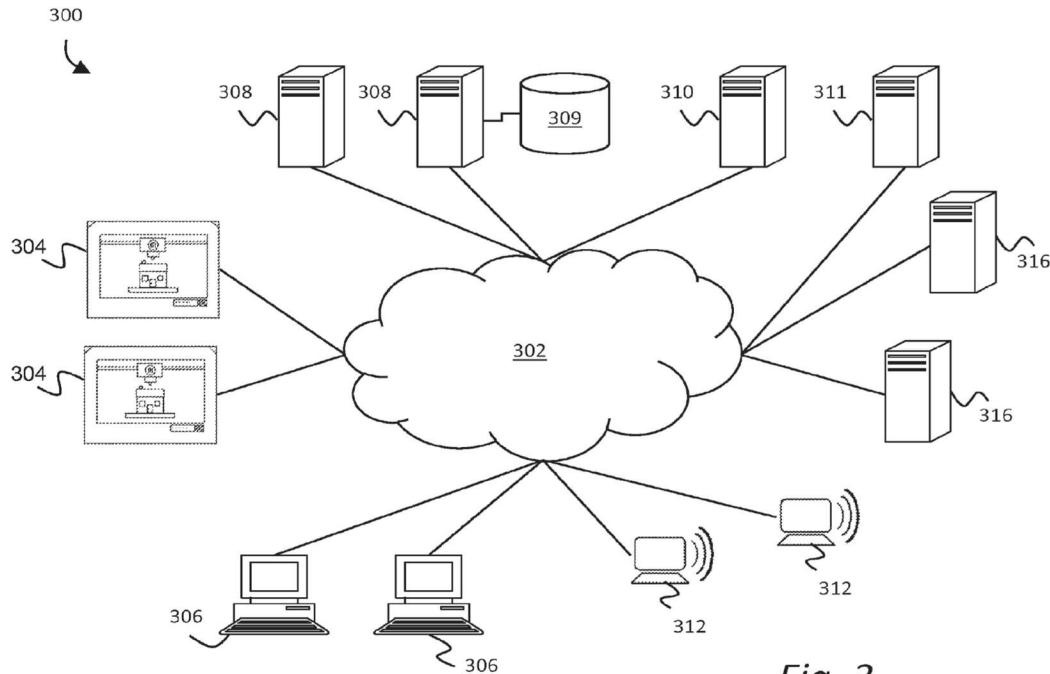


Fig. 3

Id. at Fig. 3. In particular, the '324 Patent explains that "Client devices 306 may in general be devices within the environment 300 operated by users to initiate and monitor print jobs at the three-dimensional printers 304." *Id.* at 8:49-51. "This may include desktop computers, laptop computers, network computers, tablets, or any other computing device that can participate in the environment 300 as contemplated herein." *Id.* at 8:51-54.

121. As I explained in my Summary of the '324 Patent (Section V.A), the '324 Patent provides a flowchart in Figure 7 "for operating a three-dimensional printer with a video camera and a network interface."

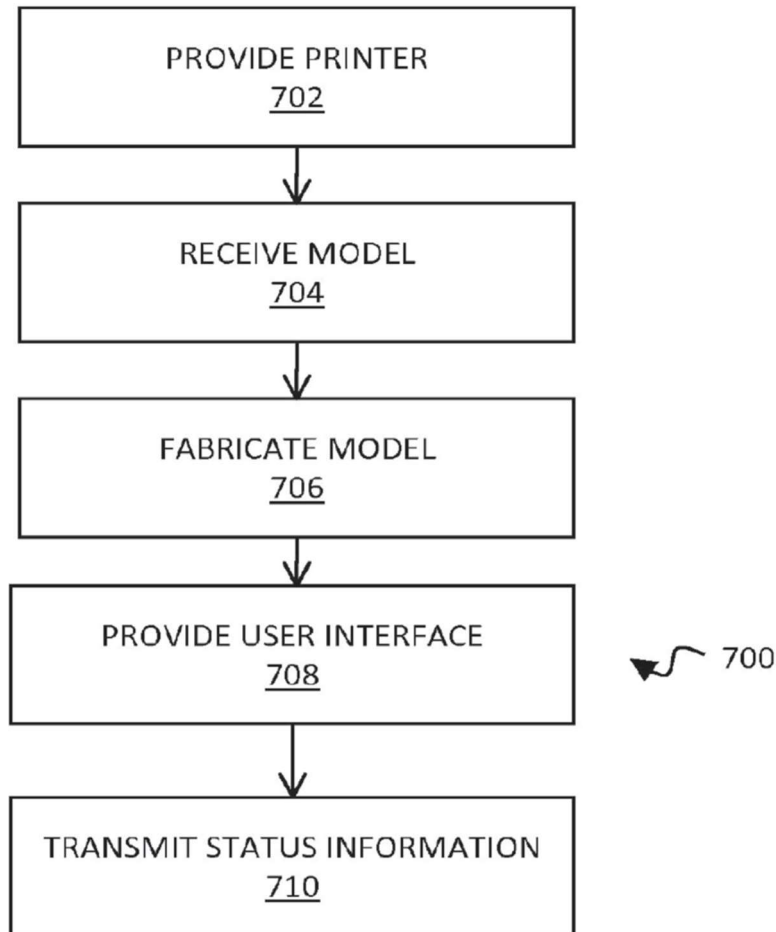


Fig. 7

Id. at Fig. 7, 24:24-26. “In particular, the method 700 of FIG. 7 emphasizes incorporation of data from the video camera into operation and management of the three-dimensional printer.” *Id.* at 24:26-28. “As shown in step 708, the method 700 may include providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build

volume from the camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* at 24:47-52.

122. I also explained in my Summary of the '324 Patent (Section V.A) that the '324 Patent provides a user interface (500) for networked three-dimensional printing.

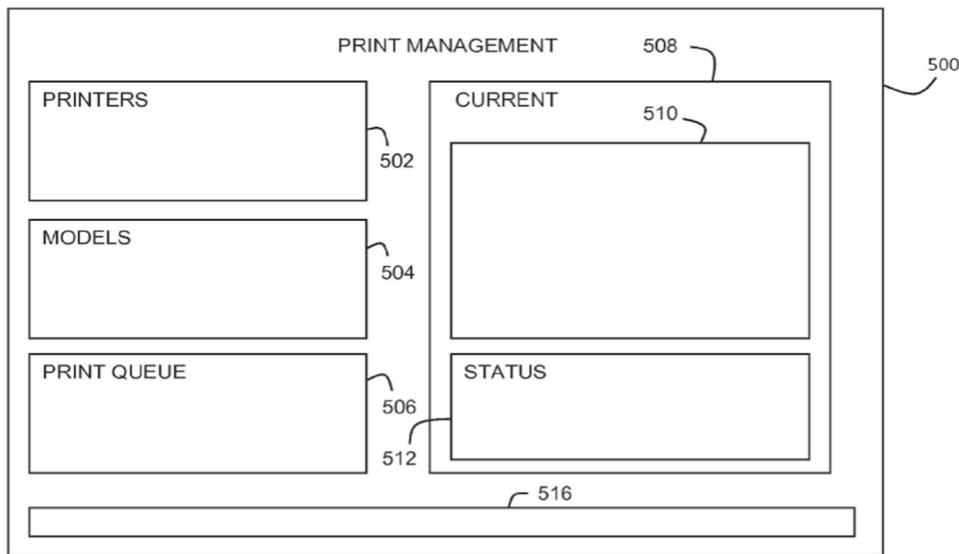


Fig. 5

Id. at Fig. 5, 21:18-19. As the '324 Patent explains, “a user may visually monitor progress or status of a remote print job through the user interface 500.” *Id.* at 22:56-57. The visualization area 510 in user interface 500 “displays a visual representation of the print job.” *Id.* at 22:41-42. For example, “a current tool path of the printer that is executing the print job,” “also or instead [] a simulated print object,” and “also or instead [] an image of a working volume.” *See id.* at 22:41-55.

123. While this disclosure might contemplate options of displaying the current tool path, simulated print object, or image, a POSITA would not have understood that the tool path, simulated print object, and image may be presented at different times. For example, there is no description of switching between the display of the tool path, simulated print object, or image. As I discussed above, Figure 7 shows a flowchart where a single step (708) provides the user interface that must present both the image and projection. *See id.* at Fig. 7. Additionally, the description in the specification of the '324 Patent explains the purpose of presenting both the image and projection at the same time. This technique enables “comparing actual to expected two-dimensional or three-dimensional results” so that the “fabrication process can be expeditiously aborted and restarted or otherwise addressed without waiting for completion and physical inspection of the constructed object.” *Id.* at 25:45-49. Thus, the description in the specification of the '324 Patent is consistent with the plain meaning of the claims, which require presenting the image and projection at the same time instead of presenting the image and projection at different times.

124. While the description of the '324 Patent does not describe presenting the image and projection at different times sequentially, a POSITA would have understood the '324 Patent does describe sequential operations in other contexts. For example, the '324 Patent explains sequential prints of objects:

Many current three-dimensional printers require significant manufacturing time to fabricate an object. At the same time, certain printers may include a tool or system to enable multiple, sequential object prints without human supervision or intervention, such as the conveyor belt described above.

Id. at 15:19-22. Further, as another example, the '324 Patent explains that a print server can communicate periodically with printers to obtain status information, such as the availability of printer or status of particular print jobs, and that any one of these can be subsequently presented to a user through the web server.

A print server 308 may also communicate periodically with three-dimensional printers 304 in order to obtain status information concerning, e.g., availability of printers and/or the status of particular print jobs, any of which may be subsequently presented to a user through the web server.

Id. at 9:17-22. As yet another example, the '324 Patent describes that certain content can be given priority after the user limits the number of objects fabricated.

In one aspect, the processor may be configured to adjust prioritization based upon a history of fabrication when a number of objects fabricated from one of the plurality of sources exceeds a predetermined threshold. Thus, for example, a user may limit the number of objects fabricated from a particular source, giving subsequent priority to content from other sources regardless of an objectively determined priority for a new object from the particular source.

Id. at 15:59-63.

125. In addition to the disclosures in the '324 Patent itself, a POSITA would have understood that the prosecution history of the application leading to the '324 Patent confirms the plain meaning of the claims that require the presentation of the image and projection at the same time. As I discussed above in the Summary of the

Prosecution History (*supra* Section V.B), the applicant distinguished the claims over the prior art reference, Taminger. *See* EX1002, at 160-61. In particular, the applicant explained the claims as they relate to the user interface presenting both an image and projection at the same time.

The applicant has devised a personal manufacturing device, e.g., a three-dimensional printer, configured for use as a remote network resource. In addition to receiving a model through a network interface and controlling the printer to fabricate a model, a processor provides a user interface that shows both a video of an object being manufactured and a three-dimensional model of the object. Further, in order for a remote user to monitor progress of fabrication in a meaningful way, the three-dimensional model is rendered in the user interface from the perspective of the video camera that provides the image, thus advantageously permitting side-by-side comparison by a remote user of the model and the resulting object. This feature is expressly claimed as a processor configured to “present in the user interface an image of the build volume from the camera *and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.*”

Id. (emphasis in italics added by the applicant). In the following paragraph, the applicant addressed why Taminger differs from the claims.

Taminger does not teach or suggest any processor that provides an interface to a remote user that includes both an image from a camera *and* a two-dimensional rendering of a model from the point of view of the camera. The outstanding rejection refers generally to col. 11, l. 20 - col. 12, l. 10 of *Taminger* as disclosing this feature, however, this passage of *Taminger* provides no specific teaching of such a user interface, and no suggestion that such a feature is useful, or any more general suggestion that visual rendering of a two-dimensional digital model might improve the disclosed devices.

Id. (emphasis added by the applicant); *see also* EX2012 (*Taminger*), 11:20-12:10.

As I discussed above in the Summary of the Prosecution History (*supra* Section

V.B), in allowing the claims, the examiner expressly referred to these arguments made by the applicant in concluding that Taminger does not teach the limitation of “presenting the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” *Id.* at 174.

126. As I also explained in the Summary of the Prosecution History (*supra* Section V.B), the applicant also expanded on his argument regarding Taminger, acknowledging that Taminger discloses a networking system and camera in which there are interconnected systems through a network with a user interface for user control, as well as that Taminger suggests remote control and monitoring of a three-dimensional process.

The cited passage of *Taminger* instead provides a range of teachings concerning possible instrumentation of an electron beam deposition system. For example, in this passage *Taminger* discloses various instrumentation subsystems such as lighting systems, networking systems, a camera, and a variety of sensors. Taminger appears to further contemplate that such systems and others may in general be interconnected through a network, and that a user interface may be provided for user control. “[T]he operator makes the appropriate command inputs through the computer user interface and the control software makes the appropriate commands to the various subsystems and manages the process.”

As most generously construed, *Taminger* thus suggests remote control and monitoring of a three-dimensional fabrication process; however, there is nothing in this general suggestion that specifically leads to the applicant’s claimed user interface, which provides both video and model views from the same point of view in order to permit side-by-side comparison of model and results by a remote user.

Taminger cannot anticipate the invention of claim 1 because *Taminger* does not teach a processor configured to provide a user interface [to a remote user] that includes an image of a build volume from a video camera *and* a two-dimensional projection of a three-dimensional model from the point of view of the video camera.

Id. at 160-61 (internal citations omitted) (emphasis in italics by the applicant) (citing *Taminger* (EX2012), at 11:20-27, 11:37-48, 12:3-7). Thus, the applicant concluded that *Taminger* does not lead to the claimed user interface that provides “both video and model views from the same point of view in order to permit side-by-side comparison of model and results by a remote user.” *Id.* at 161. Therefore, a POSITA would have understood that the prosecution history is consistent with the plain meaning of the claims, as described by the ’324 Patent, which require presenting the image and projection at the same time instead of presenting the image and projection at different times.

127. Under the plain meaning of the claims, the Mazumder-Mori combination, according to Petitioner’s second assertion, does not teach a user interface that presents an image and projection from the same point of view because a POSITA would have understood that the claims do not encompass presenting the image and projection at different times. As I discussed above with respect to Petitioner’s first assertion, Mazumder as used in the combination does not teach or disclose the display of virtual images from the same point of view as an image of the

camera because Mazumder only shows a video. *See* EX1004, 6:30-43, 8:14-17; *see also id.* at 2:34-50, 7:27-28.

128. Further, Mori as used in the combination does not teach or disclose a user interface that presents an image and projection at the same time. As I explained in my Overview of Mori (*supra* Section VI.B), Mori has two different disclosures of its machine status monitoring apparatus. As I explain below, neither of these disclosures teaches a user interface that presents an image and projection at the same time.

129. Mori describes the first apparatus/method in its Abstract and Summary of the Invention. The first apparatus/method in Mori displays either actual images or sectional images depending on whether the tool is hidden. When the tool is not hidden, Mori's first apparatus/method always displays actual images. *See* EX1005, [0022] ("Therefore, actual images in which the distal end of the tool is not hidden can be always displayed. Thereby, the operator can always visually recognize the machining status of a workpiece through the displayed images, wherein it is possible to sufficiently monitor the machining status."), [0029] ("Thus, according to the machining status monitoring method and machining status monitoring apparatus of the present invention, among the image data obtained from the actual imaging means, the image data in which the distal end of the tool is not hidden can be always displayed. Therefore, the operator can sufficiently monitor the machining status of

a workpiece.”), Abstract (“and a display control section for selecting one virtual CCD camera corresponding to the virtual two-dimensional image data in which the distal end of the tool is not hidden by the workpiece among the generated two-dimensional image data, and displaying the actual two-dimensional image data generated by the actual CCD camera corresponding to the selected virtual CCD camera on a display device”).

130. However, when the tool is hidden, Mori’s first apparatus/method displays sectional image data. *See* EX1005, [0024] (“In the case of hole machining or groove machining, the distal end of the tool is hidden by the workpiece. Therefore, even if a plurality of the actual imaging means is provided, the distal end of the tool is hidden by the workpiece in all of the actual two-dimensional image data generated by the actual imaging means. In this case, the operator cannot monitor the machining status of a workpiece through the images displayed on the display means.”), [0023] (“It may be configured so that the machining status monitoring apparatus has a sectional image generating means for, based on the model data updated by the model data updating means, generating sectional image data including the tool and a sectional shape appearing when at least the workpiece is cut along a plane passing through the distal end of the tool and the display control means checks, based on the virtual two-dimensional image data generated by the virtual image generating means, whether the distal end of the tool is hidden by the workpiece in all of the

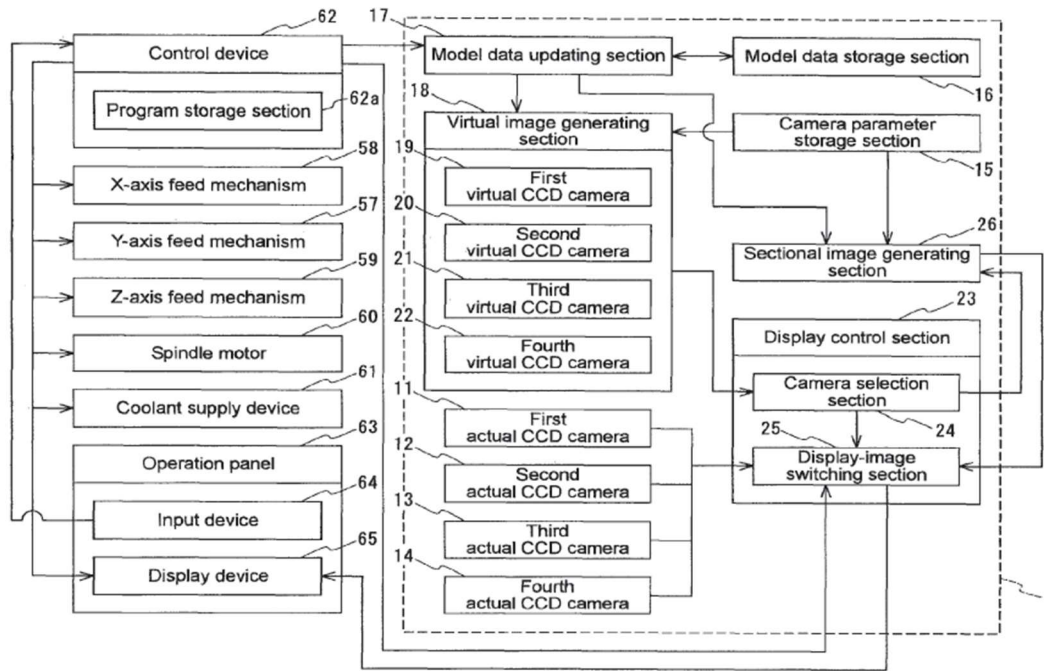
virtual two-dimensional images, and displays on the display means the sectional image data generated by the sectional image generating means when determining that the distal end of the tool is hidden in all of the virtual two-dimensional images.”); *see also id.* at [0025]-[0028].

131. I note that Mori’s first apparatus/method does not display the virtual images themselves. Rather, the first apparatus/method uses the virtual images to determine whether the distal end of the tool is hidden, which determines whether to display actual images (when the tool is not hidden) or sectional images (when the tool is hidden). *See e.g., id.* at [0023] (“displays on the display means the sectional image data generated by the sectional image generating means when determining that the distal end of the tool is hidden in all of the virtual two-dimensional images”); *see also id.* at Abstract (“a display control section for selecting one virtual CCD camera corresponding to the virtual two-dimensional image data in which the distal end of the tool is not hidden by the workpiece among the generated two-dimensional image data, and displaying the actual two-dimensional image data generated by the actual CCD camera corresponding to the selected virtual CCD camera on a display device”), [0022] (“Therefore, actual images in which the distal end of the tool is not hidden can be always displayed.”), [0025] (“when it is configured so that sectional image data is displayed on the display means in the case where the distal end of the tool is hidden in all of the virtual two-dimensional images”), [0029] (“among the

image data obtained from the actual imaging means, the image data in which the distal end of the tool is not hidden can be always displayed”). Thus, a POSITA would have understood that Mori’s first apparatus/method does not teach a user interface that provides both an image and a projection at the same time.

132. Similarly, a POSITA would have understood that Mori’s second apparatus/method does not teach a user interface that provides both an image and a projection at the same time. As I explained in my Overview of Mori (*supra* Section VI.B), Mori has two different disclosures of its machine status monitoring apparatus. Mori describes its second apparatus/method in its “Description of Embodiment” and the corresponding figures (Figures 1-12). A POSITA would have recognized that, compared to Mori’s first apparatus/method, Mori’s second apparatus/method adds the ability to switch to displaying virtual image data when coolant is being supplied. As shown in Figure 1, Mori’s second apparatus/method includes display-image switching section 25.

Fig. 1



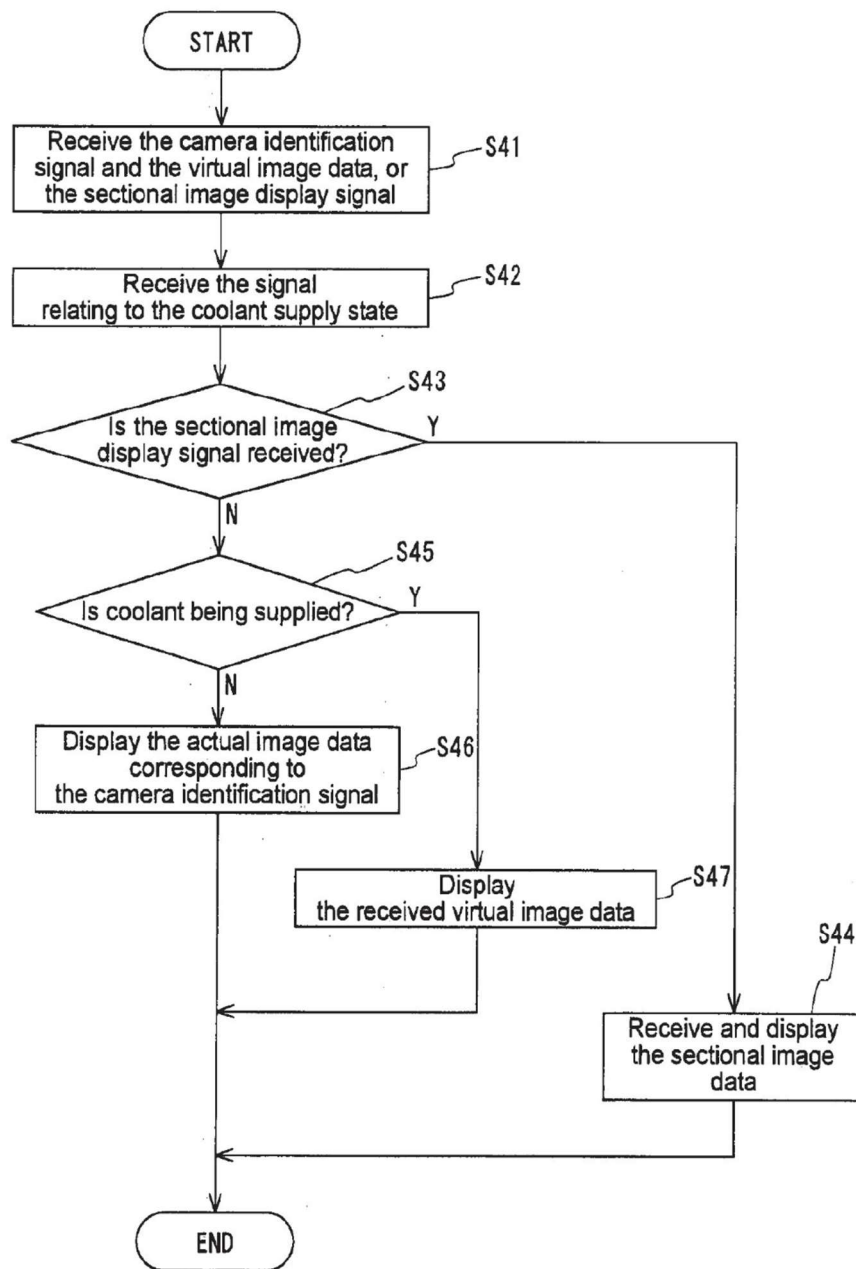
Id. at Fig. 1. As Mori explains, display-image switching section 25 switches the image displayed between one of three options: actual image data, virtual image data, or sectional image data. *See id.* at Fig. 1, [0070]. I understand that Dr. Wolfe testified the following about display-image switching section 25:

Q Why does display image switching section 25 switch the image display between the actual image data, the virtual image data, and the sectional image data?

A I'm not sure it gives us any details. It's an ordinary video switch. That's just a common -- common structure at the time.

EX2010 at 67:11-17. However, a POSITA would have recognized that Figure 9 of Mori provides a flow chart of the display-image switching section (25) to show its functionality.

Fig. 9



EX1005, Fig. 9, [0038] (“FIG. 9 is a flowchart showing a series of processes in a display-image switching section of the embodiment.”). If the sectional image display signal is received at step S43, because the tool is hidden, display-image

switching section (25) displays the sectional image data at step S44. *See id.* at [0071]-[0073], Fig. 9. However, if coolant is being supplied at step S45, display-image switching section (25) displays the virtual image data at step S47. *See id.* Otherwise, display-image switching section (25) displays the actual image data at step S46. A POSITA would have recognized that Mori does not teach displaying the actual image data with the virtual image data or sectional image data at the same time. Indeed, Mori teaches the opposite, that there are very good reasons never to show the actual image data with the virtual image data, because coolant is being supplied or not supplied, and never to show the actual image data with the sectional image data, because the tool is hidden or not hidden. *See id.*

133. I understand that Dr. Wolfe testified the following with respect to the purpose of Mori switching between actual images and virtual images based on whether coolant is being supplied:

Q What's your understanding of why Mori has a decision block for whether the coolant is being supplied?

A Because in this particular embodiment of Mori, the supply of coolant is very important to the user. And if there's a coolant problem, that would not be in the model, so it would be important to display the actual image.

EX2010 at 61:12-19. I disagree with Dr. Wolfe's explanation about a "coolant problem" being the reason why Mori has a decision block for whether coolant is being supplied. In my view, a person would need to be familiar with destructive

machining tools to understand Mori's disclosure. As I mentioned, I have teaching experience in machining processes dating back to the early 1990s. A person familiar with destructive machining tools would have understood that a coolant, such as a liquid, was commonly used to cool the contact portion between the tool and workpiece. *See* EX1005, [0044] ("a coolant supply device 61 for supplying coolant to the contact portion of the tool T and the workpiece W"), [0087] ("Further, since the operator can visually recognize the machining status of the workpiece W through the virtual image when coolant is being supplied to the contact portion of the tool T and the workpiece W, and through the actual image when coolant is not being supplied, the operator can monitor the machining status of the workpiece W even when coolant is being supplied."). Such a person would also have recognized that the use of coolant obstructs the view of the destructive machining tool. *See* EX2011 at 1-2 ("In order to introduce vision-based roughness measurement technique to CNC machines a number of scientific as well as technical issues needs to be overcome including scene visibility issue, coolant and cut chips obstructing the visual scene, camera mounting, lighting, Authorized licensed effects of machine vibration on the quality of obtained roughness measurement, selection of a roughness parameter to be employed, and machining parameters effects on acquired roughness measurement."). Although Exhibit 2011 is dated from 2011, its disclosure as to coolant and cut chips obstructing the visual scene are representative of what a

person familiar with destructive machining tools, such as me, would have understood by 2010. As shown in the image below, the use of coolant substantially obstructs an operator's view of what the cutting tool is doing when interacting with the workpiece.



EX2013 at 1. Although Exhibit 2013 is an article dated from 2022 about selecting different types of coolants, the image at the top of the article is representative of what a person familiar with destructive machining tools, such as me, would have understood by 2010 about the obstructions that the use of coolant presents. Thus, Mori has a decision block for whether coolant is being supplied because actual images of the tool will not be helpful to the operator and thus Mori switches to displaying virtual images. *See, e.g.,* EX1005, Fig. 9. Again, Mori's second

apparatus/method does not teach displaying actual images and virtual images at the same time.

134. I understand that Petitioner has argued (see Petition at 22 (“As such, the system displays virtual images of the model”)) and Dr. Wolfe has explained that “in the resulting Mazumder-Mori system, based on the teachings of Mori, the system displays virtual images of the model in the user interface as if captured from ‘virtual CCD cameras’ that ‘are respectively arranged at the same positions and in the same orientations as the actual CCD cameras.’” EX1003, ¶110, 135 (citing EX1005, [0061]-[0062]). However, I also understand that Dr. Wolfe testified that the proposed combination of Mazumder and Mori does not include cooling as Mori teaches. EX2010, 57:21-58:3 (“Q And you mentioned that you were not using all aspects of Figure 9 in the combination of Mazumder and Mori. Right? **A Correct. For example, the coolant is not relevant.**”), 61:15-20 (“Q Would there be any other reason that a person of ordinary skill in the art would understand Mori to be considering whether a coolant is being supplied, besides there being a coolant problem? **A There could be many. Again, I didn’t rely on the supplying of coolant as part of my combination. And I don’t think that the teachings of Mori with regard to showing images are in any way dependent on the way that it makes decisions related to cooling.**”). As I explained above in this section and in the Overview of Mori above, Mori teaches two different disclosures of its machine

status monitoring apparatus and method. *Supra* Section VI.B (Overview of Mori). The first apparatus/method displays sectional image data when the tool is hidden by the workpiece and actual image data otherwise. *See* EX1005, Abstract, [0004]-[0029]. The first apparatus/method does not display virtual images. *See id.* Mori's second apparatus/method displays sectional image data when the tool is hidden, virtual image data when coolant is supplied, and actual image data otherwise. *See* EX1005, Fig. 9, [0071]-[0073]. Petitioner and Dr. Wolfe conclude that the combination would display virtual images but as Dr. Wolfe testified the proposed combination of Mazumder and Mori does not include cooling as Mori teaches. EX2010, 57:21-58:3, 61:15-20. Without Mori's teachings about cooling, as Dr. Wolfe testified, a POSITA would have understood that the combination does not teach displaying the virtual images at all because Mori teaches that virtual images are displayed when cooling is supplied. *See* EX1005, Fig. 9, [0071]-[0073]; *see also* EX2010, 57:21-58:3, 61:15-20.

135. Because Mori's first apparatus/method and second apparatus/method do not teach presenting actual images and virtual (or sectional) images at the same time, as I discuss above, a POSITA would have understood that the Mazumder-Mori combination does not teach presenting actual images and virtual (or sectional) images at the same time.

136. With regards to Petitioner's third assertion that the combination would have been modified so that the video camera images and virtual images are presented simultaneously, I understand that Petitioner asserts that presenting both actual and virtual images in the combination would have enabled the user to visually compare the two images. *See* Petition at 11, 23-24. However, a POSITA would have understood that there is no motivation to combine or modify the Mazumder-Mori combination to present actual and virtual images at the same time.

137. On page 24, Petitioner cites Paragraph 113 of Dr. Wolfe's declaration in support of its third assertion. This paragraph states in full as follows:

A POSITA would have additionally recognized that, in the predictable combination of Mazumder with Mori, it would have been obvious to display the actual image and the virtual image of the product simultaneously, which would have helped further achieve the advantages that I discussed above. For example, the presentation of the actual images captured by the camera and the virtual images simultaneously within the user interface would have beneficially aided the remote user to more easily visually compare the actual image and virtual image to quickly identify any defects or problems with the fabrication process. Indeed, this is consistent with both Mazumder's goals and Mori's suggested benefits.

EX1003, ¶113. I disagree with Dr. Wolfe's conclusion. As I discussed above with respect to Petitioner's second assertion, neither Mazumder nor Mori teach displaying both the actual image and virtual image. Further, Dr. Wolfe does not cite any evidence in Paragraph 113 of his declaration.

138. I understand that Petitioner made a similar argument on page 11 of the Petition and cited to Mazumder (EX1004), 7:27-28, Mori (EX1005), [0061]-[0062], and Paragraph 85 of Dr. Wolfe's Declaration. *See* Petition at 11. The cited portion of Mazumder states "wherein the manufacturing information includes visual images of the product being fabricated." EX1004, 7:27-28. A POSITA would have understood that Mazumder's language simply refers to its disclosure of displaying a video. *See* EX1004, 6:36-43, 8:14-17. The cited portion of Mori states as follows:

[0061] Next, a three-dimensional space having the same coordinate system as the coordinate system of the machine tool 50 is virtually set (step S23). And, based on the read parameters and the received model data (the model data of the tool T, workpiece W and a part of the table 56 among the model data of the entire machine tool 50), in the set virtual three-dimensional space, three-dimensional models of the tool T, workpiece W and a part of the table 56 are arranged and virtual CCD cameras 19, 20, 21 and 22 (first virtual CCD camera 19, second virtual CCD camera 20, third virtual CCD camera 21 and fourth virtual CCD camera 22) are set and arranged as many as the actual CCD cameras 11, 12, 13 and 14 (step S24).

[0062] The fi[r]st virtual CCD camera 19 corresponds to the first actual CCD camera 11; the second virtual CCD camera 20 corresponds to the second actual CCD camera 12; the third virtual CCD camera 21 corresponds to the third actual CCD camera 13; and the fourth virtual CCD camera 22 corresponds to the fourth actual CCD camera 14. Since the virtual CCD cameras 19, 20, 21 and 22 are respectively arranged at the same positions and in the same orientations as the actual CCD cameras 11, 12, 13 and 14 based on the read extrinsic parameters, the view points of the virtual CCD cameras 19, 20, 21 and 22 match the view points of the actual CCD cameras 11, 12, 13 and 14, respectively. Since the intrinsic parameters of the virtual CCD cameras 19, 20, 21 and 22 are respectively set to be the same as the intrinsic parameters of the actual CCD cameras 11, 12, 13 and 14 based on the read intrinsic parameters, the conditions of the virtual CCD cameras 19, 20, 21 and

22 match the conditions of the actual CCD cameras 11, 12, 13 and 14, respectively.

EX1005, [0061]-[0062]. A POSITA would have understood that these portions of Mori simply refer to the arrangement of the virtual CCD cameras according to the arrangement of actual CCD cameras such that each virtual camera corresponds to an actual camera. As I explained above, Mori's first apparatus/method does not teach displaying the virtual image data (but rather teaches displaying the actual or sectional image data) and Mori's second apparatus/method does not teach displaying the actual and virtual images at the same time to allow for side-by-side comparison because Mori switches between them based on whether coolant is being supplied. *See, e.g.* EX1005, Abstract, [0022]-[0029], Fig. 9, [0071]-[0073], [0087]; *supra* Section VI.B (Overview of Mori).

139. Finally, paragraph 85 of Dr. Wolfe's declaration addresses the Mazumder-Mori combination by citing Henke (EX1014) to assert that "a POSITA would have recognized that such observation of the process and visual comparison to the intended outcome would have allowed the user to 'adjust' aspects of the model or the fabrication process (e.g., temperature of the build environment) 'in case of fault . . . to achieve a fault free solution.'" EX1003, ¶85 (citing EX1014, 5). I disagree with Dr. Wolfe's conclusion. Henke does not teach a visual comparison and does not show an image of a build volume of a three-dimensional printer much less a projection of a three-dimensional model. *Supra* Section VI.J (Overview of Henke);

EX1014, 3-5. Henke’s model is a simulation of a control algorithm. *See id.* I discuss Henke in more detail below when addressing Ground 2A of the Petition, which involves the combination of Kritchman, Tay, and Henke. *Infra* Section X (Ground 2A). Thus, there is no motivation to modify the Mazumder-Mori combination to present both the image and projection such that they are presented at the same time.

140. Thus, there is no teaching in the Mazumder-Mori combination of “present[ing] in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” EX1001, at 27:25-35; *supra* Section II (“The Challenged Claims of the ’324 Patent”), Claim Element 1.d.

C. Claim 5

141. Claim 5 of the ’324 Patent recites “[t]he device of claim 1 wherein the two-dimensional projection is dynamically updated to correspond to a state of physical completion of the object.” EX1001, at 27:46-48.

142. I understand that Petitioner contends that in the Mazumder-Mori combination, in which the automated manufacturing process is an additive rather than substrative process, the virtual image from Mori is dynamically updated to correspond to a state of the physical completion of the product. *See* Petition at 26. Alternatively, Petitioner argues that displaying video camera images is sufficient to teach claim 5 under the infringement contentions. *See id.*

143. Regarding Petitioner’s alternative assertion, as I explained above for claim 1, there is no assertion that the same images satisfy both the image and projection. *Supra* Section VII.B (Claim 1); *see also* EX1016, at 41-44, 46. Therefore, a video does not satisfy both the image and projection. *See id.* Thus, a POSITA would have understood that the Mazumder-Mori combination does not teach claim 5 under Petitioner’s alternative assertion.

144. Regarding Petitioner’s primary assertion, I disagree with Petitioner that there would have been a motivation to combine Mazumder and Mori in the manner that it proposes in claim 5. I also disagree that the proposed combination would be predictable. As I discuss below, Mori’s teachings about its virtual images are dependent on a destructive machining system and the nature of its operation.

145. Mori describes generating its virtual and sectional images based on model data that corresponds to “the entire machine tool 50.” Namely, The model data updating section (17) “updates the model data of the entire machine tool 50 stored in the model data storage section 16” including data for the bed (51), first saddle (52), second saddle (53), spindle head (54), spindle (55), table (56), tool (T), and workpiece (W). *Id.* at [0052]-[0054]; *see also id.* at Fig. 5, [0054]-[0058] (describing Fig. 5). In addition, the virtual image generating section (18) generates virtual image data of the tool, workpiece, and part of table 56 based on parameters in camera parameter storage section (15) and model data updating section (17). *Id.*

at [0059]; *see also id.* at Figs 6.-7, [0060]-[0064] (discussing Figs. 6-7), [0014], [0018]-[0019]. More specifically, Mori explains that “if the model data of the tool T and the model data of the workpiece W partially overlap each other, the model data updating section 17 calculates the overlap area (cutting area), and generates the model data of the workpiece W so that this cutting area is removed therefrom.” *Id.* at [0056]. A POSITA would have understood that these teachings are very specific to a destructive machine tool. For example, a cutting area that overlaps between the tool and workpiece, as well as removing a cutting area from model data, are unique problems to destructive machining tools. Thus, a POSITA would have recognized that Mori does not provide any indication of how to generate virtual or sectional images or how to update model data for an entire three-dimensional printer. Similarly, a POSITA would have recognized that Mazumder does not provide any indication of how to generate virtual images. *See, e.g.,* EX1004 at 3:58 (“CAD/CAM data and sensor updates”).

146. Further, there is no motivation for a POSITA to use virtual images from Mori’s virtual CCD cameras in a three-dimensional printer because the actual CCD cameras provide a view of the object being fabricated. As Mori explains, its virtual CCD cameras are “set and arranged” in the same way as its actual CCD cameras, in which each virtual CCD camera corresponds to a particular actual CCD camera.

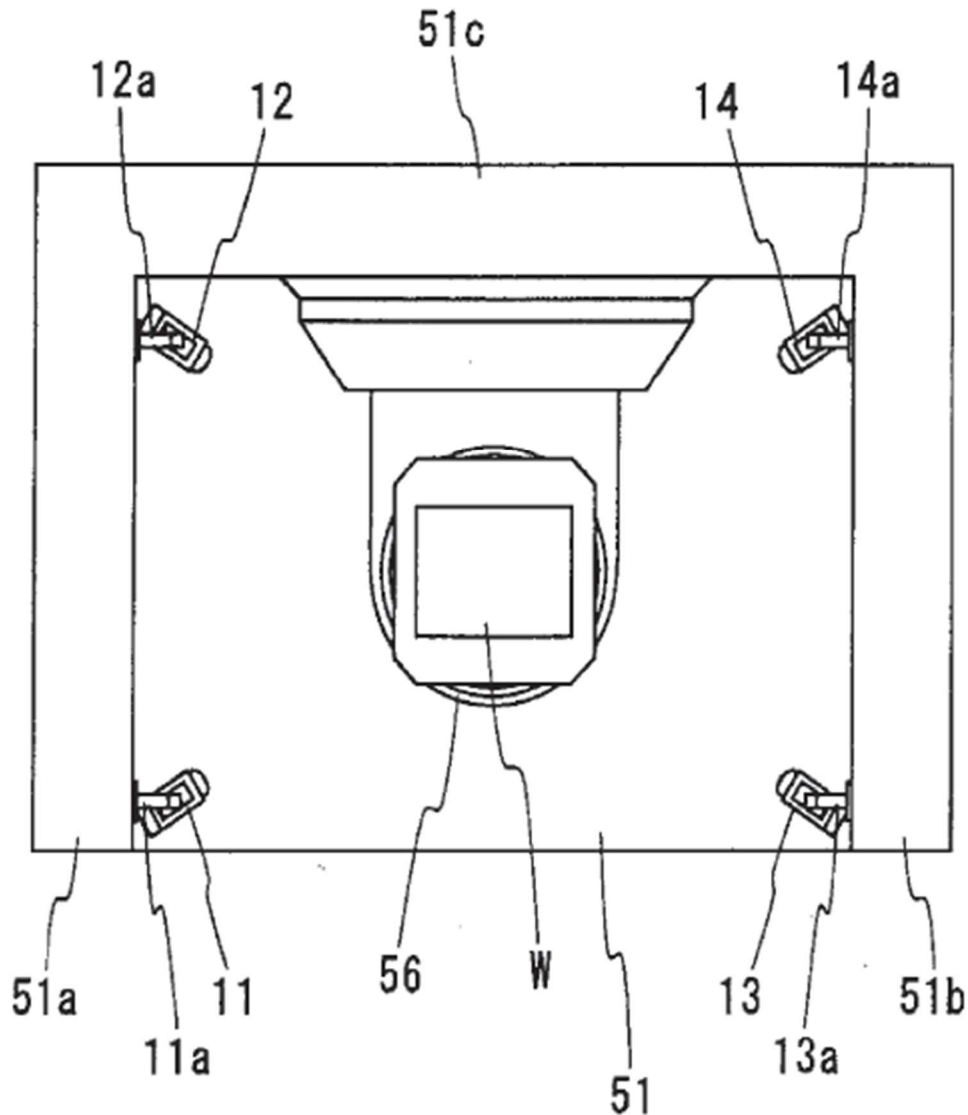
[0061] Next, a three-dimensional space having the same coordinate system as the coordinate system of the machine tool 50 is

virtually set (step S23). And, based on the read parameters and the received model data (the model data of the tool T, workpiece W and a part of the table 56 among the model data of the entire machine tool 50), in the set virtual three-dimensional space, three-dimensional models of the tool T, workpiece W and a part of the table 56 are arranged and virtual CCD cameras 19, 20, 21 and 22 (first virtual CCD camera 19, second virtual CCD camera 20, third virtual CCD camera 21 and fourth virtual CCD camera 22) are set and arranged as many as the actual CCD cameras 11, 12, 13 and 14 (step S24).

[0062] The first virtual CCD camera 19 corresponds to the first actual CCD camera 11; the second virtual CCD camera 20 corresponds to the second actual CCD camera 12; the third virtual CCD camera 21 corresponds to the third actual CCD camera 13; and the fourth virtual CCD camera 22 corresponds to the fourth actual CCD camera 14. Since the virtual CCD cameras 19, 20, 21 and 22 are respectively arranged at the same positions and in the same orientations as the actual CCD cameras 11, 12, 13 and 14 based on the read extrinsic parameters, the view points of the virtual CCD cameras 19, 20, 21 and 22 match the view points of the actual CCD cameras 11, 12, 13 and 14, respectively. Since the intrinsic parameters of the virtual CCD cameras 19, 20, 21 and 22 are respectively set to be the same as the intrinsic parameters of the actual CCD cameras 11, 12, 13 and 14 based on the read intrinsic parameters, the conditions of the virtual CCD cameras 19, 20, 21 and 22 match the conditions of the actual CCD cameras 11, 12, 13 and 14, respectively.

Id. at [0061]-[0062]. As shown below, Mori illustrates that each of the four actual cameras are located at different locations around the machine tool.

Fig. 3



Id. at Fig. 3. As discussed, Mori's second apparatus/method displays virtual images when coolant is supplied and sectional images when the tool is hidden. *See e.g., id.* at Fig. 9. However, a POSITA would have recognized that, in a three-dimensional

printer, the deposition head is at or above the top surface of the object being fabricated, whereas in Mori's machining tool, the tool is hidden in a hole or groove. *See e.g.*, EX1001 ('324 Patent), at Fig. 1 (object 112); EX1005 (Mori), at [0085] ("Therefore, even if machining in which the distal end of the tool T is hidden by the workpiece W, such as hole machining or groove machining, is performed, the operator can monitor the machining status of the workpiece W through the displayed images."). If Mori's multiple CCD camera solution were used in a three-dimensional printer, a POSITA would have recognized that at least one of the cameras (such as the four cameras shown in Figure 3 of Mori above) would have provided an unobstructed view of the deposition head. Thus, a POSITA would have understood that there is no motivation to use virtual camera images, such as those generated in Mori, in a three-dimensional printing solution. Therefore, the combination does not teach claim 5.

147. Moreover, if a POSITA were to follow Petitioner's assertion to adapt Mori's virtual images based on model data updates for an entire destructive machining tool for a three-dimensional printer, there would have been no reasonable expectation of success. A POSITA would have understood that three-dimensional printers fabricate objects in an additive manner. As explained above, unlike Mori's destructive machining tool, the deposition tool paths in three-dimensional printing do not cut into the material being deposited. Rather, the deposition head of the three-

dimensional printer is located at or above the surface of the object being fabricated. *See e.g.*, EX1001 ('324 Patent), at Fig. 1 (object 112). And, as explained above, neither Mazumder nor Mori provide any indication to a POSITA of how to adapt virtual image generation for a destructive machining tool for a three-dimensional printer. Thus, a POSITA would not have had a reasonable expectation of success in adapting Mori's teachings about virtual image generation into the three-dimensional printer of the combination. Therefore, the Mazumder-Mori combination does not teach claim 5 for this additional reason.

D. Claim 6

148. Claim 6 of the 324 Patent recites "[t]he device of claim 1 wherein the two-dimensional projection is a video image from the video camera." EX1001, at 27:49-50. I understand that Petitioner asserts Mazumder describes displaying a video image from a video camera. *See* Petition at 26. Petitioner also asserts that the same images in Mazumder for claims 1 and 19 are "an image of the build volume from the video camera" and for claim 6 are "the two-dimensional projection is a video image from the video camera." *See* Petition at 20, 26. I understand that Petitioner points to the images that are transmitted remotely in Mazumder to be displayed "on a TV screen or shown on the remote computer monitor as streaming video." EX1004, 6:36-43, 8:14-17 (cited by Petition at 22).

149. Under Petitioner’s interpretation of the claims, the same images displayed and captured by a video camera would satisfy both claims 1 and 19, as well as claim 6. However, as I explained above for claim 1, there is no assertion that the same images satisfy both the image and projection in the claims. *Supra* Section VII.B (Claim 1); *see also* EX1016, at 41-44, 46. Therefore, Mazumder’s video cannot satisfy both the image and projection. *See id.*

150. Moreover, a POSITA would have recognized that the ’324 Patent does not suggest that the same images can be both the image and video image from the video camera. *See, e.g.*, EX1001, at 22:53-55 (“This may, for example, include a digital still image (which may be updated periodically) or a video image captured from a video camera at the three-dimensional printer.”), 22:66-23:2 (“For example, the user interface may include at least one control to capture a frame of data from the video camera as a video image and to transmit the video image to a remote location through the data network.”).

151. Thus, a POSITA would have understood that the Mazumder-Mori combination does not teach claim 6.

E. Claim 19

152. Claim 19 is an independent claim with elements similar to claim 1. For example, claim 1 recites “the processor further configured to provide a user interface to a remote user accessing the device through the network interface, and to present

in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera” (claim element [1.d]), whereas claim 19 recites “providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera” (claim element [19.d]) EX1001, at 27:29-35, 28:41-46.

153. For claim element [19.d], Petitioner refers back to its arguments for claim element [1.d]. *See* Petition at 29. As I explained for claim 1, there is no teaching in the Mazumder-Mori combination of “present[ing] in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” EX1001, at 27:25-35; *supra* Section II (“The Challenged Claims of the ’324 Patent”), Claim Element 1.d; *supra* Section VII.B (claim 1). For at least these reasons, there is no teaching in the Mazumder-Mori combination of a user interface that “presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” EX1001, at 28:41-46; *supra* Section II (“The Challenged Claims of the ’324 Patent”), Claim Element 19.d.

VIII. GROUNDS 1B-1G: CHALLENGED CLAIMS WOULD NOT HAVE BEEN OBVIOUS

154. I understand that Petitioner has asserted several grounds, Ground 1B-1G, that do not separately challenge independent claims 1 and 19, and dependent claims 5 and 6. *See* Petition at 1; *see also* Petition at 30-54.

Ground	Claims	References Cited
1A	1, 3, 5-7, 9-10, and 19-22	Mazumder (USP 6,580,959; EX1004) in view of Mori (US 2010/0063615; EX1005)
1B	4	Mazumder and Mori in further view of Tian (US 2009/0015668; EX1006)
1C	8	Mazumder and Mori in further view of Hull (JP2000218708; EX1007, translated in EX1008)
1D	11	Mazumder and Mori in further view of Seki (USP 5,278,479; EX1009)
1E	17	Mazumder and Mori in further view of Waehner (US 2006/0171452; EX1010)
1F	18	Mazumder and Mori in further view of Lan (EX1011)
1G	20-22	Mazumder and Mori in further view of Anderson (US 2004/0207662; EX2012)

Thus, it is my opinion that Grounds 1B-1G fail to teach their respective challenged dependent claims for at least the reasons I provided above for Ground 1A with respect to independent claims 1 and 19. *Supra* Section VII.B (Claim 1), VII.E (Claim 19).

IX. GROUND 1C: CLAIM 8 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 1C (COMBINATION OF MAZUMDER, MORI, AND HULL)

155. In Ground 1C of the Petition, Petitioner asserts that claim 8 is obvious over the combination of Mazumder, Mori, and Hull. *See* Petition at 33-34.

156. I have reviewed Petitioner's challenges in Ground 1C, and it is my opinion that Ground 1C fails to teach or suggest all elements of claim 8 for the additional reasons provided below.

157. Claim 8 of the '324 Patent recites "[t]he device of claim 1 wherein the processor is configured to provide credential-based access to the user interface." EX1001, at 27:54-55.

158. I understand that Petitioner asserts Hull discloses that a remote user must enter a password to obtain access to a local fabrication system for a three-dimensional printer. *See* Petition at 34. Petitioner also asserts that in the Mazumder-Mori-Hull combination, credential-based access would have been required to access the local site and the three-dimensional printer and thus teaches claim 8. *See id.* I understand that Dr. Wolfe came to similar conclusions. EX1003, ¶155.

159. I disagree with Petitioner and its expert. A POSITA would have understood that Hull does not disclose that a remote user must enter a password to access the local fabrication system for a three-dimensional printer. Rather, a POSITA would have understood that the remote user in Hull already has access to the local fabrication system and three-dimensional printer and thus there would be

no reason for credentials to access the local fabrication system and three-dimensional printer in the Mazumder-Mori-Hall combination.

160. In particular, Hull discloses that its “remote user” is at the fabrication system of the local site, at a computer. A POSITA would have recognized that Hull refers to this computer as a process computer or control computer, which runs MS-DOS, is connected to a slice computer via Ethernet, and merges sliced files for printing. *See* EX1008, [0458], [0508] (disclosing that the slice and control computers are connected via Ethernet), [0143] (disclosing that the slice and process computers are connected via Ethernet); *see also id.* at [0143] (disclosing that the process computer uses MS-DOS), [0248] (disclosing that the control computer uses MS-DOS); *see also id.* at [0143] (disclosing that the process computer merges object and support files), [0337] (disclosing that a merge “process step[]” is “run on” the control computer), Figs. 46-47 (reproduced below).

[FIG. 46]

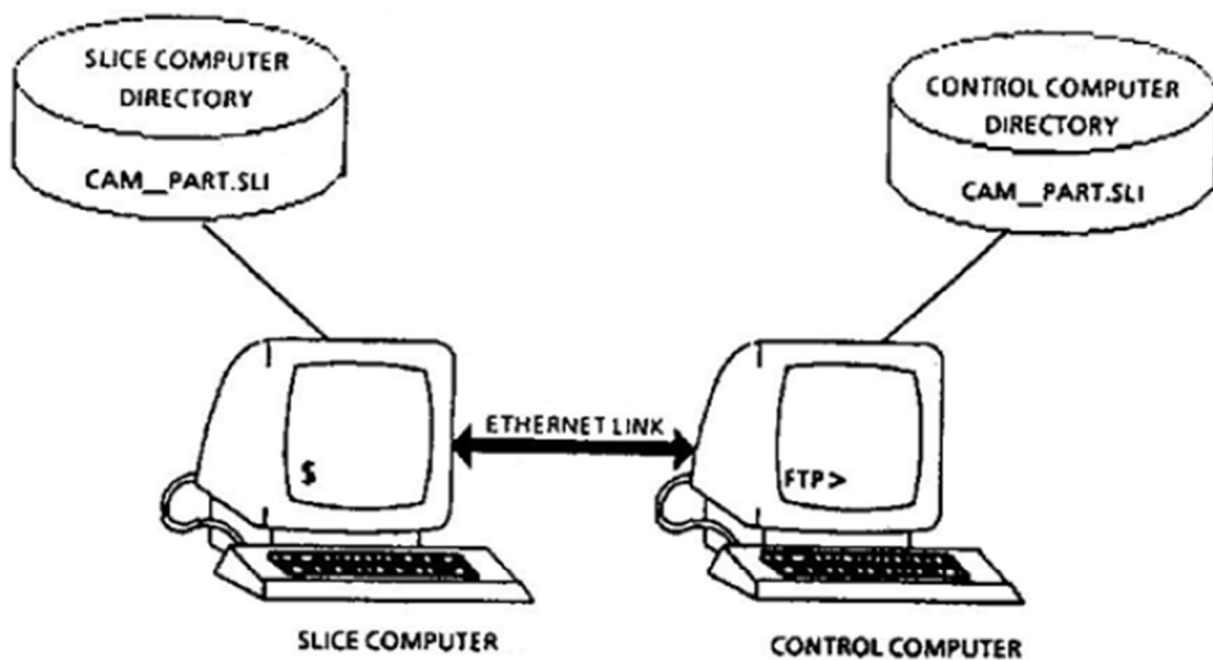


FIG. 46

[FIG. 47]

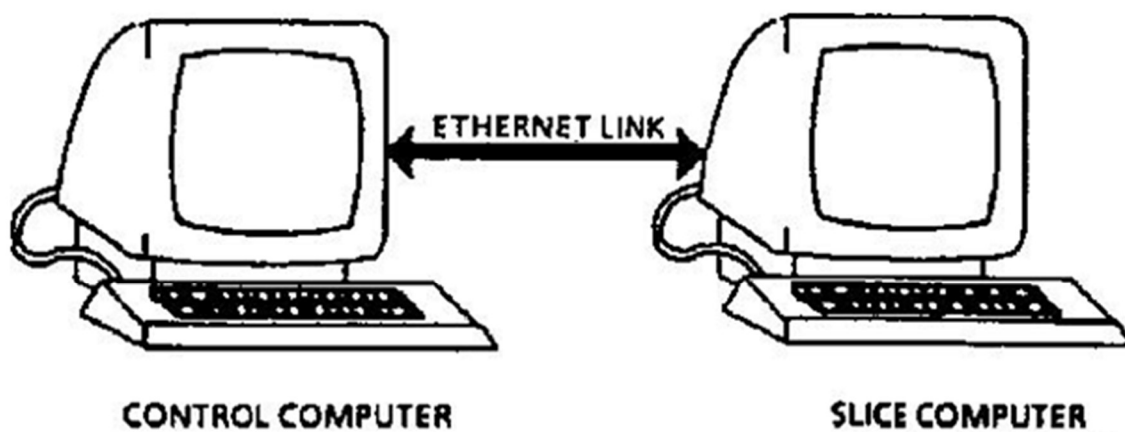


FIG. 47

161. Hull describes that its “remote user” is a local user at the process/control computer and that this user must type in the address of the “slice computer” that is connected via Ethernet to the process/control computer. *See* EX1008 at [0157] (“In response to (to) prompt, type address of slice computer and press ENTER” and “In response to Remote user prompt, type the name of your directory and press ENTER”). This description in Hull is found in Section 8.2, entitled “How to Transfer Files from Slice Computer to Process Computer,” which is part of Section 8 of Hull, which is entitled “SLA-1 Operation.” *See id.* at [0156]-[0157]. As Hull explains, and a POSITA would have recognized, SLA refers to “a stereolithography apparatus,” which is the three-dimensional printer in Hull. *See id.* at [0006], Fig. 13a. Hull also explains in Section 8.1, which is the “Turn-On Procedure” for the SLA, the steps for a user to start using the SLA. *See id.* at [0156]. With respect to a remote user, Hull explains that a “remote user” is an option to remotely operate the slice computer from the keyboard of the control computer. *See id.* at [0499] (“REMOTE USER A Network Menu option used to remotely operate the Slice Computer from the Control Computer keyboard.”). Thus, a POSITA would have recognized that the remote user in Hull is local to the three-dimensional printer and can remotely operate the slice computer from the keyboard of the process/control computer. *See id.*

162. After entering the address of the slice computer, a POSITA would have understood that Hull's "remote user" that is local at the process/control computer then provides a password to access the slice computer in order to "get" the sliced files from the slice computer to the process/control computer. This process is shown by the excerpt of Hull below.

f. In response to Remote user prompt, type the name of your directory and press ENTER.

g. In response to Password prompt, type your password and press ENTER.

h. In response to (ftp) prompt, type GET and press ENTER.

i. In response to (remote-file) prompt, type name of desired file usually followed by .sli (example - test.sli) and press ENTER.

j. In response to (local-fill test .sli in default) prompt, press ENTER (unless you want to change name).

(The FTP routine will now transfer the file to the process computer. It will prompt when the transfer is complete.)

k. To exit from FTP, in response to (ftp) prompt, type BYE and press ENTER. (The sliced files have now been transferred to the SLA-1 process computer.)

Id. at [0157]. Thus, a POSITA would have understood that the "remote user" in Hull does not need a password to access the local fabrication system and three-dimensional printer because the user already has access to the local fabrication system and three-dimensional printer. Therefore, a POSITA would have understood that there is no rationale to require credential-based access for the remote user to access the local site with the local fabrication system / three-dimensional printer, or

to require credential-based access to a user interface provided by the local site with the local fabrication system / three-dimensional printer in the Mazumder-Mori-Hull combination. *See id.*

163. Accordingly, the combination in Ground 1C fails to teach or suggest all the elements of claim 8. In addition, the combination of Ground 1C fails to teach or suggest all elements of claim 8 for the additional reasons I discussed above.

X. GROUND 2A: CLAIMS 1, 3, 5-7, 9-10, 19-22 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 2A (COMBINATION OF KRITCHMAN, TAY, AND HENKE)

164. In Ground 2A of the Petition, Petitioner asserts that claims 1, 3, 5-7, 9-10, and 19-22 are obvious over the combination of Kritchman, Tay, and Henke. *See* Petition, at 54-55 (Overview of Kritchman), 56-57 (Overview of Tay), 58-59 (Overview of Henke), 59-64 (Asserted Kritchman-Tay-Henke Combination), 64 (1.pre (preamble)), 64-65 (1.a), 65-66 (1.b), 66-68 (1.c), 69-74 (1.d), 74-76 (claim 3), 76 (claim 5), 76-78 (claim 6), 78-79 (claim 7), 79 (claim 9), 80 (claim 10), 80 (19.pre (preamble)), 80-82 (19.a), 82 (19.b, 19.c, 19.d), 83 (claim 20), 83-84 (claim 21), 84 (claim 22).

165. I have reviewed Petitioner's challenges in Ground 2A, and it is my opinion that Ground 2A fails to teach or suggest all elements of claims 1, 3, 5-7, 9-10, and 19-22. I explain my opinion below in detail.

A. Field of Invention of Henke and '324 Patent

166. I understand that Petitioner has asserted a combination of Kritchman, Tay, and Henke in which “[m]ultiple reasons would have prompted a POSITA to further apply Henke’s suggestions to the Kritchman-Tay system.” *See* Petition at 61. As I discuss below, a POSITA would have understood that Henke and the '324 Patent are not in the same field of invention. In particular, Henke teaches tools for simulating and testing control algorithms whereas the 324 Patent teaches a three-dimensional printer whose operation is controlled by a user interface to a remote user that presents both an image of the build volume and a two-dimensional projection of a three-dimensional model from the same point of view.

167. Henke is entitled “Rapid Prototyping Modules for Remote Engineering Applications.” EX1014 at Title. Henke’s hardware is a system for testing a water-level control algorithm.

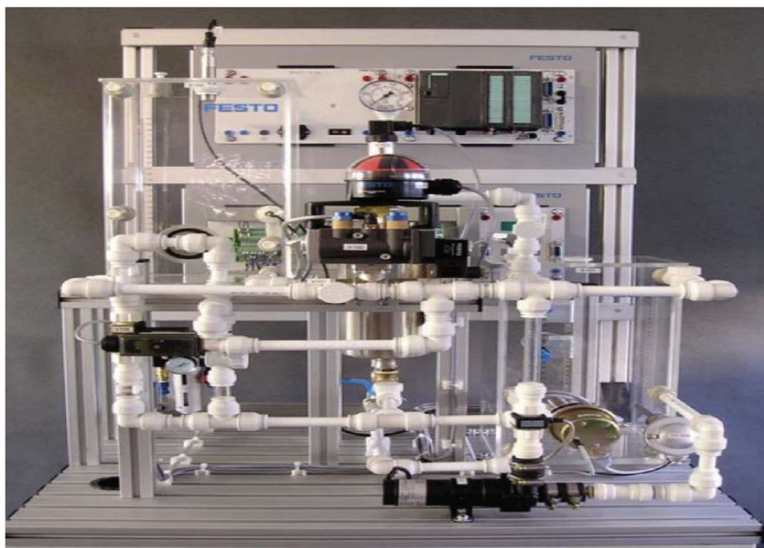


Figure 3. Hardware model of the Water level control unit

Id. at 3. As Henke explains, “This contribution describes a concept for an integration of microcontroller- and FPGA- based Rapid Prototyping modules into a Remote Lab system and its implementation.” *Id.* at 1. In particular, “Students have the possibility to test a designed control algorithm directly within a hardware environment by uploading a source file to the Remote Lab server.” *Id.* “During the *synthesis* phase, code for the processor (software) and/or for the programmable logic (hardware) is generated by different design tools. Both parts (software and hardware) can be executed and evaluated on the hardware platform directly.” *Id.* at 3. When testing the algorithm on the hardware platform, the student can “watch the laboratory procedure by supervising the model and environmental variables inside an I/O monitor or by observing the hardware model directly via a Web-Cam.” *Id.* As shown in Figure 3 above, the hardware consists of a water level control unit that is used for testing a water-level control algorithm.

168. As Henke explains, “Generally, only a simulation of predetermined malfunctions is possible” and thus “a fault free design algorithm finally should be tested on real electro-mechanical models (e. g. the Water level control unit, shown in Figure 3) in the Remote Laboratory (rapid prototyping).” *Id.* at 3. Thus, Henke’s remote tools for simulating, testing, and verifying the functionality of control algorithms allow students to achieve a fault free algorithm by testing the algorithms on real hardware that is shared with others. *See id.* at 1 (“It is more and more

necessary to allow and organize a shared use of equipment, but also specialized software, for example simulators.”).

169. Henke also explains its concerns. Reducing travel and improving education by removing the “obstacles of cost, time-inefficient use of facilities, inadequate technical support and limited access to laboratories.” EX1014 at 1; *see also id.* at 8 (“Using both, online tool support and laboratories, has the potential of removing the obstacles of cost, time-inefficient use of facilities, inadequate technical support and limited access to design and laboratory resources.”). Henke also seeks to “benefit” people with “special needs.” *Id.* at 1, 8. In this manner, Henke seeks to share real hardware between students because “disturbances can occur, causing special working conditions” that are “contrary to simulation” and because real hardware should “stimulate student’s interest in the design of safety critical control systems.” *Id.* at 3-4.

170. In contrast to Henke, as I explained above, the ’324 Patent teaches a three-dimensional printer whose operation is controlled by a user interface to a remote user that presents both an image of the build volume and a two-dimensional projection of a three-dimensional model from the same point of view. *Supra* Section VII.A (Field of Invention of Mori and ’324 Patent). The hardware implemented in the ’324 Patent is a three-dimensional printer or additive manufacturing/fabrication. EX1001, Figs. 1, 3. The claims of the ’324 Patent relate to a device or method that

comprises “a three-dimensional printer including a build volume” in Claims 1 and 19. *Id.* at 27:20-21, 28:31-33. The title of the ’324 Patent is “Networked Three-Dimensional Printing” and the Abstract refers to tools for “networked use of three-dimensional printers.” *Id.* at Title, Abstract; *see also id.* at 1:34-35. The ’324 Patent includes figures that illustrate printing environments, methods, and a user interface. *See id.* at 1:41-61; *see also id.* at 1:65-66 (“Described herein are devices and methods for using networked three-dimensional printers”). As described by the ’324 Patent, three-dimensional printing refers to “any and all such additive fabrication process unless a different meaning is explicitly stated or otherwise clear from the context.” *Id.* at 2:8-13. As I discussed above in my Summary of the ’324 Patent, it describes providing a user interface to a remote user that presents an image of the build volume of the three-dimensional printer within which the three-dimensional model is being fabricated as an object and a two-dimensional projection of the three-dimensional model that is from the same point of view as the image. *Supra* Section V.A (Summary of the ’324 Patent); *see also* EX1001, 24:43-25:5, Fig. 7.

171. A POSITA would have understood that the ’324 Patent does not teach a concern with remotely testing the control algorithms of the three-dimensional printer. Thus, Henke is not in the same field as the ’324 Patent.

B. Henke is not reasonably pertinent

172. In addition to Henke not being in the same field as the '324 Patent, as I discussed above, a POSITA would have understood that Henke is not reasonably pertinent to the problem faced by the inventor of the '324 Patent.

173. As I discussed above, Henke's tools for simulation, hardware testing, and verifying the functionality of control algorithms allows students to achieve a fault free algorithm. *See, e.g.*, EX1014 at 1, 3. Henke expresses concerns with reducing travel, improving education, benefitting people with special needs, and sharing hardware between students. *See id.* at 1, 8, 3-4.

174. However, such problems and concerns are not reasonably pertinent to the problem that the inventor of the '324 Patent was concerned with, which was to enable remote users to control and monitor three-dimensional printers fabricating three-dimensional objects. *See* EX1001, Abstract, 1:32-38, 1:41-61; 1:65-2:5, 2:8-16, Figs. 1, 3-7, 24:43-25:5, 27:20-21, 28:31-33. As I discussed above, the hardware of the '324 Patent is a three-dimensional printer (EX1001, Figs. 1, 3), the claims of the '324 patent recite "a three-dimensional printer including a build volume" (*id.* at 27:20-21, 28:31-33), and the Title and Abstract refers to tools for "networked use of three-dimensional printers." *Supra* Section V.A (Summary of the '324 Patent). A POSITA would have understood that Henke's hardware (e.g., a water level control lab tool) is not structurally similar to the '324 Patent and its three-dimensional

printers. *See, e.g.*, EX1014 at 1, 3, 5, Fig. 3. Nor does Henke's hardware function in a similar manner to the hardware in the '324 Patent. For instance, Henke does not fabricate any objects or build any objects. *See id.* Moreover, a POSITA would have recognized that the term "rapid prototyping" has many uses in different contexts. In the context of Henke, students are rapid prototyping a control algorithm. *See id.* But in the context of the '324 Patent, a three-dimensional printer is printing an object and thus rapid prototyping objects that represent three-dimensional models. *See, e.g.*, EX1001, 1:16-18 ("A variety of three-dimensional fabrication techniques have been devised to support rapid prototyping from computer models."); EX1014, Abstract ("This contribution describes a concept for an integration of microcontroller- and FPGA- based Rapid Prototyping modules into a Remote Lab system and its implementation."). Thus, the use of the term "rapid prototyping" in Henke is not reasonably pertinent to the use of the term to refer to three-dimensional printing. Moreover, a POSITA would not have understood that the simulation and use of existing hardware to test control algorithms designed by students would logically have received an inventor's attention when considering the problem of a user interface to provide an image of a build volume and a two-dimensional projection of the three-dimensional model from the same point of view, which enables side-by-side comparison. Thus, a POSITA would have understood that Henke is not reasonably pertinent to the problem that the inventor of the '324 Patent faced.

175. Because Henke is not in the same field of endeavor as the '324 Patent (*supra* Section X.A) and is not reasonably pertinent to the particular problem the '324 Patent is concerned with, a POSITA would not have understood Henke to be analogous to the '324 Patent.

C. Claim 1

176. Claim 1 of the '324 Patent requires, among other elements, “to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” (part of claim element [1.d]) EX1001 at 27:25-35. Claim 1 also requires, among other elements, “a three-dimensional printer including a build volume” and “a video camera positioned to capture video of the build volume from a point of view.” *Id.* at 27:21, 27:23-24.

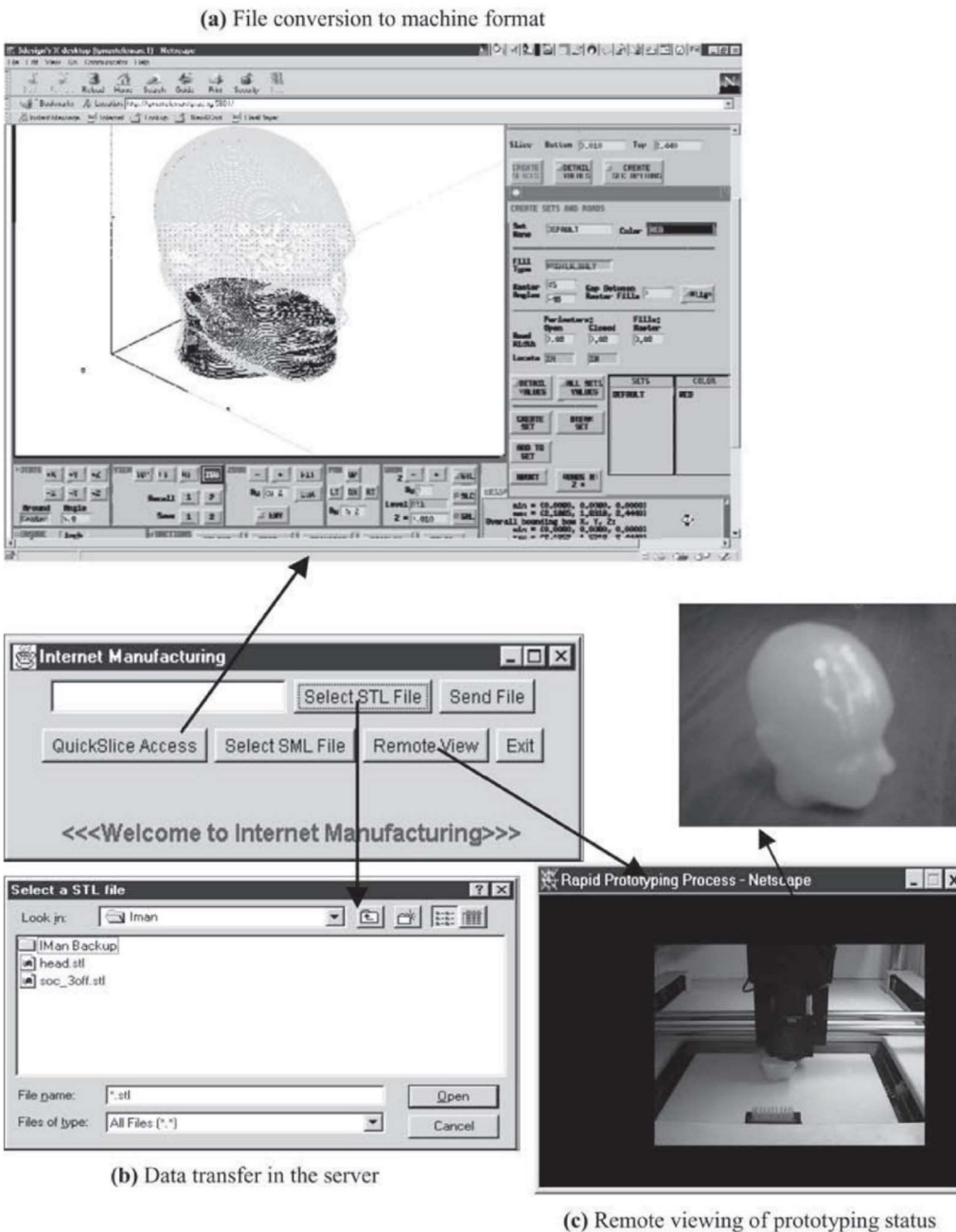
177. I understand that Petitioner appears to assert that Tay discloses these claim elements because it shows an image and projection at different times. *See* Petition at 71. As I explained above for Ground 1A and claim 1, the plain meaning of the term terms in claims 1 and 19 is that the image and projection are presented at the same time. *Supra* Section VII.B (Ground 1A, Claim 1); *see also* EX1001, 27:29-35, 28:41-46, Abstract, 1:31-38, 1:16-28, 8:49-54, 9:17-22, 15:19-22, 15:59-63, 21:18-19, 22:41-57, 24:24-28, 24:47-52, 25:45-49, Figs. 3, 7; EX1002, at 160-161, 174; EX2012, 11:20-12:10. Under a plain meaning of the claims, the Tay

reference as applied in the combination does not teach a user interface that presents an image and projection from the same point of view because a POSITA would have understood that the claims do not encompass the presentation of the image and projection at different times.

178. As I explained above for Figure 3 of Tay, Tay teaches several distinct steps.

Figure 3

(a) File conversion to machine format (b) Data transfer in the server (c) Remote viewing of prototyping status



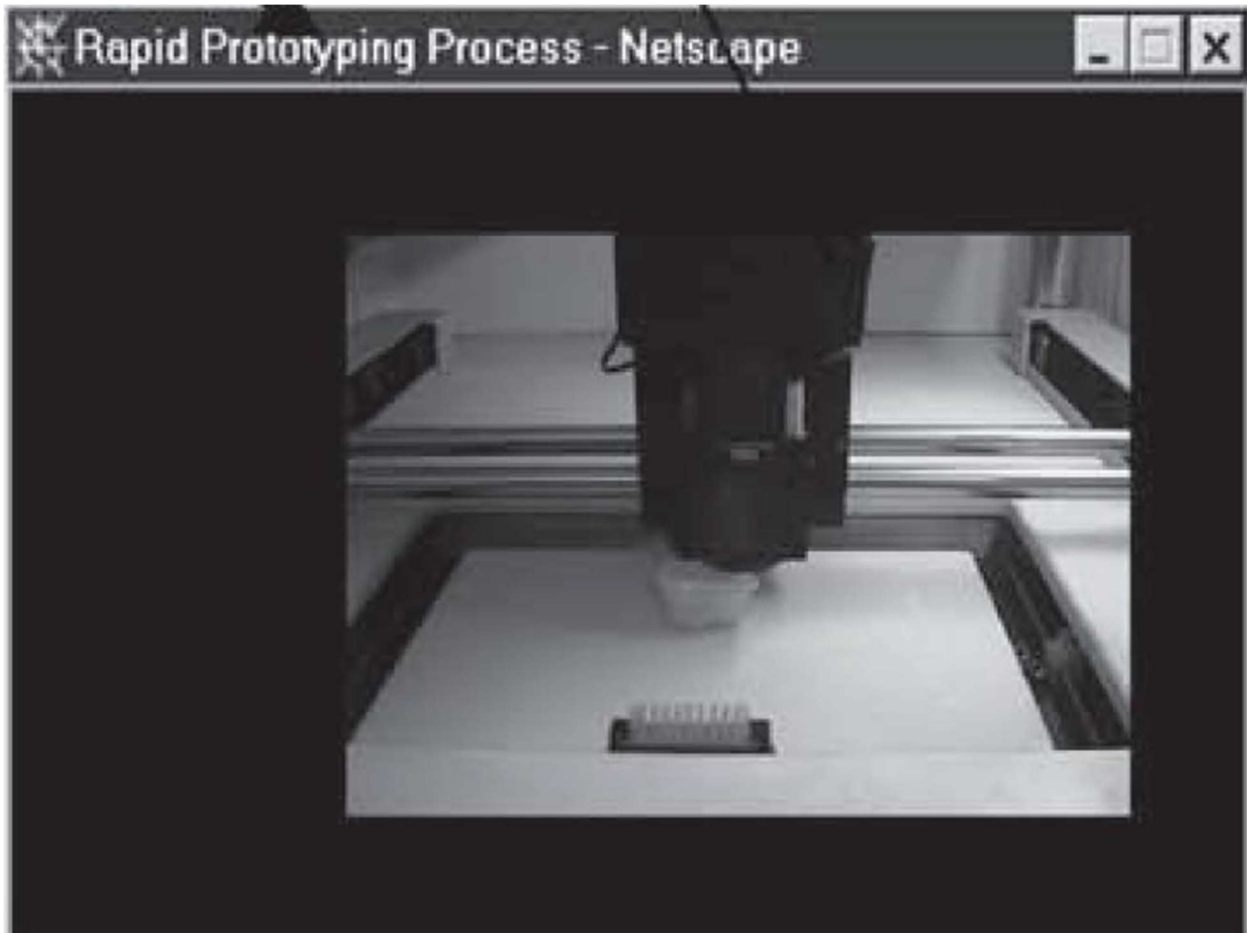
EX1013 at Fig. 3. Step (a) is for file conversion to machine format, step (b) is data transfer in the server, and step (c) is remote viewing of prototyping status. *See id.* at 4-5. At the end of the fabrication process, Tay “show[s] that the quality of the

prototype fabricated using the IMAN system is not susceptible to varying conditions of the network link, especially the data transfer mode.” *Id.* at 4. As shown in Figure 3 of Tay above, the completed object (a human head) appears to have been removed from the three-dimensional printer and placed on a surface with a wood-grain, which is a different surface than the three-dimensional printer’s white build platform, as shown in step (c) of Figure 3 for the “Remote viewing of prototyping status.” *See id.* at Fig. 3. Further, it appears that a camera that is not part of the three-dimensional printer has been used to take a photo of the completed object from a point of view that is different than the point of view of the object being fabricated in step (c) of Figure 3. *See id.*

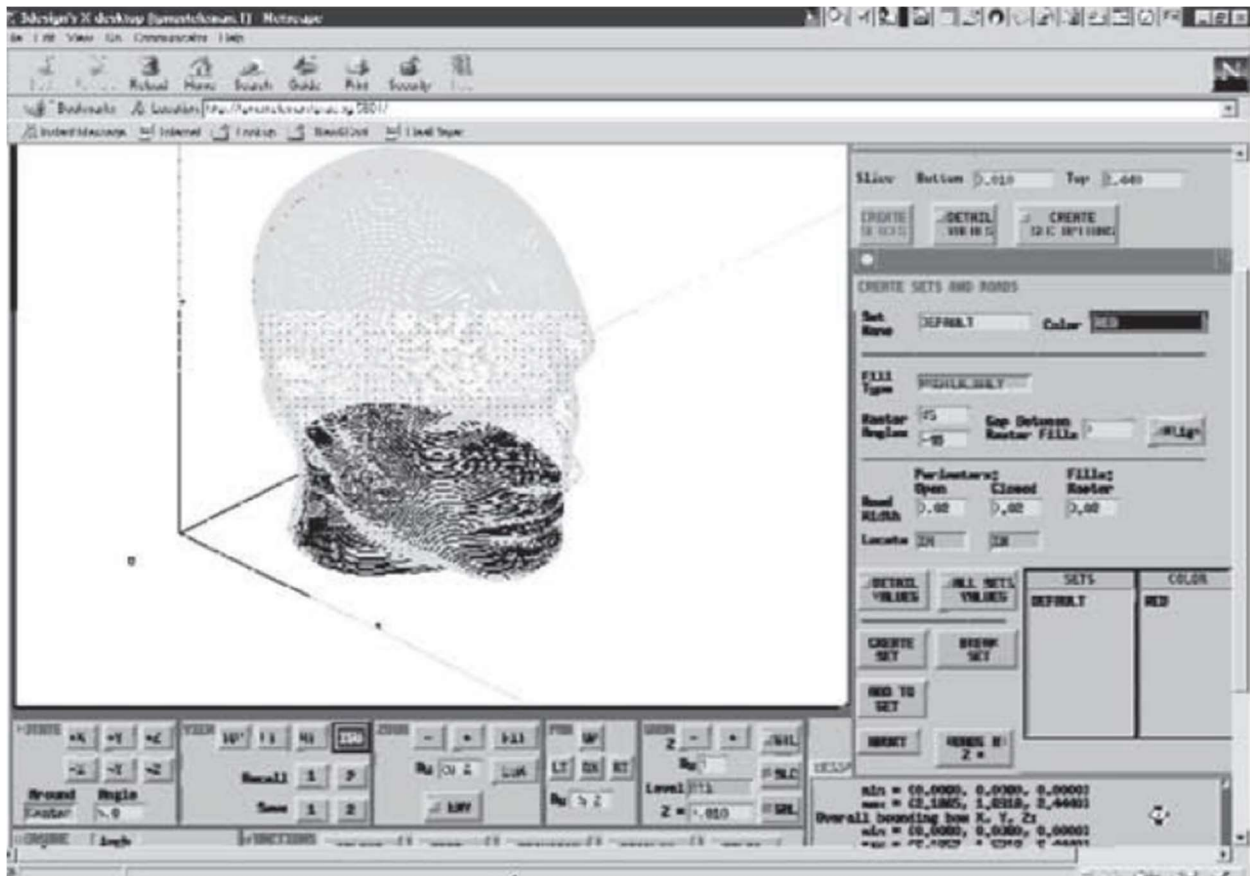
179. Based on these disclosures, a POSITA would have understood that Tay does not describe these distinct steps as presenting both an image and projection. I understand that Petitioner has identified step (a) as the projection of the three-dimensional model and step (c) as an image of the build volume. *See* Petition at 71 (annotating Figure 3 of Tay). Nothing in Tay suggests that steps (a) and (c) are performed at the same time. Rather, a POSITA would have understood that the file conversion is performed before printing the object. Further, there are numerous differences between the image in step (a) and the image in step (c). For example, the image in step (a) shows a black portion filling the human head. A POSITA would have recognized that this black portion of the image labelled "File conversion to

machine format" corresponds to a volume of material at a given 3D printer layer height in the file that has been converted to machine format (i.e. sliced). Indeed, Dr. Wolfe testified that the "black portion had been converted to the tool path." EX2010, 97:14-16. As another example, the image in step (a) shows that the human head in the file is aligned near a corner of the build surface as indicated by the three axis lines in the file conversion software. However, the image in step (c) shows that the human head is rear-centered on the build surface. *See* EX1013 at Fig. 3. Thus, a POSITA would have understood that step (a) for the file conversion takes place prior to 3D printing. Nothing in Tay suggests that 2D projections from the file conversion process are subsequently displayed in the user interface together with the video. Thus, Tay does not teach presenting both steps (a) and (c) at the same time.

180. In addition, Tay does not teach that the objects in steps (a) and (c) of Figure 3 are from the same point of view.



Id. at Fig. 3 (excerpt of step (c)). As shown above, step (c) for remote viewing shows an image of the part being 3D printed. As I mentioned above, the object is being printed in a rear-center portion of the plate surface. A POSITA would have understood that the camera is positioned in front of the 3D printer looking approximately down the middle of the printing platform. The image clearly shows that the front and rear edges of the platform that the part is being built on are approximately horizontal. I note that there is no indication or teaching in Tay that this remote view is from the same perspective of step (a) in Tay, which is shown below.

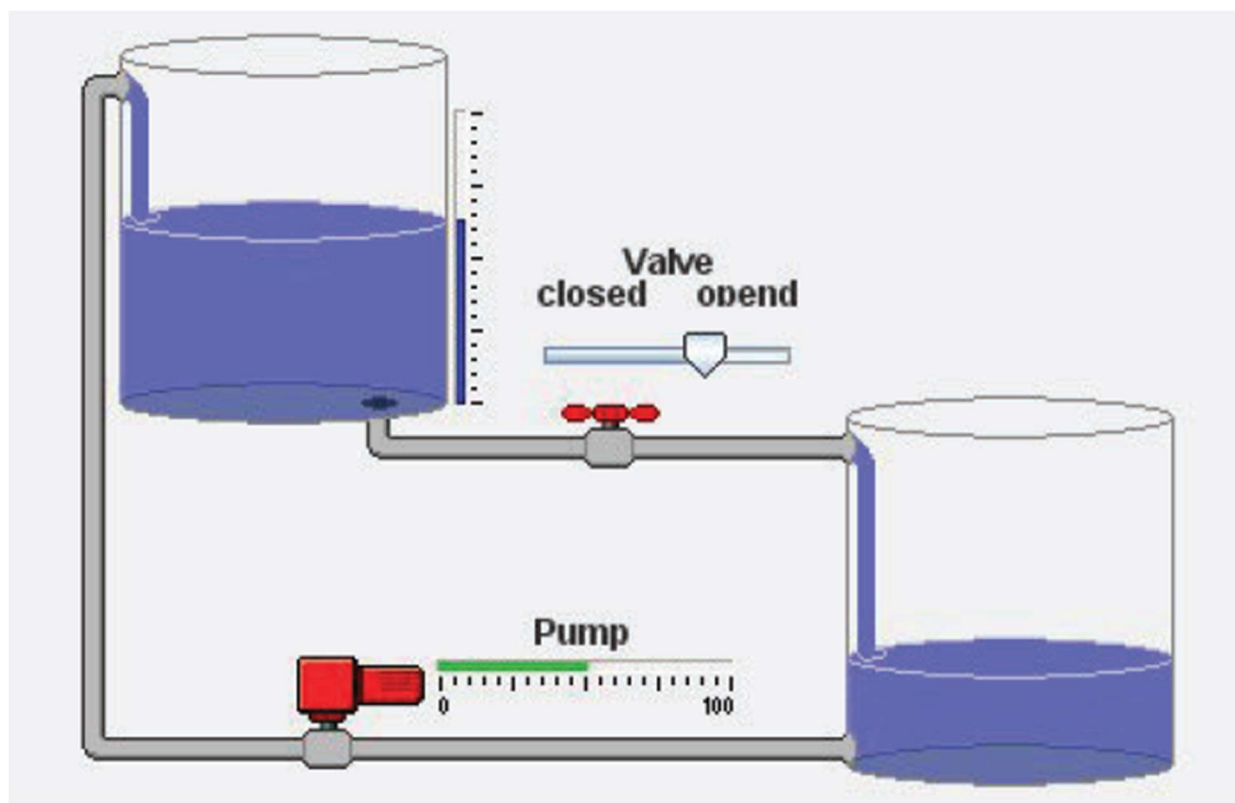


Id. at Fig. 3 (excerpted for step (a)). As shown, the object is in the corner of the build surface and the view of the object appears to be from an isometric view based on the diagonal orientations of the two lines representing the left and rear edges of the build platform. Thus, a POSITA would have recognized that step (a) is not from the same point of view as step (c). Thus, Tay does not teach presenting an image and projection from the same point of view.

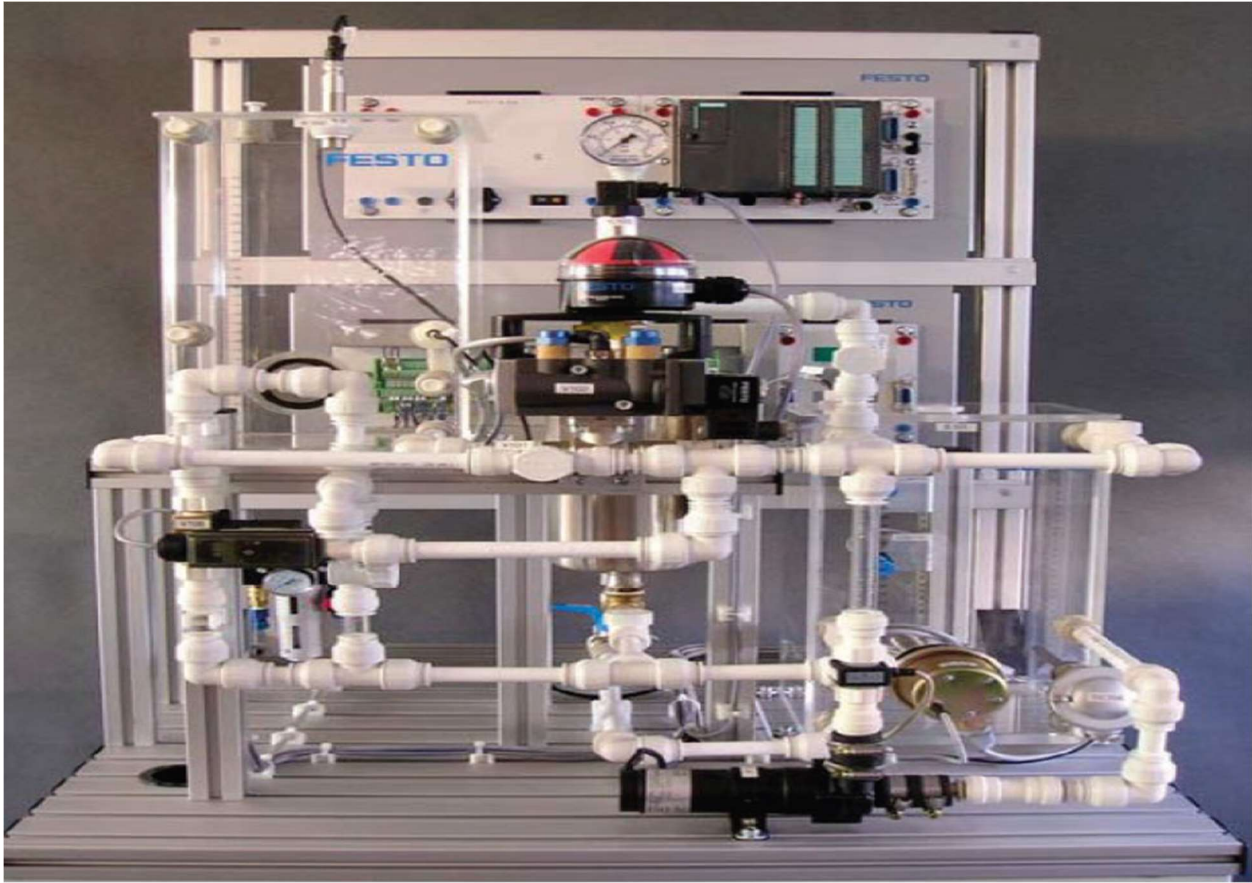
181. I understand that Petitioner has also asserted, based on Henke, that the combination teaches a video image and model from the same point of view at the same time. *See* Petition at 72-73. Petitioner asserts “a POSITA would have

recognized” that this combination “beneficially allowed an onscreen comparison to quickly identify whether the fabrication process is proceeding correctly and that the object matches the model.” *Id.* However, a POSITA would have understood that, like Tay, Henke does not teach presenting an image and projection from the same point of view at the same time. As discussed above, Tay teaches sequential steps (a) through (c) for prototyping and that the images in steps (a) and (c) are from different points of view. Tay also teaches a photo of the completed object that appears to have been taken from outside of the three-dimensional printer, on a wood-grain surface, as opposed to the white build platform of shown in step (c). *See* EX1013 at Fig. 3.

182. In addition, Henke does not teach presenting an image, which is of a build volume of a three-dimensional printer, and a projection, which is of a three-dimensional model, at the same point of view. Henke does not teach a three-dimensional model or an object in view that is being fabricated by a three-dimensional printer. *See* EX1014, 3-4. According to Dr. Wolfe, the model in Henke is the “underlying simulation.” EX2010, 82:8-17. However, if Henke’s model is a simulation of an algorithm’s functionality, it is not a three-dimensional model or a two-dimensional projection of a three-dimensional model. Accordingly, a POSITA would have recognized that the model in Figure 2 of Henke only visualizes an underlying simulation of water-level control with two water levels, a valve, and a pump.



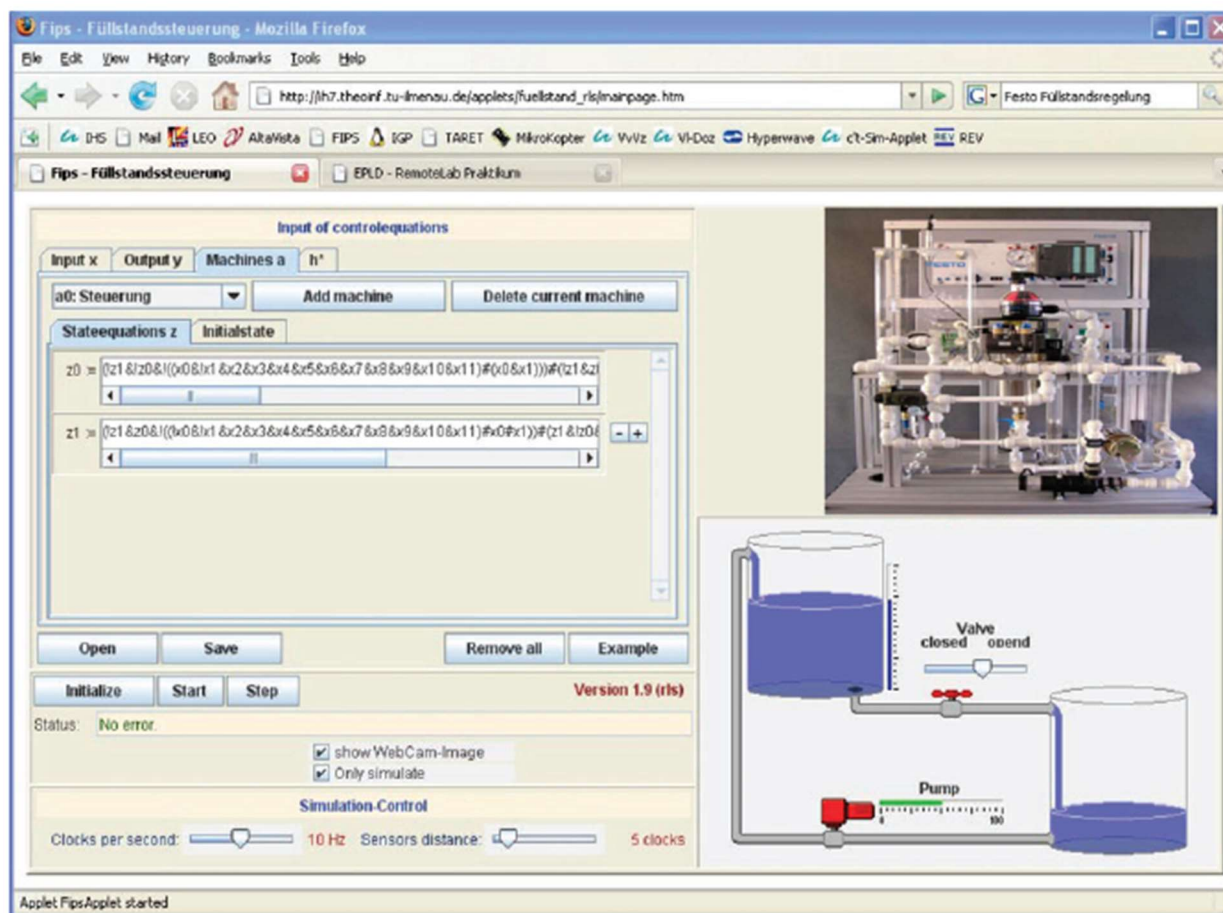
EX1014, at Fig. 2. In contrast, Figure 3 of Henke, which shows the hardware configuration, shows a much larger set of components akin to the plumbing system in a home.



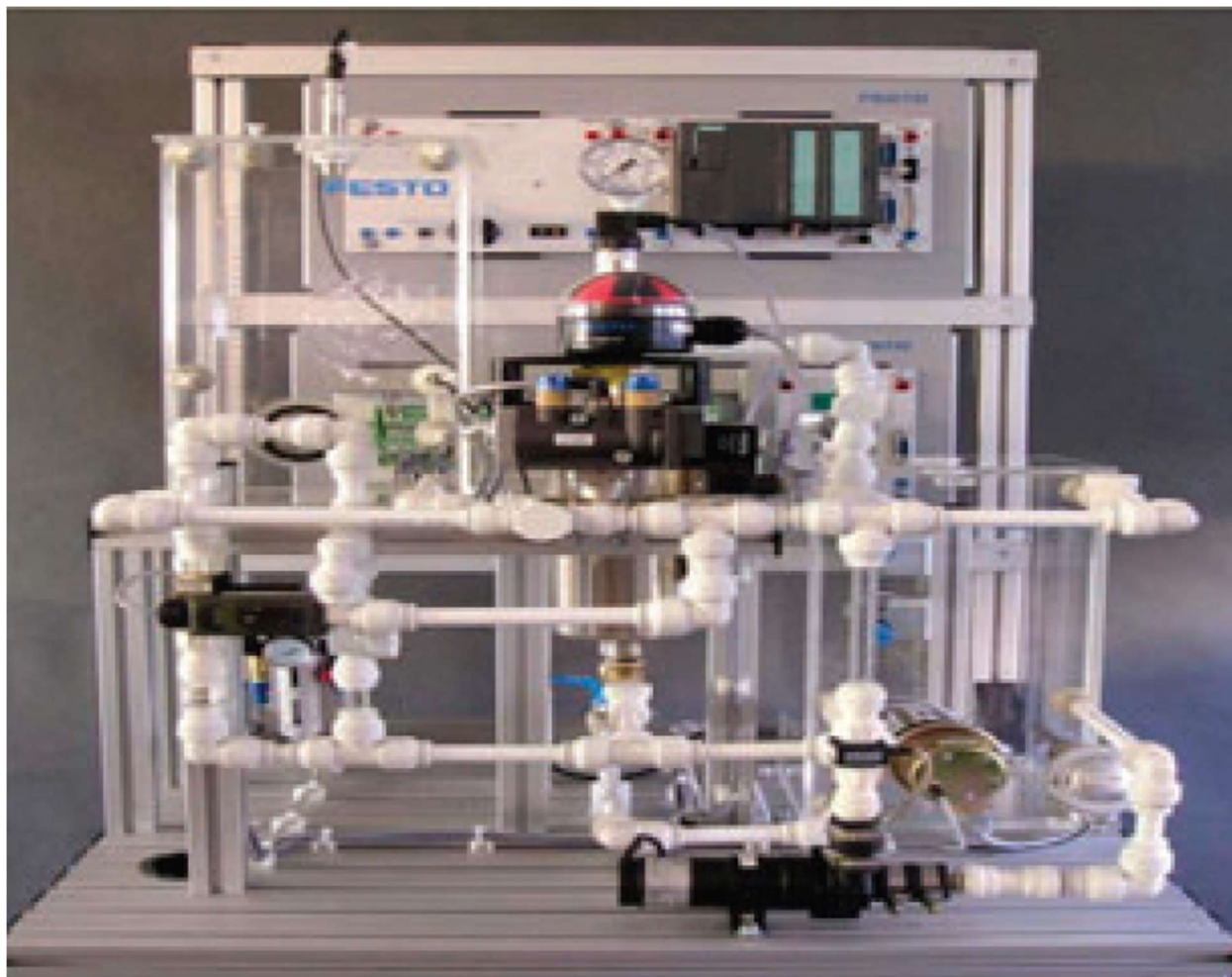
Id. at Fig. 3. Thus, Figure 2 of Henke (or the corresponding portion in Figures 7 and 8 of Henke) is not a two dimensional projection of the three-dimensional model fabricated by a three-dimensional printer and is not even a two-dimensional projection of what is shown in Figure 3 (or the corresponding portion in Figure 8 of Henke) of Henke. *See id.* at Figs. 2, 3, 7, 8. Further, a POSITA would have understood that the camera in Figures 3 and 8 of Henke is not part of the hardware testing apparatus and thus is not a camera part of Henke's device. *Supra* Section II (The Challenged Claims of the '324 Patent), Claim element 1.pre and 1.c; *see also* EX1014 at Figs. 3, 8. Instead, it appears that the camera in these figures is mounted

on a tripod or other device external to Henke's hardware testing apparatus. *See id.* Based on these disclosures in Henke, a POSITA would not have been motivated to modify Kritchman and Tay to present a two-dimensional projection of a three-dimensional model based on Henke.

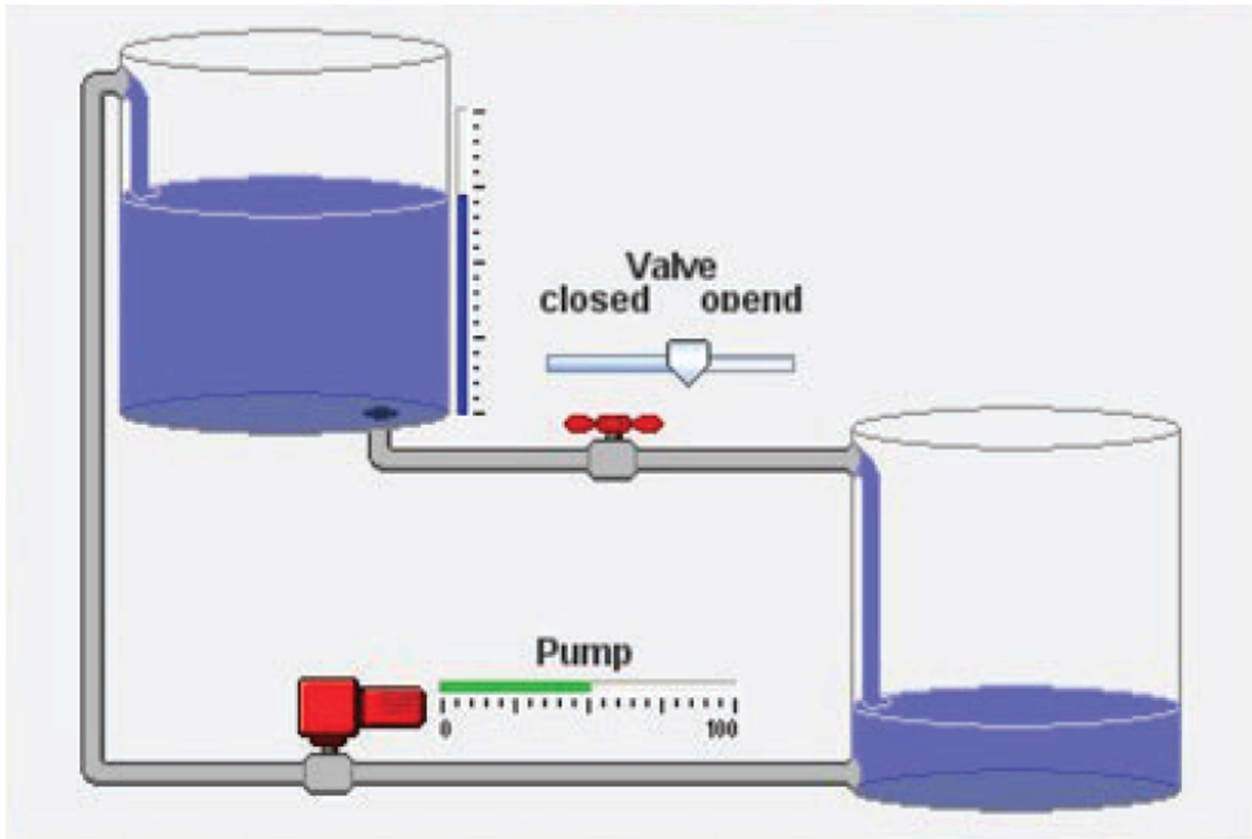
183. Moreover, a POSITA would have understood that Henke does not teach that the simulation (in Figure 2, or corresponding portion in Figures 7 and 8) and view of hardware (in Figure 3, or corresponding portion in Figure 8) are provided from the same point of view. *See id.* at Figs. 2, 3, 7, 8. As shown below, Figure 8 of Henke shows online control of the water level algorithm with a simulation and view of hardware.



Id. at Fig. 8. As shown by the excerpt of Figure 8 below, a POSITA would have recognized that the hardware does not appear to be operating or functional and thus the simulation and hardware do not show correspondence between each other.



Id. at Fig. 8 (excerpted for hardware view). Indeed, none of the screens appear to be displaying any information and the pressure gauges appear to be at zero. *See id.* By contrast, the simulation view (shown below) is both operating and functional.



Id. at Fig. 8 (excerpted for simulation view). In particular, the valve is partially opened, the pump has partial setting to pump water, and the two storage volumes have differing levels of water. *See id.* Thus, a POSITA would have understood that the state of the simulation view does not correspond to the state of the hardware view. While Henke does not show the specific functionality of his user interface, it appears that he recognizes the shortcomings of the hardware view, explaining that instead of “observing the hardware model directly via a Web-Cam,” students can “watch the laboratory procedure by supervising the model and environmental variables inside an I/O monitor.” EX1014, at 5; *see also* EX2010 (Deposition Transcript of Dr. Wolfe), 83:20-84:17 (stating that the input and output tabs in

Figure 8 correspond to Henke's "I/O monitor"). Thus, the Kritchman-Tay-Henke combination does not teach presenting "in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera." EX1001, at 27:25-35; *supra* Section II ("The Challenged Claims of the '324 Patent"), Claim Element 1.d.

D. Claims 3 and 5

184. Claim 3 of the '324 Patent recites "[t]he device of claim 1 wherein the two-dimensional projection is simulated based upon operation of the three-dimensional printer" and claim 5 of the '324 Patent recites "[t]he device of claim 1 wherein the two-dimensional projection is dynamically updated to correspond to a state of physical completion of the object." EX1001 at 27:39-41, 27:36-48. I understand that Petitioner asserts that the model in Henke is updated as the video feed of the actual process proceeds. *See* Petition at 74-76. However, as I explained above, a POSITA would have understood that the hardware view and simulation view, as presented in Henke, do not correspond to each other because, unlike the simulation view, the hardware view does not appear to be operating. *Supra* Section X.C (Claim 1); EX1014, at 5. Indeed, Henke shows that the algorithm should be tested in hardware after it is simulated, not while it is being simulated. *See* EX1014, at Figs. 7, 8. Henke explains that "a fault free design algorithm finally should be

tested on real electro-mechanical models” and that “[d]uring the *synthesis* phase, code for the processor (software) and/or for the programmable logic (hardware) is generated by different design tools. Both parts (software and hardware) can be executed and evaluated on the hardware platform directly.” *Id.* at 3. Accordingly, Henke teaches that students can “watch the laboratory procedure by supervising the model and environmental variables inside an I/O monitor or by observing the hardware model directly via a Web-Cam.” *Id.* Thus, Henke does not teach or disclose simulating the algorithm while testing the algorithm on hardware but rather shows simulating the algorithm followed by testing it on hardware.

185. Thus, the Kritchman-Tay-Henke combination does not teach claims 3 and 5.

186. I understand that Petitioner has asserted, in the alternative, that displaying video camera images is sufficient to teach claims 3 and 5 under the infringement contentions. As I explained above for claim 1 in Ground 1A, there is no assertion in the infringement contentions that the same images satisfy both the image and projection. *Supra* Section VII.B (Claim 1); *see also* EX1016, at 41-44, 46. Therefore, the same video does not satisfy both the image and projection. *See id.* Thus, a POSITA would have understood that the Kritchman-Tay-Henke combination does not teach claims 3 and 5 under Petitioner’s alternative assertion.

E. Claim 6

187. Claim 6 of the 324 Patent recites “[t]he device of claim 1 wherein the two-dimensional projection is a video image from the video camera.” EX1001, at 27:49-50. I understand that Petitioner asserts that both Tay and Henke describe displaying a video image from the video camera of the object as it is fabricated. *See* Petition at 76. Petitioner also asserts that the same images in Tay and Henke for claims 1 and 19 are “an image of the build volume from the video camera” and for claim 6 are “the two-dimensional projection is a video image from the video camera.” *See* Petition at 71, 72-73, 76. I understand that Petitioner points to the remote viewing of prototyping status in step (c) of Figure 3 of Tay and to the hardware view in Figure 8 of Henke. *See id.*; *see also* EX1013, Fig. 3; EX1014, Fig. 8.

188. As I explained for claim 6 in Ground 1A, under Petitioner’s interpretation of the claims, the same images displayed and captured by a video camera would satisfy both claims 1 and 19, as well as claim 6. However, as I explained above for claim 1 in Ground 1A, there is no assertion that the same images satisfy both the image and projection in the claims. *Supra* Section VII.B (Claim 1); *see also* EX1016, at 41-44, 46. Therefore, a POSITA would have understood that Tay and Henke do not teach claim 6 as the images that Petitioner has identified are the same images for the “image of the build volume” in claim 1.

F. Claim 19

189. Claim 19 is an independent claim with elements similar to claim 1. For example, claim 1 recites “the processor further configured to provide a user interface to a remote user accessing the device through the network interface, and to present in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera” (claim element [1.d]), whereas claim 19 recites “providing a user interface to a remote user accessing the device through the network interface, wherein the user interface presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera” (claim element [19.d]) EX1001, at 27:29-35, 28:41-46.

190. For claim element [19.d], Petitioner refers back to its arguments for claim element [1.d]. *See* Petition at 82. As I explained for claim 1, there is no teaching in the Kritchman-Tay-Henke combination of “present[ing] in the user interface an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” EX1001, at 27:25-35; *supra* Section II (“The Challenged Claims of the ’324 Patent”), Claim Element 1.d; *supra* Section X.C (claim 1). For at least these reasons, there is no teaching in the Kritchman-Tay-Henke combination of a user

interface that “presents an image of the build volume from the video camera and a two-dimensional projection of the three-dimensional model from the point of view of the video camera.” EX1001, at 28:41-46; *supra* Section II (“The Challenged Claims of the ’324 Patent”), Claim Element 19.d.

XI. GROUNDS 2B-2G: CHALLENGED CLAIMS WOULD NOT HAVE BEEN OBVIOUS

191. I understand that Petitioner has asserted several grounds, Ground 2B-2G, that do not separately challenge independent claims 1 and 19. *See* Petition at 1; *see also* Petition at 85-98.

Ground	Claims	References Cited
2A	1, 3, 5-7, 9-10, and 19-22	Kritchman (US 2006/0054039; EX1015) in view of Tay (EX1013) and Henke (EX1014)
2B	4	Kritchman, Tay, and Henke in further view of Tian (EX1006)
2C	8	Kritchman, Tay, and Henke in further view of Hull (EX1007, translated in EX1008)
2D	11	Kritchman, Tay, and Henke in further view of Seki (EX1009)
2E	17	Kritchman, Tay, and Henke in further view of Waehner (EX1010)
2F	18	Kritchman, Tay, and Henke in further view of Lan (EX1011)
2G	3, 5, 9-10, 20-22	Kritchman, Tay, and Henke in further view of Anderson (EX1012)

Thus, it is my opinion that Grounds 2B-2G fail to teach their respective challenged dependent claims for at least the reasons I provided above for Ground 2A with

respect to independent claims 1 and 19. *Supra* Sections X.A and X.B (regarding Henke), X.C (Claim 1), X.F (Claim 19).

XII. GROUND 2G: CLAIM 5 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 2G (COMBINATION OF KRITCHMAN, TAY, HENKE, AND ANDERSON)

192. Claim 5 of the '324 Patent recites “[t]he device of claim 1 wherein the two-dimensional projection is dynamically updated to correspond to a state of physical completion of the object.” EX1001, at 27:46-48.

193. I understand that in Ground 2G, which involves the combination of Kritchman, Tay, Henke, and Anderson, that Anderson teaches updating a model to show the completed portion as “filled-in” based on the “number of passes completed by the printhead.” *See* Petition at 94-95. However, a POSITA would have recognized that claim 5 requires dynamic updates to the two-dimensional projection that correspond to the state of physical completion. As I discuss below, a POSITA would have understood that Anderson only teaches updating the amount of fill in a fixed wireframe representation of a model that is updated periodically based on the pass number.

194. Figure 2 of Anderson shows its wireframe representation.

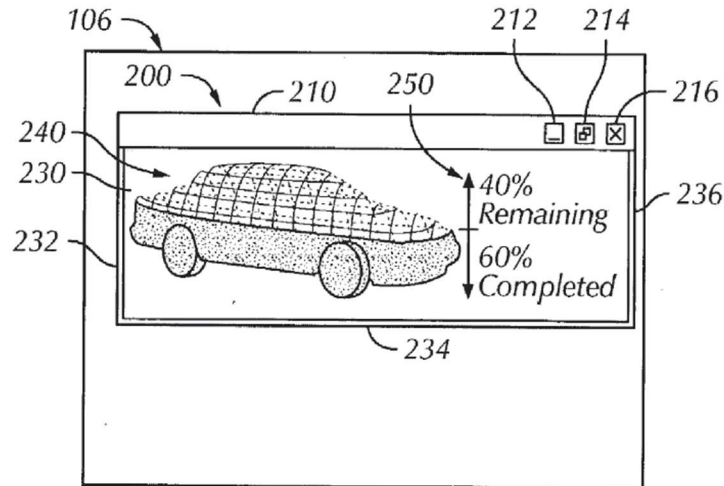


FIG. 2A

EX1012 at Fig. 2A. Anderson teaches that at “a specified interval, the server polls the printer for the pass number.” *Id.* at [0018]. “After each polling, the 3D wireframe model representation is re-rendered to show the completed portion as a filled-in (e.g., solid colored) area.” *Id.* Rather than providing dynamic updates, Anderson only provides periodic updates. *See id.* Moreover, a POSITA would have recognized that the orientation of the wireframe model remains the same throughout the build in Anderson, whereas the claim 5 requires “dynamic updates” to the two-dimensional projection of the three-dimensional model, such that the updated projection corresponds to “a state of physical completion of the object.” Thus, a POSITA would have understood that Anderson in the combination of Ground 2G does not teach claim 5.

XIII. GROUND 2C: CLAIM 8 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 2C (COMBINATION OF KRITCHMAN, TAY, HENKE, AND HULL)

195. In Ground 2C of the Petition, Petitioner asserts that claim 8 is obvious over the combination of Kritchman, Tay, Henke, and Hull. *See* Petition at 86.

196. I have reviewed Petitioner’s challenges in Ground 2C, and it is my opinion that Ground 2C fails to teach or suggest all elements of claim 8 for the additional reasons provided below.

197. Claim 8 of the ’324 Patent recites “[t]he device of claim 1 wherein the processor is configured to provide credential-based access to the user interface.” EX1001, at 27:54-55.

198. I understand that Petitioner asserts that Hull would have been applied to the Kritchman-Tay-Henke combination to require a “remote user” to “type your password and press enter” to remotely access the 3D printer. *See* Petition at 86. Petitioner also asserts that in the combination of Kritchman, Tay, Henke, and Hull, credential-based access would have been required to access the 3D printer and thus teaches claim 8. *See id.* I understand that Dr. Wolfe has made similar assertions. EX1003, ¶¶ 266.

199. As I explained for Ground 1C which also involved the proposed application of Hull, I disagree with Petitioner and its expert. *Supra* Section IX. A POSITA would have understood that Hull does not disclose that a remote user must enter a password to access the local fabrication system for a three-dimensional

printer. Rather, a POSITA would have understood that the “remote user” that is local to the fabrication system and three-dimensional printer already has access to the local fabrication system and three-dimensional printer and thus there would be no reason for credentials to access the local fabrication system and three-dimensional printer in the combination of Ground 2C. *See* EX1008, [0458], [0508], [0143], [0248], [0337], Figs. 46-47, [0157], [0499]. Accordingly, the combination in Ground 2C fails to teach or suggest all the elements of claim 8. In addition, the combination of Ground 2C fails to teach or suggest all elements of claim 8 for the additional reasons I discussed above.

XIV. CONCLUSION

200. For the reasons set forth above, it is my opinion that claims 1, 3-11, and 17-22 of U.S. Patent No. 8,562,324 would not have been obvious to a person of ordinary skill in the art at the relevant time.

201. In signing this Declaration, I understand it will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I understand I may be subject to cross-examination in this case, and that any cross-examination will take place in the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

202. I declare that all statements made herein of my knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

203. I declare under penalty of perjury under the laws of the United State that the forgoing is true and correct.

Executed on this 10th day of September, 2025.

Denis Cormier

Dr. Denis R. Cormier

APPENDIX A

Denis R. Cormier

Curriculum Vitae

Earl. W. Brinkman Professor
AMPrint Center Director
Rochester Institute of Technology
Department of Industrial and System Engineering
Phone: (585) 475 - 2713
Fax: (585) 475 - 2520
E-mail: drceie@rit.edu
Citizenship: U.S.

Areas of Specialization

- 29 years of experience with additive manufacturing and 3D printing processes
- Computer Aided Design and Manufacturing (CAD/CAM)
- Electromechanical Systems Integration

Education

- B.S., Systems Engineering, 1989, University of Pennsylvania, Philadelphia
- M.S. Industrial Engineering, 1991, State University of New York at Buffalo
- Ph.D. Industrial Engineering, 1995, North Carolina State University

Professional Experience

- 2011-present Professor, Industrial Engineering Dept., RIT
- 2014 – present Program Faculty Member, Materials Science & Engineering, RIT
- 2010-present Core Faculty, Microsystems Engineering, RIT
- 2009 – 2011 Associate Professor, Industrial Engineering Dept., RIT
- 2005 – 2009 Affiliate Faculty, Biomedical Engineering, NC State University
- 2002 – 2006 Director, Furniture Mfg. and Management Center, NC State University
- 2001 – 2009 Associate Professor, Industrial Engineering Dept., NC State University
- 1995 - 2001 Assistant Professor, Industrial Engineering Dept., NC State University
- 1994 - 1995 Visiting Researcher, Industrial Engineering Dept., NC State University

Professional Awards and Honors

- 2024 Solid Freeform Fabrication FAME career achievement award for contributions to additive manufacturing and 3D printing R&D
- 2023 Fellow of the Institute of Industrial and Systems Engineers (IISE)
- 2022 Fulbright Specialist
- 2020 Smart Manufacturing Magazine's 20 Most Influential Faculty in Smart Manufacturing
- 2018 IISE Manufacturing and Design Outstanding Service Award

- Editorial Advisory Board - Additive Manufacturing Journal
- Editorial Advisory Board - Rapid Prototyping Journal
- 2014-2015 Chairman of SME's Rapid Technologies and Additive Manufacturing (RTAM) technical community
- Outstanding Young Manufacturing Engineer Award, Society of Manufacturing Engineers, 2003

Issued Patents

- Cormier, D., Badesha, S., and Sambhy, V. "Metal Drop Ejecting Three-Dimensional (3D) Object Printer Having An Increased Material Deposition Rate", US Patent 12370604B2, issued 07/29/2025.
- Mantell, D., Chungbin, C., Cormier, D., Cormier, D., Meda, M., and Jayabal, D. "Method and System for Operating a Metal Drop Ejecting Three-Dimensional (3D) Object Printer To Form Electrical Circuits On Substrates", US Patent US12186992B2, issued 01/07/25.
- Cormier, D., Badesha, S., and Sambhy, V. "Metal Drop Ejecting Three-Dimensional (3D) Object Printer Having An Increased Material Deposition Rate", US Patent US 11,904,388 B2, issued 02/20/24.
- Cormier, D., Badesha, S., and Sambhy, V. "Metal Drop Ejecting Three-Dimensional (3D) Object Printer Having An Increased Material Deposition Rate", European Patent EU4023369C0, issued 04/24/24.
- Cormier, D., Badesha, S., and Sambhy, V. "Metal Drop Ejecting Three-Dimensional Object Printer" US Patent No. US 11,737,216 B2, issued 08/22/23.
- Mantell, D., Chungbin, C., Cormier, D., Cormier, D., and Jayabal, D. "Method and System for Operating a Metal Drop Ejecting Three-Dimensional (3D) Object Printer To Form Electrical Circuits On Substrates", US Patent US 11,731,366 B2, issued 08/22/23.
- Mantell, D., Chungbin, C., Liu, C.H., Vader, S., Vader, Z., Sukhotskiy, V., Cormier, D., and Tawil, K. "Method and System for Operating a Metal Drop Ejecting Three-Dimensional (3D) Object Printing to Compensate for Geometric Variations During An Additive Manufacturing Process", US Patent No. US 11565475 B2, issued 01/31/23.
- Mahajan, C., Cormier, D., Irving, M., Williams, S., Borkholder, D., and Alfadhel, A. "Magnetic Field Patterning of Electrically Anisotropic Nickel Nanofibers Using Precursor Ink", US Patent No. US 11254156 B2 issued 02/22/2022.
- Borkholder, D., Forouzandeh, F., Carter, R., Cormier, D., Walton, J., Frisina, R. "Peristaltic Micropumps and Fluid Delivery Devices That Incorporate Them", US Patent No. US 11,020,524 B1 issued 6/1/21.
- Cormier, D., Taylor, J., and West, H. "Methods and Apparatus for Rapidly Prototyping Three-Dimensional Objects from a Plurality of Layers", US Patent US-6324438-B1, issued 11/27/01.

Pending Patent Applications

- Borkholder, D., Ouyang, J., Cormier, D., and Alfadhel, A. "Pulse Energy Manipulation of Material Properties", US Patent Application US-2023-0276709-A1, filed 05/08/23.

- Cormier, D., Poddar, P., Tarr, X., Kon, J., and Foster, A. "Extrusion System for Additive Manufacturing", US Patent Application US-2023-0173751-A1, filed 11/03/21.
- Cormier, D., Badesha, S., and Sambhy, V. "Building An Object With A Three-Dimensional Printer Using Vibrational Energy", US Patent Application US-2022-0219381 A1, filed 12/31/20.
- Cormier, D., Badesha, S., and Sambhy, V. "Method and System for Operating a Metal Drop Ejecting Three-Dimensional (3) Object Printer to Form Vias In Printed Circuit Boards With Conductive Metal", US Patent Application US-2022/0240387 A1, filed 01/22/21.
- Cormier, D., Jayabal, D., Cormier, D., Badesha, S., and Sambhy, V. "Fabrication of Lattice Structures With A Three-Dimensional Printer", US Patent Application US-2022-0212249, filed 12/31/20.
- Cormier, D., Rifat, U., and Mehta, P. "Building An Object With A Three-Dimensional Printer Using Burst Mode Jetting", US Patent Application US-2022-0184708, filed 12/15/20.

Relevant Patent Law Consulting

- Served as an expert witness on behalf of Markforged in its 2018-2019 Desktop Metal V. Markforged patent infringement and patent invalidity case. Was involved in all aspects of the case through and including the jury trial.

Research Funding

Career funding as the principal investigator for additive manufacturing and 3D printing research exceeds \$30M. A full listing of research grants/contracts is available upon request.

- Government research sponsors include the Department of Energy, the Air Force Research Labs, the Office of Naval Research, the National Science Foundation, the National Institutes of Health, the U.S. Army Materiel Command, and NASA.
- Industry research sponsors include Boeing, Lockheed Martin, Northrop Grumman, Xerox, Corning, Intel, General Electric, and many others.

Publications

Books

- Walsh, R., and Cormier, D. (2005) *Machining and Metalworking Handbook 3rd Edition*, McGraw-Hill, NY.

Book Chapters

- Cormier, D. and Poddar, P. (2020) "Durability of Additively Manufactured Composite Systems", Chapter 7 in *Durability of Composite Systems*, K. Reifsnider (editor), Elsevier.
- Parekh, D., Cormier, D., and Dickey, M. (2015) "Multi-functional Printing: Incorporating Electronics into 3-D Parts Made by Additive Manufacturing", *Additive Manufacturing*, Amit Bandyopadhyay (editor), CRC Press.

- Khatri-Chhetri, P., Datar, A., and Cormier, D. (2012) "Novel SOFC Processing Techniques Employing Printed Materials." *Advances in Materials Science for Environmental and Energy Technologies: Ceramic Transactions* 236 (2012): 129.
- Harrysson, O., and Cormier, D. (2006) "Direct Fabrication of Custom Orthopedic Implants Using Electron Beam Melting Technology", in *The Use of Advanced Manufacturing Technology for Medical Applications*, I. Gibson (editor), John Wiley & Sons, West Sussex, UK.
- Cormier, D., Young, R., and Bartlett, W. (2002) "Evaluation of Rapid Prototyping and Tooling Technologies," in *Economic Evaluation of Advanced Technologies: Techniques and Case Studies*, J. Lavelle, H. Liggett, and H. Parsaei (editors), Taylor & Francis, New York, NY, pp. 35 - 50.
- Weintraub, A., Zozom, A., Cormier, D., and Hodgson, (2001) T. "Evaluating Alternative Process Plans In Large Manufacturing Systems" in *Computer-aided Process and Assembly Planning*, J. Usher (editor), Gordon and Breach, Chapter 12.
- Cormier, D., and O'Grady, P. (1997) "A Constraint-Based Genetic Algorithm for Concurrent Engineering", in *Manufacturing Decision Support Systems*, Hamid Parsaei (editor), Chapman and Hall, pp. 256-281.

Journal Articles

- Myers, Jade; Phillips, Daniel; Cormier, Denis., (2025) "Assessing 3D printable density-graded lattice structures to minimize risk of tissue damage from compression-release stabilized sockets" *Prosthetics and Orthotics International*, 49(1):p 76-82, DOI: 10.1097/PXR.0000000000000406.
- Assad, A., Bevans, B.D., Potter, W., Rao, P., Cormier, D., Deschamps, F., Hamilton, J.D. and Rivero, I.V., 2024. Process mapping and anomaly detection in laser wire directed energy deposition additive manufacturing using in-situ imaging and process-aware machine learning. *Materials & Design*, p.113281, <https://doi.org/10.1016/j.matdes.2024.113281>.
- Lee, S., Lin, H., Kahn, B.E., Malakhov, A., Kovach, B., Tran, Q.T., Ghosh, S., Liu, P., Cormier, D. and Minh, N.Q., (2023). Development of Novel 3D Cell Structure and Manufacturing Processes for Highly Efficient, Durable, and Redox Resistant Solid Oxide Electrolysis Cells. *ECS Transactions*, 111(6), p.825, DOI 10.1149/11106.0825ecst.
- Hamilton, J., Trauernicht, D., Cormier, D., and Rivero, I. (2023) "Laser-based Directed Energy Deposition Remanufacturing of Gray Cast Iron using Stainless Steel 316L and Inconel 625 Filler Materials", *Advanced Engineering Materials*, 25(24), <https://doi.org/10.1002/adem.202301212>.
- Liu, Li; Xu, Zhiheng; Molina Vargas, Adrian Moises; Dollery, Steve ; Schrlau, Michael; Cormier, Denis (D.); O'Connell, Mitchell; Tobin, Gregory; Du, Ke, (2023) "Aerosol Jet Printing Enabled Dual-Function Electrochemical and Colorimetric Biosensor for SARS-CoV-2 Detection", *Analytical Chemistry*, 95(22) pp 11997-12005, <https://doi.org/10.1021/acs.analchem.3c01724>.
- Ramesh, S., Xu, Z., Rivero, I.V. and Cormier, D.R., (2023). Computational fluid dynamics and experimental validation of aerosol jet printing with multi-stage flow focusing lenses. *Journal of Manufacturing Processes*, 95, pp.312-329, <https://doi.org/10.1016/j.jmapro.2023.03.035>.
- Liu, L., Xu, Z., Awayda, K., Dollery, S.J., Bao, M., Fan, J., Cormier, D., O'Connell, M., Tobin, G.J. and Du, K., (2022) "Gold Nanoparticle-Labeled CRISPR-Cas13a Assay for the Sensitive Solid-State Nanopore Molecular Counting" *Advanced Materials Technologies*, p.2101550.

- Hamilton, J., Sorondo, S., Greeley, A., Zhang, X., Cormier, D., Li, B., Qin, H., and Rivero, I. (2022) "Property-Structure-Process Relationships In Dissimilar Material Repair with Directed Energy Deposition: Repairing Gray Cast Iron using Stainless Steel 316L, *Journal of Manufacturing Processes*, 81, pp. 27-34, <https://doi.org/10.1016/j.jmapro.2022.06.015>.
- Ramesh, S., Mahajan, C., Gerdes, S., Gaikwad, A., Rao, P., Cormier, D., and Rivero, I. (2022) "Numerical and Experimental Investigation of Aerosol Jet Printing" *Additive Manufacturing*, 59, p. 103090.
- Poddar, P., Olles, M., and Cormier, D. (2022) "Mechanical Response of Carbon Composite Octet Truss Structures Produced Via Axial Lattice Extrusion ", *Polymers*, 14(17), p. 3553.
- Meda, M., Mehta, P., Mahajan, C., Kahn, B., and Cormier, D. (2021) "Magnetohydrodynamic liquid metal droplet jetting of highly conductive electronic traces" *Flexible and Printed Electronics*, 6(3), p. 035002.
- Meda, M., Sukhotskiy, V., and Cormier, D. (2021) "Pinhole formation in printed electronic traces fabricated via molten metal droplet jetting" *Electronics*, 10, 1568. <https://doi.org/10.3390/electronics10131568>.
- Srikanthan Ramesh, Yunbo Zhang, Denis R. Cormier, Iris V. Rivero, Ola L.A. Harrysson, Prahalad K. Rao, Ali Tamayol, (2021) Extrusion bioprinting: Recent progress, challenges, and future opportunities, *Bioprinting*, <https://doi.org/10.1016/j.bprint.2020.e00116>.
- Ge, C., Cormier, D. and Rice, B., (2020). "Damping and cushioning characteristics of Polyjet 3D printed photopolymer with Kelvin model" *Journal of Cellular Plastics*, p.0021955X20944972.
- Mahajan, C., Marotta, A., Kahn, B., Irving, M., Gupta, S., Hailstone, R., Williams, S., and Cormier, D. (2019) "Formation of copper nickel bimetallic nanoalloy film using precursor inks", *Materials Sciences and Applications*, 10(4), pp 349-363, DOI:[10.4236/msa.2019.104026](https://doi.org/10.4236/msa.2019.104026).
- Mahajan, C., Alfadhel, A., Irving, M., Kahn, B., Borkholder, D., Williams, S., Cormier, D. (2019) "Magnetic Field Patterning of Nickel Nanofibers Using Nickel Precursor Ink", *Materials*, 12, 928, DOI:[10.3390/ma12060928](https://doi.org/10.3390/ma12060928).
- Ouyang, J., Cormier, D., Borkholder, D., (2019) "Piezoelectric property enhancement of PZT thick film via pulsed flash poling during sintering" *ACS Applied Energy Materials*, 2(1), pp. 338 – 343.
- Forouzandeh F., Zhu X., Alfadhel A., Ding B., Walton J.P., Cormier D., Frisina R.D., Borkholder D.A., (2019) "A nanoliter resolution implantable micropump for murine inner ear drug delivery" *Journal of Controlled Release*, 298, pp. 27 – 37.
- Zope, K., Cormier, D., and Williams, S. (2018) "Reactive Silver Oxalate Ink Composition with Enhanced Curing Conditions for Flexible Substrates", *ACS Applied Materials & Interfaces*, 10(4), pp. 3830-3837.
- Alfadhel, A., Ouyang, J., Mahajan, C., Cormier, D., and Borkholder, D. (2018) "Inkjet Printed Polyethylene Glycol as a Fugitive Ink for the Fabrication of Flexible Microfluidic Systems" *Journal of Materials and Design*, V150, pp. 182-187.
- Mudgal, T., Bhadrachalam, K., Bischoff, P., Cormier, D., Manley, P., and Hirschman, K. (2017) "CMOS Thin-Film Transistors via Xe Flash-Lamp Crystallization of Patterned Amorphous Si" *ECS Journal of Solid State Science and Technology*, 6(12), pp. Q179-Q181.

- Priyadarshini, L., Pan, L., Tuber, J., Cormier, D., and Ge, G. (2017) "A Preliminary Study of Cushion Properties of a 3D Printed Thermoplastic Polyurethane Kelvin Foam", *Packaging Technology and Science*, DOI: 10.1002/pts.2330, pp. 1-8.
- Fan, R., Piou, M., Darling, E., Cormier, D., Sun, J., & Wan, J. (2016). Bio-printing cell-laden Matrigel–agarose constructs. *Journal of Biomaterials Applications*, 0885328216669238.
- Wadwa, A., Cormier, D., and Williams, S. (2016) Improving run-time stability with aerosol jet printing using a solvent add-back bubbler" *Journal of Print and Media Technology Research*, V5 N3, pp. 207-214. DOI: 10.14622/JPMTR-1610
- J. Ouyang, D. Cormier, S. A. Williams, and D. A. Borkholder, (2016) "Photonic Sintering of Aerosol Jet Printed Lead Zirconate Titanate (PZT) Thick Film Transducers" *Journal of the American Ceramics Society*, 99(8), pp. 2569-2577.
- Yang, L., Harrysson, O., West, H., and Cormier, D. (2015) "Mechanical Properties of 3D Re-Entrant Honeycomb Auxetic Structures Realized Via Additive Manufacturing", *International Journal of Solids and Structures*, V69, pp. 475-490.
- Das, S., Cormier, D., and Williams, S. (2015) "Potential for Multi-Functional Additive Manufacturing Using Pulsed Photonic Sintering", *Procedia Manufacturing*, V1, pp. 366-377.
- Yang, L. Harrysson, O., Park, C., West, H., Cormier, D., and Peters, K. (2015) "Low-energy drop weight performance of cellular sandwich panels", *Rapid Prototyping Journal*, 21(4), pp. 433-442, <http://dx.doi.org/10.1108/RPJ-08-2013-0083>.
- Yang, L., Harrysson, O., Cormier, D., West, H., Gong, H., and Stucker, B. (2015) "Additive Manufacturing of Metal Cellular Structures: Design and Fabrication" *Journal of Materials*, 67(3), DOI: <http://dx.doi.org/10.1007/s11837-015-1322-y>.
- West, H., Harrysson, O., Horn, T., Cormier, D., Aman, R. and Marcellin-Little, D. (2015) "Novel Materials and Structures Fabricated by Electron Beam Melting" *Microscopy and Microanalysis*, 21(S3), pp.461-462.
- Mugdal, T., Reepmeyer, C., Manley, R., Cormier, D., and Hirschman, K. "Crystallization of Amorphous Silicon and Dopant Activation Using Xenon Flash-Lamp Annealing (FLA)", *MRS Proceedings*, 1666, pp. 91-96.
- Yang, L. Harrysson, O., West, H., and Cormier, D., (2013) "A Comparison of Bending Properties for Cellular Core Sandwich Panels", *Materials Sciences and Applications*, V4, pp. 471-477, DOI:10.4236/msa.2013.48057.
- Kumar, V., Cormier, D., and Harrysson, O. (2012) "Electrical Conductivity of Hexagonal Periodic Lattice Structures", *Virtual & Physical Prototyping*, 7(1), pp. 81-90.
- Srisawadi, S., Cormier, D., Harrysson, O., and Modak, S. (2012) "Computational Design of Electrode Networks for Preferentially Aligned Short Fiber Composite Component Fabrication via Dielectrophoresis", *International Journal of CAD/CAM*, 12(1).
- Yang, L. Harrysson, O., West, H., and Cormier, D., (2012) "Modeling of uniaxial compression in a 3D periodic re-entrant lattice structure", *Journal of Materials Science*, DOI: 10.1007/s10853-012-6892-2.

- Yang, L., Cormier, D., West, H., Harrysson, O., and, Knowlson, K. (2012) "Non-Stochastic Ti-6Al-4V Foam Structures With Negative Poisson's Ratio", *Materials Science and Engineering A*, pp. 579-585, <http://dx.doi.org/10.1016/j.msea.2012.08.053>.
- Yang, L. Harrysson, O., West, H., and Cormier, D., (2012) "Compressive properties of Ti-6Al-4V auxetic mesh structures made by Electron Beam Melting", *Acta Materialia*, V60, pp. 3370-3379. <http://dx.doi.org/10.1016/j.actamat.2012.03.015>
- Purser, M., Richards, A., Cook, R., Osborne, J., Cormier, D., and Buckner, G., (2011) "A Novel Shape Memory Alloy Annuloplasty Ring for Minimally Invasive Surgery: Design, Fabrication and Evaluation", *Annals of Biomedical Engineering*, 39(1), pp. 367-377.
- Jernigan, S., Chanoit, G., Veeramani, A., Owen, B., Hilliard, M., Cormier, D., Laffitte, B., and Buckner, G. (2010) "A Laparoscopic Knot-Tying Device for Minimally Invasive Cardiac Surgery", *European Journal of Cardio-thoracic Surgery*, 37(3), pp. 626 - 630.
- Purser, M., Richards, A., Cook, R., Osborne, J., Cormier, D., and Buckner, G. (2009) "Evaluation of a Shape Memory Alloy Reinforced Annuloplasty Band for Robot-Assisted Mitral Valve Repair", *Annals of Thoracic Surgery*, 88(4), pp. 1312-1316.
- Cansizoglu, O., Harrysson, O., West, H., Cormier, D., and Mahale, T. (2008) "Applications of Structural Optimization in Direct Metal Fabrication", *Rapid Prototyping Journal*, 14(2), pp. 114-122.
- Harrysson, O., Cansizoglu, O., Marcellin-Little, D., Cormier, D., and West, H. (2008) "Direct Metal Fabrication of Titanium Implant Components With Tailored Materials and Mechanical Properties Using Electron Beam Melting Technology", *Materials Science & Engineering C*, 28(3), pp. 366-373.
- Cansizoglu, O., Harrysson, O., Cormier, D., West, H., and Mahale, T. (2008) "Properties of Ti-6Al-4V Non-stochastic Lattice Structures Fabricated Via Electron Beam Melting", *Materials Science & Engineering A*, 492(1-2), pp. 468-474.
- Cormier, D., Harrysson, O., Mahale, T., and West, H. (2007) "Freeform Fabrication of Titanium Aluminide via Electron Beam Melting Using Prealloyed and Blended Powders," *Research Letters in Materials Science*, vol. 2007, Article ID 34737, 4 pages, 2007. doi:10.1155/2007/34737
- Jernigan, S.R., Buckner, G.D., Eischen, J.W., and Cormier, D.R. (2007) "Finite Element Modeling of the Left Atrium to Facilitate the Design of an Endoscopic Atrial Retractor", *ASME Journal of Biomechanical Engineering*, V129, pp. 825-837.
- Aman, R., West, H., and Cormier, D. (2007) "An Evaluation of Loose Tenon Joint Strength In Furniture Applications", *Forest Products Journal*, 58(3), pp. 61-64.
- Cormier, D., Harrysson, O., and West, H. (2004) "Characterization of High Alloy Steel Produced Via Electron Beam Melting", *Rapid Prototyping Journal*, 10(1), pp. 35 - 41.
- Cormier, D., Harrysson, O., and Mahale, T. (2003) "Rapid Manufacturing in the 21st Century", *Journal of the Chinese Institute of Industrial Engineers*, 20(3), pp. 193 - 201.
- Harrysson, O., Cormier, D., Marcellin-Little, D., and Jajal, K. (2003) "Rapid Prototyping for Treatment of Canine Limb Deformities", *Rapid Prototyping Journal*, 9 (1), pp. 37 – 42.

- Zozom, A.J. Jr., T.J. Hodgson, R.E. King, A.J. Weintraub, and D. Cormier, (2003) "Integrated Job Release and Shop Floor Scheduling to Minimize WIP and Meet Due-Dates," *International Journal of Production Research*, 41(1), pp. 31 - 45.
- Cormier, D., Taylor, J. and West, H. (2002) "An Investigation of Selective Coloring With 3-D Laser Printing", *Journal of Manufacturing Processes*, 4(2), pp. 148 - 152.
- Cormier, D. and Taylor, J. (2001) "A Process for Solvent Welded Prototype Tooling", *Robotics and Computer-Integrated Manufacturing*, 17(1/2), pp. 151 – 157.
- Taylor, J., Cormier, D., Joshi, S., and Venkataraman, V. (2001) "Contoured Edge Slice Generation in Rapid Prototyping Via 5-axis Machining" *Robotics and Computer-Integrated Manufacturing*, 17(1/2), pp. 13 - 18.
- Cormier, D., Unnanon, K., and Sanii, E. (2000) "Specifying Non-Uniform Cusp Heights As A Potential Aid for Adaptive Slicing", *Rapid Prototyping Journal*, 6(3), pp. 204 - 211.
- Cormier, D. and Unnanon, K. (2000) "Virtual Interference Checking of Furniture Assemblies", *Forest Products Journal*, 50(5), pp. 1-5.
- Zozom, A., Weintraub, A., Cormier, D., and Hodgson, T. (2000) "Implementation of a Virtual Factory Cell Scheduling System" *Engineering Valuation and Cost Analysis*, Vol. 2, pp. 395 - 407.
- Weintraub, A., Cormier, D., Hodgson, T., King, R., Wilson, J., and Zozom, A. (1999) "Scheduling With Alternatives: A Link Between Process Planning and Scheduling" *IIE Transactions*, Vol 31, pp. 1093 – 1102.
- Hodgson, T., Cormier, D., Weintraub, A., and Zozom, A. (1998) "Note. Satisfying Due Dates in Large Job Shops" *Management Science* 44(10), pp. 1442 - 1446.
- Cormier, D., and O'Grady, P., (1998) "Survival of the Fittest Designs: Using Evolution In Concurrent Engineering" *International Journal of Production Research*, 36(6), pp 1679 – 1697.
- Weintraub, A., and Cormier, D., (1997) "A Testbed for Scheduling with Alternative Process Plans," *International Journal of Intelligent Automation and Soft Computing*, 3, No. 3, pp. 231 - 238.
- Kim, K., Cormier, D., O'Grady, P., and Young, R. (1995) "A System for Design and Concurrent Engineering Under Imprecision," *Journal of Intelligent Manufacturing*, 6, pps. 11 - 27.

Selected Conference Papers (Representative Listing)

- Chibuikem Iheonu, Jade Myers, Denis Cormier, Patricia Iglesias "Additive Manufacturing of Textured Polymer Surfaces for Potential Friction and Wear Reduction in Hip Replacements: A Preliminary Study", Proceedings of the ASME 2025 International Mechanical Engineering Congress and Exposition IMECE2025 November 16-19, 2025, Memphis, TN
- Marin-Montealegre, V., Mehta, P., Rochani, A. and Cormier, D., 2025. Porous zinc structures using molten metal jetting additive manufacturing. *Transactions on Additive Manufacturing Meets Medicine*, 7(S1), pp.2246-2246.
- Williams, S.A., Jones, K.E, and Cormier, D.R. (2024) "Shaping the Future of Glass: 3D Printing of with Optimized Sol-gel Inks for Complex and Functional Structures" NRO First Conference, Chantilly, VA, Aug. 21, 2024.

- Myers, J., Phillips, D., Cormier, D. (2023). Using 3D Printable Density-Graded Lattice Structures to Minimize Risk of Tissue Damage from Compression-Release Stabilized Sockets. *ISPO 19th World Congress, Guadalajara, Mexico, April 24-27*.
- Munagauuru, D. and Cormier, D. (2022) "3D Printed Continuous Fiber Composites With Woven Structures" Proceedings of the 2022 Institute of Industrial Engineering Annual Research Conference, May 21-24, Seattle WA. Finalist for Best M&D Paper Award.
- Cormier, D., Liu, R., Iglesias Victoria, P., Zhang, S., and Greeley, A. (2022) "Effect of Inherently Porous Structure Produced By Metal Fused Filament Fabrication On the Tribological Behavior of Lubricated Steel-Steel Contact" *2022 International Manufacturing Science and Engineering Conference*.
- Greeley, A., and Cormier, D. (2021) "Vibration-Actuated Powder Dispensing for Directed Energy Deposition Systems", *Proceedings of the 2021 Solid Freeform Fabrication Symposium*.
- Alfadhel, A., Ouyang, J., Cormier, D., and Borkholder, D., (2020) "Enhanced properties of Aerosol Jet Printed PZT: Towards Realizing Flexible Automotive Sensors" IEEE Sensors Conference.
- Hamilton, J.D., Sorondo, S., Greeley, A., Kahn, B.E., Cyr, P., Cormier, D., Rivero, Iris V., 2019, October, "Hybrid Manufacturing: Influence of Directed Energy Deposition Parameters on Microstructure and Layer Adhesion of Stainless Steel 316L," Heat Treat 2019: Proceedings of the 30th ASM Heat Treating Society Conference, Detroit, Michigan.
- Jayabal, D., Zope, K., and Cormier, D. (2018) "Fabrication of Support-Less Engineered Lattice Structures Via Jetting of Molten Aluminum Droplets", Solid Freeform Fabrication 2018 Proceedings, Aug. 15th, 2018, Austin TX, pp. 757-764.
- Forouzandeh, F., Alfadhel, A., Xhu, X., Walton, J.P., Cormier, D., Frisina, R., and Borkholder, D. (2018) "A Wirelessly Controlled Fully Implantable Microsystem for Nano-Liter Resolution Inner Ear Drug Delivery" 2018 Solid-State, Actuators, and Microsystems Workshop, May 2018.
- Ge, C., Cormier, D., and Rice, B. (2018) "Damping and Cushioning Characteristics of a Polyjet 3D Printed Photopolymer Kelvin Foam", 21st IAPRI World Conference On Packaging.
- Poddar, P., and Cormier, D. (2017) "Engineered Lattice Structures With Axially Aligned Fibers", International Conference on Computational & Experimental Engineering Science, June 28th, 2017.
- Ouyang, J., Mahajan, C., Alfadhel, A., Cormier, D., and Borkholder, D., (2017) "Inkjet-printed Polyethylene-glycol sacrificial layer for Flexible Microfluidic Electronics", submitted to Transducers 2017 Conference Proceedings.
- Ooi, Y.K., Ugras, C., Gandhi, S., Cormier, D., and Zhang, J. (2017) "Integration of 3D printed dome-shaped lens with InGaN light-emitting diodes with enhanced light extraction efficiency" SPIE Photonics West Conference Proceedings, San Francisco, CA.
- Yang, L., Harrysson, O., Cormier, D., West, H., Zhang, X., Gong, H., and Stucker, B. 2016 "Design for Additively Manufactured Lightweight Structures: A Perspective", Solid Freeform Fabrication 2016 Proceedings, pp. 2165-2180.
- Cormier, D. (2016) "Frontiers and Challenges In Additive Manufacturing" DURACOSYS 2016 Conference Proceedings, Arlington, TX, June 13-15.
- Poddar, P., Williams, S., and Cormier, D. (2016) "Reduction of Coffee-Ring Defects in Inkjet Printed Electronics via High Speed Drying" *Proceedings of the 2016 Industrial and Systems Engineering Research Conference, IIE, Anaheim, CA*.

- Yang, L., Harrysson, O., Cormier, D., and West, H. (2015) "Shear Properties of Re-Entrant Auxetic Cellular Structures Made Via Electron Beam Melting" Solid Freeform Fabrication Symposium Proceedings, pp. 1394-1410.
- Mahajan, C., and Cormier, D. (2015) "3D Printing of Carbon Fiber Composites With Preferentially Aligned Fibers", *Proceedings of the 2015 Industrial and Systems Engineering Research Conference*, IIE, Nashville, TN. *Paper received ISERC Best Student Paper award.
- Ouyang, J., Penmetcha, A.R., Cormier, D. and Borkholder, D.A., 2015, November. Photonically Sintered PZT Energy Harvester. In *ASME 2015 International Mechanical Engineering Congress and Exposition* (pp. V010T13A024-V010T13A024). American Society of Mechanical Engineers.
- T. Mudgal, C. Reepmeyer, R.G. Manley, D. Cormier, and K.D. Hirschman (2014) "Crystallization of Amorphous Silicon and Dopant Activation using Xenon Flash-Lamp Annealing (FLA)" MRS Proceedings, Volume 1666, DOI: <http://dx.doi.org/10.1557/opl.2014.722>.
- Yang, L., Harrysson, O., Cormier, D., West, H., Park, C., and Peters, K. "Design of Auxetic Sandwich Panels for Structural Applications", 2013 Solid Freeform Fabrication Symposium Proceedings, Aug. 12-14, Austin, TX.
- Folgar, C., Folgar, L., and Cormier, D. "Multifunctional Material Direct Printing for Laser Sintering Systems", 2013 Solid Freeform Fabrication Symposium Proceedings, Aug. 12-14, Austin, TX.
- Ninkov, Z., Robinson, R., Bhaskaran, S., Arp, U., and Cormier, D. "Quantum Dot Coating of COTS CMOS Detector Arrays to Enhance UV and X-ray Sensitivity", 2013 SPIE Conference Proceedings.
- Khatri-Chhetri, P., Cormier, D., Chen, F., and Majumdar, P. (2011) "Printed Fuel Cell Electrodes With Engineered Porosity" NIP 27 and Digital Fabrication 2011 Proceedings. pp. 645.
- Johnson, D.G., Getpreecharsawas, J., Balasubramanian, S., Datar, A., Cormier, D., and Borkholder, D.A. (2011) "Hybrid MEMS: Extending Micro Manufacturing With Direct Write Processes" *Technologies for Future Micro/Nano Manufacturing Workshop - Technical Digest*, Aug. 8-10, Napa CA.
- Yang, L., Harrysson, O., West, H., and Cormier, D. (2011) "Design and characterization of orthotropic re-entrant auxetic structures made via EBM using Ti6Al4V and pure copper", *Proceedings of the 2011 Solid Freeform Fabrication Symposium*, Austin TX, Aug. 8-10 2011.
- Yang, L., Harrysson, O., West, H., and Cormier, D. (2011) "Characterization of Ti6Al4V 3D Auxetic Structures Fabricated via the Electron Beam Melting Process", *Proceedings of the 2011 Materials Science & Technology Conference*, Columbus OH, Oct. 17-19.
- Kumar, V., Manogharan, G., and Cormier, D. (2009) "Design of Periodic Cellular Structures for Heat Exchanger Applications" Proceedings of the 2009 Solid Freeform Fabrication Symposium, Austin, TX, August 3-5.
- Frigola, P., Agustsson, R., Boucher, S., Murokh, A., Badakov, H., Musumeci, P., Rosenzweig, J. Travish, G., Faillace, L., Cormier, D., and Mahale, T. (2009) "Development of Solid Freeform Fabrication (SFF) for the Production of RF Photoinjectors" Proceedings of the 12th European Particle Accelerator Conference.
- Frigola, P., Agustsson, R., Boucher, S., Murokh, A., Rosenzweig, J. Travish, G., Faillace, L., Cormier, D., and Mahale, T. (2008) "A Novel Fabrication Technique for the Production of RF

Photoinjectors” Proceedings of the 11th European Particle Accelerator Conference, Genoa, Italy, June 23-27.

- Mahale, T., Cormier, D., Harrysson, O., and Ervin, K. (2007) “Advances in Electron Beam Melting of Aluminum Alloys” Proceedings of the 2007 Solid Freeform Fabrication Symposium, Austin, TX, August 6-8.
- Cansizoglu, O., Harrysson, O., West, H., Mahale, T., Cormier, D. (2007) Direct Metal Fabrication of Geometrical Models Designed Using Optimization Techniques for Medical and Structural Applications, ICMA Proceedings 2007, May 28-30, Singapore.
- Harrysson, O. Deaton, B. Bardin, J., West, H., Cansizoglu, O., Cormier, D., and Marcellin-Little, D. (2006) “Evaluation of Titanium Implant Components Directly Fabricated Through Electron Beam Melting Technology”, Materials & Processes for Medical Devices, Boston, MA, November 14-16, 2005.
- Cormier, D., West, H., Harrysson, O. and Knowlson, K. (2004), “Characterization of thin walled Ti-6Al-4V components produced via electron beam melting”, *Solid freeform fabrication symposium* (pp. 440-447).
- Cormier, D., Harrysson, O., Low, J., and Knowlson, K. (2004) "Optimization of the Electron Beam Melting Process", Proceedings of the 11th Industrial Engineering Research Conference, Houston, Texas, May 16 – 18, 2004.
- Cormier, D., Harrysson, O. "Contoured Machining of Orthopedic Surfaces for Biomedical Implants” Proceedings of the 11th Industrial Engineering Research Conference, Portland, OR, May 18 – 21, 2003.
- Harrysson, O.L., Cormier, D.R. and Jajal, K., 2003, January. Custom Design and Manufacturing of Canine Knee Implant. In *IIE Annual Conference. Proceedings* (p. 1). Institute of Industrial Engineers-Publisher.
- Harrysson, O. L. A., D. R. Cormier, D. J. Marcellin-Little, and K. R. Jajal. (2003) "Direct fabrication of metal orthopedic implants using electron beam melting technology." In *Solid Freeform Fabrication Symposium Proceedings*, pp. 439-446. 2003.
- Cormier, D. and Harrysson, O., 2002, January. Mass Customization Via Rapid Manufacturing. In *IIE Annual Conference. Proceedings* (p. 1). Institute of Industrial Engineers-Publisher.
- Cormier, D., Taylor, J., Unnanon, K., Kulkarni, P. and West, H., 2000, August. Experiments in layered electro-photographic printing. In *Proceedings of the SFF Symposium* (pp. 267-274).
- Mahale, T.R., Taylor, J.B. and Cormier, D.R., 2000. Five axis freeform fabrication of the thermoplastic parts via SWIFT. In *Proceedings of the SFF Symposium* (pp. 289-297).
- Weintraub, A.J., Zozom Jr, A., Hodgson, T.J. and Cormier, D., 1997, December. A simulation-based finite capacity scheduling system. In *Proceedings of the 29th conference on Winter simulation* (pp. 838-844). IEEE Computer Society.

Graduate Student Advising

The following sections list only those graduate students whose committees I have either chaired or co-chaired. It does not include service as M.S. and Ph.D. committee member (too many to list).

PhD Students Chaired or Co-Chaired

Student	Topic	Status
Valeria Marin-Montealegre	Metal Jetting of Bioresorbable Zinc Alloys	In-Progress
Irtaza Razvi	Multi-Nozzle Liquid Metal Droplet Jetting	In-Progress
Sai Sri Nidhi Munaganuru	3D Printed Carbon Fiber Composites	In-progress
Usama Rifat	Magneto Jet Printed 4008 Aluminum	In-progress
Khushbu Zope	Multi-Scale Modeling of Molten Metal Droplet Jetting	In-progress
Paarth Mehta	Metal Additive Manufacturing Using Magnetohydrodynamic Liquid Metal Jetting	In-progress
Gabriel Stash	Molten Metal Melt Shaping	In-progress
Kareem Tawil	Computation Fluid Dynamics of Molten Metal Droplet Jetting	In-progress
Saidur Roney	Progressive Cavity Dispensing of Molten Metals	In-progress
Andrew Greeley	Powder Feed Efficiency In Hybrid Metal Additive Manufacturing	2023
Pritam Poddar	3D Printed Carbon Fiber Composite Axial Lattice Structures	2022
Manoj Meda	Printed Electronics Via Magnetohydrodynamic Liquid Metal Jetting	2021
Chaitanya Mahajan	Reactive Metal Alloy 3D Printing	2019
Ronald Aman	Bioresorbable Magnesium Alloy Bone Implants	2013
Li Yang ¹	Design and Analysis of Auxetic Cellular Materials	2012
Sasitorn Srisawadi	Freeform Fabrication of Composite Lattices	2011
Molly Purser	Annuloplasty Ring with Integrated Shape Memory Alloy Frame	2009
Tushar Mahale	Electron Beam Melting Material Development	2009
Ade Febransyah	Integration of Process Planning and Scheduling	2001
Kittinan Unnanon	Adaptive Slicing of Rapid Prototyping Models	2000
Alexander Weintraub ²	Scheduling With Alternatives In A Resource Constrained Environment	1998

Master's Students Chaired or Co-Chaired

Student	Topic	Status
Amelia Cardinali	An Exploration of 3D Multi-Material 3D Printing With Rigid and Compliant Polymers	2024
Chris Ventre	Design of a Rod Feeding Mechanism for Molten Metal Droplet Jetting	2024
David Olney	Automated Analysis of Engineered Lattice Structures in nTop Software	2023
Hope Scott	Development of an In-Situ Metal Droplet Jet Stability Monitoring System	2023
Bobby Kovach	Fabrication of a Novel Solid Oxide Electrolyzer Support Layer Structure Via Nanoparticle Inkjet Printing	2023
Usama Rifat	Magneto Jet Printing of 4008 aluminum	2023

Evan Cole	Strength Properties of Recycled and Virgin PEEK in Additive Manufactured Carbon Fiber Composite Parts	2022
Koral Fries	Mechanical Properties of 3D Printed Engineered Lattice Structures	2022
Ajinkya Patil	5-Axis Fused Filament Fabrication	2022
Alex Kibbe	Hybrid Additive/Subtractive Manufacturing Process Planning	Spring 2021
Anubhav Mukherjee	Preferential Alignment of Carbon Fibers in Wire Frame Structures using Fused Filament Fabrication and effects of conditioning on CF - Nylon composite	2020
Steve Sutton	Laser Powder Bed Fusion of a Custom Invar Alloy (MS Project)	2020
Dan Martin	Exploration of Generative Design for a Bicycle Frame	2020
Abishek Shankar	Metal Fused Filament Fabrication Study	2020
Sara Hernandez	KNN-Based Energy Harvesting	2019
Paritosh Mhatre	Multi-Nozzle 3D Printing With A Rotary Axis	2019
Dinesh Jayabal	Engineered Lattice Structures Printed Via Magnetohydrodynamic Liquid Metal Jetting	2019
Manoj Meda	Reactive Copper Ink Formulation and Curing for Printed Electronics	2019
Anthony Tantillo	Fused Filament Extrusion In A Nitrogen Atmosphere	2019
Shaunak Gandhi	3D Printed Optics	2018
Smruti Sahoo	3D Printed Electronic Device Interfaces	2017
Dhananjay Dubey	Pulsed Photonic Curing of Silicone Rubber	2017
Kshitij Luthria	A Study of 3D Printed Assembly Clearances	2016
Sourav Das	Influence of Slope and Distance In Photonic Curing of Conformally Printed Electronics	2015
Pritam Poddar	Pulsed Photonic Curing of Screen Printed Copper Oxide	2015
Akanksha Umrani	Fabrication of Micro Pillar Arrays Via Aerosol Jet Printing	2015
Matthew Jackson	Infrared Drying Parameter Optimization	2015
Arjun Wadhwa	Run-time Ink Stability in Pneumatic Aerosol Jet Printing using a Split Stream Solvent Add Back System	2014
Chaitanya Mahajan	3D Microextrusion of Aligned Carbon Fiber Composite Materials	2014
Swaroop Yerassi	Electro-Spinning of Ceramic Nano-Fibers	2014
Omkar Rishi	Feedrate Effects In Freeform Filament Extrusion	2014
Anuj Datar	A Microextrusion Process Parameter Model	2012
Sundareshan Balasubramanian	Thin film aerosol jet deposition of Cerium Oxide Nanoink	2012
Niranjan Damle	Controlled Porosity in SOFC Cathodes Produced Via Aerosol Jet Printing	2012
Tejas Bendarkar	Multi-material pneumatic microdispensing	2012
Prasanna Khatri Chhetri	Functionally Graded Electrodes In Solid Oxide Fuel Cells	2011
Lionel Senyana	An Evaluation of Electron Beam Melting As An Alternative To Forging	2011
Guha Manogharan	Analysis of Non-Stochastic Lattice Structure Design for Heat Exchanger Applications	2009

Vikas Kumar	Freeform Fabrication of Advanced Heat Exchanger Geometries	2009
Abhishek Kapur	Microwave Sintering of SOFC Materials	2008
Sayantan Modak	Freeform Fiber Alignment Via Dielectrophoresis	2008
Sasitorn Srisawadi	Rapid Tooling for Electrochemical Machining	2006
Ada Villalon	Improving the Surface Finish of Electron Beam Melted Components	2005
Ketan Jajal	Design of Custom Canine Knee Implant	2003
Tushar Mahale	Three-Dimensional Laser Printing	2003
Pradeep Mahadeven	3-D Laser Printing Process Optimization	2003
Parikshit Kulkarni	CAD-Based Training of a Robot Vision System	2001
Akhil Oltikar	Computer-Aided Upholstery Furniture Design and Manufacture	2001
Tiajian Feng	A Constraint Network Approach to Software Testing	1998
Kittinan Unnanon	Computer-Aided Assembly Planning	1997

Invited Talks

I give approximately 10 invited talks per year and have given invited talks in the U.S., Canada, France, Germany, England, Ireland, Portugal, Japan, and China. For the sake of brevity, a small sampling of noteworthy talks are provided below. A full list is available upon request.

- **Keynote Address:** 2025 International Conference on Mechanics and Industrial Engineering, Paris France.
- **Keynote Address:** 2024 Solid Freeform Fabrication Symposium, Austin TX.
- **Keynote Address:** 2023 HIAM Conference, Halifax Nova Scotia.
- **Invited Talk:** 2023 Additive International Conference, Nottingham UK
- **Invited Talk:** 2023 Techblik Conference, Berlin Germany
- **Invited Talk:** 2022 Fulbright Faculty Fellow Address, Waterford Ireland
- **Keynote Address:** Vibration Institute Annual Conference, Rochester NY
- **Invited Talk:** 2017 CHINano Conference, Suzhou China
- **Plenary Address:** 2016 DURACOSYS Conference, Madeira Portugal
- **Keynote Address:** 2016 HPICS Conference, Seattle WA

Representative Courses Taught

RIT

ISE 789: Metal and Composite Additive Manufacturing
ISE 789: Personalized 3D Printing
ISE 789: Functional Printing
ISE 789: CAD/CAM
ISE 727: Advanced Manufacturing Processes
ISE 761: 3D Printing
ISE 801: Design for Manufacture and Assembly
Multidisciplinary Senior Design

North Carolina State University

ISE 216: Manufacturing Practicum
ISE 330: Furniture Product Engineering
ISE 453: Material Handling
ISE 514: Product Engineering
ISE 715: Manufacturing Process Engineering
ISE 791B: Rapid Prototyping and Manufacturing

Service Activities

- **RAPID + TCT Trade Show:** Serve on the RAPID + TCT Conference Organizing Committee (2009 – present)

- **International Scientific Advisory Committee** (Canada) – Holistic Innovation in Additive Manufacturing (HI-AM) Consortium
- **Additive Manufacturing Journal (Elsevier)** – Editorial Board member and reviewer.
- **Rapid Prototyping Journal (Emerald Publishing)** – Editorial Board member and reviewer.
- **NSF:** Serve as a research grant proposal reviewer for 3-5 panels per year for the National Science Foundation
- **Solid Freeform Fabrication Symposium** - Annual service at SFF Symposium to judge nominations for career achievement (FAME) awards, best paper awards, best poster awards, etc.
- **Consultant:** Frequently asked to serve as business and venture capital consultant to gage commercial potential of new additive manufacturing technologies.
- **ASTM F-42** – Founding member of committee that develops standards pertaining to additive manufacturing processes and materials.
- **Navy Direct Digital Manufacturing of Metallic Components Workshop** - invited expert to help develop Navy's additive manufacturing research priority roadmap.
- **NSF Additive Manufacturing Roadmap** - invited expert to prepare a long term research-needs roadmap.