



Transcript of Andrew Wolfe, Ph.D.

Date: January 23, 2026

Case: Shenzhen Tuozhu Technology Co., Ltd. -v- Stratasy, Inc. (PTAB)

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1 (1 to 4)

1 UNITED STATES PATENT AND TRADEMARK OFFICE 2 ----- 3 BEFORE THE PATENT TRIAL AND APPEAL BOARD 4 ----- 5 SHENZHEN TUOZHU TECHNOLOGY CO., LTD., 6 Petitioner, 7 v. 8 STRATASYS, INC., 9 Patent Owner. 10 ----- 11 Case IPR2025-00531 12 U.S. Patent No. 9,168,698 13 Case IPR2025-00532 14 U.S. Patent No. 10,556,381 15 ----- 16 17 REMOTE DEPOSITION OF 18 ANDREW WOLFE, PH.D. 19 January 23, 2026 20 21 Reported by: Susan S. Klinger, RMR-CRR, CSR 22 Job No. 616852	3 1 A P P E A R A N C E S: 2 3 Attorneys for Petitioner: 4 Joshua A. Griswold, Esquire 5 FISH & RICHARDSON 6 1717 Main Street, Suite 5000 7 Dallas, Texas 75201 8 214.747.5070 9 10 Attorneys for Patent Owner: 11 Aashish Kapadia, Esquire 12 McDERMOTT WILL & SCHULTE 13 300 Colorado Street, Suite 2200 14 Austin, Texas 78701 15 512.726.2600 16 17 18 19 20 21 22
2 1 January 23, 2026 2 10:03 a.m. 3 4 5 6 Remote Deposition of ANDREW WOLFE, PH.D., held 7 before Susan S. Klinger, a Registered Merit 8 Reporter and Certified Realtime Reporter of the 9 State of Texas. 10 11 12 13 14 15 16 17 18 19 20 21 22	4 1 I N D E X 2 3 WITNESS PAGE 4 ANDREW WOLFE, PH.D. 5 EXAMINATION BY MR. KAPADIA 5 6 7 E X H I B I T S 8 (Not attached.) 9 10 No. Description Page 11 Exhibit 1003 Wolfe declaration, '698 10 12 Exhibit 1003 Wolfe declaration, '381 10 13 Exhibit 1004 Warren reference 74 14 15 16 17 18 19 20 21 22

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2 (5 to 8)

5 1 PROCEEDINGS 2 ANDREW WOLFE, PH.D., 3 having been first duly sworn testified as follows: 4 EXAMINATION 5 BY MR. KAPADIA: 6 Q Dr. Wolfe, can you please state your full 7 name? 8 A Andrew Wolfe. 9 Q Because we're conducting a remote 10 deposition today, you and I are not in the same 11 room, and so I'm going to ask you a few questions 12 about your environment. I think we have been 13 through this before. 14 First thing, do you have any materials, 15 whether written or electronic, with you today? 16 A Yes. 17 Q Okay. And what do you have with you? 18 A So I have printed out a number of 19 documents. My declarations for each of the IPR 20 matters, both of which are labeled Exhibit 1003, 21 the '698 and '381 patents, and then the Warren and 22 Calderon references. My copies all came from the	7 1 Q How about on your phone, do you have any 2 chat or messaging applications running on your 3 phone? 4 A My phone is in the next room. 5 Q Okay. How about email, do you have access 6 to email or do you have email applications open? 7 A They're not open. 8 Q Okay. 9 A I don't have any notifications. 10 Q Okay. All right. Is there anyone else in 11 the room with you? 12 A No. 13 Q Okay. During the deposition today, if 14 anyone else does enter the room, will you let us 15 know? 16 A I will. 17 Q Okay. All right. Dr. Wolfe, you have 18 been deposed before, right? 19 A Yes, I think I've been deposed by you 20 before. 21 Q Yes. Do you know how many times you have 22 been deposed?
6 1 PTAB website. 2 And then I'm sitting at my computer. It 3 has got millions of documents on it, but none of 4 them are open. 5 Q Okay. Anything else? 6 A No. 7 Q Okay. You mentioned you have millions of 8 documents on your computer. Do you intend to open 9 any of those materials today during the 10 deposition? 11 A No. If you ask me to I will, but that 12 would be the only exception. 13 Q Okay. And if you want to open any 14 materials that are accessible to you, just let us 15 know so that we can mark them and keep the record 16 of this deposition clean; is that okay? 17 A Okay. 18 Q Okay. On your computer do you have access 19 to any chat or messaging applications besides this 20 Zoom application that we're using today? 21 A As far as I know, nothing else is 22 currently running.	8 1 A No, certainly more than 100. 2 Q Yeah. All right. Well, you know, as 3 usual I will ask questions. You're under oath to 4 answer. Your counsel may object, you still have 5 to answer; is that okay? 6 A I understand. 7 Q Okay. After I ask you a question, just, 8 you know, please answer that question that I've 9 asked you and not anything else. Does that make 10 sense? 11 A I will do my best. 12 Q Okay. As usual, I will take a break when 13 needed. I will certainly ask if we want to take a 14 break periodically. All I ask is that if anyone 15 wants to take a break, we just finish your 16 response to any pending question before we take 17 that break; is that okay? 18 A I understand. 19 Q All right. Is there any reason that you 20 cannot testify truthfully today? 21 A Not that I'm aware of. 22 Q Okay. And you mentioned that you have a

9 1 pair of declarations in front of you, correct? 2 A Yes. 3 Q Okay. Those declarations are in support 4 of, I believe, two petitions for inter partes 5 review. The first one is IPR2025-00531 for U.S. 6 Patent Number 9,168,698, and then the other one is 7 for IPR2025-00532 for U.S. Patent Number 8 10,556,381. Does that sound right to you? 9 A It does. Unfortunately the copies that I 10 have don't have the -- the proceeding number on 11 them, but they do have the patent numbers, so... 12 Q Okay. And do those patent numbers 13 match -- 14 A They do. 15 Q -- the patent numbers that I've mentioned? 16 A Yes. 17 Q For those inter partes reviews, do you 18 know if the petitioner is Shenzhen Tuozhu 19 Technology Company, Limited? 20 A They are labeled Shenzhen Tuozhu 1003, so 21 I assume so. 22 Q Okay. And I -- I think you had done this	11 1 them. This is the '698 patent. 2 Q Yes. 3 A Okay. I have them. 4 Q Okay. So and do you have it open as well? 5 A Yes. 6 Q Okay. Excellent. So is the one that you 7 have open that I mentioned for the '698, that is 8 -- Exhibit 1003, is that a copy of your 9 declaration for the IPR for the '698 patent? 10 A It appears to be, yeah. 11 Q Okay. And so that we can keep everything 12 straight, but also simple, is it all right if I 13 refer to this as your '698 declaration today? 14 A Yes. 15 Q Okay. And if you open up the second 16 document that I uploaded, that is for the '381 17 patent, correct? 18 A Right. 19 Q Okay. If I refer to that declaration 20 today as the '381 declaration, would that be okay? 21 A Yes. 22 Q Okay. And from time to time I might refer
10 1 earlier, but whenever I refer to U.S. Patent 2 Number 9,168,698 I might just say the '698 patent; 3 is that okay? 4 A Yes. 5 Q Then for U.S. Patent Number 10,556,381, I 6 might just say the '381 patent; is that okay? 7 A Yes. 8 Q Okay. Let me start out by introducing a 9 couple of exhibits into the chat and we will do -- 10 A Okay. And then those are exhibits I 11 should download? 12 (Exhibits 1003 discussed.) 13 Q Yes. Here is one. Let me give it a 14 second. So the first exhibit that I dropped into 15 the chat -- they're both exhibit -- in respective 16 proceedings they're Exhibit 1003. The first one 17 is for proceeding IPR2025-00531 and then the 18 second one is for IPR2025-00532. 19 Let me know when you have received those 20 two and you can go ahead and just open up the -- 21 the first one, the one for the IPR2025-00531? 22 A Again, they don't have the IPR numbers on	12 1 to "your declarations," meaning both the '698 and 2 the '381 declaration. Would that be okay? 3 A It is going to depend on the question. I 4 may need clarification. 5 Q Okay, sure. If you need clarification, 6 you will let me know though, right? 7 A Yes. 8 Q Okay. Let's talk about your declarations, 9 Dr. Wolfe. Was anyone else involved in creating 10 them? 11 A Yes. 12 Q Who else was involved? 13 A I worked with counsel. I -- I developed 14 my opinions and discussed my opinions with counsel 15 and then they worked with me to -- to write 16 portions of it. But I had the final say over 17 everything that went into the declaration. 18 Q Okay. Anyone else? 19 A No. 20 Q And do you recall which counsel you worked 21 with? 22 A I recall working with Mr. Griswold and

13 1 Mr. Gupta, but there may have been others as well. 2 Q Okay. Besides counsel, did anyone else 3 contribute to your declaration? 4 A I cite documents written by other people, 5 but I prepared all the opinions in the matter that 6 I -- that I explained before. 7 Q Okay. For each of your declarations, I 8 think there are two page numbers at the bottom of 9 each page. And so to keep things simple, I'm 10 going to refer to the bottommost of those two page 11 numbers, I believe that starts with page 1 and 12 then goes to the last page of whatever the 13 document is. Would that be okay? 14 A That is fine. 15 Q So that should correspond to the page 16 number -- if you have the PDF viewer up, the page 17 number of the PDF viewer? 18 A It appears to, yes. 19 Q All right. Do you recall how many hours 20 you spent in preparing your declarations? 21 A No. 22 Q Was it approximately 10 hours?	15 1 And then I started becoming familiar with 2 3D printers in the early 2010s, and then again, 3 started teaching megatronics classes, I believe, 4 in 2014. And at that point I started actually 5 using and teaching students to use and maintain 6 consumer grade 3D printers. So I've been teaching 7 about them and using them since 2014 and I still 8 do today. 9 Q Okay. So you mentioned that you started 10 becoming familiar specifically with 3D printers in 11 the early 2010s; is that right? 12 A Yeah, yeah. The first one I used was the 13 MakerBot, but I was familiar with other ones that 14 were being developed in the industry as well. 15 Q Okay. You mentioned in the 1980s you 16 started working with additive manufacturing 17 techniques. What types of additive manufacturing 18 techniques were you working with back then? 19 A So primarily material deposition in layers 20 to manufacture displays and touch sensors. So 21 these were various techniques for -- for applying 22 layers of materials generally or removing portions
14 1 A I think it was probably more than that, 2 but I don't recall. 3 Q Okay. Let's -- let's talk a little bit in 4 relation to these declarations, your declarations. 5 I would like to discuss your background. So the 6 first question I have for you is what sort of 7 industry experience do you have related to 3D 8 printing? 9 A In the 1980s, I started working with 10 additive manufacturing techniques and subtractive 11 manufacturing techniques and building factory 12 equipment or modifying factory equipment to make 13 products using those techniques, using a variety 14 of materials. I continued to do that through the 15 mid '90s or so. 16 I also worked in and taught in areas 17 related to automation, what we typically refer to 18 as megatronics. So electronically controlled 19 moving systems primarily, again, for factories. 20 When I was at Princeton in the '90s, I worked with 21 General Motors and other companies on -- on both 22 control and sensing for manufacturing equipment.	16 1 of layers of materials with masks. 2 So we would use stencils, we would use 3 thick film materials, pastes, gels, inks, we would 4 put through them. We would use thin film 5 materials that would be deposited in vacuum 6 chambers using plasma deposition and sputtering. 7 We would use adhesives, which would be extruded 8 using machines that would be designed to extrude 9 them in particular patterns, all those things. 10 And of course, my training included 11 training in semiconductor manufacturing, which 12 although it happens on a much smaller scale, also 13 is -- tends to be additive and subtractive 14 manufacturing. 15 Q Okay. So you mentioned it was -- that 16 sort of additive manufacturing was for displays 17 and touch sensors. Was there anything else that 18 it was used for? 19 A We might have done something else, because 20 we had all the equipment. We made night lights, 21 but it was mostly focused around displays and -- 22 and touch sensors.

17 1 Q Okay. So that is additive manufacturing 2 techniques. How about subtract -- I think you 3 said subtractive manufacturing techniques? 4 A Right. So there you would typically do 5 something like put down a layer of material, then 6 put down a photo mask on top of it or a stencil on 7 top of it. And then use water or acid or 8 something to remove the portions that -- that 9 didn't belong there. 10 Q Okay. So those were for manufacturing of 11 similar products to, was it touch sensors? 12 A Yeah. And of course, you know, we also 13 did die cutting, which is a very simple 14 subtractive manufacturing technique where you just 15 cut a piece out. 16 Q And die cutting, are you referring to 17 semiconductor dies? 18 A No, no. I don't know why they're called 19 dies, but they're -- they're basically very 20 heavy-duty cookie cutters that you press down on 21 the material and it cuts a piece out. 22 Q Okay.	19 1 printing and a couple of them have built 3D 2 printers or 3D scanners. 3 Q Okay. Let's -- let's talk a little bit, 4 you mentioned that you -- some of your work 5 related to, I think touch -- was it touch sensors; 6 is that right? 7 A Yes. 8 Q What were those touch sensing -- I don't 9 know if that is the right term, touch sensors or 10 touch sensing devices? 11 A Well, I primarily worked on components and 12 integration. In the earliest days when I started 13 doing it around '83, they would have been 14 information kiosks. We put one in Logan Airport, 15 a bunch in Macy's and Neiman Marcus, some in 16 tourist destinations. Later in Epcot Center where 17 you would walk up and you would touch the CRT 18 screen and get some kind of information, you know, 19 like -- like -- like -- the wares, the store at 20 the mall kind of display. 21 Later on we did a lot of the early 22 handheld products. I did the first prototype for
18 1 A Tool and die manufacturer is the way we 2 think of it traditionally. 3 Q Okay. So let's -- that is industry 4 experience, how about research experience. Have 5 you had research experience related to 3D 6 printing? 7 A No. I had a little bit, again, related to 8 additive manufacturing for displays and touch 9 sensors, but my direct 3D printing experience has 10 been teaching about what is known in the industry, 11 not inventing it myself. 12 Q Okay. And you mentioned that you teach a 13 course, I think, was it in mechatronics? 14 A Yes. I also teach a -- I also teach an 15 electronic prototyping class as well, that also 16 some years uses 3D printing and always uses 17 printed circuit board manufacturing. 18 Q Okay. And besides those classes, do you 19 have any other teaching experience related to 3D 20 printing? 21 A Yes. I've supervised over 70 senior 22 thesis projects, and a number of them have used 3D	20 1 the Apple Newton, the first prototype for the IBM, 2 the first smartphone, Motorola's first smart PDA. 3 I did the first tablet computer and also what we 4 call point of sale or signature capture devices 5 where, you know, you would sign for your credit 6 card receipt. We did one for Sears, one for 7 McDonald's. So those were kind of the flavor of 8 the things that we were typically working on. 9 Q Okay. Were any of those devices that you 10 mentioned were they used as part of like a 3D 11 printer? 12 A Probably not. That was probably too early 13 for anybody to be really using the term 3D 14 printer, but they were often used to control 15 factory equipment, manufacturing equipment. 16 Q Okay. So let's -- let's talk about some 17 of those devices. You had mentioned that there 18 was a device used in the information kiosk like in 19 Logan Airport, for instance. 20 What did that device -- you mentioned a 21 CRT, what else did that device do? You know, what 22 was its functionality?

21 1 A I believe it had a telephone modem and an 2 old Apple II inside the kiosk. And it was 3 operated by Fidelity Investments and it would tell 4 you why you should invest in mutual funds. 5 Q Really interesting. So a user walks up to 6 the CRT, I suppose, and then they touch the -- the 7 glass screen of the CRT. Is that how it would 8 work? 9 A Yeah, there were different kinds, but that 10 particular one had a glass screen. It wasn't a 11 glass screen of the CRT. We put another piece of 12 glass in front of it, and that was one selectively 13 coated with what we call indium tin oxide, a -- a 14 thin film transparent conductor that would measure 15 the capacitance of your skin. 16 Q So -- so it measures the capacitance of 17 your skin and then what does it -- what does it do 18 with that? 19 A That particular one actually just had, I 20 think, 32 different locations on the screen. And 21 it would tell the Apple computer which one you 22 were touching, and then in that particular case I	23 1 multiple resistive films. And later ones that had 2 a continuous capacitive surface that could 3 triangulate where you were touching. I don't 4 actually remember which one we put into Macy's and 5 Neiman Marcus. 6 Q Okay. Let's -- let's talk about the you 7 said dual resistive layers; is that right? 8 A Uh-huh. 9 Q How does that work? 10 A Again, there were a variety of ways, but 11 typically you would send a DC voltage across the 12 lower layer. You would use the top layer as a 13 probe. There would be -- again, through this 14 additive manufacturing, we would add a bunch of 15 little, very, very tiny insulator dots onto the 16 lower layer of the plastic that would hold the top 17 layer up. But when you touched it, you would 18 press it down and compress those dots and make 19 contact and probe the lower surface. And then we 20 would flip the circuits around and you would use 21 the lower surface to probe the upper surface. 22 We had other designs where we could
22 1 actually wrote all the software too. So then that 2 would go and -- you know, if you picked tell me 3 about mutual funds, it would bring up a little 4 script to tell you about mutual funds. 5 Q Okay. And so the -- was it that thin film 6 layer would -- it would detect a -- is it a 7 capacitance of the finger, how did that work 8 exactly? 9 A There was a circuit that measured the 10 capacitance of that piece of metal. And when you 11 touched it, your capacitance added to that piece 12 of metal. In that particular case there is what 13 was called an RC oscillator. And when you added 14 capacitance it would slow down. And I -- I had a 15 circuit that was counting the pulses, and when it 16 slowed down we would know you were touching that 17 spot. 18 Q Okay. And does that -- that same basic 19 functionality, does that apply to the kiosk that 20 went into, say, Macy's and Neiman Marcus? 21 A I don't remember. We made a number of 22 different technologies including ones that had	24 1 actually get the electricity to run in both 2 directions on the lower surface linearly and you 3 would always use the upper surface as a probe. So 4 again, we would -- we would manufacture these 5 different layers additively, the -- the -- take 6 the substrate, we would just buy, just plastic 7 film, deposit the conductor on it sometimes in a 8 patterned way. Sometimes deposit silver or carbon 9 inks to change the resistivity on top of that and 10 then deposit a UV curable plastic gel that we got 11 from 3M that would create the separator dots and 12 then another conductive layer on another substrate 13 on top. And then we would typically die cut kind 14 of a ring of adhesive to go around the outside 15 that would hold all the pieces together. 16 Q On the outside of the display? 17 A Yeah. 18 Q Okay. Would any of these displays be able 19 to distinguish between, you know, like maybe 20 someone who is more experienced with the touch 21 display and barely touches the display versus, 22 like, a child who smashes on it with their thumb

25 1 or something like that? 2 A Some of them could, some of them could 3 not. 4 Q Which ones could kind of just make that 5 distinguish? 6 A You know, we had different software or 7 different firmware for different ones. And if 8 people wanted that kind of touch distinguishing, 9 you know, the strength of the touch or the, you 10 know, the size of the user, there are ways we 11 could measure that. I didn't have any -- it was 12 on a -- almost everything was designed for an 13 individual customer, customized for an individual 14 customer. So you know there were -- there were 15 hundreds or thousands of individual products. 16 Q So would you take, say, one physical 17 product and then adjust the -- you mentioned, I 18 think, firmware or software for the particular 19 customer or would you custom design the entire 20 system? 21 A Both. Oftentimes every display was a 22 different size, so we would have to do a custom	27 1 A It has been 30 plus years. Generally we 2 didn't measure the touch force on most of those 3 products, but we had the capability to measure it. 4 And we would only measure it -- again, we're 5 talking a long time ago. So in those days, we 6 didn't want to use our CPU time to measure it if 7 the customer didn't care, so we would only turn on 8 the -- that particular measurement phase. Again, 9 we're talking the '80s now, if the customer needed 10 that information, but we knew how to do it. 11 Q Okay. So you mentioned that that was in 12 the '80s. Did you work on similar types of 13 systems in the '90s? 14 A Yeah, through about the mid '90s, yeah, up 15 until I moved to California. 16 Q Okay. And -- and was the same sort of 17 focus was that in play in the '90s where you 18 didn't want to use the CPU time to measure it if 19 the customer didn't care to, I guess, perform a 20 particular measurement? 21 A I think that was generally true for air 22 products. You know there were all kinds of -- you
26 1 design for every customer at that point. 2 Q Okay. Were there any designs for the 3 display itself where you would have to make design 4 changes in order to accommodate a customer request 5 to distinguish between, let's say, one customer 6 who is pushing on a display very hard versus a 7 customer who is just barely touching the surface? 8 A We did that. I mean, you know, there were 9 -- there were cases where people would want to 10 touch it, drag it around and push harder to click. 11 So -- so there were instances of that, yes. 12 Q So for that example where a customer, you 13 know, touches a display, drags around their finger 14 and pushes even harder to click, would you have to 15 make design changes to the display? 16 A Not to display, but to the touch sensor 17 software -- 18 Q Okay. 19 A -- and that firmware. 20 Q So what sort of changes -- help me 21 understand what sort of changes would you make to 22 the touch sensor software?	28 1 know, there were competitors that all kinds of 2 force sensing technology and it was very 3 well-known, but wasn't the bulk of the market at 4 that point. 5 Q Okay. You mentioned tablet computers as 6 well, you have experience with tablet computers? 7 A I do. 8 Q Do those tablet computers accept input 9 from a pen, for instance? 10 A From a stylus, yeah. 11 Q Stylus? 12 A The -- the first one I did was -- was -- 13 always used a stylus, the later ones could use a 14 stylus or a finger. 15 Q Okay. What kinds of sensors were used on 16 those systems so that you could accept input from 17 a stylus? 18 A In those particular systems, ones I worked 19 on, again they were either capacitive touch 20 sensors or resistive touch sensors. 21 Q So did they use similar sorts of sensors 22 to what you had described earlier with films,

29 1 whether it be one or more layers? 2 A The ones I worked on did. 3 Q And for those systems where you would have 4 a stylus as an input, do you recall if those 5 systems would distinguish between, for instance, a 6 stylus that has just touched the screen or maybe a 7 harder press that might correspond to a click? 8 A I don't recall that being part of any of 9 the commercial systems, the actual systems that I 10 worked on. I mean, again, they were known in the 11 industry, but not the ones that I worked on. 12 Q Okay. So aside from the stylus input or a 13 touch input from a human finger, did you work on 14 other sorts of touch systems for a touchscreen? 15 A I'm not sure I understand the question. I 16 worked on things that would detect a stylus and 17 things that would detect a finger. 18 Q Okay. But not -- those two objects, 19 nothing else? 20 A They might have responded to other things, 21 but that wasn't the normal usage -- 22 Q Okay.	31 1 amount of force to turn it on. 2 Q Okay. So you have used the term force 3 sensor a few times. It sounds like you're 4 familiar with it. What -- in your view what is a 5 force sensor? 6 A Again, it varies among industries and 7 context, and it varies over time. But generally a 8 force sensor is a device that can be used as part 9 of a system to measure a force. 10 Q Can you give me an example of a force 11 sensor? 12 A A strain gauge is one that is commonly 13 used, something called a load cell. It can be a 14 variable resistor within -- with a spring. It can 15 be -- we have what we call capacitive force 16 sensors where we press two plates together and 17 measure the capacitance. There are piezoelectric 18 force sensors where we call them force sensors. 19 They don't literally measure force, they actually 20 measure changes in force. Accelerometers and 21 gyroscopes can be force sensors. They can measure 22 force depending on how you hook them up and how
30 1 A -- matter. 2 Q Okay. I think you -- 3 A I mean the resis -- the resistive 4 touchscreens, if you -- if you put a brick on 5 them, that would count as a touch as long as you 6 had enough pressure to overcome the -- the 7 separators. 8 Q So you mentioned just now if you had 9 enough pressure you had also mentioned that there 10 were force sensing. So is there -- is that 11 basically the same thing, like, having enough 12 pressure and the force sensing capability of these 13 systems or is that a different capability? 14 A In the touchscreen world, we would use the 15 term "force sensing" when we were measuring it, 16 but we might have had a force threshold even if we 17 weren't measuring the force. Just was it enough 18 to turn it on or not enough, right. 19 So again, it takes a certain amount of 20 force to turn on the ordinary light switch in my 21 office, right, but nobody calls a light switch a 22 force sensor even though it requires a certain	32 1 you use them. 2 Q Any other examples come to mind? 3 A I'm sure there is others. We just used 4 something called a force sensing resistor. It was 5 an actual, like, a thick film material that would 6 respond to force. There may be other kinds of 7 force sensors out there. It is a pretty 8 well-known and rich field. 9 Q Let's -- let's talk about some of those 10 sensors you mentioned. I think the first one you 11 mentioned was a strain gauge? 12 A Yes. 13 Q How does a strain gauge work? 14 A I don't know all the material science 15 involved, but I can tell you just as a -- as a 16 person who would typically use a strain gauge, I 17 believe that it has two thin pieces of metal. And 18 when you put a force on it, one or both of them 19 bend and the resistance of the metal changes when 20 it is deformed. 21 Q So is -- is a strain gauge measuring 22 resistance of the metal or a change in resistance?

33 1 A It is measuring force. It is used to 2 measure force, but the mechanism for measuring the 3 force is by measuring the change in the resistance 4 to metal. And -- and again, you can't directly 5 measure resistance, I don't think. So what you do 6 is you measure the response to a current or a 7 voltage. That is how we measure resistance. 8 Q Okay. So you -- so the strain gauge will 9 measure a response to a current or a voltage and 10 then by understanding that change corresponding to 11 resistance it will then be able to measure a 12 force; is that right? 13 A Correct, that is the way it is typically 14 used. It is a standard kind of a force sensor. 15 Q Okay. I think you had also mentioned 16 capacitive sensor? 17 A Yes. 18 Q How does a capacitive sensor work? Is 19 that the same way as a strain gauge? 20 A No. Capacitive sensors typically have two 21 metal plates that are separated by some 22 insulation. That insulation can be air or vacuum	35 1 forces and making measurements and -- and -- and 2 graphing it yourself, so that you know the 3 response. The response isn't going to change over 4 time. 5 Q Okay. So does the -- are there any -- 6 what variables go into that response? Is it just 7 a simple I measure different capacitance values 8 and then I know the force from it? 9 A You would measure capacitance in known 10 forces. 11 Q Okay. 12 A You know, you would -- you would draw a 13 curve, same as any other sensor. 14 Q Okay. And so earlier I think you had 15 mentioned that for some touchscreens you would 16 use, say, a finger, for instance. Would it matter 17 whether you are using a finger to apply the force 18 or something else? 19 A In the capacitive touchscreens it would. 20 But in -- for a -- for a capacitive force sensor, 21 generally not. 22 Q Okay. What is the distinction between a
34 1 or it can be some other material. And typically 2 the force that is being measured will -- will push 3 them closer together. And when you push metal 4 plates closer together, the capacitance between 5 them changes and that can be, again, measured with 6 a simple circuit. 7 Q Okay. And so when the capacitance 8 changes -- so you measure, I guess, a change in 9 the capacitance, does that -- so the sensor just 10 measures capacitance, it doesn't measure force? 11 A The sensor measures force and then 12 represents that force in the form of a 13 capacitance. And then the user measures the 14 capacitance as a representation of the force. 15 Q Okay. And for, like, a capacitive sensor, 16 how would you know like if I -- I'm going to make 17 up a capacitance, I don't know, 10 -- 10 18 nanofarads, how would you know what 10 nanofarads 19 means? 20 A Either you would be provided that 21 information by the manufacturer or you would 22 characterize it by applying a variety of different	36 1 capacitive touchscreen and a capacitive force 2 sensor? 3 A A capacitive touchscreen is measuring the 4 capacitance of the person, which will vary as a 5 function of force as a side effect of the fact 6 that -- that your finger is deformable and that it 7 is made up of a complex set of liquids and solids. 8 So it is not -- not -- it is different for each 9 person. And it could only be measured with a very 10 general level of accuracy. 11 The capacitive force sensors are much more 12 precise and they're not tied to the capacitance of 13 the body or any of the other material properties 14 of the body. The force acts on some type of a 15 spring, usually one that doesn't look like what we 16 think of as a spring, but -- but is simply part of 17 the -- of the natural materials of the sensor. 18 And that causes the distance between the sensor 19 plates to vary and that is much more predictable 20 and much more reliable. 21 Q Could someone use a capacitive force 22 sensor with their finger, I guess?

37 1 A It depends on the range of the sensor, 2 right? I mean, if the sensor was designed to -- I 3 mean, yes, you could, right. The question is 4 whether or not you could apply enough force with 5 your finger to trigger that particular sensor. 6 For some sensors you could, for some sensors you 7 could not. 8 Q Could -- what if -- what if I have -- I 9 don't know, an older person who has very squishy 10 fingers. You mentioned earlier fingers -- your 11 finger can deform if you touch something. Is that 12 a reason why maybe you can't apply enough force 13 for a capacitive force sensor for a particular 14 capacitive force? 15 A No, no. There -- there are capacitive 16 force sensors at very different ranges, right. So 17 there might be one to -- to measure the force of a 18 suspension of a truck, right. If you try to apply 19 that much force with your finger you would just 20 shatter the bones, right? We're not talking about 21 subtleties here, right? 22 You can build -- you can buy capacitive	39 1 Now, if it wasn't applied uniformly could 2 there be a difference in measurements of .001 3 percent, I don't know, because it is so irrelevant 4 to any application I have ever seen that I've 5 never seen anybody measure that. 6 Q Okay. So we've talked about strain gauges 7 and capacitive sensors. Have you ever -- I think 8 you also mentioned piezoelectric sensors; is that 9 right? 10 A Yes. 11 Q How do those work? 12 A Piezoelectric materials generally are 13 crystals. One of the properties of them is that 14 if you apply a change in force to the crystal, it 15 will generate a voltage that corresponds to the 16 change in force. So for example, sometimes 17 they're used in microphones to measure the 18 difference in air pressure. 19 Q Okay. So again, you're -- you're 20 measuring a change in voltage; is that right? 21 A Not so much you're measuring. You're 22 measuring the change in force, but it gets
38 1 force sensors over, you know, three, four orders 2 of magnitude. And some of them are suitable for 3 interaction with a person and some of them are 4 suitable for interaction with -- with, you know, a 5 locomotive. 6 Q And when the -- so for the ones that are 7 suitable for interaction with a person, would it 8 matter how much the person's finger, for instance, 9 deforms when they use the sensor? 10 A Not significantly for most applications, 11 right. Certainly not -- not, you know, not to two 12 decimal places or something like that. It would 13 not -- not in a way that -- that any application I 14 have ever seen would care. 15 Q Okay. So -- and so you mentioned two 16 decimal places. Help me understand what is the 17 distinction here between the deformation of the 18 finger and -- and what you care about? 19 A Well, it might be that the deformation of 20 the finger could -- could change the amount of 21 force that is being applied. I mean, all that 22 matters is the amount of force.	40 1 represented in the signal as a voltage. 2 Q So the signal from the piezoelectric 3 sensor is a change in voltage? 4 A Yes. I mean, you can't put a force on 5 a -- you can't represent a force electrically on a 6 wire, right? So the whole point of a sensor -- of 7 a force sensor is to turn the force into some type 8 of an electrical signal. 9 Q Okay. 10 A That is why we use electronic force 11 sensors is to perform that translation. We call 12 them transducers. They -- they -- they take in 13 one form of energy and output a different form of 14 energy. 15 Q Okay. And so you're -- you're saying 16 that, so your output to signal is a different form 17 of energy than the force, but you then use -- 18 A Right. 19 Q -- that signal to perform a measurement? 20 A That would be a typical thing to do, 21 right? I mean, if -- if you didn't need to 22 transform it, you wouldn't need a sensor, right?

41 1 So that is why we use sensors is to -- is to take 2 one type of energy or one type of other physical 3 phenomenon and transform it into another. 4 Q And -- and how would you know, for 5 instance, what sort of signal corresponds to a 6 given force? 7 A Typically when you buy the sensor, it just 8 tells you in the instructions. But if you didn't 9 have that, you would perform a simple experiment 10 with it to -- to characterize it. 11 Q Okay. Let's talk about some other -- 12 other types of sensors, I think you might have 13 heard of these before. 14 Are you familiar with optical sensors 15 being used as a force sensor? 16 A There are lots of different kinds of 17 optical sensors. Optical sensors can be used to 18 determine if something is being deformed, that can 19 be a force sensor. They can be used to measure 20 distance. If you know the correspondence between 21 distance and force, that can -- that can work. 22 There are probably other kinds of optical	43 1 in shape in this optical system? 2 A In some of them, you are looking to see if 3 something bends. But again, there are other ones 4 as well that will actually, you know, measure 5 distance with time of flight or use some kind of 6 interference pattern between lights. You know, 7 there are a variety of different ways to do this, 8 but again, these are -- these are simple 9 components. 10 Generally you just go buy one. It gives 11 you a chart that says, you know, here is how the 12 signal represents the force. And it gives you 13 instructions on how to connect it up and that is 14 what you do. 15 Q Okay. And how would an optical sensor -- 16 so you have a certain amount of deformation. How 17 would you know, let's say, 1 millimeter of 18 deformation, how -- how do you translate that to 19 force? 20 A It depends on the materials involved, but 21 again, you know, the deformation of -- of 22 materials is well-known. It can be described by
42 1 force sensors as well, but I haven't used any 2 other ones. 3 Q Okay. So I think the two things you 4 mentioned is that the optical sensors are used to 5 determine if something is deformed and to 6 understand or to measure distance; is that right? 7 A Those are the two that I mentioned. 8 Q Okay. And for the -- for the first one 9 where you are looking at or trying to determine if 10 something is deformed, how does the optical sensor 11 do that? 12 A Again, I don't know -- you know, to use 13 these sensors you don't necessarily have to know 14 how they work all the time, right, because they 15 come in instructions. So that has been my -- you 16 know, that would be my normal way of interacting 17 with them. But I do know from some of the work 18 that I've done at the university that one way to 19 do that is -- is that you basically look at 20 something and see whether or not its shape has 21 changed. 22 Q Okay. So you're just looking for a change	44 1 spring constants, it can be -- in some cases just 2 read off of charts, and other cases you can run it 3 through a tool, a finite element analysis tool 4 what, you know, what would be an ordinary CAD 5 tool. So it depends on the circumstances, but 6 again, people who build things out of materials 7 understand how to characterize the deformation as 8 a function of the force. And that is only one way 9 to do it. 10 Q Okay. How about have you heard of a 11 potentiometric sensor? 12 A Yes, I had mentioned that before when we 13 were talking about the variety of sensors. 14 Q And how does a potentiometric sensor work? 15 A So a potentiometric refers to something 16 using a potentiometer. A potentiometer is a word 17 for a variable resistor. Generally, I mean there 18 are lots the different kinds of sensors like that, 19 but if you want it to be a force sensor, generally 20 you would combine the potentiometer with a spring. 21 The length of the -- sorry. The length of the 22 spring would vary as a function of the applied

45 1 force. 2 The potentiometer would be adjusted to 3 match the length of the string -- of the spring, 4 right. So essentially, there are potentiometers 5 that you push and pull on them, right. 6 And then the potentiometer's length would 7 correspond to the spring length, which would 8 correspond to the force. And you can measure the 9 resistance of the potentiometer as a function of 10 its length. It could also be done rotationally as 11 well. 12 Q And earlier I think you had mentioned that 13 you don't measure resistance directly. Does that 14 apply in this circumstance as well? 15 A I think that is right. You always measure 16 -- you know, resistance, current and voltage are 17 always in a fixed relationship according to Ohm's 18 Law. So what you do is you -- to measure one, you 19 use the other two. So if you want to measure 20 resistance, you look at the relationship between 21 voltage and current. 22 Q Okay. And so for a potentiometric sensor	47 1 doesn't measure your weight, right. It doesn't 2 measure -- it measures the deformation of either a 3 potentiometric sensor or a capacitive sensor that 4 correspond to the force of gravity on your body. 5 We still think of a scale as measuring weight in 6 normal usage. 7 Q Okay. Okay. I see what you are saying. 8 How about an acoustical sensor, can that 9 be a force sensor? 10 A It could. I've seen it in the literature. 11 Again, I think it is primarily measuring 12 deformation or distance, but there could be other 13 kinds as well. Again, you know, as a person of 14 ordinary skill in the art, we don't have to 15 understand the underlying physics of every sensor, 16 because you just buy them with documentation on 17 how to use them, anymore than somebody has to 18 understand how their TV works to watch TV. 19 Q Have you ever -- so for all the sensors 20 that you have used in your experience, do they all 21 have the documentation that you need in order to 22 understand how to use them for, say, a force
46 1 you are looking at, let's say, a measurement of 2 the resistance and that corresponds to a change in 3 the length of a -- of a spring; is that right? 4 A In a common one. Again, they can be built 5 differently, it can be based on torque. I'm sure 6 there are lots of different configurations, but 7 that is the common one that I'm -- that I'm used 8 to. 9 Q Okay. So in that circumstance, then, is a 10 potentiometric sensor a force sensor? 11 A Yes, it is measuring force. 12 Q So -- so help me, maybe I'm 13 misunderstanding something. I thought we just 14 said that it was measuring the length of a spring? 15 A Right. But a spring, according to Hooke's 16 Law, the length is going to be a function of the 17 applied force, right. I mean, that -- that is the 18 nature of measurement, right. You measure things 19 by -- by -- by understanding the physical 20 relationships and taking advantage of those 21 relationships, right. 22 Your -- your -- your bathroom scale	48 1 sensor? 2 A Not always, but that is always a option. 3 If you need a force sensor, you can always get one 4 when it comes documentation. 5 Q Yes. 6 A Some -- some people just buy surplus or, 7 you know, things that are just, you know, have -- 8 come in bins. But typically if you go to a 9 manufacturer, either -- either it comes with 10 documentation or they will work with you to 11 generate the documentation. 12 Q Okay. So aside from having the 13 documentation or working with the manufacturer 14 to -- to generate it upon request, what else would 15 someone do if you get it from -- something from a 16 parts bin, what would someone do to understand how 17 that sensor works? 18 A It is what we call characterizing a 19 sensor. So today is Friday. On Tuesday, my 20 students built their own sensors, right, they were 21 distance sensors. They built them themselves. I 22 didn't really tell them much about the parts, so

49 1 they had to characterize them. 2 So they did a very simple experiment. 3 Took them about 45 minutes where they placed the 4 sensor 5 centimeters, 10 centimeters, 15 5 centimeters, 20 centimeters from the wall and they 6 measured its output. And then they drew a graph 7 and now they knew what the transfer function was 8 of that sensor. A very elementary kind of a thing 9 to do. 10 Q Okay. So that was measuring -- was that a 11 sensor that was measuring distance? 12 A That was a distance sensor. 13 Q Okay. And -- 14 A And an optical distance sensor in that 15 case. 16 Q Okay. And -- and so let's say you have 17 the readings from the sensor for this optical 18 distance sensor and now you know what distance 19 that corresponds to, right? 20 A Right. 21 Q Do you refer to that as a transfer 22 function, I believe?	51 1 other type of, say, electrical metric directly? 2 A No, they measure what they're intended to 3 measure. It could be a force, it could be a 4 distance. It could be a person's capacitance. 5 And again, they're transducers. That is what 6 sensors generally are. So they then output some 7 signal. In today's world, it could be a digital 8 signal, but traditionally it would be a voltage or 9 a current or a frequency or a resistance or a 10 capacitance. Some electrical parameter that is 11 well-known and that any electrical engineering 12 student would know how to measure. 13 Q Okay. So you had mentioned a couple of 14 things that I understood in terms of capacitance, 15 voltage, current, but then you also mentioned 16 things like frequency. How does frequency work 17 into a measurement for an electrical parameter? 18 A There is -- there are circuits that will 19 oscillate at a frequency that is reflective of the 20 resistance capacitance and/or inductance of the 21 circuit. So for example, that very first 22 capacitive touchscreen that I use -- that I sold
50 1 A Yes. 2 Q Would that transfer function be used to 3 tell you what sort of force, for instance, was 4 used to -- to have that sort of distance? 5 A No. In this case this was a distance 6 sensor so it just measured distance. This was not 7 a force sensor in this case, but you would do the 8 same process with a force sensor. Instead of 9 making measurements at known distances you would 10 make measurements at known forces. 11 Q Okay. So you would apply a particular 12 force and then what would you measure? 13 A Whatever the output of that particular 14 sensor is. Again, in electronics it is usually a 15 voltage or a current, but it could be a frequency 16 or something else. You know, we have -- there 17 are -- there are a dozen or more very, very common 18 techniques. Sensors have been around for hundreds 19 and hundreds of years. 20 Q And so are all these types of sensors 21 we've been talking about essentially just 22 measuring a voltage or a current or some sort of	52 1 that I told you about in Logan Airport I had a 2 circuit that would vary its oscillation frequency 3 as a function of the person's capacitance that was 4 touching it. 5 And it would get slower when a person 6 touched it because the RC delay -- the resistive 7 capacitance product that impacted the timing of 8 the oscillation would increase. So I would simply 9 count the number of oscillations for a 10th of a 10 second or something. And if there were more 11 oscillations then I knew it was not being touched. 12 If there were fewer oscillations, then I would 13 know the frequency had gone down and it had been 14 touched. 15 Q So you were looking for a change in 16 frequency over time? 17 A In that case. Well, no, I was -- I was 18 looking for what is the current oscillation 19 frequency right now, because in that particular 20 case, that would tell me the current capacitance 21 on the circuit. 22 Q Okay.

53 1 A But for example, if I had a capacitive 2 force sensor that might be the way that I would 3 interface with it, is that I would connect it to a 4 oscillator and as its capacitance would change, my 5 oscillation rate would change. 6 Q Okay. So you might measure the -- the 7 frequency of the oscillation and then from there 8 determine what the capacitance is? 9 A Correct. 10 Q And then -- 11 A And again -- 12 Q -- how would it go -- 13 A -- I would know from the documentation or 14 from my characterization how the capacitance 15 describes the applied force. 16 Q Okay. Okay. So -- so you get the 17 frequency, then you get the capacitance, and then 18 you looked at the documentation to understand what 19 applied force corresponds to a particular 20 capacitance? 21 A Yes. And again, that has just been a 22 normal way to use sensors of all kinds for	55 1 touchscreens? 2 A The ones we use on phones, yes. Cars 3 sometimes are still resistive. Other kinds of, 4 you know, cheaper devices may be resistive, but -- 5 low-end tablets, but most of our phones are what 6 we call projective capacitive touchscreens, which 7 were, you know, they were -- they were made 8 popular by the iPhone. 9 Q What does projective mean in this context? 10 A It has to do with the fact that there is a 11 -- an electric field that is actually jumping from 12 one strip of conductor to another. And it -- 13 it -- it goes out into the space above the flat 14 touchscreen. So they think of the electric field 15 as being projected up into the area where your 16 finger would be. 17 Q So what does it measure? Is it still 18 measuring capacitance? 19 A It is. It is measuring what is called 20 mutual capacitance. And it is very complicated, 21 because depending on the circuit parameters it is 22 measuring both the ability of your finger to
54 1 hundreds of years. 2 Q Okay. When you are dealing with a 3 touchscreen, is that -- is that relationship 4 uniform across the entire screen? 5 A It depends what kind of touchscreen it is. 6 Q Well, what -- what are the different types 7 of touchscreens? 8 A There are many. There are probably more 9 than 20 that I've worked with. But there are 10 touchscreens called zone capacitive touchscreens 11 where you just break the screen into regions. 12 There is some that we used to call analog 13 capacitive touchscreens, where the capacitive 14 response varies across the screen, and you have to 15 triangulate it by making measurements from various 16 edges. And there are what we primarily use today 17 on our phones, which are called projective 18 capacitive touchscreens, where there are rows and 19 columns and we interpolate the signals between the 20 rows and columns. 21 Q Okay. So for the screens that I think 22 most of use today, those are capacitive	56 1 couple -- again, these are AC signals, between the 2 stripes, but also the ability for you to take the 3 signals and absorb them, and, you know, bring them 4 down to the ground through your feet. And 5 different manufacturers emphasize different 6 combinations of those two capabilities. 7 Q So then is it possible to detect when 8 someone is, I guess, close to the screen instead 9 of actually smashing their finger on to it? 10 A It is. In various -- we call that 11 hovering usually in the business. And most -- 12 most phone manufacturers try to avoid responding 13 to that, because it is very hard to control your 14 finger when it is not touching something, but -- 15 but it is certainly possible to measure in that 16 kind of a phone. 17 Q Okay. I think another type -- I don't 18 think we have discussed this today, but are you 19 familiar with Hall effect sensors? 20 A Yes. 21 Q What are those? 22 A Boy, again, I can't get too much into

57 1 physics, because it is way down in the quantum 2 world. But a Hall effect sensor is a 3 semiconductor device whose conductivity will 4 change in the presence of a magnetic field. 5 Q So let's break that down, because I don't 6 know if I follow everything you said. 7 So you have a magnetic field. What is 8 generating the magnetic field? 9 A Usually a magnet. 10 Q Okay. So you have a separate magnet that 11 generates the magnetic field and then -- and then 12 you have the Hall effect sensor to -- to, I guess, 13 detect changes? 14 A Yes. Now, oftentimes a Hall effect sensor 15 is integrated with a switch, so it will actually 16 make a switch happen at a certain threshold. But 17 let me give you some examples of where they're 18 used today. 19 When I open and close the windows in my 20 house, there are Hall effect sensors to 21 communicate with the alarm system, right. So the 22 window frame has a magnet on it. When I close the	59 1 switch, but we will specify literally how many 2 newtons of force we want to have as being the -- 3 the threshold for when we treat the switches being 4 pressed. 5 Q Okay. So the spring -- help me understand 6 that, where the spring comes into play? 7 A The spring naturally responds to force 8 with distance, right. So the position of a spring 9 is a function of the force that is applied on it. 10 Hall effect sensors can measure the 11 position of a magnet. So if you connect the 12 magnet to a spring, the position of the magnet 13 will be a function of the applied force on the 14 spring, which we can then measure with a Hall 15 effect sensor. 16 Q Okay. So it is a combination of -- of, I 17 guess, distance, the spring moving the magnet, but 18 then also you're not measuring the distance. You 19 are measuring -- what did you say earlier, the 20 magnetic -- 21 A Position. 22 Q Okay.
58 1 window, that magnet is in front of the Hall effect 2 sensor, and it tells the alarm that the window is 3 closed. 4 If you were to buy a very high end gaming 5 keyboard or joystick, a Hall effect sensor would 6 be used to measure the -- the keypresses, because 7 they don't wear. We use them in my lab. My 8 students we use them as motor encoders. We put 9 the magnets around the shaft of the motor. We use 10 two Hall effect sensors. As the motor spins, the 11 magnet will pass by the Hall effect sensor and 12 create a pulse. We can determine how fast the 13 motor is running. 14 Q Okay. 15 A But there are other kinds as well. You 16 could combine a Hall effect sensor with a spring 17 and produce a force sensor. 18 Q So is that what is done in these, like, 19 the keyboards you mentioned? 20 A Yes. In fact, when we -- when we go to 21 purchase a Hall effect key from a key 22 manufacturer, again, that one has got a built-in	60 1 A Oh, you are measuring the position of the 2 magnet by measuring the magnetic field. 3 Q Okay. 4 A Again, you know, all modern transducers, 5 all modern sensors use a combination of effects. 6 Q Okay. Okay. So in that sort of 7 configuration, the Hall effect sensor is a force 8 sensor? 9 A It would be a component of a force sensor. 10 The whole thing is the force sensor. The 11 combination of the spring, the magnet and the Hall 12 effect sensor. 13 Q Okay. How about have you heard of an 14 electromagnetic Eddy current sensor? 15 A I have. I actually do not know the 16 physics of how they work, but I know that you can 17 use them to measure variations in Eddy currents in 18 materials that vary as a function of force. It is 19 somewhat -- it is very similar to a string gauge 20 in that the material itself changes its properties 21 as a function of force. 22 Q Okay. You mentioned Eddy currents and I

61 1 know I used the term, too, but I don't -- I don't 2 actually know what the term means. Do you know 3 what an Eddy current is? 4 A You know, I use it in certain contexts, 5 but I don't know if I know the formal definition. 6 I think an Eddy current is basically a current 7 that is just kind of going in whatever creation it 8 wants as opposed to directly between the two 9 points so that -- that you are concerned about. 10 Q Okay. And so that -- that goes back to 11 what you were saying earlier about current, was it 12 current voltage and resistance have a 13 relationship? 14 A Yes. 15 Q Okay. And is that why you think Eddy 16 current sensors are similar to string gauges? 17 A In both cases you have got a situation 18 where in circuit the current varies as a function 19 of the force, because of the material properties 20 vary. Again, this is beyond my real expertise, 21 but I believe it just has to do with -- with the 22 molecules being pressed closer together and	63 1 one downloaded and opened? 2 A That is the '381 patent. 3 Q I guess, the first thing I have a question 4 about is you have reviewed both the '698 and '381 5 patents before, right? 6 A Yes. 7 Q Do those two patents have the same 8 figures? 9 A As far as I can tell, yes. 10 Q Okay. Let's start with the '698 patent. 11 I'm going to use the page numbers again at the 12 bottom of the page to direct you to various pages. 13 So on the second page of the '698 patent you 14 should see figure 1. Do you see figure 1? 15 A Yeah, give me a chance to rotate it here. 16 Q Yeah, you may need to rotate it. 17 A Okay. 18 Q Figure 1 is a block diagram of a 3D 19 printer, right? 20 A Yes. 21 Q Okay. I wanted to ask you about some 22 parts of figure 1. Which -- which portion of
62 1 further apart. 2 Q Okay. We've been going for a little over 3 an hour now, if you want to take a short break and 4 then we can resume. 5 A Sure. 6 (Recess, 11:09 to 11:18 a.m.) 7 Q All right, Dr. Wolfe, welcome back. 8 During the break we just had, did you 9 speak to anybody? 10 A No. 11 Q Did you receive any chats or messages? 12 A I don't know, I didn't check. 13 Q Okay. And did you open any materials? 14 A No. 15 Q Okay. I'm going to drop into the chat the 16 patents. We're going to start with -- we will do 17 one at a time. Let me know when you have 18 downloaded this one. 19 A Okay. That is the '698 patent. 20 Q Okay. And let me then drop in the other 21 one. This way we keep them separate, this is 22 another patent. Let me know when you have that	64 1 figure 1 -- are you familiar with the term 2 "extruder"? 3 A In various contexts, yes. 4 Q Which portion of figure 1 is the extruder? 5 A I believe the patent refers to 106 as the 6 extruder. 7 Q And what are all of those things kind of 8 around the extruder? What does an extruder of a 9 3D printer include? 10 A It is going to vary from printer to 11 printer. 12 Q How about here in figure 1? 13 A The patent language is all permissive. It 14 all says what it may include. It talks about 15 chamber 122 and extrusion tip 124 and a heater 126 16 and a motor 128. But it neither limits it to 17 those things nor says that it must include those 18 things. 19 Q So if you look at figure 1, how would you 20 -- how does -- help me understand how does the 21 extruder work. It has -- it shows these various 22 elements that you just described, but what is it

65 1 doing? 2 A Well, the patent doesn't necessarily tell 3 us in detail what it is doing, but it tells us 4 some aspects of what it might be doing. It talks 5 about a whole bunch of different ways they can do 6 it, but -- but generally, it is being fed some 7 type of -- again, in the art, it would be fed some 8 type of a thermal plastic type material. 9 The patent mentions ABS, which was a 10 horrible to use plastic that was popular at the 11 time. HDPL, which is high density polyethylene, 12 which I think is basically cutting boards. And 13 PLA, polylactic acid, which is a corn derived 14 plastic that has become very, very popular since 15 that time. 16 And again, this particular one is not 17 specific. Ordinarily, it does talk about being 18 fed in as a -- from a spool as a filament. The 19 other way to do it would be as a -- as pellets. 20 And then the heater would ordinarily melt it down 21 to -- the patent calls it a liquid, you might also 22 refer to it more as a paste. It is kind of a	67 1 Q Okay. So you put that down selectively, 2 because you want to build something. And how does 3 -- so you just have a bunch of, like, I guess to 4 use one of your terms, a bunch of paste that goes 5 down. Is that -- is that -- you are just putting 6 one -- 7 A Yeah, again -- 8 Q -- paste that -- 9 A -- I'm not a material science person, but 10 yeah, I would characterize it as -- as kind of a 11 paste or a very viscose fluid at that point. And 12 it is just -- it is like squirting toothpaste out 13 of a tube and trying to draw something on the 14 table, right, by moving it around. And typically, 15 it is hot enough that when you put one layer on 16 top of another layer they will -- they will fuse 17 to each other. 18 Q Okay. How does it -- I mean, if I put a 19 bunch of toothpaste down, I haven't done this 20 since I was kid, but I'm pretty sure it just like 21 -- it just forms some sort of like mush. How do 22 you actually create, like, you mentioned you put
66 1 viscus liquid. And then the motor, again, 2 depending on design, the motor can either be used 3 to keep feeding more filament in or it can be used 4 to create pressure for the -- for the liquid. 5 And then the extruder tip is usually more 6 of kind of a nozzle. And again, depending on the 7 design it may be controlled or it may be 8 uncontrolled and I don't think the patent limits 9 it either way. 10 Q Okay. And so you had mentioned that the, 11 I guess, the plastic is melted down. Is it with 12 the heater; is that right? 13 A That is the way it is typically done. And 14 that is one of the embodiments that is at least 15 somewhat described in the spec. 16 Q Okay. And then does -- does the paste or 17 liquid, the viscose material, does that come out 18 of the nozzle? 19 A The extruder tip 124. 20 Q Okay. The extruder tip? 21 A Yes, and selectively if you want to be 22 able to build anything.	68 1 it in a powder and make an object. It seems like 2 if it is all paste it would be a bunch of junk at 3 the end of the day. 4 A Well, I've actually done it. I mean not 5 with paste, but I've built 3D printers that use 6 clay or -- or -- or plaster. The idea is that you 7 want to get some kind of a phase change soon after 8 deposition. 9 So in these particular printers typically 10 what you will do is you will heat it just to the 11 liquefaction point. The idea is that when you put 12 it down it cools and it becomes solid again. So 13 that way by the time you go and try to put 14 something else on top, it is pretty solid. 15 Q So in the printers that you have used, 16 what is that typically, the cooling rate, what is 17 that typically? Is that -- are you talking about 18 milliseconds or how long does it take? 19 A I don't know. Typically you don't -- you 20 do one layer at a time in these deposition 21 printers. So it is not unusual for it to take a 22 minute to an hour before you come back. So I've

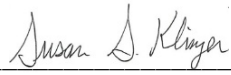
69 1 never tried to figure out what the cooling time 2 is. But PLA -- see if I remember the number here, 3 PLA I think would typically deposit at about 200 4 to 230 degrees Celsius. And my guess is that by 5 the time it would cool by 10 percent, it would 6 kind of harden. 7 Q Okay. 8 A I don't know how long that takes. I am 9 sure it has to do with airflow and -- and again, 10 oftentimes the build platform is heated so there 11 is a lot of factors in there. But it is -- it 12 is -- you know, been a solved problem for a lot of 13 time, how to extrude things. 14 Q If you are heating the build platform, 15 what sort of temperature is -- is that typically 16 heated to? 17 A Again, for PLA I typically use 60 C. For 18 polycarbonate, which was the other thing I've 19 printed recently, I think it was 110 C. I think 20 for PETG, which is another common material today, 21 we typically use 85 C. And that is to prevent 22 warping, so that when it cools it doesn't warp.	71 1 are printing if you want to do a pattern, is that 2 printed onto the bed? 3 A Normally. 4 Q And so is the bed usually the same thing 5 as this -- like, so we mentioned different types 6 of plastics, PLA, ABS, polycarbonate, is the bed 7 usually the same thing as those? 8 A No, my experience is the bed is steel or 9 aluminum. 10 Q Okay. Do you ever -- have you ever 11 printed metals, 3D printed metals? 12 A I have not. 13 Q Okay. When -- so you mentioned that you 14 do a layer and then your experience is when you 15 come back around to do the next layer that the 16 previous layer has sufficiently cooled, right? 17 When -- when plastics -- 18 A Or hardened, right. With thermoplastics 19 it is cooled, with other materials sometimes it is 20 evaporative hardening or UV hardening or catalytic 21 hardening. 22 Q Okay. Does the shape of the material
70 1 Q Okay. You had also mentioned I think what 2 you said is a horrible material, ABS; is that 3 right? 4 A Yes. 5 Q What is the sort -- does it have the same 6 sort of temperatures ABS the -- 7 A I believe that the polycarbonates were a 8 substitute for ABS. I think they were about the 9 same temperature. I think they -- the platform 10 would have been up in -- well -- well, I mean part 11 of the problem is a lot of the ABS work that was 12 done 10, 15 years ago didn't use heated platforms 13 so it did all warp, which was part of the problem. 14 But ABS temperatures, again, I think you 15 deposit them up around 250, 260 C and you try to 16 keep the bed temperature up in the 85 to 100 17 range. But again, I'm not a materials person, so 18 I don't -- you just -- you buy it and it is -- it 19 is printed on the box. 20 Q Yeah. Okay. And you mentioned the bed. 21 So before you -- when you first start printing, is 22 that -- is that first layer of material that you	72 1 change at all from when you first put it down to 2 when it hardens or cools? 3 A I'm sure it does, but it is kind of on a 4 microscopic level that an ordinary user generally 5 doesn't concern themselves with, but a 3D printer 6 designer probably is aware of that. 7 Q Okay. So -- so you don't know if it does 8 cool, if it does change you don't know by how 9 much, for instance? 10 A Right. I would expect there to be some 11 change, but I don't know by how much and I think 12 it is -- it is very complicated. 13 Q Okay. Are you familiar with the -- the 14 term "Young's modulus"? 15 A Yes, but I have no idea what it is. 16 Q So you have heard -- you have heard of the 17 term before? 18 A Yes. As I said, I've worked on -- on -- 19 on 3D printer designs before, and I know that that 20 was an important issue, but I was able to send the 21 students off to talk to a mechanical engineering 22 specialist to figure it out. So I actually don't

73 1 know what the -- what the definition of a Young's 2 modulus is. 3 Q Okay. So you don't know what a Young's 4 modulus might pertain to? 5 A Not really. I think it has something to 6 do with deformation or -- or -- or 7 compressibility, but I don't -- it is not 8 something I really understand. 9 Q Okay. So for -- if it does pertain to 10 deformation, do you know the relationship between 11 Young's modulus and deformation? 12 A No. 13 Q If it pertains to compressibility, do you 14 know the relationship between Young's modulus and 15 compressibility? 16 A No. 17 Q Okay. I'm going to drop into the chat 18 another reference, give me a second. Let me know 19 when you have downloaded and opened this one. 20 A I have it. 21 Q So in your declarations I believe you 22 express opinions regarding a reference named	75 1 21 in context. Figure 1 doesn't generally get 2 discussed in the spec. It is described as a 3 figure, but in the context of what is discussed in 4 the spec, a reader, a POSITA would have been able 5 to understand figure 21. 6 Figure 21 is showing the relationship 7 between a vibration signal amplitude on the 8 material deposition tip and frequency, because 9 Warren teaches that you can use the vibration 10 signal amplitude at one or more selected 11 frequencies as a force measurement signal. So in 12 that vein, that sensing mechanism has been 13 characterized here for one example, very similar 14 to the way that I told you before. 15 So what they have done is with no 16 additional force from contact with the underlying 17 substrate or -- or object, they have looked at the 18 vibration signal amplitude at a variety of 19 frequencies and they've grafted it, and that is 20 what element number 1 is. 21 Q And then how about element number 2 in 22 figure 21, what is that?
74 1 Warren; is that right? 2 A Yes, I believe in each of the 3 declarations. 4 (Exhibit 1004 discussed.) 5 Q Do you recognize the exhibit I dropped in 6 the chat, Exhibit 1004? 7 A That appears to be the Warren reference as 8 it was presented to the PTAB. 9 Q Okay. And do you know if the same Warren 10 reference was used in both of your declarations? 11 A I believe it was. 12 Q Okay. I'm going to use the page numbers 13 again at the bottom of the page, so that should 14 correspond to the -- the PDF viewer page. If you 15 could turn to page 18 of Warren, please? 16 A Okay. 17 Q And specifically I want to draw your 18 attention to figure 21 at the bottom of page 18. 19 Do you see figure 21? 20 A Yes. 21 Q What does the number 1 in figure 21 show? 22 A So let's -- let's start by putting figure	76 1 A Element number 2 appears to be a 2 measurement after contact. 3 Q Okay. And you had mentioned, I think, 4 that this figure 21 has both X and Y axes to it, 5 right? 6 A I don't think I mentioned that, but it 7 does. 8 Q Okay. And for the -- for the Y axes, you 9 mentioned vibration signal amplitude, I believe? 10 A Correct. 11 Q And what are the units for vibration 12 signal amplitude? 13 A Here there are no units. It just says you 14 can use arbitrary units, but typically you could 15 pick whatever units you wanted and it would really 16 depend on how you're measuring the vibration 17 signal. But typically by the time you were to 18 characterize it, it would be in, you know, 19 millivolts or something like that, because it is a 20 signal. 21 Q And then for the X axes you said 22 frequency. What are the units for the X axes?

77 1 A Again, the SI unit, the typical metric 2 unit would be hertz cycles per second, but, you 3 know, could be megahertz or kilohertz. It doesn't 4 really matter. 5 Q Okay. And so we talked about element 1 6 and element 2 of figure 21. What is element 3 of 7 figure 21? 8 A It says it is the change of the signal 9 after the contact X30, so it seems to be a 10 differential. It does not seem to be the 11 difference between 1 and 2. It seems to be after 12 a different contact. 13 Q Okay. So help me understand that, the 14 difference between 1 and 2 is not what element 3 15 represents? 16 A It doesn't appear to be, if you just look 17 at it visually. And it doesn't say just change of 18 signal after contact. It says after the contact 19 X30. So I think it is a different contact that 20 was measured in figure 2. 21 Q Okay. And -- and do you know what X30 22 means?	79 1 various ranges for 3, 400 years, so, you know, 2 pick your favorite implementation and measure the 3 signal amplitude. That is what you -- 4 Q So if someone asked you can you tell me 5 what the amplitude of signal or element 1 is, how 6 would you go about determining that? 7 A Well, from the figure, I would just simply 8 say, you know, it is up as high as approximately 9 30 units. But if I were to replicate this process 10 the way it is taught, I would put an instrument on 11 it and I would use the units that the instrument 12 measures, for example, millivolts. 13 Q Okay. Okay. And so you -- you had 14 mentioned that, you know, it is as high as 15 approximately 30 units, so it is not 30 units 16 across -- I guess, you were talking about the Y 17 axes, it is not 30 units across the entire X axes? 18 A No. And again, the teaching of the patent 19 is not that you have to measure it every 20 frequency. It is that you pick one or more 21 frequencies and do your measurements at that 22 frequency, and then it might be helpful to do a
78 1 A Not off the top of my head. 2 Q Okay. 3 A But, again the whole process is described 4 in the text. So you know, figure 21 is really 5 just an illustration of what is being taught 6 elsewhere in the specification. 7 Q Okay. And across the frequencies, if you 8 will, what -- what sort of amplitude is shown in 9 figure 21? 10 A Vibration signal amplitude. 11 Q So there is not -- there is not a 12 particular number or units associated with that 13 amplitude? 14 A There would always be a unit in practice, 15 but -- but -- but the teachings aren't tied to a 16 particular unit. It could be millivolts, it could 17 be tens of millivolts. 18 Q So would you say that, say, element 1 of 19 figure 21 is 10 millivolts? 20 A It would be implementation dependent. I 21 mean, it doesn't matter, right? I mean, people 22 have been dealing with sensor signal amplitudes of	80 1 graph like this to help to choose a good 2 frequency. 3 Q So in the example in figure 21, what 4 frequency would -- would you choose? 5 A I would probably choose something around 6 the extremities of figure 3. So either where 7 figure 3 goes very low showing a big negative 8 difference in the signal after contact of X30 or 9 one of the top peaks. 10 Q Okay. And you said figure 3, are you -- 11 A I'm sorry, signal 3. 12 Q Signal 3, okay. 13 So you would pick either a trough or a 14 peak of signal 3? 15 A Yes. Although it would work fine if I 16 picked many other -- I mean, I wouldn't want to 17 pick something where it is a zero crossing, but 18 there were many frequencies where -- where it 19 would work fine. But -- but the best ones would 20 probably be the ones that show the biggest change. 21 Q Okay. And earlier you had mentioned that 22 it appears that signal 3 or element 3 is a

81 1 different type of contact than what is shown 2 between, I think you were referring to elements 1 3 and 2 or signals 1 and 2? 4 A Not necessarily a different type of 5 contact, but a different -- a different degree of 6 contact. 7 Q Okay. So you would -- you would look to, 8 like, a different degree of contact. And the -- 9 the amplitudes for that contact as a signal 3 to 10 figure out which frequencies to use for a 11 particular amplitude? 12 A So again, just the text tells me that it 13 is going to work at pretty much any frequency that 14 I choose and that I can use a combination of 15 frequencies, right, and it is almost certainly 16 going to work. 17 But if I wanted to optimize it, I would 18 perform the kinds of contacts that I want to 19 distinguish, and I would find the largest changes 20 in response to those contacts. 21 Q So why wouldn't you pick the frequency -- 22 if you look at figure 21 on the, say, the	83 1 A Okay. I think that is just the first 2 measurement point. 3 Q Yes. So if you look at that measurement 4 point, would that be one of the examples of the 5 points where you think it would -- you could pick 6 that frequency and it would -- it would give you 7 the information you need? 8 A If I needed to detect contacts like X30, I 9 think I could derive the -- the information from 10 that, right? In other words, I would measure that 11 difference. That difference is maybe 3 in the 12 measured arbitrary units. And yeah, I think a 13 person of ordinary skill could build a system that 14 would then be able to detect and respond to 15 that -- to that type of contact. 16 Q Okay. And if you look at lines 1 and 2 or 17 signals 1 and 2 at that same point, what is the 18 sort of difference between those -- those two 19 lines or signals? 20 A There it is not noticeable from this 21 graph. So if I wanted to measure -- to be able it 22 distinguish the contact shown in signal 2, I
82 1 left-hand side of figure 21, why wouldn't you pick 2 one of those sorts of frequencies? 3 A Well, the one where the number 3 is 4 pointing would be a perfectly fine frequency to 5 pick. 6 Q Okay. Anything to the left of that? 7 A I wouldn't want to pick the one that gave 8 me a zero difference, right, but those are few and 9 far between, right. If I picked something halfway 10 between the -- the point where the 3 is pointing 11 and the zero, I think it would still work fine. 12 Q Okay. 13 A I mean, you don't have to get it perfect, 14 you know, you just have to be able to detect the 15 contact. 16 Q So let's say -- let's say, you're looking 17 at -- do you see the part of figure 21 where it is 18 to the left of the number 3 and the -- the line, 19 if you will, ends? Do you see that point? 20 A The line ends. 21 Q Or you might think of it as the line 22 beginning?	84 1 wouldn't choose that point. I would choose a 2 different point. 3 Q Okay. 4 A And again, the teachings allow me to 5 choose multiple points. So I could measure 6 multiple kinds of contacts although claims don't 7 require that. 8 Q And if I look at these signals we could 9 pick, let's say, signal 1 as an example, is the 10 frequency proportionate to the amplitude? 11 A No. 12 Q Is it -- is it the same answer for signal 13 2, is the frequency proportionate to the 14 amplitude? 15 A Yeah, I don't think the frequency is ever 16 proportional to the amplitude. 17 Q Okay. Okay. Why don't we turn to -- 18 we've been looking at figure 21. If you could 19 turn to page 21 of Warren. 20 A Okay. 21 Q I believe for this one you may need to 22 rotate it as well.

85 1 A Let me do that. 2 Q Do you see figures, I think, 23A and 23B 3 and 23C? 4 A Okay. 5 Q What is -- do you see the number 100 in 6 figures 23A and 23C? 7 A Yes. 8 Q What is 100 referring to generally? 9 A I don't recall off the top of my head. Is 10 it something I discussed in my declaration? 11 Q Well, I think you discussed Warren so I'm 12 asking you about this figure in Warren? 13 A Again, I don't think -- I don't recall 14 relying on this in my declaration, but I can look 15 and see what Warren says about it. I think in 16 general Warren just refers to any material 17 dispenser as 100. 18 Q Okay. And so if I -- if I follow, let's 19 say, figure 23A, as an example, there are one, 20 two, three, four material dispensers? 21 A In that particular embodiment, yes. 22 Q Okay. And do you know if Warren describes	87 1 Even -- so -- so with thermoplastics, the 2 most common way to do it today is to apply some 3 pressure on the material that you are dispensing 4 so that it will bond well with the layer below, 5 but not necessarily actually applying pressure on 6 the previous layer, right? 7 So I believe there are even systems that 8 are somewhat like this that are out there 9 commercially today with thermoplastics. And the 10 idea is that since only one of them is extruding, 11 the actual material deposition happens a few 12 fractions -- a fraction of a millimeter below the 13 nozzle. 14 So that if you really are -- are 15 depositing material with the appropriate 16 precision, other nozzles of the same height 17 wouldn't interfere. But of course, you know, big 18 picture Warren also doesn't require that you have 19 multiple nozzles. He also describes embodiments 20 that don't have multiple nozzles. 21 Q Okay. And you had mentioned some, I 22 guess, thermoplastic printers today where you
86 1 using them -- I mean, to use one at a time, use 2 them all together, do both? 3 A It certainly describes being able to use 4 them individually. I don't remember whether or 5 not he described using them simultaneously. 6 Q Okay. So if I look at the right -- the 7 three dispensers on the right-hand side, they kind 8 of look similar, right, in figure 23A? 9 A In the figure they do. 10 Q And if those three dispensers are at the 11 same -- sort of the bottom of the dispensers at 12 the same level, how would you -- how would you be 13 able to use one, you know, while another one is 14 not being used? Wouldn't that, like, touch the 15 material that you already -- like the pattern of 16 material that you have already put down? 17 A Not necessarily. Again, you know, this is 18 only one of his embodiments. And it would depend 19 on maybe the shape you are doing and whether or 20 not it is oriented along that line. But also, he 21 describes various embodiments in a variety of 22 materials.	88 1 apply pressure. Do you know how the pressure is 2 applied? 3 A I believe just by extruding under 4 pressure. 5 Q Okay. So the -- the extruder -- the 6 output from it, the materials under pressure, is 7 that what you mean? 8 A Yes. I don't know where that pressure 9 comes from in modern devices, whether it is just 10 the weight of the material above it or the force 11 of the filament motor. But it is my understanding 12 that in most modern devices there -- in other 13 words, the material is not just dripping out. It 14 is being pushed out, again, kind of like 15 toothpaste. 16 Q Okay. All right. Let's go to the next 17 page of Warren, page 22. And this time at the top 18 of the page, do you see figure 24? 19 A I do. Again, I don't think this is 20 something I relied on, but I see it. 21 Q And do you see where it says, cells 22 deposited right above the label figure 24?

89 1 A Yes. 2 Q What sort of industry experience do you 3 have with deposition of cells? 4 A None. 5 Q Do you have research experience related to 6 depositing cells? 7 A I don't, but Warren again, talks about a 8 lot more than that including deposition of 9 inorganic materials and specifically the 10 deposition of polymers. 11 Q How about a teaching experience? Do you 12 have teaching experience related to depositing 13 cells? 14 A No. I mean, not – not human – not 15 biological cells, no. 16 Q Okay. What non-biological cells do you 17 have experience with deposition on? 18 A That – just that word might be used to 19 describe other materials. But again, I don't have 20 any – I don't have any experience in depositing 21 biological materials. 22 Q Okay. Okay. All right. I think with	91 1 CERTIFICATE OF SHORTHAND REPORTER 2 3 I, Susan S. Klinger, Certified Reporter 4 before whom the foregoing deposition was taken, do 5 hereby certify: 6 That ANDREW WOLFE, PH.D., the witness 7 whose deposition is hereinbefore set forth, was 8 duly sworn by me before the commencement of such 9 deposition, and that such deposition was taken 10 before me and is a true record of the testimony 11 given by such witness, that said testimony was 12 taken by me stenographically and thereafter 13 reduced to typewriting under my direction. 14 I further certify that the adverse party, 15 Shenzhen Tuozhu represented by counsel at the 16 deposition. 17 I further certify that the deposition of 18 ANDREW WOLFE, PH.D., occurred remotely on the 19 23rd, January 2026, commencing at 10:03 to 11:52. 20 TIME USED: 21 Mr. Kapadia: 01:40 22 Mr. Griswold: 00:00
90 1 that I don't have any further questions. 2 MR. KAPADIA: Josh, the witness is yours. 3 MR. GRISWOLD: I don't have any questions, 4 thank you. 5 (Deposition adjourned at 11:52 a.m.) 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	92 1 I further certify that reading and signing 2 was not discussed. 3 I further certify that I am not related to 4 any of the parties to this action by blood or 5 marriage, I am not employed by or an attorney to 6 any of the parties to this action, and that I am 7 in no way interested, financially or otherwise, in 8 the outcome of this matter. 9 IN WITNESS WHEREOF, I have herunto set my 10 hand on the 25th of January, 2026. 11 12 13  14 Susan S. Klinger, RMR-CRR, CSR 15 Texas CSR 6531, Exp: 10/31/27 16 California CSR 14487, Exp: 11/30/26 17 18 19 20 21 22

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Transcript of Andrew Wolfe, Ph.D.
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