UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GARMIN INTERNATIONAL, INC. AND GARMIN USA, INC.
Petitioners

v.

LOGANTREE, LP
Patent Owner

Case No. IPR2018-00565
Patent No. 6,059,576

DECLARATION OF DR. ANDREW C. SINGER

I, Andrew C. Singer, hereby declare the following:

I. INTRODUCTION

1. I, Andrew C. Singer, have been retained by counsel for Petitioners as a technical expert in the above-captioned case. Specifically, I have been asked to render certain opinions in regards to the IPR petition with respect to U.S. Patent No. 6,059,576 ("the '576 patent"). I understand that the Challenged Claims are claims 1, 2, 4, 5, 7-14, 56-58, 140, 144, and 146. My opinions are limited to those Challenged Claims.

2. My compensation in this matter is not based on the substance of my opinions or the outcome of this matter. I have no financial interest in Petitioners. I am being compensated at an hourly rate of $500 for my analysis and testimony in this case.

3. In reaching my opinions in this matter, I have reviewed the following materials:

- EX1001 – U.S. Patent No. 6,059,576 to Brann ("the '576 patent");
- EX1003 – File History of Reexamination Request No. 90/013,201 ("'576 patent reexamination file history");
- EX1004 – U.S. Patent No. 5,978,972 to Stewart et al. ("Stewart");
- EX1006 – U.S. Patent No. 5,546,609 to Rush, III ("Rush");
- EX1007 – U.S. Patent No. 5,197,489 to Conlan ("Conlan");
- EX1008 – U.S. Patent No. 5,474,083 to Church et al. ("Church");
- EX1009 – U.S. Patent No. 5,976,083 to Richardson et al. ("Richardson");
- EX1011 – J.R.W. Morris, "Accelerometry – A Technique for the Measurement of Human Body Movements," J. Biomechanics, Vol. 6, Pergamon Press (1973, pp. 729-736) ("Morris");
- EX1012 – U.S. Patent No. 3,797,010 to Adler et al. ("Adler");

- EX1013 – U.S. Patent No. 5,803,740 to Gesink et al. ("Gesink");
- EX1014 – UK Patent Application No. GB 2,225,459A to Holder ("Holder");
- EX1015 – C. Verplaetse, "Inertial proprioceptive devices: Self-motion-sensing toys and tools," IBM Systems Journal, Vol. 35, Nos. 3&4 (1996, pp. 639-650) ("Verplaetse");
- EX1016 – Alan Freedman, *The Computer Desktop Encyclopedia*, The Computer Language Company Inc. (1996) ("Freedman"); and
- EX1017 – Robert C Cantu, *Head injuries in sport*, Br J Sports Med 30 (289-296; 1996) ("Cantu").

A. **Background and Qualifications**

4. I am currently a Professor in the Department of Electrical and Computer Engineering, where I hold a Fox Family endowed Professorship. I also serve as Director of the Technology Entrepreneur Center for the College of Engineering at the University of Illinois at Urbana Champaign.

5. I received a Bachelor of Science degree in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 1990; a Master of Science degree in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 1992; and a Ph.D. in Electrical Engineering from Massachusetts Institute of Technology in 1996.

6. Since 1990, I have been active in the signal processing and communications fields. I have authored and/or co-authored numerous publications, including books and refereed journal publications and conference articles on the topic of signal processing and communication systems and devices.

A focus of many of these publications is on methods for improving efficiency, reducing power and preserving battery life in such systems.

7. I have designed, built, and patented various components of communication and signal processing systems. These include various radio-frequency, SONAR, LIDAR, air-acoustic and underwater acoustic signal processing systems as well as wire-line, wireless, optical and underwater acoustic communication systems. An important aspect in many of these systems is the design of low power systems and the use of algorithms and methods to reduce power and preserve battery life.

8. I have taught both undergraduate and graduate level courses in signal processing, and communication systems. For example, I have taught Digital Signal Processing and Embedded DSP Laboratory classes. Additional examples of courses I have taught at the University of Illinois at Urbana Champaign include: Advanced Digital Signal Processing; Digital Signal Processing; Digital Signal Processing Laboratory; Probability with Engineering Applications; Random Processes; Optical Communication Systems; Advanced Lectures in Engineering Entrepreneurship; Embedded DSP Laboratory; Developing Design Thinking; Technology Commercialization; and Senior Design Laboratory. I have also overseen numerous PhD and Master's students researching topics related to signal processing and communication systems.

9. I was the co-founder and CEO of Intersymbol Communications, Inc., a communications component manufacturer focused on the development of signal processing-enhanced components used in optical communication networks. Intersymbol Communications, Inc. was acquired by Finisar Corporation, the world's largest supplier of optical communication modules and subsystems.

10. I was appointed the Director of the Technology Entrepreneur Center (TEC) in the College of Engineering, where I direct a wide range of entrepreneurship activities. The TEC directs the campus-wide Illinois Innovation Prize, celebrating our most innovative students on campus, as well as our annual Cozad New Venture Competition. I am also the Principal Investigator for the National Science Foundation's Innovation Corps Sites program at the University of Illinois, working with faculty and student startup companies.

11. My research and commercial experience led to my authoring of numerous papers. I have authored over 200 papers on digital signal processing and communication systems, several of which were voted "Best Paper of the Year" by technical committees of the IEEE. Citing these and other contributions, I was elected Fellow of the Institute of Electrical and Electronics Engineers ("IEEE") "for contributions to signal processing techniques for digital communication." I was also selected as a Distinguished Lecturer of the Signal Processing Society.

12. I hold ten granted U.S. patents, all in the field of communication systems.

13. In summary, I have over 25 years of experience related to signal processing and communication systems.

14. I have attached my curriculum vitae as Appendix A, which includes a list of all publications I have authored within the last ten years.

II. LEGAL FRAMEWORK

15. I am a technical expert and do not offer any legal opinions. However, I have been informed that the '576 Patent has expired and that, in such a case, the words of a claim are given their ordinary and customary meaning as would have been understood by a person of ordinary skill in the art at the time of the invention (November 1997).

16. I have also been informed that the implicit or inherent disclosures of a prior art reference may anticipate the claimed invention. Specifically, if a person having ordinary skill in the art at the time of the invention would have known that the claimed subject matter is necessarily present in a prior art reference, then the prior art reference may "anticipate" the claim. Therefore, a claim is "anticipated" by the prior art if each and every limitation of the claim is found, either expressly or inherently, in a single item of prior art.

17. Counsel has also informed me that a person cannot obtain a patent on an invention if his or her invention would have been obvious to a person of ordinary skill in the art at the time the invention was made. A conclusion of obviousness may be founded upon more than a single item of prior art. In determining whether prior art references render a claim obvious, counsel has informed me that courts consider the following factors: (1) the scope and content of the prior art, (2) the differences between the prior art and the claims at issue, (3) the level of skill in the pertinent art, and (4) secondary considerations of non-obviousness. In addition, the obviousness inquiry should not be done in hindsight. Instead, the obviousness inquiry should be done through the eyes of one of skill in the relevant art at the time the patent was filed.

18. In considering whether certain prior art renders a particular patent claim obvious, counsel has informed me that courts allow a technical expert to consider the scope and content of the prior art, including the fact that one of skill in the art would regularly look to the disclosures in patents, trade publications, journal articles, industry standards, product literature and documentation, texts describing competitive technologies, requests for comment published by standard setting organizations, and materials from industry conferences. I believe that all of the references that my opinions in this IPR are based upon are well within the

range of references a person of ordinary skill in the art would consult to address the type of problems described in the Challenged Claims.

19. I have been informed that the United States Supreme Court's most recent statement on the standard for determining whether a patent is obvious was stated in 2007 in the KSR decision. Specifically, I understand that the existence of an explicit teaching, suggestion, or motivation to combine known elements of the prior art is a sufficient, but not a necessary, condition to a finding of obviousness. Thus, the teaching suggestion-motivation test is not to be applied rigidly in an obviousness analysis. In determining whether the subject matter of a patent claim is obvious, neither the particular motivation nor the avowed purpose of the patentee controls. Instead, the important consideration is the objective reach of the claim. In other words, if the claim extends to what is obvious, then the claim is invalid. I further understand the obviousness analysis often necessitates consideration of the interrelated teachings of multiple patents, the effects of demands known to the technological community or present in the marketplace, and the background knowledge possessed by a person having ordinary skill in the art. All of these issues may be considered to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent.

20. I have also been informed that in conducting an obviousness analysis, a precise teaching directed to the specific subject matter of the challenged claim

need not be sought out because it is appropriate to take account of the inferences and creative steps that a person of ordinary skill in the art would employ. I understand that the prior art considered can be directed to any need or problem known in the field of endeavor at the time of invention and can provide a reason for combining the elements of the prior art in the manner claimed. In other words, the prior art need not be directed towards solving the same specific problem as the problem addressed by the patent. Further, the individual prior art references themselves need not all be directed towards solving the same problem. Under the KSR obviousness standard, common sense is important and should be considered. Common sense teaches that familiar items may have obvious uses beyond their primary purposes.

21. I have been informed that the fact that a particular combination of prior art elements was "obvious to try" may indicate that the combination was obvious even if no one attempted the combination. If the combination was obvious to try (regardless of whether it was actually tried) or leads to anticipated success, then it is likely the result of ordinary skill and common sense rather than innovation. I further understand that in many fields it may be that there is little discussion of obvious techniques or combinations, and it often may be the case that market demand, rather than scientific literature or knowledge, will drive the design of an

invention. I understand that an invention that is a combination of prior art must do more than yield predictable results to be non-obvious.

22. I have also been informed that for a patent claim to be obvious, the claim must be obvious to a person of ordinary skill in the art at the time of the invention. I understand that the factors to consider in determining the level of ordinary skill in the art include (1) the educational level and experience of people working in the field at the time the invention was made, (2) the types of problems faced in the art and the solutions found to those problems, and (3) the sophistication of the technology in the field.

23. I have been informed that at least the following rationales may support a finding of obviousness:

- Combining prior art elements according to known methods to yield predictable results;
- Simple substitution of one known element for another to obtain predictable results;
- Use of a known technique to improve similar devices (methods, or products) in the same way;
- Applying a known technique to a known device (method, or product) ready for improvement to yield predictable results;
- "Obvious to try"—choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- A predictable variation of work in the same or a different field of endeavor, which a person of ordinary skill would be able to implement;
- If, at the time of the alleged invention, there existed a known problem for which there was an obvious solution encompassed by the patent's claim;

- Known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on technological incentives or other market forces if the variations would have been predictable to one of ordinary skill in the art; and/or
- Some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior-art reference or to combine prior-art reference teachings to arrive at the claimed invention.

24. I have been informed that even if a *prima facie* case of obviousness is established, the final determination of obviousness must also consider "secondary considerations" if presented. In most instances, the patentee raises these secondary considerations of non-obviousness. In that context, the patentee argues an invention would not have been obvious in view of these considerations, which include: (a) commercial success of a product due to the merits of the claimed invention; (b) a long-felt, but unsatisfied need for the invention; (c) failure of others to find the solution provided by the claimed invention; (d) deliberate copying of the invention by others; (e) unexpected results achieved by the invention; (f) praise of the invention by others skilled in the art; (g) lack of independent simultaneous invention within a comparatively short space of time; (h) teaching away from the invention in the prior art.

25. I have further been informed that secondary considerations evidence is only relevant if the offering party establishes a connection, or nexus, between the evidence and the claimed invention. The nexus cannot be based on prior art features. The establishment of a nexus is a question of fact. While I understand

that Patent Owner has not offered any secondary considerations at this time, I will supplement my opinions in the event that Patent Owner raises secondary considerations during the course of this proceeding.

III. OPINION

A. Background of the Technology

26. Inertial sensors, such as accelerometers and gyroscopes, have been used to monitor human motion for several decades. For example, researchers began using accelerometers to measure human movement as early as the 1950s. EX1011, *Morris* at 729 ("Many bioengineers involved with the study of human movement have at some time attempted to use an accelerometer for that quantitative measure of that movement. Some of the attempts have been reported (Saunders et al., 1953; Gage, 1964) . . .").

27. By the early 1970s, accelerometers attached to the human leg were being used to measure movements in multiple degrees of freedom for purposes of gait analysis. *Id.* at 731 ("Accelerometers of the type shown in Fig. 2 are used to obtain data on the accelerations of the leg between the knee and ankle . . . Five accelerometers are mounted on the perspex platform shown in Fig. 3. . . The platform is mounted over the flat, antero-medial surface of the tibia."). As shown in the following figure, the sensor platform was small enough so as to not impede the subject's movements:

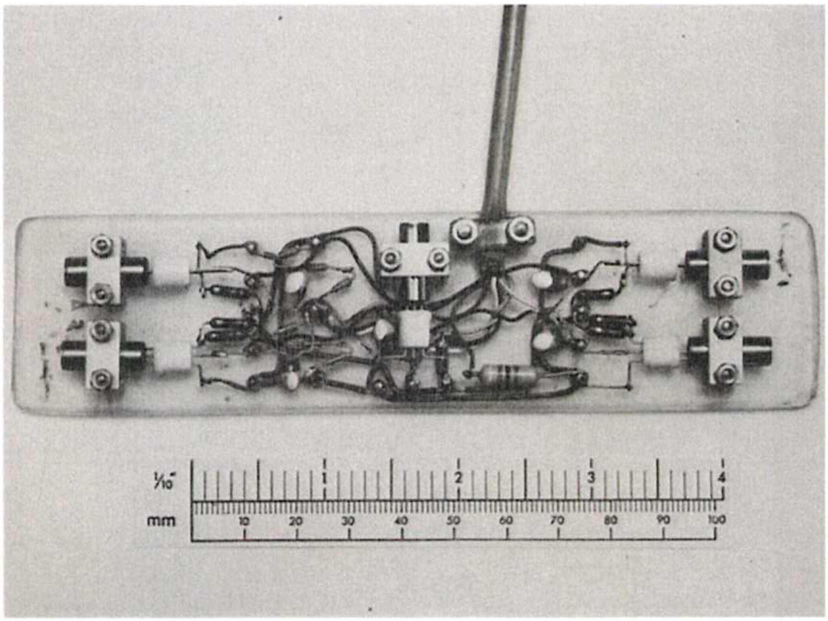


Fig. 3. The accelerometer mounting platform, showing five accelerometers and other associated electrical components.

Id. at Fig. 3.

28. The signals output by the accelerometers were stored in a portable recorder held by the subject and subsequently analyzed by a computer. *Id.* at 731 ("Signals from the accelerometers can be recorded either on a portable subject-carried tape recorder . . . . The entire analysis of the signals is done on a small interactive digital computer with analogue input facilities and a visual display.").

29. By the 1970s, "jogging computers," such as that described by U.S. Patent No. 3,797,010 to Adler et al., were also being developed "for measuring and indicating physical exercise achievement attained through exercises, for example,

walking, running and/or jogging in place or over a distance course in accordance with a predetermined exercise regimen." EX1012, *Adler*, at Abstract.

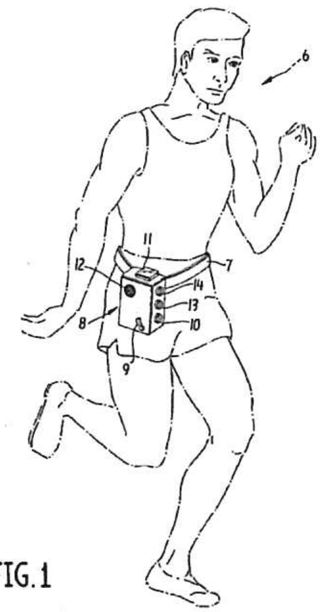


FIG.1

Id. at Fig. 1.

30. Adler's portable device included "a digital computer to which is fed the output from an electromechanical sensor adapted to generate an electrical impulse in response to each step taken by an individual while walking, running or jogging at or above a predetermined rate." *Id.* at Abstract.

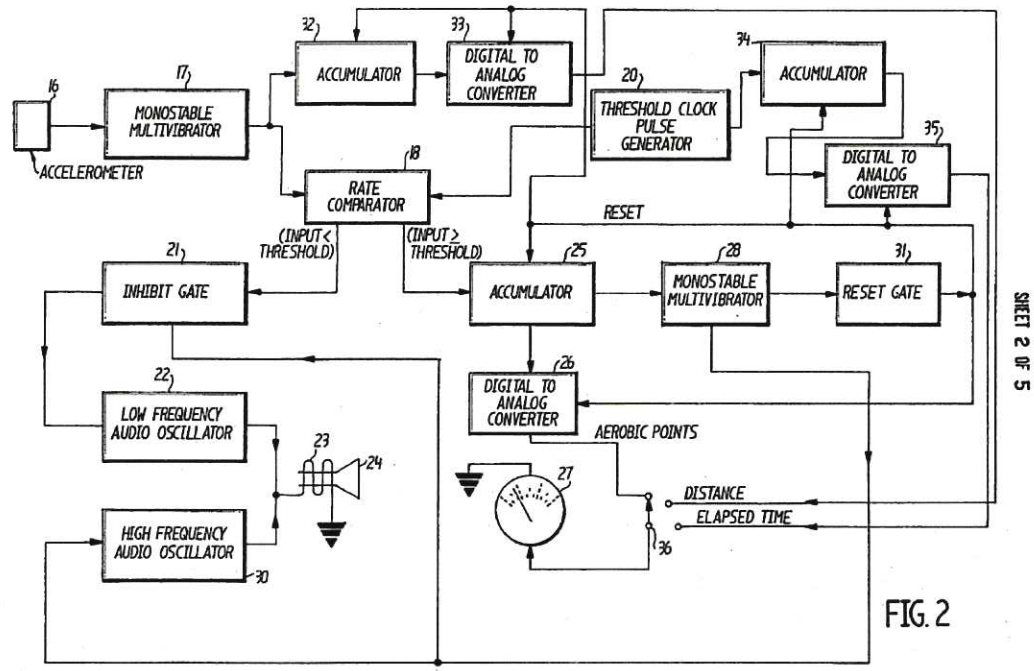


FIG. 2

Id. at Fig. 2.

31. Adler's device "accumulated" input data integrated across a measured exercise and "compared the level of the integral to a pre-programmed exercise regimen schedule." *Id.* at 3:8-10. When the compared level reached a user-defined "threshold level," a signal could be presented to the exerciser to help "avoid the possibility of inadvertently over-exercising." *Id.* at 3:11-25, 4:37-57.

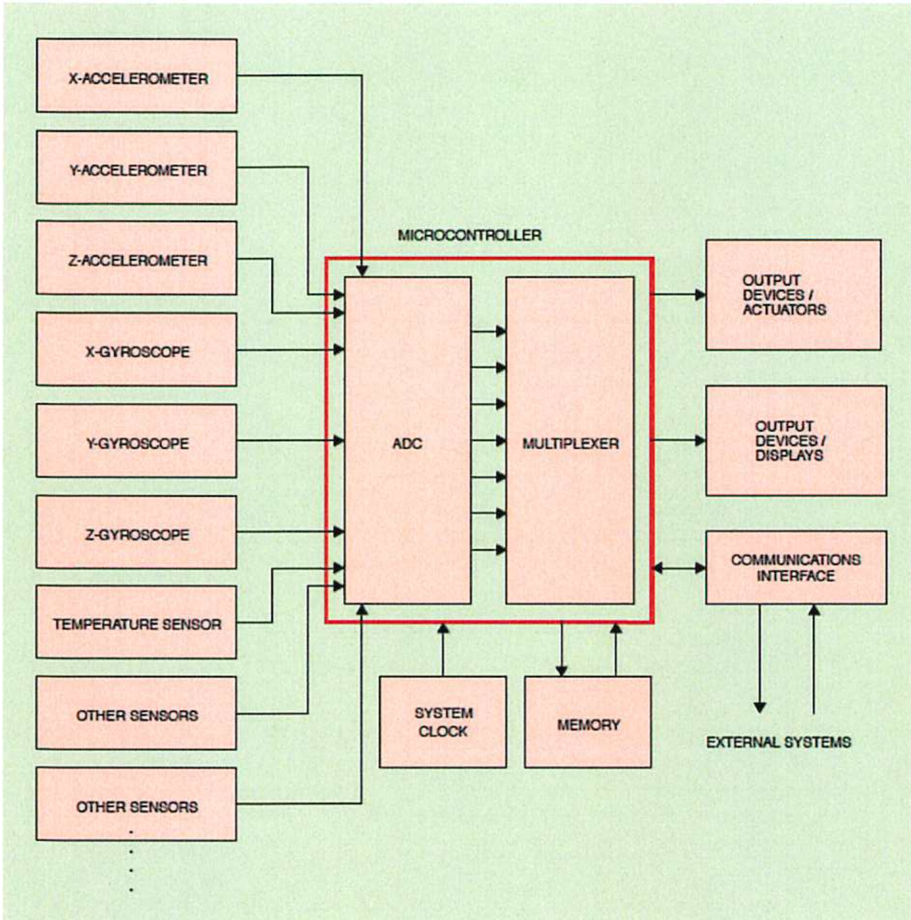
32. Versions of human movement monitoring devices available in the 1990s could sense displacement from walking as well as rotation of orientation in order to determine if a threshold amount of "veer" had been surpassed. EX1013, *Gesink* at 2:45-56, 13:53-59, 16:16-31. Particularly, the device taught by Gesink allowed for a user to enter a custom level of allowed veer, and announced the time

at which that allowed level was exceeded. *Id.* at 13:53-59. Gesink's device also included memory to "facilitate the storage of information regarding the use" of the device "so this data can later be downloaded to an external storage device." *Id.* at 18:62-67.

33. By this time, such storage of data captured regarding the state of a user was well known to persons of ordinary skill. For instance, devices known since the 1980s, such as that described in GB 2225459 to Holder, monitored human physical conditions such as temperature, respiration rate, and oxygen level, and store information in non-volatile memory when a preset alarm limit is crossed. EX1014, *Holder* at pp.1-2. Further, Holder's device stored real-time clock data alongside the sensed physical data for analysis, thus "time stamping" the data. *Id.* at p.1.

34. In 1996, Verplaetse proposed a motion-sensing "proprioceptive device" that could be incorporated into common objects such as shoes. EX1015, *Verplaetse* at 642. Verplaetse's proprioceptive device included accelerometers and gyroscopes for sensing motion in six degrees of freedom. *Id.* at Fig. 2. The sensor signals were input into a microcontroller that "either stores the sensor data for later use, or it performs some type of real-time analysis and invokes the appropriate output." *Id.* at 643.

Figure 2 Schematic of general proprioceptive system



Id. at 644.

35. When incorporated into shoes, for example, Verplaetse envisioned "a proprioceptive shoe system [that] could not only tell its wearer how far and fast he or she is walking, but could also diagnose gait abnormalities or alert the wearer that it is time to replace the shoe soles." *Id.* at 642.

36. Therefore, by 1997, the field of portable, motion sensing devices was well developed, and devices that both recorded the sensed data and analyzed the sensed data for purposes of alerting the user to user defined events were well known.

B. Level of a Person Having Ordinary Skill in the Art

37. In determining the characteristics of a hypothetical person of ordinary skill in the art of the '576 Patent at the time of the claimed invention, which counsel has informed me is November 21, 1997, I considered several factors, including the type of problems encountered in the art, the solutions to those problems, the rapidity with which innovations are made in the field, the sophistication of the technology, and the education level of active workers in the field. I also placed myself back in the time frame of the claimed invention and considered the colleagues with whom I had worked at that time.

38. In my opinion, a person of ordinary skill in the art would be a person with a Bachelor of Science Degree in Electrical Engineering or Computer Engineering or equivalent, and at least two years of experience in embedded signal processing systems or a related field.

39. Based on my education, training, and professional experience in the field of the claimed invention, I am familiar with the level and abilities of a person of ordinary skill in the art at the time of the claimed invention. In my 25 years

active in the industry, I have developed and performed research related to many embedded signal processing systems, including systems for United States Army and Navy for the purpose of detecting and tracking airborne, land-based, and underwater objects. These included self-contained systems for use on the battlefield, as well as embedded systems that were connected to aircraft and subsea vehicles. I have also developed systems that employed SONAR, LIDAR, and ultrasound for sensing, communications, and localization of and between objects. I have taught courses in embedded processing, including Embedded Digital Signal Processing, Digital Signal Processing Laboratory, and senior Design, each of which cover aspects of the design, construction, and testing of such embedded electronics and signal processing systems. Thus, I was at least a person having ordinary skill in the art as of the priority date of the '576 Patent.

C. Stewart Inherently Discloses a Real-Time Clock

40. It is my understanding that certain claims of the '576 patent, including claims 1 and 13, require a real-time clock. Petitioners have asked me to opine on whether or not a real-time clock is an inherent feature of Stewart's disclosure (EX1004). For the reasons discussed below, it is my opinion that Stewart's monitoring device necessarily includes real-time clock.

41. Stewart describes "[a] system designed to measure and record **in real time** data relating to translational and angular acceleration of an individual's head

during normal sporting activity." EX1004, *Stewart* at Abstract (emphasis added). Stewart's system includes a monitoring device incorporated into conventional sporting gear, such as a helmet. *Id.* at 4:45-46 ("The HAT is designed as a standard component of otherwise conventional sporting gear, in particular the helmet."), Fig. 2A. The monitoring device includes at least three orthogonal accelerometers that detect motion in three dimensions and output analog readings to an A/D converter. *Id.* at 6:13-16 ("It is found that a minimum of three orthogonal accelerometers 10-12 are sufficient to provide data which corresponds directly to motion of the head in three dimensional space . . . ."); 8:40-43 ("The output of the first accelerometer 10 is input to channel 0 of the A/D converter 46, the output of the second accelerometer 11 is input to channel 1, and the output of the third accelerometer 12 is input to channel 2."), Fig. 1.

42. A "processor 52 controls the storage of the data from the A/D converter 46 to the data storage 51." *Id.* at 8:58-59.

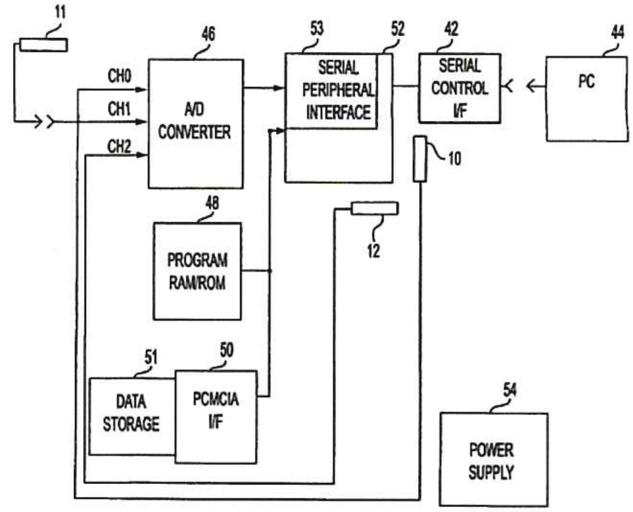


FIG. 1

Id. at Fig. 1.

43. "The processor 52 comprises any conventional processor device, including a microcontroller or a microprocessor, and controls the operation of the HAT system." *Id.* at 8:59-62.

44. Stewart also discloses that the processor executes time-based, user-defined commands that "set the general parameters of the data storage operation of the HAT." *Id.* at 11:53-54; *see also, id.* at 11:30-33 ("Storage of data from the outputs of the accelerometers 10-12 is started and stopped by the processor 52 via commands transmitted through the serial control interface 42."). For the reasons explained below, a person having ordinary skill in the art at the time of the '576 patent would recognize Stewart's disclosure of user-defined time commands as

necessarily requiring the processor to access a real-time clock to determine when to start and stop recording data.

45. Stewart discloses the following exemplary time-based commands that cause the processor to perform time-based functions:

- "'1 SET_MS' : sets the sample time to 1 ms. (Note that other sampling rates greater or less than 1 ms sampling can be implemented.)" *Id.* at 12:20-22
- "'n R_INTERVAL C!' : sets the number of minutes n between each round of data being collected." *Id.* at 12:31-32.
- "'GO': prompts the user for the present time and start time for data collection." *Id.* at 12:43-44.

46. Regarding the "GO" command, the a skilled artisan would understand that the processor could not perform the function of setting the present time to a time provided by the user without a real time clock. Once the user sets the present-time, if a start time of data collection is to be inferred, by necessity a real-time clock must be present to measure that start time. In other words, this command inherently requires the capability for real-time measurement, including the capability to know the real time against which to measure the start time for data collection. Thus, a person having ordinary skill would expect and understand that Stewart's processor necessarily accesses a real-time clock to implement this command.

47. Regarding the "1 SET_MS" command, for example, the processor 52 in Stewart's monitoring device would necessarily require a real-time timer in order to determine when 1 millisecond has passed and data received from the A/D converter should be sampled. Additionally, once the time has been set by the user (as discussed with reference to the GO command), the real-time timer would become a real-time clock.

48. Regarding the "n R_INTERVAL C!" command, the processor 52 would necessarily require a real-time timer in order to determine if n minutes have passed between data collection intervals. And again, once the time has been set by the user (as discussed with reference to the GO command), the real-time timer would become a real-time clock.

49. Thus, a person having ordinary skill in the art would recognize that Stewart's disclosure of a user programming the processor to start and stop data collection at specific times inherently discloses a real-time clock.

50. Alternatively, it would have, at a minimum, been obvious to a person having ordinary skill in the art at the time of the '576 patent to include a real-time clock as part of Stewart's monitoring device for all of the above reasons. As discussed above, the processor must be able to set the present time and keep track of time in order to implement the user-defined commands disclosed by Stewart. Accessing a real-time clock would have been an obvious and predictable way of

enabling the processor determine the current time thereby allowing it to compare the current time to the start/stop times dictated by the user-defined time commands. Therefore, a skilled artisan would be motivated to include a real-time clock in order to enable the processor to perform the disclosed time-based commands.

D. Obvious to Combine Stewart and Rush

1. Claim 1

a. receiving, interpreting, storing and responding to said movement data based on user-defined operational parameters

51. Claim 1 recites the limitation, "receiving, interpreting, storing and responding to said movement data based on user-defined operational parameters." As I discussed above, Stewart's user-defined commands "set the general parameters of the data storage operation of the HAT." EX1004, *Stewart* at 11:53-54. Stewart also describes an embodiment where the processor "record[s] in real-time detailed data only when the accelerations exceed a defined threshold." *Id.* at 5:4-7; *see also, id.* at 14:6-11 ("[I]n boxing, it is possible to correlate certain responses of the accelerometers 10-12 with desirable punches exceeding a predetermined threshold. . . It might also be possible to determine if a football player is improperly using his helmet (e.g., illegal spearing).").

52. The processor receives accelerometer data from the A/D converter 46 and then interprets the acceleration data to determine if the accelerations exceed

predetermined threshold. *Id.* at 8:64-67, 5:4-7, 14:6-11. If the accelerations do exceed the thresholds, then the processor stores the associated "real-time detailed data." *Id.* at 5:4-7.

53. While Stewart discloses that the acceleration thresholds are "defined" and "predetermined," Stewart does not disclose *who* defines/predetermines the thresholds. Rush also describes a monitoring device incorporated into a football helmet that uses a sensor for detecting "an axial load caused, for example, by a spearing movement of the wearer." EX1006, *Rush* at 9:40-54. The threshold value for detecting a spearing movement is "preferably adjustable so that the magnitude of the axial impact experienced may be varied to accommodate players of different ages and sizes and to minimize the accidental actuation of the signal." *Id.* at 9:54-58; *see also, id.* at 3:13-18 ("In another embodiment, it is a still further object of this invention to provide a helmet with a signal device to sound an audible alarm signal or to display a visual indication when the helmet wearer experiences an axial compressive force above a selected force level such as occurs when the wearer engages in head spearing.").

54. Based on the teachings of Rush, it would have been obvious to a person having ordinary skill in the art to enable the user to define Stewart's acceleration thresholds. A skilled artisan would have been motivated to enable Stewart's thresholds to be adjusted in order to accommodate different players as

taught by Rush. This modification would have predictably resulted in Stewart's processor receiving, interpreting, and storing the acceleration data based on user-defined acceleration thresholds.

55. Stewart already discloses that the data collection operations performed by the processor 52 are based on user-defined commands. EX1004, *Stewart* at 11:30-33 ("Storage of data from the outputs of the accelerometers 10-12 is started and stopped by the processor 52 via commands transmitted through the serial control interface 42."); 11:53-54 ("These commands set the general parameters of the data storage operation of the HAT."); 12:4-59. As such, it would have been obvious to enable the user to adjust the acceleration thresholds using Stewart's disclosed user-defined commands. This would have predictably resulted in allowing the user to further customize the data collection operations performed by Stewart's monitoring device. This modification to Stewart would not have changed the principle of operation or rendered it inoperable for its intended purpose.

56. Rush's helmet also includes "a signal device 103 which may be audible but may also or in the alternative provide a visual signal." EX1006, *Rush* at 9:42-45. The signal device may be a light and/or small speaker. *Id.* at 9:46-48 ("A small speaker 107 and/or a light 109 is installed such as at the rear of the helmet opposite the face mask."). The signal device is activated whenever a

spearing movement is detected. *Id.* at 9:48-54 ("In use, the sensor 100a, when activated by an axial load caused, for example, by a spearing movement of the wearer, will function to close the circuit 111 between the battery and the device 103 to produce the audible and/or visual signal so that the supervisor or coach will be alerted to the spearing action of the wearer and thus be able to caution the individual against such action."); 10:31-41; Figs. 19, 20.

57. Based on the teachings of Rush, it would have similarly been obvious to a person having ordinary skill in the art to enable Stewart's helmet to respond to acceleration data exceeding a predetermined threshold by producing an audible or visual signal. Specifically, it would have been obvious to similarly include a signal device, such as a light and/or speaker, connected to Stewart's processor to provide an audible and/or visual alert whenever the processor detects that the acceleration data exceeds a predetermined threshold indicative an event, such as a spearing event. This modification would have predictably enabled Stewart's monitoring device to provide real-time feedback to the user whenever a spearing event is detected.

58. A skilled artisan would have been motivated to use Stewart's monitoring device to respond to detected events by providing output to the user when dangerous motions, such as spearing motions in football, are detected in order to prevent serious head injuries and provide a real-time indication to the user

when one may have occurred. For example, it would have been obvious to enable Stewart's processor to detect a spearing event by comparing the accelerometer data with a predetermined threshold and subsequently respond by activating a signal device in order to alert the wearer and/or the wearer's coach as to the occurrence of the event. This modification would have had the benefits of alerting the user and/or the user's coach as to the occurrence of a potential head injury in real time while also providing real-time feedback to allow the user to more effectively self-monitor his or her behavior and improve his or her tackling technique.

b. *detecting a first user-defined event based on the movement data and at least one of the user-defined operational parameters regarding the movement data*

59. Claim 1 recites the limitation "detecting a first user-defined event based on the movement data and at least one of the user-defined operational parameters regarding the movement data." Stewart discloses "detection of the precise motions of the head which precede the occurrence of a severe head injury." EX1004, *Stewart* at 5:2-3. For example, Stewart discloses that the processor is able to detect events, such as "if a football player is improperly using his helmet (e.g., illegal spearing)" based on determining whether or not the accelerometer data exceeds a predetermined threshold. *Id.* at 14:6-11 ("[I]n boxing, it is possible to correlate certain responses of the accelerometers 10-12 with desirable punches exceeding a predetermined threshold. . . It might also be possible to determine if a

football player is improperly using his helmet (e.g., illegal spearing)."); *see also, id.* at 5:4-7 ("For this purpose HAT could be modified to record in real-time detailed data only when the accelerations exceed a defined threshold."). For the reasons discussed above, it would have been obvious to a person having ordinary skill in the art to enable the user to define Stewart's acceleration thresholds based on the teachings of Rush. See, ¶¶53-55. This would have predictably resulted in Stewart's processor detecting a first user-defined event, such as a spearing movement, based on the acceleration data and the user-defined acceleration threshold value.

c. *storing first event information related to the detected first user-defined event along with first time stamp information reflecting a time at which the movement data causing the first user-defined event occurred*

60. Claim 1 recites the limitation "storing first event information related to the detected first user-defined event along with first time stamp information reflecting a time at which the movement data causing the first user-defined event occurred." Stewart's processor stores acceleration data in memory 51. EX1004, *Stewart* at 8:58-59 ("The processor 52 controls the storage of data from the A/D Converter 46 to the data storage 51."). In one embodiment, the processor stores "real-time detailed data only when the accelerations exceed a defined threshold." *Id.* at 5:4-7. For the reasons discussed above, it would have been obvious to enable Stewart's processor to detect a first user-defined event, such as a spearing

movement, based on the acceleration data and a user-defined acceleration threshold value. *See*, ¶59. Thus, Stewart teaches storing information related to a detection of a first user-defined event, such as a spearing movement. However, Stewart does not disclose whether or not any additional information, such as time stamp information, is stored with the acceleration data.

61. Rush's monitoring device is in wireless communication with a recording means, such as a hard disk drive, that is used "to record instances in which the potentially injurious activity has taken place." EX1006, *Rush* at 9:61-10:2, 10:14-23. Rush expressly discloses storing "**time and date of each instance** in which the potentially injurious activity occurs." *Id.* at 10:26-28 (emphasis added).

62. Based on the teachings of Rush, it would have been obvious to modify Stewart's processor to store a first timestamp, including the time and date the spearing event was detected, in memory with the acceleration data. One purpose of Stewart's system is providing "real-time storage of data over a length of time such that cumulative exposure effects and thus limits can be established for further or future participation in the sport by the individual wearing the helmet equipped with the present invention." EX1004, *Stewart* at 4:65-5:2. Stewart states that the system can also be used to "detect[] the precise motions of the head which precede the occurrence of a severe head injury." *Id.* at 5:2-4.

63. A skilled artisan would have appreciated that well-known medical guidelines at the time dictated specific timelines for returning to a sport after confirmed head injuries:

Table 6 Guidelines for return to sports after concussion

	First concussion	*Second concussion*	*Third concussion*
Grade 1 (mild)	May return to play if asymptomatic for 1 week	Return to play in 2 weeks if asymptomatic at that time for 1 week	Terminate season; may return to play next season if asymptomatic
Grade 2 (moderate)	Return to play after asymptomatic for 1 week	Minimum of 1 month; may return to play then if asymptomatic for 1 week; consider terminating season	Terminate season; may return to play next season if asymptomatic
Grade 3 (severe)	Minimum of 1 month; may then return to play if asymptomatic	Terminate season; may return to play next season	

EX1017, *Cantu* at 294.

64. Storing the date/time of each detected potential head injury would have predictably aided in the determination of appropriate limits for future participation in sports based on the recorded dates/times of the detected events. Therefore, a person having ordinary skill in the art would have been motivated to enable Stewart's processor to include a timestamp reflecting the date/time of each detected event.

65. As discussed above, Stewart's monitoring device inherently includes (or alternatively, it would have been obvious to include) a real-time clock. *See*, ¶¶ 40-50. A skilled artisan would have appreciated that it would have been simple to program Stewart's processor to retrieve and store a date/time stamp from the real-time clock whenever an acceleration threshold is exceeded.

66. A person having ordinary skill would have also understood that this simple modification to Stewart's monitoring device would not have changed its principle of operation or rendered it inoperable for its intended purpose.

d. an output indicator connected to said microprocessor for signaling the occurrence of user-defined events

67. Claim 1 recites the limitation "an output indicator connected to said microprocessor for signaling the occurrence of user-defined events." For the reasons discussed above, it would have been obvious to a person of ordinary skill to similarly include a signal device (i.e., "output indicator"), such as a light and/or speaker, connected to Stewart's processor to provide an audible and/or visual alert whenever the processor detects that the acceleration data exceeds a predetermined threshold indicative an event, such as a spearing event. *See*, ¶¶56-58. This modification would have predictably enabled Stewart's processor to signal the occurrence of user-defined events such as a spearing event.

E. <u>Obvious to Combine Stewart, Rush, and Church</u>

1. Claim 11

68. Claim 11 recites the limitation, "The device of claim 1 wherein said output indicator is tactile." For the reasons discussed above, it would have been obvious to a person having ordinary skill in the art to include a signal device (i.e., "output indicator"), such as a light and/or speaker, in Stewart's helmet to provide a visual and/or audible alerts based on the teachings of Rush. *See*, ¶67. However, Rush does not disclose providing tactile feedback.

69. Church describes "a microprocessor based system utilizing electromyographic sensor to monitor muscle force for lift training and exercise training." EX1008, *Church* at Abstract. Church's monitoring device may be worn on a belt "secured to just above the waist of a user." *Id.* at 3:15-16. The monitoring device includes a microprocessor "coupled to a indicator means 27, which can be auditory and/or vibrational for indicating to the user a lifting condition which exceeds preset parameters programmed into the microprocessor." *Id.* at 3:47-51.

70. Based on the teachings of Church, a person having ordinary skill in the art would have understood that Stewart's device could be further modified to provide vibrational (i.e., "tactile") feedback. Designing user interfaces to communicate information to the user was a well-known problem in the field of

electronics at the time of the '576 patent for which there was a finite number of well-known and often used solutions. A skilled artisan would have understood that providing tactile feedback was one well-known way to communicate information to a user (with the other ways including visual and audible feedback).

71. A person of ordinary skill could have included an actuator in Stewart's device capable of producing vibrations when activated. This would have predictably enabled the processor to activate the actuator to provide vibrational feedback whenever the acceleration threshold is exceeded. This would have predictably enabled the device to "buzz" the user whenever the processor detects a spearing event thereby successfully signaling the occurrence of the event to the user.

F. Obvious to Combine Richardson and Stewart

1. Claims 1 and 13

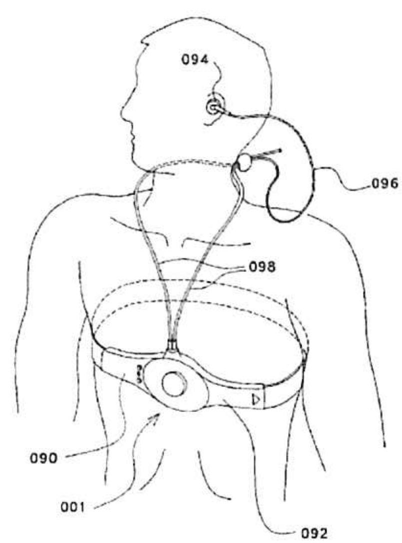
a. a movement sensor capable of measuring data associated with unrestrained movement in any direction and generating signals indicative of said movement

72. Claims 1 and 13 recite the limitation "a movement sensor capable of measuring data associated with unrestrained movement in any direction and generating signals indicative of said movement." I have been informed that counsel is applying two different interpretations to this limitation including an

interpretation where "measuring data associated with unrestrained movement in any direction" means measuring the user's movement in three dimensions.

73. Richardson describes "a personal fitness monitoring device that may be worn by an individual while the individual is exercising." EX1009, *Richardson* at 1:6-8. The monitoring device is portable and includes "an accelerometer for measuring and outputting data representing the vertical accelerations caused by each step of the individual as the individual is walking or running." *Id.* at 1:27-31; *see also, id.* at Title ("Portable aerobic fitness monitor for walking and running.").

74. The monitoring device may be worn on the user's chest or on the user's head and is self-contained in a housing 092:



Id. at Fig. 7.

> FIG. 7 shows how one preferred embodiment of a fitness monitor 001 invention is worn on the human body. A system

> housing 092 is held around the chest, just below the breasts, by an elastic chest strap 090.

Id. at 15:29-32.

> In another physical embodiment, the present invention might be entirely worn on the user's head. A headband could hold an accelerometer 122 tightly, while also holding an electronics assembly and being connected to, and partially supporting, another assembly in the external ear opening.

Id. at 16:42-46.

75. Thus, Richardson suggests an embodiment where the monitoring device is "entirely worn on the user's head." However, Richardson also acknowledges that a more advanced accelerometer would be needed for the embodiment where the monitoring device is attached to the user's head. *Id.* at 16:51-54.

76. Stewart's monitoring device was specifically designed to be placed on the user's head and teaches using up to nine accelerometers to measure the angular and translational movements of a monitored body part or the user's body in general in three dimensions. EX1004, *Stewart* at 4:45-59, 6:10-45. Like Richardson, Stewart also teaches monitoring a user while the user is running. *Id.* at 5:13-17 (discussing applying the device to study accelerations experienced by sprinters). Based on the teachings of Stewart, it would have been obvious to a person having ordinary skill to substitute Richardson's accelerometer with Stewart's at least three

accelerometers in order to enable Richardson's device to measure the user's movements in three dimensions.

77. As I discussed above in the Background of the Technology section above, motion sensing devices sensing user's movements in a full six degrees of freedom were well known in the art prior to the invention of the '576 patent. *See*, ¶¶ 34-35. Moreover, a person having ordinary skill would have appreciated that adding additional accelerometers capable of measuring the user's movement in a full three dimensions would have advantageously allowed Richardson's monitoring system to analyze additional aspects of the user's movement. As suggested by Stewart, substituting Richardson's accelerometer subsystem for the accelerometers taught by Stewart would have enabled Richardson's device to perform a more detailed analysis of a sprinter's movement when coming off starting blocks, for example. For these reasons, a person having ordinary skill in the art would have been motivated to include accelerometers capable of measuring movement in three dimensions in Richardson's monitoring device.

78. Richardson explicitly envisions other methods of determining position and movement, including global positioning systems or the use of Doppler measurements as well as augmenting the system with additional components:

> Similarly, pedometer 015 is not a requirement of the invention because other methods of detecting and reporting distance traveled, speed of traveling, or expended energy in general might be employed, such as global positioning systems or

> Doppler sound ranging techniques. In a like manner, fitness prediction arrangement 019 is not a requirement of the invention because the fitness monitoring function can be fully realized by computing and reporting the user's current fitness without regard to or need to predict the future trends in fitness. In summary, the constituent components of this invention can be assembled into numerous configurations by including some components and leaving others out. All such useful combinations would be consistent with the invention. On the other hand, the invention may be augmented with additional components without changing the nature of this invention.

EX1009, *Richardson* at 5:19-35.

b. *wherein said movement sensor measures the angle and velocity of said movement*

79. Claims 1 and 13 also recite the limitation, "wherein said movement sensor measures the angle and velocity of said movement." For the reasons discussed above, it would have been obvious to substitute Richardson's acceleration subsystem with the accelerometers taught by Stewart, which measures translational and angular movement in three dimensions. *See*, ¶¶72-77.

80. Stewart also discloses using accelerometers "which perform on-board calculation of velocity and displacement . . . to track events and permit additional kinematic and kinetic analyses to be performed." EX1004, *Stewart* at 7:35-38. Based on the teachings of Stewart, it would have been obvious to a person having ordinary skill in the art to similarly include an accelerometer subsystem in Richardson's monitoring device that measures translational and angular motions in multiple dimensions and performs on-board calculation of velocity and

displacement. Such accelerometers and arrangements of accelerometers were well known in the field of motion tracking before the invention of the '576 patent.

81. Moreover, this simple substitution Richardson's accelerometer subsystem with Stewart's accelerometers would have yielded predictable results. In particular, a person of ordinary skill would understand that incorporating a motion sensor capable of on-board calculation of velocity into Richardson's device would have predictably removed the need for Richardson's microprocessor to calculate the velocity thereby reducing the processing demands on the microprocessor. When incorporating a motion sensor that performs on-board calculation of velocity into Richardson's device, a skilled artisan would have appreciated that the "monitor sensors process 154" could be modified to scan the accelerometer subsystem for both acceleration and velocity outputs. Given the amount of additional analysis performed by Richardson's monitoring device, a PHOSITA would have been motivated to reduce the computational demands on the microprocessor to ensure timely processing and interpretation of each detected step.

82. As indicated in paragraph 78 above, Richardson envisioned "other methods of detecting and reporting distance traveled, speed of traveling, or expended energy in general might be employed, such as global positioning systems or Doppler sound ranging techniques." Not only are position, velocity, and

acceleration related through known laws of physical motion, such that position and velocity may be calculated from measurements of acceleration by means of an accelerometer, but it was also well known at the time of the invention how to build systems employing sensors and other measurement means for estimating any of these quantities based on measurements, calculations, and combinations of the two.

c. *a computer running a program capable of interpreting and reporting said movement data based on said operational parameters*

83. Claim 13 recites the limitation "a computer running a program capable of interpreting and reporting said movement data based on said operational parameters." Richardson teaches a reporting program capable of interpreting the movement data and generating a variety of reports, including, for example, "a prior week report, a prior month report, a distance history report, an energy history report, and a fitness history report." EX1009, *Richardson* at 19:11-14. Reports are generated based on the user's personal data (i.e., "operational parameters") and the movement data. For example, one report "calculates the fitness of the individual as the individual exercises using personal data provided by the individual in combination with the data outputs of the pedometer and the heart rate monitor without requiring a predetermined exercise regime." *Id.* at 1:22-26.

84. In the primary embodiment, software on Richardson's monitoring device generates the reports and then delivers them to the user via the audio

subsystem. *Id.* at 19:7-15. Richardson also discloses that output may be reported "as a text display" and that "the format of the output is not a requirement of the invention and it may vary considerably." *Id.* at 4:46-49. Richardson does not disclose running the reporting software on a separate computer. However, Richardson does disclose that the movement data may be transmitted to a remote computer. *Id.* at 5:43-47.

85. Stewart's system includes an external computer and teaches transferring the movement data from the monitoring device to the computer "for further processing." EX1004, *Stewart* at 13:9-12. In one embodiment, the computer runs a program convert the data into a format suitable for observation. *Id.* at 13:20-24. Based on the teachings of Stewart, it would have been obvious to a person having ordinary skill in the art to include a computer capable of running Richardson's reports as part of Richardson's system. A skilled artisan would have understood that the user might prefer to receive reports via a display instead of audibly via Richardson's audio subsystem. Therefore, a skilled artisan would have been motivated allow the user to transfer the movement data to a computer capable of running the reports. This would have predictably improved the usability and flexibility of the system thereby increasing user satisfaction by giving the user the option of seeing rather than hearing their reports.

d. *a download device electronically connected to said movement measuring device and said computer for transmitting said movement data and operational parameters between said movement measuring device and said computer for analysis, reporting and operation purposes*

86. Claim 13 also recites "a download device electronically connected to said movement measuring device and said computer for transmitting said movement data and operational parameters between said movement measuring device and said computer for analysis, reporting and operation purposes." As I discussed above, it would have been obvious to enable the user to transmit movement data from Richardson's device to a computer for analysis/reporting purposes. *See,* ¶¶83-85.

87. Stewart also discloses an embodiment where the monitoring device and a PC are electronically connected via a RS-232 cable (i.e., "download device"). EX1004, *Stewart* at Fig. 1. In this embodiment, the movement data may be transmitted from the monitoring device to the computer and user-defined commands may be transmitted from the computer to the monitoring device. Id. at 11:33-39, 11:51-58, 11:64-12:3. It would be similarly obvious to enable the user to enter his or her personal information and desired alarm parameters via a computer as taught by Stewart. A skilled artisan would appreciate that the user's information and alarm settings could then be transmitted from the computer to Richardson's monitoring device via a RS-232 cable as taught by Stewart.

88. A person having ordinary skill would understand that users may prefer to input their personal data and alarm settings via a computer rather than through making use of Richardson's audio interface. As such, a skilled artisan would have been motivated to modify Richardson in this way in order to improve the usability of the system. This would have predictably increased user satisfaction by making it easier for users to enter their personal data and customized alarm parameters.

89. Richardson envisioned a variety of means of the user entering "personal data:"

> Current option presentation signal 047 may be presented in any of a number of modalities, including but not limited to an audio output 003 of recorded or synthesized speech as described above. Alternatively, an LCD display or other conventional output device could be employed instead.

EX1009, *Richardson* at 10:1-5. While the audio interface was envisioned as a means of simplifying the user interface, it was well known at the time how to use buttons, keyboards, or other means in combination with an "LCD display" as indicated above for entering such data. It would have been obvious to consider use of a computer with such an interface for simplifying entry of such personal data.

IV. CONCLUSION

90. 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 that these statements were made with the knowledge that willful false statements and

the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: 2/20/2018

By: Andrew C. Singer
Andrew C. Singer

Appendix A

Andrew C. Singer

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CURRENT ACADEMIC POSITIONS

Fox Family Professor
Interim Director, Siebel Center for Design
Director, Technology Entrepreneur Center and Special Advisor to the Dean
for Innovation and Entrepreneurship, College of Engineering
Professor, Department of Electrical and Computer Engineering,
Department of Industrial and Enterprise Systems Engineering,
Department of Business Administration, College of Business
Interim Innovation Thread Lead, Carle-Illinois College of Medicine
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PROFESSIONAL INTERESTS

Research and teaching in electrical and computer engineering, and engineering entrepreneurship. Research interests include adaptive and statistical signal processing, communication systems, and machine learning.

EDUCATION

June 1996	**Massachusetts Institute of Technology**, Cambridge, MA Ph.D. degree in Electrical Engineering and Computer Science
Feb. 1992	**Massachusetts Institute of Technology**, Cambridge, MA S.M. degree in Electrical Engineering and Computer Science
Feb. 1990	**Massachusetts Institute of Technology**, Cambridge, MA S.B. degree in Electrical Engineering and Computer Science

AWARDS/HONORS

2016	Technical University of Munich Institute for Advanced Study Fellow
2014	Invested as Fox Family Endowed Professor, for "scholarship and teaching focus on economic development, entrepreneurship, and transfer of technology locally, in the state, and in the nation."
2014	Selected as a Distinguished Lecturer for the Signal Processing Society of the Institute of Electrical and Electronics Engineers (IEEE).
2013	Entrepreneur Advocacy Award, Champaign County Innovation Celebration.
2012	Inaugural Curation Board of the National Center for Engineering Pathways to Innovation (Epicenter), an initiative funded by the National Science Foundation.
2010	Invited to serve as a Franklin Fellow at the U.S. Department of State.
2009	Elected to the grade of Fellow in the Institute of Electrical and Electronics Engineers, "for contributions to signal processing techniques for digital communication."
2009	Special-Topic Evening Session Award, for the talk entitled, "Trends and Challenges in Optical Communications Front-End," International Solid State Circuits Conference.

2008	Best Paper Award for the IEEE Signal Processing Magazine for the paper entitled "Turbo Equalization," which appeared in the January 2004 issue.
2008	Selected for participation in National Academy of Engineering, "Frontiers of Engineering" symposium.
2006	Best Paper Award for the IEEE Journal of Solid State Circuits for the paper entitled, "An MLSE Receiver for Electronic Dispersion Compensation of OC-192 Fiber Links."
2002-2009	Donald Biggar Willet Faculty Scholar, College of Engineering, University of Illinois at Urbana-Champaign.
2000	Xerox Award for Outstanding Faculty Research, College of Engineering, University of Illinois at Urbana-Champaign.
2000	National Science Foundation CAREER Award.
2000	Office of Naval Research Special Research Award in Ocean Acoustics.
2000,2001	Incomplete List of Teachers Ranked Excellent by their Students, University of Illinois at Urbana-Champaign, Spring 2000, Fall 2000, Fall 2001.
1998	Lockheed Martin Special Recognition Award.

APPOINTMENTS AND RELATED EXPERIENCE

4/07-Present **Consultant and Expert Witness**

Recent cases include: Fujitsu Network Communications, Inc. v. **Tellabs, Inc.,** No. 1:09-cv-4530 (Filed 7/27/2009 in the Northern District of Illinois); **Tellabs, Inc.** v. Fujitsu Network Communications, Inc., No. 08-CV-3379 (Filed 6/11/2008 in the Northern District of Illinois); In re Certain Semiconductor Chips and Products Containing Same, ITC Inv. No. 337-TA-753, on behalf of **Rambus** (Filed 12/1/2010 at the International Trade Commission); **Hill-Rom, Inc**. v. Stryker Corp., No. 1:11-CV-01120-JMS-DKL (Filed 8/15/2011 in the Southern District of Indiana); Mobile Telecommunications Technologies, LLC v. **Clearwire Corporation, Clearwire Wireless, LLC**, and **Clearwire US**, **LLC**, No. 2:12-CV-308 (Filed 5/24/2012 in the Eastern District of Texas); Mobile Telecommunications Technologies, LLC v. **Sprint Nextel Corp**., No. 2:12-cv-832-JRG-RSP (Filed 12/31/2012 in the Eastern District of Texas); Inter Partes Reexamination of: U.S. Patent No. 7,568,246, No. 95/002,051, on behalf of **Hill-Rom** (Filed 7/20/2012 at the PTAB); Spherix Inc. v. **Cisco Systems, Inc**., No. 1:14-cv-393-SLR (Filed 3/28/2014 in the District of Delaware); Inter Partes Review of U.S. Patent No. 6,744,375, No. IPR2014-01379, on behalf of **Garmin International** (Filed 8/25/2014 at the PTAB); Cellular Communications Equipment LLC v. **LG Electronics, Inc., et a**l., No. 6:14-CV-00982-JRG (Filed 12/19/2014 in the Eastern District of Texas); Core Wireless Licensing S.a.r.l. v. **Apple Inc**., Nos. 3:15-cv-5007-RS and 5:15-cv-5008-PSG (Filed 9/10/14 in the Northern District of California); In re Certain Audio Processing Hardware and Software and Products Containing the Same, ITC Inv. No. 337-TA-949, on behalf of **Conexant** (Filed 2/9/2015 at the International Trade Commission); Cellular Communications Equipment LLC v. **AT&T Inc., et al.,** No. 2:15-cv-0576 (Filed 4/30/2015 in the Eastern District of Texas); Certain Audio Processing Hardware, Software, and Products Containing the Same, ITC Inv. No. 337-TA-1026, on behalf of **Samsung** (Filed 9/19/2016 at the International Trade Commission); Andrea Electronics Corp. v. **Samsung Electronics America, Inc. et al**., No. 2:16-cv-05217-JMA (Filed 9/19/2016 in the Eastern District of New York); TC Technology LLC v. **Sprint Corp**. & **Sprint Spectrum L.P**., No. 1:16-cv-153-RGA (Filed 3/10/2016 in the District of Delaware); Quanergy Systems, Inc. v. **Velodyne LiDAR, Inc**., No. 5:16-cv-05251-EJD (Filed 9/13/2016 in the Northern District of California)

12/16 – Pres. **LISNR, Inc.** Technical advisor for acoustic communications.

11/14 – Pres. **OceanComm, Incorporated**, Champaign, IL. Co-Founder and Chief Executive Officer. SBIR-and ONR-funded technology company commercializing underwater acoustic wireless communication technology.

12/08 – Pres. **Diagnostic Photonics,** Chicago, IL. Member of Board of Directors.

12/07 – 12/15 **Mimosa Acoustics,** Champaign, IL. Member of Board of Directors.

02/10 – 6/12 **Innovate @ Illinois,** Champaign, IL. Host of monthly television program showcasing entrepreneurship and innovation in the University of Illinois Community.

8/13 – Pres. **University of Illinois at Urbana-Champaign**, Urbana, IL
Fox Family Professor with primary academic appointment as Professor in the Electrical and Computer Engineering Department. Research sponsors include the Office of Naval Research, the National Science Foundation, Department of Energy, Defense Advanced Research Projects Agency, and commercial industry. Assistant Director and Stochastic Information Processing Systems theme-lead for the Systems on Nanoscale Information fabriCs (SONIC) Center, one of six STARNET centers funded by DARPA and SRC. Director, Signal Processing and Communication Systems Laboratory.

06/05 – Pres. **University of Illinois at Urbana-Champaign**, Urbana, IL
Interim Director, Siebel Center for Design; Director, Technology Entrepreneur Center; Unit Head, Innovation, Leadership, and Engineering Entrepreneurship; Special Advisor to the Dean for Innovation and Entrepreneurship, College of Engineering; Championed the creation of and oversee all activities in the College of Engineering relating to the new bachelor's degree in Innovation, Leadership, and Engineering Entrepreneurship (ILEE), and all curricula for undergraduate and graduate and distance learning programs for entrepreneurship and innovation. Oversee the Faculty Entrepreneurial Fellows Program, as well as the activities of the Innovation Living Learning Community, the Illinois Innovation Prize, the V. Dale Cozad New Venture Competition, Silicon Valley and Chicago Student Trips, among a host of other on-campus student and faculty-oriented activities. Co-chair for the Campus Roundtable on Entrepreneurship. Chair of the Provost's Core Committee for the creation of the Siebel Center for Design. Interim Innovation Thread Lead, Carle-Illinois College of Medicine.

8/08 – 8/13 **University of Illinois at Urbana-Champaign**, Urbana, IL
Professor in the Electrical and Computer Engineering Department and the Coordinated Science Laboratory. Network Connectivity theme leader across the five centers of the Microelectronics Advanced Research Corporation (MARCO) Focus Center Research Program. Co-PI for ONR Multi-University Research Initiative on Underwater Acoustic Communications.

3/07 - 2/09 **Finisar Corporation,** Champaign, IL
Sr. Scientist in Optical Products Division (upon acquisition of Intersymbol Communications, Inc., 3/2007). Research and development in new product areas and Director of the Intersymbol Communications division.

8/00 - 3/07 **Intersymbol Communications, Inc.**, Champaign, IL
Co-Founder and Chief Executive Officer. Co-founded and raised over $10M for a venture capital-backed integrated circuit (IC) company creating signal processing-enhanced optical communications ICs. Designed and built the world's first 10Gb/s adaptive MLSE-based receivers for electronic dispersion compensation in high-speed

optical communications. Intersymbol was acquired by Kodeos Communications in March, 2006 and by Finisar Corporation (NASDAQ:FNSR) in March, 2007.

8/03 – 8/08 **University of Illinois at Urbana-Champaign**, Urbana, IL
Associate Professor in the Electrical and Computer Engineering Department and the Coordinated Science Laboratory.

8/98 - 8/03 **University of Illinois at Urbana-Champaign**, Urbana, IL
Assistant Professor in the Electrical and Computer Engineering Department and the Coordinated Science Laboratory.

9/96 - 8/98 **Sanders, A Lockheed Martin Company** (Now BAE Systems), Nashua NH
Principle investigator under the Army Research Laboratory Program for Advanced Telecommunications. Signal processing lead for ATD-111 Airborne LIDAR mine and submarine detection program. Research areas include underwater acoustic and wireless RF communications; detection systems; real-time algorithm development and implementation, and multi-sensor data fusion. Air-acoustic and underwater acoustic adaptive beamforming and automatic target detection and classification systems.

5/96-9/96 **Research Laboratory of Electronics (RLE), MIT**, Cambridge, MA
Postdoctoral Affiliate in the Digital Signal Processing Group at RLE.

BOOKS AND BOOK SECTIONS

N. Shanbhag, A.C. Singer, and H-M Bae, "Signal Processing for High Speed Links," Section for Chapter on "Applications," *Handbook of Signal Processing Systems,* Edited by S.S. Bhattacharyya, E.F. Deprettere, R. Leupers, and J. Takala, Springer, 2010.

J. Buck, M. Daniel, and A. Singer*, Computer Explorations in Signals and Systems Using Matlab*, Prentice Hall *Signal Processing* Series, Prentice Hall, November 1996. Second Edition 2001. Over 17,000 copies sold.

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1. A.C. Singer, G.W. Wornell, and A.V. Oppenheim, "Nonlinear Autoregressive Modeling and Estimation in the Presence of Noise," *Digital Signal Processing*, vol. 4, no. 4, pp. 207-221, October 1994.
2. A.C. Singer and A.V. Oppenheim, "Circuit Implementations of Soliton Systems," *International Journal of Bifurcation and Chaos*, vol. 9, no. 4, pp. 571-590, April 1999.
3. A.C. Singer, A.V. Oppenheim, and G.W. Wornell, "Detection and Estimation of Multiplexed Soliton Signals," *IEEE Transactions on Signal Processing*, vol. 47, no. 10, pp. 2768-2782, October 1999.
4. A.C. Singer and M. Feder, "Universal Linear Prediction by Model Order Weighting," *IEEE Transactions on Signal Processing*, vol. 47, no. 10, pp. 2685-2699, October 1999.
5. D. Baron and A. C. Singer, "On the Cost of Worst-Case Coding Constraints" *IEEE Trans. Information Theory*, vol. 47, pp. 3088-3090, November 2001.

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T.J. Riedl, A.C. Singer, "System and method for broadband doppler compensation," US Patent number 9,608,738, issued Mar 28, 2017.

UNIVERSITY SERVICE (past 5 years)

Interim Director of the Siebel Center for Design. Campus Core Committee Chair, Design Center Initiative and Building. Oversee $48MM project for the development, design, and construction of a new campus-wide design center.

Innovation, Leadership, and Engineering Entrepreneurship (ILEE) degree and academic unit founding Director and Unit Head.

Director, Technology Entrepreneur Center and Special Advisor to the Dean on Innovation and Entrepreneurship, College of Engineering, providing undergraduate and graduate curricula and activities in engineering entrepreneurship and innovation for COE students with over 5000 students enrolled in courses and programs annually.

Organizer and host of annual Illinois Innovation Prize, Cozad New Venture Competition, and NSF I-Corps Site, supervise operation of the Student Innovation Incubator and the Innovation Living Learning Community.

Departmental Committees: ECE Advisory Committee, ECE Faculty Representative to the Faculty Senate, Chair, ECE Conflict Management Oversight committee.

College Committees: Chair, Center for Innovation and Design; Co-Chair Provost's Roundtable on Entrepreneurship.

National Science Foundation Innovation Corps (NSF I-Corps) Program (PI for Illinois I-Corps Site and co-PI for Illinois-Michigan-Purdue Regional Node).

PROFESSIONAL SOCIETY SERVICE

Computing in Science and Engineering, Editorial board member, IEEE Signal Processing Society liaison.

Inaugural Curation Board Member of the National Center for Engineering Pathways to Innovation (Epicenter), an initiative funded by the National Science Foundation.

Invited participant on National Science Foundation review panels for Information Technology Research, Signal Processing, Mathematical Foundations, Career Award, Small Business Innovative Research, Engineering, and Computer Communications Research.

Invited reviewer for science funding agencies from the United States, Canada, Israel, Switzerland and the European Union.

Invited annual reviewer for Venturewell (formerly National Collegiate Inventor and Innovators Alliance) proposals.

Invited external reviewer of graduate thesis research and served as Doctoral dissertation outside international expert for theses in Norway on Underwater Acoustic Communications and Turbo Equalization (Norwegian University of Science and Technology, Trondheim), Germany on Turbo Equalization (Technical University of Munich) and Information-Theoretic Quantization and Analog/Digital Conversion (Technical University of Munich), Israel on Generalized Sampling Theory (Tel Aviv University) and Switzerland on Digital Estimation (ETH).

MIT Educational Council Regional Chair, 2017-present, member, 1994-present.

Associate Editor, *IEEE Transactions on Signal Processing* (2 terms), Guest Editor-In-Chief, *IEEE Transactions on Signal Processing -- Special Issue on Machine Learning Methods in Signal Processing*, Guest Associate Editor *IEEE Transactions on Information Theory – Special Issue on Facets of Coding Theory: From Algorithms to Networks,* 2010. Guest Editor-In-Chief, *IEEE Journal on Special Topics in Signal Processing – Special Issue on Special Issue on Soft Detection for Wireless Transmission, 2011.*

Program committee for *IEEE DSP Workshop*, annually 2004-2012, *IEEE Statistical Signal Processing Workshop*, annually 2003-2012, *IEEE International Conference on Acoustic Speech and Signal Processing*, annually 2003-2012, *IEEE International Symposium on Information Theory*, 2008, 2011, 2012.

Member of IEEE Signal Processing Society, IEEE Communications Society, IEEE Information Theory Society, IEEE Oceanic Engineering Society.

Conference organizing committee and Publicity Chair, *IEEE International Symposium on Information Theory*, 2004, Technical Co-Chair *Allerton Conference on Communications, Computing, and Control*, 2005, General Co-Chair, *Allerton Conference on Communications, Computing, and Control*, 2006, Publicity Chair, *IEEE International Conference on Acoustics Speech and Signal Processing*, 2008.

Member of the Signal Processing Theory and Methods (SPTM) technical committee of the IEEE Signal Processing Society, 2004-2011, and the IEEE Machine Learning for Signal Processing technical committee of the IEEE Signal Processing Society, 2007-2012.

Regularly review articles for *IEEE Transactions on Signal Processing, IEEE Signal Processing Letters, IEEE Journal on Special Topics in Signal Processing, IEEE Transactions on Information Theory*, *IEEE Transactions on Circuits and Systems, IEEE Transactions on Communications, IEEE Journal of Oceanic Engineering, Acoustical Society of America, Eurasip Journal on Signal Processing, Journal of Applied Optics, Journal of the Optical Society of America, Physica D, SIAM, and others.*

BACKGROUND AND OTHER INTERESTS

United States citizen. Married. Enjoy swimming, biking, running, triathlon, ultra-distance running and triathlon, and trail running.