UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TETRA TECH CANADA INC.,

Petitioner,

v.

GEORGETOWN RAIL EQUIPMENT COMPANY,

Patent Owner.

Case IPR2019-01581
Patent No. 8,081,320

DECLARATION OF ALAN CONRAD BOVIK, PH.D.

GEORGETOWN RAIL EXHIBIT 2001
Tetra Tech Canada Inc. v. Georgetown Rail Equipment Co.
Case IPR2019-01581

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I. INTRODUCTION

Alan Conrad Bovik, Ph.D. declares as follows:

1. I have been retained as a technical expert on behalf of the patent owner Georgetown Rail Equipment Company ("Patent Owner") to provide my expert opinion on matters in this *Inter Partes* Review ("IPR") relating to the technology set forth in claims 1-17 of U.S. Patent No. 8,081,320 ("the '320 patent") and relating to the validity of those claims as raised in the Petition for *Inter Partes* Review of U.S. Patent No. 8,081,320 dated September 18, 2019 ("Petition") and in the Declaration of Nikos Papanikolopoulos, Ph.D. ("Papanikolopoulos Declaration"). It is my understanding that the '320 patent is Exhibit 1001, and the Papanikolopoulos Declaration is Exhibit 1004, to the IPR Petition.

2. I am being compensated at the rate of $500 per hour for my time spent on this matter. My compensation is not contingent on obtaining a particular result or reaching any specific conclusion or opinion. My compensation is also not tied to any future promise of compensation by the Patent Owner or their IPR counsel. I have no financial interest in the Patent Owner or the Petitioner Tetra Tech Canada Inc., or in any of their respective subsidiaries. I have no financial interest in the '320 patent.

II. SUMMARY OF OPINIONS

3. Based on my education, training, knowledge of the state of the art as of the effective filing date of the ’320 patent, analysis of the Petition and the Papanikolopoulos Declaration and the references they cite, and applying the understanding that a person having ordinary skill in the art (“POSITA”) would have had as of the effective filing date of the ’320 patent, it is my opinion that claims 1-17 of the ’320 patent are patentable over the references cited in the Petition and the Papanikolopoulos Declaration that form the basis for their assertions of unpatentability. In forming my opinions, counsel for the Patent Owner has asked me to assume that the effective filing date of the ’320 patent is June 23, 2009, as the Petition asserts on page 6. Each of my opinions, and the basis for those opinions, are stated in complete detail below. Where appropriate, I have identified the most pertinent source or sources for the information on which I have relied.

III. BACKGROUND

4. I hold a Ph.D. in in Electrical and Computer Engineering from the University of Illinois, Urbana-Champaign (awarded in 1984). I also hold a master’s degree in Electrical and Computer Engineering from the University of Illinois, Urbana-Champaign (awarded in 1982).

5. I am a tenured full Professor and I hold the Cockrell Family Regents Endowed Chair at the University of Texas at Austin. My appointments are in the

Department of Electrical and Computer Engineering, the Department of Computer Sciences, and the Department of Biomedical Engineering. I am also the Director of the Laboratory for Image and Video Engineering ("LIVE").

6. My research is in the general area of digital television, digital cameras, image and video processing, computational neuroscience, and modeling of biological visual perception. I have published over 800 technical articles in these areas and hold eight issued U.S. patents. I am also the author of The Handbook of Image and Video Processing, Second Edition (Elsevier Academic Press, 2005); Modern Image Quality Assessment (Morgan & Claypool, 2006); The Essential Guide to Image Processing (Elsevier Academic Press, 2009); and The Essential Guide to Video Processing (Elsevier Academic Press, 2009); and numerous other publications.

7. I have been selected to receive the 2019 IEEE Fourier Award with citation: "For seminal contributions and high-impact innovations to the theory and application of perception-based image and video processing." This Technical Field Award and medal is one of the highest honors accorded by the 423,000-member IEEE.

8. I received the 2017 Edwin H. Land Medal from the Optical Society of America in September 2017 with citation: For substantially shaping the direction

and advancement of modern perceptual picture quality computation, and for energetically engaging industry to transform his ideas into global practice.

9. I received a Primetime Emmy Award for Outstanding Achievement in Engineering Development, for the Academy of Television Arts and Sciences, in October 2015, for the widespread use of my video quality prediction and monitoring models and algorithms that are widely used throughout the global broadcast, cable, satellite and internet Television industries.

10. Among other awards and honors, I have received the 2013 IEEE Signal Processing Society's "Society Award," which is the highest honor accorded by that technical society ("for fundamental contributions to digital image processing theory, technology, leadership and education"). In 2005, I received the Technical Achievement Award of the IEEE Signal Processing Society, which is the highest technical honor given by the Society, for "broad and lasting contributions to the field of digital image processing"; and in 2008 I received the Education Award of the IEEE Signal Processing Society, which is the highest education honor given by the Society, for "broad and lasting contributions to image processing, including popular and important image processing books, innovative on-line courseware, and for the creation of the leading research and educational journal and conference in the image processing field."

11. My technical articles have been widely recognized as well, including the 2009 IEEE Signal Processing Society Best Journal Paper Award for the paper "Image quality assessment: From error visibility to structural similarity," published in IEEE Transactions on Image Processing, volume 13, number 4, April 2004; this same paper received the 2017 IEEE Signal Processing Society Sustained Impact Paper Award as the most impactful paper published over a period of at least ten years; the 2013 Best Magazine Paper Award for the paper "Mean squared error: Love it or leave it?? A new look at signal fidelity measures," published in IEEE Transactions on Image Processing, volume 26, number 1, January 2009; the IEEE Circuits and Systems Society Best Journal Paper Prize for the paper "Video quality assessment by reduced reference spatio-temporal entropic differencing," published in the IEEE Transactions on Circuits and Systems for Video Technology, vol. 23, no. 4, pp. 684-694, April 2013; the 2017 IEEE Signal Processing Letters Best Paper Award for the paper A. Mittal, R. Soundararajan and A.C. Bovik, "Making a 'completely blind' image quality analyzer," published in the *IEEE Signal Processing Letters*, vol. 21, no. 3, pp. 209-212, March 2013. This paper describes a unique "blind" (no-reference) video quality tool called NIQE that is being used to control the quality of cloud-based streaming videos globally. Also, the 2018 EURASIP Best Paper Award of the European Association for Signal Processing for 2018, for the paper "Full-Reference Quality Assessment of Stereopairs Accounting for Rivalry,"

Signal Processing: Image Communication, vol. 28, no. 10, pp. 1143-1155, October 2013, and the Best Paper Award of the 2018 *Picture Coding Symposium* for the paper, "Detecting Source Video Artifacts with Supervised Sparse Filters."

12. I received the Google Scholar Classic Paper citation twice in 2017, for the paper "Image information and visual quality," published in the *IEEE Transactions on Image Processing*, vol. 15, no. 2, pp. 430-444, February 2006 (the main algorithm developed in the paper, called the Visual Information Fidelity (VIF) Index, is a core picture quality prediction engine used to quality-assess all encodes streamed globally by Netflix), and for "An evaluation of recent full reference image quality assessment algorithms," published in the *IEEE Transactions on Image Processing*, vol. 15, no. 11, pp. 3440-3451, November 2006. (the picture quality database and human study described in the paper, the LIVE Image Quality Database, has been the standard development tool for picture quality research since its first introduction in 2003). Google Scholar Classic Papers are very highly-cited papers that have stood the test of time and are among the ten most-cited articles in their area of research over the ten years since their publication.

13. I have also been honored by other technical organizations, including the Society for Photo-optical and Instrumentation Engineers (SPIE), from which I received the Technology Achievement Award (2013) "For Broad and Lasting Contributions to the Field of Perception-Based Image Processing," and the Society

for Imaging Science and Technology, which accorded me Honorary Membership, which is the highest recognition by that Society given to a single individual, "for his impact in shaping the direction and advancement of the field of perceptual image processing." I was also elected as a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) "for contributions to nonlinear image processing" in 1995, a Fellow of the Optical Society of America (OSA) for "fundamental research contributions to and technical leadership in digital image and video processing" in 2006, and as a Fellow of SPIE for "pioneering technical, leadership, and educational contributions to the field of image processing" in 2007.

14. Among other relevant research, I have worked with the National Aeronautics and Space Administration ("NASA") to develop high compression image sequence coding and animated vision technology, on various military projects for the Air Force Office of Scientific Research, Phillips Air Force Base, the Army Research Office, and the Department of Defense. These projects have focused on developing local spatio-temporal analysis in vision systems, scalable processing of multi-sensor and multi-spectral imagery, image processing and data compression tools for satellite imaging, AM-FM analysis of images and video, the scientific foundations of image representation and analysis, computer vision systems for automatic target recognition and automatic recognition of human activities, vehicle structure recovery from a moving air platform, passive optical modeling, and

detection of speculated masses and architectural distortions in digitized mammograms. My research has also recently been funded by Netflix, Qualcomm, Facebook, Texas Instruments, Intel, Cisco, and the National Institute of Standards and Technology (NIST) for research on image and video quality assessment. I have also received numerous grants from the National Science Foundation for research on image and video processing and on computational vision.

15. Additional details about my employment history, fields of expertise, and publications are further described in my curriculum vitae, Exhibit 2002.

IV. MATERIALS REVIEWED

16. In forming my opinions, I reviewed the Petition and its Exhibits 1001 through 1042, the Decision for Institution of *Inter Partes* Review *35 U.S.C. § 314* entered on February 25, 2020, as well as the other materials and exhibits discussed in this declaration.

17. I have also applied my education, training, knowledge, and experience in the fields of electrical and computer engineering and also in the more specific field of image and video processing and analysis, and my understanding of the knowledge, creativity, and experience of a POSITA in forming my opinions expressed in this declaration. I have been asked to assume that each of the references on which the Petition and the Papanikolopoulos Declaration relies qualifies as prior art to the ’320 patent.

V. THE ’320 PATENT

18. The ’320 patent relates to a system and method that includes a light generator, a camera, and a processor adapted to determine whether rail seat abrasion is present along the track, such as by using image data to measure rail seat abrasion at various places along the track and to compensate for a tilt of the track. Ex-1001 at abstract; col. 2, lines 22-43. For example, claim 1 recites a system that includes at least one light generator adapted to project a beam of light across the track, at least one camera for receiving at least some of the reflected light to generate at least one image of a profile of some portion of the track, and a processor adapted to analyze the at least one image and determine whether rail seat abrasion is present along the railroad track and compensate for a tilt of the railroad track. Ex-1001 at col. 15, lines 38-55.

VI. THE APPLICABLE LAW

19. I am not a lawyer, and I express no opinion on matters of law. I have been instructed that the legal standards set forth below are applicable to determining issues of patentability. I have applied those standards in forming my expert opinions for this IPR.

A. Level of Ordinary Skill in the Art

20. I understand that the following factors may be considered in determining the level of ordinary skill in the art: (1) the educational level of the

inventor; (2) the type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology; and (6) educational level of active workers in the field.

B. Validity

21. It is my understanding that a patent validity analysis involves two steps. First, the scope and meaning of the claim language must be determined. Second, the construed claim language is compared to the alleged prior art references.

22. I also understand that a patent claim at issue in an IPR should be given its ordinary and customary meaning to a POSITA at the time of the invention in view of the content of the patent, its prosecution file histories, and any other relevant evidence. Unless otherwise noted, my opinions in this declaration are consistent with the plain and ordinary meaning of the claims to a POSITA as of the assumed effective filing date of the ’320 patent.

C. Anticipation

23. I understand that anticipation is considered on a claim-by-claim basis. To be anticipated, I understand that a single prior art reference must disclose every limitation of the claim, either expressly or inherently. To disclose a claim limitation inherently, the limitation must necessarily be present in the reference or be the natural result of the combination of elements explicitly disclosed in the reference.

24. It is my understanding that the Petition does not allege that any of the '320 patent claims at issue in the IPR are anticipated by the prior art.

D. Obviousness

25. It is my understanding that, for a claim to be considered obvious and thus unpatentable, the Petitioner must prove that the subject matter of claims would have been obvious to a POSITA in view of the prior art at the time that the invention of the claim was made.

26. It is also my understanding that an analysis of obviousness is based on specific factual findings, including: (1) the scope and content of the prior art, (2) the differences between the claimed invention and the prior art, (3) the level of ordinary skill in the art, and (4) objective indicia, or "secondary considerations," of non-obviousness, such as commercial success of the patented invention.

27. It is my understanding that, to succeed in proving obviousness, Petitioner must prove that the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious to a POSITA at the time the invention was made.

28. It is my understanding that obviousness requires proof that the prior art includes references that cover each limitation of the claim, but also that obviousness requires proof that a POSITA would have selected and combined the prior art references without relying on hindsight from knowledge of the invention itself.

29. It is my understanding that, as part of the obviousness inquiry, it is relevant to consider whether a prior art reference "teaches away" from the invention in the patent claims. I understand that a reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the applicant. I also understand that, even if a reference is not found to teach away, its statements regarding preferences are relevant to a finding regarding whether a skilled artisan would be motivated to combine that reference with another reference.

30. I understand that, although there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole or individually, as filtered through the knowledge of one skilled in the art. I also understand that the inferences and creative steps that a POSITA would employ are also relevant to the issue of obviousness.

31. I further understand that an obvious inquiry may involve assessing the whether there was a sufficient reason for a POSITA to combine references. The prior art references themselves may provide a suggestion, motivation, or reason to combine, but other sources may also support a rationale for combining two or more references. I understand that there is no rigid rule that a reference or combination of

references must contain a teaching, suggestion, or motivation to combine the references but that the teaching, suggestion, or motivation test can be a useful guide in establishing a rationale for combining prior art elements. This test, I understand, poses the question whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention, and that it seeks to counter the use of impermissible hindsight in which the claimed invention is used as a blueprint for assembling the prior art elements in the manner claimed.

32. It is also my understanding that the combination of familiar elements according to known methods could be obvious when it involves no more than the predictable use of prior art elements according to their established functions to yield predictable results. When a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field of invention or in another. If a POSITA can implement a predictable variation and would see the benefit of doing so, that variation is likely to have been obvious. In many fields there may be little discussion of obvious combinations and, in these fields, market demand, not scientific literature, may drive design trends.

33. I further understand that, if the prior art does not suggest that combining the prior art elements as claimed would yield an improvement, then it is unlikely that the claimed invention would have been obvious.

VII. ANALYSIS OF PATENTABILITY

34. In paragraph 29 of his declaration, Dr. Papanikolopoulos opines that a POSITA, as of June 23, 2009, would have had a bachelor's degree in electrical engineering, computer engineering, mechanical engineering, computer science, physics, or a related field, and at least four years' experience (or the academic equivalent) in the field of computer or machine vision. He also states that an academic equivalent example may include a master's degree in electrical engineering, computer engineering, computer science, physics (or a closely related field) and at least two years of experience (or the academic equivalent) in the field of computer or machine vision. He further states that another academic equivalent example may include a Ph.D. in electrical engineering, computer engineering, computer science, physics (or a closely related field) and at least one year of experience in the field of computer or machine vision.

35. I agree with Dr. Papanikolopoulos in his assessment of a POSITA, and I apply that level of skill as part of my opinions in this declaration. I also note that I was at least a person of ordinary skill in the art as of that date.

A. Claim Construction

36. I understand that the both Petitioner and the Patent Owner have proposed that the claim terms of the '320 patent be given their ordinary and customary meaning to a POSITA at the time of the invention. Unless noted

otherwise, my opinions are consistent with the plain and ordinary meanings of these terms to a POSITA as of the assumed effective filing date of the '320 patent.

B. Patentability of Claims 1-17 of the '320 Patent in General.

37. The '320 patent claims 1-17 generally concern the application of computer or machine vision to achieve a specific task in a specific way. The art of computer vision, also sometimes referred to as machine vision, is a field of artificial intelligence in which computers are programmed or trained to interpret and understand the visual world. The programmed computers use digital images from cameras or videos, their programming, and oftentimes deep learning models to identify and classify objects and, in some cases, react to what they "see." Either two-dimensional or three-dimensional images can be used in computer vision system.

38. Computer vision is an "art" and must be treated as such. It is not an area of technology that involves simple mechanics. Although computer vision has been a topic of study for decades (since at least the 1960's for two-dimensional systems and since at least the 1970's for three-dimensional systems), creating a computer or machine vision system with a specific feature, especially a new feature, is difficult and generally is not an obvious endeavor. People in the art of computer or machine vision typically study at great length and work for many years, or frequently most of their careers, on small tasks or very specific tasks because

implementing even simple tasks in machine vision is generally difficult, extremely time-consuming, and requires special expertise.

39. For that reason, it generally would not be obvious to a POSITA to combine a task or technique performed by a manual or automated method, apparatus, or system disclosed in a prior art reference that does not use machine vision with a prior art reference that discloses the use of machine vision, unless the vision system already performs that task or technique. Similarly, it generally would not be obvious to a POSITA to implement a formula, an equation, or measurement technique (manual or otherwise) disclosed in a prior art reference in an existing computer vision system. The process of taking such a task, technique, formula, or equation and synthesizing it into one that operates in computer vision system is very burdensome.

40. In my opinion, the specific contentions in the Petition and the Papanikolopoulos Declaration stretch the concept of what would have been obvious from the references too far. Referring to a prior art reference, like Choros, that performs the task of manually measuring rail seat abrasion, and then referencing prior art that implements computer or machine vision, like Villar, would not have made it obvious to implement the determination or measurement of rail seat abrasion in a computer vision system. The content of a prior art reference that utilizes computer vision simply would not have been helpful to a POSITA in implementing

those manual tasks or techniques in computer vision. The Petition and the Papanikolopoulos Declaration might as well point to a computer vision textbook for all the value it would have provided to a POSITA under the circumstances.

C. Patentability of Claims 1-2, 5-7, 10-13, and 16-17 Over Villar, Choros, Casagrande, and Szwilski.

41. The Petition and the Papanikolopoulos Declaration assert that claims 1-2, 5-7, 10-13, and 16-17 of the '320 patent would have been obvious based on the reference Villar (Ex-1005) in combination with the references Choros (Ex-1007), Casagrande (Ex-1008), and Szwilski (Ex-1009). Petition at 20-63; Ex-1004, ¶¶36-118.

42. For the reasons stated in detail below, in my opinion, claims 1-2, 5-7, 10-13, and 16-17 of the '320 patent would not have been obvious based on Villar in combination with Choros, Casagrande, and Szwilski.

1. Claim 1

43. The Petition and the Papanikolopoulos Declaration assert that claim 1 of the '320 patent would have been obvious based on Villar in combination with Choros, Casagrande, and Szwilski. Petition at 20-54; Ex-1004, ¶¶36-92.

44. For the reasons stated in detail below, in my opinion, claim 1 would not have been obvious based on Villar in combination with Choros, Casagrande, and Szwilski.

a. Claim 1 [preamble], [a], [b], [c], and [d]

45. The Petition and the Papanikolopoulos Declaration assert that the parts of claim 1 they label as elements "[preamble]," "[a]," "[b]," "[c]," and "[d]" are disclosed by Villar. Petition at 32-37; Ex-1004, ¶¶52-63.

46. In my opinion elements "[preamble]," "[a]," "[b]," "[c]," and "[d]" of claim 1 are disclosed by Villar.

b. Claim 1[e]: "determining whether rail seat abrasion is present along the rail road track"

47. The Petition and the Papanikolopoulos Declaration assert that the parts of claim 1 they label as element "[e]" would have been obvious based on Villar and Choros. Petition at 37-45, 20-32; Ex-1004, ¶¶64-77, 36-51.

48. In my opinion element "[e]" would not have been obvious based on Villar and Choros. The Petition and Dr. Papanikolopoulos assert that it "would have been obvious" to combine "*Villar* and *Choros* to make and use an automated railroad track inspection vision system" having a litany of features. Petition at 25; Ex-1004, ¶41. Relating to element [e], they contend that the combined system would have "an image processor for analyzing the at least one image to determine whether rail seat abrasion is present along the railroad track by measuring a vertical distance between rail base and crosstie top surface heights." Petition at 25; Ex-1004, ¶41.

49. The Petition and Dr. Papanikolopoulos assert that a POSITA "would have understood that *Choros* discloses measuring RSA [rail seat abrasion] at each

of the left rail/tie … and right rail/tie … seats" by means of a human inspector using "an RSA measurement gauge device that fits between an abraded tie and the rail base to measure rail seat abrasion" "by determining the depth or vertical distance between" the rail base and the abraded top surface of the tie. Petition at 37-38; Ex-1004, ¶¶64-65. They then contend that "it would have been obvious" to a POSITA "to implement *Villar*'s automated railroad track inspection vision system with *Choros*' method of measuring RSA (i.e., measuring a vertical distance between rail base and crosstie top surface heights) to automatically determine whether RSA is present along a railroad track." Petition at 39; Ex-1004, ¶66. More specifically, they argue that "similar to how an inspector in *Choros* would manually measure the vertical distance or depth of RSA and associate the vertical distance with a known criterion by which to determine actionable RSA, so too would a programmer implement *Villar*'s automated vision system to determine the presence of RSA." Petition at 45; Ex-1004, ¶76.

50. However, in my opinion, Villar and Choros do not teach or suggest element [e]. Villar does not disclose or suggest determining whether rail seat abrasion is present or measuring it. Choros does not disclose or suggest a processor (let alone an image processor), or a processor that analyzes a railroad track image to measure distances of any kind (let alone the vertical distance between the rail base

and the crosstie top surface heights), or a processor that determines or measures rail seat abrasion.

51. In addition, in my opinion, a POSITA would not have combined the references in any event. The Petition and Dr. Papanikolopoulos assert that a POSITA "could have easily implemented" the combination with "predictable results" because both references "describe a railroad track inspection device and method for identifying alignment defects of railroad track components." Petition at 30-31; Ex-1004, ¶¶48-49.

52. However, a POSITA would not have modified Villar with Choros because there is a vast chasm between Choros' manual method and an automated method that uses machine vision, like Villar. It is not trivial or obvious to write an algorithm to implement a manual method because, as stated above, implementing even the simplest concept into machine vision is very difficult and time consuming. A special amount of invention and creativity is necessary to write and implement such an algorithm. For that reason, combining the technique for measuring rail seat abrasion disclosed in Choros with a computer vision system, like that disclosed in Villar, to create a machine vision system that measures rail seat abrasion would not have been obvious.

53. Villar is at best a starting point for the creation of another invention, not an obvious endeavor. Even if a POSITA were motivated to add the feature of

determining rail seat abrasion to Villar, a POSITA would need to create a model, create code for the model, and then experiment and test the resulting code and system to make certain that they work properly. The disclosure in Choros is not helpful to that endeavor because Choros does not contain a model, an algorithm, or code for determining rail seat abrasion.

54. Further, a POSITA would not have modified Villar with Choros because their techniques are diametrically opposed. Choros employs a simple technique using human visual inspection to locate the rail seat followed by manual placement of a gauge, ruler, or similar measurement tool in or near the rail seat to physically measure the distance between the rail seat and the abraded top surface of the crosstie. In contrast, Villar employs a vastly more complicated technique that involves automated imaging of virtually every object inspected and all surrounding areas, recording an image of the height of each object's entire visible surface and of the surrounding areas, to create multiple images, and analyzing those images to locate certain objects and measure various aspects of the railroad track and its components.

55. There is an additional reason why a POSITA would not have combined Villar and Choros. Villar expressly teaches away from the manual measurement and visual inspection disclosed in Choros. Villar states that its disclosed "invention" for an automated vision railroad track bed inspection system "is directed to overcoming,

or at least reducing the effects of, one or more of the problems set forth" in its background section. Ex-1005 at ¶[0007]. One of those problems is that "railroad inspectors attempt to grade the condition of crossties" and, in that procedure, the "grading is most often done with a visual inspection." Ex-1005 at ¶[0004]. This method is problematic because "[t]he process of visual inspection is quite time consuming." Ex-1005 at ¶[0004]. In fact, a crew of 3 or 4 inspectors may only be able to manually grade about 5 to 7 miles of railroad track a day. Ex-1005 at ¶[0004]. To overcome the problem of visual and manual inspection, Villar discloses a laser/camera line optical scanning and analysis system that can automatically determine certain measurable aspects of a railroad track, including condition and location of crossties, aspects of tie plates, fasteners, and insulators, size and height of ballast, and rail break or separation. Ex-1005 at ¶[0008].

56. In contrast to Villar's teachings, Choros discloses a manual measurement and visual inspection method. Ex-1007 at 11-13. Specifically, Choros discloses the use of a tool called "an abrasion measurement gauge" that is physically placed "between the abraded tie and the rail base" to "measure the void between the rail and tie" and thus "measure concrete tie abrasion" as compared to the unabraded crosstie surface. Ex-1007 at 11. Choros adds that "similar feeler gages or a ruler" can also be used the same way. *Id.*

57. Villar expressly teaches away from using this type of measurement system. Choros discloses a manual technique in which a person visually locates the rail seat, and then physically determines or measures, and visually observes the amount of, rail seat abrasion, while Villar expressly teaches "overcoming" or "reducing" the "problems" of "visual inspection" by an "inspector walking along the track to inspect and record" the data. Ex-1005, ¶¶[0007], [0004]. Villar thus explicitly criticizes, discredits, and discourages use of Choros' type of system. Accordingly, a POSITA would not have been motivated to combine Choros with Villar for this additional reason.

58. In an apparent attempt to support a motive for combining Villar and Choros, the Petition and Dr. Papanikolopoulos contend that Choros discloses "both manual and automatic inspection methods" because Choros purportedly "describes using geometry cars to collect pertinent data for identifying critical locations that have excessive rail seat abrasion and present a safety issue," and thus "disclos[es] that data collected on geometry cars is considered as an alternative method for identifying critical locations of RSA." Petition at 31, 28; Ex-1004, ¶¶45, 49; *see* Petition at 37; Ex-1004, ¶64.

59. However, Choros says only the following:

> Methods to detect areas that have excessive rail seat abrasion and present a safety issue are under investigation by FRA. Data collected

> on geometry cars is considered as an alternative method for identifying critical locations. However, for these measurements to be reliable the required frequency of inspections may be too high based on the availability of existing geometry cars. A simpler method is being considered for field forces, either FRA or railroad inspectors, to evaluate a site once it has been detected by a geometry car or during a visual inspection by an inspector.

Ex-1007 at 11. This "simpler method" is the manual and visual measurement system discussed above. *Id.* Choros thus discloses that the automated geometry car systems can, at best, detect potential locations where RSA might exist, but to determine if there is RSA, and to measure RSA, requires that a track inspector must subsequently visit those locations to view and physically measure RSA at each rail seat on each crosstie. Accordingly, rather than suggesting automated determination of RSA, Choros instead emphasizes the importance of using visual inspection and manual measurement to determine the existence of RSA.

60. Information from Petitioner's other exhibits are consistent with this conclusion. Those exhibits state that geometry cars are capable of measuring "loaded track geometry data" only in the form of "rail cant," "rail profile," and "gage widening," and that such data can "indicate" "possible" or "potential" track locations where RSA might be present, such that the possible presence of RSA can, as a result, be further investigated and measured by "Manual/Visual Inspection" methods "on-

the-ground" "by inspectors" "to verify whether [RSA] exists." *See* Ex-1019 at 3, 18; Ex-1015 at 2-3; Ex-1017 at 3-4.

61. The Petition and Dr. Papanikolopoulos otherwise provide an insufficient reason why a POSITA would have combined Villar and Choros. They rely on a motivation "to yield an 'automated'" "machine vision system" because "automating manual inspection tasks" "obviate[s] time, accuracy, and safety issues associated with a human inspector's RSA inspection and measurement," and would have been "further to and consistent with rules promulgated to the railroad industry by" the "Federal Railroad Administration ('FRA')." Petitioner at 25-27; Ex-1004, ¶¶41-44.

62. However, the FRA rules do not provide the motivation Petitioner describes. The FRA rules Petitioner references did not come into effect until November 8, 2011, over two years after the '320 patent's effective filing date. *See* Ex-1017 at 1. They thus provided no impetus to a POSITA in the relevant timeframe. Also, the FRA expressly recognized that existing automated and manual technologies were sufficient to satisfy those rules. In that regard, the Association of American Railroads ("AAR") petitioned the FRA to reconsider the proposed rule because "today's automated inspection equipment cannot measure rail seat deterioration at all, let alone within 1/8 of an inch." Ex-1017 at 3. The FRA agreed that the AAR's position "is technically correct that automated equipment cannot

currently *measure* rail seat deterioration," and the FRA noted that, in contrast, "today's automated equipment can [only] *indicate* locations of rail seat deterioration." *Id.* (emphasis original). The FRA then clarified that its rules require only the use of automated equipment to "indicate" areas of the track where there is "possible rail seat deterioration," and that "on-the-ground visual verification must be done by inspectors" to locate, determine, and measure actual rail seat deterioration. Ex-1017 at 3-4. Accordingly, for this additional reason, the FRA rules would not have motivated a POSITA to implement an automated system for rail seat abrasion measurement.

63. It is also notable that, as stated above, the rules and proposed rules, and the commentary all took place well after the '320 patent's effective filing date. *See* Ex-1017 at 1, 3-4. Thus, even the FRA's discussion of the existing capability of geometry cars and other technologies cannot be used to determine the patentability of the '320 patent claims at issue.

64. Finally, it should be noted that, in support of its argument, the Petition and Dr. Papanikolopoulos include a series of figures labeled "*Choros*, FIG. 8 (annotated)" (Petition at 39, 40, 44; Ex-1004, ¶¶66, 68, 74), but none of them are part of Choros. The illustrations are Choros' Figure 8 "annotated" with extra imagined features apparently taken from Villar. In those locations and related paragraphs, Dr. Papanikolopoulos attempts to create the appearance of an algorithm

like the one claimed in element [e] from a combination of Villar and Choros where no such algorithm exists in those references, and to further suggest that it would be simple and obvious to do implement such an algorithm. *See* Ex-1004, ¶¶66-75. However, as stated above, even assuming that a POSITA would have combined the references, implementing Choros' manual technique into machine vision would not have been that trivial or obvious. Dr. Papanikolopoulos does not explain how each step of the algorithm would be implemented in light of the fact that Choros does not disclose a model, algorithm, or computer code for its measurement of rail seat abrasion. Each step of the procedure proposed by Dr. Papanikolopoulos raises a research problem that would first need to be fully investigated and then, as discussed above, a model would need to be created, an algorithm and software code created based on the model, and then the resulting code and system would need to be tested to make certain that it works properly. Such an approach would not have been obvious.

c. Claim 1[f]: "wherein, when determining whether rail seat abrasion is present, the at least one processor compensates for a tilt of the rail road track."

65. The Petition and the Papanikolopoulos Declaration assert that the parts of claim 1 they label as element "[f]" would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 46-54; Ex-1004, ¶¶78-92.

66. In my opinion element "[f]" would not have been obvious based on Villar, Choros, Casagrande, and Szwilski.

i. Combination of Villar, Choros, and Casagrande

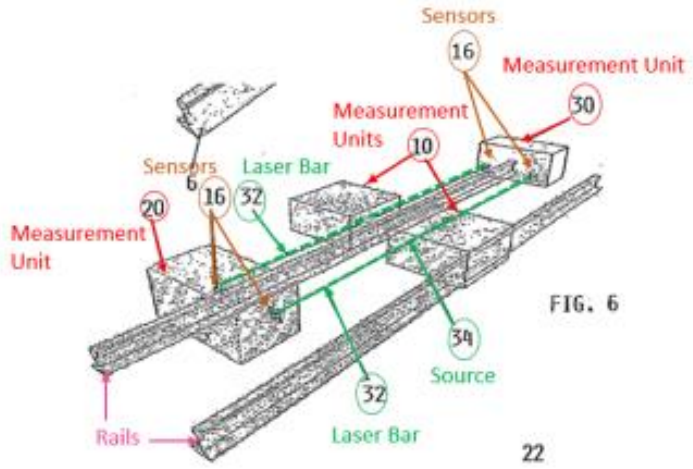
67. The Petition and Dr. Papanikolopoulos assert that it was "well-known at the relevant time to compensate for th[e] tilt of a railroad track when determining a railroad track component defect, as evidenced by, e.g., *Casagrande*." Petition at 46; Ex-1004, ¶78. They conclude as a result that "[i]t would have been obvious" to a POSITA "to have implemented *Villar* and *Choros*' automated RSA railroad track inspection vision system with *Casagrande*'s tilt compensation software to automatically compensate measurements of imaged railroad track components for any vertical alignment errors associated with the deformation of the railway or vehicle-mounted vision system, as taught by *Casagrande*." Petition at 49; Ex-1004, ¶82.

68. In my opinion, however, Casagrande does not disclose or suggest the critical features of element [f]. Casagrande discloses using up to three measurement units that each have laser beams illuminating the rails, and cameras that capture the images, to obtain the rail profiles. Ex-1008, ¶¶[0001], [0004]-[0006], [0020]-[0025], [0029]-[0030]. If three such units are used, the measurements obtained on the two rails enable the processor to calculate various track geometry coordinates,

including rail wear, gauge, radius of curvature, horizontal alignment, vertical alignment, and skew. *Id.*, ¶¶[0025], [0029]-[0030], [0007], [0009], [0011].

69. Casagrande does not disclose or suggest "determining whether rail seat abrasion is present," as the first part of element [f] requires. Although Casagrande discloses some rail related measurements that its system can make, it does not mention rail seat abrasion. *See id.*, ¶¶[0007]-[0043]. Further, although broadly stating an objective of "measur[ing] all the parameters of a railway or tramway line," and that the system can "calculate the various parameters of the track geometry" (Ex-1008, ¶¶[0008], [0030]), Casagrande is in fact incapable of measuring rail seat abrasion. Casagrande's system measures points on, and obtains profiles of, the "two rails," "each rail," and "the top of the rail head," not any other components, such as the crossties. *See* Ex-1008, ¶¶[0022]-[0030] & Figs. 1-5. Because Casagrande makes no mention of illuminating, capturing images of, or making any measurements relating to the crossties, Casagrande is incapable of determining or measuring the difference in height between the rail seat and the unabraded crosstie surface, and thus cannot determine the existence of, or measure, rail seat abrasion. Accordingly, because Casagrande cannot determine whether rail seat abrasion is present, it then follows that Casagrande likewise cannot disclose or suggest "compensat[ing] for a tilt of the rail road track" when making such a determination, as the second part of element [f] requires.

70. The Petition and Dr. Papanikolopoulos contend in the alternative that, "[t]o the extent *Casagrande* does not explicitly disclose compensating an RSA measurement for vertical tilt error, *Casagrande* describes compensating imaged rail profile and other measured geometric parameters (e.g., gauge, radius of curvature, horizontal and vertical alignment, and skew) for vertical alignment errors." Petition at 49; Ex-1004, ¶83. Their argument relies on the Casagrande embodiment shown in Figure 6. The Petitioner's and Dr. Papanikolopoulos' annotated version of that figure is reproduced below:



Casagrande, FIG. 6 (annotated).

Petition at 48; Ex-1004, ¶80. In this embodiment, the "position in height of" the "two end measurement units 20 and 30 is monitored by a laser bar 32" emitted from the center unit and "received by a sensor 16" in the end units that provides "a precise alignment of the points of measurement." *Id.*, ¶[0036]. If the sensors are not aligned

with the laser, the software uses the resulting signal "to automatically compensate the resultant measurement errors." *Id.*

71. However, utilizing that feature, the processor in Casagrande does not "compensate[] for a tilt of the railroad track," as element [f] requires. As Casagrande expressly acknowledges, its system's objective "is to effect all the rail measurements with the measurement apparatus insensitive to oscillation and deformation of the vehicle on which it is mounted." Ex-1008, ¶[0012]. Accordingly, unlike element [f], this feature of Casagrande instead provides only the ability to "compensat[e] for the errors due to elastic deformation of the railway or tramway carriage" so that each rail measurement "is insensitive to elastic deformation and oscillation of the railway carriage on which [the device] is mounted." Ex-1008, ¶¶[0036], [0043]. In other words, this feature adjusts only for measurement errors caused by "oscillations" or "elastic deformation" of the "vehicle" or "carriage" (whether a "railway carriage" or a "tramway carriage") on which the measurement units are mounted. It does not in any manner detect, measure, or adjust for the "tilt" of the rails or the vertical displacement of one rail in regard to another rail.

72. The Petition and Dr. Papanikolopoulos thus incorrectly label this aspect of Casagrande as "tilt compensation software" that can "automatically compensate" "for any vertical alignment errors associated with the deformation of the railway or vehicle-mounted system." Petition at 49; Ex-1004, ¶82. Casagrande does not

compensate for rail "tilt." On its face, Casagrande never discusses tilt, nor does it disclose or suggest a way to compensate for tilt. Ex-1008, ¶¶[0007]-[0043]. As stated above, Casagrande compensates only for measurement errors caused by "oscillations" or "elastic deformation" of the "vehicle," "railway carriage," or "tramway carriage." Also, to the extent that, by the Petition's and Dr. Papanikolopoulos' statement that Casagrande images "railroad track components," they mean to suggest that Casagrande images any component other than the "two rails," "each rail," and "the top of the rail head," the suggestion is incorrect. Casagrande measures points on and obtains profiles of only the two rails, not any other components. Ex-1008, ¶¶[0022]-[0030] & Figs. 1-5.

73. Moreover, Casagrande is incapable of measuring or compensating for "tilt of the railroad track" as element [f] requires. If, because of a curve or bend in the track, the track is tilted to one side, any vehicle traveling on the tracks—including Casagrande's vehicle, railway carriage, or tramway carriage carrying the measurement units—will lean or tilt because it is riding on the track rails. Because the entire vehicle or carriage tilts, each measurement unit mounted on the vehicle or carriage will likewise tilt the same as the vehicle, which means that such a tilt will not disturb the alignment between the front, middle, and back measurement units as monitored by the laser bar 32 and sensors 16. Consequently, Casagrande's system

will not even notice or register the existence of the railway tilt, nor will it be able to "compensate for" that "tilt" as element [f] requires.

74. Finally, the Petition and Dr. Papanikolopoulos claim that a POSITA "could have easily implemented" Casagrande in combination with Villar and Choros to obtain RSA "measurement for vertical tilt errors," "and doing so would yield nothing more than predictable results." Petition at 49; Ex-1004, ¶83; *see* Petition at 46-49; Ex-1004, ¶¶78-83. However, for the reasons stated above, even if a POSITA had sufficient reason to combine the references, the claimed invention would not have been attained. Instead, the only "predictable result" of adding Casagrande to the combination of Villar and Choros would be a measurement system that compensates for oscillations and elastic deformation of the carriage on which the measurement device is mounted, and which is capable of measuring the gauge, radius of curvature, horizontal and vertical alignment, and skew of the rails (as Casagrande discloses). The Petition and Dr. Papanikolopoulos refer to nothing in the references, or otherwise provide sufficient reason, demonstrating why a POSITA would have further modified the combined references to include element [f]'s requirements. *See* Petition at 46-49; Ex-1004, ¶¶78-83.

75. Moreover, in my opinion, a POSITA would not have sufficient reason to combine the references to achieve element [f]. As stated above, a POSITA would not have combined Villar with Choros because a POSITA would not have looked to

a reference disclosing a primitive manual method of measurement, like that in Choros, to modify a sophisticated machine vision system, like that in Villar.

ii. Combination of Szwilski with Villar and Choros

76. The Petition and Dr. Papanikolopoulos next rely on Szwilski as a potential source for element [f]'s requirements to contend that Szwilski's combination with Villar and Choros renders that element obvious. Petition at 50-52; Ex-1004, ¶¶84-87. They characterize Szwilski as "disclos[ing] a mobile track surveying and monitoring apparatus using image-capturing technology to obtain railroad track component position data" that also "[a]ccount[s] for vertical track inclination errors to accurately represent imaged railroad component position data when determining rails defects." Petition at 50; Ex-1004, ¶84. The Petition and Dr. Papanikolopoulos conclude that, "in light of Szwilski's teachings extending vertical tilt compensation corrections to 'other rail [] defects,'" "it would have been obvious … to implement *Villar* and *Choros*' automated RSA railroad track inspection system to account for vertical track inclination errors to accurately represent the imaged railroad component position data when determining whether a well-known 'rail [] defect[],' such as RSA, is present." Petition at 51-52; Ex-1004, ¶87.

77. In my opinion, however, the combination of Szwilski with Villar and Choros cannot render element [f] unpatentable because, like Casagrande, Szwilski does not disclose the requirements of that element. Szwilski discloses using two

GPS receivers on a mobile platform that travels on a railroad track, with one receiver mounted higher than the other, and both receivers vertically aligned over the same rail. Ex-1009 at 5-6, 10-12 & Fig. 3. Using a base station GPS receiver in conjunction with the two mobile receivers to create an overall "High Accuracy Differential Global Positioning System (HADGPS)," the position data received in each receiver allows for a calculation of the track inclination angle and the vertical and horizontal errors associated with that angle. *Id.* at 9, 5, 12, 16 & Fig. 3.

78. The Petition and Dr. Papanikolopoulos effectively admit that Szwilski does not disclose the use of a tilt correction to determine if rail seat abrasion is present (as element [f] requires), but instead expressly discloses only correcting for the vertical and horizontal errors in measuring "rail displacement." Petition at 51; Ex-1004, ¶86. They rely instead on Szwilski's general statement that these error corrections could also apply to "other rail … defects." Petition at 51; Ex-1004, ¶86; Ex-1009 at 20. The basis that the Petition provides for applying that disclosure to obtain element [f] is the statement from Dr. Papanikolopoulos' declaration stating that "it would have been obvious" to apply that correction mechanism to "RSA" because "[t]he combination would have yielded the claimed subject matter." Petition at 51-52; Ex-1004, ¶87. However, the statement is unsubstantiated because it provides no technical analysis or explanation.

79. Even if Szwilski's disclosure in this regard somehow suggests combining Szwilski with Villar and Choros, Szwilski nevertheless does not disclose element [f]. Element [f] is a step performed by "at least one processor" as part of "analyzing the at least one image" "of a profile of at least a portion of the rail road track" as recited in elements [b], [c], and [d]. Szwilski's determination of track inclination is based on the positions of its GPS receivers and calculations based on those positions, rather than based on any image, or profile in an image, of a railroad track. The Petition and Dr. Papanikolopoulos effectively acknowledge Szwilski's deficiency in this regard. *See* Petition at 52; Ex-1004, ¶88.

80. Another reason why the purported combination falls short is that Szwilski's measurements are unrelated to the position of the rail seats, and thus cannot be used to obtain element [f]. Szwilski's mobile platform rides on top of the rails, and its GPS receivers are attached to that platform. Ex-1009 at 1, 5-6, 10-12, 16-17, Fig. 1, 3. As a result, Szwilski's measurements are based on the location of the rail tops because, as the position of the tops changes or undulates (such as from rail wear), the position of the platform and the GPS receivers likewise move to mimic those changes. *See, e.g.*, Ex-1009 at 10-11, 16-17, Fig. 3. However, element [f] concerns determining abrasion relating to the "rail seat" or the bottom of the rail, and thus the relative position of the rail "seat," not the rail's top surface. *See, e.g.*, Ex-1001 at 15:38-39, 50-55, 12:64-14:6, Fig. 17. A change in the rail top's position

due to wear of the rail top will not translate to the rail seat because the rail seat abrades, and thus changes position, in its own distinct manner. Because Szwilski's vertical error and inclination measurements are based on the rail top rather than the rail seat, even if a POSITA would have combined Szwilski with Villar and Choros, element [f] would not have been attained because Szwilski has no application to determining or measuring rail seat abrasion or compensating for a tilt in the track in making that determination or measurement.

81. Moreover, a POSITA would not have looked to or implemented Szwilski to compensate for railroad track tilt in determining rail seat abrasion because Szwilski's system is far too inaccurate. Szwilski states that the GPS "position coordinate accuracies [that] can be achieved by [its] system" are "a vertical coordinate component of less than 2.5 cm" (less than 1 inch) and that the "average accuracies" include "2.2 cm (0.87 ins) vertical for platform velocities of 5, 10 and 15 mph." Ex-1009 at 6, 7. It further states that its "HADGPS coordinates" can only be "generated every 14.6 feet" if, for example, the mobile platform is moving "at 10 mph." *Id*. at 12.

82. In my opinion, it is readily apparent from this disclosure that a POSITA would have viewed Szwilski's system as useless for determining the presence of, or measuring, rail seat abrasion, including for compensating for track tilt in making such a determination or measurement. Rail seat abrasion is a measure of the vertical

distance or depth of abrasion into the top surface of a crosstie. Ex-1001 at Fig. 17; Ex-1007 at 9, 11-12, & Figs. 1, 3, 8); Ex-1012 at 7 (Fig. 4). The Federal Railroad Administration's rules mandate that crossties cannot be "[d]eteriorated or abraded at any point under the rail seat to a depth of ½ inch or more." Petition at 20; Ex-1041 at 1-2; Ex-1021 at 17 (46 C.F.R. §213.109(e)(4)). Also, Choros provides a table of "maximum abrasion[s]" that, depending on the class of track and rail wear, range from "2/16" to "11/16" inches (0.125 to 0.6875 inches). Ex-1007 at 14 (Table 2).

83. Szwilski's vertical error (*i.e.*, vertical distance or depth) of "less than" one inch and an "average" of 0.87 inches is far too inaccurate to determine rail seat abrasion under these standards. The error is significantly larger than the FRA's maximum allowed abrasion of 0.5 inches. It is also larger than all of Choros' disclosed "maximum abrasion[s]" of between 0.125 inches to 0.6875 inches. Thus, a POSITA would have viewed Szwilski's system as useless for measuring RSA or determining if RSA is present, let alone to apply Szwilski to compensate for track tilt.

84. In addition, crossties and the rail fasteners are spaced about 20 inches apart. Ex-1005, ¶[0004]. Because there is one rail seat between each rail and crosstie, a useful system for determining RSA thus must be able to measure vertical distance or depth at least every 20 inches. Because Szwilski is able to determine its coordinates (vertical and horizontal) only about every "14.6 feet," it obtains such

coordinates and measures vertical error only once over a span that includes roughly eight to nine crossties. The measurement thus takes place over about eight to nine rail seats on each rail or, in other words, a combined total of roughly sixteen to eighteen rail seats on both rails over the full track. Consequently, instead of providing the precise location of any vertical distance (or depth) measurement, or the appropriate place to apply a tilt correction, over a specific rail seat, Szwilski would at best identify and large area of track containing between about sixteen to eighteen rail seats. For this additional reason, in my opinion, a POSITA would have viewed Szwilski's system as useless to use for measuring RSA or determining if RSA is present, or for implementing Szwilski's system to compensate for track tilt as element [f] requires.

85. Another reason why a POSITA would not have looked to implement Szwilski with Villar and Choros in my opinion is that, as stated above, its measurements are unrelated to the position of the rail seats. Because Szwilski's vertical measurements and inclination measurements are based on the rail top rather than the rail seat, a POSITA would not have combined Szwilski with Villar and Choros to obtain element [f] because Szwilski has no application to determining rail seat abrasion. Finally, for the reasons stated above, a POSITA would not have combined Villar with Choros in the first instance, let alone add Szwilski to that combination.

iii. Combination of Villar, Choros, Casagrande, and Szwilski

86. The Petition and Dr. Papanikolopoulos finally rely on combining Casagrande and Szwilski with Villar and Choros to supposedly render element [f] unpatentable. Petition at 52-54; Ex-1004, ¶¶88-92. They essentially repeat their arguments on the combination of Casagrande, Villar, and Choros but then briefly mention Szwilski. Specifically, the Petition and Dr. Papanikolopoulos assert that Casagrande calculates "the 'vertical alignment' or tilt of the track" and, when combined with "*Villar* and *Choros*' automated RSA railroad track inspection system," it "would simply provide another track component defect" "to automatically identify and correct" and thus the combination would have been obvious. Petition at 52-54; Ex-1004, ¶¶89-91. The Petition and Dr. Papanikolopoulos then state only that, "[a]nd further to *Casagrande* and *Szwilski*'s teachings, when determining whether RSA is present," "*Villar*'s system would compensate the RSA measurement for any vertical alignment error." Petition at 54; Ex-1004, ¶91.

87. In support, the Petition and Dr. Papanikolopoulos include a figure labeled "*Choros*, FIG. 8 (annotated)" (Petition at 54; Ex-1004, ¶91), but that figure is not in Choros. The illustration is taken from Choros' Figure 8 but then "annotated" with extra imagined features from Villar, Casagrande, and Szwilski.

88. In my opinion, even if a POSITA had sufficient reason to combine the references, the combination of Villar, Choros, Casagrande, and Szwilski lacks element [f]'s features. As set forth above, neither Casagrande nor Szwilski disclose or suggest any capability for making measurements relating to the rail seats, and thus both are incapable of compensating for a tilt in the railroad track in making that determination, as element [f] requires. As further described above, even putting aside their lack of ability to make RSA-related measurements, Casagrande is incapable of detecting, measuring, or adjusting for rail tilt for any railroad track measurement, and Szwilski's rail tilt measurement not only does not relate to and cannot be applied to rail seat measurements, but Szwilski's tilt measurement is also far too wildly inaccurate to apply to compensate for tilt in any rail seat measurement. Accordingly, in my opinion, even if a POSITA had sufficient reason to combine the four references, the claimed invention would not have been achieved. The Petition and Dr. Papanikolopoulos refer to nothing in the references, or otherwise provide a sufficient reason, demonstrating why a POSITA would have further modified the combined references to include element [f]'s requirements. Further, in my opinion, a POSITA would not have combined Villar and/or Casagrande with Choros and/or Szwilski for the reasons stated above.

2. Claim 2

89. The Petition and the Papanikolopoulos Declaration assert that of claim 2 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 54-56; Ex-1004, ¶¶93-100.

90. In my opinion claim 2 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Claim 2 depends on claim 1. Because claim 1 is patentable for the reasons stated above, claim 2 is patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claim elements 2[a] through 2[e] are unpatentable relies on their reasoning why claim elements 1[e] and/or 1[f] are unpatentable. Petition at 54-56; Ex-1004, ¶¶93-100. As stated above, those arguments fail.

91. Further, contrary to the Petition's and Dr. Papanikolopoulos' argument, Villar, Choros, Casagrande, and Szwilski do not disclose or suggest claim 2 for another reason. None of the references disclose or suggest the use of any "tilt correction factor" or an "actual delta" for the rail bases, as elements [c] and [d] of claim 2 require. In fact, the Petition and Dr. Papanikolopoulos do not allege any of the references disclose or suggest "determining a tilt correction factor." Petition at 55; Ex-1004, ¶95. Specifically, neither Casagrande nor Szwilski (the references on which the Petition and Dr. Papanikolopoulos rely for tilt compensation) use those terms or any similar term, or disclose or suggest the application of any similar

concept. *See* Ex-1008; Ex-1009. Accordingly, claim 2 would not have been obvious based on the combination of Villar, Choros, Casagrande, and Szwilski.

3. Claim 5

92. The Petition and the Papanikolopoulos Declaration assert that of claim 5 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 57-58; Ex-1004, ¶¶101-103.

93. In my opinion claim 5 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Claim 5 depends on claim 2, which depends on claim 1. Because claims 1 and 2 are patentable for the reasons stated above, claim 5 is patentable.

94. Further, contrary to the Petition's and Dr. Papanikolopoulos' argument (Petition at 57-58; Ex-1004, ¶¶101-103), Villar, Choros, Casagrande, and Szwilski do not disclose or suggest claim 5 for an additional reason. Claim 5 requires that "the step of determining the actual delta is accomplished based upon the tilt correction factor." As stated above relating to claim 2, none of the references disclose or suggest the use of any "tilt correction factor" or an "actual delta" for the rail bases. They likewise do not disclose or suggest using the tilt correction factor to determine the actual delta or the application of any similar concept. Accordingly, claim 5 would not have been obvious based on the combination of Villar, Choros, Casagrande, and Szwilski

4. Claim 6

95. The Petition and the Papanikolopoulos Declaration assert that of claim 6 would have been obvious based on Villar, Choros, and Casagrande. Petition at 58; Ex-1004, ¶104.

96. In my opinion claim 6 would not have been obvious based on Villar, Choros, and Casagrande. Claim 6 depends on claim 2, which depends on claim 1. Because claims 1 and 2 are patentable for the reasons stated above, claim 6 is patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claim 6 is unpatentable relies on their reasoning why claim element 2[e] is unpatentable. Petition at 58; Ex-1004, ¶104. That reasoning fails for the reasons stated above.

5. Claim 7

97. The Petition and the Papanikolopoulos Declaration assert that of claim 7 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 59-60; Ex-1004, ¶¶105-107.

98. In my opinion claim 7 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Contrary to the Petition's and Dr. Papanikolopoulos' argument (Petition at 59-60; Ex-1004, ¶¶105-107), the combination of Villar, Choros, Casagrande, and Szwilski do not disclose or suggest claim 7. Regarding all elements except element [b], the Petition and Dr. Papanikolopoulos rely on their reasoning why those references purportedly

disclosed the elements of claims 1 and 2. Petition at 59; Ex-1004, ¶105. That reasoning fails for the reasons stated above.

6. Claims 10 and 11

99. The Petition and the Papanikolopoulos Declaration assert that of claims 10 and 11 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 60-61; Ex-1004, ¶¶108-109.

100. In my opinion claims 10 and 11 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Claims 10-11 depend on claim 7. Because claim 7 is patentable as stated above, claims 10-11 are patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claims 10 and 11 are unpatentable relies on their reasoning why claim 5 and claims 1 and 5 are unpatentable, respectively. Petition at 60-61; Ex-1004, ¶¶108-109. As stated above, those arguments fail.

7. Claim 12

101. The Petition and the Papanikolopoulos Declaration assert that of claim 12 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 61-62; Ex-1004, ¶¶110-115.

102. In my opinion claim 12 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Contrary to the Petition's and Dr. Papanikolopoulos' argument (Petition at 61-62; Ex-1004, ¶¶110-115), the

combination of Villar, Choros, Casagrande, and Szwilski do not disclose or suggest claim 12. Regarding the preamble and elements [a]-[e] of claim 12, the Petition and Dr. Papanikolopoulos rely on their reasoning why those references purportedly disclose the same elements of the preamble and elements [b], [e], and [f] of claim 1. *Id.* That reasoning fails for the reasons stated above.

8. Claims 13, 16, and 17

103. The Petition and the Papanikolopoulos Declaration assert that of claims 13, 16, and 17 would have been obvious based on Villar, Choros, Casagrande, and Szwilski. Petition at 62-63; Ex-1004, ¶¶116-118.

104. In my opinion claims 13, 16, and 17 would not have been obvious based on Villar, Choros, Casagrande, and Szwilski. Claim 13 depends on claim 12 and claims 16-17 depend on claim 13. Because claim 12 is patentable as stated above, claims 13, 16, and 17 are patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claims 13, 16, and 17 are unpatentable relies on their reasoning why claims 1-2, claim 5, and claim 6 are unpatentable, respectively. Petition at 62-63; Ex-1004, ¶¶116-118. As stated above, those arguments fail.

D. Patentability of Claims 3, 8, and 14 of the '320 Patent Over Villar, Choros, Casagrande, Szwilski, and Khattak

105. The Petition and the Papanikolopoulos Declaration assert that of claims 3, 8, and 14 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak. Petition at 64-73; Ex-1004, ¶¶119-133.

106. In my opinion claims 3, 8, and 14 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak for the reasons stated in detail below.

1. Claim 3

107. The Petition and the Papanikolopoulos Declaration assert that of claim 3 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak. Petition at 64-72; Ex-1004, ¶¶119-131.

108. In my opinion claim 3 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak. Claim 3 depends on claim 2. Because claim 2 is patentable for the reasons stated above, claim 3 is patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claim 3 is unpatentable relies on their reasoning why claim elements 1[f] and claim 2 are unpatentable. Petition at 64; Ex-1004, ¶119. As stated above, those arguments fail.

109. In addition, contrary to the Petition's and Dr. Papanikolopoulos' argument (Petition at 64-72; Ex-1004, ¶¶119-131), Villar, Choros, Casagrande, Szwilski, and Khattak do not disclose or suggest claim 3. Claim 3 recites, among other things, "determining vertical pixel counts for each of the heights of the left rail base, right rail base, left crosstie and right crosstie." Ex-1001 at 16:1-3. The Petition and Dr. Papanikolopoulos assert that "it would have been obvious" to a POSITA "to implement Villar's system to identify and assess the rail base and crosstie top surface

height contours via contour line-fitting and orientation comparison algorithms by determining the left and right rail base and crosstie heights by determining and comparing vertical pixel counts in the image for the left and right rail base heights" "and left and right crosstie heights." Petition at 66-67; Ex-1004, ¶123.

110. However, Villar does not disclose determining the vertical pixel counts for determining any height measurement. The only use of pixel summing disclosed in Villar is averaging or summing the value of pixels in an entire region of interest to determine the presence of a crosstie. The reason for that summing is that the contour of a crosstie is composed of dark pixels and a frame that includes a crosstie will have a greater average or sum of pixels than a frame that does not include a crosstie. Ex-1005 at ¶[0046]. This teaching dramatically differs from determining vertical pixel counts to determine a height as recited by claim 3.

111. As support for their contention, the Petition and Dr. Papanikolopoulos cite paragraphs [0047], [0050], [0052], and [0055] of Villar. Petition at 64-67; Ex-1004, ¶¶119-123. They assert that, in these paragraphs, "Villar discloses determining the distance in pixels" "between a contour of a rail" and "a tie plate" and "determining a height in pixels" "of ballast" "relative to [a] crosstie." Petition at 65-66; Ex-1004, ¶¶121-122. However, the cited paragraphs of Villar do not mention the term "pixel," let alone the counting of pixels or using pixel counts for determining either these or other height measurements. Ex-1005 at ¶¶[0047],

[0050], [0052], [0055]. Rather, these portions of Villar discuss using best fit or curve fitting techniques, edge detecting techniques, and line fitting techniques to determine the distances or heights involved. *Id.*

112. The Petition and Dr. Papanikolopoulos appear to recognize this shortcoming elsewhere in the Petition and the Papanikolopoulos Declaration. They allege that claim 3 would have been obvious because Villar discloses "determining … track heights of the left rail base, right rail base, left crosstie and right crosstie via well-known machine vision contour line-fitting and orientation comparison algorithms," and then they add that "[s]uch algorithms would necessarily include determining vertical pixel counts for each rail base and crosstie top surface heights." Petition at 64; Ex-1004, ¶119. The Petition and Dr. Papanikolopoulos cite no support for this allegation other than the paragraphs from Villar discussed above, and that contain no such disclosure. Moreover, contrary to the Petition's and Dr. Papanikolopoulos' allegations, algorithms using the various techniques Villar discloses—curve fitting, edge detecting, and line fitting—do not necessarily include determining vertical pixel counts. This is evidenced by the fact that the Petition and Dr. Papanikolopoulos fail to reference a single instance where Villar discloses determining vertical pixel counts to determine a height. *See* Petition 64-67; Ex-1004, ¶¶119-123. Accordingly, claim 3 would not have been obvious based on the combination of Villar, Choros, Casagrande, Szwilski, and Khattak.

2. Claims 8 and 14

113. The Petition and the Papanikolopoulos Declaration assert that of claims 8 and 14 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak. Petition at 72-73; Ex-1004, ¶¶132-133.

114. In my opinion claims 8 and 14 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Khattak. Claim 8 depends on claim 7, while claim 14 depends on claim 13 (which depends on claim 12). Because claims 7, 12, and 13 are patentable for the reasons stated above, claims 8 and 14 are patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claims 8 and 14 are unpatentable relies on their reasoning why claim 3 is unpatentable. Petition at 72-73; Ex-1004, ¶¶132-133. As stated above, that argument fails.

E. Patentability of Claims 4, 9, and 15 of the '320 Patent Over Villar, Choros, Casagrande, Szwilski, and Andersson

115. The Petition and the Papanikolopoulos Declaration assert that of claims 4, 9, and 15 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson. Petition at 73-76; Ex-1004, ¶¶134-138.

116. In my opinion claims 4, 9, and 15 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson for the reasons stated in detail below.

1. Claim 4

117. The Petition and the Papanikolopoulos Declaration assert that of claim 4 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson. Petition at 73-75; Ex-1004, ¶¶134-136.

118. In my opinion claim 4 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson. Claim 4 depends on claim 2. Because claim 2 is patentable for the reasons stated above, claim 4 is patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claim 4 is unpatentable relies on its reasoning why claim elements 1[d] and [e] and claim 2 are unpatentable. Petition at 73-74; Ex-1004, ¶134. As stated above, those arguments fail.

119. In addition, contrary to the Petition's and Dr. Papanikolopoulos' argument (Petition at 73-75; Ex-1004, ¶¶134-136), Villar, Choros, Casagrande, Szwilski, and Andersson do not disclose or suggest claim 4. Claim 4 adds the requirement "wherein the step of determining the tilt correction factor is accomplished based upon the left and right rail base heights and a standard tilt correction factor."

120. The "standard tilt correction factor" in claim 4 is a factor distinct from the "tilt correction factor" in claim 2. By using different wording to label each "factor," the plain claim language demonstrates that fact. The specification

reinforces that conclusion. With reference to the embodiment in Figure 17, it states that "the tilt correction factor (TC)" is "based upon the" "equation: $TC=(H^{Lrail}-H^{Rrail})$." Ex-1001 at 13:45-49. In other words, the tilt correction factor in that example is the difference measured between the left and right rail base heights due to a tilt in the railway. *See* Fig. 17. Regarding the "standard tilt correction factor," the specification states:

> [D]uring significant empirical and mathematical research for the present invention, a standard tilt correction factor of 0.12 was determined. This tilt correction factor is incorporated into algorithms of the present invention in order to adjust for tilt caused by variations in vehicle suspension, rail height placement standards, and other factors unrelated to rail seat abrasion.

Ex-1001 at 13:11-17.

121. Unlike the "tilt correction factor," the "standard tilt correction factor" is not merely based on the simple error in vertical height measurements based on tilt of the railway, but instead factors in "variations in vehicle suspension" and "rail height placement standards," among other "factors unrelated to rail seat abrasion." Accordingly, claim 4 at a minimum requires the use of another factor, one that is distinct from the "tilt correction factor" required by claim 2, and thus compensates for the tilting not caused by a tilt in the railway. Also, because it is a "standard"

factor, and stated to be a fixed number ("0.12") in the specification, the factor is a fixed factor applied to all curves and other parts of the railway.

122. The Petition and Dr. Papanikolopoulos allege that it "would have been obvious to one of ordinary skill in the art to implement a standard tilt correction factor to pre-emptively compensate imaged measurements for such vertical alignment tilt errors through use of a standard tilt correction factor, as evidenced by, e.g., *Andersson*." Petition at 74 (emphasis original); Ex-1004, ¶134; *see* Petition at 75; Ex-1004, ¶136. However, Andersson does not disclose a standard tilt correction factor, let alone one distinct from a tilt correction factor. Andersson discloses measuring the tilt of a rail car body as it travels through curves along a portion of railroad track, storing the tilt measurements made on every pass through each curve, and using the individual stored measurements to compensate for the tilt of the rail car body in a subsequent pass through each of the individual measured curves. Ex-1011 at 3:45–6:18. Andersson discloses a database of individual tilt corrections, one for each curve, along a section of track rather than a standard tilt correction factor that is applied to every curve.

123. The Petition and Dr. Papanikolopoulos recognize that "*Andersson* discloses a control system that uses a stored tilt correction factor associated with a track curve to tilt a train car body in real-time when the train passes through the track curve." Petition at 74; Ex-1004, ¶135. Indeed, Andersson states that "[d]ata about

the geometry of each curve track along a route are stored in the train computer in a database in the form of sampled values for the track curvature and the rail superelevation angle for each track curve." Ex-1011 at 4:1-4. If the system of Andersson used a standard tilt correction factor, it would not need to store data about the geometry of each curve along a route in a database. *See* Ex-1011 at 4:1-4.

124. Further, Andersson teaches that it calculates an "angular value" that is "multiplied" "by a compensation factor which possibly may vary with the speed of the train through the curve." Ex-1011 at 6:38-41. As is evident from the '320 patent's disclosure, the standard tilt correction factor is a fixed number, rather than a variable number that changes from curve to curve, because it adjusts for tilt caused, for example, by variations in vehicle suspension, rail height placement standards, and other factors unrelated to rail seat abrasion, rather than adjusting for the tilt of each individual curve. *See* Ex-1001 at 13:11-17. Thus, Andersson does not disclose use of a standard tilt correction factor, but a stored tilt correction factor that varies for each individual curve. Accordingly, Andersson's disclosure cannot render claim 4 unpatentable.

125. Finally, in my opinion, a POSITA would not look to Andersson to further modify the combination alleged by Petitioner of Villar, Choros, Casagrande, and Szwilski. Claim 4 requires use of both the "tilt correction factor" recited in claim 2 and the separate "standard tilt correction factor" recited in claim 4.

Assuming that, as Petitioner asserts, Casagrande and/or Szwilski combined with Villar and Choros would detect the tilt of the railroad track and compensate for that measured tilt to more accurately determine rail seat abrasion, a POSITA would not add the feature disclosed in Andersson to that combination. Because Andersson measures and stores the tilt in each curve, that measured tilt, and any compensation based on that tilt, includes any tilting in the railway caused by uneven heights of the rails, rail seat abrasion, and other physical conditions in the railway that, based on Petitioner's contention, the systems used in Casagrande and/or Szwilski measure and/or use as compensation for tilt as well. The additional use of the compensation employed by Andersson would thus act to overcompensate for all these other overlapping factors that cause any tilting in the railway, such as those caused by uneven heights of the rails, rail seat abrasion, or other physical conditions in the railway.

2. <u>Claims 9 and 15</u>

126. The Petition and the Papanikolopoulos Declaration assert that of claims 9 and 15 would have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson. Petition at 76; Ex-1004, ¶¶137-138.

127. In my opinion claims 9 and 15 would not have been obvious based on Villar, Choros, Casagrande, Szwilski, and Andersson. Claim 9 depends on claim 7, while claim 15 depends on claim 13 (which depends on claim 12). Because claims

7, 12, and 13 are patentable for the reasons stated above, claims 9 and 15 are patentable. Further, the Petition's and Dr. Papanikolopoulos' argument that claims 9 and 15 are unpatentable relies on their reasoning why claim 4 is unpatentable. Petition at 76; Ex-1004, ¶¶137-138. As stated above, that argument fails.

VIII. CONCLUSION

128. For the reasons stated above, it is my opinion that claims 1-17 of the '320 patent are not rendered obvious by the prior art references cited, or for the reasons stated, in the Petition or the Papanikolopoulos Declaration.

IX. DECLARATION

129. I declare that all statements made in this declaration of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements have been 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.

130. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on this 14TH day of May 2020.

Alan Conrad Bovik, Ph.D.