

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MOBILEYE GLOBAL, INC.,
Petitioner

v.

MANDLI COMMUNICATIONS, INC.,
Patent Owner

IPR2024-01111
U.S. Patent No. 9,671,328 B2

**DECLARATION OF NIKOLAOS PAPANIKOLOPOULOS, PH.D.
IN SUPPORT OF PATENT OWNER'S RESPONSE**

TABLE OF CONTENTS

I.	INTRODUCTION	4
II.	BACKGROUND AND QUALIFICATIONS	5
III.	COMPENSATION	10
IV.	MATERIALS CONSIDERED	11
V.	UNDERSTANDING OF LEGAL PRINCIPLES	13
A.	Claim Construction	13
B.	Invalidity Based on Prior Art	14
1.	Prior Art	14
2.	Anticipation.....	17
3.	Obviousness	19
VI.	LEVEL OF ORDINARY SKILL IN THE ART	23
VII.	BACKGROUND OF THE ‘328 PATENT	24
VIII.	OVERVIEW OF THE CITED PRIOR ART	26
A.	U.S. Patent Application Publication No. 2002/0063638 to Gallagher (“Gallagher”, Ex. 1005).....	26
B.	U.S. Patent No. 5,796,094 to Schofield et al. (“Schofield”, Ex. 1006).....	29
C.	U.S. Patent No. 5,313,262 to Leonard (“Leonard”, Ex. 1009).	32
D.	U.S. Patent No. 5,202,742 to Frank (“Frank”, Ex. 1007)	32
E.	WO9617258A2 to Popovich (“Popovich”, Ex. 1010).	34
IX.	CLAIM CONSTRUCTION	34
A.	“configured to detect objects of interest within the field of view and for each object of interest ... determine whether the object of interest includes a reflective surface [and] ... determine whether the reflective surface is a road marker” (‘328 Patent, cl. 1) / “configured to detect objects of interest within the field of view and for each object of interest: determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view” (‘328 Patent, cl. 9).....	34

X.	THE REMAINING CHALLENGED CLAIMS OF THE '328 PATENT ARE NOT ANTICIPATED AND ARE NOT RENDERED OBVIOUS	45
A.	Ground 2: Claims 1-4 and 8-13 of the '328 Patent Are Not Rendered Obvious by Gallagher and Schofield	45
1.	A POSITA Would Not be Motivated to Combine the Teachings of Gallagher and Schofield in the Manner Claimed	46
2.	Claim 9	51
3.	Claims 10-13	58
4.	Claim 1	58
5.	Claims 2-4 and 8	62
B.	Ground 2: Claims 15-16 of the '328 Patent Are Not Rendered Obvious by Gallagher, Schofield, and Frank	62
1.	A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, and Frank in the Manner Claimed	63
2.	Claim 15: The proposed combination does not disclose or suggest “the computer processing system is further configured to determine exemplary angular displacements of incident light for each light intensity measurement from a reference position relative to the field of view as part of the assessment of the discrete location of the road marker within the field of view.”	66
3.	Claim 16:	71
C.	Ground 3: Claim 14 of the '328 Patent Is Not Rendered Obvious by Gallagher, Schofield, Frank and ASTM	71
1.	A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, Frank and ASTM in the Manner Claimed	72
2.	Claim 14: The cited prior art does not disclose or suggest “the computer processing system is further configured to determine an entrance angle”	73
D.	Ground 4: Claims 5-7 of the '328 Patent Are Not Rendered Obvious by Gallagher, Schofield, Leonard, and Popovich	76
1.	Popovich is Not Analogous Art	77
2.	A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, Leonard, and Popovich in the Manner Claimed	80

3.	Claim 5: The Cited Prior Art Does Not Disclose or Suggest “comparing the light vector to one of a plurality of predetermined vectors based on a light source angle characterization”	83
4.	Claim 5: Petitioner improperly combines the incompatible disclosures of distinct embodiments of Popovich without explanation or a motivation to combine	85
XI.	CONCLUSION.....	87

I, Nikolaos Papanikolopoulos, of Minneapolis, Minnesota, declare that:

I. INTRODUCTION

1. I have been retained by Patent Owner Facet Technology Corp. (“Patent Owner” or “Facet”) in this *inter partes* review proceeding number IPR2024-01111 (“IPR”), filed by Petitioner Mobileye Global, Inc. (“Mobileye” or “Petitioner”). I understand that this IPR proceeding involves U.S. Patent No. 9,671,328 (the ’328 patent) and that the remaining challenged claims are claims 1-16 (the “Challenged Claims”).

2. I have been asked to provide my objective, independent analysis of the ’328 patent in view of the asserted prior art references cited in the Petition and to provide my opinion regarding the allegations in the Petition, as well as the supporting opinions of Dr. Charles Thorpe.

3. I have based my opinions on the information available to me as of the date of this declaration. I understand that additional information may become available after this declaration is submitted. If I become aware of additional information following my submission of this declaration I may, if I am permitted, offer additional opinions (including by amending and/or supplementing this declaration) taking into account such new information.

4. I am not currently, nor have I ever been, an employee of Facet. I received no compensation for this declaration beyond my normal hourly

compensation based on my time actually spent working on this IPR. I will not receive any added compensation based on the outcome of this IPR, any other IPR, or any other proceeding involving the '328 patent.

II. BACKGROUND AND QUALIFICATIONS

5. My qualifications are most accurately reflected in my curriculum vitae, which is Exhibit 2024. The following is a brief summary of some of my relevant experience and qualifications.

6. I am the McKnight Presidential Endowed Professor and Distinguished McKnight University Professor in the Department of Computer Science and Engineering of the University of Minnesota in Minneapolis, Minnesota. I am also the Director for the Minnesota Robotics Institute.

7. I have been a professor at the University of Minnesota (originally as an assistant professor, and then as an associate professor) since the Fall 1992. Between Fall 2001 and Spring 2004, and between Fall 2010 and Spring 2013, I was the Director of Undergraduate Studies of the Department of Computer Science and Engineering.

8. In 1992, I received my Ph.D. in Electrical and Computer Engineering from Carnegie Mellon University. My thesis was entitled "Controlled Active Vision" and focused on using computer vision in a controlled fashion to detect, track, and manipulate objects in the environment. In 1988, I also received my M.S. in

Electrical and Computer Engineering from Carnegie Mellon University. My B.S. in Electrical Engineering was received in 1987 from the National Technical University in Athens, Greece.

9. For over thirty years, my research and teaching work has focused on image processing, computer vision, intelligent transportation systems, and robotics. This research has included detection and tracking of humans and objects such as faces using information from stationary or moving cameras. It has also included main object detection and recognition including work with artificial intelligence and pattern recognition systems for surveillance applications.

10. I currently teach or have been teaching three courses related to image processing and computer vision: (i) CSci 5561 Computer Vision, (ii) CSci 5511 Artificial Intelligence, and (iii) CSci 5551 Introduction to Intelligent Robotic Systems. In particular, I have been teaching the class in Computer Vision since 1992.

11. I am currently serving as a Senior Editor in the IEEE Transactions on Intelligent Transportation Systems with responsibility in the area of imaging. I was Associate Editor in the same journal for twelve years.

12. I have received research grants for various projects involving computer vision and image processing as applied to medicine and surveillance, including face detection and tracking of humans. My industrial experience includes founding a robotics company in 2005 named ReconRobotics Inc. that develops different robotic

platforms. I have also been a consultant since 1997 for numerous companies and provided technical expertise in developing computer vision algorithms for human tracking, object recognition, fingerprint recognition, vehicle tracking, camera calibration, inspection, and precision agriculture. In one of my consulting assignments, I had to develop computer vision algorithms for inspection of industrial parts by using different illumination sources (Banner Engineering). I have licensed my algorithms to several industries with the most recent one being Sentra Inc., which is using image processing and image segmentation for precision agriculture.

13. My research has produced more than 380 journal and conference publications. More than 90 publications are in refereed journals including top journals in imaging such as IEEE Trans. on Pattern Analysis and Machine Intelligence, IEEE Trans. on Image Processing, and International Journal of Computer Vision. Many of my publications and research grants relate to human detection and tracking systems. Some examples include:

- Walczak, N., Fasching, J., Cullen, K., Morellas, V., and Papanikolopoulos, N.P., “Toward Identifying Behavioral Risk Markers for Mental Health Disorders: An Assistive System for Monitoring Children’s Movements in a Preschool Classroom,” Machine Vision and Applications, Volume 29, No. 4, May 2018, PP. 703-717.
- Cook, D., Morris, T., Morellas, V., and Papanikolopoulos, N., “An Automated System for Persistent Real-Time Truck Parking Detection and Information

Dissemination,” Proceedings of the 2014 IEEE Int. Conference on Robotics and Automation, Hong Kong, China, May 31 – June 7, 2014, PP. 3989-3994.

- Somasundaram, G., Sivalingam, R., Morellas, V., and Papanikolopoulos, N.P., “Classification and Counting of Composite Objects in Traffic Scenes Using Global and Local Image Analysis”, IEEE Trans. on Intelligent Transportation Systems, Volume 14, No. 1, March 2013, PP. 69-81.
- Veeraraghavan, H., Atev, S., Bird, N., Schrater, P., and Papanikolopoulos, N., “Driver Activity Monitoring through Supervised and Unsupervised Learning,” Proceedings of the IEEE 8th Int. Conf. on Intelligent Transportation Systems (ITSC 2005), PP. 895-900, Vienna, Austria, September, 2005.
- Wahlstrom, E., Masoud, O., and Papanikolopoulos, N., “Vision-based Methods for Driver Monitoring,” Proceedings of the IEEE 6th Int. Conf. on Intelligent Transportation Systems (ITSC 2003), PP. 903-908, Shanghai, China, October 12-15, 2003.
- Masoud, O., and Papanikolopoulos, N.P., “A Novel Method for Tracking and Counting Pedestrians in Real-time Using a Single Camera,” IEEE Trans. on Vehicular Technology, Volume 50, No. 5, September 2001, PP. 1267-1278.
- Singh, S., and Papanikolopoulos, N. P., “Monitoring Driver Fatigue Using Facial Analysis Techniques,” Proceedings of the 1999 IEEE/IEEEJ/JSAP International Conference on Intelligent Transportation Systems, PP. 314- 318, Tokyo, Japan, October 5-8, 1999.

14. My work in vehicle detection and tracking has focused on using image and video processing techniques, including object detection, tracking, and recognition, to accurately track vehicles in real-time. These algorithms have been

applied to different scenarios, such as urban traffic monitoring and surveillance. Moreover, machine learning techniques have helped in the improvement of these methodologies.

15. My paper “Detection and Classification of Vehicles,” published in the IEEE Transactions on Intelligent Transportation Systems in March 2002, is one of the most cited papers in the history of this journal (more than one-thousand citations). The paper, among other contributions, shows how to segment the main object from videos and images in low-light conditions. I also have nine patents in pertinent areas. One of them is the “Crowd Counting and Monitoring” with P. Kilambi and O. Masoud. It discloses a system and method for accurately estimating the number of people in a crowded area and monitoring their behavior. The invention utilizes computer vision techniques and machine learning algorithms to analyze video feeds from cameras overlooking the target area. It employs techniques such as background subtraction, main object detection, and tracking to identify individual people within the crowd.

16. Our research work has been funded by several government funding agencies. For example, we have received funding from the Department of Homeland Security to monitor threats at Mass Transit Sites like the 30th Street Station in Philadelphia, PA, and the Light Rail Station in the Minneapolis-Saint Paul

International Airport. Tracking humans was an essential task for which we developed a variety of image processing algorithms and tools.

17. I have received numerous honors and awards for my research and contributions. I have been a Distinguished McKnight University Professor at the University of Minnesota since 2007 and have been a McKnight Presidential Endowed Professor in Computer Science since 2016. Also in 2007, I was nominated and became an IEEE Fellow. In 2016, I received the IEEE RAS George Saridis Leadership Award in Robotics and Automation as well as the Center for Transportation Studies Research Partnership Award. I have also received the IEEE VTS 2001 Best Land Transportation Paper Award for the paper “A Novel Method for Tracking and Counting Pedestrians in Real-Time Using a Single Camera” (with Osama Masoud).

18. As a result of my work and research, I am familiar with the design, operation, and functionality of systems such as those described in the '328 patent.

III. COMPENSATION

19. I am being compensated as an expert witness in this case at my standard hourly rate in addition to out-of-pocket expenses. I have received no additional compensation for my work on this matter and my compensation does not depend, and has not ever depended in any way, on my opinion as expressed in this matter, in any testimony that I may give, or on the outcome of this matter. I am not and have

never been employed by Facet. I have no financial stake in Facet, the '328 Patent, or the outcome of this IPR or any other matter involving the '328 Patent.

IV. MATERIALS CONSIDERED

20. In formulating my opinions, I have relied upon my training, knowledge and experience that are relevant to the '328 Patent. I have also considered the '328 Patent and its file history, the Petition ("Pet.") and attached exhibits, the Patent Owner preliminary response, Petitioner's preliminary reply, Patent Owner's preliminary surreply, the Board's decision on institution, Patent Owner's director review request, Petitioner's response to Patent Owner's director review request, the asserted prior art references, the declaration of Dr. Thorpe and the materials cited therein, and the deposition transcripts of Dr. Thorpe in this IPR and co-pending IPR IPR2024-01111. In addition to the materials cited elsewhere in this declaration, I have also considered the following:

Exhibit No.	Description
2003	U.S. Provisional Patent Appl. No. 60/296,596
2025	Transcript of Deposition of Dr. Thorpe, taken in IPR2024-01110 on May 30, 2025
2026	Transcript of Deposition of Dr. Thorpe, taken in IPR2024-01111 on May 29, 2025
2027	Definition of "photodiode," A Dictionary of Physics, Oxford University Press. (6 ed.) <i>available at</i> , https://www.oxfordreference.com/display/10.1093/oi/authority.20110803100324432?p=emailAIVd1F/alp5o2&d=/10.1093/oi/authority.20110803100324432&print

2028	National Institute of Standards and Technology, OSAC Lexicon, Definition of “Lux,” <i>available</i> at https://www.nist.gov/glossary-term/26871
2029	Fiorentin, P. & Iacomussi, Paola & Rossi, Giuseppe. (2005). Characterization and Calibration of a CCD Detector for Light Engineering. Instrumentation and Measurement, IEEE Transactions on. 54. 171 - 177. 10.1109/TIM.2004.834055., <i>available</i> at https://www.researchgate.net/publication/3090945_Characterization_and_Calibration_of_a_CCD_Detector_for_Light_Engineering
2030	U.S. Patent No. 6,266,442 to Laumeyer et al.
2031	Thorpe, Chuck, et al. "Dependable perception for robots." (2001). https://kilthub.cmu.edu/articles/journal_contribution/Dependable_Peception_for_Robots/6552518/1/files/12033863.pdf
2032	Nov. 5, 2024 NHTSA Investigation Notice of Tesla, <i>available</i> at https://static.nhtsa.gov/odi/inv/2024/INIM-PE24031-27346.pdf

21. In particular, I have reviewed Patent Owner Exhibit Nos. 2027-2029 and 2031-2032. As noted above, each of those exhibits are publications or web pages. Based on my review I believe each of those exhibits to be genuine copies of what they are identified in the above chart. As to each of the journal articles or book publications, they appear to be authentic because they are formatted and written consistently with genuine publications based on my experience reviewing similar publications. For each of those exhibits which are printouts from a website, I have confirmed that they accurately reflect what is on the website.

V. UNDERSTANDING OF LEGAL PRINCIPLES

22. I am not an attorney. I have been asked to provide opinions on the validity of the Asserted Claims of the Patents-in-Suit from the perspective of a POSITA.

A. Claim Construction

23. I have been provided certain legal principles relating to the construction of patent claims. I understand that “claim construction” is the interpretation of the meaning of patent claims. I understand that words of a claim are generally given their ordinary and customary meaning, which is the meaning the term or phrase would have to a person of ordinary skill in the art at the time of the invention. I understand that both intrinsic and extrinsic evidence can be used to assist in understanding the meaning of a claim. Intrinsic evidence includes the claim language, language in other claims of the patent, the specification, and the prosecution record. I further understand that, unless required by the claim language or specification, claims should generally not be limited to embodiments in the specification, including preferred embodiments. I understand that extrinsic evidence, which consists of all evidence external to the patent and prosecution history including expert and inventor testimony, dictionaries, and learned treatises, may also be relevant to claim construction.

B. Invalidity Based on Prior Art

24. I understand that each claim of an issued patent is presumed to be valid.

I understand that a party challenging the validity of a patent claim in an IPR must present a preponderance of the evidence to demonstrate validity.

1. Prior Art

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

26. I understand that a U.S. or foreign patent qualifies as prior art to an asserted patent if the date of issuance of the patent is prior to the invention of the asserted patent. I further understand that a printed publication, such as an article published in a magazine, academic journal, conference proceedings, or trade publication, or U.S. or foreign published patent application qualifies as prior art to an asserted patent if the date of publication is prior to the invention of the asserted patent.

27. I understand that a U.S. or foreign patent qualifies as prior art to an asserted patent if the date of issuance of the patent is more than one year before the priority date of the asserted patent. I further understand that a printed publication, such as an article published in a magazine, academic journal, conference proceedings, or trade publication, or U.S. or foreign published patent application

constitutes prior art to an asserted patent if the publication occurs more than one year before the priority date of the asserted patent.

28. I understand that, absent an assertion by the patentee otherwise, the date of invention is the filing date of the patent. I understand that a U.S. patent qualifies as prior art to the asserted patent if the application for that patent was filed in the United States before the invention of the asserted patent.

29. I understand that a system or device qualifies as prior art to the asserted patent if it was known or used in the United States prior to the invention of the asserted patent. I further understand that a system or device qualifies as prior art to the asserted patent if it was in public use or on sale in the United States more than one year prior to the priority date of the asserted patent.

30. I understand that if a device was used by others in this country before the date of the invention, or if it was in public use in this country more than one year before the effective date of application, the device qualifies as prior art. I understand that, under either scenario, for a non-patentee's use to qualify as prior art, the purported use must have been available to the public. I understand that the following factors may be helpful in analyzing whether there was a public use: (1) the nature of the activity that occurred in public; (2) the public access to and knowledge of the public use; and (3) whether there was any confidentiality obligation imposed on persons who observed the use. I further understand that where a non-patentee's

public use puts all the claimed features of an invention in the public's possession, this cannot be negated by evidence that other, unclaimed aspects of the non-patentee's device were not publicly available. Conversely, I understand that for a non-patentee's uses to constitute prior art, that use must have placed each of the claimed features of an invention in the public's possession. And, I understand that a non-patentee's secret or confidential uses do not invalidate later-filed patents.

31. I understand that a patent claim may be anticipated where, before the invention thereof, the invention was made in this country by another inventor who had not abandoned, suppressed, or concealed it. I further understand that when the non-patentee's invention's "inner workings" are the essence of the invention, it is those "inner workings" that must not be suppressed or concealed in order for the invention to constitute prior art.

32. I also understand that prior art can include work by a prior inventor if that prior inventor: (1) conceived of the claimed invention before the conception date of the patentee, (2) was reasonably diligent in reducing the invention to practice from just prior to the conception date of the patentee, and (3) has not abandoned, suppressed or concealed the invention.

33. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims without undue experimentation.

34. I understand that documents and materials that qualify as prior art can be used to invalidate a patent claim as anticipated or as obvious.

35. I understand that, in an IPR, invalidity must be shown by a preponderance of the evidence. Furthermore, I understand that a preponderance of the evidence means that it is more likely than not to be true.

2. Anticipation

36. I understand that, pursuant to 35 U.S.C. § 102, a claim of a patent is invalid for anticipation if, among other things, any of the following is true: (i) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent, (ii) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country more than one year prior to the date of the application for patent in the United States, or (iii) the invention was described in another's United States patent or published patent application which issued from a patent application filed in the United States before the invention by the applicant for patent.

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

38. I understand that a prior art reference “anticipates” an asserted claim, and thus renders the claim invalid, if all elements of the claim are disclosed in that prior art reference, either expressly or inherently (i.e., necessarily present), arranged in the same way as in the claim. I understand that, for inherent anticipation, it is required that the missing descriptive material is necessarily present in the prior art reference.

39. I understand that to anticipate an asserted claim, an allegedly anticipatory prior art reference has to have an enabling disclosure. I understand an enabling disclosure describes the claimed invention in sufficient detail to enable a person of ordinary skill in the art to carry out the claimed invention.

40. I understand that a patent is anticipated if, before such invention thereof, the invention was made in this country by another inventor who had not abandoned, suppressed, or concealed it.

41. A patent claim is also anticipated if there is proof that, more than one year before the priority date of the patent, the claimed invention was: in public use or on sale in the United States; patented anywhere in the world; or described in a printed publication anywhere in the world. This is called a statutory bar.

42. I have written this declaration with the understanding that, in an IPR, anticipation must be shown by a preponderance of the evidence. I understand that a preponderance of the evidence means that it is more likely than not to be true.

3. Obviousness

43. I understand that even if a patent is not anticipated, it is still invalid pursuant to 35 U.S.C. § 103 if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in the pertinent art (henceforth, a “POSITA” or “POSA”).

44. I understand that a POSITA provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents one from using his or her own insight or hindsight in deciding whether a claim is obvious.

45. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the Asserted Claims, (3) the level of ordinary skill in the pertinent art, and (4) the existence of secondary considerations (also called objective indicia of non-obviousness).

46. I understand that the test of obviousness is whether the claimed invention, as a whole, would have been obvious to one of ordinary skill in the art as of the date of the invention in light of the prior art.

47. I understand that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I understand that most, if not all, inventions rely on building blocks long since

uncovered, and claimed discoveries, almost of necessity, will likely be combinations of what is already known. I understand that it is important to identify whether a reason existed at the time of the invention that would have prompted a person of ordinary skill in the art in the relevant field to combine the known elements in the way the claimed invention does. I understand that the use of hindsight must be avoided when considering whether the alleged invention would have been obvious to the person of ordinary skill in the art. In assessing obviousness, I have been instructed to consider the distortion caused by hindsight bias, guard against slipping into the use of hindsight, be cautious of arguments that rely upon after-the-fact reasoning, and avoid the temptation to read into the prior art the teachings of the invention in issue.

48. I understand that secondary considerations of non-obviousness (also known as objective indicia of non-obviousness) may include: (1) a long felt but unsolved need; (2) commercial success; (3) unexpected results; (4) industry praise; (5) licensing; and (6) copying by others. I also understand that there must be a relationship or nexus between any such secondary considerations and the claimed invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination.

49. I understand that any secondary consideration must bear a nexus to the claimed invention. Where the offered secondary consideration actually results from

something other than what is both claimed and novel in the claim, there is no nexus to the merits of the claimed invention. I further understand that the patentee bears the burden of demonstrating that the relevant secondary indicia is attributable to the claimed invention, as opposed to other economic and commercial factors unrelated to the technical quality of the patented subject matter. I understand that a nexus is presumed where the secondary considerations are tied to a particular product which: (i) embodies the claimed invention and (ii) is coextensive with the claimed invention. In analyzing whether a product is coextensive with the claimed invention, I understand that there is no requirement for a perfect correspondence between the claims and the product, and that the presumption of a nexus can still apply when unclaimed features present in the product amount to nothing more than additional insignificant features.

50. I further understand that, as a safeguard against hindsight bias, all secondary considerations of non-obviousness must be considered prior to reaching an obviousness conclusion.

51. I understand that an obviousness evaluation can be based on a combination of multiple prior art references. I understand that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but other times the nexus linking two or more prior art references can be based on the ordinary understandings available to a POSITA. I further understand that obviousness

analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

52. It is further my understanding that a proper obviousness analysis focuses on what was known or obvious to a POSITA, not just the patentee. Accordingly, I understand that any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

53. I understand that whether a prior art reference “teaches away” from the claimed invention is a fact to be considered in determining obviousness. I understand that it is improper to combine references where the references teach away from their combination. However, I understand that the nature of the teaching is highly relevant and must be weighed in substance – a known or obvious composition does not become patentable simply because it has been described as somewhat inferior to some other product for the same use. Furthermore, I understand that the prior art’s mere disclosure of more than one alternative does not constitute a teaching away from any of those alternatives because such disclosure does not criticize, discredit, or otherwise discourage the solution claimed.

54. I understand that, in an IPR, obviousness must be proven by a preponderance of the evidence such that a POSITA at the time of the alleged

invention would have had a reason (or reasons) for combining the teachings of those prior art references to achieve the claimed invention, and that same POSITA would have had a reasonable expectation of success from combining those teachings.

VI. LEVEL OF ORDINARY SKILL IN THE ART

55. My opinions herein are based from my standpoint of a person of ordinary skill in the art at the time of invention of the '328 Patent, which I refer herein as a "POSITA."

56. I understand that, for the purposes of proceeding, the '328 Patent is entitled to a priority date no later than August 10, 2001, the filing date of U.S. Pat. Appl. No. 09/98,218 (U.S. Patent No. 6,891,960). Ex. 1001 at p. 2 ("Related U.S. Application Data"). I also understand that the '328 Patent claims priority to U.S. Provisional Patent Application Nos. 60/224,761 (filed on Aug. 12, 2000), and 60/296,596 (filed on Jun. 7, 2001). *Id.* None of my opinions herein would change if the '328 Patent was determined to be entitle to either of the priority dates of those provisional applications.

57. I understand that Petitioner and its expert Dr. Thorpe have proposed that a POSITA would have had "at least a bachelor's degree in mechanical engineering, electrical engineering, computer science, physics, or related discipline, and four years of experience in research, design, or development in computer vision systems." Pet. at 6; Ex. 1003 ¶31. In my opinion, that is an excessive level of

ordinary skill in the art, and I believe instead a POSITA would more likely have two years of experience rather than four years. However, none of my opinions herein would change if Petitioner’s identification of the level of skill in the art were adopted instead.

58. Under either Party’s proposed definition of the level of ordinary skill in the art, at the relevant time frame, I was a person of more than ordinary skill in the art. I also worked with and managed many people who fit the characteristics of the POSITA (as proposed by either party), and I am familiar with their level of skill.

VII. BACKGROUND OF THE ‘328 PATENT

59. The ‘328 patent is entitled “SYSTEM AND ASSESSMENT OF REFLECTIVE OBJECTS ALONG A ROADWAY” and issued on May 10, 2016. Ex. 1001. It claims priority, through a chain of continuations and divisions, to non-provisional U.S. Patent Appl. No. 09/928,218, which was filed on Aug. 10, 2001. *Id.* at pp. 1-2 (field (60)). It also claims priority to U.S. Provisional Patent Application Nos. 60/224,761 (filed on Aug. 12, 2000), and 60/296,596 (filed on Jun. 7, 2001). *Id.*

60. The ‘328 Patent generally relates to recognizing road markers—which can include road signs or pavement markings—using a video camera. Ex. 1001 (‘328 Patent), Abstract. As the ‘328 Patent explains, in order to be visible when lit by a vehicle’s headlights at night, road markers are generally designed to be

retroreflective. *Id.* at 1:64-2:15. That is, when light hits their retroreflective surfaces, they reflect nearly all the light back towards the source light or slightly off-angle from the source light. *Id.*; *see also* Ex. 2003 ('596 Prov. App.) at 66-67.

61. However, road markers are not able to achieve that function if the retroreflective surfaces become damaged, deteriorated, or otherwise degraded in performance, such as due to a breakdown in pigments or reflective material. Ex. 1001 at 2:8-12. Thus, highway and street maintenance departments would like to check that the reflective performance of installed road markers has not degraded, so that they can continue to be seen by drivers. *Id.* at 2:16-27. But the '328 patent explains that systematic evaluation of road markers by maintenance departments had been difficult, often requiring holding a handheld retro reflectometer directly in front of a sign. *Id.*

62. Thus, the inventors of the '328 Patent targeted a critical problem in identifying and creating an accurate inventory of road and traffic signs along a given street or highway. In particular, it describes using an automated system to detect and determine the reflective surfaces along a roadway. It does so by capturing images along the roadway, using a light sensor to illuminate the roadway and measure light intensity, and using a computer processing system connected to the image capture system and light sensor that can detect objects of interest within the field of view of the light source. *Id.* at 3:66-4:8. The patent further describes that the

computer processing system can determine an object's location, whether the object includes a reflective surface, the retroreflectivity of the surface, and whether the reflective surface is a road marker. *See id.* at 4:13-17.

VIII. OVERVIEW OF THE CITED PRIOR ART

A. U.S. Patent Application Publication No. 2002/0063638 to Gallagher (“Gallagher”, Ex. 1005)

63. The Gallagher reference is dedicated to the problem of assessing the integrity of reflective pavement markers. Ex. 1005 (Gallagher), Abstract, [0034]. In particular, it uses a vehicle with an array of photodiode sensors—typically five or ten photodiodes in total—which divide the field of view and are pointed down at the road, as well as lights that illuminate the area of the road that the sensors point at. *Id.*, Figs. 1-2, [0035]-[0039]. Photodiodes are a light sensors that measure the intensity of light using a semiconductor, where current increases proportional to the amount of light received by the sensor. *See, e.g.* Ex. 2027; Ex. 2026, 28:5-7.

64. In Gallagher, the operator must “initiate[] the measurement process,” which causes the light array and sensors to be turned on. *Id.*, [0046]. Once a measurement session has begun, Gallagher’s photodiodes output signals to analog-to-digital converters (ADCs), which convert them to corresponding to numeric values, which are then provided to Gallagher’s computer according to a pre-specified sampling rate. *Id.* [0047], [0056], Fig. 3. The computer is programmed with an algorithm to analyze the data collected from the photodiodes to determine whether

pavement markers meet predetermined retroreflectance levels, and notes the physical location (using GPS or gearbox sensors) of pavement markers. *Id.*, [0049]-[0053].

65. In particular, Gallagher’s algorithm uses a series labeled “step a” through “step l.” In step (a), the computer collects the sensor data from the analog-to-digital converters (ADC) which are connected to each light sensor. Ex. 1005, [0056]. In step (b), the sensor values are smoothed by averaging values in a set of sample readings. *Id.*, [0057]. In step (c), the smoothed ADC values for each sensor are multiplied by a “predetermined calibration factor” for that sensor to obtain reflectivity values. *Id.*, [0058]-[0059]; *see also id.*, [0017]. In step (d), the previously collected sensor data is used to provide visual indicators to the vehicle operator as to the direction of current highest reflectance reading to allow the rider center the vehicle (and its sensors) on the path of the pavement markers. *Id.*, [0060]-[0061]. That is, the indicator simply provides the raw output of *which sensor is currently* “reading the highest reflectance reading” at any one time. *Id.* Indeed, Dr. Thorpe appears to agree. Ex. 2026, 15:9-11. Notably, the indicator means in step (d) of the currently highest-reading sensor does not appear to be used in any later steps of assessing the reflectivity of the pavement markers, but rather is strictly used during the data collection process to ensure the integrity of the data collected. *Id.*

66. In step (e), location information is collected from the vehicle gearbox to continually record the distance from where the test started, which can be used in later steps to tag the road markers. Ex. 1005, [0063]-[0064]. In step (f), the algorithm determines background reflectance levels to establish a non-marker reflectance level, i.e. it identifies how dark the dark parts of the sensor readings so as to establish a cutoff where anything below the cutoff reflects no marker is present. *Id.*, [0065]. Finally, in step (g), the computer reviews the previously smoothed and calibrated reflectance levels from steps (a)-(c) and identifies which responses are “peak responses,” (i.e. those above the non-marker reflectance levels). *Id.*, [0066]. The presence of a peak response is taken to conclude the presence of a pavement marker. *Id.* That is, Gallagher’s system sets a threshold and then assumes any value above that threshold indicates that a retroreflector must be present. *See also* Ex. 2026, 26:1-27:16.

67. After identifying the location of road markers using peak responses, Gallagher performs a few final steps to record the data in a useful format. In step (h), it performs any conversion necessary of the detected peak number so that it is in a format that corresponds to specific standard for retroreflectivity, either as a percent of a standard level or an absolute CIL (coefficient of luminous intensity) value in millicandela per lux. Ex. 1005, [0067]. In step (i), that value is compared to the predetermined acceptable reflectance level, and tagged as acceptable or not

acceptable. *Id.*, [0068]. In step (j), the location and reflectance levels of the tagged markers are saved on a storage medium. *Id.*, [0069]. In step (k), road markers which are entirely absent (rather than just being merely degraded) are inferred from breaks in the pattern of valid road marker spacing. *Id.*, [0070]. The final results are provided in a user understandable graphical or numerical format. *Id.*, [0071].

B. U.S. Patent No. 5,796,094 to Schofield et al. (“Schofield”, Ex. 1006).

68. Schofield is directed to vehicle control systems, and in particular, controlling the “high-beam state” of a vehicle’s headlights by detecting the headlights or taillights of other vehicles. Ex. 1006, Abstract, 1:12-32. In particular, Schofield’s system focuses on identifying the unique characteristics of headlights and taillights so that the high-beam setting can be switched off, without having false positives from ambient lighting. *Id.* at 1:33-62. Such characteristics include the spectral characteristics of the light source (e.g., color or distribution of intensity of various wavelengths along the visible light spectrum) and the “spatial layout” of the light source (i.e., that headlights and taillights typically come in pairs which are spaced apart). *Id.* at 1:62-67. Schofield uses a solid-state camera (e.g. CCD or CMOS), and can spatially divide the camera image into different regions, so that it can ignore weak intensity headlights or taillights that are far off the axis of the headlights, as those lights reflect vehicles that are further away and thus unlikely to be affected by high-beam state. *Id.* at 2:36-46, 3:1-3.

69. In particular, Schofield's camera is mounted near the windshield so as to capture an area of the road ahead of the vehicle comparable to the view of a driver's view out the front windshield. Ex. 1006, 3:64-67, 4:8-10, Fig. 11a. It uses an array of 512 x 512 pixels and a filter array for separating light in specific spectral bands. *Id.* at 4:16-35, Fig. 2. In particular, the spectral characteristics can be isolated by alternating the color of the spectral filter on different frames of the camera. *Id.* at 5:50-55. The camera's output is sent to a digital signal processor 13, which includes an analog-to-digital converter that converts the camera's pixel values to digital values (i.e. integer numbers). *Id.* at 4:44-49.

70. The taillight detection circuit detects red light sources having an intensity about a pre-specified threshold: if a red pixel's red intensity exceeds a pre-specified multiplier above the intensity of adjacent green and blue pixels, it is classified as a red light source. *Id.* at 4:62-5:1, 6:50-7:4. If that red light source's intensity is above the pre-specified threshold, it is determined to be a tail light and a "tails found" signal is sent. *Id.* at 5:1-3, Fig. 3. Headlight detection circuit 78 detects white light sources by identifying where adjacent red, green and blue pixels all exceed a particular threshold. *Id.* at 5:4-11. The circuit then classifies the light source as white light source if those red, green and blue pixels are all close in intensity (e.g. within 20 percent of each other), and a "heads found" signal is sent. *Id.*; *id.* at Fig. 3, 7:5-17. Different spectral filters and exposure periods can be used

for detecting taillights versus headlights (e.g. using a filter that only passes red light to create red pixels for red light, and using a longer exposure period for the relatively weaker taillights than the stronger headlights). *Id.* at 5:52-16. The high-beam setting is controlled by how many red taillight pixels or white headlight pixel groups are counted and whether they exceed a specified threshold for a sufficient period of time (to avoid false detections). *Id.* at 6:57-58, 7:14-57.

71. Schofield discloses that its invention is “capable of identifying point sources of light.” Ex. 1006, 9:24-26. However, it can further eliminate some erroneous headlight/taillight detections by limiting detections of the point sources to only certain regions of the camera image. *Id.*, 9:26-38. That is, it can be configured to ignore off-axis headlights or taillights (i.e., lights not close to where the vehicle’s headlights are pointing) unless they are closer to the vehicle (and thus of greater intensity). *Id.* That is, it “detect[]s light sources at a lower threshold centrally of the scene and at a higher threshold at the periphery of the scene,” such as by requiring a higher intensity threshold value for detected white or red pixels located at the image’s periphery. *Id.* at 9:58-61, 10:6-12. It also discloses that it could use “pattern recognition” in the form of detecting that “headlights and taillights are usually occur in pairs.” *Id.* at 10:66-11:7. Schofield also mentions generally how its invention could be adapted to detect colored street lights, colored traffic signs, and lane

markers, but does not contain any implementation details of how to do so. *Id.* at 11:58-12:5, 12:40-43.

C. U.S. Patent No. 5,313,262 to Leonard (“Leonard”, Ex. 1009).

72. Leonard is directed to laser-based object detection systems (i.e. a laser radar system) used in vehicles. Ex. 1009, Title, Abstract, 1:7-9. In particular, Leonard addresses the problem that such systems typically want to illuminate a wide beam path reflecting the entire field of view of the road ahead, but prior solutions typically resulted in reduced intensity of illumination of objects—particularly distant objects, harming object detection. *Id.* at 1:19-43. Other prior art systems illuminate a relatively narrower area to detect retroreflectors in a particular space (e.g. Gallagher’s area A pointed down at the road to detect pavement markers), but such systems can be harmed by changes in vehicle configuration, weight, etc. causing the scene to deviate from the intended field of view. *Id.* at 1:44-55. And simply increasing the intensity of a light beam can cause objects close to the vehicle to become washed out or cause a false object detection by excessively illuminating the background. *Id.* at 1:55-65.

D. U.S. Patent No. 5,202,742 to Frank (“Frank”, Ex. 1007)

73. Frank is directed to a laser radar system used in an automatically steered vehicle to “look[] ahead” down the roadway to anticipate changes in roadway geometry (i.e. curves in the road ahead). Ex. 1007, Title, Abstract, 1:12-29, 2:66-

3:3. Frank attempts to overcome the problems of prior art automated highway systems which only sensed close to the vehicle and thus had difficulty with rapid changes in roadway geometry. *Id.* at 2:3-16, 2:55-3:7. Frank accomplished this by using a laser radar system to measure the distance and angle of retroreflective markers placed along the side of a highway. *Id.*, at 3:8-13, 4:10-50, Figs. 1-2. By modulating the laser and noting differences in phase in the received signal, Franks' system is able to calculate the transit time for light to travel to the retroreflector and back to a sensor on the same vehicle, and is then able to calculate distance by dividing the travel time by the speed of light. *Id.* at 7:37-41, 8:37-46, 9:49-10:1. In one of Frank's embodiments using a single, wide-FOV light sensor, the laser radar system uses a servo-controlled mirror to physically control the direction laser beam, and returns the angle θ corresponding to the angle of beam at the time of the reading. *Id.*, 7:42-47. In a different of Frank's embodiments, as opposed to a servo controlled laser, a single "floodlight beam" laser is used instead of the servo-controlled scanning fan beam. *Id.*, 10:54-11:4. In that embodiment, an array of light sensors is used, and the angle θ is calculated by the position of the received light pulse on the array. *Id.* In either embodiment, by identifying distance D and angle θ for successive retroreflectors, the system is able to calculate road curvature. *Id.* at 5:41-65.

E. WO9617258A2 to Popovich (“Popovich”, Ex. 1010).

74. Popovich is directed to optical-based systems for detecting the position of a human head, especially of a device operator in front of a video display screen, such as for virtual reality game purposes. Ex. 1010, Title, Abstract, 1.¹ In particular, Popovich attempts to provide a safe, cost-effective, and simplified way for measuring the head position by using optical triangulation. *Id.*, 1. Popovich uses two beams (e.g. laser beams or comparable narrow-wavelength beams) designed to converge at somewhat opposing sides of the user’s head, on which is mounted a specifically designed retroreflector device (e.g. on special glasses). *Id.*, 1-3, Figs. 1, 3. The reflections of each beam by the retroreflector are detected by two sets of light detection devices (e.g. depending on the embodiment, cameras or photodiodes). *Id.* By comparing differences in the readings from each light detection device (e.g., location of maximum intensity in a camera’s pixel grid) Popovich’s system is able to identify the position of the retroreflector, and thus the user’s head. *Id.*

IX. CLAIM CONSTRUCTION

A. “configured to detect objects of interest within the field of view and for each object of interest ... determine whether the object of interest includes a reflective surface [and] ... determine whether the reflective surface is a road marker” (’328 Patent, cl. 1)

¹ Popovich includes two sets of page numbering—the original page numbers of the application, and the additional pdf page numbers apparently added by counsel for Petitioner. It appears that Dr. Thorpe and Petitioner have used the original pagination when pin-citing, and thus, unless otherwise noted, I will do the same herein.

/

“configured to detect objects of interest within the field of view and for each object of interest: determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view” (’328 Patent, cl. 9)

75. As discussed in further detail below, it is my opinion that each of these limitations require that the “determin[ing]” steps be performed on “object[s] of interest” which have already been previously “detect[ed]” in the “detect object of interest” step. Moreover, it is my opinion that the “detect” and “determine” steps cannot be simultaneously satisfied by the same act being performed on the same particular object of interest.

76. Claim 1 recites, among other things, a computer processing system that is configured to both “detect objects of interest” and “for each object of interest, determine whether” it includes “a reflective surface” and “determine whether the reflective surface is a road maker.” Petitioner and Dr. Thorpe appear to map each of these “determin[ing]” steps in claim 1 solely to Gallagher’s disclosures. Ex. 1003 ¶¶ 112, 114; Pet at 39-41. They also map the “detect objects of interest” in claim 1 to both Gallagher and Schofield. Ex. 1003 ¶¶ 110-111; Pet at 38-39. As discussed in detail below, for both “determin[ing]” steps of claim 1, Petitioners reference the same cited disclosures of Gallagher—Gallagher’s paragraph [0066], which discusses identifying “peak responses” in the light intensity sensors as corresponding to road markers. Ex. 1003 ¶¶ 110-111; Pet at 40-41. Similarly, in connection with

Petitioner’s theory for the “detect objects of interest,” they point to their theories for limitation [9D], which in turn also rely on Gallagher’s paragraph [0066]. Ex. 1003 ¶¶ 110; Pet. at 39.

77. Similarly, claim 9 recites, among other things, a computer processing system that is configured to both “detect objects of interest” and “and for each object of interest: determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view.” Petitioner and Dr. Thorpe appear to map both the “detect objects of interest” step and the “determin[ing]” step of claim 9 solely to Gallagher’s disclosures. Ex. 1003 ¶¶ 70, 72, 73-74; Pet at 20-23. And, as discussed in detail below, for both the “detect” and “determin[ing]” steps of claim 9, Petitioners reference the same cited disclosures of Gallagher—Gallagher’s paragraph [0066], which discusses identifying “peak responses” in the light intensity sensors as corresponding to road markers. Ex. 1003 ¶¶ 71, 74; Pet at 20-23.

78. In my opinion, Petitioner’s application of the prior art to claims 1 and 9 requires determining the scope of these claim terms and, in particular, whether they require different steps being performed in a particular sequence, or whether they can all be read on the same step.

79. In my opinion, a POSITA reading the text of claim 1 would immediately envisage that the claims require a computer configured to perform

separate steps in a particular sequence. In particular, claim 1 recites “detect objects of interest within the field of view and for each object of interest:” followed by the three “determine” steps, the first of which recites “determine whether *the* object of interest includes...” Notably, this recites two different acts (detect and determine) and the reference of the result of the first step (object of interest) as the object of analysis in the second step. This would immediately indicate to a POSITA a specific step of object detection, followed by a separate step of determination performed on one of the previously detected objects. Similarly, the output of the first determine step is a determination as to whether there is a “reflective surface,” which is the object upon which a determination is performed in the third determine step (“determine whether the reflective surface is a road marker...”). This textual structure would immediately indicate to a POSITA a specific determination as to the presence of a reflective surface occurs prior to a separate step of determining whether it is a road marker.

80. Similarly, in my opinion, a POSITA reading the text of claim 9 would immediately envisage that the claims require a computer configured to perform separate steps in a particular sequence. In particular, claim 9 recites “detect objects of interest within the field of view and for each object of interest:” followed by a “determine” and “analyze” steps, the first of which recites “determine whether *the* object of interest includes ...” Like claim 1, claim 9’s recitation of two different

acts (detect and determine) and the reference of the result of the first step (object of interest) as the object of analysis in the second step would immediately indicate to a POSITA a specific step of object detection, followed by a separate step of determination performed on one of the previously detected objects.

81. Indeed, in the field of computer vision, it is well-understood that object detection—which tells you that there is an object (i.e. “detect objects of interest”)—is distinct from object recognition which tells you something about what an object is (i.e. “determine whether the reflective surface is a road marker” or “determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker”).

82. My interpretation of these limitations is also consistent with the specification of the ‘328 Patent. In particular, the ‘328 Patent recites that:

A computer processor 450 **identifies an object of interest 460** in a portion of the intensity frame 420 **and determines the object of interest attributes 465 associated with that object of interest.** Preferably, the **objects of interest are identified from the digital imagery stream 390** generated by the color image capture system 250 in the manner as taught by U.S. Pat. No. 6,266,442. Alternatively, other techniques known in the art for isolating an object of interest in a videostream can be used.

‘328 Patent at 8:31-40 (emphasis added). Notably, U.S. Patent No. 6,266,442 in turn describes:

Thus, the present invention transforms frames of digital video depicting roadside scenes using a set of filters that are logically combined together with OR gates or combined algorithmically and

each output is equally weighted, and that each operate quickly to capture a differentiable characteristic of one or more road sign of interest. **Frequency and spatial domain transformation, edge domain transformation (Hough space)**, color transformation typically from a 24 bit RGB color space to either a $L^*u^*v^*$ or LCH color space (using either fuzzy color set tuning or neural network tuning for objects displaying a differentiable color set), in addition to use of morphology (erosion/dilation), and a moment calculation applied to a previously segmented image frame is used to **determine whether an area of interest that contains an object is actually a road sign**. The aspect ratio and size of a potential object of interest (an “image” herein) can be used to confirm that an object is very likely a road sign.

Ex. 2030 at 5:10-26 (emphasis added). Notably, these techniques, particularly various transformations including Hough transformations, are techniques used in the field of computer vision for object detection in an image. They are forms of object detection, and are very much unlike the types of determinations recited in the “determine” steps in claim 1, which are determining properties of an already identified object.

83. Indeed, the preferred embodiment of the ‘328 Patent discloses a system having a separate “color image capture system 250” and “light intensity sensor 280.” ‘328 Patent at 7:67-8:6. As shown above, the preferred embodiment only attempts to identify objects from the images captured by the “color image capture system 250.” However, in contrast, as shown below, the determination of reflective surfaces is performed using the images captured by the “light intensity sensor 280.” ‘328 Patent at 9:16-18. In particular, after an object of interest is identified from the image

data from the “color image capture system 250,” the “computer processor 450 correlates the portion of an image frame of the digital imagery stream 290 with a similar portion of the intensity frame 420 containing the object of interest 460.” ‘328 Patent at 8:40-43. However, “[s]ince most of the objects in the scene are not reflective, and due to the high setting of the threshold range in the light intensity sensor(s) 280, the reflected light intensity frames 420 will actually show very few objects.” *Id.* at 10:65-11:1. Thus, a POSITA would understand the step of correlating the previously identified objects of interest to corresponding reflective portions in the light intensity image (if any) to be a determination that the object of interest includes a reflective surface based on light intensity values.

84. Only then does the preferred embodiment of the ‘328 Patent analyze the surface of the detected objects of interest and calculate retroreflectance values. In particular, it discloses that “background intensity measurement 470” and “foreground intensity measurement 480” are generated from the image from the light intensity sensor 280. ‘328 Patent at 8:44-46. Then, “[u]sing an intensity algorithm 490, a light intensity sensor characterization 275 and a look-up-table 475, the computer processor 450 determines a background luminance value 500 and a foreground luminance value 510.” *Id.* at 8:46-49. Finally, using those luminance values, as well as “a characterization of light source wavelength 540, the background sheeting color 505 and the foreground sheeting color 506,” the computer processor

450 calculates foreground and background retroreflectance values (R_A) for the object of interest. *Id.* at 8:50-56. These retroreflectance values allow the computer to conclude that an object is a road marker, because “at least one object face surface 130 which exhibits retroreflectivity over at least a relatively narrow conical volume of magnitude of several degrees from a normal vector 180 originating from said object face surface 130.” *Id.* at 9:7-11. Finally, the road marker is classified using an algorithm for classifying the object into one of several known signs according to color and sheeting types. *Id.* at 16:31-67. Thus, the ‘328 Patent makes clear that the detection of objects of interest, the determination of reflective surfaces, and classification of a reflective surface as a road marker are all separate steps, and that the determination and classification only occurs after detection of objects of interest.

85. I understand that, in its preliminary response and preliminary surreply, Patent Owner argued that, consistent with my above opinions, that the ‘328 Patent claim 1 requires performing the first “determin[ing]” step of claim 1 on an “already detected” object of interest and perform the second “determin[ing]” step of claim 1 on a reflective surface identified in the first “determin[ing]” step. Paper No. 6 at 13-19. However, I understand that Petition argued in its preliminary reply that the “detect[ing]” steps of claims 1 and 9 can be performed simultaneously with the “determin[ing]” steps in those claims. Paper 7 at 1-4. In particular, Petitioner cited to column 5, lines 41-45 and lines 52-57, which mentions that “[e]ither concurrent

with or subsequent to the identification of road signs 30 and generation of asset management database 24, the computer processor 22 evaluates that portion 32 of each video frame or image that depicts a road sign 30 to determine a set of color values 40, 42 for each of a plurality of colors on the road sign 32.” ‘328 Patent at 5:52-57. In particular, Petitioner argued that Patent Owner’s interpretation of the claim would “read[] out the ‘concurrent with’ embodiment of the specification.” Paper 7 at 3. I also understand, in its institution decision, the Board accepted this argument in its preliminary claim construction. ID at 29-30.

86. I respectfully disagree with Petitioner’s arguments and the Institution Decision’s preliminary conclusion regarding the interpretation of these steps. In particular, the “concurrent with or subsequent to” language in the specification has nothing to do with the “determin[ing]” steps of claims 1 and 9, which relate to the determination as to whether an already detected object of interest includes a reflective surface of a road marker. Notably, unlike the passages I cite above from the ‘328 Patent’s specification, the parts of column 5 cited by Petitioner do not even mention “reflective surfaces.” Rather, the cited passage merely notes that identification of *colors* of a road sign can occur simultaneously with identification of the same road signs as objects of interest. That is not surprising, because, as discussed above, the ‘328 Patent’s preferred embodiment uses a “color image capture system 250” for object detection and a separate black and white “light

intensity sensor 280” for determining whether an object has a reflective surface. ‘328 Patent at 7:65-8:18, 8:35-56, 10:28-43; Fig. 3 (element 250 vs. element 280, “B/W Intensity Sensor”); Fig. 4 (camera elements 360 vs. intensity sensor(s) 280). Thus, the cited sentence in column 5 stating that “determ[in]ing a set of color values” “concurrent with or subsequent with the identification of road signs” makes sense—color identification has to use the color camera, and the patent discloses preferably using the same color camera for object detection. However, the determination of reflective surfaces is not a part of either color identification or object identification. Rather, determination of reflective surfaces in the preferred embodiment uses imagery obtained from the separate intensity sensors (e.g., black and white camera). ‘328 Patent at 4:8-17, 8:44-56, 10:28-34.

87. Later in the same paragraph in which the “concurrent with” language cited by Petitioner appears, there is a discussion of the calculation of retroreflectivity values, stating that: “A retroreflectivity value is generated for each color portion 34, 36 on each frame of the tagged videostream 20 containing the road sign 30 that represents a different color value 40, 42..” ‘328 Patent at 5:57-60. However, nothing in the paragraph indicates that the calculation of retroreflectivity values is occurring concurrent with the identification of road signs.

88. Rather, the preferred embodiments in specification consistently teach that the calculation of retroreflectivity values is a separate and later step after object

detection and the determination of color values. For example, the Abstract of the ‘328 Patent states:

A system for classifying different types of sheeting materials of road signs depicted in a videostream compares estimated retroreflectivity values against known minimum retroreflectivity values for each of a plurality of colors. **Once a road sign has been identified in the videostream**, the frames associated with that road sign are analyzed to **determine each of a plurality of colors present** on the road sign. An estimated **retroreflectivity** for each of the plurality of colors present on the road sign is **then determined**.

‘328 Patent, Abstract (emphasis added). Similarly, the “Summary of the Invention” discloses that:

Once a road sign has been identified in the videostream, the frames associated with that road sign are analyzed to **determine each of a plurality of colors present on the road sign**. An estimated **retroreflectivity** for each of the plurality of colors present on the road sign is **then determined**. ...

In a preferred embodiment, a system for the automated **determination of retroreflectivity values** for reflective surfaces disposed along a roadway is **utilized to establish the retroreflectivity values for both foreground and background colors** of a road sign

...

A computer processing system is used to **identify a portion of the light intensity values associated with a reflective surface and analyze the portion of the light intensity values to determine at least one retroreflectivity value for that reflective surface**. **Color images** of the area and locational information **are also generated** by the system and are used together with a characterization profile of the light source to enhance the accuracy of the determination of retroreflectivity values.

‘328 Patent at 3:53-4:17 (emphasis added). These passages make clear that, in the preferred embodiments, color identification is an initial step that occurs prior to and separate from the determination of reflective surfaces and the calculation of retroreflectivity. Only after identifying the colors of a sign (e.g. the red background and white legend of a stop sign) there are separate retroreflectivity values for those colors created, in a separate process.

89. In short, the “concurrent with or subsequent to” language cited by the Petitioner and the Board is entirely irrelevant to the question of whether the “determin[ing]” steps can occur at the same time as the step of object detection. Instead, as discussed above, the specification repeatedly makes clear that determining reflective surfaces occurs *after* the objects are detected.

X. THE REMAINING CHALLENGED CLAIMS OF THE ’328 PATENT ARE NOT ANTICIPATED AND ARE NOT RENDERED OBVIOUS

A. Ground 2: Claims 1-4 and 8-13 of the ’328 Patent Are Not Rendered Obvious by Gallagher and Schofield

90. Petitioner contends, and Dr. Thorpe opines, that claims 1-4 and 8-13 of the ’328 Patent are rendered obvious by the combination of the Gallagher and Schofield references. As set forth below, I disagree.

1. A POSITA Would Not be Motivated to Combine the Teachings of Gallagher and Schofield in the Manner Claimed

91. Petitioner presents a few theories for the motivation to combine Gallagher and Schofield. First, in connection with limitation 9[F] of claim 9, Petitioner argues that “POSITA would have been motivated to implement Schofield’s determination of a light source’s location within a field of view [using a camera] because doing so would have improved Gallagher’s computer by allowing it to differentiate between road markers ‘that are spaced apart on the road.’” Pet. at 23-24; Ex. 1003 ¶ 77. Second, in connection with limitation 1[A] of claim 1, Petitioner argues that it would have been obvious to “incorporate Schofield’s imaging sensor module 14 into Gallagher’s apparatus to improve the apparatus’ ability to identify objects of interest along the roadway.” Pet. at 35; Ex. 1003 ¶ 103. Third, in limitation 1[E], Petitioner argues “a POSITA would have found it obvious to operably connect Gallagher’s computer processing system ... to Schofield’s imaging sensor module to further improve the detection of objects of interest.” Pet. at 39; Ex. 1003 ¶ 110. Thus, each of theories argues that it would be obvious to combine Schofield’s camera-based approach with Gallagher to improve object recognition. I disagree that Petitioner or Dr. Thorpe have articulated an adequate motivation to combine Gallagher and Schofield as proposed.

92. First, neither Petitioner nor Dr. Thorpe provide any details explaining *how* they are proposing to integrate Schofield’s camera-based approach with Gallagher’s sensing of peak intensity using photodiodes. As Dr. Thorpe’s testimony demonstrates, there could be any number of potential ways one could try to do so. *See* Ex. 2026, 105:2-7 (“there are different ways of combining Schofield and Gallagher” “[t]hey can be combined at the sensor level. They can be combined at the algorithm level. They could be combined at the system level.”), 106:22-25 (“Could you point Schofield's camera down to match the illumination from Gallagher's lights? Yes, that's one way you could do things.”), 107:12-21 (“A person of ordinary skill in the art would have five different ways” of combining Gallagher and Schofield to “track the object as it's getting closer to the vehicle and passing from one sensor to another”), 110:13-14 (“what it would require is another module that sits on top of [Gallagher and Schofield] and takes recognition data from the two and fuses them appropriately”). In my opinion, properly reaching a conclusion of obviousness would require analyzing a particular proposed way of combining the references, which Petitioner and Dr. Thorpe have failed to provide. *Id.* at 111:4-5 (“I’m saying there's multiple ways to combine them.”).

93. Indeed, the combination of data from two or more sensors to understand the environment is referred to as “sensor fusion.” *See* Ex. 2031, 6. However, neither Schofield nor Gallagher provide any suggestion or motivation to

use such a sensor fusion approach, and Petitioner's and Dr. Thorpe's explanation that such sensor fusion would "improve" Gallagher's object detection is entirely conclusory.

94. Indeed, a POSITA would recognize that there would have been a number of difficulties with the sensor fusion proposed by Petitioner. In particular, Schofield's camera-based approach is using a different kind of sensor than Gallagher (i.e. a camera versus a photodiode array), pointed at a different area (i.e. pointed ahead out the windshield, as opposed to at the ground 2.3m in front of the vehicle). Cameras synchronize the capture process across all pixels simultaneously or in coordinated sequences. Creating an image represents a coherent snapshot of a scene at a specific moment. By contrast, a photodiode array (without modifications for coordination) would produce disconnected light measurements rather than spatially and temporally coherent images.

95. Moreover, both Gallagher and Schofield are based on operating on ordinary highways at normal highway speeds (Ex. 1005, [0032]; Ex. 1006, Fig. 11a, 1:17-31, 3:48-53, 10:41-43), which makes the processing requirements of sensor fusion even more difficult. In my opinion, as of earliest priority date of the '328 Patent in 2001, performing sensor fusion of a computer based vision system (such as Schofield) with a photodiode based system pointed down at the road way (such as Gallagher) would have not had a reasonable expectation of success at the highway

speeds that both such systems operate using the hardware available or foreseeable at the time. Indeed, as Dr. Thorpe himself said in a publication in 2001 “working outdoors, and at high speeds, and in close proximity to people, perception is still incomplete.” Ex. 2031, 1. And while sensor fusion was recognized as a promising way of helping solve those problems, it had faced significant challenges in 2001. *Id.*, 6. In particular, in 2001, successful object detection in the vehicular space was still facing significant challenges, with difficulties outside “clean” environment unless the “vehicles move slowly.” *Id.*, 1.

96. But, both Schofield and Gallagher are directed to operation on actual roadways—which are not clean environments. And, modifying either Schofield or Gallagher to move slowly would violate the essential goals of those references. Ex. 1005, Abstract, [0032]; Ex. 1006, Title, Abstract, 1:14-32. Indeed, as Dr. Thorpe’s research shows, sensor fusion of highly dissimilar sensors, as Petitioner advocates was not a solved problem and was entirely experimental (and thus the proposed combination would not be predictable) in 2001. Ex. 2031. Indeed, even today, over 20 years later, consistently reliable object detection and recognition at highway speeds using camera based systems continues to be elusive. *See* Ex. 2032.

97. Additionally, the proposed combination has several additional problems beyond that of typical sensor fusion difficulties as of 2001. In particular, tracking objects would be problematic because each of the photodiodes in

Gallagher's sensor array respond to light in a relatively large portion of the road—the 3 meter wide area is divided by five or ten sensors. Ex. 1005, [0035], [0038]. Thus, it would be difficult to confidently identify which particular light intensity reading at which point in time corresponds to a point light source previously detected by Schofield, particularly while travelling at highway speeds. Moreover, because the proposed combination requires tracking road markers transiting from Schofield's camera FOV to different Gallagher's photodiode-array FOV, there would be a need to correlate which readings in the different FOVs correspond to the same object, but that would also require detailed speed and location information (such as an internal navigation system or at least equipment for measurement of the vehicle's steering wheel and velocity) to ensure that a light intensity reading by one of the photodiodes actually corresponded to a light source identified by Schofield given the constantly moving vehicle's effect on the relative positioning of objects outside the vehicle. Neither Gallagher nor Schofield provide such disclosure, and Petitioner articulates no reason why a POSITA would not consider the costs of such non-standard hardware to outweigh the purported benefits in object detection.

98. Thus, in my opinion, a POSITA would not have proposed to combine Gallagher and Schofield as suggested by Petitioner, and any such combination would not be predictable and would not have a reasonable expectation of success.

2. Claim 9

a) Limitations [9D] & [9E]: Neither reference discloses or suggests a computer configured to both “detect objects of interest within the field of view and for each object of interest: determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view.”

99. As discussed above, it is my opinion that these limitations, as properly construed, require that the “determin[ing]” step be performed on an “object of interest” which has already been previously “detect[ed]” in the “detect object of interest” step, and that the “detect” and “determine” steps cannot be simultaneously satisfied by the same act being performed on the same particular object of interest. However, none of the cited disclosures suggest or disclose these limitations, as properly construed.

100. Petitioner and Dr. Thorpe rely solely on the disclosures of Gallagher for these limitations. In particular, as to limitation 9D (which references “detect[ing] objects of interest”) they point to paragraphs [0033], [0045], [0047] and [0055]-[0066] of Gallagher. Ex. 1003 ¶¶ 71-72; Pet. at 20-22. Paragraph [0033] of Gallagher is merely a general description of Gallagher’s function (i.e. testing reflectivity of road markers), and thus does not provide details sufficient to disclose these limitations. Paragraph [0045] merely notes that there is a computer with computer program to test the integrity of road markings, which is similarly inadequately detailed to show these limitations. Paragraph [0047] merely explains

that the output of Gallagher's light sensors are output into analog-to-digital converters, and the sampling rate of those converters. This is part of the data collection process, prior to any analysis of the data, and thus no detection of an object of interest can have occurred yet, and thus paragraph [0047] cannot satisfy these limitations.

101. Finally, paragraphs [0055]-[0066] of Gallagher begin the description of Gallagher's enumerated "step" by "step" algorithm for identifying road markers, up through "step g" in paragraph [0066]. Ex. 1005, [0055]-[0066]. As discussed above, Gallagher's steps (a), (b) and (c) (paragraphs [0055] through [0059]) respectively involve the collection, filtering, and calibrating of Gallagher's sensor data. *Id.*, [0055]-[0059]. However no analysis of that data occurs yet, and thus no detection of an object of interest can have occurred yet, and thus paragraph [0055] through [0059] cannot satisfy these limitations. *See also* Ex. 2026, 85:3-86:6 (agreeing no objection detection occurs in steps (a)-(c)). Similarly, step (e) in paragraph [0063] of Gallagher is merely a data collection step (collecting the gearbox data), without any analysis or determinations, and thus cannot satisfy these limitations. *Id.*, [0063]. Although step (f) involves an analysis resulting in a determination, it is a determination of the "non-marker reflectance levels." Ex. 1005, [0065]. This cannot satisfy these limitations for two reasons: (1) it is merely determining an overall background reflectance level, which has not connection with any particular road

marker, surface, or object of interest; and (2) non-marker levels refer to the general background of the roadway, which is not an object of interest and does not have reflective surfaces. *See also* Ex. 2026, 18:13-23.

102. The remaining steps in Gallagher cited by Petitioner are step (d) and step (g). In step (d), Gallagher “determin[es] the vehicle position on the road and provid[es] an audio and/or visual indicator means for the operator of the vehicle” to “enable[] the operator to maintain the vehicle 3 in a proper position on the road.” Ex. 1005, [0060]-[0062]. Gallagher’s computer does this by “detect[ing] which light sensor 6 is reading the highest reflectance reading” at any point in time and “prov[iding] the operator with that information.” *Id.* Step (d) cannot satisfy these limitations for several reasons. First of all, it is not detecting any object of interest. Rather, it merely reflects a raw output of the sensor with the current highest intensity reading to a visual indicator to the operator. *Id.* Thus, no object has been “detect[ed].” Indeed, as described, an indicator for one of the sensors would be active even in on a patch of roadway with no reflectors because at least one of the sensors will always have the highest reading among all of the sensors. Second, step (d) cannot satisfy, alone or in combination with the other steps, the requirement that an object of interest be detected and then a determination be performed on that object of interest. In particular, that is because the determination of the currently highest intensity sensor, and the resulting indicator(s) in step (d) are not mentioned or used

in any of the following steps. In particular, step (g) uses the data collected back in step (a) (and processed in steps (b) and (c)). Ex. 1005, [0066]. Thus, step (d) cannot satisfy this limitation.

103. Finally, step (g) in Gallagher does make a determination as to “which reflectance levels” in the data previously collected in step (a) (and processed in steps (b) and (c)) “indicate a road marker” by using the “peak responses” (i.e. those responses above the non-marker reflectance levels determined in step (f)). Ex. 1005, [0066]. However, this cannot satisfy the requirements of this limitation because it is only a single step. As discussed above, this claim as properly construed requires a “detect[ion]” of an object of interest, followed by a determination performed on that already detected object of interest. Gallagher’s single step approach—reflected in step (g)’s mere identification of “peaks” of intensity in photodiode data as corresponding to road markers—cannot be both a detection of an object of interest and a determination performed on an already detected object of interest. *See also* Ex. 2026, 26:1-27:15 (In Gallagher, “If you get a strong enough return, above threshold B, you have a functioning marker” “if you did not see one where you expected to see one, then there is either a degraded or a missing road marker”), 37:9-14 (Gallagher does not “contemplate” “how to distinguish peaks from road markers as opposed to peaks from other bright sources).

104. Thus for the foregoing reason, none of the disclosures in the prior art cited by Petitioner disclose or suggest these limitations.

b) Limitation 9[F]: Neither reference discloses or suggests a computer configured to “analyze the at least one light intensity value to determine an assessment of a discrete location of the road marker within the field of view.”

105. Petitioner and Dr. Thorpe present two alternative theories for this limitation. First, they argue that this limitation is disclosed by Schofield, noting that Schofield discloses that its sensors “divide the scene forward of the vehicle into spatially separated regions, and light sources are identified, at least in part, according to their spatial distribution across the regions.” Pet at 23; Ex. 1003 ¶ 76 (citing Ex. 1006, 2:36-41, 9:26-32). Their second, alternative theory, is that Gallagher discloses this limitation by disclosing “determin[ing] the location of each road marking” using either the vehicle’s “gearbox revolution sensor 14” or a “GPS interface 15” “as measurements are being taken.” Pet. at 25-26; Ex. 1003 ¶ 80 (citing Ex. 1005, [0009], [0038], [0048], [0063]). However, in my opinion, neither Schofield nor Gallagher disclose or suggest this limitation.

106. In particular, as discussed above, Schofield’s division of the scene into spatially separated regions is used during Schofield’s point light source detection algorithm by “increase[ing]” the “intensity detection thresholds” for regions of the scene which are “off axis” (i.e. far from the center of the screen, which corresponds to the axis of the vehicles’ direction). Ex. 1006, 9:25-61, 10:6-12. Thus, by

requiring a higher “intensity detection threshold” for some regions of the field of view, it minimizes “false detection of light sources not of interest such as streetlights, building lights, and the like.” *Id.*; *see also* Ex. 2026, 56:4-8 (“because your camera is pointed roughly the direction you're going, things near the axis are, of course, of much more concern to you than things off axis”), 55:22-56:1 (“If you're not worried about things which are next to you but you're more worried about things straight in front of you, then you can have a lower resolution in your periphery than you have in your central field of view.”). But that is not at all what this claim limitation recites—the claim recites that an intensity value is analyzed to determine the discrete location of a road marker in the field of view. Schofield discloses that you may have a lower resolution in your periphery and greater resolution in the center. This has to do with Schofield’s process, and not with what the claim limitation is.

107. In my opinion, the cited disclosures of Gallagher also fail to disclose or suggest this limitation. In particular, Gallagher logs GPS data and gearbox data (i.e. distance since the test session was started), which it correlates with the detections of road markers. Ex. 1005, [0020], [0048], [0063]. But these disclosures only give the location of the vehicle at the time the road marker is detected, which Gallagher uses as a rough approximate for the location of the road marker itself. *Id.* This is not the location of a road marker in a field of view—the field of view is *ahead* of the vehicle in Gallagher. *Id.*, [0035] (beam scanning 2.3 meters from a platform mounted on

the front of the vehicle), Figs. 1-2. Indeed, in connection with Ground 4, Petitioner and Dr. Thorpe admit that Gallagher’s “GPS position of the vehicle corresponds to the location of the active sensor.” Accordingly, a POSITA would have recognized that additional steps would have been necessary to also determine the location of the markers.” Pet. at 70; Ex. 1003 ¶ 176.

108. Moreover, Gallagher uses five to ten photodiodes to scan a field of view that is 3 meters wide (i.e. almost 10 feet wide). *Id.*, [0009], [0035], [0038]. However, Gallagher has no disclosure of analyzing or storing any location information of *where* a road marker was identified within the field of view, i.e. within the “Area A.” *Id.* Indeed, this is shown in Gallagher’s Figure 5, which provides the data output of Gallagher, and which merely shows the “location of each marker” as a “distance travelled in kilometers from the start point in the test run,” i.e. the location of the vehicle at the time of detection of the road marker. *Id.*, Fig. 5, [0079] Thus, Gallagher does not disclose or suggest “an assessment of a discrete location of the road marker within the field of view.” Moreover, even if Gallagher did (it does not), Gallagher certainly does not disclose making the assessment of the location *within the field of view* based on an intensity value. Rather, Gallagher discloses that GPS / gearbox location data and light intensity data are simply two sets of data that are recorded together—the light intensity data is not used in Gallagher to determine location within a field of view.

109. Thus for the foregoing reason, none of the disclosures in the prior art cited by Petitioner disclose or suggest these limitations.

3. Claims 10-13

110. Claims 10-13 depend from claim 9. '328 Patent, claims 10-13. Because claim 9 is valid over the combination of Gallagher and Schofield, claims 10-13 are valid for the same reasons discussed above for claim 9.

4. Claim 1

a) Limitations 1[E], 1[F], and 1[G] Neither reference discloses or suggests a computer configured to “detect objects of interest within the field of view and for each object of interest: determine whether the object of interest includes a reflective surface based on the light intensity values; [and] determine whether the reflective surface is a road marker based on an assessment of the reflective surface”

111. In my opinion, the cited disclosures do not disclose or suggest a computer configured to “detect objects of interest within the field of view and for each object of interest: determine whether the object of interest includes a reflective surface based on the light intensity values; [and] determine whether the reflective surface is a road marker based on an assessment of the reflective surface” as recited in claim 1 of the '328 Patent.

112. Petitioner and Dr. Thorpe's theories for these limitations largely mirror their theories for limitations 9[D] and 9[E] of claim 9, which fail for the reasons discussed above. In particular, like limitation 9[E], Petitioner relies solely on Gallagher for limitation 1[F], and cites the same portions of Gallagher's algorithm.

Ex. 1003, ¶ 113 (citing Ex. 1005, [0065]-[0066]). As further explained above, Gallagher’s single-step approach of identifying road markers based solely on peak responses in light intensity values does not perform a “determin[ation]” on an already detected object of interest. *Supra*, X.A.2.a. Accordingly, Petitioner’s theories for these limitations of claim 1 fail for the same reasons. Indeed, none of the differences between the text of claim 1 and claim 9, or in the evidence and argument presented by Dr. Thorpe and Petitioner for claim 1, alter my conclusion that the prior art does not disclose or suggest these limitations.

113. One difference is that, as opposed to claim 9, in claim 1 Petitioner and Dr. Thorpe also rely on Schofield for “detecting objects of interest” in limitation 1[e]. Pet at 38-39; Ex. 1003 ¶ 111. But, they rely on Schofield merely to argue that it would be obvious to use Schofield’s camera to perform detection of objects of interest. *Id.*; Ex. 1003 ¶¶ 103-107. Thus, neither Petitioner nor Dr. Thorpe present any argument that Schofield cures Gallagher’s failure to disclose an algorithm which: (1) detects objects of interest; and (2) performs a determination on an already detected object of interest. Indeed, neither Petitioner nor Dr. Thorpe even explain how the algorithm of the combined system works or is different from Gallagher’s algorithm other than to argue that it would be obvious to use Schofield’s camera and pattern recognition. *Id.*

114. Even if Petitioner were permitted to advance such a theory, a POSITA would not recognize the cited disclosures of Schofield as disclosing the claimed multi-step (“detect” followed by “determine”) configuration of claim 1. In particular, Petitioner relies on the “pattern recognition” teachings in Schofield in limitation 1[A], but Schofield does not use “pattern recognition” to *detect* objects of interest or to make a determination as to a reflective surface (indeed, Schofield does not mention measuring reflectivity or any way of identifying a reflective nature among various light sources). But a POSITA would understand Schofield as only disclosing pattern recognition as part of its “spatial filtering” approach to identify that a particular light source is one which may be ignored, i.e. to *exclude* already detected light sources. *See, e.g.*, Ex. 1006, 10:35-11:12 (describing, for example, excluding “adjacent red and white light sources” as “not of interest as oncoming headlights or taillights,” and excluding objects that do “not occur in pairs” as headlights or taillights). Indeed, that is the only way that pattern recognition could plausibly work in the context of Schofield’s disclosures because Schofield teaches that detection of a point light source (i.e. the objects Schofield is configured to analyze) occurs via the pixel-by-pixel identification of particularly intense pixels of particular colors—e.g., strong intensity “red” or “white” (i.e. equally red, blue and green) pixels. *Id.*, at 4:62-5:11, 6:28-7:44.

115. Another difference between claim 1 and 9 is that claim 1 includes two “determine” limitations, the second of which—claim limitation 1[G]—“determine whether the reflective surface is a road marker based on an assessment of the reflective surface.” As discussed above in my opinions on claim construction, a POSITA would interpret this claim as requiring determining the presence of a reflective surface (i.e. limitation 1[F]) occurs prior to a separate step of determining whether it is a road marker (i.e. limitation 1[G]). However, Petitioner and Dr. Thorpe rely solely on Gallagher’s step (g) (paragraph [0066]) in their analysis of limitation 1[G]. Pet. at 40-41; Ex. 1003 ¶ 115. However, that is the same disclosure in Gallagher of identifying road markers based on “peak” responses in intensity data that Petitioner relies on for limitation 1[F] and 1[E]. As discussed, Gallagher’s single-step approach of detecting peak response is not consistent with the multi-step structure of this claim, including the “determin[ing]” step of limitation 1[G].

b) Limitation 1[H]: Neither reference discloses or suggests a computer configured to “determine a location of the road marker.”

116. Petitioner and Dr. Thorpe rely solely on Gallagher for this limitation. Pet. at 41; Ex. 1003 ¶¶ 116-117. Petitioner’s theory for this limitation is essentially as its alternative “Gallagher” theory for limitation 9[F]. *Compare id. with* Ex. 1003 ¶ 80. That theory fails for the same reasons discussed above in connection with limitation 9[F]. *Supra*, X.A.2.b. In particular, as discussed in claim 9[F], Gallagher logs GPS data and gearbox data *of the vehicle* at the time the road marker is detected,

which Gallagher uses as a rough approximate for the location of the road marker itself. Ex. 1003, [0020], [0048], [0063], Fig. 5. But that is not the location of a road marker, which can be anywhere in a 3m x 0.5m rectangle located 2.3m from the vehicle at the time the GPS or gearbox data is recorded. *Id.*, [0035]. Indeed, in connection with Ground 4, Petitioner and Dr. Thorpe admit that Gallagher’s “GPS position of the vehicle corresponds to the location of the active sensor” and “[a]ccordingly, a POSITA would have recognized that additional steps would have been necessary to also determine the location of the markers.” Pet. at 70; Ex. 1003 ¶ 176. Thus, Gallagher does not disclose or suggest this limitation.

5. Claims 2-4 and 8

117. Claims 2-4 and 8 depend from claim 1. ‘328 Patent, claims 2-4, 8. Because claim 1 is valid over the combination of Gallagher and Schofield, claims 2-4 and 8 are valid for the same reasons discussed above for claim 1.

B. Ground 2: Claims 15-16 of the ‘328 Patent Are Not Rendered Obvious by Gallagher, Schofield, and Frank

118. Petitioner contends, and Dr. Thorpe opines, that claims 15-16 of the ‘328 Patent are rendered obvious by the combination of the Gallagher, Schofield, and Frank references. As set forth below, I disagree.

119. Claims 15-16 both depend from claim 9, and thus I understand both of those claims contain all of the limitations of claim 9, in addition to the further limitations recited in each claim. Petitioner’s theory in Ground 2 for claims 15-16

as to the limitations of claim 9 appears to rely on Petitioner's theory in Ground 1 for obviousness over Gallagher and Schofield. Pet. at 47, 51; Ex. 1003 ¶¶ 131, 138 (mentioning only the "additional limitations" of claims 15 & 16). In particular, neither Petitioner nor Dr. Thorpe offers any argument that Frank cures any of the deficiencies I discuss above regarding Petitioner's proposed combination of Gallagher and Schofield with respect to claim 9. Accordingly, in my opinion, Petitioner's and Dr. Thorpe's obviousness theories in Ground 2 for claims 15 and 16 fail for all of the same reasons discussed above regarding claim 9 in Ground 1.

1. A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, and Frank in the Manner Claimed

120. In addition, in my opinion, Petitioner's theories in Ground 2 for the additional limitation of claims 15-16 also fail to demonstrate obviousness of those claims. In particular, Petitioner and Dr. Thorpe argue that A POSITA would have found it obvious to combine Frank's pulse-modulated light source (i.e. laser radar) with Gallagher to determine the distance to road markers, and then use that distance to calculate the observation angle to the road marker to ensure that Gallagher's intensity measurement (and calculation of retroreflectivity) occur when the observation angle is at the level required by road authority standards (e.g. 0.2°). Pet. at 49-50; Ex. 1003 ¶¶ 135-137. In my opinion, Petitioner's obviousness theory has a number of fatal flaws.

121. In my opinion, a POSITA would not be motivated to make Petitioner's proposed combination because of the problems of sensor fusion relating to incorporating such disparate types of systems, using very different sensors to achieve different goals. As discussed above in Ground 1, sensor fusion was a significant problem at vehicle speeds as of the 2001 time period. The proposed combination of Ground 3 proposes fusing three different types of data: (1) Gallagher's photodiode data; (2) Schofield's pixel-based data from its camera; and (3) the distance-and-angle data generated by Frank's laser radar system. Adding an additional type of sensor only exacerbates the problems I discuss above in Ground 1. As discussed, Gallagher focuses on assessing the quality and integrity of passive road markings through controlled illumination and reflection analysis algorithms for an area 2.3m ahead of the vehicle. However, Frank's system is designed for active vehicle guidance by detecting and precisely locating discrete retroreflector elements near the roadway at much further distances to determine roadway curvature.

122. In particular, a laser radar system (as used in Frank) is a very precise measurement system—precisely measuring the distance and angle from an point illuminated by a laser. By comparison, Gallagher's photodiode array is imprecise in that each photodiode provides a single intensity measurement, despite each sensor covering a wide portion of the field of view (i.e. depending on embodiment, 1/5 or 1/10th of the 3m x. 0.5m FOV area of Gallagher's area). Ex. 1005, [0035], [0038];

see also Ex. 2026, 133:8-11 (In Gallagher, “You may not know exactly where it is left and right because of the size of the field of view of the sensor, and that will have some effect on the observation angle.”). Thus, the only way Gallagher can work is by assuming that the “peak” result will be the result at the correct observation angle—i.e. when the road marker’s retroreflective surface is perfectly aligned to the photodiode to ensure maximum intensity of reflected light. Ex. 1005, [0040]-[0041], [0067]. Petitioner and Dr. Thorpe’s proposed combination would require ignoring the peak result of Gallagher’s photodiodes and instead looking at a result when calculations based on the laser radar result indicate exactly a 0.2° observation angle. But given the order-of-magnitude difference in polling rates between Frank’s 100 KHz scanning rate (Ex. 1007, 13:25-31) and Gallagher’s 10 kHz sampling rate (Ex. 1005, [0047]), that is not feasible—there would be many laser radar samples for each of Gallagher’s samples, so it would not be possible to ensure that a particular one of Gallagher’s intensity measurements lined up to the 0.2° observation laser radar sample (especially since observation angle changes significantly the closer the road marker gets to the vehicle). And increasing Gallagher’s sampling rate would only increase noise, i.e. random fluctuations in the photodiode results. Ex. 1005, [0057].

123. Moreover, the modulation required for Frank’s laser would likely interfere with Gallagher’s intensity measurements in ways unlikely to be resolved by Gallagher’s simple multiplicative calibration scheme could address. In short,

neither Dr. Thorpe nor Petitioner articulate any plausible way that Frank’s laser radar system could improve Gallagher’s system. Nor do they articulate any reason why the significant computational and hardware costs by adding Frank’s laser radar system to Gallagher would be outweighed by benefits in improved accuracy of calculating retroreflectance.

2. Claim 15: The proposed combination does not disclose or suggest “the computer processing system is further configured to determine exemplary angular displacements of incident light for each light intensity measurement from a reference position relative to the field of view as part of the assessment of the discrete location of the road marker within the field of view.”

124. In addition to my opinions regarding motivation to combine, it is also my opinion that the cited disclosures of the references, as proposed to be combined by Petitioner and Dr. Thorpe, do not practice the additional limitation of claim 15 or otherwise disclose or suggest its limitations.

a) Petitioner fails to articulate how the proposed combination’s determination of exemplary angular displacements are “as part of the assessment of the discrete location of the road marker within the field of view”

125. Petitioner and Dr. Thorpe appear to entirely ignore the language of claim 15 (and thus claim 16, which depends from claim 15), that the determination of exemplary angular measurements is performed “as part of the assessment of the discrete location of the road marker within the field of view.” Indeed, neither Dr. Thorpe nor Petitioner provide any explanation for how their proposed combination

satisfies this claim language. To the contrary, their theory—ensuring that Gallagher’s intensity measurements are made at the appropriate observation angle—only requires determining the relative distance between the marker and Gallagher’s vehicle, not the location of the marker in the field of view.

126. Moreover, Petitioner and Dr. Thorpe provide no explanation for how their theory for claim 15 relates to their theory for limitation 9F of claim 9, which recites the “determine an assessment of a discreet location of the road marker within the field of view” that provides the antecedent basis for claim 15’s “as part of the assessment of the discrete location of the road marker in the field of view.” That is, claim 15 requires the determination of exemplary angular displacements be performed as part of the determination of location within the field of view of limitation 9F. However, neither of Petitioner’s two theories for limitation 9F have any apparent connection to their theory for claim 15.

127. In particular, Petitioner’s primary theory for limitation 9F is that a POSITA relies on Schofield’s division of “the scene forward of the vehicle into spatially separated regions” and “pattern recognition.” Pet. at 23; Ex. 1003 ¶¶ 76-79. However, Petitioner’s theory for claim 15 does not even mention Schofield, other than a brief mention to argue that a POSITA could use Schofield’s camera array to receive Frank’s laser radar data. Pet. at 47-51; Ex. 1003 ¶¶ 131-137. Thus, neither Petitioner nor Dr. Thorpe articulate any reason how or why a POSITA would

have combined Frank’s determination of a distance (or the calculation of an observation angle using that distance) as part of Schofield’s headlight/taillight recognition or division of the scene “into spatially separated regions.” Ex. 2026, 128:10-22 (“it’s not bringing Schofield into the main analysis of claim 15”). Moreover, in my opinion, there is no apparent reason to do so—Schofield’s headlight/taillight recognition and separation of the scene into spatially separated regions is part of Schofield’s pixel-by-pixel analysis, which has no apparent use for distance or observation angle.

128. As to Petitioner’s secondary theory for limitation 9F—Gallagher’s GPS and gearbox data—as discussed above, that is the location of Gallagher’s vehicle, not a location *within* a field of view. *Supra* X.A.2.b, X.A.4.b. Petitioner and Dr. Thorpe present no theory for how Gallagher’s GPS and gearbox data could be combined with Frank’s distance measurements (or a resulting observation angle determination) to determine the location of a road marker within the field of view, or why a POSITA would be motivated to do so.

b) The proposed combination does not, for a particular road marker, “determine” multiple “exemplary angular displacements” “for each light intensity measurement from a reference location”

129. Petitioner and Dr. Thorpe also ignore that the claim recites determining multiple “exemplary angular displacements” (plural) “*for each light intensity measurement from a reference location*” as part of the determination of the discrete

location of one road marker in the field of view. This is illustrated in preferred embodiment of Fig. 10 of the '328 Patent and described in the accompanying text. Ex. 1001, Fig. 10, 14:14-15:46. In particular, the '328 Patent describes that because observation angle is not zero in the real-world, and because real-world materials experience beam divergence, estimated retroreflectivity values may be different at different locations along a ray from the road marker. *Id.*, 13:45-49, 14:6-13. Additionally, entrance angle (Fig. 12, item 160)—the angular displacement of the incident light relative to the normal vector from the sign's surface—also affects retroreflectivity measurements. Ex. 1001, 5:19-23, 7:43-64, Fig. 12. However, by knowing a sign's normal vector (Fig. 12, item 180)—e.g. what angle a sign is pointed at with respect to the roadway—one can reliably extrapolate the retroreflectance values for different points along the roadway than the ones actually measured. *Id.* at 5:1-11, 15:29-46, Figs. 9, 10. This allows accurate calculation of retroreflectance values for any potential observer location using data collected in a single vehicle pass in real-world circumstances. *Id.*; *see also* Ex. 2003 at pdf pg. 26 ('596 Prov. Apple, incorp. by reference at Ex. 1001, 1:22-27) (describing creating a “full 3D R_A profile” for a road marker using a “‘point cloud’ of data points”), at pdf page 29 (“the retroreflectivity calculation for a sign at a given point along the roadway does not require the acquisition vehicle actually occupy a particular portion of the roadway”).

130. Although a normal vector can be “assumed” if one assumes that signs are consistently aligned perpendicular to the roadway (i.e. the normal vector is parallel to the roadway), that assumption is not always correct. Ex. 1001, 14:18-22. Thus, in one embodiment, the ‘328 Patent teaches using a laser (i.e. laser radar) to calculate distances and angles from the road sign. *Id.* at 14:22-25, 14:32-51, 15:9-28. By using a scanner “fast enough ... to capture at least several individual discrete measurements across the object’s face surface,” the laser scanner produces many discrete locations on the road marker’s surface which, combined with the vehicle’s location and heading vector, can be used to determine the road marker’s normal vector. *Id.* at 15:19-28. However, the Frank reference contains no analogous disclosure of using a sufficiently fast laser radar system to take multiple angular displacement measurements for a single road marker from a single reference location—it does not even disclose if its laser radar is fast enough to do so. Nor does Petitioner nor Dr. Thorpe articulate any reason to combine the references so as to determine multiple exemplary angular displacements for a single light intensity measurement at a single reference location, as claimed. Instead, they articulate a proposed combination using *one* distance measurement from Frank’s laser radar system per each of Gallagher’s intensity measurements / locations down the road to identify the intensity measurement that is taken at a distance corresponding to the

specified 0.2 degree observation angle. Pet. at 50; Ex. 1003 ¶¶ 135-136. Thus, the proposed combination does not satisfy this aspect of claim 15.

3. Claim 16:

131. Claim 16 depends from claim 15 (which depends from claim 9). Petitioner and Dr. Thorpe present no separate arguments for claim 16. Pet. at 51; Ex. 1003 ¶ 138. Thus, their arguments for claim 16 fail for the same reasons discussed above for claim 15 and claim 9.

C. Ground 3: Claim 14 of the '328 Patent Is Not Rendered Obvious by Gallagher, Schofield, Frank and ASTM

132. Petitioner contends, and Dr. Thorpe opines, that claim 14 of the '328 Patent is rendered obvious by the combination of the Gallagher, Schofield, Frank, and ASTM references. As set forth below, I disagree.

133. Claim 14 depends from claim 9, and thus I understand it contains all of the limitations of claim 9, in addition to the further limitations recited in claim 14. Petitioner's theory in Ground 3 for claim 14 as to the limitations of claim 9 appears to rely on Petitioner's theory in Ground 1 for obviousness over Gallagher and Schofield. Pet. at 57; Ex. 1003 ¶ 150 (mentioning only the "additional limitations" of claim 14). In particular, neither Petitioner nor Dr. Thorpe offers any argument that Frank and/or ASTM cures any of the deficiencies I discuss above regarding Petitioner's proposed combination of Gallagher and Schofield with respect to claim 9. Accordingly, in my opinion, Petitioner's and Dr. Thorpe's' obviousness theories

in Ground 3 for claim 14 fails for all of the same reasons discussed above regarding claim 9 in Ground 1.

1. A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, Frank and ASTM in the Manner Claimed

134. Petitioner’s theory for combining Gallagher, Schofield, Frank, and ASTM in Ground 3 as to claim 14 relies on Petitioner’s theory for combining Gallagher, Schofield and Frank in ground 2, claim 15. Pet. at 57; Ex. 1003 ¶ 151. Thus, Petitioner’s theory in Ground 3 as to claim 14 fails the reasons discussed above regarding Claim 15 in Ground 2. In particular, the motivation to combine Gallagher, Schofield and Frank in a system to modify Gallagher to identify the intensity measurements corresponding to the 0.2° observation (as determined using calculations derived from the distance measurement of Frank’s laser radar) fail in this Ground 3 for the reason discussed above in Ground 2. *See supra* X.B.1. In particular, Petitioner and Dr. Thorpe provide no explanation why ASTM solves the problems I identify above with respect to the Gallagher-Schofield-Frank combination of Ground 2.

135. Also, like Ground 2, in Ground 3, Petitioner and Dr. Thorpe appear to entirely ignore the language of claim 14—which mirrors the language of claim 15—that the determination of entrance angle and observation angle of is performed “as part of the assessment of the discrete location of the road marker within the field of

view.” *See supra* X.B.2.a. As in Ground 2, in Ground 3, neither Dr. Thorpe nor Petitioner provide any explanation for how their proposed combination satisfies this claim language, or how their proposed combination relates to their theories for limitation 9F. Thus, those arguments fail for the same reasons discussed above in further detail in Ground 2 as to claim 15. Indeed, Petitioner’s theory in Ground 3 for claim 14 is even more problematic than their theory in Ground 2. In Ground 3, Petitioner argues a POSITA would have been motivated to measure an entrance angle because ASTM discloses that its minimum reflectance level standard depends on both observation angle and entrance angle. Pet. at 58-49; Ex. 1003 ¶ 152. However, that provides no reason to determine an entrance angle and an observation angle *as part of the assessment of the discrete location of the road marker* as claimed. *See* Ex. 2026, 143:10-144:20 (agreeing that, in proposed combination, “the entrance and observation angles are helping you determine the quality of the reflectivity of the retroreflector”, and interpreting “the assessment of the discrete location of the road marker,” to mean, “taking into account the location of the road marker, let's calculate” “entrance angle and observation angle”).

2. Claim 14: The cited prior art does not disclose or suggest “the computer processing system is further configured to determine an entrance angle”

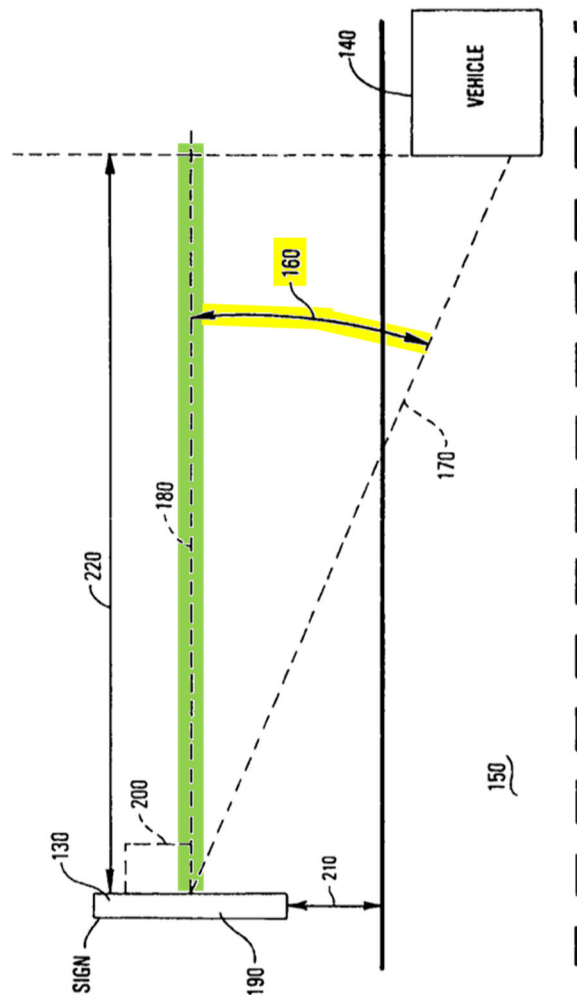
136. Petitioner and Dr. Thorpe points to Frank’s disclosure of the Frank’s determination of its angle α (alpha) as disclosing determining an entrance angle. Pet.

at 59; Ex. 1003 ¶ 154. However, angle α is not an angle “determined” by Frank’s system, and has nothing to do with an entrance angle. Rather, as Dr. Thorpe admitted at his deposition, angle α is the “scanning angle”—i.e. maximum angular sweep—of the laser in the embodiment of Frank using a servo-controlled scanning laser that sweeps back and forth in a scanned area in the arc defined by angle α . Ex. 1007, Fig. 2A, 3, 5:22-40, 6:12-39. Indeed, Dr. Thorpe admitted this at his deposition. Ex. 2026 at 140:14-17

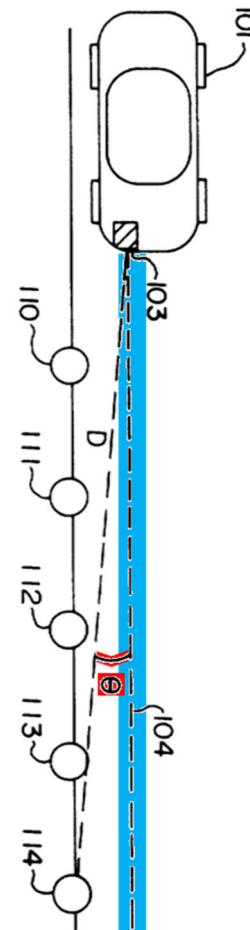
137. However, at his deposition, Dr. Thorpe attempted to change his theory to identify Frank’s angle θ (theta) as the entrance angle. Ex. 2026 at 140:14-17 (“I believe you may be correct that alpha may be the full sweep and I should, instead of using Figure 2A, should have used Figure 2 to indicate theta which is the angle to the retroreflector.”). However, if Petitioner were allowed to rely on such a theory, it would still fail to disclose or suggest the limitations of claim 14, as Frank’s angle θ is clearly not an entrance angle, as claimed.

138. In particular, as shown Figure 2 of the ‘328 Patent, an entrance angle (yellow) is the “the angular displacement of the incident light 170 relative to the normal vector 180 [green] from the object face surface 130.” Ex. 1001, Fig. 2A, 7:55-61 (emphasis added). By contrast, as shown in Frank’s Figure 12, angle θ (red) is the angle “formed between axis 104 [blue] and an imaginary line drawn between

vehicle 101 and a retroreflector,” i.e. the angle between the *vehicle’s normal vector* and angle of incident light on the retroreflector. Ex. 1007, 4:37-42.



Ex. 1001 ('328 Patent), Fig. 2. (annotated)



Ex. 1007 (Frank), Fig. 12 (annotated & rotated)

139. In short, these are two entirely different angles which measure deviation from two entirely different normal vectors (the normal vector of the sign versus the normal vector of the vehicle). Indeed, the '328 Patent itself uses a “scanning laser,” (i.e. laser radar), which, like Frank’s laser radar system, provides “both distance and direction of the measured point.” ‘328 Patent, 15:16-17. However, the ‘328 Patent

correctly recognizes that a reading output from the scanning laser is insufficient on its own to determine either the entrance angle or the normal vector of the sign. ‘328 Patent, 15:23-28. Instead, it requires “the lateral series of discrete locations” of the sign, and “triangulation methods [] used to combine: (i) the vehicle location, (ii) vehicle heading vector, and (iii) scanned sign point[s].” *Id.*

140. Indeed, those two measurements—the ‘328 Patent’s entrance angle and Frank’s angle θ —are only convertible using geometry when the vehicle and the sign happen to be at certain orientations, such as when the vehicle is driving perfectly straight down a straight segment of road and the sign is perfectly perpendicular to the road. But, as the ‘328 Patent teaches, that would simply be *assuming* the angles—the whole point of actually *determining* the entrance angle, as recited in claim 14, is because road signs are often not so perfectly aligned. Ex. 1001, 7:55-61, 14:16-22, 15:23-46; Ex. 2003, pdf. pp. 26-27, 50 (Fig. 14). Thus, in my opinion, the cited prior art references neither disclose nor suggest determining an entrance angle.

D. Ground 4: Claims 5-7 of the ‘328 Patent Are Not Rendered Obvious by Gallagher, Schofield, Leonard, and Popovich

141. Petitioner contends, and Dr. Thorpe opines, that claims 5-7 of the ‘328 Patent is rendered obvious by the combination of the Gallagher, Schofield, Leonard, and Popovich references. As set forth below, I disagree.

142. Claims 5-7 all depend (directly or indirectly) from claim 1, and thus I understand they contain all of the limitations of claim 1, in addition to the further limitations they recite. Petitioner's theory in Ground 4 for claims 5-7 as to the limitations of claim 1 appears to rely on Petitioner's theory in Ground 1 for obviousness over Gallagher and Schofield. Pet. at 69; Ex. 1003 ¶ 175, 180 (mentioning only the "additional limitations" of claim 14). In particular, neither Petitioner nor Dr. Thorpe offers any argument that Leonard and/or Popovich cure any of the deficiencies I discuss above regarding Petitioner's proposed combination of Gallagher and Schofield with respect to claim 1. Accordingly, in my opinion, Petitioner's and Dr. Thorpe's' obviousness theories in Ground 4 for claims 5-7 fails for all of the same reasons discussed above regarding claim 1 in Ground 1.

1. Popovich is Not Analogous Art

143. I understand a POSITA would not be motivated to select a reference for combination if it is not analogous art. I understand a reference is analogous art to a subject patent (e.g. the '328 Patent) if either of two tests is met: (1) it is in the "same field of endeavor" of the subject patent; or (2) a POSITA would recognize that it is reasonably pertinent to the problem being solved in the claim of the subject patent, i.e. considering similarities and differences in structure and function, that prior art reference would logically have commended itself to the inventor's attention in

considering his problem. Applying these standards, in my opinion, Popovich is not analogous art to the ‘328 Patent, and particularly claims 5-7.

144. In particular, Popovich is not in the same field of endeavor of the ‘328 Patent. The ‘328 Patent is in “field of automated object recognition” and more specifically, identifying, measuring, and classifying road markers from a vehicle. Ex. 1001, 1:31-47, 3:51-4:30. By contrast, Popovich is in the field of “optical position sensing,” and in particular, head-position measurement for interactive television or software applications. Ex. 1010, 1. Dr. Thorpe argues that Popovich and the ‘328 Patent are both in the field of “automated object recognition.” I disagree that that is the name for a particular field, but in any event, Popovich does not practice object *recognition*. In particular, Popovich makes no effort to identify any particular type of object as distinguished from any other object—it solely attempts to compute the position of a particular target without any attempt of figuring out what that target is. Ex. 1010, 1-4. Indeed, because Popovich’s system operates in a relatively static environment with one-predetermined target that is custom designed to work in Popovich’s system, Popovich has no need for object recognition. *Id.*, 6, Fig. 1, 3. By contrast, claim 1 of the ‘328 (from which claim 5 depends), actually emphasizes object recognition, i.e. “determine whether the reflective surface is a road marker.” Ex. 1001, cl. 1.

145. Additionally, in my opinion, a POSITA would not find Popovich reasonably pertinent to the problems addressed by the '328 Patent. In particular, given the significant differences in structure and function of Popovich, a POSITA would not find Popovich to be pertinent. In particular, Popovich is designed to operate with a target mounted at a user's head in front of a television or computer, which is at comparatively *very* close distances from Popovich's light sources and camera. Ex. 1010, 1-4. Moreover, the cited embodiments of Popovich require light sources that are *angled* to converge to produce a relatively small, illuminated volume of space at a specific, close distance in which it can perform position detection. Ex. 1010, 6-7, 9-10, Fig. 1, 3. A POSITA would recognize that, to work, Popovich's approach requires the light sources to be of sufficiently large laterally spaced distance as compared to the distance of the object from the light sources, to ensure that the cameras and light sources are somewhat orthogonal (i.e. you need to see two sides of the person's head). *Id.* But a POSITA would recognize that, in trying to identify road markers on a highway (as recited in claim 1), given the curving nature of roads, it would be impossible to consistently ensure that two light sources were angled to be targeted to converge in a specific volume as identified by Popovich such that the light marker would be in the volume. Indeed, even attempting to have the system designed so that two light sources could converge to form a volume of sufficient size at distances relevant to highway-measurement of signs would require

the light sources to be laterally spread so far apart that they would be impractical to be used on a vehicle on a roadway, as recited in claim 1. In short, a POSITA would recognize that Popovich's methods were specific to the very controlled, and very close distances of a human-computer-interaction environment as opposed to the messy and spread out real world of vehicles on roadways, which is where the problem addressed by the '328 Patent arises.

2. A POSITA Would Not be Motivated to Combine the Teachings of Gallagher, Schofield, Leonard, and Popovich in the Manner Claimed

146. Petitioner argues that a POSITA would be motivated to combine Leonard's sub-field approach for expanding a field of view of a sensor to expand Gallagher's "Area A" to use a wider FOV and thereby simultaneously measure multiple markers at once. Pet. at 65-67; Ex. 1003 ¶¶ 166-168. Additionally, they further argue a POSITA would be motivated to use Popovich's technique for triangulating a retroreflector in space using a light detection device that receives light from two spaced beams to improve the detection of the location of the marker in that expanded field of view to "improve the accuracy of the determined location for each marker." Pet. at 67-69; Ex. 1003 ¶¶ 171-172. Petitioner's motivation to combine theories suffer from several fatal flaws.

147. As a threshold issue, Petitioner does not mention Schofield at all in their motivation to combine analysis, despite the fact that Schofield is part of the proposed

combination in Ground 4. Pet. at 2, 61; Ex. 1003 at p. 93 (identifying combination as “Gallagher, Schofield, Leonard, and Popovich”), ¶¶ 165-179 (not discussing Schofield). Also, notably in claim 1 (from which claim 5 depends), Petitioner argues that a POSITA would be motivated to use Schofield and its camera-based approach to provide improved identification of objects of interest. Pet. at 38-39; Ex. 1003 ¶ 103. But in Ground 4, they argue that Popovich and Leonard would be combined to improve detecting, locating, and measuring road markers. Pet. at 64; Ex. 1003 ¶ 165. And in Ground 1 in claim 9, they argue that Schofield is capable of identifying the location of road markers in a field of view. Pet. at 23-26; Ex. 1003 ¶¶ 76-78. Thus, this raises the question of how the additional modifications based on Leonard and Popovich providing benefits to the Gallagher-Schofield combination beyond what Schofield already provides. Neither Petitioner nor Dr. Thorpe answer that question in the Petition, and Dr. Thorpe was unable to provide a meaningful explanation at his deposition. Ex. 2026 at 164:16-165:21 (“I do not think it necessary to bring Schofield in at this point”). Thus, the proposed combination of Ground 4 seems to be nothing more than using hindsight to map the limitations of claim 5 to arbitrary combinations of references with similar sounding terms.

148. Moreover, Petitioner’s proposed modification of Gallagher would actually harm Gallagher’s operation. In particular, the premise of Petitioner’s argument is that it would be beneficial to expand Gallagher’s FOV “to

simultaneously detect and measure the reflectivity of multiple road markers at once.” Pet. at 65-66; Ex. 1003 ¶¶ 166, 168-169. But, that would render Gallagher inoperable. As discussed, Gallagher functions by using a photodiode array to sweep a strip of road ahead of the vehicle, and by identifying the peak responses of light intensity measured by that array as corresponding to the presence of road markers, and then using a multiplicative factor to convert those light intensity measurements into a measure of retroreflectance. Ex. 1005, [0015]-[0018], [0038]-[0039], [0066]-[0068]. A POSITA would understand that Gallagher’s 0.5m FOV would be designed to ensure that only one road marker is within the FOV, given that Gallagher teaches that markers are usually spaced 5-20m apart. *Id.*, [0034], [0035]. By expanding Gallagher’s FOV to include multiple road markers in, Gallagher’s photodiodes would be receiving light from multiple road markers and thus Gallagher would not be able to accurately measure the retroreflectance of individual road markers (its entire purpose).

149. Finally, as discussed above in connection to whether Popovich is analogous art, a POSITA would recognize that Popovich’s system—which uses a relatively static environment at the close distances of human-computer interaction (e.g. on the order of a few feet)—would be entirely inapplicable to the messy, real-world measurement of road markers on a non-linear roadway at roadway speeds and distances (e.g. the expanded FOV located 2.3m+ away from Gallagher’s vehicle in

the proposed combination). Ex. 1005, [0035]; Ex. 1010, 1 (describing the system tracking of the viewer's head "in front of a video display screen.").

3. Claim 5: The Cited Prior Art Does Not Disclose or Suggest "comparing the light vector to one of a plurality of predetermined vectors based on a light source angle characterization"

150. In my opinion, Petitioners also fail to show that any of the references disclose or suggest this limitation. Rather than citing any such disclosure or suggestion, Petitioner and Dr. Thorpe only present the conclusory argument that "[b]ecause the intensity of the light source varies relative to its heading, a POSITA would have found it obvious to compare the determined light vector to one of a plurality of predetermined vectors based on a light source angle characterization." Pet. at 71; Ex. 1003 ¶ 178. However, they do not attempt to cite any prior art as creating a plurality of predetermined vectors based on a light source angle, or comparing those vectors to another vector, or make any non-conclusory argument that such a technique was even known or apparent.

151. Petitioner and Dr. Thorpe do cite to Popovich's "angular intensity distribution profile" (*id.*), but Popovich's angular intensity distribution profile is not and does not contain a plurality of predetermined vectors, nor does Petitioner or Dr. Thorpe present any argument that it does. Instead, as Dr. Thorpe admits, Popovich's angular intensity distribution profile is simply a graph of light intensity in the Y-axis versus angle of illumination in the x axis. Ex. 1003 ¶ 162 (citing Ex. 1010, 5, 10,

Fig. 3a). Moreover, Popovich does not disclose, suggest or mention comparing *anything* to its angular intensity distribution profile to any vector. Instead, it simply describes its angular intensity distribution profile to describe the properties of a light source needed to make its invention work. Ex. 1010 at 10 (requiring one of the light sources to have a “uniform angular intensity” as shown in Fig. 3b and the other to have a non-uniform symmetrical profile” as shown in Fig. 3a).

152. Petitioner and Dr. Thorpe do point to Popovich’s statement that “[b]y measuring the position in the matrix of the sensor(s) of the peak of the spot’s intensity profile or, in the case of a spot having a flat topped profile, its centroid and using the known orientation in space of the sensor camera it is possible to define a ray vector that passes through the center of the retroreflector.” Pet. at 63; Ex. 1003 ¶ 171, Ex. 1010, 6-7. However, the “intensity profile” referenced there is not the angular intensity distribution profile of the *light*, it is the 8-bit (i.e. 256 value) grey level values output by the *sensor* a spot observed on a camera (or similar 2D sensor) that corresponds to Popovich’s head-mounted retroreflector. Ex. 1010, 6-7 (“the sensor image is formed on a two-dimensional array of photodetectors” “spot intensity is characterised in terms of a number of grey levels - typically up to 256.”). That is, the ray is identified as simply corresponding to the spot with the greatest intensity (or where the spot on the intensity map has relatively equal intensity throughout the spot—i.e. a “flat topped profile”—it is the centroid—i.e. the center

of the spot). *Id.*; *see also id.* at 7 (“The determination of the spot position in this embodiment is carried out by electronic circuitry 24,25 associated respectively with optical heads 1,2 and which each automatically locates the peak intensity in the matrix of associated sensor 20 by searching for the maximum intensity along each line of data in a frame as it is read out of that sensor.”) Said simply, Popovich is just teaching that the location of the center of a retroreflector can be determined by identifying a bright spot in a camera, and that such center defines a line from the reflector to the camera. *Id.* at 6-7.² That has nothing to do with this claim limitation—which requires already having a light vector and comparing it to a plurality of vectors based on a light source angle characterization.

4. Claim 5: Petitioner improperly combines the incompatible disclosures of distinct embodiments of Popovich without explanation or a motivation to combine

153. Notably, throughout their arguments for claim 5, Petitioner and Dr. Thorpe are citing to and combining incompatible disclosures of distinct embodiments of Popovich without explanation or a motivation to combine, which I understand to be legally improper. In particular, Popovich’s disclosure of “measuring the position in the matrix of the sensor(s) of the peak of the spots intensity profile ... to define a ray vector that passes through the center of the

² Popovich then discloses using such ray from each of the two cameras to calculate head position in 3D space, i.e.. that the two orthogonal 2D grids from each of the cameras can define the location of the reflector 3D space. Ex. 1010, 7.

retroreflector 3” comes from Popovich’s first embodiment (illustrated in Fig. 1), which uses two cameras and two light sources to measure light intensity. Ex. 1010, 6-7 (cited by Ex. 1003 ¶ 163, 171, 177). However, Popovich’s disclosure of the “angular intensity distribution profile” comes from Popovich’s “third embodiment” (illustrated in Fig. 3) which uses two pairs of light sources, with one source in each pair having a different wavelength and angular intensity distribution profile from the other source, and where pairs of single element detectors (i.e. photodiodes) are configured to only measure such wavelength. Ex. 1010, 9-11. Popovich expressly states that this third embodiment *does not use* the disclosure on page 7 of the first embodiment which Petitioner and Dr. Thorpe cite and rely on. Ex. 1010, 10 (“Unlike the aforementioned embodiments in which sensors 20 determine the trajectory of light 19, 23 reflected from retroreflector 3 by the position of ‘spots’ formed on the sensors, in this embodiment the sensors 200 measure the intensity of incident light” as “[t]he received intensity will be a function of the angular bearing with respect to each light source 5A, 5B and the distance of the retroreflector 3 from each light source.”). This further emphasizes that Popovich does not contain the disclosure that Petitioner and Dr. Thorpe ascribe to it.

XI. CONCLUSION

154. I currently hold the opinions that I have expressed in this declaration. However, my analysis may continue, and I may acquire or receive additional information or insights that may result in revised or supplemental observations or opinions.

155. I understand this declaration will be used as evidence in a contested case before the PTAB.

156. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 or Title 18 of the United State Code, and that such willful false statements may jeopardize the validity of the '328 Patent.

I declare under penalty of perjury that the foregoing is true and correct.

Executed: June 17, 2025



Dr. Nikolaos Papanikolopoulos