

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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MOBILEYE GLOBAL, INC.,  
Petitioner

v.

MANDLI COMMUNICATIONS, INC.,  
Patent Owner

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IPR2024-01110  
U.S. Patent No. 9,335,255 B2

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

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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 IPR2024-01110 (“IPR”), filed by Petitioner Mobileye Global, Inc. (“Mobileye” or “Petitioner”). I understand that this IPR proceeding involves U.S. Patent No. 9,335,255 (the ‘255 patent) and that the remaining challenged claim is claim 15 (the “Challenged Claim”).

2. I have been asked to provide my objective, independent analysis of the ‘255 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 '255 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 '255 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 ‘255 Patent, or the outcome of this IPR or any other matter involving the ‘255 Patent.

#### IV. MATERIALS CONSIDERED

20. In formulating my opinions, I have relied upon my training, knowledge and experience that are relevant to the ‘255 Patent. I have also considered the ‘255 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 rehearing petition, the Board’s decision on Patent Owner’s rehearing petition, the asserted prior art references, and the declaration of Dr. Thorpe and the materials cited therein, and the deposition transcripts of Dr. Thorpe in this IPR and co-pending IPR IPR2024-01110. 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                                                                                                                                                                                                                  |
| 2009        | National Institute of Standards and Technology, “Redefinition of ‘Candela,’” <i>available</i> at <a href="https://www.nist.gov/si-redefinition/candela">https://www.nist.gov/si-redefinition/candela</a>                                                      |
| 2010        | International Commission on Illumination, Standard. No. CIE S 017:2020 ILV: International Lighting Vocabulary, 2nd edition., entry no. 17-21-050, <i>available</i> at <a href="https://cie.co.at/eilvterm/17-21-050">https://cie.co.at/eilvterm/17-21-050</a> |
| 2011        | Excerpts from Stefanov, Konstantin D. CMOS Image Sensors. Bristol, UK: IOP Publishing, 2022.                                                                                                                                                                  |
| 2012        | Ang, Bernard, Keysight Technologies, “How to Achieve Accurate Sensor Characterization Using a Digital Multimeter”                                                                                                                                             |

|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|      | (Feb. 21, 2019), <i>available at</i> <a href="https://www.keysight.com/blogs/en/tech/bench/2019/01/24/how-to-achieve-accurate-sensor-characterization-using-a-digital-multimeter">https://www.keysight.com/blogs/en/tech/bench/2019/01/24/how-to-achieve-accurate-sensor-characterization-using-a-digital-multimeter</a>                                                                                                                                                                                                    |
| 2013 | Steely, Sidney L., H. S. Lowery III, and R. H. Fugerer. "Laser-based direct-write scene generation methods for closed-loop focal-plane-array diagnostics." Technologies for Synthetic Environments: Hardware-in-the-Loop Testing. Vol. 2741. SPIE, 1996.                                                                                                                                                                                                                                                                    |
| 2014 | Collins Dictionary Entry for "profile," <i>available at</i> <a href="https://www.collinsdictionary.com/us/dictionary/english/profile">https://www.collinsdictionary.com/us/dictionary/english/profile</a>                                                                                                                                                                                                                                                                                                                   |
| 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> , <a href="https://www.oxfordreference.com/display/10.1093/oi/authority.20110803100324432?p=emailAIVd1F/alp5o2&amp;d=/10.1093/oi/authority.20110803100324432&amp;print">https://www.oxfordreference.com/display/10.1093/oi/authority.20110803100324432?p=emailAIVd1F/alp5o2&amp;d=/10.1093/oi/authority.20110803100324432&amp;print</a>                                                                           |
| 2028 | National Institute of Standards and Technology, OSAC Lexicon, Definition of "Lux," <i>available at</i> <a href="https://www.nist.gov/glossary-term/26871">https://www.nist.gov/glossary-term/26871</a>                                                                                                                                                                                                                                                                                                                      |
| 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 at</i> <a href="https://www.researchgate.net/publication/3090945_Characterization_and_Calibration_of_a_CCD_Detector_for_Light_Engineering">https://www.researchgate.net/publication/3090945_Characterization_and_Calibration_of_a_CCD_Detector_for_Light_Engineering</a> |

21. In particular, I have reviewed Patent Owner Exhibit Nos. 2009-2014, and 2027-2029. As noted above, each of those exhibits are publications or web pages relating to the meaning of certain terms. 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. A party challenging the validity of a patent claim in an IPR must present a preponderance of the evidence to demonstrate invalidity.

### **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 ‘255 Patent, which I refer herein as a “POSITA.”

56. I understand that, for the purposes of proceeding, the ‘255 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 ‘255 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). None of my opinions herein would change if the ‘255 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 7; Ex. 1003 ¶ 33. 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 '255 PATENT

59. The '255 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 '255 Patent generally relates to recognizing road markers—which can include road signs or pavement markings—using a video camera. Ex. 1001 ('255 Patent), Abstract. As the '255 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 1:61-2:4. 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 2:5-12. Thus, highway and street maintenance departments would desire 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 2:12-18. But the '255 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 '255 Patent identified 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 reflectiveness of 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 3:60-4:10. 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 4:12-17, 8:53-9:13, 12:1-36, cl. 12.

## **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 sensor 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.

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 to 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.* 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 are so as to establish a cutoff where anything below the cutoff reflects no marker being 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.

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. John J. Lumia, A Mobile System for Measuring Retroreflectance of Traffic Signs, Optics, Illumination, and Image Sensing for Machine Vision V, Donald J. Svetkoff, Editor, Proc. SPIE 1385, pp. 15-26 (1991) (“Lumia”, Ex. 1014).**

68. Lumia is directed to a system for evaluating the nighttime visibility of traffic signs via a system in a car moving at highway speeds. Ex. 1014, 15-17. In particular, it uses a vehicle with a CCD (charge-coupled device) video camera, a

xenon camera flash (e.g., like would be associated with still photography), a laser range finder, and a computer. *Id.* While driving along the road, a human operator manually aims the video camera at a target sign, and when a range finder determines that the camera is within a predetermined distance to the sign, a gray-scale image is automatically taken from the video camera using a frame grabber. *Id.*, 15, 17-20. Images are manually annotated by the operator with the sign type, and stored on a hard drive for analysis “at the end of the run.” *Id.*, 18, 20.

69. The image from the frame is then passed to a computer, which uses software to “extract the sign image,” i.e. it automatically crops (or what Lumia calls “thresholding”) the image so that the sign is essentially the only thing in the cropped image, as shown in Fig. 3(a). Ex. 1014, 16-17, 24. Next, the software creates a histogram of the gray scale image, where the histogram’s bins correspond to the each of the 256 different 8-bit grayscale values possible in the image (i.e. 0 to 255) and each pixel in the image corresponds to one data-point in the histogram. *Id.*, 16-17, 24. Lumia teaches that the histogram is expected to have three peaks. *Id.*, 17. One peak corresponds to the sign surround (i.e. the part of the image that are not part of the sign itself). *Id.* One peak corresponds to the sign’s legend—the typically brighter part of the sign, which is the relatively smaller portion of the sign’s area, (e.g. the white “STOP” text on a stop sign). *Id.* And finally, one peak corresponds to the

sign's background—the largest area of the sign, typically less bright than the legend (e.g. the red part of the stop sign). *Id.*

70. Lumia's software automatically excludes the sign surround by ignoring the first four bins in the histogram (i.e. the darkest areas of the image). Ex. 1014, 17. Then the software identifies the largest remaining peak in the histogram as corresponding to the sign's background, and the next largest peak of brighter values as corresponding to the sign's legend. *Id.* Finally, the portions around each peak are averaged to create an average 8-bit value for the sign background and an average 8-bit value for the sign's legend. *Id.* Notably, throughout the entire process of creating and analyzing the histogram, the 8-bit gray level values remain *intensity* values, i.e. corresponding to how much light intensity was received on a single element of the camera's sensor. *See, id.* at 15 ("histograms of the retroreflected intensity distribution are exploited to yield average legend and background values).

71. The last steps in Lumia convert the 8-bit gray level intensity values for the sign background and legend into coefficients of retroreflection values. Ex. 1014, 24. In particular, Lumia describes that a calibration procedure is performed prior to the analysis portion of the system's operation. *Id.* That calibration is performed on a single "image of a calibrated white sheeting material." *Id.* Moreover, because Lumia's system is centered around ensuring images are taken at a specific distance (i.e., triggering the image capture when the laser range finder is at the pre-specified

distance), a POSITA would understand that calibration is performed at only at the single, specified distance where actual signs will be measured—in this instance, 200 feet. *Id.*, 24, 20.<sup>1</sup> The result of the calibration is a “scale factor,” which is multiplied by the 8-bit gray level intensity values for the sign background and legend to provide coefficient of retroreflection (i.e.  $R'$ ) values for the sign background and legend. *Id.*, 24.<sup>2</sup> Because the scale factor is simply multiplied by the 8-bit grey level intensity values to create the  $R'$  values, a POSITA would understand that, during the calibration process, the scale factor is created by dividing the known retroreflectivity value of the calibrated white sign by the 8-bit grey levels measured from that the sign by the same video camera using the same flash, etc. Lumia discloses that, in

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<sup>1</sup> Notably, although Lumia describes a 200 foot highway mode and a 100 foot local mode, it does not describe or discuss a calibration procedure which can handle more than one distance at a time. Ex. 1014, 20, 24. Rather, a POSITA would understand that switching between highway mode and local mode would require the operator to manually change the laser range finder settings and run separate calibration procedures to create separate scale factors for each.

<sup>2</sup> Lumia discloses that coefficient of retroreflection is measured in candelas per footcandle per square foot. Ex. 1014, 16. However, it can also be measured in different units of the same type (e.g. switching to metric length or area measurements or switching between candelas and millicandelas).

static testing (i.e., not actually driving), its system obtained comparable results to existing hand-held retroreflectometer devices. *Id.*, 24-26.

72. Lumia discloses that its system operates using a number of principles that result in some degree of imperfect estimation and provide limitations on use. As noted, it requires an operator's manual targeting of signs. Ex. 1014, 20. And, to avoid the problem of ambient illumination throwing off readings, it suggests limiting measurement times to when the sun is above 20 degrees elevation. *Id.*, 22. Because the performance characteristics of different retroreflective materials respond to changes in observation angle differently, Lumia must use a tightly controlled distance window for capturing the image to attempt to ensure a 0.2 degree observation angle. *Id.*, 21. And Lumia simply ignores the effects of differing entrance angle as having limited effect by having that distance window sufficiently far away from the vehicle ("appreciable distances") to minimize the effect of changes in entrance angle. *Id.* Moreover, as discussed, Lumia relies on automatic cropping or thresholding software, which it explains can provide incorrect thresholding, resulting in erroneous results. *Id.*, 24.

73. Early in the Lumia reference, prior to the actual discussion of how Lumia's system operates, Lumia describes certain "Background" principles, including principles of retroreflection, types of retroreflective materials, and equations relating the coefficient of retroreflection into different properties. Ex.

1014, 16. In particular, Lumia includes equation (2), that relates the coefficient of retroreflection ( $R'$ ) to the quotient of luminance ( $L$ ) of the reflected light and the normal illumination incident on the retroreflector ( $E_n$ ). *Id.* However, Lumia does not describe a system that actually uses equation (2) or tries to calculate retroreflection in that way. Indeed, as discussed, Lumia's scale factor directly converts 8-bit grey level light intensity values into coefficient of retroreflection values, and thus Lumia never describes an automated system trying to measure, calculate, or determine luminance of the reflected light or the normal illumination incident on the retroreflector. Ex. 1014, 24.

74. As part of Lumia's background section, Lumia identifies background principles for how one can conceptualize calculating retroreflectance using a camera. Ex. 1014, 16. In particular, Lumia notes that:

“The use of a video camera effectively divides the FOV defined by the system magnification into smaller FOV's, thereby creating individual luminance meters at each sensing element site. In effect, the use of a video camera is a practical way for obtaining a large number of measurement samples from the sign so that representative legend and background retroreflectances may be calculated.”

Ex. 1014, 16. However, a POSITA would not understand this as disclosing or suggesting determining a luminance value. Rather, it is simply describing a background principle of how one can conceptualize the relationship between a

camera and the principles of equation (2). As noted by the word “effectively,” a camera is not actually a luminance meter.

75. Indeed, luminous intensity is a measurement of how bright something appears (i.e., the intensity of light in a specific direction) and is measured in candelas. Ex. 2009, 4 (“While ‘radiant intensity’ is the intensity of light without adjustments for human vision, luminous intensity is a ‘photometric’ unit that compensates for human visual sensitivity.”), 6 (“Using solid angles as part of the candela definition specifies light that shines in a particular direction”). It is distinguished from luminous flux, which is the total amount of light emitted by a source, irrespective of direction, and is measured in lumens (defined as one candela-steradian). *Id.*, 6 (“lumens, which tells you how much light it puts out in total—telling you its brightness in all directions”). Luminance is a measurement of the amount of light travelling per unit area in a given direction (e.g., how much light a surface emits), provided in units like candelas per square meter or candelas per square foot). Ex. 2010, 1-2. Illuminance is a measurement of how much light is received by a surface, regardless of the sources or direction of that light, and is provided in lux (defined as one lumen per square meter). Ex. 2028. Thus, a camera’s measurement of received light intensity does not determine a luminance value.

## IX. CLAIM CONSTRUCTION

### A. “a characterization profile of the at least one light intensity sensor” (’255 Patent, cl. 15)

76. Claim 15 recites, among other things “determining a luminance value utilizing the plurality of light intensity values and *a characterization profile of the at least one light intensity sensor.*” Petitioner and Dr. Thorpe map this limitation to Lumia’s “calibration.” Ex. 1003 ¶ 115; Pet. at 45. Lumia describes its calibration process as “accomplished by acquiring an image of a calibrated white sheeting material and computing a scale factor to convert the 8-bit digital gray levels of the calibration target image to R' values.” Ex. 1014, 24. A POSITA would understand that the scale factor depends on distance during the calibration, i.e. a scale factor created via static calibration at 200 feet would be applicable for operating the system in the 200 feet highway mode, and a separate scale factor created via a separate static calibration process would have to be created for the 100 foot local mode, although Lumia does not actually describe calibration for other distances. Ex. 1014, 24, 20. Different scale factors would be required for different distances, as Lumia teaches, retroreflectivity is inversely proportional to  $E_n$  (the normal illumination incident on the retroreflector) and  $E_n$  is inversely proportional to the square of the distance to the detector. Ex. 1014, 7. Thus, in my opinion, Petitioner’s application of the prior art to claim 15 requires determining the scope of “a characterization profile of the at least one light intensity sensor,” and in particular, whether a “characterization

profile” can simply be the calculation of a scale factor based on a single sample in a single set of conditions.

77. In my opinion, based on my background and experience, a POSITA reading claim 15 would immediately envisage the concept of “sensor characterization,” which is a well-understood concept in the field of sensors and computer vision. This is further confirmed by the specification of the ’255 Patent, which discloses “Using 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” (Ex. 1001 at 8:37-41) and that “Luminance (expressed in candelas per square meter, or  $\text{cd/m}^2$ ) will vary according to the intensity sensor characterization profile 275 of the light intensity sensor(s) 280 and the color of the material from which light is reflected” (*id.* at 10:65-11:3). Similarly, Fig. 7 of the ’255 Patent depicts “intensity sensor characterization 275” being used with “Background Intensity” values and “Foreground Intensity” values to, respectively, calculate “Background  $R_A$  [retroreflectivity]” and “Foreground  $R_A$  [retroreflectivity].” *Id.*, Fig. 7. Like the characterization profile of claim 15, these passages and figure describe and depict the light intensity sensor characterization 275 as being used to determine luminance values from light intensity values. Thus, they further confirm to a POSITA that the

“characterization profile” of claim 15 is intended to reflect the well-understood concept of sensor characterization.

78. Notably, it is well understood (and was at the time of the ‘255 Patent’s earliest priority date in 2001) that “sensor characterization” is the process of describing the properties and performance characteristics of a sensor across *various* conditions. Ex. 2011 at 10-11 (§5.1) (sensor characterization “aims to experimentally measure the parameters of the sensor under different operating conditions”); Ex. 2012 at 2-3 (“Sensor characterization is necessary to ensure a guaranteed level of readout accuracy over various operating conditions ... Manufacturers need to characterize the sensors they produce to analyze their dynamic range, linearity bandwidth, response time, noise and stability ... [to] allow[] users to know how to use sensors in their applications effectively.”); Ex. 2013 at 1-2 (describing developing “electro-optical sensor characterization and evaluation” as involving “[t]esting and evaluation (T&E) and modeling and simulation (M&S) of electro-optical sensor systems to assess their operational characteristics [and] their performance limits” and noting that “a sensor will generally have a particular set of important design and test parameters that characterize its operation, function, and performance”). In my opinion, the word “profile” is intended to indicate that the sensor characterization has been compiled into a set of characteristics presented in a format usable by the system of the ’255 Patent. *See, e.g.*, Ex. 2014 at 3 (defining

“profile” as, among other things, “5. a. a graph, diagram, piece of writing, etc. presenting or summarizing data relevant to a particular person or thing”).

79. Indeed, it is well-recognized in the field that calibration and characterization, while related, are distinct. For example, one could simply *calibrate* a CCD camera’s pixels to obtain a luminance value. Ex. 2029, 1 (“A camera calibration procedure gives for each pixel of the CCD array the value that links the A/D converter output with the luminance of the pixel-framed surface (luminance calibration coefficient).”). However, characterization goes beyond mere calibration to take into account various conditions:

The knowledge of the **calibration values is not enough** to obtain accurate measures **because several parameters could influence the pixel reading** in real measurement conditions (linearity, spectral sensitivity, dark frame, presence of saturated pixels, ghost images, etc.). ...

The calibration could be applied for **different camera conditions**, and the influence of each parameter on the device performance could be easily obtained ... This is a very time-consuming procedure: It is possible to reduce the **characterization** time by considering bigger groups of pixels, but, obviously, this brings lower accuracy.

Ex. 2029, 172.

80. Accordingly, I believe that the ordinary meaning, and the appropriate construction of “a characterization profile of the at least one light intensity sensor” is “**a compilation, presented in a usable format, of the description of the properties and performance characteristics of a sensor across various**

**conditions.”** In my opinion, that construction is also consistent with the ’255 Patent’s specification, which describes that “[t]he light intensity sensor characterization 275 is *empirical* information about the light intensity sensor 280 that is used to create the LUT 475.” Ex. 1001 (’255 Patent), 11:56-59. Notably, the ’255 Patent describes that, in a preferred embodiment, “look-up-table (LUT) 475” “is a digital table stored in memory that uses the indexes of intensity (a single gray level value from the intensity measurement 300) and sheeting color to determine the luminance.” *Id.* at 11:53-56. That is, because LUT 475 is designed to handle signs of various colors, a POSITA would understand that, in the preferred embodiment, light intensity sensor characterization 275 would have to describe the properties of the sensors under various conditions (e.g. measuring signs of various colors). This is further confirmed by the ’255 Patent specification’s statement that “light intensity sensor 280 characterization is essential for high precision computations since N photons of a given particular color (or wavelength) of light will represent a different gray value (intensity level) in the sensor than N photons of another color (or wavelength) of light.” *Id.* at 11:48-53. Thus, a POSITA would understand the specification as confirming the above construction of “a characterization profile of the at least one light intensity sensor.”

81. Additionally, the above construction is also consistent with the ’255 Patent’s specification’s use of the term “characterization” and “profile” for things

other than the light intensity sensor. For example, the specification describes “characterization profile of the light source” as including “[l]ight source angle characterization” “whereby empirical data from the light is modeled to establish the light intensity for *numerous* discrete vectors from the center of the light” and “light source color characterization” describing intensity at different wavelengths “throughout the visible spectrum.” Ex. 1001 (’255 Patent) at 12:9-51 (emphasis added), Fig. 8. That is, the *single* light intensity sensor characterization profile models the performance of the light sensor under *various* conditions.

82. I understand that Patent Owner advanced an explanation consistent with my above-described understanding of this term in its preliminary response. Paper 7 at 12. I understand that, in its pre-institution preliminary reply brief, Petitioner did not provide an express construction, but argued that a “characterization profile” includes “a histogram” “of collected data from sensors.” In my opinion, that is plainly incorrect. In particular, not all data collected from sensors is a “sensor characterization.” Rather, as noted in the documents I cited above, sensors collect data all the time—but a POSITA would not understand all sensor data to be a sensor characterization. Rather, data collected by sensors can be used for sensor characterization if they are collected in a particular way (i.e. under the various conditions adequate to describe the performance and properties of the sensor as required for the purpose at hand). Similarly, data collected by sensors can

be used to create a sensor characterization profile if they are organized in a way to be usable for achieving that purpose (i.e., to ensure sensor output is appropriately processed in various conditions despite non-uniform responses in how the sensor reacts to various inputs). However, that does not mean that every histogram created from sensor data is a sensor characterization.

83. I understand that, in its institution decision, the Board adopted a preliminary construction of “characterization profile” as “a conversion factor to convert measured light intensity into luminance.” Paper 16, 21 (citing Ex. 1001, 11:41-53, 11:53-56). I respectfully disagree with the Board’s preliminary construction. First, in my opinion, the Board’s construction improperly conflates the specification’s “look-up-table 475” with the specification’s “light intensity sensor characterization 275.” Because these are described in the specification as two different things, in my opinion, a POSITA would understand the terms to have different meanings. In particular, the specification describes “look up table 475” as converting “indexes of intensity (a single gray level value from the intensity measurement 300) and sheeting color” into “luminance.” Ex. 1001 (‘255 Patent), 11:53-56. By contrast, as noted, “light intensity sensor characterization 275 is empirical information about the light intensity sensor 280 that is used to create the LUT 475.” *Id.*, 11:56-59. Thus, the Board’s preliminary construction is consistent with how the ‘255 Patent’s specification describes “look-up-table 475,” rather than

“light intensity sensor characterization 275” (which is what a POSITA would understand as corresponding to the claimed “characterization profile”).

84. I understand that in its decision on Patent Owner’s request for rehearing, the Board concluded that “requir[ing] a single characterization profile to include values for multiple conditions ... is at odds with the disclosure of the ’255 patent.” Paper 20, 6. However, I respectfully disagree. In particular, in my opinion, a single profile including values for multiple conditions is fully consistent with the ’255 Patent’s specification, and in particular, Fig. 7. Most notably, in the preferred embodiment illustrated, Figure 7 of the ’255 Patent depicts the same sensor characterization “275” as being input into the same “Intensity LUT [look-up table]” (475) for both background RA and foreground RA, whereas a different sheeting color is identified for both foreground (506) and background (505). This is consistent with a single sensor characterization profile being created that can handle various different colors. Indeed, the specification’s description of the preferred embodiment only ever describes *one* sensor characterization profile 275, which is used to create look-up-table 475, despite the fact that look-up table 475 can handle various colors (*id.* at 11:53-56), and despite the fact that “characterization” of “light intensity sensor 280” is described as “essential” to address the sensor’s differential intensity responsiveness to *different* wavelengths of light (*id.* at 11:41-43, 11:48-53). In my opinion, the only conclusion a POSITA would read from these combined

disclosures would be that the '255 Patent's specification teaches that a single characterization profile must address various conditions.

85. The '255 Patent's specification does state that “By knowing the background or foreground color of the object of interest 460 along with the light intensity sensor's 280 ability to sense, or the light intensity sensor's 280 profile for a particular color, the intensity value 300 for a particular color can be converted into a luminance value.” '255 Patent, 11:43-48. However, a POSITA would understand “light intensity sensor's 280 profile for a particular color” as referring to, in the preferred embodiment, the portion of the profile relating to a particular color—rather than disclosing that each color had its own separate profile. Indeed, the visible spectrum includes a huge number of different colors, i.e. different wavelengths of light between about 400nm and 700nm. *See, e.g., id.*, Fig. 8. Accordingly, a POSITA would recognize that it would be impractical to create separate profiles to handle all the various colors that may be received by the light intensity sensors of the '255 Patent.

86. Thus, as explained above, I believe that the ordinary meaning, and the appropriate construction of “a characterization profile of the at least one light intensity sensor” is **“a compilation, presented in a usable format, of the description of the properties and performance characteristics of a sensor across various conditions.”**

**X. THE CHALLENGED CLAIMS OF THE '255 PATENT ARE NOT ANTICIPATED AND ARE NOT RENDERED OBVIOUS**

**A. Ground 2: Claim 15 of the '255 Patent is Not Rendered Obvious by Gallagher and Lumia**

87. Petitioner contends, and Dr. Thorpe opines, that claim 15 of the '255 Patent is rendered obvious by the combination of the Gallagher and Lumia references. As set forth below, I disagree.

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

88. Petitioner argues, and Dr. Thorpe opines, that “A POSITA would have found it obvious to implement Lumia’s determining a luminance value utilizing the plurality of light intensity values and a characterization profile of the at least one light intensity sensor to allow Gallagher’s apparatus<sup>3</sup> to calculate the retroreflectivity

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<sup>3</sup> Based on this statement, I understand Petitioner and Dr. Thorpe to be proposing, in this Ground, to use Lumia’s camera-based techniques with Gallagher’s photodiodes (which are part of Gallagher’s apparatus), and are not proposing not actually modifying Gallagher to use a camera. This was also confirmed by the Board’s decision in rehearing, which stated that “Petitioner proposes to use Gallagher’s array of sensors to measure luminance in the manner taught by Lumia.” Paper 20 (Reh’g. Dec.) at 7. This understanding was also confirmed by Dr. Thorpe’s deposition. Ex. 2025 at 56:7-9 (“in the combination proposed in [paragraph] 116, this is still using the Gallagher apparatus with the sensors pointing down.”)

of road markers” because “several road authorities specified minimum retroreflectivity values for road markings along a roadway” and that Lumia would help allow the apparatus “to identify and tag any markers “that do not meet the predetermined minimum acceptable reflectance level” for countries that require a minimum retroreflectivity level for road markers.” Ex. 1003 ¶116 (cited by Pet. at 46). In my opinion, this motivation to combine theory suffers from at least three fundamental flaws: (1) neither Petitioner nor Dr. Thorpe articulates any reason for combining the references so as to “determin[e] a luminance value,” as retroreflectivity is distinct from luminance; (2) Gallagher already provides a complete and adequate disclosure of how to calculate retroreflectivity which does not benefit from combination with Lumia’s disclosures; and (3) Lumia’s teachings are fundamentally inapplicable to Gallagher because of the fundamental differences in their systems.

**a) Neither Petitioner nor Dr. Thorpe articulates any reason for combining the references so as to “determin[e] a luminance value,” as opposed to retroreflectance values**

89. First, in my opinion, Petitioner’s motivation to combine theory fails because it provides no motivation whatsoever for a POSITA to combine Gallagher and Lumia in a manner that “determin[es] a *luminance* value” as recited by claim 15. In particular, Petitioner’s motivation to combine theory would only provide a motivation to create a system that results in calculating *retroreflectivity* values—but

“luminance” as recited in claim 15 is entirely distinct and different from retroreflectivity in general, as well as the specific retroreflectivity figures in Gallagher (i.e. Gallagher’s “reflectance level of the road marker in a value of millicandela per Lux (CIL) or as a percentage of the predetermined Standard reflectance level,” Ex. 1005, [0067) or Lumia (i.e. Lumia’s “Coefficient of Retroreflection, or R’, in units of candelas per footcandle per square foot,” Ex. 1014, 16.<sup>4</sup> The metric equivalent units would be candelas per lux per square meter. Indeed, at his deposition, Dr. Thorpe admitted that retroreflectivity and luminance “use different units” and did not dispute that they are different. Ex. 2025 (Thorpe 5-30-2025 Depo Tr.) at 39:10-20.

90. Additionally, neither Gallagher nor Lumia disclose determining luminance values as part of their process of their retroreflectivity calculations. As discussed in further detail above, in Gallagher, to determine whether a marker has adequate retroreflectivity values, Gallagher’s computer: (i) receives values from

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<sup>4</sup> The exhibit containing the Lumia reference (Ex. 1014) contains two sets of page numberings: (1) the original journal page numbering where the first page of the article starts on page 15, and (2) an additional set of page numberings apparently added to the document by Petitioner’s counsel, where the first page of the article starts on page 6 of 17. Ex. 1014, 15. Consistent with the apparent usage by Dr. Thorpe and Petitioner, I will use the original journal numbering herein when pin-citing to Lumia.

analog-to-digital converters connected to each of its photodiode light sensors (Ex. 1005, [0056], [0016]), (ii) averages the numeric values over a period of time to smooth out fluctuations (Ex. 1005, [0057]), (iii) multiplies the resulting average by a calibration factor (Ex. 1005, [0058], [0017]), (iv) identifies peak values above a non-marker reflectance level (Ex. 1005, [0065]-[0066]), and (v) compares the calibrated number value for a peak result with the “reflectance level” or CIL (coefficient of luminance intensity) permitted by the standard (Ex. 1005, [0067]-[0068]). A POSITA would not understand any of these disclosures as being consistent with determining a luminance value.

91. Rather, Gallagher’s photodiodes represent numeric light *intensity* values. Ex. 1005, [0039], [0046]-[0047], [0056]; Ex. 2027. Because steps h and i of Gallagher perform a comparison against “predetermined” acceptable reflectance level defined by CIL (coefficient of luminance intensity) in millicandela per lux, a POSITA would understand that the result of the calibration in Gallagher’s step c would similarly result in values in CIL (coefficient of luminance intensity) in millicandela per lux. Ex. 1005, [0057], [0067]-[0068]. That is, Gallagher discloses no further manipulation of the calibrated data values output by step c before the comparison with the predetermined standard / minimum acceptable reflectance level in steps h and i, and thus an apples-to-apples comparison (as would be needed to calculate a “percentage” in step h) would require the calibrated values to similarly

be values for of coefficient of luminance intensity in the same units. As is well established, coefficient of luminous intensity—which is what Gallagher calculates—is a measurement of *retroreflectivity* (usually expressed in units of candelas, or millicandelas, per lux per square meter, i.e.,  $\text{cd/lx/m}^2$ ), not luminance (usually expressed in candelas per square meter, i.e.,  $\text{cd/m}^2$ ). Ex. 1008, 451 (§ 3.1.1); Ex. 1005, [0067]; Ex. 2010, 2 (note 8). Thus, Gallagher only discloses *directly* converting light intensity values to retroreflectivity values without ever determining a luminance value.

92. Similarly, Lumia discloses directly converting light intensity values to retroreflectivity values, rather than determining luminance values. As discussed in further detail above, Lumia’s system calculates the retroreflectivity of a sign by: (i) a human operator manually aims a video camera at a sign and activates a range finder (Ex. 1014, 20); (ii) when the vehicle is at a pre-specified distance from the sign, the rangefinder triggers an electronic flash and the camera’s capture of an image of the sign (Ex. 1014, 18, 20 (Fig. 8)); (iii) software extracts the sign (i.e. crops) from the captured image (Ex. 1014, 16, 17 (Fig. 3(a))); (iv) software creates a histogram of the numeric frequency of different light intensity values of the pixels in the cropped image (i.e. how many pixels of each 8-bit grey value between 0 to 255 appear in the image) (Ex. 1014, 16-17); (v) software identifies gray level values corresponding to peaks in the histogram, excluding the first four grey levels as likely being associated

with the capture of areas surrounding the sign (as opposed to the sign itself) (*Id.*); (vi) software identifies the greatest-quantity peak in the histogram as the sign background (i.e. the red part of a stop sign) and the smaller-quantity peak with greater intensity as the sign legend (*Id.*); (vii) software averages the grey values associated with each of the two peaks to create an average grey value for the sign legend and an average grey value for the sign background (*Id.*); (viii) the coefficient of retroreflectivity of the sign legend and background are calculated by multiplying the average 8-bit grey value for each against a pre-calculated “scale factor” (Ex. 1014, 24). Notably, Lumia discloses that the “scale factor” directly “convert[s] the 8-bit digital gray levels of the calibration target image to R' values” i.e. a multiplication operation converts the 8-bit grey levels to coefficient of retroreflection values in candelas per footcandle per square foot. Ex. 1014, 24, 16. As discussed further above, none of these steps involve the determination of a luminance value.

93. In the Board’s decision on institution, the Board noted that “Patent Owner defines ‘luminance’ as ‘the luminous intensity projected on a given area and direction, i.e. the amount of visible light leaving a point on a surface in a given direction’” and “[b]y measuring the intensity of light reflected off a traffic sign, Lumia measures the sign’s luminance.” Paper 16 at 27. I respectfully disagree. As discussed further above, Lumia’s camera cannot and does not measure the sign’s

luminance because luminance represents the intensity of light directed in a particular direction *per unit area* (Ex. 2010, 1, 2, note 8), whereas Lumia’s camera can merely determine the *intensity* of light received at each pixel of the camera’s sensor. Ex. 1014, 16; *see also* Ex. 2029, 171 (“CCD detectors are integrating devices: the number of charges stored in each pixel is directly proportional to exposure time and to array irradiance”). That is, the CCD sensor within Lumia’s’ camera (Ex. 1014, 18) has no sense of the direction of how photons reach each of its pixels, or the area covered—it merely outputs raw light intensity information for each pixel.

94. Although certainly one *could* create a scale factor to convert the light intensity factor from a camera sensor into *luminance* values (Ex. 2029, 171), that is not what Lumia suggests or discloses. Rather, Lumia’s system only discloses converting from 8-bit grey value light intensity values into retroreflectivity values without ever determining a luminance value. Ex. 1014, 24. The petition and the Institution Decision point to Lumia’s disclosure that “The use of a video camera effectively divides the FOV defined by the system magnification into smaller FOV’s, thereby creating individual luminance meters at each sensing element site.” Ex. 1014, 16. However, as discussed above, and as demonstrated by the word “effectively,” a POSITA would not understand that the sensing element sites in Lumia’s camera are *luminance* meters, but only that they could be used for measuring luminance. However, Lumia does not actually disclose or suggest using

the camera pixel's values to determine luminance values. Rather, as discussed above, Lumia bypasses "determining a luminance value" to directly convert the 8-bit grey level light intensity values into retroreflectance measurements.

95. Indeed, this understanding of Lumia was confirmed by Dr. Thorpe during his deposition. In particular, Dr. Thorpe explained that in Lumia:

Q. So is Lumia converting the gray scale image on -- in Figure 3(a) into a number that goes from zero to 255?

A. Each pixel in 3(a) has a recorded brightness from 0 to 255. These brightnesses have not been calibrated as luminances scale values from the camera.

The histogram records how many of the pixels in image 3(a) have brightness zero, how many have brightness 1, how many have brightness 2, et cetera, up through how many have brightness 255.

Q. And so those are light intensity values; is that correct?

A. Those are the sensed intensity values from the camera. That is correct.

Ex. 2025 (Thorpe 5-30-2025 Depo Tr.) at 17:18-18:9.

96. I understand that Dr. Thorpe testified at his deposition that a POSITA *could* use Lumia's equation (2) that includes luminance and the coefficient of retroreflectivity to calculate a luminance value. Ex. 2025 at 8:8-13, 12:2-12, 40:1-13; *see also id.* at 32:2-4 (testifying that Gallagher's sensors could be "calibrated to create ... a luminance value, if desired"). In my opinion, there are several flaws in such a theory. First, that theory is evidently a product of hindsight rather than

actually identifying a motivation for a POSITA to combine the systems in the manner claimed at the time of invention. Indeed, when asked “Q. Do you identify somewhere in your declaration, for your theories for claim 15, a need to determine luminance?” Dr. Thorpe answered “Since claim 15 says determining a luminance, Lumia teaches how the luminance can be determined” and explained that “I was responding to [claim] 15 determining a luminance value, then saying it's obvious to do so.” Ex. 2025 at 40:14-41:2. That is plainly hindsight reasoning.

97. Second, in my opinion, Dr. Thorpe’s new theory at his deposition fails because it would require undisclosed modifications to the references without any apparent motivation. As discussed, Lumia’s equation (2) is related to the “Background” concepts, not how Lumia’s system actually works. Thus, Dr. Thorpe’s equation (2) theory is beyond Lumia’s disclosures relating to any ostensibly “automated method” as recited in claim 15. Consequently, rather than merely combining aspects of Gallagher and Lumia’s disclosures, Dr. Thorpe’s theory newly disclosed at his deposition would instead require modifying an automated system to use Lumia’s equation (2) instead of the scale factor that Lumia actually uses (which calculates retroreflectivity values). But, neither the Petition nor Dr. Thorpe’s declaration mentions such a modification or any motivation for such a modification. Third, the alleged motivation to combine identified in Dr. Thorpe’s declaration—retroreflectivity standards—would motivate *against* modifying Lumia

to calculate luminance values. Lumia itself already *directly* calculates retroreflectivity values—the ultimate goal identified in Dr. Thorpe’s declaration’s motivation to combine section for claim 15. Ex. 1014, 16-17; Ex. 1003 ¶116. Calculating luminance values would simply waste computing resources with no benefit toward the goal of calculating retroreflectivity values. Fourth, equation (2) in Lumia also recites—in addition to the coefficient of retroreflection and the luminance— $E_n$  or the “normal illumination incident of the retroreflector,” i.e. how much light is striking the sign, and thus using equation (2) to calculate luminance would also require determining the  $E_n$  value. Ex. 1014, 16. But, Lumia contains no description of how to actually measure or calculate  $E_n$  in its automated system, merely noting that one theoretically could “infer the illumination from the source intensity, or  $E = I/d^2$  where  $I$  is the intensity and  $d$  is the distance from the source to the detector (assuming that for the distances involved the source behaves as if it were a point). At his deposition, Dr. Thorpe pointed to section 5.3, page 23 of Lumia as containing a discussion relevant to calculating  $E_n$ , noting that Lumia has “a very detailed discussion of the amount of illumination needed” and noting that such page contains the number “28,500 candela-seconds.” Ex. 2025 at 12:20-13:8. However, that theory does not appear in Dr. Thorpe’s declaration. Moreover, section 5.3 of Lumia only teaches how much intensity must be provided by a light source to “provide an adequate amount of additional exposure above the ambient signal so that

the retroreflection due to the illumination system may be appropriately detected isolated.” Ex. 1014, 23. That is, as Lumia itself acknowledges, ambient light will be present—and will vary. Thus the mere knowledge of the intensity of the 28,500 candela-second light source in Lumia is insufficient to actually calculate  $E_n$ , as  $E_n$  measures *all* illumination incident of the retroreflector, including illumination from ambient sources of unknown and varying amplitudes.

**b) There is no motivation to combine Gallagher and Lumia because Gallagher already calculates retroreflectivity and does not benefit from combination with Lumia’s disclosures**

98. Additionally, in my opinion, Petitioner’s and Dr. Thorpe’s motivation to combine theory—that road authorities publish minimum retroreflectivity levels for road markers (Ex. 1003 ¶ 116)—also fails because Gallagher already teaches determining whether road markers meet published standards for minimum retroreflectivity levels. Indeed, as Petitioner and Dr. Thorpe readily acknowledge, the entire point of Gallagher is “assessing the integrity of road markers and markings” “to ensure they continue to meet minimum standards of reflectivity/retroreflectivity” by comparing “data measured on the reflectance level” of road markings to a “predetermined acceptable reflectance level” for such marking. Ex. 1005, [0001], [0003], [0012]; *see also id.*, [0067]-[0068][0049], [0077], [0079]; Ex. 1003 ¶ 55, 57. Thus, Petitioner’s theory raises the question—how does combining Lumia’s teachings with Gallagher better serve this goal of calculating

retroreflectivity of road markers? In my opinion, neither the Petition nor Dr. Thorpe's declaration provide any explanation for that.

99. Moreover, the inadequacy of Petitioner's theory was further demonstrated at Dr. Thorpe's deposition. In particular, when asked "If Gallagher already discloses a system for assessing whether markers meet the retroreflectivity standards, how is Lumia improving Gallagher in [Dr. Thorpe's] proposed combination?" Dr. Thorpe pointed to Lumia's equations as purportedly allowing one of skill in the art to calibrate for various different distances and also contended that Lumia "provides for higher precision." Ex. 2025 at 60:5-61:5. However, in my opinion, those alleged benefits are beyond the scope and entirely unrelated to the alleged motivation to combine identified in the Petition and Dr. Thorpe's declaration. Indeed, Dr. Thorpe admitted that he "did not spell it out in [his] declaration." Ex. 2025 at 64:25-2. Accordingly, I understand such theory to be beyond the scope of this proceeding.

100. Moreover, even if Petitioner were permitted to rely on such new theories, in my opinion, they also fail to provide a motivation to combine. In particular, Gallagher operates by sweeping photodiodes along the road in a narrow window ahead of the vehicle as the vehicle drives down the road. Ex. 1005, [0035], Fig. 1; Ex. 2025 at 55:13-18. Moreover, Gallagher discloses that the angle of the unit containing the sensor and light (and thus the distance of the sensor's window on

the road from the front of the vehicle) can vary between 1 to 30 degrees. Ex. 1005, [0036]. Additionally, Gallagher discloses that the calibration factor depends on the position of the sensors and can accommodate “different tracking distances.” *Id.*, [0039], [0058]-[0059]. Thus, Dr. Thorpe’s new theory at his deposition still provides no apparent benefit obtained from combining Lumia with Gallagher.

101. Thus, in my opinion, because Gallagher already teaches determining whether road markers meet published standards for minimum retroreflectivity levels, Petitioner’s identified motivation to combine provides no reason to combine Lumia’s teachings with Gallagher.

**c) There is no motivation to combine Gallagher and Lumia—and such combination would not be predictable—because Lumia’s teachings are fundamentally incompatible with Gallagher’s apparatus**

102. Third, in my opinion, Lumia’s teachings are fundamentally incompatible with Gallagher’s apparatus. In particular, Dr. Thorpe and Petitioner identified Lumia’s teachings relating to its histogram as being combined with Gallagher. Ex. 1003 ¶ 114. Moreover, Dr. Thorpe and Petitioner’s proposed combination uses Gallagher’s light sensor array in the proposed combination as the claimed “light intensity sensor”. Ex. 1003 ¶¶ 87, 116 (“Gallagher’s apparatus”), Ex. 2025 at 29:23-331:25. Also, as discussed, Gallagher uses photodiodes as its light sensor. Ex. 1005, [0039]. Indeed, Dr. Thorpe confirmed at his deposition that the proposed combination in his declaration used Gallagher’s photodiodes rather than

Lumia’s camera. Ex. 2025 at 33:13-34:4. And nowhere did Dr. Thorpe or Petitioner articulate a reason to modify Gallagher to use a video camera.

103. Notably, neither Petitioner nor Dr. Thorpe provides any explanation for how Lumia’s teachings are applicable to Gallagher’s apparatus. Ex. 1003 ¶¶ 114-117. Nor is it somehow clearly evident without explanation. Rather, in my opinion, a POSITA would not recognize Lumia’s histogram method as being applicable to Gallagher’s apparatus. In particular, as noted, Gallagher’s apparatus divides a field of view of a roadway via five or ten photodiode sensors. Ex. 1005, [00398]-[0040]. Each of those sensors must be sufficiently wide scope to be able to capture enough reflected light to detect “peaks” above the background non-marker reflectance level, which Gallagher uses to infer the presence of a retroreflective pavement marker. *Id.*, [0065]-[0066].

104. By contrast, as discussed, Lumia’s histogram method relies on a CCD camera, which has a resolution of 491 x 384 pixels (Ex. 1014, 18), which totals 188,544 individual pixel sensing cites. Lumia needs so many individual pixels because it has to have adequate granularity in its data to be able to aggregate grey values to find peaks in a histogram. Ex. 1014, 17. But even in Gallagher’s embodiment with the most disclosed sensors, the ten photodiodes of Gallagher are an order of 18,000 times fewer light intensity readings than Lumia’s camera at any point in time. That is far too few to use a histogram method as disclosed in Lumia—

simply put, you cannot identify and differentiate sharp peaks in a histogram (as disclosed in Lumia) if you only have a handful of total data points in the histogram (as would be generated by Gallagher’s photodiode array). Nor would it be practical to modify Gallagher to use thousands of photodiodes—the problems of managing alignment, calibration, timing, synchronization, and signal processing for so many individual photodiodes alone would render that impractical. Without having the detailed granularity provided by the thousands of sensing sites in Lumia’s camera, you cannot identify peaks, little less precisely average the grey-level values around the identified peaks, as Lumia discloses. Ex. 1014, 17. Because that is critical for how Lumia operates and obtains precise results, a POSITA would recognize Lumia’s teachings as entirely inapplicable to Gallagher’s system.

105. Lumia’s teachings are also inapplicable because, as discussed, Lumia requires precise aiming (by an operator) and framing of a traffic sign’s image, with a precisely timed xenon bulb, at a particular distance (determined precisely by laser rangefinder) to provide a high quality image on which its histogram method can be performed. Ex. 1014, 17-20, 24. Such manual aiming is not an “automated method” as recited in claims 12 and 15, nor is it similar to Gallagher’s system where the photodiodes’ outputs are continuously recorded once the operator “initiates the measurement process.” Ex. 1005, [0046], [0056], Fig. 5. Moreover, as discussed, Lumia relies on capturing images at an “appreciable distance” (e.g. 100 to 200 feet)

to minimize the effect of entrance angles, which is inconsistent with the proposed combination, which Dr. Thorpe admits to involve pointing the camera “down” at the roadway ahead. Ex. 1014, 20, 21; Ex. 2025 at 56:7-9.

106. In contrast to Lumia’s precisely capturing discrete images of individual signs, Gallagher’s apparatus simply continually sweeps the roadway in front of it for pavement markers, using continuous lighting and having the photodiodes capturing a wide FOV area of 0.5 by 3 meters (i.e. about 1.6 x 9.8 feet) which is located 2.3 meters (i.e. about 7.5 feet) in front of the vehicle. Ex. 1005, [0032], [0035], [0046]-[0047]. Moreover, a POSITA would recognize that Gallagher’s system requires a sufficient dwell time over each pavement marker than its peak responses can be detected. *See id.; id.*, [0066]. Such a wide FOV and long dwell time are inconsistent with Lumia’s approach of precisely calibrating the pixel values using a narrowly framed (i.e. cropped image) taken at an exact distance. In particular, compared to each pixel of Lumia’s camera, each of Gallagher’s photodiodes has a wide enough FOV to receive a blend of light coming from many more points on the roadway within the FOV. Ex. 1005, [0040] (“Reflected light from these markers can be detected simultaneously by desirably two of the light sensors.”). This simply would not work with Lumia’s histogram approach, which requires precise intensity measurements (i.e. 0 to 255) corresponding to precise points so as to quantify the relative frequency of different light intensity values at different points.

107. Indeed, unlike Lumia's camera, a photodiode array (such as in Gallagher), by itself, cannot even form coherent images, as it lacks the optical elements necessary to focus and direct light onto the sensing elements in a controlled manner. A camera integrates external lenses, apertures, and focusing mechanisms with the sensor array to ensure that light from specific points in the scene maps to corresponding locations on the sensor, creating spatial correspondence between the real world and the detected signal. Because Gallagher's array lacks such components, it could not perform Lumia's method even if it were somehow modified to use thousands of times more photodiodes and used photodiodes with an extremely narrow FOV angle.

108. Additionally, a POSITA would recognize that Gallagher's photodiodes would be too polluted by ambient light sources (i.e. sources other than retroreflectors) to be effective at the longer distances described at Lumia to obtain useful values for calculating retroreflectivity values. Indeed, a POSITA would recognize that photodiode arrays require precise optical alignment, stable measurement geometry, and controlled environmental conditions to achieve accurate measurements, which is entirely different than Lumia's manually aimed system. Thus, these differences are further reasons why a POSITA would recognize Lumia's teachings as entirely inapplicable to Gallagher's system.

## 2. Claim 15

### a) Neither reference discloses or suggests “The automated method of claim 12, further comprising determining a luminance value”

109. In my opinion, the cited disclosures do not disclose or suggest “[t]he automated method of claim 12, further comprising determining a luminance value” as recited in claim 15 of the ’255 Patent.

110. In particular, Dr. Thorpe identifies this disclosure as being purportedly provided by Lumia. Ex. 1003 ¶ 114. In particular, he cites to the disclosures in Lumia’s “Background” section which mentions that a camera can “effectively” “creat[e] individual luminance meters.” *Id.* (citing Ex. 1014, 16).

111. However, as discussed in further detail above in my summary of the Lumia reference and my analysis of Petitioner’s motivation to combine theory, the cited disclosures of Lumia do not disclose or suggest this claim element. *Supra* VIII.B, X.A.1.a In particular, as noted by the use of “effectively”—in Lumia’s section of “Background” principles—this is simply a discussion of how one can conceptualize how to calculate retroreflectance. Ex. 1014, 16. But simply mentioning the existence of equations which recite luminance is not an “automated method” that “determin[es]” a luminance value.

112. Indeed, as discussed, Lumia’s method of operation uses a “scale factor” to directly convert 8-bit gray level light intensity values into coefficient of

retroreflectivity values without ever “determining” any luminance values. Ex. 1014, 24.<sup>5</sup> This is quite different from the method disclosed and claimed in the ‘255 Patent. *See, e.g.*, ‘255 Patent, cl. 15, Fig. 7 (in a preferred embodiment, depicting “background luminance” as input to “Background R<sub>A</sub>” and “foreground luminance” as input to “Foreground R<sub>A</sub>”). And as discussed, neither Dr. Thorpe nor Petitioner articulate any reason for modifying the operation of Lumia (either alone or in combination with Gallagher) to determine a luminance value instead of using Lumia’s direct conversion of light intensity values to retroreflectance values. Thus, the cited references do not disclose or suggest this limitation.

**b) Neither reference discloses or suggests “utilizing ... a characterization profile of the at least one light intensity sensor”**

113. In my opinion, the cited disclosures do not disclose or suggest “utilizing ... a characterization profile of the at least one light intensity sensor” as recited in claim 15 of the ‘255 Patent.

114. In particular, Dr. Thorpe identifies this disclosure as being purportedly provided by Lumia. Ex. 1003 ¶ 114-115. In particular, he identifies Lumia’s “Lumia’s calibration to disclose a characterization profile.” Ex. 1003 ¶ 115.

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<sup>5</sup> As noted, Dr. Thorpe admits the 8-bit grey level values of Lumia’s histogram are light intensity values, not luminance values. Ex. 2025 at 17:18-18:9.

115. As discussed above, Lumia’s calibration uses a single “scale factor” which is calibrated based on a single sign measured at a single distance. Ex. 1014, 24. And, as discussed above, I believe the appropriate construction of “a characterization profile of the at least one light intensity sensor” is **“a compilation, presented in a usable format, of the description of the properties and performance characteristics of a sensor across various conditions.”** Because Lumia’s calibration procedure only measures a single sign at a single distance, it is not describing the properties or performance characteristics of Lumia’s sensor (i.e. video camera) across *various* conditions. Thus, in my opinion, the cited references neither disclose nor suggest this claim limitation as properly construed.

## **XI. CONCLUSION**

116. 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.

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

118. 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 '255 Patent.

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

Executed: June 16, 2025

A handwritten signature in black ink, appearing to be 'N. Papanikolopoulos', written over a light gray rectangular background.

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Dr. Nikolaos Papanikolopoulos