

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ADB Safegate Sweden AB,
ADB Safegate BV, and
ADB Safegate Americas, LLC

Petitioner,

v.

Honeywell International Inc.,

Patent Owner.

Case PGR2023-00053
U.S. Patent No. 11,538,349

EXHIBIT 1003
DECLARATION OF MARK CAMPBELL, PH.D.

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I. INTRODUCTION

1. My name is Mark Campbell. I am an expert in sensor fusion and planning in autonomous systems such as self-driving cars, robotics, UAVs, and spacecraft. I have been retained as an expert witness to provide my independent opinion regarding certain matters at issue in post grant review of U.S. Patent No. 11,538,349 (“the ’349 patent”). I have been retained by ADB Safegate Sweden AB, the Petitioner in these proceedings (“Petitioner” or “Safegate”). Patent Owner is Honeywell International Inc. (“Patent Owner” or “Honeywell”).

2. For my work on this case, I am being compensated at my typical consulting rate of \$500 per hour. I am also being reimbursed for reasonable expenses that I incur during the course of this work. My compensation does not depend on the substance of my opinions or the outcome of any issues in this case.

3. My analysis of the materials produced in this matter is ongoing and I will continue to review any new material as it is provided. This declaration represents only those opinions I have formed to date. I reserve the right to amend or supplement my opinions based on additional documents or evidence I am presented, including without limitation any arguments or expert declarations advanced by Patent Owner in this case.

4. I am not a legal expert and offer no opinions on the law. However, I have been informed by counsel of the various legal standards that apply, and I have applied those standards in arriving at my conclusions.

II. QUALIFICATIONS

5. I am currently a Professor of Mechanical & Aerospace Engineering at Cornell University in Ithaca, New York. At the same institution since 2001, I have served in several faculty and administrative positions, including as an Assistant Professor and Associate Professor of Mechanical Engineering, Member of the Graduate Fields of Electrical and Computer Engineering and Computer Science, Director (Chair) of the Sibley School of Mechanical & Aerospace Engineering, and as the John A. Mellowes '60 Professor of Mechanical & Aerospace Engineering.

6. I graduated from Carnegie Mellon University, Pittsburgh PA in 1990 with a Bachelor of Science (B.S.) in the field of Mechanical Engineering. I graduated from Massachusetts Institute of Technology in Cambridge MA in 1993 with a Masters of Science (M.S.) degree in Aeronautics and Astronautics and in 1996 with a Doctor of Philosophy (Ph.D.) degree in Control and Estimation.

7. I teach several courses related to the estimation, sensor fusion, and autonomous control of systems including robotics and aircraft. My research interests include most aspects of autonomous systems including sensor fusion,

perception, machine learning, control and planning. The research has included both algorithmic development, as well as experimental prototypes of self-driving cars, autonomous aircraft, and autonomous satellites. I have given and occasionally continue to give seminars and presentations worldwide to academia and to industry including broader keynotes such as to the National Academy of Sciences and National Academy of Engineering.

8. I have received research funding from the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), the U.S. Air Force Office of Scientific Research (AFOSR), the Office of Naval Research (ONR), Army Research Office (ARO) and a number of private companies, including major technology companies.

9. I have authored and co-authored more than 200 peer-reviewed articles and advised over 70 PhD student and Postdoctoral Research Associates. A partial list of my publications appears in my *curriculum vitae* attached as Appendix 1.

10. In recognition to the significance of my research contributions, I was elected to Fellow status (highest distinction) in three societies: American Institute of Aeronautics and Astronautics (AIAA), American Society of Mechanical Engineers (ASME), and Institute of Electrical and Electronic Engineering (IEEE).

11. In addition to my academic experience, I spent a sabbatical in 2005 working with a small autonomous airplane company (The Insitu Group, subsequently purchased by Boeing) developing and integrating sensor fusion and tracking algorithms for gimbaling cameras in the nose cone, tracking ground objects such as cars. In 2019-20, I spent a sabbatical working at Draper Labs sensor fusion using cameras and lidar to localize and navigate aircraft without the need for GPS.

12. I was also a member of the U.S. Air Force Science Advisory Board from 2016-20, a group composed of academics, industry leaders, and retired U.S. Air Force leaders whose goal is to advise Air Force leadership on science, technology and investments. As a member, I participated and led reviews of research at the Air Force Research Labs. In addition, I also took part in several in-depth science and technology studies in the areas of Test and Evaluation, Sensor Fusion, and Unintended Behaviors of Autonomy; the latter study I led and gave briefings to the leadership of the U.S. Air Force. For my work with the Air Force Science Advisory Board, I received the U.S. Air Force Chief of Staff Award for Exceptional Public Service, the highest-level award granted by the U.S. Air Force to non-employee civilians.

13. I have served as Editor and Associate Editor for major conferences and journal publications including the AIAA Journal of Guidance, Control and

Dynamics, the IEEE Transactions on Aerospace and Electronics, and the International Conference on Robotics and Automation (ICRA) among others. I currently serve on the Board of Directors of the AIAA Journal of Guidance, Control and Dynamics.

14. I am qualified by education and experience to testify as an expert with respect to subject matter in the fields of sensor fusion, estimation, machine learning, and planning and control related to robotics, self-driving cars, aircraft and spacecraft.

15. I have attached a current copy of my curriculum *vitae* as Appendix 1, which includes a list of my publications.

III. LEGAL STANDARDS

16. I am not a lawyer, and I do not intend to offer any opinions as to the interpretation of the law. When considering the '349 patent and stating my opinions, I rely on the following legal standards as described to me by the attorneys for Petitioner.

A. Priority Date

17. I understand that the analysis of alleged obviousness of the Patent should be performed from the perspective of a person of ordinary skill in the art (POSITA) as of the priority date of the Patent. The '349 Patent claims priority to

August 3, 2020. My opinions in this matter are from the perspective of a POSITA as of that date.

B. Level Of Ordinary Skill In The Art.

18. My opinions in this declaration are based on the understandings of a person of ordinary skill in the art, as of the time of the invention. I understand that the person of ordinary skill in the art is a hypothetical person who is presumed to have known the relevant art at the time of the invention. By “relevant,” I mean relevant to the challenged claims of the ’349 patent.

19. I understand that various factors should be considered when determining the person of ordinary skill in the art in connection with a particular patent. I understand that these factors include, without limitation, the type of problems encountered in the art, the prior solutions to those problems found in the prior art references, the rapidity with which innovations are made, the sophistication of the technology, the level of education of active workers in the field, and my own experience working with those of skill in the art at the time of the invention.

20. I am readily familiar with the level of ordinary skill in the art as of the priority date of the Patent. My qualifications at that time far exceeded that of a POSITA, and I had worked with, as well as supervised, many POSITA’s throughout my work in the field.

21. Based upon my knowledge of this field, I conclude that a POSITA at the time of the alleged invention of the '349 patent, and for that matter, at all subsequent times through the present, would have held at least a degree in electrical engineering, computer engineering, computer science or a similar discipline, with at least two years of relevant industry or research experience, including experience designing, planning, or implementing sensor networks using LIDAR, radar and/or cameras and corresponding data analysis. Additional work or research experience can substitute for less or different education, and vice-versa.

22. Based on my experience, education, and training, I meet the definition of a POSITA as of the priority date of the '349 Patent. My qualifications at that time far exceeded that of a POSITA. My opinions concerning the '349 Patent claims and the prior art are from the perspective of a POSITA, as set forth above.

23. As further discussed below, my opinions as stated in this declaration are valid even if the Board adopts a slightly different level of ordinary skill in the art.

C. Claim Construction.

24. I understand that claims in a patent-at-issue in a PGR are generally interpreted according to the district court-type claim construction.

25. I further understand that claim terms are interpreted as they would have been interpreted by a person of ordinary skill in the art at the time of the invention, in light of the specification and the patent's prosecution history in the patent office.

D. Patent Eligibility Legal Standard.

26. I understand that a claimed invention maybe patent-eligible if it is a new and useful process, machine, manufacture, or composition of matter, but that this includes exceptions, i.e., laws of nature, natural phenomena, and abstract ideas are not patentable. I understand that the patent eligibility analysis follows a twostep framework. I understand that the first step of that inquiry is to ask whether the claim at issue is directed to a patent-ineligible concept, such as an abstract idea. I understand that this inquiry requires looking at the focus of the claims, which may be informed by analyzing the specification to understand the problem facing the inventor.

27. If a claim is directed to an abstract idea, I understand that the second step in the inquiry requires an examination of the claim elements to determine whether they contain an inventive concept sufficient to transform the claimed abstract idea into a patent-eligible application. I also understand that merely appending conventional steps, specified at a high level of generality, is not enough to supply an inventive concept.

28. I have been informed that the U.S. Patent and Trademark Office (“USPTO”) has issued guidance (“Guidance”) for applying the two-part test described above. I understand that, at Step 1 of the Guidance, the USPTO looks to whether the claimed subject matter falls within the four statutory categories of patentable subject matter: process, machine, manufacture, or composition of matter. I further understand that Step 2 of the Guidance is divided into multiple parts. I understand that Step 2A, Prong 1 of the Guidance asks whether a claim recites a judicial exception, i.e., whether a law of nature, natural phenomenon, or abstract idea is set forth or described in the claim. I further understand that, at Step 2A, Prong 2 of the Guidance, one determines whether the claim as a whole integrates the recited judicial exception into a practical application of the exception. Finally, I understand that Step 2B of the Guidance asks whether the claim recites additional elements that amount to significantly more than the judicial exception.

E. Anticipation Legal Standard.

29. I understand that, once the claims of a patent have been properly construed, 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.

30. I understand that in order for a claim to be anticipated, each and every requirement of the claim must be found, expressly or inherently, in a single prior art reference as recited in the claim.

31. I understand that a prior art reference “inherently” discloses a limitation if that limitation is necessarily present in the prior art reference.

32. I understand that it is impermissible for anticipation to combine multiple, separate embodiments, even if they are described in a single prior art reference.

F. Obviousness Legal Standard.

33. I understand that a patent claim is unpatentable if the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the invention.

34. I understand that an obviousness analysis involves comparing a claim to the prior art to determine whether the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the invention in view of the prior art and in light of the general knowledge in the art as a whole. I also understand that obviousness is ultimately a legal conclusion based on underlying facts of four general types, all of which must be considered: (1) the scope and content of the prior art; (2) the level of ordinary skill in the art; (3) the differences between the claimed invention and the prior art; and (4) any objective indicia of

non-obviousness, including any praise of the invention. Objective indicia of non-obviousness may include, for example, commercial success of an embodiment, a long-felt need, skepticism, failure by others to find the solution provided by the claimed invention, copying by others of the subject matter of the claim invention, unexpected results of the claimed invention, acceptance of others and industry praise, and licensing of the patents.

35. I also understand that obviousness may be established under certain circumstances by combining or modifying the teachings of the prior art. However, I have been informed that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I have been informed that many, if not all, inventions rely on building blocks already previously known, and claimed discoveries almost of necessity will likely be combinations of what is already known. I have been informed that it is important to identify whether a reason existed at the time of the invention that would have motivated a person of ordinary skill in the art in the relevant field to combine the known elements in the way the claimed invention does. Specific teachings, suggestions, or motivations to combine any first prior art reference with a second prior art reference can be explicit or implicit, but must have existed before the date of purported invention. I understand that prior art references themselves may be one source of a specific teaching or suggestion to combine features of the prior art,

but that such suggestions or motivations to combine art may come from the knowledge that a person of ordinary skill in the art would have had.

36. I understand that a reference may be relied upon for all that it teaches, including uses beyond its primary purpose, but also including teachings that lead away from the invention. I understand that a reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, although the mere disclosure of alternative designs does not teach away.

37. I further understand that whether there is a reasonable expectation of success in combining references in a particular way is also relevant to the analysis.

38. I understand that it is improper to use hindsight to combine references or elements of references to reconstruct the invention using the claims as a guide. My analysis of the prior art is made from the perspective of a person of ordinary skill in the art at the time of the invention.

39. I am not offering any legal opinions in this declaration nor am I qualified to do so. I only consider such legal standards in framing my opinions and conclusions. Additionally, from a subject matter perspective, I understand that Petitioner always has the burden of persuasion regarding a challenge of patentability of an invention under a post grant review.

IV. **BACKGROUND TECHNOLOGY**

40. Prior to August 3, 2020, when the '349 Patent was filed, all of the technology disclosed and claimed in the '349 Patent had already been established as well understood, routine, and convention in the context of aircraft airport ground navigation and docking. After landing at an airport, each aircraft must navigate through the airport ground system to park at a specific dock (or ramp or apron) connected to the airport structure. EX1005, 1:4-2:24; 2:57-3:47. While parked, the aircraft goes through maintenance and fueling while passengers, luggage and garbage/food are unloaded and re-loaded. EX1004, ¶¶0078, 0081, 0133, 0137, 0140. These areas of the airport ground system, particularly the docking areas, are dense with dynamic moving vehicles such as other aircraft, moving carts, cars and people, and stationary objects such as gas and food trucks. To maintain the safety of the aircraft and passengers, it is critical that each aircraft reliably navigate the airport and park and release from its dock. This reliable navigation/parking/releasing is typically accomplished by the pilot in small airports, or the air traffic control and dock systems at larger airports using either personnel or technology (or a combination).

41. While the aircraft docking scenario is challenging, there other domains that are substantially similar. For example, cars navigate dense traffic as well as parking garages (*see* EX1009, 2-3; EX1010, ¶¶0001-0023), and ships

navigate dense harbor domains to dock at their prescribed location. See EX1011, 3, 8; EX1012, 2-4. Given the similarities in these domains and their associated challenges, technology developed to augment and improve safety and reliability in one domain, typically can be leveraged in the other domains as well.

A. Technology: Sensors

42. A key technology used to maintain and improve safety and reliability of airport ground systems and similar domains are different sensors. See EX1004, Figs. 1-3, ¶¶0117-0119, 0131-0132; EX1013, 2-4; EX1014, 4-6, 9, 33. The three most common “environmental” sensors (sensors that take measurements about an environmental area such as the aircraft dock area) are lidar (or lasers), radar, and cameras. These sensors can be stationary and monitor an area (such as attached to the dock) or can be attached to a moving vehicle (such as aircraft or self-driving cars).

43. Lidar sensors are a set of individual lasers mechanically rotating, or a 2D grid of mirrors (solid state), that use time of flight of the laser returns from the environment to yield set of points in space. See EX1005, 2:2-12, 3:48-4:22, 5:58-7:5; EX1013, 2-4. These 3D “point clouds” can be quite dense, and can capture the structure of the environment, such as a flat road or the shape of an object such as an aircraft or a car. The main benefit of lidar sensors is their high level of accuracy (sub-cm), whereas the main drawbacks are their high costs, lower

density of points on objects further away, lack of returns from darker objects, and slight degradation due to weather such as rain. *Id.*, 3.

44. Radar sensors use relative frequency shift of electro-magnetic waves to detect velocity and have been used for decades by the police to measure speed of vehicles. *See* EX1004, ¶¶0117, 0119; EX1013, 2-5. While most radar sensors suffer from many returns around an object of interest, most companies integrate software to filter the data and return only one measurement per object. More recently, industry has been developing radar sensors with multiple returns for larger, 3D objects – similar to lidar sensors though less dense. *See* EX1015, 2-3. The main benefits of the radar sensors are their accuracy with velocity and reliability in poor weather, whereas the main drawbacks are false returns, inaccuracy of position/range, and problems detecting non-metal objects such as aircraft made of composites. EX1013, 3.

45. Camera sensors are optical sensors typically sensing light and colors (but also temperature in thermal cameras). *See* EX1004, 0131; EX1013, 3-5. The main benefits of cameras are their ability to capture context of a scene (i.e. understanding that an object is a car as opposed to a cement barrier of the same size and shape), and their low cost, whereas the main drawbacks are the lack of depth information (except for a stereo/pair of cameras or added depth estimation software), and poor performance in poor lighting or environmental conditions,

such as at night or when the weather is poor such as in rain or fog, distorting the image from the camera. *Id.*, 3.

46. Additional (non-environmental) sensors are also known to be used in the aircraft (and car/ship) domains. GPS/INS is often used for locating a vehicle within the world environment or within a given map. See EX1017, 2, 5, 9. The Automatic Identification System (AIS) is a well-known shipboard broadcast system used to broadcast ID information, and the Automatic Dependent Surveillance–Broadcast (ADS–B) is similarly well-known for broadcasting location and ID information of an aircraft.

B. Technology: Problems and Algorithm Solutions

47. The different sensors can be used in their raw form, combined together, and/or combined with contextual information (such as, how an aircraft moves on the ground) to support airport docking as well as the other domains. More specifically, the sensors support a set of functions about the domain, such as the aircraft ground and docking area. There is a set of common terms associated with these functions. While many of these terms are defined in other domains such as robotics, computer vision, and self-driving cars, they are also prevalent in the aircraft ground domain. See EX1004, Figs. 1-3; EX1013, 2, 4-5; EX1018, 2-5, 9.

1. Pose

48. Pose is the 3D position and 3D orientation of an object (EX1016, 2-4) in some coordinate system (global coordinates such as latitude/longitude/altitude, or relative to a map or sensor such as the aircraft docking system). Mund defines pose in the aircraft ground domain as “rigid body ... as 3 rotational and 3 translational parameters (6D).” EX1018, 6.

2. Detection

49. Detection is implemented as an algorithm that locates an object from environmental sensor data. The detection can include finding a 3D point cloud of the object within the sensor returns or a bounding box around the object/returns. In the case of a camera image, the detection can be a 2D set of pixels or 2D box around the object within the image. Richman, for example, describes its invention as “view[ing] an arriving aircraft and the dock area to detect the aircraft and any obstacles which may be in the travel path.” EX1005, 1:5-8. Mund details performance results of detecting aircraft using multi-scan lidar. *See* EX1018, 8-11.

3. Tracking

50. Object tracking is locating and keeping track of an object in space over time including position, velocity, orientation, and direction of motion. *See* EX1019, 2-4, 7-9. Position can be directly measured via a sensor (e.g., 3D point

clouds via lidar, camera with depth estimation). Velocity and direction of motion can be measured by a radar sensor or estimated via an algorithm such as the Kalman filter or similar variants. Mund describes detection and tracking as a core function of “safer airport operations.” *See* EX1018, 2-3. Berkmo describes its invention as “detecting and tracking of the approaching aircraft and/or other objects in the stand area [] based on output data.” EX1004, ¶0029.

4. Classification

51. Classification is an algorithm that predicts the “class” or “type” of object. *See* EX1016, 3-4, 6-7, 11-12. Classification can include, for example, aircraft vs car or a Boeing 737 vs Airbus A320 aircraft. *See id.*

5. Prediction/Forecasting

52. Prediction or forecasting corresponds to the future pose (3D position and orientation) of an object in time, from its current pose. *See* EX1020, 2-5, 9-11. For aircraft on the ground, Berkmo details its “arrangement is configured to predict if the approaching aircraft is on a collision course with any of said other objects. The prediction may be achieved using tools readily available to the skilled person. For example ... a Kalman filter acting as a time filter to combine measurements (observations) and a model of the dynamics of the detected obstacles.” EX1004, ¶0135. Richman details using predictions for “signaling a

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pilot of the aircraft with guidance data for piloting the aircraft along the travel path
into the dock.” EX1005, 8:6-9.

6. Localization

53. Localization is the process of locating a vehicle (e.g., find its pose, or 3D position and 3D orientation in a global or map-based coordinate system) using sensors integrated as part of the vehicle, such as GPS/INS, or an image localizing the vehicle within a map. *See* EX1017, 2, 5, 9; EX1021, 2-4, 8, 11-12.

C. Technology: Multi-Sensor Fusion

54. The sensors (lidar, radar, camera) can be used to perform each of the above functions, individually or collectively. Importantly, both the performance and the reliability of the functions are dependent on, and can be improved by, combining sensor information data together, which can be referred to as multi-sensor data fusion. *See* EX1004, 0011, 0019-0020, 0044, 0125-0130, 0135, 0139; EX1013, 2-5; EX1022, 2-5, 12, 14, 17. For example, Kalman Filter theory indicates that each additional sensor only improves the estimates (tracking, localization, etc,) when the sensor errors are well modelled. To accurately combine multiple sensors, it is critical to know the pose of each sensor in a common coordinate system (i.e., calibration), and it is critical to synchronize the timing of each measurement. *See* EX1014, 4-5. Aircraft navigating the airport ground and docking domain create many examples where multiple sensors are

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critical to reliable functionality. *See* EX1004, ¶¶00110038, 0125-0130; EX1013,
2-5. The following are some of the key reasons it is known to combine more than
one sensor, including in the context of the aircraft ground domain.

1. Accuracy

55. If one sensor detects (locates) an object with a given accuracy, then adding a second sensor improves the accuracy of locating that object, which is true whether the sensors are the same or different. *See* EX1022, 12, 26. Thupakula additionally reinforces that more than one independent sensor provides robustness and fault tolerance. *See* EX1013, 2, 4. Miller details how initial detection and tracking of a moving car with radar (with a 5-10m accuracy) drastically improves once lidar is fused with radar (to <1m accuracy). *See* EX1019, 9-11.

56. Berkmo details several embodiments for using multiple sensors to improve detection and tracking accuracy of taxiing aircraft approaching a ramp/dock/apron. *See* EX1004, Figs. 1-3, ¶¶0116-0132. Berkmo also details a data fusion process for the output data of those sensors based on, for example, a spatially resolved weighted average of the combined output data, wherein the weighted average is determined based on statistical weights for the radar system and the one or more additional systems.” *Id.*, ¶¶0023-0025, 0130. This data fusion of data from multiple sensors improves accuracy of the point cloud, including

point locations, reduces uncertainty in each point, and eliminates outliers in the same manner as radar and lidar sensor fusion for cars. *See* EX1019, 9-11.

2. Complementary

57. Sensors have complementary benefits that make a combination of sensors much better than an individual sensor. For example, while lidar provides very accurate position information, and radar provides very accurate velocity, their combination provides both, which are key components in tracking. *See* EX1019, 9-11. Since camera/image data is more accurate for classification, the combination of lidar and a camera can give improvements in detection and classification, e.g., the accurate location of a specific object such as a car or aircraft. Finally, if a sensor has poor performance in weather, as can be the case with cameras, a radar or lidar can provide better quality measurements. *See* EX1004, ¶¶0048, 0075, 0125, 0128-0130, 0139, 0142.

58. Berkmo details several embodiments in its invention that uses multiple sensors to improve detection and tracking accuracy, including weather (visibility) and object type (composite vs metal). *Id.*, 0048, 0075, 0116-0130, 0139, 0142. Specifically, a “radar-based system provides increased sensitivity in low visibility conditions.... Imaging systems provide an improved spatial resolution in good weather.” *Id.*, ¶0011. Berkmo describes several possible multi-sensor configurations, including lidar and radar (Fig. 1) lidar and camera (Fig. 2),

and lidar, radar, and camera (Fig. 3) to detect and track aircraft in the dock area by selecting the best sensor based on visibility (Fig 4). *Id.*, ¶¶0116-0132. In addition, Berkmo notes how imaging systems can detect smaller objects: “the imaging system may provide output data having higher spatial resolution than the output data of the radar-based system and/or the output data of the laser-based system. This may be an advantage as the imaging system may spot also smaller objects present in the stand area.” *Id.*, ¶0036. Further teaching how sensors can be complementary, Berkmo notes “object detection based on images may result in image artifacts such as shadows being erroneously identified as real objects. By verifying the alleged existence of the object with the radar-based system and/or e.g. a laser-based system, this potential drawback of the imaging system may be overcome.” *Id.*

3. Occlusions/Sensor field of view

59. Placing sensors at different locations can improve functions such as detection and classification, particularly in dense and changing environments. Sensors at two locations viewing a similar space can ensure that one object is not behind (occluded by) another. Thupakula reinforces that different sensor views can give a complete view of an object or scene. *See* EX1013, 3. A common example is GPS ranging: the location of a GPS receiver (such as in your phone or car) is found by “triangulating” the range/distances to 3+ satellites at different

locations; your location can only be found using three or more relative measurements from the receiver to GPS satellites at different locations.

60. Berkmo details how sensors at multiple locations can overcome occluded (blocked fields of view). Specifically, with reference to Fig. 3, Berkmo describes how “two or more systems of the combined systems each are distanced from each other so as to, at each position in time, detect the approaching aircraft using different collection angles.” EX1004, ¶0037; *see also* ¶0132. Berkmo’s Fig. 6 shows how multiple sensors can be configured to mitigate a passenger bridge from blocking the stand area. *Id.*, ¶0140.

D. Technology: Detection and Classification of Aircraft via 3D Models

61. Detection of objects in 2D images has been a classical computer vision task for many decades. *See* EX1023, 2, 8. The advent of multi-laser lidar and gaming sensors such as stereo cameras and the Kinect sensor (RGB+depth) between 2005 and 2010 led to a revolution in detection, classification and tracking using point cloud data. *See* EX1024, 2-5. Point clouds have the ability to capture 3D shapes and their locations (i.e., detection) very accurately over time (i.e., tracking). *See* EX1016, 2-6. Accurate locations of objects is critical for vehicle navigation, such as an aircraft moving through an airport to dock. The use of

point clouds can also be used for classification based on the shape of the object.

See EX1018, 2-5.

62. Camera sensors were eventually augmented with depth estimation which, when combined with novel top-down views, also produced 3D point clouds called “pseudo-lidar.” *See* EX1029, 2-7, 9. Accordingly, the same algorithmic approaches to detection, tracking and estimation for lidar point clouds can also be used for camera-based pseudo-lidar.

63. By combining point clouds of similar and varying viewpoints, complete 3D shapes of objects can be realized. *See* EX1016, 2, 4, 6. These partial point clouds can be from different sensors at different locations at the same time or the same sensor at a different time (assuming either the object or sensor are moving to another viewpoint). In the aircraft ground domain, Thupakula describes how complementary sensor configurations allow each sensor to view one part of a larger object and combining them to provide a complete view. EX1013, 2-3. Berkmo describes merging of data from different sensors via “pixel-by-pixel” matching using raw data from each sensor (the same sensor such as lidar, or different sensors such as lidar, radar, and or camera). *See* EX1004, ¶0129. The data is combined using “statistical weights” of each sensor, with the product being a higher accuracy, more complete 3D point cloud of an object and its location. *See id.*

64. Partial or full 3D point clouds of objects such as for an aircraft, can then be used for many of the key ground domain functions including detection, classification, tracking, and prediction. For example, comparing a current point cloud to a similar point cloud at a prior time-step leads to an understanding of its motion over time or tracking. *See* EX1005, 1:5-14, 2:3-14.

65. Detection and classification using 3D point clouds can be realized in several ways. One approach to detection of aircraft as detailed in Richman is to identify unique aircraft features from its shape, such as the wheels, number of engines, wheel width, wing-span, etc. *See id.*, 1:5-14; 4:1-7. Berkmo analyzes data to determine “dimensions” of the aircraft and compares those to a database in order to determine aircraft “type.” EX1004, ¶0126. In addition, the partial or full 3D point clouds can be compared to a prior, known models of aircraft. *See* EX1025, 2-5. These models can be, for example 3D CAD (computer aided design) models, 3D point clouds, mesh models, or grids. *See* EX1026, 2-4. The approach to matching point clouds to a model within a library of 3D models is called “template matching.” *See* EX1004, ¶0126; EX1005, 1:5-14, 3:48-4:34; EX1027, 2-6. Finally, camera image data can be fused with the point clouds to provide semantic information, such as the aircraft doors or windows. Since 2016, the car industry has accelerated development in these areas using deep learning methods,

where prior data is used to train models rather than use a library of templates. *See* EX1027, 2-6; EX1028, 2-8, 12, 14.

E. Technology: Pilot Display

66. Given the well-known use of technology (sensors and algorithms) in the aircraft dock area, the ultimate goal of its use is to provide safe navigation for the aircraft and its passengers. As Thupakula notes for the aircraft ground domain problem, “the object shape, type and position data from the object identification stage is provided as input to the next stage in the airport traffic monitoring system to track the object movements for collision prediction.” EX1013, 2.

67. One manner for implementing collision avoidance is to provide the pilot with guidance that includes a path to the goal location and information about other objects and potential collisions. Richman describes a display in the aircraft docking system “readily seen by the pilot through the cockpit windshield as the aircraft proceeds along a taxiway and during a turning of the aircraft from the taxiway into the dock.” EX1005, Abstract. The display shows the aircraft travel path, as represented by successive locations and orientations of the aircraft, compared with the required travel path. *See id.*, Abstract, 1:5-14, 2:4-24. Berkmo discloses providing “based on said detection and tracking of the approaching aircraft, pilot maneuvering guidance information on a display for aiding a pilot of the approaching aircraft in maneuvering the aircraft towards said parking

position.” EX1004, ¶0097. In addition, “[the airport stand] arrangement is further configured to predict if the approaching aircraft on a collision course with any of said other objects, and, in response to a collision course being predicted, to provide further pilot maneuvering guidance information instructing the pilot to stop the aircraft.” *Id.*, ¶0079.

V. OVERVIEW OF THE ‘349 PATENT

68. The ‘349 Patent describes a method for tracking and docking an aircraft in a ramp area of an airport that purportedly overcomes prior art problems. EX1001, Abstract; 1:7-9. The ‘349 Patent admits that earlier non-manual approaches have used laser/LIDAR systems or camera systems to track and dock aircraft but such systems have problems with that approach path, detection range, and weather conditions. *Id.*, 1:54-2:9. The ‘349 Patent also admits that earlier approaches have used camera systems, but such systems have issues with distance accuracy and require precise calibration. *Id.* As discussed in the Background section, these limitations on laser/LIDAR and camera systems were well-known prior to the ‘349 Patent. *See* ¶¶42-46 *supra*.

69. Fig. 1 of the ‘349 Patent shows an aircraft ramp area arrangement having a sensor array 102 with a camera image sensor and a LIDAR/RADAR sensor. EX1001, Fig. 1; 3:53-5:36. The ‘349 Patent suggests using the camera sensor to provide detection of aircraft from longer distances, but using the

LIDAR/Radar sensor to provide clear guidance to the aircraft for precise docking.

Id., 5:20-24. As discussed in the Background section, the use of multiple sensors including cameras, LIDARs, and radars to track and guide an aircraft in a ramp area was well-known prior to the '349 Patent. *See* ¶¶42-46, 56-60 *supra*.

70. The '349 Patent discloses fusing or merging the data from the camera and LIDAR/RADAR sensors to provide a data set to track and provide guidance to the aircraft from entry into the ramp area to docking. EX1001, 5:25-28. The LIDAR/RADAR provides data as a plurality of LIDAR/Radar data points. *Id.*, 6:16-23. This collection of data points can be referred to as a point cloud that are collected as the LIDAR/Radar scans surfaces of the aircraft. *Id.* The camera in the '349 Patent provides image data captured from an imaging sensor. *Id.*, 6:41-45; 8:37-43. The captured image data represents frames of video data or one or more still images taken in a sequence that can be used to create a 3D model of the aircraft. *Id.* As discussed in the Background section, it was well-known prior to the '349 Patent for LIDAR, radar, and camera to produce such data. *See* ¶¶42-46, 56-60 *supra*.

71. The '349 Patent describes a data fusion process for the data from the sensors that uses qualities of each data set together. EX1001, 8:64-67. In one process, a 3D point cloud is formed from the LIDAR/RADAR sensor, a transformation is calculated between the coordinates of the LIDAR/RADAR point

cloud and a vision coordinate system of the camera, and an estimated pose of the 3D model is determined. *Id.*, 8:67-9:10. This transformation and correlation can be accomplished by mapping both data sets to a virtual space having a common coordinate system. *Id.*, 9:23-38. Again, as discussed in the Background section, the process of combining, merging, or fusing LIDAR, radar, and camera data was well-known prior to the '349 Patent. *See* ¶¶56-65 *supra*.

72. The '349 Patent describes using the merged data to derive the speed and position of the aircraft and to provide information for pilot unit display messages indicating directional and/or speed guidance to the pilot. EX1001, 6:57-65; 10:5-15. While indicating that the merged data is used to provide this information, the '349 Patent does not provide much if any detail regarding how a POSITA would actually derive that information from the merged data. Nevertheless, as discussed in the Background Section, using merged data from the LIDAR, radar, and camera to provide displayed guidance to a pilot was well-known prior to the '349 Patent. *See* ¶¶52, 67 *supra*.

73. The '349 Patent describes a computing device, as shown in Fig. 5, to provide ramp area aircraft movement functions. EX1001, 10:47-50. Computing device 543 “is a typical computing device” that can be used as the airport computing system, central docking system controller, ramp docking system controller, and/or pilot unit, as described in FIG. 3. *Id.*, 10:50-54. Computing

device 543 includes a processor 545 and memory 547, which can include data 555 and instructions 551 executable by the processor 545. Id., 10:56-60. A POSITA would certainly understand that computing device 543 and memory 547 are conventional, well-known components.

VI. OPINIONS

A. Ground #1: Claims 1-20 are invalid under 35 U.S.C § 101

74. Based on the my understanding of the law under 35 U.S.C. § 101, it is my opinion that claims 1-20 of the '349 Patent are unpatentable as being directed to the abstract idea that merely recite well-understood, routine, and conventional functions without requiring any nonconventional computer, sensor, or display components.

75. Guidance Step 1: Statutory Category

76. Applying Step 1 of the Guidance, it is clear that claims 1-17 recite “a method” (i.e., a process) and claims 18-20 recite “a system” (i.e., a machine).

77. Guidance Step 2A, Prong 1: The '349 Patent claims recite the abstract idea of receiving data, merging it, and displaying messages with the merged data, a mental process that can be performed in the human mind.

78. Applying Step 2A, Prong 1 of the Guidance to claim 1, it is my opinion that claim 1 simply describes the abstract idea of receiving image and sensor data, merging it, and displaying messages with the merged data. This abstract idea is one

that can be performed in the human mind. I also noted that claim 1 does not recite any tools for performing the abstract idea.

79. It is my understanding under the Guidance that “mental processes” are considered an abstract idea. It is also my understanding that an exemplary mental process under the Guidance is “collecting information, analyzing it, and displaying certain results of the collection and analysis.” This example is essentially identical to the steps of claim 1 of receiving (“collecting”), merging (“analyzing”), and displaying.

80. It is also my understanding that, when the claim is directed to an abstract idea, it must be determined if the claims are integrated into a practical application. Since it is not enough to “merely include[] instructions to implement an abstract idea on a computer,” “merely use[] a computer as a tool to perform an abstract idea,” or “add[] insignificant extra-solution activity to the judicial exception,” it is my opinion that nothing in the claims recites any element that improves the functioning of the technology involved. Rather, it is my opinion that the claims recite well-understood, routine, and conventional components, as discussed in the Background section, to address perceived inefficiencies in aircraft turnaround times and aircraft detection under varying conditions.

81. Notably, the claimed steps simply use or involve conventional and off-the-shelf electronic components. As a result, the claims are therefore focused on

the abstract idea of collecting sensor data, merging it, and displaying messages with the merged data, not improving any computer functionalities or resolving a technological problem.

82. More specifically, the only hardware elements recited in the claims are commercially-available, conventional, or well-known to a POSITA, as discussed in the Background section. The '349 Patent even discloses some of these hardware elements are conventional. For example, the “computing device” (*see* claims 2 and 16-20 of the '349 Patent) is described as “a typical computing device that can be used as the airport computing system.” EX1001, 10:50-51. The '349 Patent describes the “memory” (*see* claims 2 and 18 of the '349 Patent) as simply a location in which to store data and instructions. *See, e.g., id.*, 10:56-62; 11:14-24; 11:32-50. The '349 Patent also fails to identify or describe the “camera image sensor” or the “LIDAR or RADAR sensor” (*see* claim 18 of the '349 Patent) as being anything other than conventional versions of the sensors. *See, e.g., id.*, 1:57-64 (“conventional laser/LIDAR systems); 6:9-45 (describing standard components and functionality for a LIDAR/Radar system and camera image system).

83. There is nothing special about any of these hardware elements. As discussed in the Background section, the recited hardware elements simply perform their conventional functions, and those functions can be performed by conventional, commercial off-the-shelf versions of each. Accordingly, in my opinion, the claims

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of the '349 Patent are only using pre-existing hardware tools to perform the abstract idea of collecting sensor data, merging it, and displaying messages with the merged data.

84. Guidance Step 2B: The '349 Patent claims do not provide an “inventive concept.”

85. As explained in the Background section, all of the functions recited in the claims were already well-known and conventional in aircraft tracking systems prior to the August 2020 priority date of the '349 Patent. It was already well-known in the context of detect, tracking, and guiding taxiing aircraft to use multiple sensors for the detection and tracking, to use a fusion process to combine the data from those sensors, and to determined guidance from the combined data. Since each of the claimed functions was already well-known, in my opinion there is nothing “inventive” about the claims.

86. The additional claim elements simply append well-understood, routine, and conventional aircraft tracking activities to the abstract idea.

87. While most of the claims do not even recite any hardware elements, the ones that are recited are simply commercial off-the-shelf tools. For example, the camera sensor, LIDAR sensor, and RADAR sensor recited in claim 18 can be implemented with any commercially available version of any of those sensors. Notably, neither the claims nor the specification provide any limitation on the type

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of sensors nor do the functions recited in the claim require anything other than standard sensors to perform the functions. Similarly, as noted by the ‘349 Patent, the computing device can be any “typical” computing device having a processor and memory. EX1001, 10:47-60. Having examined the ‘349 Patent in detail, I do not see anything that notes any improvements or modifications to these conventional components to implement any disclosed method or system. Accordingly, in my opinion based on 101 law as explained to me, these hardware elements do not add anything inventive to the abstract idea. Moreover, the functionality recited in connection with these hardware elements is conventional in aircraft tracking systems as explained in the Background section above.

Elements [1.1, 1.2]: *“receiving camera image data of the aircraft while the aircraft is approaching a ramp area for parking the aircraft on an airside of an airport;” and “receiving LIght Detection And Ranging (LIDAR) or RADio Detection And Ranging (RADAR) sensor data of the aircraft while the aircraft is approaching or in the ramp area;”*

88. Elements [1.1, 1.2] of representative claim 1 merely recite the well-known steps of receiving (i.e., collecting) data from multiple different sensors as explained in the Background section above. By 2020 when the ‘349 Patent was filed, collecting data from multiple sensors for tracking and guiding aircraft to a gate was routine.

Element [1.3]: *“merging the camera image data and the LIDAR/RADAR-sensor data into a merged data set; and”*

89. Element [1.3] of representative claim 1 recites merging the camera image data and sensor data into a merged data set. This element does not provide any details about the merging. It recites nothing about how the data is merged, nothing about the structure of the merged data, and nothing about how the data is stored or accessed.

Element [1.4]: *“wherein the merged data set includes at least one of: data for determining position and orientation of the aircraft relative to the position and orientation of the ramp area, data for determining speed of the aircraft, data for determining direction of the aircraft, data for determining proximity of the aircraft to a particular object within the ramp area, and data for forming a three dimensional virtual model of at least a portion of the aircraft from the merged data; and”*

90. Element [1.4] of representative claim 1 recites the type of data included in the merged data. This limitation simply defines the data included in the merged data and is therefore limited to the data itself.

Element [1.5]: *“displaying messages to provide directional and speed guidance to a pilot with the merged data set.”*

91. Element [1.5] of representative claim 1 simply recites displaying messages to provide guidance with the merged data set. There is nothing in this element that even indicates how the guidance is determined from the merged data set.

92. Having review claim 1 and the '349 Patent, in my opinion a POSITA would have found all of the functions performed in claim 1 were well-known,

routine, and conventional functions for performing aircraft tracking and guidance to a gate by 2020. Accordingly, in my opinion, there is nothing in claim 1 that provides an inventive concept.

93. **The ordered combination of elements does not add “significantly more” to the abstract idea of presenting and settling an invoice.**

94. It is also my opinion that the ordered combination of these conventional functions for performing aircraft tracking and guidance to a gate is conventional. A POSITA would have understood that the order of steps in claim 1 are the only way they could be performed as each prior step is a prerequisite to performing the subsequent step. In other words, the sequence of steps in claim 1 simply reflects the ordinary course of using sensor data to track and guide an aircraft to a gate.

95. **Independent claims 10 and 18 are substantially similar to representative claim 1 and are thus patent ineligible.**

96. Having examined independent claims 10 and 18 relative to claim 1, it is my opinion that the claims are substantially similar to claim 1 and accordingly directed to the same abstract idea. Claim 10 recites the same steps as claim 1 and adds steps of “determining a portion of the camera image data associated with the aircraft” and “determining a portion of the LIDAR/RADAR sensor data associated with the aircraft.” These “determining” steps are part of the same basic process recited in claim 1. Claim 18 recites the exact same functionality as claim 1 while adding conventional, well-known elements for performing that functionality, i.e.,

camera image sensor, LIDAR sensor, RADAR, sensor, computing device, and memory. In my opinion, a POSITA would have found these hardware elements to be well-understood, routine, and conventional. The hardware element thus do nothing to transform claim 18 into an inventive concept.

97. **The dependent claims of the '349 Patent are directed to the same abstract idea and add only trivial and conventional elements**

98. The dependent claims of the '349 Patent do not add anything meaningful to transform the abstract idea into an inventive concept.

99. Claims 2-3, 5-7, 11-12, and 20 all recite steps for comparing or analyzing data to identify aircraft type or presence. These claims all involve nothing more than mental processes and do not add any hardware elements.

100. Claim 4 recites that the LIDAR/RADAR sensor scans the aircraft in at least a horizontal or vertical direction. That the LIDAR/RADAR sensor scans an object in this manner is entirely well-known, routine, and conventional as explained in the Background section above.

101. Claims 8 and 9 recite that the proximity data includes proximity of a certain type. These claims thus do nothing more than further define data as particular data.

102. Claims 13-17 simply require sending information to a device. There is no limitation to the manner of sending nor any hardware elements to perform

sending. Sending information to a device is entirely well-known, routine, and conventional as explained in the Background section above.

103. Claim 19 recites analyzing sensor data using a point cloud process. A point cloud process is entirely well-known, routine, and conventional as explained in the Background section above.

104. In sum, the dependent claims of the '349 Patent are directed to the same abstract idea as independent claims 1, 10, 18, and add only trivial and conventional elements that are insufficient to transform the abstract idea into an inventive concept.

B. Ground #2: Claims 1, 6-10, 13-16, and 18-20 Are Invalid as Anticipated by and/or Obvious Over Berkmo

105. In my opinion, every limitation of claims 1, 6-10, and 13-20 is met either expressly or inherently by Berkmo. On that basis, Berkmo anticipates those claims under 35 U.S.C. § 102. If it found that any limitations are not expressly or inherently taught by Berkmo, then it is my opinion such limitations are obvious over Berkmo, and claims 1, 6-10, and 13-20 are obvious under 35 U.S.C. § 103.

1. Summary of Berkmo

106. Berkmo discloses a very similar system to the system in the '349 Patent. Specifically, Berkmo discloses an airport stand arrangement configured to aid a pilot to maneuver an aircraft to a stand parking position. EX1004, Abstract; ¶0001. The airport stand is also referred to as the dock, apron, or gate area. In one of Berkmo's

examples, an airport stand arrangement 300 includes a combined system 310 employing a radar system 110R, a laser system 110L, and an imaging system 110C each one having respective coverage areas 312R, 312L, and 312C, as shown in annotated Fig. 3 below. *Id.*, ¶¶0116-0119, 0131-0132. The imaging system 110C includes a camera. *Id.*

107. An annotated version of Fig. 3 is provided below. The imaging system 110C (in blue), radar system 110R (in green), and laser system 110L (in red) are arranged at different positions to detect an approaching aircraft 10 using different collection angles. *Id.*, ¶0132.

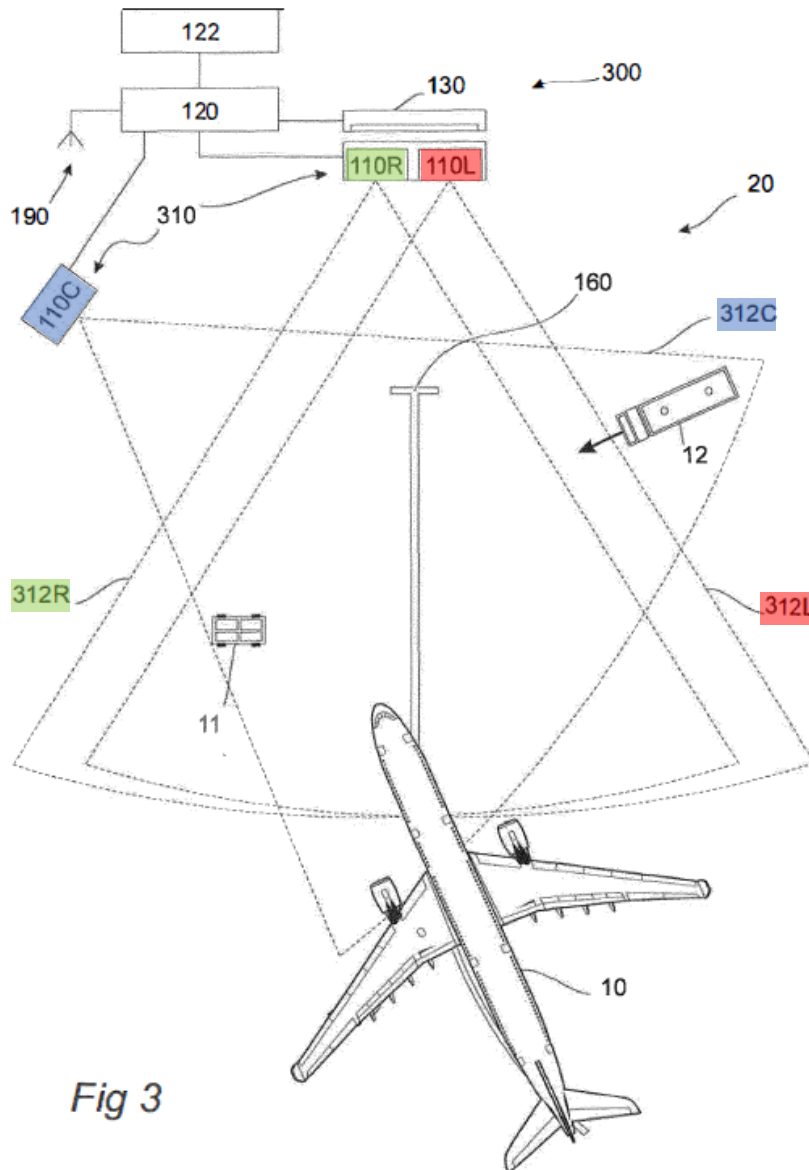


Fig 3

Each sensor system is arranged at a different position, which enables arrangement 300 to detect an approaching aircraft 10 using different collection angles. *Id.*, ¶0132. Berkmo's uses of three sensor systems at three different locations and viewing angles allows the full aircraft to be seen instead of just a portion. This arrangement of different sensors at different locations and viewing angles mitigates problems that

can arise from obstructions such as a passenger ramp or luggage truck in the way of a sensor.

108. The output data of combined system 310 is combined together, and airport stand arrangement 300 detects and tracks an approaching aircraft 10 based on the combined output data. *Id.*, ¶¶0129-0130, 0134. In addition to detecting and tracking aircraft 10, airport stand arrangement 300 can also detect and track other objects within stand area 20. *Id.*, ¶¶0132-0134. Those other objects include, for example, dolly 11 and truck 12. *Id.* In addition, the detection and tracking of the other objects is based on the combined output data from combined system 310. *Id.*

109. Berkmo discloses using a weighted average to combine or merge the output data. For example, Berkmo discloses determining a spatially resolved weighted average of the combined output data, such as based on statistical weights for each system of combined system 310. *Id.*, ¶¶0022-0025, 0129-0130. The weighted average can be a matrix of average data values, where each average data value corresponds to a specific spatial location in the stand area and is calculated as a sum of weighted data values corresponding to the same spatial location, but detected using the radar system and one or more additional sensor systems. *Id.*, ¶¶0025, 0130.

110. The combined data from the combined system includes data that can be used to determine information about aircraft 10 and objects 11, 12, including data

EX1003 - Expert Declaration of Dr. Mark Campbell for determining position, orientation, speed, and direction of the aircraft 10. *Id.*, ¶¶0126, 0136. The combined data also includes data for determining proximity of aircraft 10 to objects (e.g., dolly 11, truck 12) in stand area 20. *Id.*, ¶¶0134-0135. Although Berkmo does not expressly disclose forming a 3D model of aircraft 10, at least the laser-based system 110L necessarily and inherently produces data sufficient to form a 3D mode of aircraft 10. Moreover, Berkmo does disclose “controller 120 may also perform a data analysis of the received output data to determine the dimensions of the aircraft 10.” EX1004, ¶0126. A POSITA would understand that determining dimensions of aircraft 10 corresponds to 3D information of aircraft 10.

111. Berkmo discloses providing maneuvering guidance information for aiding the pilot to maneuver aircraft 10 to a parking position 160 according to the detection and tracking of aircraft 10 and other objects in stand area 20. EX1004, ¶0127. A control unit 120 determines the pilot maneuvering guidance information by analyzing the combined data from the combined system. *Id.* The pilot maneuvering guidance information can be displayed on display 130 of airport stand arrangement 100 or wirelessly transmitted to aircraft 10 to view on a cockpit display. *Id.*, ¶¶0120, 0128.

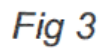
2. Claim 1

a. “A method for tracking an aircraft, comprising:”

112. The preamble of claim 1 is met by Berkmo because Berkmo teaches “an airport stand arrangement (100) is configured, based on output data from said combined system (110), to *detect and track* (S108,S110) *an aircraft* (10) within a stand area (20) when said aircraft (10) is approaching a stand within the stand area (20). EX1004, Abstract; *see also* Figs. 1-3, ¶¶0125-0126, 0129, 0143.

b. “receiving camera image data of the aircraft while the aircraft is approaching a ramp area for parking the aircraft on an airside of an airport;”

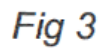
113. Berkmo’s imaging system 110C performs this step of claim 1. Berkmo discloses imaging system 110C includes “a camera sensitive to optical or infrared radiation” that “provides output data pertaining to an imaging system coverage 112C at the stand area 20.” EX1004, Figs. 2-3, ¶0131. The annotated version of Fig. 3 below shows how the imaging system coverage 112C detects aircraft 10.



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c. “receiving Light Detection And Ranging (LIDAR) or Radio Detection And Ranging (RADAR) sensor data of the aircraft while the aircraft is approaching or in the ramp area;”

115. Berkmo’s laser system 110L and radar system 110R both meet this limitation. Berkmo discloses laser system 110L “emit[s] continuous or pulsed laser radiation towards a target,” “capture[s] and detect[s] laser radiation backscattered from the target,” and “provides output data pertaining to a laser-based system coverage 312L at the stand area 20.” EX1004, Figs. 1, 3, ¶0118. While not using the term LIDAR, laser system 110L is the same thing as a LIDAR sensor. Just like LIDAR, laser system 110L emits pulsed laser radiation towards a target and captures and detects *backscattered laser radiation*. Accordingly, a POSITA would understand that laser system 110L is a LIDAR sensor. Radar system 110R “emit[s] continuous or pulsed radar signals towards a target, “capture[s] and detect[s] radar pulses backscattered from the target,” and “provides output data pertaining to a radar-based system coverage 312R at the stand area 20.” EX1004, Figs. 1-3, ¶0117. Radar system 110R is therefore a radar sensor.



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the same portion of aircraft 10 inside radar system coverage 312R (outlined in green).

d. “merging the camera image data and the LIDAR/RADAR-sensor data into a merged data set; and,”

117. Berkmo teaches imaging system 110C generates camera image data, laser system 110L and radar system 110R generate sensor data, and the output data from all three systems is combined. This combined output data in Berkmo therefore corresponds to a merged data set that merges the imaging system camera image data and the laser and radar sensor data. More specifically, Berkmo discloses detecting and tracking aircraft 10 “based on *combined output data* from said radar-based system 110R, on the one hand, and from the one or more additional systems.” EX1004, ¶0129; *see also* ¶¶0126-0127, 0130, 0134, 0137-0139. The “one or more additional systems” includes both imaging system 110C and laser system 110L, such as shown in Fig. 3 of Berkmo. *See id.*

118. Berkmo also teaches a specific method for combining or fusing (i.e., merging) the output data from each of the systems. In particular, Berkmo describes determining a spatially resolved weighted average of the combined output data, such as based on statistical weights for each of imaging system 110C, laser system 110L and radar system 110R. *Id.*, ¶¶0022-0025, 0129-0130. The weighted average can be a matrix of average data values, where each average data value corresponds to a

specific spatial location on the stand area and is calculated as a sum of weighted data values corresponding to the same spatial location. *Id.*, ¶¶0025, 0130. In this manner, Berkmo teaches a merging process that effectively uses a point cloud process, i.e., matching each point of data of each sensor system to the corresponding specific spatial location and combining the data points for that specific spatial location to determine the weighted average for that specific spatial location.

- e. **“wherein the merged data set includes at least one of: data for determining position and orientation of the aircraft relative to the position and orientation of the ramp area,”**

119. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data that can be used to determine the position and orientation of aircraft 10 relative to the position and orientation of stand area 20. Berkmo’s airport stand arrangement detects and tracks aircraft 10 approaching stand area 20 to park at parking position 160, and during that detection and tracking, a controller 120 receives the combined output data and “performs a data analysis of it so as to determine tracking data of the aircraft 10.” EX1004, ¶0126. Berkmo expressly discloses that the “tracking data include[es] the *position of the aircraft 10*, the velocity of the aircraft 10 etc.” *Id.*; see also ¶0025 (“[t]he weighted average of *the combined output data may be used to determine* spatially resolved information pertaining to *the position of the approaching aircraft*.”), ¶0082, 0089. Berkmo

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therefore uses the combined output data to determine the position of aircraft 10 relative to stand 20.

120. Berkmo's combined output data also includes data that can be used to determine the orientation of aircraft 10 relative to stand area 20. The combined output data of imaging system 110C, laser system 110L and radar system 110R to detect and track aircraft 10 includes data for position, speed, and direction of aircraft 10 relative to stand area 20 and parking position 160 or at least data that can be used to determine that position, speed, and direction. EX1004, ¶¶0025, 0080, 0082, 0089, 0126, 0136. The combined output data from imaging system 110C, laser system 110L and radar system 110R that provides data for tracking aircraft 10 would also necessarily include data that can be used to determine orientation of aircraft 10. Given the type of data produced by imaging system 110C, laser system 110L and radar system 110R, and that their combined output data includes data for determining position, speed, and direction, that combined output data is necessarily sufficient to determine the orientation of aircraft 10. A POSITA would understand that where the combined output data from these systems produces data sufficient to determine aircraft position, speed, and direction, that same combined data would necessarily be sufficient to determine aircraft orientation as well. That is particularly the case when the combined output data includes data from each of imaging system 110C, laser system 110L and radar system 110R.

121. It also would have been obvious to a POSITA that the combined output data includes data for determining aircraft orientation. The traditional definition of tracking is the “estimation of the state of a moving object based on remote measurements. This is done using one or more sensors at fixed locations or on moving platforms.” EX1030, 23. The state of an object is a vector or variables that are used to fully define the time evolution of the dynamic system, such as aircraft 10 taxiing to stand area 20. Traditional radar tracking has typically included position and velocity information in three dimensions. With the advent of 3D sensors (e.g., laser, stereo cameras, etc.), the “state” of a tracker in some applications has evolved to include the (2D or 3D) position, orientation, velocity, and direction of the object over time, as well as the 3D shape for collision prediction. *See* EX1031, 2, 4-5, 7, 9, 11, 16-17; EX1019, 2-4, 7-11 (using this formulation for tracking cars, equally applicable to taxiing aircrafts). The use of 3D sensors includes a variety of applications including self-driving cars and taxiing aircraft.

122. Berkmo specifically discloses the use of a Kalman filter on the output data from imaging system 110C, laser system 110L and radar system 110R. *See* EX1004, ¶0135. It would have been obvious and well within the ability of a POSITA to apply a Kalman filter to determine aircraft orientation from the output data of imaging system 110C, laser system 110L and radar system 110R. A Kalman filter is well-known and commonly used by a POSITA to determine orientation from the

output data of a camera, lidar, or radar. It is also noted that Berkmo explicitly teaches the use of a Kalman filter on the combined output data over time. *See id.*

123. A POSITA also would have been motivated to determine aircraft orientation from the combined output data because of the improvement to detection and collision avoidance provided by determining orientation. It is well-known and understood by a POSITA that more measurements always results in better tracking accuracy. Consequently, being able to use orientation data, as well as position, speed, and direction, provides greater accuracy and better information. For example, position data alone may create uncertainty, but combining with orientation provides greater accuracy to make determinations, particularly in the context of collision avoidance. In addition to greater accuracy, a POSITA would have been motivated to determine orientation from the combined output data to provide improved collision avoidance. Berkmo expressly teaches providing collision avoidance for aircraft 10 and objects 11, 12 in stand area 20. EX1004, ¶¶0134-0136. A POSITA would have understood that orientation is needed to predict future movement of objects and thus potential collisions. Accordingly, a POSITA would be motivated to have orientation data to provide more accurate pilot maneuvering guidance information to avoid a collision.

f. “data for determining speed of the aircraft,”

124. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data that can be used to determine speed of aircraft 10. To provide collision avoidance guidance to aircraft 10, Berkmo’s airport stand arrangement determines if other objects 11,12 are predicted to leave the stand area 20 before aircraft 10 arrives “based on at least a speed and direction of each of said other objects 11,12 and *a speed and direction of the approaching aircraft 10.*” EX1004, ¶0136, 0080, claim 50. Controller 120 in Berkmo’s airport stand arrangement performs a data analysis of the combined output data “to determine tracking data of the aircraft 10, said tracking data including the position of the aircraft 10 [and] *the velocity of the aircraft 10.*” EX1004, ¶0126. Berkmo therefore determines speed and/or velocity of the aircraft based on the combined output data of combined system 310.

g. “data for determining direction of the aircraft,”

125. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data that can be used to determine direction of aircraft 10. Berkmo’s airport stand arrangement determines if other objects 11,12 are predicted to leave the stand area 20 before aircraft 10 arrives “based on at least a speed and direction of each of said other objects 11,12 and a speed and *direction of the approaching aircraft 10.*” EX1004, ¶0136, 0080, claim 50. Controller 120 in

Berkmo's airport stand arrangement performs a data analysis of the combined output data "to determine tracking data of the aircraft 10, said tracking data including the position of the aircraft 10 [and] *the velocity of the aircraft 10.*" EX1004, ¶0126; (velocity is a vector that includes both the speed and direction of an object). Berkmo therefore determines direction of the aircraft based on the combined output data of combined system 310.

h. "data for determining proximity of the aircraft to a particular object within the ramp area, and"

126. Berkmo's combined output data, which corresponds to "the merged data set" of claim 1, includes data that can be used to determine proximity of aircraft 10 to a particular object (e.g., objects 11, 12) in stand area 20. This proximity determination is necessary to provide collision avoidance for aircraft 10. As part of the collision avoidance, Berkmo's airport stand arrangement uses the combined output data of combined system 310 to detect and track other objects 11,12 within the stand area 20 in parallel with the detection and tracking of aircraft 10 during the maneuvering of aircraft 10 towards parking position 160. EX1004, ¶0134.

127. This detection and tracking provides the basis for collision avoidance. In particular, Berkmo's airport stand arrangement predicts if approaching aircraft 10 is on a collision course with any other objects 11,12. *Id.*, ¶0135; *see also* ¶0136. If a collision course is predicted, Berkmo's airport stand arrangement provides further

pilot maneuvering guidance information instructing the pilot to stop the aircraft 10.

Id. Berkmo specifically discloses that a POSITA could use readily available tools to perform the prediction and teaches using a Kalman filter as a specific example.

Id. In particular, Berkmo teaches using a Kalman filter as a time filter to combine measurements from combined system 310 with a model of the dynamics of the detected obstacles. *Id.* Consistent with the understanding of a POSITA, the Kalman filter can combine a set of measurements over time to create the most likely positions or trajectories of obstacles, or more generally, an object that is being detected and tracked.

128. Since Berkmo uses position and trajectories of aircraft 10 and objects 11, 12 to predict collisions, and uses that information to provide pilot maneuvering guidance information, a POSITA would have understood that Berkmo necessarily determines the proximity of aircraft 10 to objects 11, 12. The converse proposition confirms this necessity. If Berkmo's airport stand arrangement did not determine the proximity of aircraft 10 to objects 11, 12, there is no way for the arrangement to provide pilot maneuvering guidance information to enable aircraft 10 to avoid colliding with objects 11, 12.

- i. **“data for forming a three dimensional virtual model of at least a portion of the aircraft from the merged data; and”**

129. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data that can be used to determine a 3D virtual model of at least a portion of aircraft 10. According to my understanding, this limitation requires that the combined output data includes data *sufficient to form* the 3D model. But it does not require the combined output actually form the 3D virtual model of at least a portion of aircraft 10. A POSITA would understand that Berkmo’s combined output data from imaging system 110C, laser system 110L and radar system 110R includes data sufficient to form a 3D virtual model of at least an aircraft portion.

130. It is known to a POSITA that, to form a 3D model of an object from sensor data (such as lidar or stereo cameras), multiple sensor measurements of the object are collected in which measurement can vary based on sensor location or over time. EX1016, 2, 6, 10, 12. The spatial data from the sensors can be fused into a 3D model of the object by transforming the data into a common reference frame using the sensor pose (position and orientation). *Id.*

131. Based on the teachings of Aldoma, a POSITA would understand that Berkmo teaches each of the key components for forming a 3D model from sensor data. In Berkmo, one or more sensors (110C, 110R, 110L) are used to detect and track aircraft 10, and each sensor can have the same location (Figs. 1-2) or different

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locations (Figs. 3, 6) with a wider field of view to take measurements of aircraft 10 and stand area 20. EX1004, ¶¶0037, 0129-0130, 0132-0134, 0143. Berkmo also teaches that “[t]he airport stand arrangement is configured to detect and track the approaching aircraft based on a spatially resolved weighted average of the combined output data.” *Id.*, ¶0130. Berkmo further teaches that “an algorithm may run ... to determine corresponding spatial regions of the output data (e.g. pixel-to-pixel matching).” *Id.*, ¶0129. Berkmo thus teaches the same process described in Aldoma of combining data from multiple sensors to a 3D model using the sensor pose information. EX1016, 2, 6-7.

132. Berkmo therefore teaches combined output data from imaging system 110C, laser system 110L and radar system 110R includes data sufficient to form a 3D virtual model of at least an aircraft portion. I also note that Berkmo discloses determining dimensions of aircraft 10 from the combined output data. EX1004, ¶0126. A POSITA would understand that dimensions of aircraft 10 correspond to a 3D model of aircraft 10 that is determined from the combined output data.

j. “displaying messages to provide directional and speed guidance to a pilot with the merged data set.”

133. Berkmo teaches displaying messages to provide directional and speed guidance to a pilot with the combined output data. Berkmo’s airport stand arrangement includes “*a display 130 for providing pilot maneuvering guidance*

information to a pilot of the approaching aircraft 10” that is “mounted on the wall of the terminal building ... in clear view of the pilot of the approaching aircraft 10.” EX1004, ¶ [0120]. To “aid[] the pilot of the approaching aircraft 10 in maneuvering the aircraft 10 towards the parking position 160 ... [t]he pilot maneuvering guidance information is determined by the control unit 120 by analyzing the output data received from the combined system 110.” *Id.*, ¶0127. Berkmo also discloses an alternative means for providing guidance to a pilot. In particular, instead of providing guidance information on display 130, Berkmo’s airport stand arrangement includes wireless transmitting means 190 connected to control unit 120. *Id.*, ¶0128. Wireless transmitting means 190 wirelessly transmits the guidance information to aircraft 10 for viewing on a display in the aircraft cockpit. *Id.*

134. Berkmo therefore teaches using the combined output data to determine pilot maneuvering guidance information, including directional and speed guidance, and displaying it on display 130 or on an aircraft cockpit display. *See* EX1004, Figs. 2-4, ¶¶0135-0136, 0143. For example, Berkmo discloses the guidance information includes “instructing the pilot to stop the aircraft,” which is providing speed guidance, i.e., speed is 0. *Id.*, ¶0143. Berkmo also discloses guidance information to “instruct the pilot to continue approaching the stand,” which is providing directional guidance, i.e., direction toward the stand. *Id.*

135. Based on my above analysis, it is my opinion that Berkmo meets every limitation of claim 1 either expressly or inherently. Accordingly, based on my understanding of 35 U.S.C. § 102, claim 1 should be found invalid as anticipated by Berkmo. In addition, if any limitation is not found to be expressly or inherently taught by Berkmo, such limitations would have been obvious in view of the teachings of Berkmo. Thus, based on my understanding of 35 U.S.C. § 103, claim 1 should alternatively be found invalid as obvious over Berkmo.

3. Claim 6: “The method of claim 1, wherein a gate arrival information is received from an airport computing system.”

136. Berkmo’s airport stand arrangement teaches receiving gate arrival information from an airport computing system. For example, Berkmo’s airport stand arrangement includes control unit 120 connected to database 122. EX1004, ¶0121. According to Berkmo, “*database 122 may be an airport operational database AODB comprising flight plans of arriving and departing aircrafts. This way, the control unit 120 may access information pertaining to the type of aircraft which will be approaching the stand area 20.*” *Id.*

137. The ’349 Patent confirms that gate arrival information includes aircraft type. In particular, the ’349 Patent discloses that its “docking system can then compare the determined aircraft type with *an aircraft type provided in gate arrival information* (e.g. from the airport computing system) to determine that the aircraft

type that is approaching or in the ramp area is the correct aircraft type.” EX1001, 7:51-55. Thus, in the same manner as Berkmo, the ’349 Patent recognizes that aircraft type provided by an airport operational database (i.e., an airport computing system) is “gate arrival information.”

4. **Claim 7: “The method of claim 1, further comprising: comparing the camera image data and the LIDAR/RADAR sensor data to identify that the aircraft is present in both the camera image data and the LIDAR/RADAR sensor data before merging the camera image data and the LIDAR/RADAR sensor data.”**

138. Berkmo compares camera image data from imaging system 110C with sensor data from laser system 110L and/or radar system 110R to identify the aircraft before the data from each system is merged. In particular, Berkmo teaches its airport stand arrangement detects and tracks objects “based on output data from the imaging system 110C” and “verif[ies] the existence of said detected and tracked object based on output data from a further system 110L of the one or more additional systems and/or output data from the radar-based system 110R.” EX1004, ¶¶0138, 0035. Although not expressly noted in ¶0138, Berkmo does expressly teach that objects detected and tracked in stand area 20 include aircraft 10. *Id.*, ¶¶0125-126, 0129-0130, 0133-0134, 0143, 0145. Since aircraft 10 is another object detected and tracked by the combined system 310, a POSITA would have understood that Berkmo

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also teaches verifying aircraft 10 by comparing camera image data of imaging system 110C with sensor data of laser system 110L and/or radar system 100R.

139. Berkmo also teaches performing this verification by comparing data before combining the data of imaging system 110C, laser system 110L, and radar system 110R. Berkmo discloses combining the output data of all three systems by using a spatially resolved weighted average. EX1004, ¶0130. Each data value output by imaging system 110C is therefore different from the combined data value. The same difference applies to each data value output by laser system 110L and radar system 100R in comparison the corresponding combined data value. Since Berkmo expressly teaches verifying an object by comparing output data of imaging system 110C to output data of laser system 110L and/or radar system 110R, and the combined data values are different the data output from these systems prior to combining the data, Berkmo necessarily and inherently requires the comparison be made before combining the output data of these systems.

140. Even if Berkmo does not expressly or inherently teach this comparison to verify aircraft 10, it would have been obvious to a POSITA to perform that comparison and verification based on the teachings of Berkmo, and a POSITA would have been motivated to do so. In particular, Berkmo notes that imaging system 110C can mistakenly detect and identify image artifacts, such as shadows, as real objects. EX1004, ¶¶0035-0036. Berkmo teaches the comparison and

verification of an object detected by imaging system 110C with radar system 110R or laser system 110L overcomes this drawback of imaging system 110C. *Id.* Accordingly, a POSITA would have been motivated to compare data of imaging system 110C to data of radar system 110R or laser system 110L to verify existence of aircraft 10. Such verification ensures imaging system 110C has detected and identified aircraft 10 correctly and is not an image artifact.

141. Similarly, if Berkmo does not expressly or inherently teach performing the data comparison before merging, it would have been obvious for a POSITA to make the comparison prior to merging. There are only two options here: performing the comparison and verification before merging; or doing so after merging. First of all, it would have been obvious to a POSITA that doing the comparison and verification before merging would have a reasonable expectation of success. Moreover, with only two options and given that the Berkmo's data merging alters the combined data, a POSITA would have been motivated to perform the data comparison prior to merging data to ensure that it is imaging system output data that is actually compared to radar or laser system output data as opposed to altered versions of such output data.

5. Claim 8: “The method of claim 1, wherein the data for determining proximity of the aircraft to a particular object within the ramp area include data for determining proximity of the aircraft to a stop point.”

142. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data for determining proximity and that proximity data can be used to determine proximity of aircraft 10 to a stop point. Berkmo’s airport stand arrangement provides “*pilot maneuvering guidance information for* aiding the pilot of the approaching aircraft 10 in *maneuvering the aircraft 10 towards the parking position 160*. The *pilot maneuvering guidance information is determined* by the control unit 120 by *analyzing the output data received from the combined system 110*.” EX1004, ¶0127. To provide guidance information to parking position 160 (i.e., stop point) based on the combined output data, a POSITA would have understood that the combined data must include data for determining proximity of aircraft 10 to parking position 160. Again, the converse proposition confirms this understanding. If Berkmo’s airport stand arrangement does not have data regarding the location of aircraft 10 proximate to parking position 160, there is no way for the arrangement to guide aircraft 10 to parking position 160.

6. **Claim 9: “The method of claim 1, wherein the data for determining proximity of the aircraft to a particular object within the ramp area include data for determining proximity of the aircraft to a piece of equipment on a ramp area tarmac surface.”**

143. Berkmo’s combined output data, which corresponds to “the merged data set” of claim 1, includes data for determining proximity and that proximity data can be used to determine proximity of aircraft 10 to a piece of equipment on stand area (i.e., ramp area tarmac surface). Berkmo’s airport stand arrangement is “configured to *detect and track other objects* within the stand area 20,” where other objects include “*a luggage dolly 11*, and a food delivery truck 12.” EX1004, ¶0133. Stand area 20 is continuously monitored “for potential objects which may be involved in causing accidents at the stand.” *Id.*

144. Berkmo’s airport stand arrangement is “further configured to *predict if the approaching aircraft 10 is on a collision course with any of said other objects 11,12, and*, in response to a collision course being predicted, to *provide further pilot maneuvering guidance information* instructing the pilot to stop the aircraft 10.” *Id.*, ¶0135. Berkmo’s collision avoidance between aircraft 10 and objects within stand area 20 must include data for determining proximity of aircraft 10 to those objects. If Berkmo’s airport stand arrangement does not have data regarding the location of aircraft 10 proximate to objects in stand area 20, there is no way for the arrangement to guide aircraft 10 to avoid collisions with those objects.

7. Claim 10

145. Except for following limitations of claim 10 I discuss herein, every other limitation of claim 10 is the same as corresponding limitations in claim 1. Those same limitations are met by Berkmo for the same reasons I discussed above.

a. “determining a portion of the camera image data associated with the aircraft:”

146. To be able detect and track aircraft 10, provide collision avoidance, and guide aircraft to parking position 160, a POSITA would have understood that Berkmo must determine the portion of the camera image data output from imaging system 110C associated with aircraft 10. Berkmo discloses the imaging system 110C is configured to detect and track objects, including aircraft 10, in stand area 20. EX1004, Figs. 1-3, ¶¶0027, 0032, 0048, 0116, 0126, 0131-0132. Berkmo also discloses analyzing its output data to provide guidance to aircraft 10. *Id.*, ¶¶0097, 0120, 0127, 0134-0136, 0143-0145. Since Berkmo discloses imaging system 110C detects and tracks objects in stand area 20 including aircraft 10, and that data is used to provide pilot maneuvering guidance information to aircraft 10 to avoid collision with objects in stand area 20 and to guide to parking position 160, Berkmo necessarily discloses determining the portion of the camera image data output by imaging system 110C corresponding to aircraft 10. Once more, the converse proposition confirms this necessity. Without determining which portion of the

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camera image data output by imaging system 110C corresponded to aircraft 10, there is no way for Berkmo to detect, track, and distinguish aircraft 10 from objects 11, 12, and no way to provide guidance information to aircraft 10 to avoid collision with objects 11, 12 and park at parking position 160.

b. “determining a portion of the LIDAR/RADAR sensor data associated with the aircraft:”

147. To be able detect and track aircraft 10, provide collision avoidance, and guide aircraft to parking position 160, a POSITA would have understood that Berkmo must determine the portion of the sensor data output from laser system 110L and radar system 110R associated with aircraft 10. Berkmo discloses the laser system 110L and radar system 110R are configured to detect and track objects, including aircraft 10, in stand area 20. EX1004, Figs. 1-3, ¶¶0027, 0032, 0048, 0116, 0126, 0131-0132. Berkmo also discloses analyzing their output data to provide guidance to aircraft 10. *Id.*, ¶¶0097, 0120, 0127, 0134-0136, 0143-0145. Since Berkmo discloses laser system 110L and radar system 110R detect and track objects in stand area 20 including aircraft 10, and that data is used to provide pilot maneuvering guidance information to aircraft 10 to avoid collision with objects in stand area 20 and to guide to parking position 160, Berkmo necessarily discloses determining the portion of the sensor data output by laser system 110L and radar system 110R corresponding to aircraft 10. Without determining which portion of

the sensor data output by laser system 110L and radar system 110R corresponded to aircraft 10, there is no way for Berkmo to detect, track, and distinguish aircraft 10 from objects 11, 12, and no way provide guidance information to aircraft 10 to avoid collision with objects 11, 12 and park at parking position 160.

8. Claim 13: “The method of claim 10, further comprising: sending at least the determined speed and direction to a ramp docking system controller device.”

148. Berkmo discloses sending combined output data, including determined speed and direction, to a ramp docking system controller device. Berkmo discloses that its “airport stand arrangement may be an *aircraft docking system*.” EX1004, ¶0012. Berkmo’s airport stand arrangement includes a controller 120 that “receives said output data and performs a data analysis of it so as to determine tracking data of the aircraft 10, said tracking data including the position of the aircraft 10, the velocity of the aircraft 10 etc.” *Id.*, ¶0126. Berkmo further discloses that its airport stand arrangement predicts collisions and provides pilot maneuvering guidance information based on the determined speed and direction of aircraft 10 and objects 11, 12. *Id.*, ¶¶0080, 0136. Since Berkmo discloses its airport stand arrangement can be an aircraft docking system (i.e., a ramp docking system controller device), includes controller 120 that receives and analyzes the combined output data, and that airport stand arrangement uses determined speed and direction to predict collisions

and provide pilot maneuvering guidance information, Berkmo sends determined speed and direction to a ramp docking system controller device.

9. Claim 14: “The method of claim 13, further comprising: sending at least the determined position and orientation to a ramp docking system controller device.”

149. Berkmo discloses sending combined output data, including determined speed and direction, to a ramp docking system controller device. Berkmo discloses that its “airport stand arrangement may be an *aircraft docking system*.” EX1004, ¶0012. Berkmo’s airport stand arrangement includes a controller 120 that “receives said output data and performs a data analysis of it so as to determine tracking data of the aircraft 10, said tracking data including the position of the aircraft 10, the velocity of the aircraft 10 etc.” *Id.*, ¶0126. Berkmo further discloses that the combined output data includes data for determining position and orientation. *Id.*, ¶¶0025, 0080, 0082, 0089, 0126, 0134-0136. Since Berkmo discloses its airport stand arrangement can be an aircraft docking system (i.e., a ramp docking system controller device), includes controller 120 that receives and analyzes the combined output data, and that airport stand arrangement uses determined position and orientation to predict collisions and provide pilot maneuvering guidance information, Berkmo sends determined position and orientation to a ramp docking system controller device.

- 10. Claim 15: “The method of claim 10, further comprising: sending at least the determined position and orientation to a ramp docking system controller device.”**

150. Claim 15 is met by Berkmo for the same reasons explained above with respect to claim 14.

- 11. Claim 16: “The method of claim 10, further comprising: sending at least one of the determined speed, direction, position, and orientation to a pilot unit computing device on the aircraft.”**

151. Berkmo sends at least one of determined speed, direction, position, and orientation to a pilot unit computing device on aircraft 10. Berkmo’s airport stand arrangement “*is configured to wirelessly transmit S116 a signal comprising said pilot maneuvering guidance information to the approaching aircraft 10*” and can be “wirelessly transmitted as a part of the radar signals emitted from the radar-based system 110R.” EX1004, ¶¶ 0128, 0068. “*The signal may be received by equipment installed within the aircraft 10 and viewed on a display in the cockpit of the aircraft.*” *Id*; see also ¶¶ 0135-0136, 0143.

152. A POSITA would have understood that the only way for aircraft 10 to receive and display the guidance information on the aircraft cockpit display is for a computing device on aircraft 10 to receive, interpret, and display it on a pilot unit computing device on aircraft 10. Even if Berkmo does not expressly or inherently teach sending the signal to an aircraft computing device, it would have been obvious

to a POSITA that the signal would be received by an aircraft computing device. In particular, a POSITA would have known that a display alone, without a computing device, cannot receive, interpret, and cause guidance information to be displayed. Of course, a POSITA would have also understood that the display itself could be configured to include the circuitry of a computing device to perform the receiving, interpreting, and displaying functions instead of a separate computing device.

12. Claim 17: “The method of claim 10, further comprising: sending at least one of the determined speed, direction, position, and orientation to a passenger computing device on the aircraft.”

153. Claim 17 is met by Berkmo for the same reasons explained above with respect to claim 16. Even if Berkmo does not expressly teach sending determined speed, direction, position, or orientation to a passenger computing device on aircraft 10, it would have been obvious to a POSITA to do so. Berkmo expressly teaches sending such information wirelessly to aircraft 10 for viewing on the aircraft cockpit display. EX1004, ¶¶0135-0136, 0145. It would have been obvious to a POSITA that this information could be sent and received to any computing device on aircraft 10 including a passenger computing device. In addition to the presence of passenger computing devices and displays for each passenger on an aircraft being well-known and commonly present, a POSITA would have been motivated to send this information to a passenger computing device for multiple reasons including

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providing passengers with aircraft status relative to gate arrival, to enable passengers to better prepare for disembarkation by knowing distance and time to gate arrival, and to provide passengers with information of interest. Providing this information to a passenger computing device is also well within the skill of a POSITA, would not require undue experimentation, and would yield predictable results. *Id.*

13. Claim 18

154. Except for following limitations of claim 18 I discuss herein, every other limitation of claim 18 is the same or substantially the same as corresponding limitations in claim 1. Those same or substantially the same limitations are met by Berkmo for the same reasons I discussed above.

- a. **“a computing device having memory associated therewith for receiving the camera image data from the camera image sensor; ... the computing device for receiving the LIDAR/RADAR sensor data and merging the camera image data and the LIDAR/RADAR sensor data associated with the aircraft into a merged data set”**

155. Berkmo’s control unit/controller 120 corresponds to a computing device having memory that receives output data from the combined system 310 and merges that data. In particular, Berkmo’s airport stand arrangement includes a control unit/controller 120 connected to the combined system and to database 122. EX1004, ¶0121. “[C]ontroller 120 receives said output data [from the combined system] and performs a data analysis of it so as to determine tracking data of the

aircraft 10, said tracking data including the position of the aircraft 10, the velocity of the aircraft 10 etc.” *Id.*, ¶0126, *see also* ¶¶0129-0130 (merging data as “spatially resolved weighted average of the combined output data”). To perform the function of receiving the output data from the combined system, merging it, and using the output data to track aircraft 10, control unit/controller 120 must include a computing device having a memory. Without a computing device and memory, control unit/controller 120 cannot receive output data from each sensor and merge the data.

14. Claim 19: “The system of claim 18, wherein the LIDAR/RADAR sensor data is analyzed using a point cloud process to correlate points in the LIDAR/RADAR sensor data to points in the camera image data.”

156. Berkmo teaches using a point cloud process to correlate data points from laser system 110L, radar system 110R, and imaging system 110C. Berkmo discloses “[a]n algorithm may run a pre-processing sub-algorithm to determine *corresponding spatial regions* of the output data (e.g. *pixel-to-pixel matching*).” EX1004, ¶0129. Using the data points from each sensor system, Berkmo teaches determining a weighted average as a matrix of average data values in which “each average data value pertains to a *specific spatial location* on the stand area and is calculated as a sum of weighted data values (of an associated output data) *pertaining to the same spatial location* but detected *using the radar system, and the one or more additional systems* [i.e., laser system 110L and imaging system 110C].” *Id.*,

¶0130. A POSITA would have understood that this matching of spatial locations from data of each system corresponds to using a point cloud process to correlate points.

15. Claim 20: “The system of claim 18, wherein the computing device analyzes the camera image data to identify that the aircraft is approaching the ramp area.”

157. Berkmo discloses controller/control unit 120 analyzes the camera image data to identify aircraft 10 in stand area 20. Berkmo discloses “controller 120 may also perform a *data analysis of the received output data* [which includes imaging system 110C data] to determine the dimensions of the aircraft 10. Said dimensions may be compared to dimensions of aircraft models stored locally in the airport stand arrangement, or in the AODB 122, to *establish an aircraft type* and model of the aircraft 10.” EX1004, ¶0126; see also ¶0048, 0054, 0121, 0137, claim 43.

C. Ground #3: Claims 1-20 Are Invalid as Obvious Over Berkmo in View of Richman

158. In my opinion, every limitation of claims 1, 6-10, and 13-20 is met either expressly or inherently by Berkmo. On that basis, Berkmo anticipates those claims under 35 U.S.C. § 102. To the extent any limitations of claims 1, 6-10, and 13--20 are not expressly or inherently taught by Berkmo, then it is my opinion that

Berkmo in view of Richman renders such limitations obvious, and claims 1-20 are invalid under 35 U.S.C. § 103 as obvious over Berkmo in view of Richman.

1. Summary of Richman

159. Richman discloses an aircraft docking system configured to guide an aircraft to a dock in very similar fashion to Berkmo. EX1005, Abstract. Richman recognizes the difficulties of guiding an aircraft to a precise position in a dock, and that these difficulties are exacerbated when the aircraft are large. *Id.*, 1:54-64. To overcome these difficulties, Richman describes an aircraft docking system having a large and simple display installed in full view of both the approaching aircraft and the pilot. *Id.*

160. Richman's docking system uses templates of 3D images of candidate aircraft and selects a template as a model that a computer rotates and scales. *Id.*, 1:65-2:2. Laser radar (ladar) obtains an image of the approaching aircraft and compares the image with the rotated and scaled model to determine the location and orientation of the approaching aircraft. *Id.*, 2:2-7. The system determines the aircraft travel path as updated by the ladar over successive locations and orientations of the aircraft and compares it with the required travel path. *Id.*, 2:7-11. The pilots sees corrective display signals, such as arrows, determined by deviations between the two travel paths. *Id.*, 2:11-15.

161. I provided an annotated version of Richman's Fig. 1 below. As shown in that annotated figures, an aircraft docking system 46 (highlighted in red) provides guidance information to a pilot including steering and speed commands and obstacle warnings. *Id.*, 3:21-24. System 46 is positioned to view a dock 18 and to be seen by a pilot as an aircraft 20 advances along a taxiway 22 before turning into dock 18. *Id.*, 3:24-28. System 46 includes a laser radar 54 to scan the dock area in both elevation and in azimuth with a beam 56 to obtain an aircraft image or obstacle image present within dock 18 and includes a display 60 to present instructions to a pilot. *Id.*, 3:32-39.

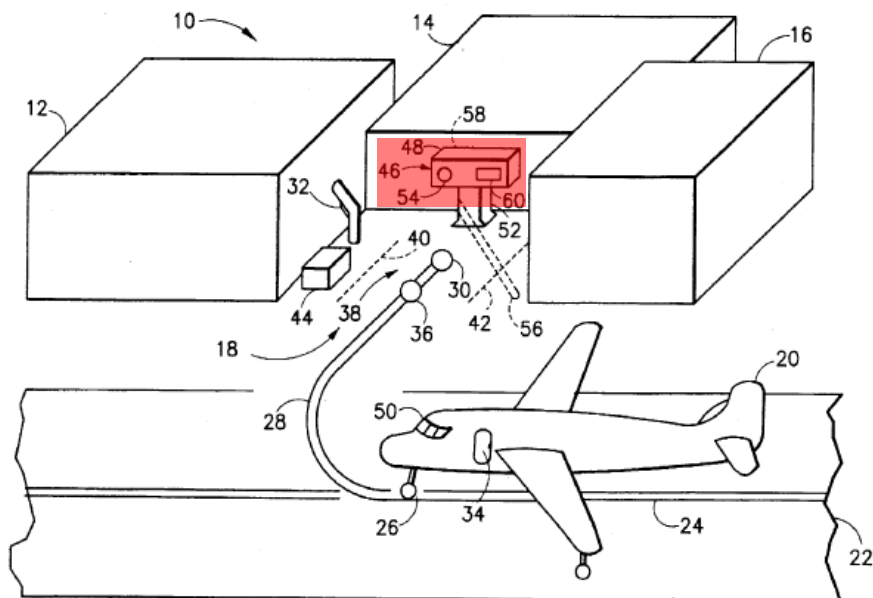


FIG. 1

162. Ladar 54 outputs and stores in memory 62 target data in the form of elevation (EL), azimuth (AZ) and range (R) data for each point of a target that

reflects light from the beam 56 back to the ladar 54. *Id.*, 3:48-53. The collection of target data points stored in memory 62 constitutes a 3D target image and is an example of a point cloud. *Id.*, 3:53-55. A memory 64 stores a library of aircraft templates corresponding to 3D representations of candidate aircraft, and a coordinate converter 66 converts the view of a selected template by rotation, scaling, and/or translating the template to match the target image stored in memory 62. *Id.*, 3:57-62. A correlator 68 compares the template output by converter 66 with the target image in memory 62 to determine the quality of the match, and a match driver 70 makes adjustments to improve the match. *Id.*, 3:64-67; 4:8-22. Feature extraction, such as nose and wing wheel distances and/or height and size of wings, fuselage and rudder can be used to determine type of aircraft. *Id.*, 4:1-7.

2. Motivation to Combine

163. In my opinion, there are numerous reasons why it would have been obvious to a POSITA to combine Berkmo and Richman. First, both Berkmo and Richman are directed to aircraft guidance docking systems using laser sensors for detecting approaching aircraft. EX1004, Figs. 1-3, ¶¶0116-0132; EX1005, 2:4-24; 3:48-4:34. Second, a POSITA would have been motivated to incorporate Richman's 3D modeling, orientation detection, and template matching functionality in Berkmo's arrangement because that functionality is provided by using laser sensor data and Berkmo already includes a laser sensor (i.e., laser system 110L).

Accordingly, a POSITA would have understood that incorporating this functionality from Richman into Berkmo's laser sensor results in a predictable combination of familiar elements according to known methods.

164. A POSITA also would have been motivated to incorporate Richman's 3D modeling, orientation detection, and template matching functionality in Berkmo's arrangement because incorporating that functionality would provide multiple benefits and improvements to Berkmo's arrangement. It is well-known to a POSITA that a key improvement in object detection using 3D models is the ability to return both *location and orientation* of the object. Richman teaches that, "[b]y comparing the image with the rotated and scaled model, the image can be interpreted to show the present location and orientation of the approaching aircraft." *Id.*, EX1005, 2:3-6. Richman thus teaches a simple way to determine orientation of an object, including an aircraft approaching a gate, apron, or stand area. Without 3D models, a POSITA typically infers orientation within the tracking algorithm (e.g., a Kalman filter) using consecutive detections and a dynamics model of the object. But this inferential determination of orientation is less accurate than using 3D models.

165. The use of 3D models for detection also lowers the number of missed detections due to partial sensor returns (e.g., partial point clouds) because it is easier to match partial shape sensor data to the 3D model as compared to detection based only on prior training data. In other words, when there are only partial sensor

returns, which may occur when only part of the aircraft is in view of a sensor, detection based on prior training data is less accurate than using 3D models.

166. A POSITA would also understand that 3D models or templates are very good at identifying the “type” of aircraft or classification. While it is common to use raw sensor detections to match a template in the library, Richman suggests using “feature extraction” from the data to match aircraft type within the library. Using “feature extraction” improves results for detecting aircraft type. To do the “feature extraction, Richman discloses that “[f]eatures such as nose wheel and wing wheel intra-wheel distances and height and size of wings, fuselage and rudder would be used to determine type of aircraft.” EX1005, 4:1-7. Using multiple specific parts of an object is an improvement over Berkmo because more detailed aircraft specific information is used to match the sensor data to the aircraft in the library of 3D models.

167. Finally, Richman teaches detecting location and orientation information from detections of objects. As a result, each object can be tracked by simply arranging these detections in series over time. Richmond teaches detecting an aircraft by “match[ing] to stored models of the aircraft with the aircraft to determine ... a tracking point of the aircraft such as the nose wheel.” EX1005, 1:4-13. The specific tracking is provided as an “aircraft travel path, as represented by successive locations and orientations of the aircraft.” *Id.*, 2:7-11.

168. In contrast, the more common but less accurate approach for aircraft tracking uses consecutive location detections only in combination with a dynamics model of how the object moves on the ground. This approach infers each variable in tracking (location, orientation, velocity, and direction) based on the combination of the model prediction and sensor data over time. The use of 3D models and orientation information, as taught by Richman, would clearly improve the accuracy of aircraft tracking in the Berkmo stand area as compared to the inferential approach. In sum, for all of these reasons, a POSITA would have been motivated to incorporate Richman's 3D modeling, orientation detection, and template matching functionality in Berkmo's airport stand arrangement.

3. Claim 1

169. As explained above, it is my opinion that every limitation of claim 1 is expressly or inherently met by Berkmo and/or obvious over Berkmo. To the extent any limitation is not anticipated by or obvious over Berkmo, it is my opinion that they are expressly met by Richman and thus claim 1 is obvious over the combination of Berkmo and Richman

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- a. **“wherein the merged data set includes at least one of: data for determining position and orientation of the aircraft relative to the position and orientation of the ramp area,”**

170. To the extent this limitation is not anticipated by or obvious over Berkmo alone, it is my opinion that Richman teaches this limitation of claim 1. Richman’s docking system detects arriving aircraft and “matches stored models of the aircraft with the aircraft to *determine orientation of the aircraft and a tracking point of the aircraft* such as the nose wheel.” EX1005, 1:4-14. By comparing the detected aircraft image with a rotated and scaled model, “the image can be interpreted to show the present *location and orientation* of the approaching aircraft.” *Id.*, 2:4-11; *see also* Abstract; 1:54-2:24; 7:55-8:13; 8:32-52; 8:65-10:11. Richman therefore expressly teaches using sensor data to determine location (i.e., position) and orientation of the approaching aircraft relative to the docking (i.e., ramp) area.

- b. **“data for forming a three dimensional virtual model of at least a portion of the aircraft from the merged data;”**

171. To the extent this limitation is not anticipated by or obvious over Berkmo alone, it is my opinion that Richman teaches this limitation of claim 1. Richman’s docking system includes ladar 54 that “outputs target data in the form of elevation (EL), azimuth (AZ) and range (R) data for each point of a target, such as an aircraft ... [where t]he collection of target data points stored in the memory 62

constitute a *three-dimensional image of the target*.” EX1005, 3:49-55. A memory 64 stores *templates as a 3D representation of candidate aircraft*, and a “correlator 68 compares the template outputted by the converter 66 with the target image outputted by the memory 62 to determine the quality of the match between the template and the image.” *Id.*, 3:57-67; *see also* Fig. 2; Abstract; 1:65-2:24; 4:23-34; 6:59-7:5; 8:13-17; 8:31-52; 8:65-10:11. Richman therefore expressly teaches using sensor data to form a 3D target image (i.e., virtual model) of the approaching aircraft.

4. **Claim 2: “The method of claim 1, further comprising: comparing the three dimensional virtual model to one or more aircraft reference models stored in memory of a computing device to find a match between the three dimensional virtual model and one of the aircraft reference models to determine an aircraft type.”**

172. It is my opinion that Richman expressly teaches this limitation. Richman’s docking system includes ladar 54 that outputs target data points of the aircraft and stores the collection of target data points as a 3D target image of the aircraft. EX1005, 3:47-55. Memory 64 stores a library of aircraft templates (i.e., aircraft reference models) corresponding to 3D representations of candidate aircraft. *Id.*, 3:55-64. Correlator 68 and match driver compare the target image to the templates to determine aircraft type, such as by using aircraft features. *Id.*, 3:65-4:22; *see also* Fig. 2; Abstract; 1:65-2:24; 4:23-34; 6:59-7:5; 8:13-17; 8:31-52; 8:65-10:11. Richman therefore expressly teaches comparing the 3D target image (i.e.,

virtual model) to templates of candidate aircraft (i.e., aircraft reference model) to find a match.

173. It is also noted that Berkmo teaches comparing information based on the combined output data with aircraft models in a database to determine aircraft type. EX1004, ¶¶0121, 0126. The combined output data include information determining the dimensions of aircraft 10. *Id.*, ¶0126. A POSITA would have understood that dimensions of aircraft 10 correspond to a 3D virtual model of aircraft 10. Accordingly, Berkmo also teaches comparing a 3D virtual model to aircraft models (i.e., aircraft reference model) to find a match.

5. Claim 3: “The method of claim 2, further comprising: comparing the determined aircraft type with an aircraft type provided in gate arrival information to determine that the aircraft type that is approaching or in the ramp area is a correct aircraft type.”

174. It is my opinion that Berkmo expressly teaches this limitation. Berkmo teaches control unit/controller 120 is connected to database 122 comprising flight plans with information pertaining to aircraft type approaching stand area. EX1004, ¶0121. Control unit/controller 120 “perform[s] a data analysis of the received output data to determine the dimensions of the aircraft 10. Said dimensions may be *compared* to dimensions of aircraft models stored locally in the airport stand arrangement, or in the AODB 122, to establish an aircraft type and model of the aircraft 10.” *Id.*, ¶0126. Berkmo’s comparison of the determined dimensions of

aircraft 10 to aircraft type from flight plan information necessarily confirms whether approaching aircraft 10 is the correct aircraft type. Moreover, it would have been obvious to a POSITA that establishing aircraft type and model of aircraft 10 by making this comparison with the flight plan information identifying aircraft type would necessarily confirm whether approaching aircraft 10 is the correct aircraft type.

6. Claim 4: “The method of claim 1, further comprising: scanning the aircraft with a LIDAR/RADAR sensor with a sweep of the LIDAR/RADAR across the aircraft in at least one of a horizontal or vertical direction or both.”

175. It is my opinion that Richman expressly teaches this limitation. Richman teaches that the beam from ladar 54 (i.e., LIDAR/RADAR sensor) is deflected “in *both horizontal and vertical direction.*” EX1005, ¶2:45-49. Laser radar 54 “scans the area of the dock 18 in *both elevation and in azimuth with a beam 56*, such as a pencil beam of infrared radiation, to obtain an image of any aircraft or obstacle which may be present within the dock 18.” *Id.*, 3:32-36. Richman thus teaches sweeping beam 56 of ladar 54 across an aircraft in both horizontal and vertical directions. Moreover, a POSITA would have understood that using laser radar 54 to scan beam 56 in both elevation and azimuth corresponds to scanning in both horizontal and vertical directions.

7. **Claim 5: “The method of claim 4, further comprising: comparing the camera image data and the LIDAR/RADAR sensor data to identify that the aircraft is present in both the camera image data and the LIDAR/RADAR sensor data.”**

176. It is my opinion that this limitation is anticipated by and/or obvious over Berkmo. Berkmo’s airport stand arrangement is “configured to detect and track an object of said other objects 11,12 *based on output data from the imaging system 110C*, and *verify the existence of said detected and tracked object based on output data from a further system 110L* of the one or more additional systems and/or output data from the radar-based system 110R.” EX1004, ¶0138; *see also* ¶¶0023-0024, 0036. Based on this teaching, Berkmo compares camera image data from imaging system 110C with sensor data from laser system 110L/radar system 110R to confirm an object in stand area 20 is present in both sets of data.

177. It is noted that Berkmo teaches that objects detected in stand area 20 include aircraft 10. *Id.*, ¶¶0125-0127, 0130, 0132-0134. As a result, Berkmo’s verification by comparison of output data from imaging system 110 and laser system 110L/radar system 110R would necessarily include verification that aircraft 10 is present in both sets of data. Even if that verification for aircraft 10 is not necessarily performed, it would have been obvious to a POSITA, and a POSITA would have been motivated to perform aircraft verification for multiple reasons. For example, performing the verification of aircraft 10 ensures approaching aircraft 10 is properly

distinguished from other objects in stand area 20. The verification also ensures pilot maneuvering guidance information is properly determined and provided to the correct aircraft.

8. Claim 6

178. Claim 6 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

9. Claim 7

179. Claim 7 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2 and as explained above for claim 5 in Ground 3.

10. Claim 8

180. Claim 8 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

11. Claim 9

181. Claim 9 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

12. Claim 10

182. Claim 10 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2 and as explained above for claim 1 in Ground 3.

13. Claim 11

183. Claim 11 is met by Berkmo in view of Richman for the same reasons as explained above for claim 2 in Ground 3.

14. **Claim 12: “The method of claim 11, wherein comparing the three dimensional virtual model to one or more aircraft reference models includes comparing at least one of: wing edge to nose end distance; tail tip height; number of windows; position of windows; size of windows: number of pilot windows; position of pilot windows; number of engines; engine cowl type; engine cowl size; fuselage length; number of windows in fuselage; wing span size; height of the nose from ground; position of engines; and nose dimensions.”**

184. It is my opinion that this limitation is met by Richman. Richman teaches comparing the 3D target image (i.e., 3D virtual model) to 3D candidate aircraft templates (i.e., aircraft reference models) by comparing features of each. EX1005, 3:48-4:34. Richman discloses that “[f]eatures such as nose wheel and wing wheel intrawheel distances and height and size of wings, fuselage and rudder would be used to determine type of aircraft.” *Id.*, 4:1-7. Richman’s compared features thus meet multiple ones listed in claim 12 including at least tail tip height, fuselage length, wing span size, height of nose from ground, and nose dimensions.

15. Claim 13

185. Claim 13 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2. It is also noted that Richman expressly teaches providing speed and direction information. *See* EX1005, 2:7-18, 3:21-24, 4:50-55, 5:22-37.

16. Claim 14

186. Claim 14 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2 and as explained above for claims 1 and 13 in Ground 3.

17. Claim 15

187. Claim 15 is met by Berkmo in view of Richman for the same reasons as explained above for claim 14 in Ground 3.

18. Claim 16

188. Claim 16 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

19. Claim 17

189. Claim 17 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

20. Claim 18

190. Claim 18 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2. It is also noted that Richman's docking system includes electronics 58 having memory 76 and processor 80 (i.e., a computing device having memory) to perform the recited functions. *See* EX1005, Fig. 2, 4:35-58; 5:9-57.

21. Claim 19

191. Claim 19 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

22. Claim 20

192. Claim 20 is met by Berkmo in view of Richman for the same reasons as explained above in Ground 2.

VII. CONCLUSION

193. For the foregoing reasons, based on my expertise and experience and the record of this case that I have reviewed, it is my opinion that the challenged claims are not shown to be disclosed or obvious.

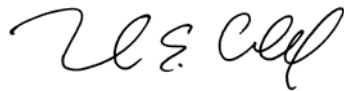
194. I understand that my opinions discussed above support a legal conclusion that the challenged claims are nonobvious.

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In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required, I will appear for cross-examination within the United States during the time allotted.

I hereby declare that all statements made herein of my own knowledge are true and all statements made herein on information and belief were and are believed by me to be true, and that all statements herein were and are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that any such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Respectfully Submitted,



September 27, 2023

Mark Campbell, Ph.D.

APPENDIX 1 TO EXHIBIT 1002

**Professor Mark E. Campbell
University**

Cornell

Mark Campbell is the John A. Mellowes '60 Professor at Cornell University. His technical and research interests are in theory and experimental validation for autonomous systems, including robotics, self-driving cars, UAVs, and spacecraft. His expertise is in sensor fusion, perception, machine learning, and control and trajectory optimization. He has led multiple collaborative research grants with DARPA, AFOSR, ARO, ONR and NSF, including leading Cornell's DARPA Urban Challenge self-driving car team, one of six finishers of the race; and the cooperative robotic MAGIC program. He spent two of his sabbaticals in industry, at Insitu where he worked on sensor fusion for geolocation in small UAVs; and at Draper Labs, where he worked on sensor fusion, machine learning and perception in autonomous vehicles. He received best paper awards from the AIAA and Frontiers in Education conference, and teaching awards from Cornell (3), University of Washington, and the ASEE. He has been recognized by NASA for his modeling and control work on the Middeck Active Control Experiment, flown in 1995. He received the U.S. Air Force Chief of Staff Award for Exceptional Public Service, the highest-level award granted by the U.S. Air Force to non-employee civilians. He has given a number of keynote talks, including NAE Frontiers in Engineering Symposium, NAS Kavli Frontiers of Science Symposium, and NAS Distinctive Voices Series. He has advised over 70 PhD students and Postdocs, and published over 200 papers. He is a Fellow of the IEEE, AIAA and ASME.

Professional Preparation

Education B.S., Carnegie Mellon, Pittsburgh, PA, Mechanical Engineering,	May 1986
M.S., MIT, Cambridge, MA, Aeronautics and Astronautics,	Feb.
1993 Ph.D., MIT, Cambridge, MA, Control and Estimation,	Jan
1996	

Appointments

John A. Mellowes '60	Cornell University, Ithaca NY	7/11-
pres Professor		
Distinguished Scientist	Draper Labs, Cambridge, MA	8/19-
pres		
Director, Sibley School	Cornell University, Ithaca NY	7/11-
6/19		
Professor	Cornell University, Ithaca NY	7/11-
6/15		
Associate Professor	Cornell University, Ithaca NY	7/04-
6/11		
ARC Int'l Fellow	Univ. of Sydney, Sydney Australia	1/06-
7/06 Visiting Scientist	The Insitu Group (UAV maker), Bingen WA	7/05-
12/05 Assistant Professor	Cornell University, Ithaca NY	9/01-
6/04 Assistant Professor	University of Washington, Seattle WA.	7/97-

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8/01 Lecturer/Res. Assoc. Massachusetts Institute of Technology, Cambridge MA 1/96-6/97 Research Assistant Massachusetts Institute of Technology, Cambridge MA 8/90-1/96 Project Engineer Lockheed Missiles & Space Co., Sunnyvale CA 6-8/91,6-8/92

Honors and Awards

- Ralph S. Watts '72 '57 College of Engineering Excellence in Teaching award, 2023
- ASME Fellow, 2021
- U.S. Air Force Chief of Staff Award for Exceptional Public Service, 2020
- AIAA Fellow, 2020
- IEEE Fellow, 2017
- Air Force Science Advisory Board (SAB), 2016-2020
- AIAA Journal of Guidance, Control and Dynamics Board of Directors, 2018-present
- John A. Mellowes '60 Professor of Mechanical and Aerospace Engineering, 2015-present
- Defense Sciences Study Group (DSSG), 2012-2013
- National Academy of Sciences, Distinctive Voices Series, Inv Speaker, 2012
- National Academy of Science Kavli Fellow, 2011.
- AIAA Best Paper from the 2011 Guidance Navigation and Control Conference
- National Academy of Eng Frontiers in Engineering Symposium, Inv Speaker, 2010
- Douglas Whitney College of Engineering Excellence in Teaching Award, 2010
- AIAA Assoc Director, American Automatic Control Council (member of IFAC)
- Australian Research Council Int'l Fellowship, Australian Field Robotics Centre, 2006
- Excellence in Teaching Award, American Society of Engineering Education, 2006.
- Stephen Miles '57 College of Engineering Excellence in Teaching award, 2005
- 2004 AIAA Best Paper
- 2004 Lockheed University Research Award
- 2000 Univ of Washington, Aeronautics and Astronautics Professor of the Year award.
- Best Paper award 1998 FIE Conference
- Certification of Appreciation from NASA for the work on MACE and STS-67
- Andrew Carnegie Society Scholar at Carnegie Mellon
- General Motors Scholar
- Bennett Prize for Academic Achievement in Mechanical Engineering at CMU

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- Y. Wang, Y. Wang, W.-L Chao, D. Garg, B. Hariharan, M. Campbell, K. Q. Weinberger (2019), "Pseudo-LiDAR From Visual Depth Estimation: Bridging the Gap in 3D Object

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