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Paper 59
Entered: May 23, 2019

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

QUANERGY SYSTEMS, INC.
Petitioner,

v.

VELODYNE LIDAR, INC.
Patent Owner.

Case IPR2018-00255
Patent 7,969,558 B2

Before CARL M. DEFRANCO, JOHN P. PINKERTON, and MICHAEL L. WOODS, *Administrative Patent Judges.*

DEFRANCO, *Administrative Patent Judge.*

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

Velodyne Lidar, Inc. ("Velodyne") is the owner of U.S. Patent No. 7,969,558 B2 ("the '558 patent"). Quanergy Systems, Inc. ("Quanergy") filed a petition requesting *inter partes* review of claims 1–4, 8, and 9 of the '558 patent. Paper 2 ("Pet."). After a preliminary consideration of Quanergy's petition, we instituted *inter partes* review of the challenged claims under 35 U.S.C. § 314(a). Paper 15 ("Inst. Dec.").

Velodyne, in turn, opposed Quanergy's petition. Paper 30 ("PO Resp."). Quanergy replied. Paper 38 ("Pet. Reply"). Following a change to the Board's trial practice guide,[1] we authorized sur-replies from the parties. Paper 37. As such, Velodyne filed a sur-reply, Paper 42 ("PO Sur-Reply"), and Quanergy followed with a sur-sur-reply, Paper 49 ("Pet. Sur-SurReply").

As part of its response to the petition, Velodyne also filed a contingent motion to amend. Paper 32. Quanergy opposed the motion to amend. Paper 39. Quanergy also filed a motion to exclude certain evidence, and Velodyne opposed. Papers 51, 52, respectively. An oral hearing was conducted on February 27, 2019. Paper 58 ("Hr'g Tr.").

We have jurisdiction over this proceeding under 35 U.S.C. § 6. After considering the parties' arguments and supporting evidence, we determine that Quanergy has *not* proven by preponderant evidence that claims 1–4, 8, and 9 are unpatentable. *See* 35 U.S.C. § 316(e). As such, we need not reach Velodyne's contingent motion to amend. Also, we deny Quanergy's motion to exclude certain of Velodyne's exhibits. We issue this Final Written Decision pursuant to 35 U.S.C. § 318(a).

I. BACKGROUND

A. Related Matters

The '558 patent is the subject of a declaratory judgment action for non-infringement in *Quanergy Systems, Inc. v. Velodyne LiDAR, Inc.*, No.

[1] Trial Practice Guide Update, 83 Fed. Reg. 39989 (Aug. 13, 2018), at 14–15 (changing sur-reply practice before the Board during AIA trial proceedings).

5:16-cv-05251 (N.D. Cal.). Pet. 1. In commencing the action, Quanergy did not challenge the validity of the ’558 patent. *Id.* Velodyne subsequently served Quanergy with a counterclaim for infringement of the ’558 patent. *Id.* The district court action was stayed on January 11, 2018, pending resolution of this proceeding and a related *inter partes* review proceeding, IPR2018-00256, in which Quanergy challenges the’ 558 patent on a different set of claims, namely, claims 16–19 and 23–25.

B. The ’558 Patent

The ’558 patent relates to a “lidar-based 3-D point cloud measuring system.” Ex. 1001, Abstract, 3:3–4. “Lidar” stands for “Laser Imaging Detection and Ranging,” which uses a pulse of light from a laser to measure distance to an object. *Id.* at 1:11–14, 3:65–66. A lidar system includes both a pulsed laser emitter and a photodiode detector. *Id.* The pulsed laser emitter sends a pulse of light toward an object and the detector detects when the pulse of light returns from the object. *Id.* at 1:13–17. The elapsed time from emission to detection is used to calculate the distance to the object. *Id*. at 1:17–18.

The ’558 patent recognizes, however, that “[w]hen multiple pulses are emitted in rapid succession, and the direction of those emissions is somehow sequentially varied,” the capture of each distance measurement creates a “pixel,” and a “collection of pixels” forms a “point cloud.” *Id*. at 1:19–24. The point clouds can then be rendered as three-dimensional (“3-D”) images. *Id*. at 1:24–31. While the ’558 patent acknowledges that “3-D point cloud systems” exist in the prior art, it further recognizes that “the needs of autonomous vehicle navigation place unrealistic demands on current systems.” *Id*. at 2:35–37.

To address these needs, the ’558 patent discloses a lidar-based, 3-D point cloud system that “includes 8 assemblies of 8 lasers each . . . or 2 assemblies of 32 lasers each forming a 64-element Lidar system.” *Id.* at 4:1–3. Figures 13 and 14 of the ’558 patent, reproduced below, illustrate an embodiment of the “64 emitter/detector pair lidar” system.

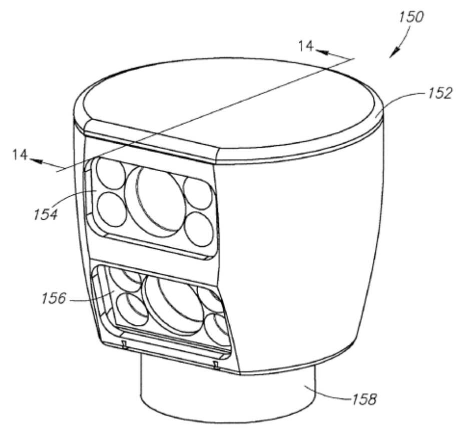

FIG.13

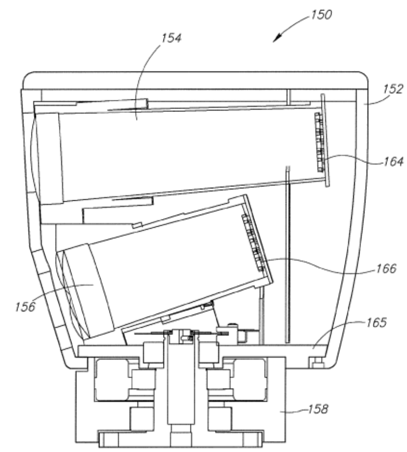

FIG.14

Figure 13 above is a perspective view of the patented lidar system, and Figure 14 above is a cross-sectional view. As shown, the system includes housing 152 mounted on base 158. *Id.* at 6:42–49. The housing is open on one side for receiving a first lidar system 154 mounted above a second lidar system 156. *Id.* at 6:44–46. Together the first and second lidar systems comprise “a configuration of 2 assemblies of 32 pairs” of pulsed laser emitters and photodiode detectors. *Id*. at 4:59–63. The second lidar system is positioned to have a line of sight at a different angle relative to horizontal than the first lidar system. *Id.* at 6:46–48.

A “high reliability brushed motor” rotates the emitter/detector pairs about the base so that the system has “a 360-degree horizontal field of view (FOV) and a 26.8-degree vertical FOV.” *Id.* at 4:3–5, 5:39–40. Importantly, the emitter/detector pairs rotate "at a rate of up to 200 Hz, thereby providing a high point cloud refresh rate." *Id.* at 4:5–8. "At this configuration, the system can collect approximately 1 million time of flight (TOF) distance points per second." *Id.* at 4:9–11. That configuration, according to the '558 patent, provides "the unique combination of 360 degree FOV, high point cloud density, and high refresh rate" all of which are necessary for autonomous navigation. *Id.* at 4:11–13; *see also id.* at 6:37–41(same).

C. The Challenged Claims

Of the challenged claims, only claim 1 is independent. Claim 1 recites:

> 1. A lidar-based 3-D point cloud system comprising:
>
> a support structure;
>
> a plurality of laser emitters supported by the support structure;
>
> a plurality of avalanche photodiode detectors supported by the support structure; and
>
> a rotary component configured to rotate the plurality of laser emitters and the plurality of avalanche photodiode detectors at a speed of at least 200 RPM.

Ex. 1001, 7:59–67.

D. The Asserted Grounds

Quanergy challenges the patentability of claims 1–4, 8, and 9 on alternative grounds of obviousness under 35 U.S.C. § 103, *first*, as obvious over Mizuno[2] alone, and, *second*, as obvious over Mizuno and Kilpelä.[3]

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[2] Japanese Unexamined Patent Appln. Pub. No. H3-6407, pub. Jan. 11, 1991 (English translation) (Ex. 1004, "Mizuno").

[3] Kilpelä, "*Precise pulsed time-of-flight laser range finder for industrial distance measurements*," REVIEW OF SCIENTIFIC INSTRUMENTS, Vol. 72, No. 4, pp. 2197–2202 (Apr. 2001) (Ex. 1005, "Kilpelä").

Pet. 3. In further support of these grounds, Quanergy proffers initial and supplemental declarations from Dr. James F. Brennan, III, an expert witness retained for purposes of this proceeding. *See* Exs. 1002, 1063. Velodyne, in turn, submits a declaration from its expert witness, J. Gary Eden, Ph.D. *See* Ex. 2115.

II. ANALYSIS

We decide whether Quanergy has proven the challenged claims unpatentable by a "preponderance of the evidence." 35 U.S.C. § 316(e). Central to our decision is the meaning of "lidar-based 3-D point cloud system," as recited in the preamble of claim 1. But before construing that phrase, we address the level of skill in the art.

A. Level of Ordinary Skill in the Art

Relying on the testimony of its expert, Quanergy contends that a skilled artisan would have had "a bachelor's degree or the equivalent in electrical engineering" and "at least four years of additional work experience in the area of light-based remote sensors, or equivalent work experience." Pet. 11 (citing Ex. 1002 ¶ 21). Velodyne proposes a "somewhat different" level of skill in the art, but nonetheless concedes that this difference "does not change the outcome." PO Resp. 7–8 (citing Ex. 2115 ¶¶ 29–32). As such, we adopt Quanergy's formulation of the level of skill in the art.

B. Claim Construction[4]

We give claim terms in an unexpired patent their broadest reasonable interpretation in light of the specification of the patent in which they appear.

[4] The recent change in the claim construction standard for *inter partes* reviews is not applicable here because the petition was filed before the effective date of the change. *See Changes to the Claim Construction*

37 C.F.R. § 42.100(b). In doing so, we are careful not to import limitations from the specification into the claims.

Notably, before staying the related declaratory judgment action (discussed above), the U.S. District Court for the Northern District of California construed several claim terms at issue here. *See* Ex. 1027 ("Claim Construction Order"). Two of the district court's constructions are relevant to our analysis—its construction of the terms "3-D point cloud" and "a plurality of laser emitters." *Id.* at 11–19, 32–33. And, although not in dispute at the time of the district court's order, the meaning of the term "lidar" has now percolated to the surface as an issue central to this case. We construe all three terms, giving considerable weight to the district court's constructions.

1. "a plurality of laser emitters"

Independent claim 1 recites "a plurality of laser emitters . . . configured to rotate . . . at a speed of at least 200 RPM." The district court construed the term "a plurality of laser emitters" to mean "two or more light sources that generate laser beams, or a single light source that generates a single laser beam that is sub-divided into two or more smaller beams." Ex. 1027, 18–19, 33. Neither Quanergy nor Velodyne disputes the district court's construction. Pet. 11; PO Resp. 8. We likewise see no reason to depart from the district court's construction, thus, adopt it for purposes of this decision.

Standard for Interpreting Claims in Trial Proceedings Before the Patent Trial and Appeal Board, 83 Fed. Reg. 51,340 (Nov. 13, 1918) (to be codified at 37 C.F.R. pt. 42).

2. "3-D point cloud"

The term "3-D point cloud" appears in the preamble of claim 1. The district court determined that the preamble—which recites specifically "[a] lidar-based 3-D point cloud system"—is limiting. Ex. 1027, 7–11, 32. We agree with the district court that the preamble is limiting because it underscores the very essence of the invention described in the specification and is essential to understanding how the recited components of claim 1 work together. *See id.* at 8–9. Indeed, beginning with the title, "High Definition Lidar System," the '558 patent focuses exclusively on the use of "lidar" for measuring distances to generate a "3-point cloud." Ex. 1001, Title, Abstract.

For instance, the specification starts with a discussion of prior art "lidar" systems and how they generate a "2-D point cloud." *Id.* at 1:45–2:60. The specification then explains that the improvement over those prior art lidar systems is a "lidar-based 3-D point cloud measuring system" that can be used for "Lidar Terrain mapping and obstacle detection." *Id.* at 3:3–4, 3:28–29, 3:40–43. The terms "Lidar" and "point cloud" are used prevalently throughout the specification to describe virtually every aspect of the invention. *See id.* at 3:65–7:9, Figs. 5–26. Given the specification's exclusive focus on a lidar-based, 3-D point cloud system for distance measurement, we agree with the district court that the preamble is a necessary limitation on the scope of the claims. Quanergy does not dispute that the preamble is limiting. Pet. 11.

Once it determined that the preamble is limiting, the district court then construed the term "3-D point cloud" to mean "a collection of distance measurements along sequentially varied directions emitted and captured in rapid succession that can be rendered as a three dimensional image or analyzed for other reasons such as detecting obstacles." Ex. 1027, 16–18, 33. We accept that construction, with one modification. According to the parties, the district court's construction may indicate that "distance measurements" are emitted from the laser, rather than derived from it. *See* Pet. 20; PO Resp. 11–12. In that regard, the specification of the '558 patent states that "pulsing a laser emitter . . . causes a burst of light to be emitted . . . [t]hen, the time it takes for that pulse of light to return to a detector mounted near the emitter is measured, and a distance can then be derived from that measurement with high accuracy." Ex. 1001, 1:11–18. In other words, the distance measurement is derived from *timing* the pulse of light, as opposed to merely detecting the pulse. Thus, consistent with the specification and in further clarification of the district court's construction, we construe the term "3-D point cloud" to be "a collection of distance measurements derived from multiple laser light pulses emitted in rapid succession along sequentially varied directions and captured in rapid succession so as to be rendered as a three dimensional image or analyzed for other reasons such as detecting obstacles."

3. "lidar"

The district court did not construe the term "lidar," as also recited in the preamble of claim 1. Nor did we construe the term "lidar" in our institution decision, for at that stage neither party disputed its meaning. After institution, however, it became apparent that the parties disagreed over the meaning of "lidar" in the context of the challenged claims. PO Resp. 8–12; Pet. Reply 2–5; Hr'g Tr. 15:9–22.

On the one hand, Velodyne argues that, in the context of the ’558 patent, “lidar” means “only pulsed ToF [time-of-flight] lidar” that “excludes triangulation and other techniques not analogous to those used in radar.” PO Sur-Reply 4; *see also* PO Resp. 12 (“Thus, ‘3-D point cloud’ works with ‘lidar-based’ to provide additional structural detail to the claims, requiring *pulsed ToF lidar* along sequential directions in rapid succession—exactly what the ’558 patent describes.”). Quanergy, in turn, argues for a broader construction that includes triangulation and other techniques because “[a] POSITA in 2006 understood triangulation to be a type of lidar.” Pet. Reply. 3 (citing Ex. 1063 ¶¶ 22–26). In support, Quanergy points to extrinsic evidence, specifically, several *non-contemporaneous* technical papers that speak of triangulation as a form of lidar. *Id.* at 3–4 (citing Exs. 1068, 1069, 1071, 1072, 1136). Although Quanergy may be correct from the standpoint of extrinsic evidence, we look first to the intrinsic evidence to assess the meaning of “lidar” in the context of the specification of the ’558 patent.

Here, the specification provides clear support for Velodyne’s construction. In particular, the specification focuses *exclusively* on a specific type of lidar system, namely, pulsed time-of-flight (“ToF”) lidar. Right from the start, the specification lays down the following premise:

> [t]he use of a pulse of light to measure distance is well known. . . . *the basic concept is that of pulsing a laser emitter*, which causes a burst of light to be emitted, usually focused through a lens or lens assembly. Then, *the time it takes for that pulse of light to return to a detector mounted near the emitter is measured, and a distance can then be derived from that measurement* with high accuracy.

Ex. 1001, 1:11–18 (emphases added). That basic concept of deriving distance by measuring the "time" of travel (i.e., flight) of the laser pulse to and from an object underlies the entire description of the '558 patent.

Notably, after laying down that basic concept, the specification describes existing lidar systems that rely on timing of the laser's pulses to generate distance measurements. For instance, the specification explains that "when multiple pulses are emitted in *rapid succession* . . . and captured in *rapid succession*," they can be used to generate "distance measurements" and create a "point cloud." *Id.* at 1:19–31 (emphases added). One such system is "a single beam lidar unit" that can "capture an entire 3-D array of distance points, albeit one point *at a time*." *Id.* at 1:32–58 (emphasis added). But, as described, these prior art pulsed lidar units have certain drawbacks—each is "inherently limited to the number of pixels it can generate due to the limitation of *how many pulses per second* are possible from a single laser." *Id.* at 2:1–3 (emphasis added). Those descriptions of existing systems, all of which refer to *timing* of the laser pulses, provide the foundation for the specification's description of the improvement over the prior art.

To that end, the specification speaks exclusively of improving on existing time-of-flight lidar systems in a way that "provides exceptional point cloud density." *Id.* at 6:37–40. For instance, the specification describes that the "Lidar system . . . can collect approximately 1 million *time of flight (TOF)* distance points per second" to uniquely provide a "high point cloud density." *Id.* at 4:3–14 (emphasis added). The specification goes on to describe how the lidar system is controlled by a digital signal processor

(“DSP”) that determines “when” the laser will fire (i.e., for pulsing), “records the *time-of-flight*,” and “calculates height data based [on] *time-of-flight*.” *Id.* at 5:11–18 (emphases added). The specification even acknowledges a “standard deviation of *TOF measurements*” that must be accounted for when converting the data “into x and y coordinates and a height value.” *Id.* at 4:13–14, 4:34–43 (emphasis added).

That the specification starts with the basic premise of utilizing the timing of laser pulses to derive distance measurements and then builds upon that premise by focusing on how to improve the pulses per second of existing pulsed lidar systems so as to generate a high- density point cloud, shows that, in the context of the specification, the claimed “lidar-based 3-D point cloud system” is limited to a pulsed ToF lidar system. Thus, we construe the term “lidar-based” in claim 1 to mean “pulsed time-of-flight (ToF) lidar.”

We note that our construction of the term “lidar” is consistent with the testimony of the parties’ experts. Neither parties’ expert speaks of the ’558 patent as describing anything but a pulsed time-of-flight lidar system. For instance, Velodyne’s expert testifies that the ’558 patent “discusses only pulsed TOF LIDAR throughout the patent” and that “[t]here is nothing in the patent that would suggest to a POSA any other definition for the term.” Ex. 2115 ¶ 60; *see also* Ex. 1064, 41–42 (testifying that “the subject of the ’558 patent” is “the use of pulses and the reflection of those pulses from the object of interest to determine the distance from the laser transmitter to that object” and, from that disclosure, “the vast majority of people would immediately think of time of flight measurements.”).

Although Quanergy's expert opines in his supplemental declaration that "lidar" may also include "triangulation" systems, all but one of the exhibits he cites in support of that opinion are *non-contemporaneous* literature published from 2014 to 2018, well after the relevant time frame of 2006. *See* Ex. 1063 ¶ 25 (citing Exs. 1068, 1069, 1071, 1072, 1136). The only contemporaneous article he cites actually supports an opposite view, for it draws a clear distinction between "triangulation-based" sensors and "time-of-flight (TOF)" sensors. *Compare* Ex. 2141, 3, 8, *with id.* at 6, 10. Indeed, the 2004 article only uses the term "lidar" to describe a "time-of-flight" sensor (*id.* at 12), which suggests that a skilled artisan at the time understood "lidar" to mean a time-of-flight system, not a triangulation system. Thus, the testimony of Quanergy's expert that the term "lidar," as used in the context of the '558 patent, encompasses more than a pulsed ToF system is not supported by the record evidence.

C. Quanergy's Obviousness Challenges

Quanergy challenges claims 1–4, 8, and 9 as obvious over either Mizuno alone or Mizuno in combination with Kilpelä. Pet. 15–36. Our analysis focuses on claim 1, from which the other challenged claims depend. The parties' dispute centers on whether Quanergy has sufficiently demonstrated that its obviousness challenges satisfy the "lidar" and "avalanche photodiode detectors" limitations of claim 1. Hr'g Tr. 8:11–14. As discussed below, because Quanergy's challenges fail to satisfy the "lidar" limitation, as properly construed, we need not reach the dispute over the "avalanche photodiode detectors" limitation. We begin our analysis with a brief overview of the prior art underlying Quanergy's challenges.

1. Mizuno (Ex. 1058)

Mizuno, published in January 1991, describes an "outer peripheral shape measurement device." Ex. 1058, 1. An annotation of Mizuno's Figure 1 is reproduced below left, and an annotation of Mizuno's Figure 5 is reproduced below right.

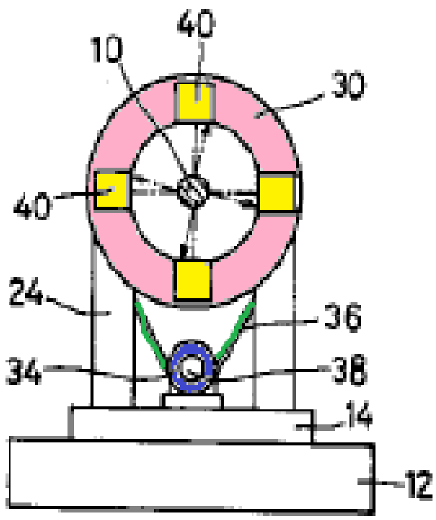

Figure 1

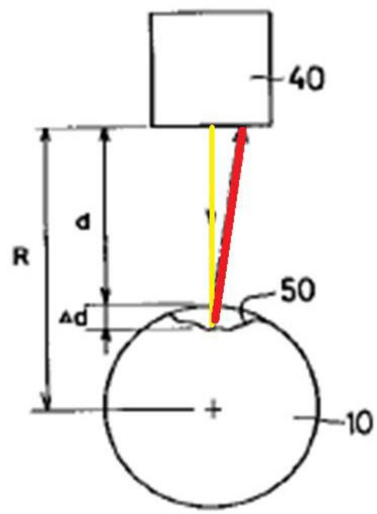

Figure 5

Annotated Figure 1, above left, is an elevation view of Mizuno's measurement device, and annotated Figure 5, above right, is a schematic of the operation of Mizuno's device. As shown in Figure 1 above, Mizuno's system includes four laser measuring instruments 40 (yellow boxes) affixed to ring-shaped plate 30 (pink ring) for rotating about steel object 10. *Id.* at 3. The laser measuring instruments are directed inward towards object 10 and configured to "rotate[] continuously in one direction through a belt 36 [green lines] by a driving motor 34 [blue ring]" as object 10 passes through the central opening in rotating plate 30. *Id*. Rotating plate 30 and laser measuring instruments 40 are capable of rotating at speeds upward of 3,000 to 5,000 rpm. *Id.* at 4.

As shown schematically in Figure 5 above, each of Mizuno's laser measuring instruments 40 "emits a laser beam" (shown in yellow) toward steel object 10 and "detects . . . the reflected light" (shown in red) from the object "using a position sensor and/or image sensor, or the like." *Id.* at 3. "[B]ased on the location at which the light is detected," the system can "measure the distance from the laser measuring instrument 40 to the location of the reflection." *Id.* According to Mizuno, as steel object 10 passes through the central opening of rotating plate 30, laser measuring instruments 40 are actuated to measure the distance to the outer surface of the object, as represented by "d" and "Δd" in above Figure 5. *Id.* at 4.

The distance signals calculated by laser measuring instruments 40 are then transmitted to an external microcomputer, which processes the signals for displaying the cross-sectional shape of the object "three-dimensionally" to detect any surface defects 50. *Id.* at 5; *see also id.* at 4 (describing Mizuno's device as taking short-range measurement of "a defect depth Δd, and the position of the defect at the circumferential direction" of the object). Significantly, as even Quanergy's expert acknowledges, "Mizuno's description of its distance measurement system is high level and does not provide any details about specific components . . . , it only describes functionality." Ex. 1063 ¶ 28; *see also* Pet. Reply 7 ("Mizuno describes its invention generally – i.e., without describing a specific measurement scheme").

2. Kilpelä (Ex. 1005)

Kilpelä reports on "the performance results of a time-of-flight (TOF) laser range finder" in which the use of laser pulses was "tested" on "targets in a range of several tens of meters (industrial measurements)." Ex. 1005, 8.

As described, a "prototype pulser" was used to evaluate various parameters of the laser pulses sent to and received from the target to be measured. *Id.* at 11. The target used in the test "was a white piece of paper." *Id.* at 12. The receiver was a commercially-available "avalanche photo diode (APD) receiver." *Id.* at 8, 11. And the parameters evaluated were error sources such as "single-shot precision, walk error and accuracy of the distance meter." *Id.* at 11. As reported by Kilpelä, the prototype resulted in inaccurate measurements at distances in the shorter-range of the test. *Id.* at 10–12.

3. Mizuno neither discloses nor suggests a "lidar" system

Quanergy initially focuses on Mizuno alone as meeting the "lidar" limitation of claim 1. Pet. 15–17. As discussed above, we construe the term "lidar" to mean "a pulsed ToF lidar system." Quanergy concedes that "Mizuno does not disclose which type of laser emission it uses." Pet. 17; *see also* Hr'g Tr. 8:11–17 (explaining "the missing [] elements of Mizuno" include "a pulsed system"). Nonetheless, Quanergy contends that, because Mizuno discloses "the same LiDAR-based technology used in the '558 patent," a skilled artisan would have understood "that the laser measurement devices 40 in Mizuno's lidar-based system use pulsed light to measure distance." Pet. 17 (citing Ex. 1002 ¶¶ 105, 106); *see also* Pet. Reply 7–8 (asserting "Mizuno's system could easily be implementing a ToF system" because "Mizuno describes its invention generally"). We disagree.

Velodyne's expert persuasively explains why Mizuno is not a pulsed ToF system. Ex. 2115 ¶¶ 127–128. Under questioning, Quanergy's expert similarly acknowledged that Mizuno's system is not a pulsed ToF system. For instance, when asked to explain how Mizuno "calculate[s] the range," Quanergy's expert explained that "[t]his is a specular reflection system *as opposed to an optical triangulation system or a time-of-flight LiDAR system*." Ex. 2156, 166:14–167:4 (emphasis added). Elaborating further, Quanergy's expert testified that Mizuno "is a very simplistic system here, whereby the light reflects specular, . . . it will reflect off of [an object] and hit another location. And so you can track that, where it actually hits. *And so this is opposed to what one would call perhaps a time-of-flight system* or an optical triangulation system." *Id.* at 168:11–169:1 (emphasis added). In the end, when asked pointedly whether the device depicted in Figure 5 of Mizuno "measure[s] the time of flight," Quanergy's expert admitted that "it does not need to." *Id.* at 178:4–9 (referencing "paragraph 88" of his declaration).

The fact that both parties' experts agree that Mizuno does not suggest a pulsed ToF system stands in sharp contrast to Quanergy's attempt to read more into Mizuno's broad disclosure than even a skilled artisan would have gleaned from it. *See* Pet. 17; Pet. Reply 8. Thus, we are not persuaded that Quanergy has shown by preponderant evidence that Mizuno alone meets the "lidar-based" limitation as properly construed.

4. *A skilled artisan would not have been led to use pulsed ToF lidar with Mizuno's system*

Realizing the gap left by Mizuno, Quanergy alternatively argues that a skilled artisan would have known "to modify the laser measurement devices 40 in Mizuno so that they emit pulsed light as disclosed in Kilpela." Pet. 21–22 (citing Ex. 1002 ¶ 119). Later, Quanergy added Berkovic[5] as another

[5] Garry Berkovic, *Optical Methods for Distance and Displacement Measurements*, ADVANCES IN OPTICS AND PHOTONICS (2012) (Ex. 2007, "Berkovic"). Although Berkovic was published six-years after the priority

reason to fill the gap in Mizuno, arguing that Berkovic shows "it was well known to use pulsed ToF techniques to measure objects at close distances, such as less than 1 m." Pet. Reply 11 (citing Ex. 2007, 10–11); *see also* Hr'g Tr. 25:7–28:2 (referencing Berkovic as "a good example of what was known in the state of the art at the time" and "what types of technology [one] might use in a Mizuno-type system"). We first address Quanergy's reliance on the teaching of Berkovic before addressing the combination that Quanergy originally asserted in its petition—Mizuno and Kilpelä.

Significantly, Berkovic teaches that time-of-flight sensors work best for measuring objects at distances *greater than 50 meters*, stating that "[f]or objects at a distance >50 m, corresponding to a round-trip transit time far greater than the pulse width, the time-of-flight can be measured by relatively simple detectors and electronics." Ex. 2007, 10; *see also* Ex. 2141, 6 ("time-of-flight (TOF) 3-D scanners are by far the preferred choice for measurements at longer ranges"). "At distances shorter than tens of meters," Berkovic explains, "accurate time-of-flight measurements need to take into account the temporal pulse shape in order to correctly measure the time delay between the peaks of the input and returned pulses." Ex. 2007, 10. That disclosure calls into question the accuracy of pulsed ToF lidar for short-range measurement, and, more aptly, suggests that the measurement accuracy degrades as the distance to the target gets shorter, as Velodyne's expert confirms. *See* Ex. 2115 ¶ 37. Thus, Quanergy does not persuade us

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date of the '558 patent, we note that both parties rely on it for the state-of-the-art. *See* PO Resp. 9, 16, 24–25; Pet. Reply 11; Hr'g Tr. 25:7–28:2. Thus, we accept it as evidence of the state-of-the art.

sufficiently that Berkovic would have led a skilled artisan to use pulsed ToF lidar in a short-range measuring device like Mizuno.

But even assuming Berkovic might suggest the use of ToF lidar for short-range measurement, we do not discern where Quanergy demonstrates that a skilled artisan would have done so with a reasonable expectation of success. Indeed, Quanergy's expert never mentions Berkovic, let alone lends support to Quanergy's argument that Berkovic evinces a reasonable expectation of success. *See* Pet. Reply 11–12; Hr'g Tr. 25:7–28:2. Instead, Quanergy's expert merely concludes, without citation to any contemporaneous evidence, that "a POSITA would have had the know-how to customize Mizuno's system, including selecting the appropriate characteristics of the laser emitters . . . photodetectors . . . [and] the type of measurement system." Ex. 1063 ¶ 30. Notably absent from his testimony is any mention of Berkovic for teaching that the selection of such components and criterion would have been undertaken with a reasonable expectation of success of achieving short-range distance measurement. *See id.* ¶¶ 28–34.

In contrast, Velodyne's expert testifies:

> [the] criterion becomes exponentially more difficult . . . as the TOF system range, if you will, shrinks. So I understand what Berkovic's point is. In Figure 10B, he's showing that if the range becomes very short, you have to measure a phase difference. . . . Can you do it? Yes, you can do it. The question is: Do you want to do it? . . . Can you do it reliably? And when it's done, can you put it into a steel factory? The answers are no.

Ex. 1064, 83:1–13. The fact that a phase difference could not be measured "reliably" when using pulsed ToF for short-range measurement indicates that, in the relevant time frame, a skilled artisan would not have had a reasonable expectation of success of using pulsed ToF lidar in Mizuno's system.

If anything, Berkovic would have led a skilled artisan to use triangulation sensors over pulsed ToF sensors in Mizuno because, as Berkovic explains, triangulation sensors provide the advantages of "fast measurement" and "high[] resolution" for short-range distances. Ex. 2007, 9. Indeed, according to Berkovic, "triangulation sensors . . . are generally applicable for distance measurements in ranges of 10 mm to 1 m," which "opens up the possibility for object shape sensing." *Id.* at 8–9. That is Mizuno's system. *See* Ex. 1058, 4–5 (describing Mizuno's device as "enabling accurate measurement of . . . defect depths and defect locations of surface defects" in "objects wherein the cross-sectional shapes vary in the axial direction.").

Other state-of-the art references corroborate Berkovic's view of triangulation sensors as the best approach for short-range measurement. For instance, English[6] explains why triangulation sensors are preferred over pulsed ToF sensors for short-range measurements of the type described in Mizuno. In particular, English instructs that pulsed lidar has "historically been used for long range measurements on the order of hundreds of meters to kilometers such as terrain mapping and large structure and building mapping largely because the precision of measuring the TOF of light can be maintained over long distances," whereas triangulation "has historically been limited to a narrow FoR [Field of Regard] and very short range (< 1 m)

[6] Chad English, *The complementary nature of triangulation and ladar technologies*, PROCEEDINGS OF SPIE, Vol. 5791, pp. 29–41 (2005) (Ex. 2162, "English")

because range precision deteriorates with the square of the range to target." Ex. 2162, 2. English further recognizes that any "overlap in performance" of the two methods "has caused some confusion in selecting appropriate technologies for a given application which is further exacerbated by a lack of standard performance metrics for 3D measurement and imaging." *Id.* That industry confusion and inconsistent performance would have informed a skilled artisan that the two methods are not interchangeable, and that, for short-range distance measurement such as Mizuno, triangulation sensors are preferred over pulsed ToF lidar.

Moreover, to the extent that Quanergy asserts it would have been "obvious for a POSITA to *try* implementing a pulsed ToF into Mizuno's system with a reasonable expectation of success," we are not persuaded. Pet. Reply 12. The only evidence that Quanergy proffers of an expectation of success is speculation from its expert about the endless possibilities of Mizuno's teachings. *Id.* (citing Ex. 1063 ¶¶ 28–34). While Quanergy's expert opines that a skilled artisan "would have had the know-how to customize Mizuno's system" with pulsed ToF lidar, the only support he provides of an expectation of success in doing so is the fact of Mizuno's failure to instruct "otherwise." Ex. 1063 ¶ 30. To that end, Quanergy's expert explains:

> Mizuno's description of its distance measurement is high level and does not provide any details about specific components . . . , it only describes their functionality. . . . [T]his allows the implementer to build the system according to his own specifications and customize according to his needs. Indeed, Mizuno's broad disclosures only highlights how advanced the state of the art was back in 1991, that it did not need to provide component and measurement technique details. . . .

> It is my opinion that Mizuno describes its system at such a high level – foregoing any specific details about the system's components, other than their functionality – because the system itself has so many uses. Likewise, Mizuno does not specifically identify the type of measurement system that it uses because of the system's versatility. . . .
>
> Mizuno merely instructs regarding structure and function but otherwise leaves the details to the implementer. *This is basic engineering and system design.* The implementer then has the option to customize the system to suit a particular need . . . Really, the items and combination of items measurable by Mizuno's system are endless.

Ex. 1063 ¶¶ 28–30 (emphasis added).

In our view, Quanergy's reliance on Mizuno's lack of detail falls far short of the evidence necessary to show that a skilled artisan would have had a reasonable expectation of success in implementing a pulsed ToF lidar into Mizuno's system. As discussed above, Berkovic explains that "[a]t distances shorter than tens of meters," pulsed ToF range sensors encounter problems with "temporal pulse shape" and "overlap in time" of the emitted and returned pulses, as well as problems with "photon-counting techniques" and "autocorrelation algorithms" in detection of the pulses. Ex. 2007, 10. Nowhere does Quanergy's expert account for those problems, despite Quanergy's reliance on Berkovic as state-of-the-art. *See* Pet. Reply 11–12; Hr'g Tr. 25:7–28:2; Pet. Sur-SurReply 3. As such, Quanergy's expert never explains how or why a skilled artisan would have had an expectation of success in overcoming those problems in implementing a pulsed ToF sensor into a short-range measurement system such as Mizuno's. *See* Ex. 1063 ¶¶ 28–34, 55–59.

Certainly, Mizuno's "broad disclosure" does not provide any clarification, for Quanergy's expert concedes that Mizuno is "high level –

foregoing any specific details about the system's components." *Id.* ¶ 29. Indeed, at the time, the industry understood that the "there is no single approach for all applications" of laser ranging technologies, and "[c]hoosing an appropriate technology requires a clear understanding of application requirements and the capabilities of each technology and sensor design." Ex. 2162, 13. Thus, we are not persuaded that implementing a pulsed ToF sensor for short-range measurement would have been simply a matter of "basic engineering and system design," as Quanergy's expert contends. Ex. 1063 ¶ 30.

Nor does Quanergy's reliance on Kilpelä to fill the gaps in Mizuno persuade us that a skilled artisan would have been led to implement a pulsed ToF lidar in Mizuno's short-range system. In particular, Quanergy relies on Kilpelä "for its teachings of pulsed laser light . . . at short ranges" in industrial applications. Pet. Reply 9–10 (citing Pet. 21–22; Ex. 1002 ¶ 119). Quanergy's reason for combining the teachings of Mizuno and Kilpelä is that "both references describe LiDAR-based systems that are used within industrial environments for precise material analysis and 3-D imaging" and that "Kilpelä's system is capable of producing high precision measurements . . . at a short range." Pet. 31–33 (citing Ex. 1058, 3; Ex. 1005, 8, 12; Ex. 1002 ¶¶ 142–144, 146, 147).

We construed "lidar" to mean "pulsed ToF lidar," and, as discussed above, Mizuno neither discloses nor suggests such a system. And, while both Kilpelä and Mizuno speak of using a laser range finder for industrial applications, nowhere does Kilpelä mention or suggest that a pulsed ToF laser range finder could be used in a short-range measuring device, such as Mizuno. Nor does Quanergy adequately explain why a skilled artisan would have had a reasonable expectation of success in implementing Kilpelä's pulsed ToF technique in Mizuno's measuring device. *See* Pet. 21–22 (citing Ex. 1002 ¶ 119); Pet. Reply 12.

Indeed, like Berkovic, Kilpelä would have discouraged a skilled artisan from using a pulsed ToF technique in the short-range distance measuring device of Mizuno. To begin, we note that Kilpelä is a 2001 article reporting on a "prototype" laser range finder that "tested" the performance of pulsed ToF "in a range of several tens of meters." Ex. 1005, 8, 11. As described, the aim of Kilpelä was to evaluate the "accuracy and single-shot precision" of pulsed ToF where "[t]he target was a white piece of paper." *Id.* at 12. That evaluation, Kilpelä reports, resulted in "[m]easurement error" in ranges of less than 5 meters and variations in "single shot precision" over the entire range of distances. *Id.*, Fig. 4.

More specifically, Figure 4 of Kilpelä, reproduced below, depicts the inaccuracies and imprecision of Kilpelä's prototype ToF device.

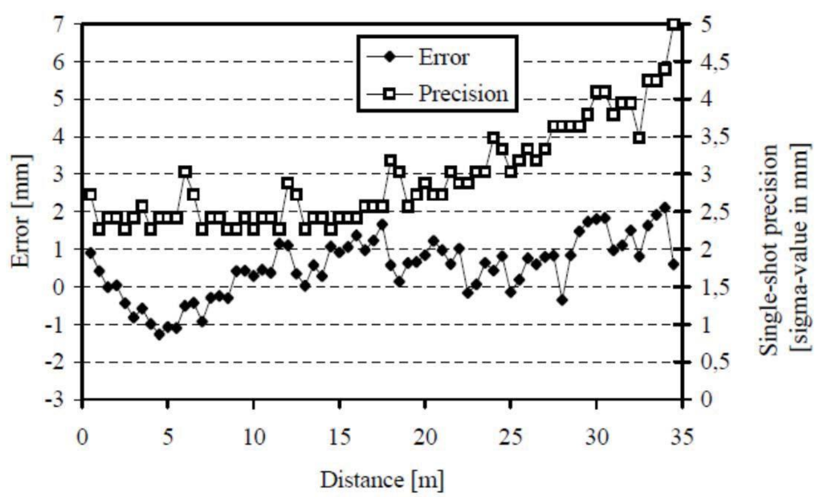


FIG. 4. Measurement error and single-shot precision of the distance meter in the range of 0.5-34.5

Ex. 1005, 12. As shown in Figure 4 above, and confirmed by Velodyne's expert, Kilpelä's prototype ToF device exhibited inaccuracies in measurements below 5 meters and imprecision in measurements over the range of 0.5 to 34.5 meters. Ex. 2115 ¶ 151. Quanergy's expert does not dispute that Figure 4 shows measurement error in Kilpelä's prototype ToF device. Ex. 1002 ¶ 147. He maintains simply that, although Figure 4 "shows that at short distance ranges, the measurement error of the disclosed Kilpelä device is generally less than 2 millimeters," this imprecision still "is desirable for certain applications such as the detection of smaller defects, using the distance measurements device 40 disclosed in Mizuno." *Id.*

In contrast, Velodyne's expert explains that:

> Kilpelä's measurement accuracy (range precision) renders Kilpelä's system incapable of reliably detecting flaws 1 mm in depth, not to mention those that are more shallow. For an industrial environment to which Mizuno is directed, this situation is intolerable . . . . Reliability and precision are paramount in the industrial environment.

Ex. 2115 ¶ 119. He further notes that "[b]elow 5 meters the inaccuracy curve [of Figure 4] has a high slope that appears to be increasing the closer it gets to 0.5 meters, the shortest distance Kilpelä attempted to measure, which in his opinion would have led a skilled artisan to "not select such a device for measurements on the short end of the range." *Id.* ¶ 152.

We find the testimony of Velodyne's expert more persuasive than that of Quanergy's expert. In particular, we agree with Velodyne's expert that Kilpelä's Figure 4 depicts an "increasing" rate of error and inaccuracy at short-range distances, i.e., below 5 meters. *Id.* Quanergy's expert never disputes that fact. *See* Ex. 1063 ¶¶ 57–59; Ex. 2194, 206:3–210:2. As such, the record evidence does not support that a skilled artisan would have had a reasonable expectation of success that Kilpelä's pulsed ToF device would work with Mizuno's short-range measuring device.

Kilpelä's Figure 4 also illustrates that the prototype ToF device was unpredictable in another way. As explained by Velodyne's expert, Figure 4 shows that Kilpelä's pulsed ToF prototype exhibited "cyclic peaks every 6 meters, starting from the beginning" of measurement. Ex. 2115 ¶ 143. Quanergy's expert had no rebuttal when presented with Kilpelä's Figure 4, testifying that he "do[es] not know" why the cyclic peaks are there and that "it's not really relevant for . . . showing that these systems existed for installing on a Mizuno [configuration]." Ex. 2156, 39:11–40:4, 58:3–59:1. Under further questioning, Quanergy's expert conceded he didn't not know "how this thing was actually [] configured and how it operates" but nonetheless presumed that Kilpelä's device "would *potentially* work well, that [it] would *probably* work well at a close-in range system like a Mizuno system." *Id.* at 53:1–54:14 (emphases added). That testimony hints at speculation on the part of Quanergy's expert.

More persuasively, Velodyne's expert testifies that, given the measurement errors shown in Figure 4 of Kilpelä, "a POSA would be suspicious of any device showing such irregular inaccuracies across the measurement range, and . . . would not want to use such a device for measurements requiring even millimeter-level accuracy and precision because of this unpredictability at different distances." Ex. 2115 ¶ 151. Although Quanergy's expert responds that a Mizuno system modified with Kilpelä's ToF system "would be calibrated" to account for any measurement error, he provides no evidentiary support for his opinion that calibration alone would have sufficed to overcome Kilpelä's known errors and accuracies. *See* Ex. 1063 ¶¶ 56, 59. If curing such errors was simply a matter of calibration, Kilpelä likely would have said so, but did not because, even after Kilpelä's findings in 2001, the industry continued to express concern with error and inaccuracy of pulsed ToF at shorter distances. *See, e.g.*, Ex. 2007, 10 ("[a]t distances shorter than tens of meters . . . input and returned pulses will overlap in time"); *see also* Ex. 2162, 13 ("[p]ulsed ladar technology has orders of magnitude worse precision at close range"). That contemporaneous evidence supports that Kilpelä's errors could not have been cured with mere calibration, as Quanergy's expert opines.

After considering the competing testimony from both sides' experts, we consider the testimony of Velodyne's expert to be more persuasive and consistent with the record evidence. It is undisputed that Kilpelä's pulsed ToF device exhibited measurement errors at relatively short-range distances of 5 meters or less. And while Quanergy's expert struggled to explain the irregularities shown across the measurement range in Kilpelä's Figure 4, Velodyne's expert testified credibly that, at a minimum, the irregularities would have raised skepticism such that a skilled artisan would have chosen a more reliable and accurate method of measurement than pulsed ToF, for example, the already proven method of triangulation. *See* Ex. 2115 ¶ 151. Thus, we find the inaccuracy and imprecision of Kilpelä's pulsed ToF device at short-range distances would have reasonably led a skilled artisan to deem it unsuitable for Mizuno's short-range measuring device, especially given the existence of more reliable and accurate methods of short-range measurement at the time.

In the end, we are not persuaded that a skilled artisan would have had a reasonable expectation of success in modifying Mizuno's short-range measuring device to use a pulsed ToF technique, be it taught by Kilpelä or otherwise.[7] Thus, we conclude that Quanergy has not met its burden of showing that Mizuno, either alone or in combination with Kilpelä, satisfies the "lidar" limitation of claim 1. Quanergy's obviousness challenge of the dependent claims stemming from claim 1 suffers the same deficiency. *See* Pet. 36–50. As such, we determine that Quanergy has not demonstrated by a preponderance of the evidence that claims 1–4, 8, and 9 are unpatentable under 35 U.S.C. § 103.

D. Objective Indicia of Innovation and Non-Obviousness

Velodyne presents compelling objective evidence of a significant leap forward in the innovation of 3-D lidar sensors for autonomous navigation. PO Resp. 52–71; PO Sur-Reply 25–28. As discussed below, that evidence of unresolved long-felt need, industry praise, and commercial success provides an additional reason for finding that the claimed invention was revelatory and not obvious.

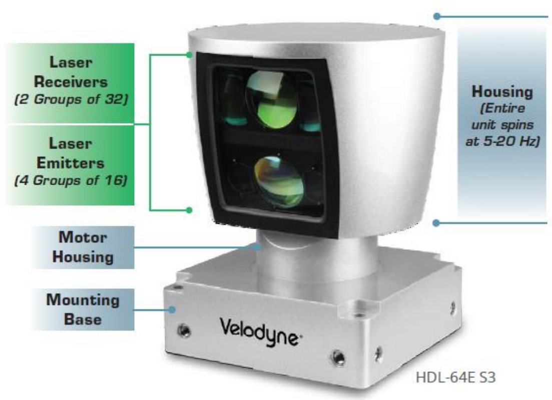
1. Nexus

Velodyne begins by showing a nexus between the claimed invention and the objective evidence of industry praise and commercial success. PO Resp. 53–57. "[T]here is a presumption of nexus . . . when the patentee shows that the asserted objective evidence is tied to a specific product and that product 'is the invention disclosed and claimed in the patent.'" *WBIP*,

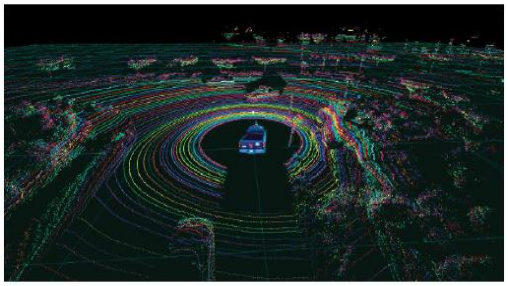
[7] We also are not persuaded by Quanergy's last-minute reliance on other "examples" of "pulsed time-of-flight (ToF) systems used for inspection devices and measuring shapes of surfaces." *See* Pet. Sur-SurReply 2–3. Aside from exceeding the proper scope of a reply, these belated "examples" are nonetheless unpersuasive as they rely on speculative expert testimony and fail to evince a reasonable expectation of success of being combined with Mizuno. *See id.* at 3 (citing Ex. 2194, 250:12–253:15, 256:24–262:9).

LLC v. Kohler Co., 829 F.3d 1317, 1329–30 (Fed. Cir. 2016); *Polaris Indus., Inc. v. Arctic Cat, Inc.*, 882 F.3d 1056, 1072–73 (Fed. Cir. 2018). Here, a nexus is presumed because Velodyne provides ample evidence that its HDL-64E, HDL-32E, VLP-32, and VLP-16 products embody the full scope of the claimed invention, and that the claimed invention is not merely a subcomponent of those products. *See* Ex. 2115 ¶¶ 218–372.

For instance, Velodyne presents product literature with photos of an actual HDL-64E sensor (below left) and a 3-D point cloud image created by the sensor's operation (below right). Ex. 2069, 1–2.



HDL-64E S3


Actual point cloud image from HDL-64E S3 showing vehicle at intersection and other vehicles in vicinity along with road features.

The above pictures show that the HDL-64E sensor has a base, a housing atop of the base for supporting 64 laser emitters and 64 laser detectors, and a motor that rotates the emitter/detector pairs to produce a dense 360-degree 3-D point cloud. *Id.* Velodyne's expert confirms that the HDL-64E sensor embodies these elements, as well as other elements relating to rotation of the emitter/detector pairs, by providing a detailed analysis mapping claim 1 to the HDL-64E sensor described in Velodyne's product literature. *See* Ex. 2115 ¶¶ 225–229, 241–242, 250–258, 273–278, 288–297 (citing Exs. 2024, 2026, 2027, 2050, 2099, 2100). Velodyne's expert performs the same detailed analysis for Velodyne's HDL-32E, VLP-32, and

VLP-16 sensors. Ex. 2115 ¶¶ 230–232, 243–244, 259–263, 279–281, 298-304 (citing Exs. 2034, 2042, 2044, 2058, 2062, 2093, 2101, 2102). The only salient difference between these sensors and the HDL-64E is the number of emitter/detector pairs, as denoted by their model numbers. *See, e.g.*, Exs. 2032, 2042, 2060.

Quanergy never disputes the testimony of Velodyne's expert showing that the HDL-64E, HDL-32E, VLP-32, and VLP-16 products embody the claimed invention, let alone point to any missing limitations. *See* Pet. Reply 20–23; *see also* Pet. Sur-SurReply 1–5 (omitting any discussion of Velodyne's objective evidence). Instead, Quanergy attempts to rebut Velodyne's evidence of a presumption by arguing that it "focuses on unclaimed features . . . that are not coextensive with the patented claims." Pet. Reply. 20. Yet the features Quanergy identifies—"360 degree horizontal field of view, wide vertical FOV, and a dense 3-D point cloud"—are clearly supported by the challenged claims. *See id.* For instance, not only do the claims expressly call for a "3-D point cloud," but the density of the cloud and the 360-degree field of view result directly from "rotat[ing] the plurality of laser emitters and the plurality of avalanche photodiode detectors at a speed of at least 200 RPM," as also called for by the claims.[8] Thus, we are not persuaded by Quanergy's assertion that Velodyne relies on

[8] By definition, the "200 RPM" limitation necessarily infers that the laser emitter/detector pairs make a complete 360-degree rotation. *See Merriam-Webster's Collegiate Dictionary*, 1001 (10th ed. 2000) (defining "revolution" as "the action by a celestial body of going round in an orbit" and "the time taken by a celestial body to make a complete round in its orbit"). Although redundant, challenged claim 8 also calls for "a full 360 degree rotation." We also note that the "3-D" limitation of claim 1 necessarily infers both a horizontal and vertical field of view.

unclaimed features to show a presumption of nexus. Nor are we persuaded by Quanergy's assertion that Velodyne's commercial success is the result of "unclaimed software," as that assertion is nothing more than conclusory attorney argument without evidentiary support. Pet. Reply 24.

Quanergy also argues that no presumption of nexus applies because Velodyne purportedly fails to account for "elements in the prior art combined according to their established functions." *Id.* at 22. As discussed above with respect to the first three *Graham* factors, we conclude that the combination of elements as claimed are neither disclosed nor suggested by the prior art. Thus, Quanergy's argument is unpersuasive and fails to rebut Velodyne's overwhelming evidence of a presumption of nexus.

2. Unresolved, Long-Felt Need

Velodyne produces contemporary evidence of an unresolved, long-felt need for a lidar sensor with a sufficiently wide field-of-view ("FoV") to rapidly render a 3-D point cloud for use in autonomous navigation. As the '558 patent recognizes, prior art lidar systems were incapable of capturing distance points at a fast enough rate and with a sufficient FoV for an autonomous vehicle to "see everywhere around the vehicle . . . in order to safely navigate today's highways." *See* Ex. 1001, 1:32–2:9, 2:22–60 (identifying problems with prior art lidar technology). For instance, in the 1990s, researchers from both the civilian and military sectors "came together to start building intelligent vehicles" as a result of an "increasing interest in safety," the "promise to smooth out traffic flow," and the military's "long desire[] to have automated scouts that can investigate hazardous areas without putting soldiers in harm's way." Ex. 2140, 1–2. While earlier work on intelligent vehicles "concentrated on forward-looking sensing" technology, researchers at the time understood that, for any "real deployment," there was "[t]he need for 360 degree safeguarding." *Id.* at 3.

That need prompted the Defense Advanced Research Projects Agency ("DARPA") to begin a "Grand Challenge" program with the goal of "fostering advances in sensing" for "autonomous ground vehicle operation." Ex. 2142. DARPA was particularly interested in generating "breakthroughs" in the use of "lidar, and other sensors" for navigating an autonomous vehicle around various obstacles. Ex. 2143. Entrants in the first of these DARPA challenges used multiple tilt-mounted lidar sensors, called "SICK LIDARs,"[9] in an attempt to obtain a suitable FOV for the vehicle. Ex. 2146, 13 (depicting winning vehicles of the 2005 Grand Challenge); *see also* Ex. 2074, 7–8 ("the winner of the 2005 Grand DARPA Challenge made use of 5 SICK LIDAR sensors mounted on the roof"). But, according to the industry,

> [t]he fundamental challenge with the SICK LIDARs [used by the 2005 challenge vehicles] is that each laser scan is essentially a cut made by a single plane, and so you had to be methodical in how you pointed them. Teams mounted them on tilting stages, in order to use them to 'sweep' a segment of space. In simple terms: SICK was a 2D LIDAR (a few beams of light in one direction).

Ex. 2074, 8. Thus, after the 2005 challenge, a need still existed for a 3-D lidar sensor with a sufficiently wide FoV for use in autonomous vehicle navigation.

Then came David Hall, the lead developer of Velodyne's HDL-64E sensor and sole inventor on the '558 patent. Ex. 1003, 75–76, 97. By the

[9] Exhibits 2173 and 2174 provide a detailed description of SICK lidar sensors in the relevant time frame.

time of the 2007 DARPA Challenge, a number of entrants had purchased Velodyne's HDL-64E sensor for use in their autonomous vehicles. Ex. 2073, 2. Notably, five of the six top finishing vehicles in the 2007 DARPA Challenge (including the first and second-place finishers) were equipped with Velodyne's HDL-64E sensor. *Id.*; *see also* Ex. 1003, 76–77, 97. An annotated photo of Stanford University's second-place vehicle equipped with the HDL-64E sensor (circled in red) is reproduced below.

Ex. 2144, 2.

Shortly after completion of the 2007 DARPA Challenge, in a contemporaneous news article, Velodyne described the operation of the HDL-64E sensor as follows:

> The unit employs 64 lasers, each fixed at a specific height across a 26-degree vertical spread. The entire unit spins, with each laser firing thousands of times per revolution, giving a 360-degree horizontal field of view. The HDL-64E generates one million distance points per second, providing for a point cloud that is much denser than previously possible.

Ex. 2082, 1. One company's lidar system developer remarked, "Most people wouldn't attempt something like that." Ex. 2076, 9. That evidence supports that the claimed invention, as embodied in Velodyne's HDL-64E sensor, resolved a long-felt need for a lidar sensor that could capture distance points rapidly in all directions and produce a sufficiently dense 3-D point cloud for use in autonomous navigation.

3. Industry Praise

Solving the long-felt need for a 3-D point cloud lidar sensor with a 360-degree FOV was so significant that Velodyne's HDL-64E lidar sensor received substantial industry praise from numerous participants in the 2007 DARPA Grand Challenge. For instance, a participant from the MIT team was quoted as saying of Velodyne's HDL-64E sensor, "it's hard to imagine building an autonomous car without one." Ex. 1003, 97. Another participant, the director of technology at Carnegie Mellon University, said "[t]he Velodyne sensor is a revolutionary device and it was critical to our success at the Urban Challenge." *Id.* And yet another prominent participant, a lead engineer from the Stanford University team, proclaimed, "The sensor supplied by Velodyne has significantly advanced the state-of-the-art in in-traffic autonomous driving." *Id.* at 77–78, Fig. 6.

Since those early days, Velodyne has gone on to become "the predominant LIDAR producer in the automotive industry," according to *The Verge*, a technical news publication. Ex. 2076, 9. In 2017, *The Verge* recounted:

> What set Hall's LIDAR apart was that it rotated, firing off short laser pulses as it spun. . . . It was a groundbreaking design, one that Hall patented in 2007, that meant you could not only see and avoid obstacles, you could localize yourself on a real-time map, allowing for navigation, even if you lost GPS. The design was audacious.

Id.

Around the same time, *Forbes* labeled Velodyne "the top supplier of advanced automotive LiDAR . . . to virtually every auto and tech company that's building or testing autonomous vehicles," including GM, Ford, Uber, Google, and Caterpillar. Ex. 2040, 1, 3. "No company other than Velodyne," *Forbes* reported, "produces comparable units in sufficient quantities to meet the growing demand." *Id.* at 3. Importantly, *Forbes* tied this praise directly to the merits of the claimed invention:

> In 2006, Hall patented one of his inventions—a multi-beam spinning LiDAR sensor—that put Velodyne, albeit almost accidentally, at the center of a revolution that's disrupting the auto and tech industries . . . Over a couple of years, Hall refined a roof-mounted LiDAR [] unit consisting of 64 lasers spun by a small electric motor; the device became a favorite of the race's winning teams. "It was revolutionary," says William "Red" Whittaker, a roboticist at Carnegie Mellon University and a father of the autonomous-vehicle movement.

Id. at 2. *Forbes* further quoted Mr. Whitaker as saying of Velodyne's HDL-64E sensor, "Some good ideas really make it and change the world." *Id.* at 6. Indeed, Velodyne was recently recognized as the fourth-most innovative company in the global transportation industry "for giving automobiles the sense of sight." Ex. 2077, 3. This widespread praise and acceptance of Velodyne's HDL-64E sensors (as well as its next generation sensors) weigh distinctly in favor of non-obviousness.

Quanergy never addresses this overwhelming evidence of industry praise. Instead, Quanergy picks at *some* of the evidence as being statements by Velodyne itself. *See* Pet. Reply 26. Although true—for example, several exhibits tilted "Business Wire" or "velodynelidar.com/blog" appear to be self-serving statements—we do not rely on those exhibits. *See, e.g.*, Exs.

2070, 2078, 2079, 2082,[10] 2096, 2097. Nonetheless, as already discussed, a plethora of other evidence is clearly objective in nature and amounts to strong evidence of industry praise. Quanergy provides no rebuttal to that objective evidence of praise.

4. Commercial Success

Velodyne also presents evidence that the claimed invention has achieved a high degree of commercial success. PO Resp. 67–71. As discussed below, Velodyne proffers persuasive financial information between 2007 and 2018 showing it received hundreds of millions in dollars of revenue resulting from significant market share in mechanical 3-D lidar sensors. This commercial success is directly attributable to sales of Velodyne's 3-D lidar sensors embodying the claimed invention, thereby serving as further evidence of non-obviousness.

More specifically, Velodyne captured the market with the release of its groundbreaking HDL-64E sensor, selling hundreds of them at around $75,000 per sensor from 2007 to 2013 for total revenue in the tens of millions of dollars. Ex. 2084, 1; *see also* Ex. 1003, 80 (indicating list price and total revenue from early sales of HDL-64E sensors); Ex. 2091, 2. Since then, Velodyne's success has continued to soar. Between 2013 and 2017, Velodyne's annual revenues from sales of sensors embodying the claimed invention went from tens of millions to hundreds of millions in dollars. *See* Exs. 2084–2087, 2095; *see also* Ex. 2040, 3 (reporting Velodyne's "revenue is expected to be about $200 million this year"); Ex. 2113 (reporting 2018

[10] Although Exhibit 2082 is not relied upon as evidence of industry praise, it is relied upon as contemporaneous evidence of the construction of Velodyne's HDL-64E sensor in 2007.

estimated revenues of "$250M" and partnerships with "[a]lmost all robotic car manufacturers"). Those revenues include sales of not only the HDL-64E sensor but also next generation sensors such as the HDL-32E, VLP-32, and VLP-16. *See* Ex. 2113, 14.

With the advent of the HDL-64E sensor, Velodyne created a new market in autonomous navigation—"rotating" 3-D lidar sensors. As Ford's technical leader for autonomous vehicles remarked, once Velodyne released the HDL-64E sensor, "there really was no other game in the market, and no one as advanced." Ex. 2040, 6. And Velodyne continues to be recognized as the "market leader" for "rotating" 3-D lidar sensors, despite the introduction of lower-cost versions by multiple competitors. Ex. 2064, 10 (*Gartner* report June 2017); *see also* Ex. 2098, 1 (*Bloomberg* reporting that, in January 2015, "the lidar industry was dominated by Velodyne Lidar Inc."); Ex. 2074, 8 ("Velodyne has long been the market leader in LIDAR").

Indeed, a comparison of Velodyne's revenue in 2016 and 2017 to overall market revenue for mechanical 3-D lidar sensors confirms Velodyne's continued dominance in terms of market share. For example, Velodyne's revenue in 2016 and 2017 from sales of sensors embodying the claimed invention accounts for well over half of the estimated $292 million in total market revenue for those two years. *Compare* Exs. 2087, 2095 (detailing Velodyne's 2016-2017 revenue), *with* Ex. 2113 (specifying total market revenue). In sum, Velodyne presents persuasive evidence of commercial success—in terms of gross sales, revenue, and market share—of its HDL-64E, HDL-32E, VLP-32, and VLP-16 products, all of which embody the claimed invention.

5. Velodyne's Objective Evidence Shows that the Claimed Invention Resulted From Innovation

We give substantial weight to Velodyne's objective evidence of unresolved long felt need, industry praise, and commercial success. In viewing that objective evidence as a whole, and even assuming Quanergy had met its initial burden of showing that the asserted combination of Mizuno and Kilpelä taught the "lidar" limitation of claim 1 and otherwise satisfied the first three *Graham* factors, we find that Velodyne's objective evidence clearly outweighs any presumed showing of obviousness by Quanergy and supports that the claimed invention is more likely than not the result of innovative steps rather than obvious ones. Thus, for this additional reason, we determine that Quanergy has *not* demonstrated by a preponderance of the evidence that claims 1–4, 8, and 9 are unpatentable as obvious.

III. MOTION TO EXCLUDE

Quanergy seeks to exclude portions of Exhibit 1150 as improper testimony. Paper 51 ("Pet. Mot."), 1. Quanergy also seeks to exclude Velodyne's Exhibits 2040, 2057, 2066, 2074, 2076, 2079, 2082, 2096, and 2098 as inadmissible hearsay, and Exhibits 2075, 2097, 2122, 2130, 2150, and 2157 as irrelevant. *Id.*

First, we do not rely on the objected to portions of Exhibit 1150 in any respect. Nor do we rely on, or give any weight to, Exhibits 2057, 2066, 2075, 2079, 2096, 2097, 2122, 2130, 2150, and 2157. Thus, Quanergy's motion is denied as moot with respect to those exhibits.

That leaves only Exhibits 2040, 2074, 2076, 2082, and 2098, which Quanergy seeks to exclude as inadmissible hearsay. Pet. Mot. 3–9, 11. We rely on those exhibits as evidence of industry praise and commercial success. For instance, Exhibits 2040, 2076, and 2098 are articles from *Forbes*, *The Verge*, and *Bloomberg*, respectively, reporting independently on the wide recognition and adoption of Velodyne's sensors by the industry. We do not consider news articles such as these to be inadmissible hearsay as they are "offered simply as evidence of what [each] described, not for proving the truth of the matters addressed in the document." *Joy Techs., Inc. v. Manbeck*, 751 F. Supp. 225, 233 n.2 (D.D.C. 1990) aff'd, 959 F.2d 226 (Fed. Cir. 1992); *Freeman v. Minnesota Mining and Manuf. Co.*, 675 F. Supp. 877, 884 n.5 (D. Del. 1987). Thus, we deny Quanergy's motion to exclude Exhibits 2040, 2074, 2076, 2082, and 2098,

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that Quanergy has *not* shown by a preponderance of the evidence that claims 1–4, 8, and 9 of the '558 patent are unpatentable;

FURTHER ORDERED that Quanergy's motion to exclude (Paper 51) is *denied*; and

FURTHER ORDERED that, because this is a Final Written Decision, any party to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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