**UNITED STATES PATENT AND TRADEMARK OFFICE**

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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ARASHI VISION (U.S.) LLC (D/B/A INSTA360),
Petitioner,

v.

GOPRO, INC.,
Patent Owner.

Patent No. 10,958,840

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*Inter Partes* Review No. IPR2024-01164

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**Petitioner's Exhibit List for *Inter Partes* Review of U.S. Patent No. 10,958,840**

| Exhibit Description | Exhibit # |
|---|---|
| U.S. Patent No. 10,958,840 B2 to Douady *et al.* | 1001 |
| File History of U.S. Patent No. 10,958,840 B2 | 1002 |
| Expert Declaration of Aggelos Katsaggelos | 1003 |
| Steven Bell, Alejandro Troccoli, and Kari Pulli, "A Non Linear Filter for Gyroscope-Based Video Stabilization," *ECCV (4)*, Vol. 8692 of *Lecture Notes in Computer Science*, pp. 294-308, Springer (2014). | 1004 |
| Scanned copy of Steven Bell, Alejandro Troccoli, and Kari Pulli, "A Non-Linear Filter for Gyroscope-Based Video Stabilization," *ECCV (4)*, Vol. 8692 of *Lecture Notes in Computer Science*, pp. 294-308, Springer (2014). | 1005 |
| U.S. Patent No. 10,027,893 to Bell *et al.* | 1006 |
| U.S. Patent No. 10,462,370 to Shi *et al.* | 1007 |
| U.S. Patent No. 8,994,838 to Sokeila *et al.* | 1008 |
| U.S. Patent No. 9,071,756 to Karpenko | 1009 |
| Declaration of Sylvia D. Hall-Ellis | 1010 |
| U.S. Patent Application Publication No. US 2013/0044228 A1 to Corey *et al.* | 1011 |
| U.S. Patent No. 8,531,535 to Kwatra *et al.* | 1012 |
| Complaint in Certain Cameras, Camera Systems, and Accessories Used Therewith, Inv. No. 337-TA-1400, March 2024 | 1013 |
| '840 Patent Infringement Claim Chart in Certain Cameras, Camera Systems, and Accessories Used Therewith, Inv. No. 337-TA-1400, March 2024 | 1014 |
| U.S. Patent No. 9,674,438 to Zhou *et al.* | 1015 |

| Exhibit Description | Exhibit # |
|---|---|
| Declaration of W. Stella Mao "Mao Decl." | 1016 |
| Supplemental Expert Declaration of Dr. Katsaggelos<br>PROTECTIVE ORDER MATERIAL | **1017**<br>**[NEW]** |
| Deposition Transcript of Patent Owner's Expert Dr. Foroosh (July 11, 2025) | **1018**<br>**[NEW]** |
| Excerpts from the Deposition Transcript of Thomas Derbanne, October 1, 2024 (RX-0331C)<br>PROTECTIVE ORDER MATERIAL | **1019**<br>**[NEW]** |
| Excerpts from the Deposition Transcript of Pablo Lema, September 11, 2024 (RX-0322C)<br>PROTECTIVE ORDER MATERIAL | **1020**<br>**[NEW]** |
| Provisional Patent Application No. 62/733237 | **1021**<br>**[NEW]** |
| GoPro internal development documentation (including original French version, certified translated version, and translation certification) (GOPRO_00183699) (RX-0154C)<br>PROTECTIVE ORDER MATERIAL | **1022**<br>**[NEW]** |
| Matthias Grundmann, Vivek Kwatra, Irfan Essa, "Auto-directed video stabilization with robust L1 optimal camera paths" ("Kwatra Paper") | **1023**<br>**[NEW]** |

The challenged claims are unpatentable for the reasons below.

## I. CLAIM CONSTRUCTION

The Board should reject GoPro's narrow construction of "low-light high-pass parameter." It should instead adopt its preliminary construction: "a parameter that controls the amount or strength of smoothing used in motion blur compensation."

### A. "Low-light high-pass parameter" is a "coined" term

"Low-light high-pass parameter" is not a term used in the field of video stabilization. (EX1017, ¶11.) The '840 patent's inventor agreed. (EX1019, 221:13-17.) Because this is "a coined term that has no ordinary meaning in the industry," one must look to the "specification, [and] the prosecution history, to determine [its] meaning." *Iridescent Networks, Inc. v. AT&T Mobility, LLC*, 933 F.3d 1345, 1351 (Fed. Cir. 2019).

### B. The specification supports Insta360's construction

The specification describes a "low-light high-pass parameter" as "a parameter that controls the amount/strength of smoothing performed to generate the smoothed trajectory." (EX1001, 21:59–22:21.) It explains that a parameter of 0 results in full smoothing (*i.e.*, "the observed motion being fully attenuated") and "no motion blur compensation," while a parameter of 1 results in no smoothing (*i.e.*, "the smoothed trajectory being same as the (observed) trajectory") and "full motion blur compensation." (*Id.*, 22:8-18.) The parameter ranges between 0 and 1

and manages the trade-off between motion smoothing and blur compensation. (EX1017, ¶¶13-18.)

A POSITA would have been aware of this trade-off. Upon reviewing the specification, they would understand that the claimed parameter leverages this trade-off to address blur by controlling the amount of smoothing. (EX1017, ¶¶13-19.)

### C. GoPro's narrow construction lacks support

GoPro proposes a construction: A parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions. (POR, 24.) GoPro improperly requires that this parameter perform blur compensation only (1) based on low-light conditions and (2) by allowing more high frequencies. Neither requirement has support.

**Low light.** This parameter does not "target[] blur from low-light conditions" (POR, 25). Rather, it addresses motion blur generally. (EX1001, 22:8-21.)

The specification explains that motion blur arises from "[i]ntra-frame motion" "encrusted" in the video frame. (*Id.*, 21:65-22:5.) It further explains that blur increases with either longer exposure times or greater device motion. (EX1001, 19:25-26, 18:37-39.) This aligns with a POSITA's understanding. As

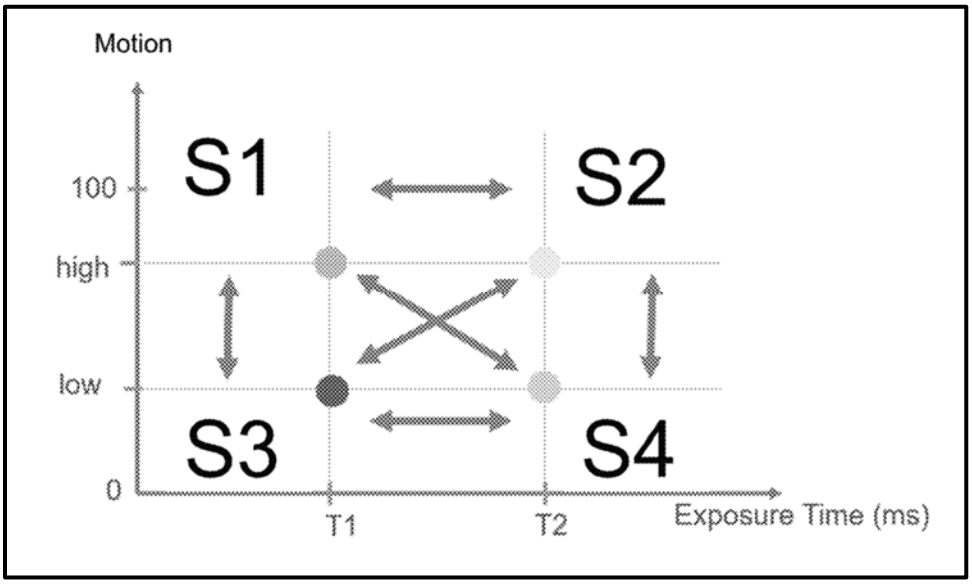
blur is caused by a device's motion during the exposure time of a single frame, increasing either the exposure time or motion results in increased intra-frame motion, and consequently, greater blur. (EX1017, ¶¶25-27.)

The specification makes clear that low light is simply one condition requiring higher exposure time. (EX1001, 19:18-25 ("[L]onger exposure time may be used with low light conditions").) Nowhere does the specification limit this parameter to address only blur caused by low light. Apart from references to the term itself, the specification mentions low light only three times. (EX1017, ¶¶22-24.) The specification discusses low light only in the context of it being one possible cause of blur. (*Id.*; EX1001, 19:18-25, 18:1-19.)

Although GoPro contends that the '840 patent "selectively addresses blur from 'low-light' conditions while maintaining smoothing strength otherwise" (POR, 24), the specification plainly says otherwise. It explains that the claimed technique adjusts smoothing strength to compensate for blur based on different factors, including the length of the exposure time and the device's motion. (EX1001, 18:62-19:12.) GoPro's expert concedes as much. (EX2001, ¶45; EX2018, ¶39.)

Figure 7 confirms that the smoothing strength varies even under identical exposure times (affected by lighting conditions), further demonstrating that the

parameter is not limited to low-light conditions. (EX1001, 19:18-25; EX1017, ¶¶27-29.)




(EX1001, Fig. 7.)

**High frequencies.** Nor does the specification require the parameter to allow more high frequencies to pass through. The '840 patent explains that its technique compensates for blur by "preserving the intra-frame motion," so that the motion of the "smoothed trajectory" is "aligned with the motion blur in the image." (EX1001, 18:1-24; EX1017, ¶¶34-35.)

The specification discusses high-frequency motion as part of the preserved intra-frame motion. (EX1001, 18:1-9.) It describes that "full motion blur compensation" "result[s] in the smoothed trajectory being same as the (observed) trajectory during the exposure periods." (*Id.*, 22:14-18.) As a result, "the output motion may include high frequencies that mask motion blur." (*Id.*, 22:17-20.)

A POSITA would understand that intra-frame motion may include both high- and low-frequency motion. Preserving intra-frame motion allows both to pass through. (EX1017, ¶¶35-36.) GoPro cites no language requiring only high frequencies to be retained.

### D. Prosecution history refutes GoPro's construction

The provisional application for the '840 patent mentions "low-light high-pass" only in the below excerpted portion:

**(2) Low-light high-pass (motion blur masking control)**

Taking into account the exposure time of every frame, Hypersmooth decomposes the observable camera motion in two categories.

- **Inter-frame motion** is the motion between frame exposure periods. This motion can be attenuated completely up to the cropping constraint.
- **Intra-frame motion** is the motion underwent by the camera during the exposure period of every frame. This motion is already encrusted in the image through the motion blur, and its attenuation causes motion blur pulsations producing a bad visual impression.

Arguably the only way to deal with the latter is to render the trajectory representing the same motion during the exposure periods, i.e., in a way that the camera always moves in the same direction and with the same speed during the exposure phase of every frame, and might then stand still between consecutive frames.

There is a positive scalar parameter controlling the gain of the corresponding high-pass filter.

- When set to 0, no motion blur compensation is done; the observed motion is fully attenuated and no camera motion during the exposure periods is taken into account. The output motion is fully smooth. This would end with a similar result as early Chopes.
- When set to 1, the entire camera displacement during the exposure periods is preserved. The output motion contains high frequencies that mask motion blur.

This parameter does not need to evolve in function of the exposure time.

- When a highly illuminated scene is being shot, the exposure time is short enough to render the intra-frame displacement negligible.
- When the camera does not move much, the intra-frame displacement is limited regardless the exposure time.

**Default value: 1.0 for MP, updated to 0.8 for Launch.**

(EX1021, 22.)

As this disclosure makes clear, the "low-light high-pass parameter" is for "motion blur masking control." (*Id.*) It does not mitigate blur only based on low-light conditions. The disclosure does not mention low light. (EX1017, ¶¶38-40.) Critically, the provisional application states that "[t]his parameter does not need to evolve in function of the exposure time." (EX1021, 22; EX1017, ¶¶38-40.) In

other words, no matter the exposure time — and thus regardless of the lighting condition — the parameter stays the same and performs blur compensation. (*Id.*)

Nor does this disclosure limit this parameter to high-frequency motion. Consistent with the '840 patent's specification, it states that the solution for "intra-frame motion" is to "render the [smoothed] trajectory representing the same [intra-frame] motion." (EX1021, 22; EX2018, ¶¶41-42.)

**E. Extrinsic evidence does not support GoPro**

GoPro argues that its construction is necessary to give meaning to the terms "low-light" and "high-pass." (POR, 24.) But it ignores that "the inventor's intention, as expressed in the specification, is regarded as dispositive." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1316 (Fed. Cir. 2005). Nor is it proper to rely "on single words . . . as opposed to the limitation[] as a whole." *Apex Inc. v. Raritan Comput., Inc.*, 325 F.3d 1364, 1372 (Fed. Cir. 2003).

GoPro's reliance on Dr. Katsaggelos's testimony (the so-called "extrinsic evidence") is unavailing. (POR, 25-26.) While low light can cause blur, this does not mean the claimed parameter targets only low-light blur. (EX1017, ¶¶30-31.) As GoPro acknowledges, the '840 patent's blur compensation technique "mask[s] motion blur." (POR, 25 (citing EX1001, 22:16-21).) The '840 technique compensates for blur ***after*** it has already formed—or "encrusted" in the video frame. (EX1001, 18:1-24, 21:66-22:7.) Because this parameter addresses blur

after formation, it is agnostic as to the cause of the blur. (EX1017, ¶¶30-31.) Moreover, no software-only technique can selectively mitigate blur based solely on lighting conditions. (*Id.*)

### F. GoPro's expert's opinion contradicts its construction

Finally, GoPro's expert offers an analysis of GoPro's allegedly practicing product that undermines GoPro's construction. Although he asserts that HERO7 includes the claimed parameter, he does not mention low light or high frequency. (EX2018, ¶182.) Instead, he opines that HERO7's [redacted] meets this limitation because it "adjusts smoothing strength based on motion blur considerations." (*Id.,* ¶182.) This is consistent with Insta360's construction — not GoPro's. (EX1017, ¶43.)

## II. GROUND 1: BELL AND SHI RENDER CLAIMS 1, 14, AND 16 OBVIOUS[1]

### A. Shi discloses "determin[ing] a smoothed trajectory" based on a "low-light high-pass parameter" (claims 1, 14, and 16))

#### 1. Shi does not address motion blur after smoothing

GoPro is wrong that "Shi's blur correction is performed in a separate, later step" after smoothing. (POR, 30.) It erroneously limits the smoothing step to generating only the initial virtual camera position $V_0(T)$. (*Id.*)

[1] In the related ITC proceeding, the initial determination found claims 1 and 14 anticipated and claim 13 not obvious under the clear and convincing standard.

Shi's system follows the standard three-step video stabilization process:

- Motion model constructor 160 for motion estimation (EX1007, 10:4-7, 8:17-23);
- Non-linear motion filtering engine 170 for motion smoothing (EX1007, 10:43-11:28);
- Image warping engine 180 for generating stabilized video (EX1007, 11:62-65).

(EX1017, ¶¶50-58.) Shi discloses that the output of the non-linear motion filtering engine 170 is used by the image warping engine 180 to "map each captured image frame to an output frame." (EX1007, 11:63-65.) A POSITA would understand that the entire process leading to the generation of the output is motion smoothing. (EX1017, ¶¶70-71; EX1001, 8:56-57, 25:62-65.)

Shi's smoothing step is not limited to generating $V_0(T)$. As GoPro concedes, Shi determines multiple virtual positions—including $V_0(T)$, $V_1(T)$, and $V_2(T)$—as part of smoothing. (POR, 28; EX1017, ¶¶61-66; EX1007, 12:54-59, 13:4-7, 13:16-49, 14:25-30, 17:47-52, .) Shi explicitly states that "using any of filtered camera position $V_0(T)$, $V_1(T)$, and $V_2(T)$ to generate a stabilizing transformation may still improve stability of video." (EX1007, 14:33-36.)

Because the third virtual camera position, $V_2(T)$, addresses motion blur, Shi's smoothing process necessarily includes blur compensation. (POR, 28 (citing EX1007, 13:16-24, 17:53-18:40; EX1017, ¶¶64, 68, 72).) Shi confirms that "the

virtual camera position can be adjusted" based on "an amount of blur in the frame" to "determine a final virtual camera position for the frame." (EX1007, 11:18-28.)

GoPro is also wrong in claiming Shi's blur compensation is a "new process involving reintroduction of real trajectory data." (POR, 30.) Both Shi and the '840 patent disclose the same technique. (EX1017, ¶¶74-78.) Like the '840 patent, Shi adjusts the virtual position to "track the real camera position, consistent with the natural blur in the image," thereby reducing perceived blur. (EX1007, 17:63-67.) Shi's method uses "at least a portion of the real motion" to adjust the virtual camera position $V_1(T)$, just as the '840 patent does. (EX1007, 18:1-6; EX1001, 18:16-24, 22:14-18.)

**2. GoPro relies on incorrect claim construction**

Relying entirely on its narrow construction, GoPro argues that Shi's coefficient is not the claimed parameter because it (1) is not based on low-light conditions and (2) does not preserve more high frequency. (POR, 30-32.) But GoPro does not dispute that Shi's coefficient addresses blur, which can arise from low-light conditions. (*See* Paper 2, 28.)

Nor is GoPro correct that Shi cannot preserve high-frequency motion. Shi's "spherical linear interpolation" is not a low-pass filter, and a POSITA would not have understood it as such. (POR, 32; EX1017, ¶¶84-88.) As GoPro concedes, Shi's interpolation blends the smoothed and original trajectories. (POR, 32.)

Retaining more of the original trajectory preserves more high-frequency movement, since the original motion often contains higher-frequency, less stable movement. (EX1007, 17:53-18:6; EX1017, ¶¶89-90.) Consistent with the '840 patent, Shi teaches reducing stabilization to lessen perceived blur. (*Id.*; EX1007, 17:57-18:1.)

GoPro's claim that the "differences between Shi and the claimed technique have real world implications" is unsupported. (POR, 32-34.) Both the '840 patent and Shi apply broadly to electronic devices like mobile phones and cameras and do not prioritize blur compensation over smoothing or vice versa. (EX1001, 6:20-29; EX1007, 5:65-67; EX1017, ¶¶95-98.)

### 3. A POSITA would have been motivated to combine Shi with Bell

GoPro argues that the Petition fails to consider how the combination of Shi with Bell would affect Bell's purported "delicate balance" between dampening and accelerating virtual camera motion. (POR, 34-36.) Not so.

As GoPro acknowledges, Bell adjusts virtual camera motion to "keep[] the virtual camera crop window within the boundaries of the image frame." (POR, 35.) This is a standard step in video stabilization. (Paper 2, 41-48; EX1017, ¶¶99-100.) The '840 patent describes a similar technique, adjusting the smoothed trajectory so that the "viewing window" does not exceed the field of view. (EX1001, 3:38-51.) This ensures that every pixel within the "viewing window"

contains actual image content from the captured frame, avoiding undefined or empty regions in the stabilized video. (*Id.*, 20:37-44; EX1017, ¶100.)

Shi's system involves a similar technique. Shi discloses that "to fill the entire output frame 235 and not leave any pixels undefined," its system adjusts the "virtual camera position" so that "the current frame and each of a set of future frames would all fully define the output frame 235." (EX1007, 13:52-64; *see also id.*, 11:18-24.)

Thus, Shi and Bell employ similar video stabilization techniques. A POSITA would have been motivated to combine Shi's motion blur coefficient with Bell's system with a reasonable expectation of success. (EX1003, ¶124; EX1017, ¶¶102-103.)

### B. Bell and Shi disclose "temporal horizon enabling approximation of intentional motion" (claims 1 and 16)

#### 1. Bell

GoPro concedes that Bell discloses a "temporal horizon of motion," acknowledging that Bell uses "a small buffer of future frames." (POR, 39 (citing EX1006, 8:63-67).) GoPro nevertheless argues that Bell's "temporal horizon" does not approximate intentional motion, because it serves only to "predict[] whether the virtual camera will approach the frame boundary at a future time." (POR, 40.) That is incorrect.

First, GoPro overlooks that Bell's goal is "to define a new virtual camera that stays static when the motion is so small that ***the intention*** is probably that the camera should remain static."[2] (EX1006, 8:51-67.) Bell's discussion of "a small buffer of future frames" — the claimed "temporal horizon" — immediately follows that disclosure. (*Id.*) This confirms that Bell's "temporal horizon" is integral to its stabilization technique, whose goal is to approximate intentional motion. (EX1017, ¶¶106-108.)

Second, Bell explicitly links the look-ahead buffer to the user's intended motion. It discloses that buffering frames allows "a larger time window of motion sensing system data [to] be examined, and sharp changes can be preemptively avoided." (EX1006, 10:10-13.) Bell further teaches that looking ahead 2 to 5 frames "provides a preemptive nudge in the right direction." (EX1006, 10:18-34.) A POSITA would understand that sharp changes often reflect unintended movement and that the "right direction" is the intended motion. (EX1017, ¶109-111.) Bell discloses using the look-ahead buffer to identify and suppress sharp changes and aligning the virtual camera's motion with the user's intention. (*Id.*)

Third, GoPro disregards the relationship between camera trajectory and crop polygon in arguing that Bell's look-ahead buffer merely prevents the crop polygon

[2] Unless specified, emphasis in quoted language is added.

from approaching the frame boundary. (POR, 40.) The crop polygon's position is based on the virtual camera trajectory. (*See* Paper 2, 41-43.) By avoiding sharp changes that cause the crop polygon to hit the boundary suddenly, Bell prevents sudden shifts in the virtual camera movement ("smoothed trajectory"), consistent with the user's intention. (EX1017, ¶112.)

Finally, GoPro's assertion that Bell merely changes the velocity used in calculating the next frame misses the point. (POR, 39.) As explained, Bell looks ahead at future frames, including frame k + 5, to determine the virtual camera position at frame k + 1. (Paper 2, 31-36.) This confirms Bell utilizes look-ahead data—the "temporal horizon"—to adjust the virtual camera's motion, ensuring it approximates intentional motion. (EX1017, ¶¶113-114.)

**2. Shi**

GoPro does not dispute that Shi discloses a "temporal horizon [] of motion. (POR, 41.) Contrary to its characterization, Shi does not "teach[] a different approach of intentionally altering motion." (*Id.*, 42.) Instead, Shi uses look-ahead frames to "reduce the impact of large or sudden movements" and to "gradually prepare for large changes in movement before the movement occurs." (EX1007, 5:17-22.) Shi explains that sudden movements are often unintentional. (EX1007, 1:9-12.) To avoid them, Shi adjusts the virtual camera's motion for smoother transitions and approximates the user's intended motion. (EX1017, ¶¶115-119.)

GoPro concedes that Shi "evaluate[s] whether consistent movement, such as panning" — the claimed "intentional motion" — is occurring. (POR, 42 (citing EX1007, 5:22-24); Paper 2, 39.) It nevertheless argues that Shi merely "impose[s] a predetermined shape or pattern," which does not "enable approximation of intentional motion." (POR, 42.) This ignores Shi's explicit teaching that a "predetermined, consistent motion pattern" may be "intended by a user of the recording device." (EX1007, 13:35-40.) Because such patterns represent intentional motion, imposing them is indeed an approximation of user intent. (EX1017, ¶¶120-122.)

## III. GROUNDS 2-4 AND 6-7

GoPro has no independent validity arguments for those grounds. (POR, 43.)

## IV. GROUND 5: BELL, SHI, AND KWATRA RENDER CLAIM 13 OBVIOUS

### 1. Kwatra

#### a) Kwatra discloses a "weight-balance parameter"

##### (1) GoPro misunderstands basic concepts

GoPro is wrong that Kwatra's linear framework does not minimize rotation. First, Kwatra is not limited to linear motion models. (EX1017, ¶125; EX1012, 5:48-50.)

Moreover, linear motion models can characterize rotation. They are mathematical tools describing how an object's state evolves over time using linear

transformations. (EX1017, ¶127.) Kwatra teaches several such models—including similarity, affine, and homography—all of which explicitly include rotation. (EX1012, 17:5-8, 11:4-11; EX1017, ¶¶127-130.)

Models like similarity and affine are called linear motion models because they satisfy the additivity and homogeneity properties of linearity — not because they can model only linear motion. (EX1017, ¶¶131-136.) Tellingly, GoPro does not *actually* contend that linear motion models cannot represent rotation. The reason is obvious: both Kwatra and a POSITA's understanding contradict any such notion. (EX1017, ¶¶126-137.)

Nor does Kwatra's disclosure of linear transformation preclude minimization of rotation. A POSITA would understand that linear transformation encompasses rotation. (EX1017, ¶135.) As GoPro concedes, "Kwatra does teach that the 2-dimensional linear motion model may be represented as a 'similarity' or 'affine' transformation with degrees of freedom for scale and ***rotation***." (POR, 46.) Its expert similarly concedes that "Kwatra's teaching is [] about the 2D rotation." (EX2018, fn.4.)

**(2) Kwatra discloses smoothing rotation**

GoPro's two convoluted arguments in Section 1 both fail. Its first argument regarding rotating an image's feature versus camera rotation (POR, 47) is unexplained in Section 1. That is addressed in a subsequent section.

GoPro's second argument—that Kwatra "expressly rejects" minimizing rotation as part of smoothing—is incorrect. (POR, 47.) GoPro relies on Kwatra's statement that smoothness constraints are imposed only on parameters "a" and "b," rather than directly on scale (s) and rotation angle (θ). (POR, 47-48.)

But GoPro's own citation refutes this argument. It concedes that Kwatra "plac[es] bounding constraints (i.e., numerical limits) on changes to scale and rotation in the smoothed camera path 'to ensure s and theta do not deviate too much.'" (*Id*.) This confirms that rotation is bounded and smoothed. (EX1017, ¶139.)

Kwatra further explains smoothing rotation (θ). (EX1017, ¶¶35-39.) Kwatra states that "a similarity transform" combines "scale, ***rotation***, and translation," with scale and rotation expressed via parameters a and b. (EX1012, 17:7-16.)

Scale: $s=\sqrt{(a^2+b^2)}$ Equation (17)

Rotation angle: $\theta=a\tan(b/a)$ Equation (18)

While directly smoothing scale and rotation is nonlinear, Kwatra instead constrains them indirectly. (EX1012, 17:17-20.)

Specifically, Kwatra discloses: "[f]or rotation, a=s*cos(θ), b=s*sin(θ), and sin(θ) and cos(θ) can be constrained to be bounded near the estimated camera rotation":

$$\cos\left(\frac{a_0}{s_0} - \varepsilon_1\right) < a < \cos\left(\frac{a_0}{s_0} + \varepsilon_1\right) \qquad \text{Equation (23)}$$

$$\sin\left(\frac{b_0}{s_0} - \varepsilon_2\right) < b < \sin\left(\frac{b_0}{s_0} + \varepsilon_2\right) \qquad \text{Equation (24)}$$

(*Id.*, 17:37-46.) Rotation (θ) is represented as:

$$\text{Rotation angle: } \theta = a\tan(b/a) \qquad \text{Equation (18)}$$

(EX1012, 17:15-17.)

Because rotation (θ) is only related to a and b, a POSITA would understand that imposing smoothness constraints on a and b smoothes rotation (θ). (EX1017, ¶142.) Although Kwatra does not operate directly on rotation (θ), constraining a and b achieves the same functional result. (EX1017, ¶¶142-143.) Thus, GoPro's argument that rotation (θ) is not directly bounded misses the point. Bounding a and b mathematically controls and smooths rotation. (EX1017, ¶143.)

**(3) Provisional application supports Insta360**

GoPro's reliance on Kwatra's provisional application fares no better. It cites disclosures favoring linear framework over non-linear optimization and concludes that "by deliberately avoiding non-linear computations," Kwatra cannot minimize rotation. (POR, 48-49.)

But linear computation simply means operations where outputs are linear functions of inputs. (EX1017, ¶144.) Kwatra's use of linear optimization for

efficiency does not preclude smoothing rotation. (*Id.*) Neither GoPro nor its expert explains why preferring linear computation would prevent minimizing rotation. As explained above and in the Petition, Kwatra includes ample disclosures of smoothing rotation. (Paper 2, 32-33.)

GoPro also faults Insta360's expert for not considering the provisional application (POR, 49). But the provisional application instead confirms that Kwatra smoothes rotation. For example, on page 4, it teaches how to solve a linear optimization problem if the optimal camera path P(t) "is restricted to be a translation." (EX2019, 4.) On the next page, it describes: "[t]his formulation can be extended to other linear transforms such as similarity and affine," implying that those linear models are not restricted to a translation—and can include rotation. (*Id*., 5; EX1017, ¶145.)

The provisional application further states: "When the camera motion model is pure translation, minimizing derivatives of P(t) is straightforward. When it is a similarity transform however, it is a combination of scale, ***rotation*** and translation." (EX2019, 5.) A POSITA would understand this confirms that Kwatra's linear models, such as similarity and affine, encompass rotation. (EX1017, ¶146.)

Thus, consistent with the patent, Kwatra's provisional application discloses linear motion models and transformations that include rotation. It does not support GoPro's claim that Kwatra fails to minimize rotation. (EX1017, ¶147.)

**(4) GoPro's reliance on Figures 8A and 8B is misplaced**

GoPro improperly relies on a single embodiment: Figures 8A and 8B. It argues because that embodiment tracks camera motion in the X and Y dimensions, Kwatra does not minimize rotation. (POR, 50-51.) But that is merely one embodiment. GoPro ignores Kwatra's numerous explicit disclosures of rotation, including Figure 5D. (EX1017, ¶149.)

GoPro also cherry-picks testimony from Insta360's ITC expert, Mr. Goodin. (POR, 51.) Although Mr. Goodin stated that Figures 8A and 8B "appear to be dealing with translational motion" (EX2021, 1369:1-5), he also testified that he did not understand that P in "in Kwatra is representing a linear path model" (EX2021, 1368:3-11). Mr. Goodin affirmed that P in Kwatra "represent[s] a combination of linear and rotational motion." (*Id.*)

**b) GoPro's argument regarding "two-dimensional approach" fails**

GoPro's next argument mischaracterizes Dr. Katsaggelos's deposition testimony. (POR, 51-53.) It argues that because Kwatra discloses only two-

dimensional models and Dr. Katsaggelos testified that such models cannot cover rotation in the 3D space, Kwatra fails to disclose the minimization limitation.

But the cited testimony makes clear that Dr. Katsaggelos did not testify that *all* two-dimensional models cannot cover camera rotation in the 3D space — only the ones they "talk[ed] about" (*e.g.*, translation model). (EX1017, ¶¶151-155.) To the contrary, certain two-dimensional models discussed in Kwatra, such as affine and homography, can represent 3D motion. (*Id.*)

Indeed, Dr. Katsaggelos explicitly stated that Kwatra discloses models such as homography and affine that can be "a three-dimensional modeling." (EX2020, 73:19-75:25.) For example, Kwatra discloses "lower to higher dimension motion models (e.g., similarity→homography)." (EX1012, 11:58-61; EX1017, ¶156.)

Moreover, GoPro's emphasis on 2D versus 3D modelling is a red herring. The '840 patent does not limit its purported inventions to 3D motion. GoPro's expert concedes that "the claims do not explicitly" reference 3D rotation. (EX2018, ¶55.) A POSITA would also understand that minimizing rotational movement does not require 3D modelling. (EX1017, ¶¶157-158.)

Even if the '840 patent is limited to 3D modeling and Kwatra is limited to 2D modeling, Bell, Shi, and Kwatra still render the '840 claims obvious. It is undisputed that Bell and Shi disclose 3D rotation. (POR, 56; EX1017, ¶159; EX1006, 7:40-42; EX1007, 11:1-11.) It would have been obvious to combine

Bell's and Shi's stabilization of 3D rotation and Kwatra's minimization of rotational velocity and rotational acceleration. (EX1017, ¶159.)

**c) Kwatra discloses minimizing the camera housing's rotation**

GoPro's final argument is because Kwatra's motion model is based on tracking feature pairs across frames (*i.e.*, image-based motion estimation), it cannot represent the physical camera's motion. (POR, 54-55.) Not so.

First, Kwatra is not limited to image-based motion estimation. It expressly states that a "camera path ***may be*** estimated by extracting trackable features in frames of the video." (EX1012, 5:43-46.)

Second, GoPro's argument contradicts video stabilization basics. (EX1017, ¶¶163-164.) As a POSITA would understand, the movement of a feature in a frame is directly proportional to camera rotation. (*Id.*) At the time of the claimed invention, computer vision systems routinely inferred and corrected motion, including rotation, using image-based motion estimation techniques. (*Id.*) Similarly, industry-standard practices have relied on 2D pixel displacement to infer and smooth camera motion — including rotation — in the 3D space. (EX1017, ¶166.)

GoPro's emphasis on 2D versus 3D also misses the point: in video stabilization, the important factor is not the actual 3D camera angle, but how

rotation manifests in the image. (EX1017, ¶165.) Minimizing how much a feature moves in pixels directly reduces perceived rotational movement. (*Id.*)

Further, a POSITA would know that 3D information (*e.g.*, depth) can be reconstructed from a 2D video. (EX1017, ¶168.) GoPro's expert's own experience confirms this. (EX1018, 24:16-25:5.) Kwatra's provisional application also shows that 3D motion can be estimated by analyzing a 2D video. (EX1017, ¶168; EX2019, 11-12.)

Third, Kwatra itself discloses that an approach based on tracking features between frames can estimate camera motion. Kwatra teaches: "Linear motion models (e.g., translation, similarity, affine) may be fit to the tracked features to ***estimate a motion of the camera*** between two frames." (EX1012, 5:48-53; EX1017, ¶167.) Kwatra also teaches "estimate[ing] ***an original motion path of a camera***" based on "motion of objects within the video." (EX1012, 2:28-31.) Thus, Kwatra's image-based motion estimation approach estimates the motion of a camera (and by extension, the camera's housing). (EX1017, ¶167.)

**d) GoPro's own characterization of Kwatra's related publication contradicts its position**

GoPro's own development of the claimed technologies confirms that Kwatra discloses the minimization limitation. GoPro's internal documents show that its research was based on a 2011 publication titled "Auto-directed video stabilization with robust L1 optimal camera paths," authored in part by Vivek Kwatra and

Matthias Grundmann—the same inventors behind Kwatra. (EX1022, 7; EX1023 ("Kwatra paper").)

Kwatra paper discloses similar subject matter as Kwatra. (EX1017, ¶172.) It teaches a stabilization technique using an image-based motion estimation approach and a linear motion model. (*Id.*) It discloses: "the camera path *C(t)* of the original video footage has been computed (*e.g.* from feature tracks) and is described by a parametric linear motion model." (EX1023, 227.)

Kwatra paper further teaches a technique using linear programming to minimize derivatives of a motion. (EX1017, ¶172; EX1023, 225.) It also discloses using "2D parametric motion models." (*Id.*, 227; EX1017, ¶172.)

Critically, Kwatra paper teaches the same minimization approach as Kwatra. It discloses that the "optimization serves to find the optimal stable camera path *P(t)* minimizing the objective" function below:

$$\mathcal{O}(P) = w_1|D(P)|_1 + w_2|D^2(P)|_1 + w_3|D^3(P)|_1 \quad (3)$$

(EX1023, 227.) Kwatra likewise discloses: "The optimization may determine a stable camera path P(t) by minimizing the cost function:"

$$a\left|\frac{dP}{dt}\right| + b\left|\frac{d^2P}{dt^2}\right| + c\left|\frac{d^3P}{dt}\right| \qquad \text{Equation (7)}$$

(EX1012, 13:65-14:5.)

The two disclosures are the same. (EX1017, ¶173.)

Even though Kwatra paper explicitly mentions rotation only twice (*id.*, ¶174; EX1023, 228), GoPro's engineers understood that it discloses rotation. GoPro's documentation describes that Kwatra paper (referred to as Grundmann) teaches that "the objective function is expressed as a combination of the camera's angular velocity and acceleration over time." (EX1022, 18.)

**Method based on linear programming**

A first attempt was based on the method of [Grundmann *et al.*, 2011]. This method is characterised by :

- **the objective function** is expressed as a combination of the camera's angular velocity and acceleration over time.
- **the set of acceptable solutions** is represented by a polytope in 3-dimensional Euclidean space, whose interior points represent the rotations for which the stabilised image remains entirely within the source image!
- **the numerical method** is linear programming.

Angular velocity means rotational velocity; angular acceleration means rotational acceleration. (EX1017, ¶176.) Thus, GoPro itself understood that Kwatra paper — and by extension, its related Kwatra — discloses rotational velocity and rotational acceleration. (*Id.*)

### 2. Combining Bell, Shi, and Kwatra would have been obvious

Mischaracterizing Kwatra, GoPro argues that it involves "fundamental [sic] different image stabilization techniques" compared to Bell and Shi. (POR, 56.) Not so. Kwatra makes clear that its technique can be broadly implemented in a generic device, including a mobile device. (EX1012, 7:6-13, 12:57-64, 26:12-21.)

Ignoring these disclosures—even in its own cited passages—GoPro argues that Kwatra is limited to server implementation. (POR, 56-57.) Its reliance on Figures 1 and 2 is unavailing. (*Id.*, 57.) Neither Figure 1 nor Figure 2's camera path translation system—Kwatra's stabilization system—mentions server. (EX1012, 5:37-39; EX1017, ¶¶186-191.)

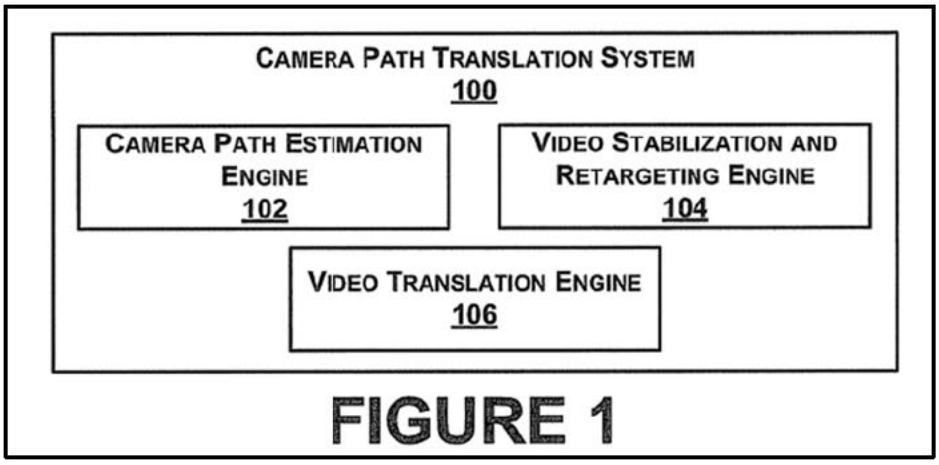



FIGURE 1

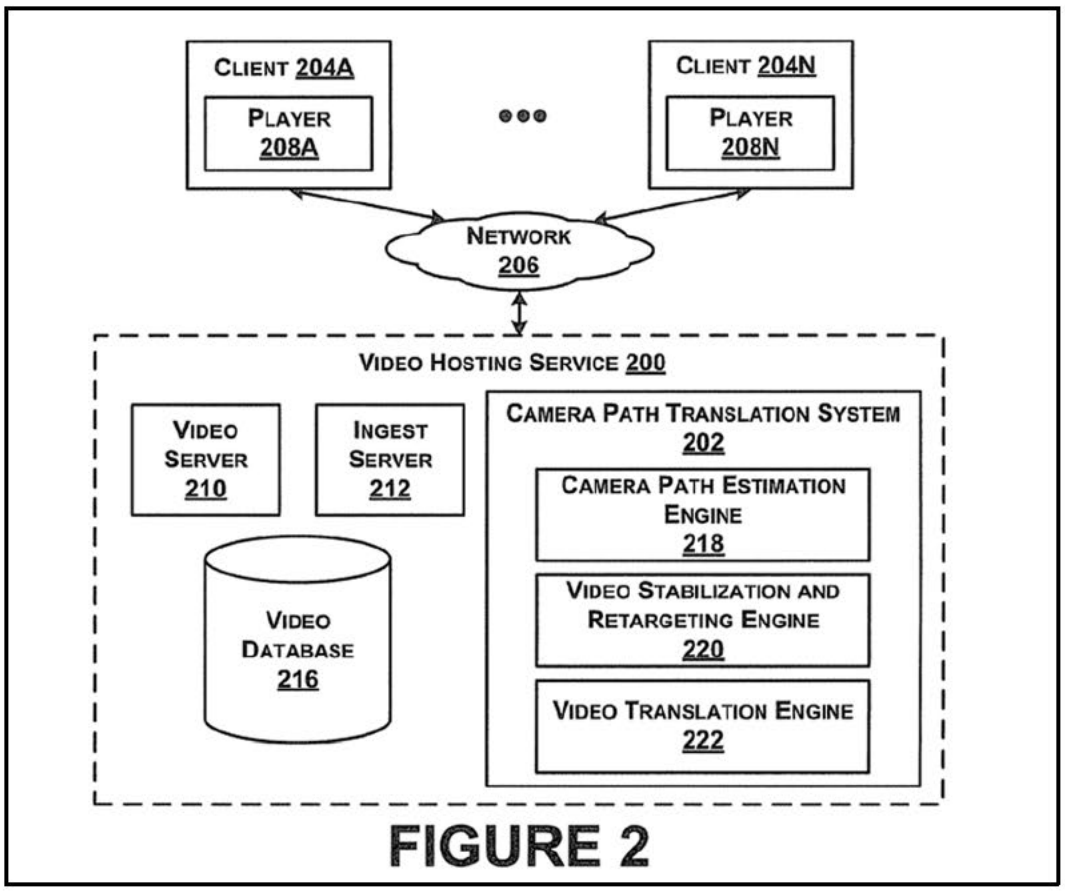



FIGURE 2

Doubling down on its mischaracterization of the art, GoPro claims that a POSITA would view trajectory optimization as too "computationally intensive" for "resource-constrained mobile device[s.] (POR, 57.) Yet GoPro provides no specifics about how complex the optimization is or how limited mobile device resources were. By 2013, mobile devices were capable of significant computation. (EX1017, ¶192.) Kwatra's technique is not computationally intensive; for instance, Equation 7 involves straightforward calculations. (*Id.*)

A POSITA would have understood that mobile devices could readily handle Kwatra's stabilization computations. (*Id.*) This is fully consistent with Kwatra's own disclosures. (*Id.*; EX1012, 26:11-21.)

Also unavailing is GoPro's argument that a POSITA would not have combined "Bell and Shi's 3D sensor-based approaches with Kwatra's 2D image-based linear optimization." (POR, 59.) Even if Kwatra were limited to image-based motion estimation, the combination would have still been obvious. The combination of Kwatra with Bell and Shi pertains solely to motion smoothing, which is distinct from motion estimation. A POSITA would understand this smoothing step is agnostic to how the original trajectory is estimated. (EX1017, ¶196.)

Kwatra addresses only the limitation of "minimiz[ing] a combination of rotational velocity and rotational acceleration," which is part of motion smoothing. (EX1017, ¶¶194-196.) In a combination, a POSITA would use Bell or Shi for motion estimation and apply Kwatra's Equation 7 for smoothing rotation, independent of the estimation method used. (EX1017, ¶196.)

Moreover, by the time of the claimed invention, the industry had adopted hybrid stabilization techniques that combined sensor and image data. (EX1017, ¶198.) Given this context, a POSITA would have had both the knowledge and motivation to apply a smoothing technique like Kwatra's—even if originally

described with image-based estimation—to a trajectory estimated using sensor data. (*Id.*)

Finally, GoPro's own development documents undercut its argument.

**A.1.1.2.5. Bibliography**

Our research is based on the following references:


1. Censi, Alberto, Andrea Fusiello, and Vito Roberto. "Image stabilization by features tracking." *International Conference on Image Analysis and Processing, 1999. Proceedings* . IEEE, 1999.
2. Karpenko, Alexandre, et al. "Digital video stabilization and rolling shutter correction using gyroscopes." *CSTR* 1 (2011): 2.
3. Jia, Chao, and Brian L. Evans. "Constrained 3D Rotation Smoothing via Global Manifold Regression for Video Stabilization." *IEEE Trans. Signal Processing62.13* (2014): 3293-3304.
4. Grundmann, Matthias, Vivek Kwatra, and Irfan Essa. "Auto-directed video stabilization with robust L1 optimal camera paths." *IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2011.* IEEE, 2011.
5. Kopf, Johannes, Michael F. Cohen, and Richard Szeliski. "First-person hyper-lapse videos." *ACM Transactions on Graphics (TOG)* 33.4 (2014): 78.
6. Joshi, Neel, et al. "Real-time hyperlapse creation via optimal frame selection." *ACM Transactions on Graphics (TOG)* 34.4 (2015): 63.
7. Fused Video Stabilization on the Pixel 2 and Pixel 2 XL [ HYPERLINK "https://ai.googleblog.com/2017/11/fused-video-stabilization-on-pixel%20-2.html" ]
8. Vankawala, Fagun, Amit Ganatra, and Amit Patel. "A survey on different image deblurring techniques." *International Journal of Computer Applications* 116.13 (2015): 15-18.


(EX1022, 7.)

GoPro's development relied on multiple references, including:

- an image-based technique using feature tracking (reference #1)
- a sensor-based technique using gyroscopes (reference #2)
- a mobile-device-based technique from the Pixel 2 smartphone (reference #7)
- the Kwatra paper (Grundmann) (reference #4)

(EX1022, 7; EX1017, ¶¶199-200.)

GoPro's development history reflects how a POSITA would approach the art. A POSITA developing stabilization technology would not limit their review to a single narrow method. Instead, they would have been motivated to combine references involving both image-based and sensor-based techniques, as well as mobile and non-mobile implementations. (EX1017, ¶202.)

## V. THE OBJECTIVE EVIDENCE DOES NOT SUPPORT NON-OBVIOUSNESS

### A. HERO7 does not practice the '840 patent

GoPro does not contend that its HERO7 camera practices any claims other than claims 1, 13, and 14—and it fails to show that HERO7 practices even those.

GoPro relies solely on Dr. Foroosh's analysis. (POR, 61.) For certain limitations (*e.g.*, 1[g](ii)), 1[h]), Dr. Foroosh cites only source code header files (.hpp and .h). (EX2018, ¶¶186, 192.) But header files merely declare code interfaces and do not implement runtime functionality. (EX1017, ¶209.) Actual program logic resides in implementation files like .cpp files. (*Id.*) Because Dr. Foroosh cites no implementation files, he cannot establish that HERO7 performs the claimed features. (*Id.*)

GoPro also fails to show that HERO7 meets 1[g(iii)]. Dr. Foroosh simply asserts that "the relevant functionality is implemented in source code files," without explaining how those files enable approximation of intentional motion.

(EX2018, ¶188.) He also relies only on internal documentation [redacted] (EX2018, ¶201), but he does not show that this technology is implemented in HERO7 or link it to any cited code. (EX1017, ¶210.)

GoPro fails to show that HERO7 practices claim 13. Although claim 13 requires minimizing "rotational velocity" and "rotational acceleration," Dr. Foroosh does not state that the cited code considers "***rotational*** velocity" or "***rotational*** acceleration," let alone minimize them. (EX2018, ¶¶195-196; EX1017, ¶211.)

Finally, GoPro fails to show that HERO7 practices claim 14. As discussed, its expert's analysis does not apply GoPro's proposed construction for "low-light high-pass parameter." (EX2018, ¶¶197-198.) Dr. Foroosh also cites no implementation file, only header files. (*Id.*; EX1017, ¶212.) He cannot show that HERO7 includes and implements the claimed "low-light high-pass feature."

### B. No nexus to the purported novel features

None of GoPro's purported novel features — (1) a "weight-balance parameter," (2) a "low-light high-pass parameter," and (3) a "temporal horizon to approximate intentional motion" — were not known in the art. (POR, 59-61.) As discussed, Bell, Shi, and Kwatra already taught one or more of these features.

Even assuming HERO7 practices the '840 patent, GoPro fails to identify any nexus between the objective evidence and the purported novel features. GoPro does not argue presumption of nexus. It makes no attempt to show how HERO7, which includes many other features, are coextensive with the challenged claims.

**No commercial success or industry praise.** At most, GoPro shows that its stabilization technology, HyperSmooth in general, has allegedly driven commercial success and received industry praise. But other features—not the purported novel ones—are responsible for those outcomes.

The '840 patent's inventor admitted that [redacted] (EX1019, 143:11-13, 242:16-19, 243:2-16, 336:11-14.) GoPro concedes that technologies covered by other patents, including the "'894, []'832, and '413 patents," "were directly responsible for GoPro's sustained commercial success." (POR, 64.) "Such unclaimed features cannot establish objective indicia of nonobviousness of what is claimed." *In re Li*, No. 2024-1209, 2025 WL 1040066, *7 (Fed. Cir. Apr. 8, 2025).

GoPro's alleged industry praise is likewise unconnected to the '840 patent. EX2010 concerns an award for "EIS technology in 2015," which predates the '840 patent's priority date. EX2011 and EX2012 are GoPro's own press releases: EX2011 mentions no specific award, and EX2012 concerns HERO10, not HERO7.

**No long-felt but unmet need.** GoPro has offered no evidence that the purported novel features addressed unmet need. Its own witnesses are [redacted] (EX1019, 83:16-21; EX1020, 150:20-151:2.) Digital stabilization techniques were widely used long before the '840 patent. (EX1017, ¶221.)

**No unexpected results/failure of others.** The claimed inventions did not yield any unexpected results. GoPro cites two documents. One is an internal study (EX2043), but GoPro engineers' belief that their developed technology outperformed others does not establish unexpected results. (EX1017, ¶222.) The other is a public review of HERO9 and HERO8, not HERO7. (EX2014; EX1017, ¶222.) Inventor Mr. Derbanne was also [redacted] (EX1019, 83:16-21.)

**No copying.** GoPro presents no evidence of copying. It relies on a few Insta360 engineering documents comparing Insta360's products to GoPro's, but none reference the purported novel features. (POR, 69-71.) At best, these documents show competitive benchmarking, not copying. (EX1017, ¶223.) [redacted] (EX1020,160:5-161:6; EX1017, ¶223.)

## VI. CONCLUSION

The Board should cancel all claims of the '840 patent.

Dated: July 18, 2025

Respectfully submitted,

By: /*Lily Yue Li*/

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**Certification of Word Count (37 C.F.R. § 42.24)**

I hereby certify that this PETITIONER'S REPLY TO PATENT OWNER RESPONSE has 5,594 words (as counted by the "Word Count" feature of the Microsoft Word™ word-processing system), exclusive of "a table of contents, a table of authorities, a listing of facts which are admitted, denied, or cannot be admitted or denied, a certificate of service or word count, or appendix of exhibits."

Dated: July 18, 2025

By /*Lily Yue Li*/
Lily Yue Li

**Certificate of Service (37 C.F.R. § 42.6(e)(4))**

I hereby certify that the attached PETITIONER'S REPLY TO PATENT OWNER'S RESPONSE was served as of the below date on the Patent Owner via e-mail (by agreement) to the following counsel of record:

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