IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ELBIT SYSTEMS OF AMERICA, LLC,
Petitioner,

v.

THALES VISIONIX, INC.,
Patent Owner.

Case No. To Be Assigned
Patent No. 6,474,159

PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,474,159 UNDER 35 U.S.C. §§ 311–319 AND 37 C.F.R. § 42.100 *et seq.*

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Ex. 1009	U.S. Patent No. 5,645,077 to Foxlin
Ex. 1010	Kenneth Stuart *et al.*, Head-Steered sensor solution for enhanced situational awareness, Proceedings of SPIE 198-204 (April 1997)
Ex. 1011	Suya You *et al.*, Orientation Tracking for Outdoor Augmented Reality Registration, 19:6 Computer Graphics and Applications, IEEE (Nov./Dec. 1999)
Ex. 1012	Anthony Lawrence, Modern Inertial Technology: Navigation, Guidance, and Control (2d ed. 1998)
Ex. 1013	Grant Fowles, Analytical Mechanics (4th ed. 1986)
Ex. 1014	M.B. Pszczel *et al.*, Review of Techniques for In-Flight Transfer Alignment, Australia Department of Defence (June 1992)
Ex. 1015	U.S. Patent No. 5,672,872 to Wu *et al*.
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Ex. 1017	James Kain et al., *Rapid Transfer Alignment for Tactical Weapon Applications*, Guidance, Navigation and Control Conference (1989)
Ex. 1018	Stephen Charles Felter, A Formation Flight Relative Navigation System (Dec. 21, 1995) (Ph.D. dissertation, Binghamton University)
Ex. 1019	U.S. Patent No. 5,757,317 to Buchler *et al*.
Ex. 1020	U.S. Patent No. 5,640,325 to Banbrook *et al*.
Ex. 1021	R. Cox *et al.*, *Advances in the State of the Art for AUV Inertial Sensors and Navigation Systems*, Symposium on Autonomous

Exhibit	**Description**
	Underwater Vehicle Technology (1994)
Ex. 1022	Eric Foxlin *et al.*, Miniature 6-DOF inertial system for tracking HMDs, Proceedings of SPIE 1–15 (April 1998)
Ex. 1023	E.R. Bachmann *et al.*, *Orientation Tracking for Humans and Robots Using Inertial Sensors*, International Symposium on Computational Intelligence in Robotics & Automation (1999)
Ex. 1024	Ronald Azuma *et al.*, *Tracking in Unprepared Environments for Augmented Reality Systems*, IEEE Transactions on Computer Graphics (1999)
Ex. 1025	U.S. Patent No. 1,183,492 to Pratt
Ex. 1026	Howard Anton, Calculus (3d ed. 1988)

I. INTRODUCTION

U.S. Patent No. 6,474,159 ("the '159 Patent") purports to claim a novel system and method for tracking the motion or orientation of an object relative to a moving reference frame. The patent gives as an example a system that tracks the orientation of a head-mounted display ("HMD") device relative to a moving platform such as a motion-based simulator cab, shown schematically in Figure 3C. Ex. 1001, 7:9–11. Figure 3D describes a "reference IMU" (inertial measurement unit) **300** fixed to the platform, *id.*, 7:14–19, and a "tracking IMU" **310**, *id.*, 8:30–31, fixed to the HMD:

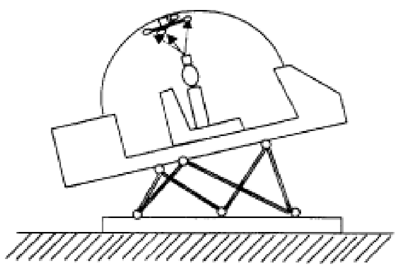

FIG. 3C

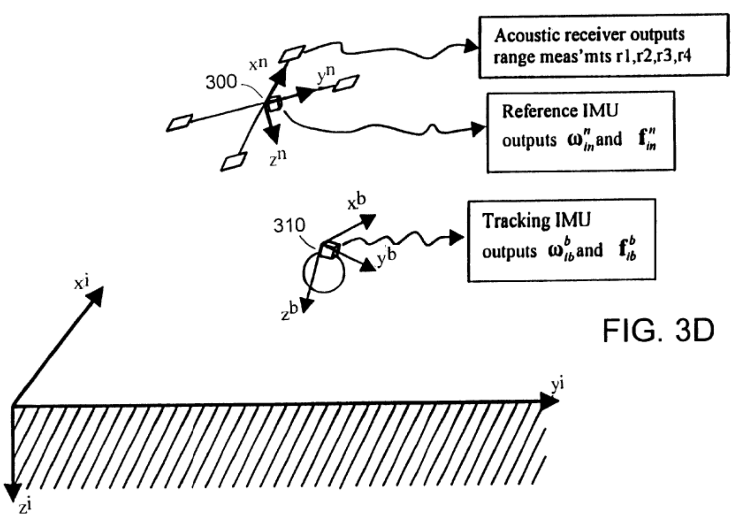

FIG. 3D

The '159 Patent acknowledged that by the April 2000 filing date , "[i]nertial tracking . . . has been demonstrated to be a successful technique for tracking objects," Ex. 1001, 1:5-7, but asserted that "[u]ntil now, inertial trackers have not been used in applications which require tracking motion relative to a *moving* platform," Ex. 1001, Abstract (emphasis added). The applicants obtained allowance by arguing that placing a second inertial measurement unit ("IMU") on a "moving reference frame," and calculating relative motion with respect to a first IMU on a tracked object distinguished the prior art, which purportedly taught inertial tracking only with reference to a static reference frame. Ex. 1002, at 80.

The prior art cited in this petition shows applicants' claim to be incorrect. For example, a patent issued to McFarlane in 1988 discloses a head mounted display device having a position detector unit 15 containing inertial sensors (gyroscopes) used to measure the orientation of the helmet. Ex. 1003, 2:12–14, 2:38–42, 2:60–64, 3:58–4:7. The orientation is measured relative to a fixed reference frame *or* to a movable reference frame, "such as a ship or aircraft." Ex. 1003, 2:33–36, 4:8–12. In the latter case, a processor receives "inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit." Ex. 1003, 4:8–19.

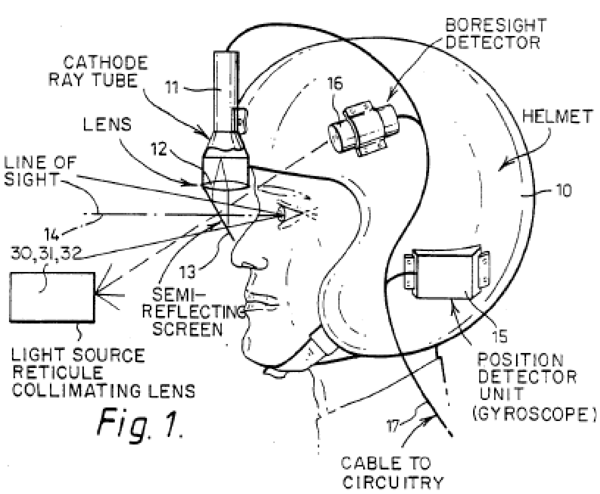

Fig. 1.

Similarly, Velger authored a textbook published in 1998 entitled "Helmet-

Mounted Displays and Sights" that includes a sub-chapter on "Head Tracking Using Inertial Sensors." Ex. 1004, 166–171. This sub-chapter describes a helmet-mounted "Inertial Measurement Unit (IMU)" containing gyroscopes and accelerometers to measure the position and orientation of the helmet. Ex. 1004, at 168. The inertial rate data generated by the sensors are corrected for "vehicle motion over the Earth's surface," Ex. 1004, at 168, and the resulting calculated orientation angles "easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required." Ex. 1004, at 171. Velger includes a block diagram of the system in Fig. 6.14 showing inputs from both the IMU (colored orange) and the vehicle master navigator (colored green, and which includes an inertial sensor):

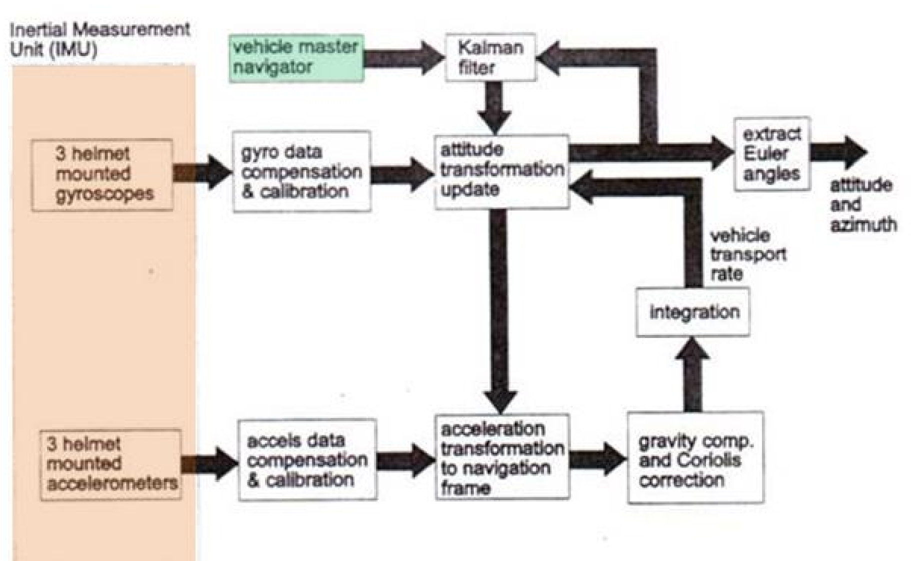

Figure 6.14 Functional block diagram of helmet-pose measurement using strapdown AHRU concept.

The independent claims of the ’159 Patent purport to broadly encompass a system or method for determining the orientation of an object relative to a “moving reference frame.” The dependent claims simply add commonplace details regarding the inertial sensors and mathematical calculations. All of these features were well-known to a person of ordinary skill in the art (“POSITA”) before April 2000.

At best, the claims at issue represent a routine and predictable combination of well-known elements. Therefore, Petitioner respectfully requests that the Board institute trial and find each of the challenged claims invalid under 35 U.S.C. § 103.

II. MANDATORY NOTICES (37 C.F.R. § 42.8(a)(1))

A. Real Party-In-Interest (37 C.F.R. § 42.8(b)(1))

The real parties in interest for this petition for *Inter Partes* Review (“IPR”) are Petitioner Elbit Systems of America, LLC (“Elbit” or “Petitioner”) and Elbit Systems Ltd.

B. Related Matters (37 C.F.R. § 42.8(b)(2))

The ’159 Patent is currently the subject of litigation against the United States of America in the Court of Federal Claims, captioned *Thales Visionix, Inc. v. United States* (Civil Action No. 1:14-cv-00513-TCW). Petitioner is a third-party defendant in the litigation. Lockheed Martin Aeronautics Co., and Rockwell Collins were also noticed as potentially interested parties under Court of Federal Claims Rule 14(b), but neither opted to respond to the Court’s notice and participate in the litigation as third-party defendants.

C. Lead and Backup Counsel (37 C.F.R. § 42.8(b)(3))

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D. Service Information (37 C.F.R. § 42.8(b)(4))

Service information for lead and back-up counsel is provided in the designation of lead and back-up counsel above.

III. FEES (37 C.F.R. § 42.103)

The undersigned authorizes the Office to charge $27,400 ($9,000 request fee, $800 request excess claims fees, $14,000 post-institution fee, and $3,600 post-institution excess claims fees) to Deposit Account No. 50-0740 for the fees set forth in 37 C.F.R. § 42.15(a) for this Petition for *Inter Partes* Review. The undersigned further authorizes payment for any additional fees that might be due in connection with this Petition to be charged to the above-referenced Deposit Account.

IV. REQUIREMENTS FOR INTER PARTES REVIEW UNDER 37 C.F.R. § 42.104

A. Grounds for Standing (37 C.F.R. § 42.104(a))

Pursuant to 37 C.F.R. § 42.104(a), Petitioner certifies that the '159 Patent is available for *inter partes* review and that Petitioner is not barred or estopped from requesting an *inter partes* review challenging the '159 Patent on the grounds identified in the present petition.

B. Citation of Prior Art

Exhibit	Reference	Publication or Filing Date	Availability as Prior Art
Ex. 1003	U.S. Patent No. 4,722,601 to McFarlane ("McFarlane")	February 2, 1988	35 U.S.C. § 102(b)
Ex. 1004	Mordekhai Velger, Helmet-Mounted Displays and Sights (1998) ("Velger")	1998	35 U.S.C. § 102(b)
Ex. 1005	European Patent Application Publication No. EP 0762363A1 to Streit *et al.* ("Streit")	March 12, 1997	35 U.S.C. § 102(b)

C. Claims and Statutory Grounds (37 C.F.R. §§ 42.104(b)(1)–(2))

The relief requested by Petitioner is that Claims 1–7, 10–13, 20, 22–28, 31–34, and 41 of the '159 Patent be found unpatentable and cancelled from the '159

Patent on the following grounds:

Ground	Claims	Basis
I	1, 22	Unpatentable under 35 U.S.C. § 103 in view of McFarlane and Velger
II	2–7, 10–13, 20, 23–28, 31–34, and 41	Unpatentable under 35 U.S.C. § 103 in view of McFarlane, Velger, and Streit

D. Person of Ordinary Skill in the Art

A person of ordinary skill in the art of the '159 Patent at the time of the alleged invention ("POSITA") would have had at least a Master's degree in Electrical Engineering or Computer Science, or related field, as well as at least two years of work experience relating to motion tracking. Ex. 1006 (declaration of Dr. Mohinder Grewal), ¶ 31.

E. Claim Construction (37 C.F.R. § 42.104(b)(3))

A claim subject to IPR is given its "broadest reasonable construction in light of the specification of the patent in which it appears." 37 C.F.R. §42.100(b); *In re Cuozzo Speed Techs., LLC*, 778 F.3d 1271, 1281 (Fed. Cir. 2015).

1. moving reference frame

Independent Claims 1 and 22 recite a "moving reference frame." Petitioner submits that the broadest reasonable construction in light of the specification for "moving reference frame" is "a movable platform or other body." The specification describes the invention as containing a "reference IMU" that is "rigidly attached to the moving platform." Ex. 1001, 1:48–49. For example, the reference IMU may be "bolted to the canopy of the simulator cab or cockpit" in the embodiment depicted in Fig. 3C. Ex. 1001, 7:19–20. The tracked object, for example, "a person's head," is tracked "relative to a maneuvering platform." Ex. 1001, 5:62–63. More broadly, the specification identifies the fundamental problem the invention seeks to address as "tracking a moving body relative to *another moving body*." Ex. 1001, 4:14–15 (emphasis added); *see also* Ex. 1006, ¶ 33.

Because the preamble of Claim 1 and the body of Claim 22 state that orientation of the tracked object is measured relative to a reference frame and the specification defines what qualifies as that reference frame, the broadest reasonable interpretation of "moving reference frame" in light of the specification is a movable platform or other body.

F. Unpatentability of the Construed Claims (37 C.F.R. § 42.104(b)(4))

An explanation of why Claims 1–7, 10–13, 20, 22–28, 31–34, and 41 of the '159 Patent are unpatentable under the statutory grounds identified above is provided in Section VI, below.

G. Supporting Evidence (37 C.F.R. § 42.104(b)(5))

The exhibit numbers of the supporting evidence relied upon to support the challenge and the relevance of the evidence to the challenge raised, including identifying specific portions of the evidence that support the challenge, are provided below in the form of explanatory text and claim charts. An Exhibit List with the exhibit numbers and a brief description of each exhibit is set forth above.

V. SUMMARY OF THE ’159 PATENT

A. Overview of the ’159 Patent

The ’159 Patent (Ex. 1001), entitled “Motion-Tracking,” issued on November 5, 2002 from U.S. Patent Application No. 09/556,135 (“the ’135 Application”), which was filed on April 21, 2000. The ’159 Patent does not claim priority to any earlier domestic or foreign patent application. Thus, publications dated before April 21, 2000 are prior art.

1. The Claims at Issue

The claims at issue in this Petition, Claims 1–7, 10–13, 20, 22–28, 31–34, and 41, are directed to systems and methods for determining the orientation and position of an object relative to a “moving reference frame” using two inertial sensors—one on the tracked object and one on a moving reference frame—and a computing element for determining the orientation (and position) of the tracked object relative to the moving reference frame. Although the specification contains extensive discussion of the mathematics for determining the position and orientation of an object relative to a moving reference frame, none of the claims recites any specific mathematical algorithm.

Claims 1 and 22 are independent claims that contain very few limitations.

Claim 1 recites "a system for tracking the motion of an object relative to a moving reference frame" comprising (1) "a first inertial sensor mounted on the tracked object"; (2) "a second inertial sensor mounted on the moving reference frame"; and (3) "an element adapted to receive signals from said first and second inertial sensors and configured to determine an orientation of the object relative to the moving reference frame" based on those signals. Claim 22 recites a "method comprising determining an orientation of an object relative to a moving reference frame based on signals from two inertial sensors mounted respectively on the object and on the moving reference frame."

The dependent claims at issue in this Petition add limitations involving well-known hardware or mathematical operations: the inertial sensors comprise three angular inertial sensors such as angular accelerometers, angular rate sensors, or angular position gyroscopes (claims 2, 23); the orientation is calculated by "integrating a relative angular rate signal" (claims 3, 24); a subsystem for "correcting drift that may occur in the inertial orientation integration" (claims 4, 25); the drift correcting subsystem uses optical, acoustic, magnetic, RF or electromagnetic technologies (claims 5, 26); computing orientation with respect to a fixed inertial reference frame using signals from the first inertial sensor, computing orientation with respect to a fixed inertial frame using signals from the second inertial sensor, and computing relative orientation based on the two orientations (claims 6, 27); and a "drift corrector" to correct drift with respect to the determined orientation of the object or of the moving reference frame (claims 7, 28).

Further dependent claims add additional commonplace elements: using non-inertial sensors to correct drift (claims 10, 31); using linear accelerometers (claims 11, 32); calculating position in addition to orientation (claims 12, 33); and calculating position using double-integration of the linear accelerometers (claims 13, 34). Finally, dependent claims 20 and 41 require the moving reference frame to be associated with a vehicle and the second inertial sensor comprise a pre-installed inertial measurement unit on the vehicle.

2. The Alleged Invention of the '159 Patent

The '159 Patent purports to solve the problem of "tracking a moving body relative to another moving body." Ex. 1001, 4:14–15. The '159 Patent alleges that, "[u]ntil now, inertial trackers have not been used in applications that require tracking motion relative to a moving platform instead of relative to the earth." Ex. 1001, 1:22–24; *see also id.* 11:29–31 ("We have described a new approach to head-tracking on moving vehicles or motion-base simulator platforms, based on differential inertial sensing."). The purported distinction over the prior art is thus the calculation of relative inertial motion between the tracked object and the moving reference frame made possible by placing a second inertial sensor on the moving reference frame in addition to the one placed on the tracked object. Ex. 1001, 1:45–49; 9:11–17.

B. Prosecution History Summary of the ’159 Patent

The application that led to the ’159 Patent contained 22 claims, all of which (except the sole method claim) were initially rejected under 35 U.S.C. § 112 for indefiniteness. All claims were also rejected under 35 U.S.C. §§ 102(b) and (e) as anticipated by three separate prior art references. Ex. 1002, at 61–62.

To overcome the anticipation rejections, applicants argued that “none of the cited references describes a system or method that determines an orientation of an object relative to a moving reference frame by using signals from an inertial sensor mounted on the moving reference frame.” Ex. 1002, at 80. Critically, applicants conceded that all references disclosed an inertial system for tracking an object. *Id.* They merely maintained that none disclosed the use of signals from an inertial sensor mounted on a *moving* frame of reference. *See* Ex. 1002, at 80. The examiner, who did not consider the prior art discussed below, accepted this argument and allowed all the claims, as well as dependent method claims that corresponded to the issued dependent system claims.

VI. THERE IS A REASONABLE LIKELIHOOD THAT PETITIONER WILL PREVAIL WITH RESPECT TO AT LEAST ONE CLAIM OF THE ’159 PATENT.

The subject matter of Claims 1–7, 10–13, 20, 22–28, 31–34, and 41 of the

’159 Patent is disclosed and taught in the prior art as explained below. As set forth in Sections VI.A–C, the references and combinations utilized in Grounds I–II render obvious each of Claims 1–7, 10–13, 20, 22–28, 31–34, and 41 pursuant to 35 U.S.C. § 103 and thus provide a reasonable likelihood that the Petitioner will prevail on at least one claim. *See* 35 U.S.C. § 314(a).

A. Prior Art

1. State of the Art in 2000

Paragraphs 10–25 of the Grewal Declaration (Ex. 1006) describe the state of the art regarding object tracking in the 2000 time frame. In summary, by 2000, inertial measurement units (IMUs) had been known for at least fifty years and were commonly used to track the orientation of objects, including the orientation of objects relative to moving reference frames. Ex. 1006, ¶¶ 12–18; *see* Ex. 1008; Ex. 1009, 2:23–35 (“Inertial navigation systems (‘INS’) using accelerometers and rate gyroscopes have been used for decades for ships, planes, missiles and spacecraft. . . . A basic type of INS is called Strapdown INS, and consists of three orthogonal accelerometers and three orthogonal rate gyros fixed to the object being tracked.”).

One common application for calculating orientation relative to a moving reference frame, which gained popularity in the early 1960s, was found in “aircraft transfer alignment” systems that calibrated the path of missiles using data from an aircraft's navigation system. Ex. 1006, ¶ 17. Using two IMUs, the orientation of a missile (the tracked object) was determined relative to the navigation system of an aircraft (the moving reference frame) to align the missile to the aircraft's navigation system for aiming and guidance purposes. Ex. 1006, ¶ 17. For example, as a 1967 NASA article on this subject explained:

> Alignment, for our purposes, is defined as determining the angular orientation of a set of fiducial axes fixed in an IMU with respect to an arbitrarily chosen set of reference axes. . . . In several moving base alignment techniques . . . the reference axes may well be the fiducial axes of a second IMU.

Ex. 1008, at 2. As seen above, and contrary to the characterization of the prior art given in the '159 Patent's "Background of Invention" (Ex. 1001, 1:5-42), it was known as far back as the late 1960s that a "second IMU," corresponding to a "moving" reference frame, could be used in conjunction with a first IMU, to compute the relative "angular orientation" of an object.

Additionally, IMUs from two aircraft flying in formation have long been used for collision avoidance where the navigation computer of one aircraft (a tracked object) was able to determine the position and orientation of the other aircraft (a moving reference frame) relative to its position and orientation. Ex. 1006, ¶ 18. Similarly, sea-based applications emerged in which the position and orientation of a towed capsule or other device containing an IMU (a tracked object) could be determined relative to the ship (a moving reference frame) based on the ship's pre-existing inertial navigation system. Ex. 1006, ¶ 18.

In the decades leading up the filing date of the '159 Patent, researchers also developed HMDs that used inertial sensors to track the orientation and position of a person's head. Ex. 1006, ¶ 19. Because HMDs project graphics onto the display's visor, in order for the correct graphics to be displayed which correspond to the user's line of sight, the orientation and position of the user's head, and hence the HMD, must be known. Ex. 1006, ¶¶ 21–22. Many of these HMDs tracked the user's head relative to a moving reference frame, which was necessary if the HMD was to be used in a moving vehicle, such as a plane or a tank. *E.g.*, Ex. 1003; Ex. 1004; Ex. 1010.[1] It is against this backdrop, as well as the prior art discussed below,

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[1] At least three factors contributed to the rapid pace of motion tracking in the 1980s and 1990s. First, multiple branches of the military, including the Army and the Air Force, awarded grants to develop motion tracking techniques. Ex. 1006, ¶ 20; *see also* Ex. 1009, 1:8–12; Ex. 1011, at 36. Second, with significant advancements being made in the field of micro-electromechanical systems, leading to the miniaturization of previously large and bulky gyroscopic sensors, inertial sensors were now small enough to comfortably be installed in HMDs. Ex. 1006, ¶ 20. Third, increases in

in which the patentability of the '159 Patent should be assessed.

2. The McFarlane Patent (Ex. 1003)

McFarlane (U.S. Patent No. 4,722,601) issued on February 2, 1988, and therefore qualifies as prior art to the '159 Patent under 35 U.S.C. § 102(b). McFarlane was neither cited nor considered during prosecution of the '159 Patent.

McFarlane discloses an HMD device that can be used with a movable reference frame such as a ship or an aircraft. Ex. 1003, 2:33–36, 4:8–9; Ex. 1006, ¶¶ 35–37. The HMD projects tactical information, such as a sighting mark or reticule, in the wearer's field of vision. Ex. 1003, 1:10–16, 2:43–54; Ex. 1006, ¶ 35. In order to accurately and continuously update the tactical display, gyroscopes—a type of inertial sensor—are mounted to the helmet and used to determine the orientation of the HMD.[2] Ex. 1003, Abstract, 1:25–27, 1:54–64; 2:12–16; 3:58–4:7; Ex. 1006, ¶ 37; *see* Ex. 1003, Fig. 1, *supra*.

Importantly, McFarlane also discloses orientation calculation using a second

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computer processing power and decreases in power consumption made smaller, less bulky HMD systems possible. *Id.*

[2] McFarlane was concerned with the head's orientation in the elevation (pitch) and azimuth (yaw) directions, but not roll because such movements are said to be "less likely". Ex. 1003, 2:19–22; 2:38–42. Accordingly, it discloses the use of either two single-axis gyroscopes or one dual-axis gyro. Ex. 1003, 2:42–43; Ex. 1006, ¶ 27.

inertial sensor mounted on a moving reference frame such as a ship or airplane. As McFarlane observes, "[i]f the [reference] frame is moving, however, then allowance has to be made for such movement." Ex. 1003, 4:14–15. At the time, most aircraft already had a pre-existing IMU installed for navigational purposes. Ex. 1006, ¶ 40. As McFarlane confirms, "it is necessary to apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit." Ex. 1003, 4:15–19.

In describing the ship or aircraft's IMU, McFarlane further explains that the moving inertial platform commonly uses gyros that are larger and more accurate than those mounted on the helmet. Ex. 1003, 2:60–64; Ex. 1006, ¶ 40. The system disclosed by McFarlane therefore determines the orientation of the helmet relative to a moving reference frame based on two sets of inertial sensors—one mounted on the helmet (the tracked object) and a second mounted on the ship or aircraft (the moving reference frame).

McFarlane also discloses an optical detector that automatically corrects for errors, such as drift, in the output of the inertial sensor when the head moves through a known reference direction, such as the center of the instrument panel. Ex. 1003, Abstract, 1:64–66, 2:60–3:53; Ex. 1006, ¶¶ 44–45. In particular, when the HMD passes through a known reference orientation, which has an optical emitter or receiver associated with it, a corresponding receiver or emitter on the HMD detects the optical signal and notifies the system that the reference orientation has been reached. Ex. 1003, 2:60–3:53; Ex. 1006, ¶¶ 44–45. To the extent that the calculated orientation from the inertial sensors does not agree with the reference orientation, appropriate corrections can be made to the azimuth and elevation outputs from the inertial sensors. Ex. 1003, 2:60–3:53; Ex. 1006, ¶¶ 44–45.

3. The Velger Book (Ex. 1004)

The Velger textbook was published in 1998. The Velger textbook therefore qualifies as prior art to the ’159 Patent under 35 U.S.C. §102(b). The Velger textbook was neither cited nor considered during prosecution of the ’159 Patent.

Velger discloses a system and a method for “head-orientation measurement” using HMDs; a technique it calls “head tracking.” Ex. 1004, at 166. Velger discloses an HMD with “an IMU to measure the 6-DOF [six degrees of freedom] head position and orientation relative to the inertial space.” Ex. 1004, at 166; Ex. 1006, ¶ 47. In order to measure position and orientation relative to all six degrees of freedom, Velger explains that the IMU consists of three miniature gyroscopes, which measure angular rate, and three accelerometers, which measure linear acceleration. Ex. 1004, at 168; Ex. 1006, ¶¶ 48–50. Because the position and orientation sensed by the IMU is relative to inertial space, the Velger textbook explains that it “easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required." Ex. 1004, at 171; Ex. 1006, ¶¶ 51–52. Velger uses the "vehicle master navigator," that is, the vehicle's pre-existing IMU, in the same way as McFarlane, and therefore illustrates a system that receives inputs from both the HMD IMU (the tracked object) and the vehicle master navigator (the moving reference frame) in Figure 6.14, shown above. *See supra* at 3.

Velger also identifies inertial drift as a problem that requires compensation. Ex. 1004, at 166; Ex. 1006, ¶ 54. Velger discloses a Kalman filter that could serve as a drift corrector to correct for inertial drift in the gyroscope measurements that determine orientation relative to the inertial reference frame. Ex. 1006, ¶ 54. In addition, Velger discloses three linear accelerometers found in the HMD as well as an equation for calculating the velocity of the HMD, which a person of ordinary skill in the art would know could easily be integrated a second time to obtain the position of the HMD. Ex. 1004, at 168–69; Ex. 1006, ¶ 53.

4. The Streit Patent Application Publication (Ex. 1005)

Streit (European Patent Application Publication No. EP 0762363A1) was published on March 12, 1997, and therefore qualifies as prior art to the '159 Patent under 35 U.S.C. § 102(b). Streit was neither cited nor considered during prosecution of the '159 Patent. Streit discloses certain well-known details regarding IMUs that contain triads of gyroscopes and accelerometers—items that appear as limitations in the dependent claims at issue.

Streit discloses a vehicle tracking and navigation system that includes an IMU that provides inertial vehicle state characteristics of the vehicle, which could be sea-, air-, or land-based. Ex. 1005, Abstract; 1:5–6, 1:17–27; Ex. 1006, ¶¶ 61–62. Streit discloses that IMUs contain inertial sensors including one to three gyros and one to three accelerometers. Ex. 1005, 1:50–52, 2:32–35, 3:31–3:33; Ex. 1006, ¶ 63. In a preferred embodiment, Streit's IMU comprises three orthogonally oriented gyros and three orthogonally oriented accelerometers to provide position and orientation information including roll, pitch and heading of the vehicle. Ex. 1005, 3:34–3:37, 3:45–3:47. Ex. 1006, ¶ 63.

The gyros measure angular rate and the accelerometers measure linear acceleration. Ex. 1005, 1:55–58. Ex. 1006, ¶ 64. Streit also discloses an inertial converter that determines the angular orientation of the vehicle by integrating the output of the gyros. Ex. 1005, 1:55–2:1, 2:42–44, 2:35–39. Ex. 1006, ¶ 64. Also in the inertial converter, the position of the vehicle is determined by integrating the accelerometer output twice. Ex. 1005, 2:1-5, 3:51–56; Ex. 1006, ¶ 64.

B. Ground I: Independent Claims 1 and 22 are invalid under 35 U.S.C. § 103 as obvious over McFarlane and Velger

McFarlane discloses an apparatus and a method for determining the orientation of a HMD relative to a moving reference frame, such as an airplane or ship, without reference to apparatus external to the helmet. Ex. 1003, 1:5–9, 1:25–27. McFarlane uses two inertial sensors: a first inertial sensor mounted on the HMD and a second inertial sensor mounted on the moving reference frame (airplane or ship). In McFarlane, the first inertial sensor is a detector unit 15, preferably comprising a gyroscopic apparatus, and in particular either two single-axis gyros or one dual-axis gyro. Ex. 1003, Abstract, 1:58–64, 2:12–14, 2:39–43.

McFarlane explains that "[t]he reference frame may be stationary, as in the case of a land-based missile tracking system, or may itself be movable, such as a ship or an aircraft." Ex. 1003, 2:34–36. McFarlane therefore uses a second inertial sensor mounted on the moving reference frame; namely, the ship or aircraft's "inertial platform." As McFarlane explains, the inertial platform is a type of IMU containing "larger and more accurate gyros" used to determine the orientation of the plane. Ex. 1003, 2:60–64, 4:15–19; Ex. 1006, ¶ 40. "Hence it is necessary to apply to the processor 22 of Figure 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be offset against movements indicated by the helmet detector unit. Such signals are indicated in Figure 2 as FAZ (frame azimuth) and FEL (frame elevation) inputs." Ex. 1003, 4:15–21. Furthermore, McFarlane discloses a display signal processor element 22 that uses signals from the inertial sensors on the HMD and the aircraft or ship for determining the orientation of the HMD relative to the aircraft or ship. Ex. 1003, 2:16–18, 2:43–54, 3:58–60, 4:8–21; Ex. 1006, ¶¶ 42–43. Once the HMD's orientation is known relative to the moving reference frame, a sighting mark or reticule can be accurately projected on the display of the HMD. Ex. 1003, 2:16–18, 2:43–54, 4:8–21; Ex. 1006, ¶¶ 35, 42–43.

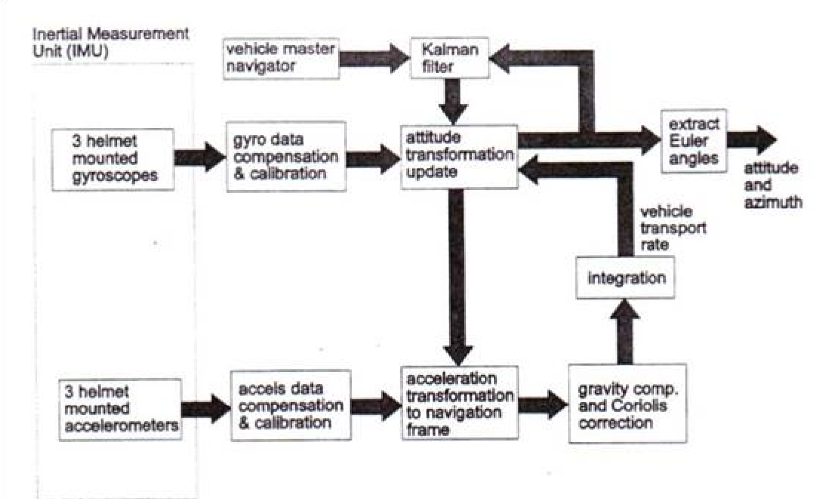
McFarlane's disclosed HMD orientation tracker is directed to both fixed reference frames like land-based missile tracking systems as well as moving reference frames like ships and aircraft. Ex. 1003, 2:33–36. Ex. 1006, ¶ 40. A POSITA desiring to implement McFarlane's teachings to build an HMD system would therefore have reason to consult Velger's reference manual on "Helmet-Mounted Displays and Sights" depending on the specific application under consideration. Like McFarlane, Velger lists as one possible application anti-aircraft aiming and tracking systems. Ex. 1004, at 266–67. In that application, Velger, like McFarlane, only discloses the need to account for two degrees of freedom, azimuth and elevation. Ex. 1004, at 267. Velger recognizes, however, that the most widely used applications for HMDs are in aviation. Ex. 1004, at 260. By 1998, the merit of HMDs had been recognized for both fixed-wing aircraft and helicopters, and Velger's view was that HMDs would "undoubtedly . . . become part of the next-generation aircraft." Ex. 1004, at 259.

The aircraft that Velger describes as already employing HMDs, as well as next generation aircraft, engage in modern air combat, which is characterized by rapid, high-G maneuvering and correspondingly unpredictable, side-to-side movements by the pilot and his HMD. *See* Ex. 1004, at 16; Ex. 1006, ¶ 57. As a consequence, a POSITA would recognize the need to account for the third degree of freedom, the side-to-side (roll) component of the HMD's movement, in aircraft applications; otherwise, erroneous symbols could be displayed on the HMD's display in certain scenarios, such as during air-to-air combat, when the need for accurate information is of paramount importance. Ex. 1004, at 144 ("In some applications, mainly if the system is to be used in fighter aircraft, the *exact position*, of the helmet in the cockpit is desired." (emphasis added)); Ex. 1006, ¶ 57.

To alleviate this problem, a POSITA would have reason to look to the teachings of the Velger book, which teaches how to account for the azimuth, elevation, *and roll* angles in an apparatus and a method for determining the position and orientation of a HMD relative to a moving reference frame. Ex. 1004, at 166, 168–71; Ex. 1006, ¶ 57–58. In particular, Velger discloses an HMD tracker, with *three* miniature gyroscopes and *three* accelerometers attached to the HMD, which provides for measuring the position and orientation of the HMD in all six possible degrees of freedom (that is, rotation about and translation along, the x, y and z axes). Ex. 1004, at 168. Ex. 1006, ¶ 56.

Further, Velger discloses the architecture of a specific system for tracking the position and orientation of the HMD and explains the mathematical equations for calculating orientation. Ex. 1004, at 168–71. Ex. 1006, ¶ 56–58. A POSITA would have reason to implement the McFarlane invention using the specific architecture and mathematics explained in the Velger text for applications where tracking the orientation of the object in all three degrees of freedom was required, for example in HMDs for aircraft as explained in Velger. Ex. 1006, ¶ 56–58. A POSITA would expect to implement Velger's teachings successfully in McFarlane with the predictable result of obtaining a functional system that tracked the orientation of the object (e.g., the HMD) relative to the moving reference frame (e.g., the ship or aircraft) in all three axes of rotation. Such an implementation would meet all of the limitations of claims 1 and 22 as shown in the chart below:

Claim 1	**Combination of McFarlane and Velger**
A system for tracking the motion of an object relative to a moving reference frame, comprising:	"This invention relates to apparatus for determining the direction of a line of sight relative to a known reference frame, and is intended particularly though not exclusively, for use with helmet-mounted sighting or display devices. Ex. 1003, 1:5–9. "It is therefore necessary to detect movements of the user's head relative to a predetermined frame of reference." Ex. 1003, 1:25–27. Ex. 1003, Claim 1. "[T]he merit of HMDs and HMSs for both fixed-wing aircraft and helicopters is now recognized; undoubtedly, they will become part of the next-generation aircraft . . . ." Ex. 1004, at 259. "Most head-coupled systems incorporate some type of device that measures the pose of the head, that is, the

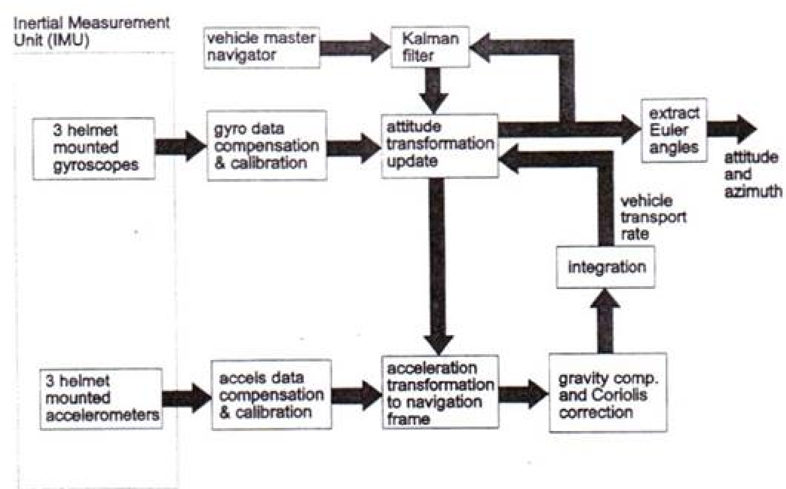
	angular orientation and the linear translations of the head." Ex. 1004, at 143.  **Figure 6.14** Functional block diagram of helmet-pose measurement using strapdown AHRU concept. Ex. 1004, at 168.
a first inertial sensor mounted on the tracked object;	"**The sighting unit carries a detector unit 15** which determines the movements of the helmet 10 without reference to apparatus external to the helmet, and preferably comprising some form of gyroscopic apparatus . . . ." Ex. 1003, Abstract. "According to the present invention there is provided apparatus for determining the direction of a line of sight relative to a predetermined frame of reference, which includes a sighting unit defining said direction, **a detector unit mounted on the sighting unit and operable to detect movements of the sighting unit without reference to apparatus external to the sighting unit** . . . ." Ex. 1003, 1:58–64. "[T]he detector unit 15 of FIG. 1 comprises an arrangement of gyroscopes arranged to detect movements of the helmet about the axiumuth [sic] and elevation axes. It is possible to use either two single-axis gyros or a single two-axis gyro as preferred." Ex. 1003, 2:39–43. Ex. 1003, Claims 1, 3, 4.

	"Head-orientation measurement using inertial sensors is mechanized by . . . **using an IMU to measure the 6-DOF head position and orientation relative to the inertial space**." Ex. 1004, at 166. "The second method utilizes a strapdown inertial attitude and heading reference unit (AHRU) concept. **A miniature IMU, composed of three miniature gyroscopes and three accelerometers, is mounted on the helmet.** The gyroscopes of the IMU measure the angular increments of the head motion while the accelerometers measure the increments of the linear velocities of the head. . . . The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and three accelerometers." Ex. 1004, at 168.
a second inertial sensor mounted on the moving reference frame; and	"**The reference frame** may be stationary, as in the case of a land-based missile tracking system, or **may itself be movable, such as a ship or an aircraft**." Ex. 1003, 2:33–36. "[T]he larger and more accurate gyros commonly used on inertial platforms." Ex. 1003, 2:62–64. "It [sic, if] the apparatus is to be used with a **movable reference frame, such as a ship or an aircraft**, then account has to be taken of the fact that any of the types of position detectors referred to above measure position, or orientation, with respect to free space. . . . If the frame is moving, however, then allowance has to be made for such movement. Hence it is necessary to apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit. Such signals are indicated in FIG. 2 as FAZ (frame azimuth) and FEL (frame elevation) inputs." Ex. 1003, 4:8–21. "The Euler angles from (6.58) measure the head

	orientation and azimuth relative to the navigation frame of reference. They easily can be **converted to the vehicle coordinate frame** by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required." Ex. 1004, at 171
an element adapted to receive signals from said first and second inertial sensors and configured to determine an orientation of the object relative to the moving reference frame based on the signals received from the first and second inertial sensors.	"Also carried on the helmet is the detector unit 15 which indicates the position of the helmet in the reference frame. . . . The . . . detector unit 15 . . . [is] connected to external electronic circuitry by a cable 17." Ex. 1003, 2:12–18. "Referring to FIG. 2, the detector unit 15, which comprises the gyro or gyros just mentioned applies signals to a detector (gyro) signal processing circuit 21. This determines changes in the azimuth and elevation angles of the line of sight from the output signals produced by the gyro or gyros. **These azimuth and elevation angles are applied to a display signal processor 22** controlling the cathode ray tube display. The display itself is produced by a display generator 23, whilst the actual position of the display on the screen of the cathode-ray tube 24 is controlled by the display signal processor 22." Ex. 1003, 2:43–54. "The embodiment described above uses one or more gyros to determine the orientation of the helmet and hence of the sight line." Ex. 1003, 3:58–60. "It [sic, if] the apparatus is to be used with a movable reference frame, such as a ship or an aircraft, then account has to be taken of the fact that any of the types of position detectors referred to above measure position, or orientation, with respect to free space. . . . If the frame is moving, however, then allowance has to be made for such movement. Hence it is necessary to **apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit**. Such signals are indicated in FIG. 2 as FAZ (frame azimuth) and FEL

	(frame elevation) inputs." Ex. 1003, 4:8–21. "As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion." Ex. 1004, at 168. "The inertial rate data is corrected for the effects of Earth rotation and the vehicle motion over the Earth's surface to obtain the head rates relative to the local level coordinate frame. Those rates are utilized to derive the direction cosine matrix (DCM) and the associated helmet attitude and azimuth angles. . . . The attitude with respect to the navigation frame of coordinates is determined from the DCM, C_H^N . . . . The navigation coordinate frame is related to the Earth coordinate frame by the transformation matrix, C_N^E . . . . The helmet attitude and azimuth angle are finally computed from the DCM (6.50). The DCM matrix is related to the Euler angles . . . . **The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. They easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required**." Ex. 1004, at 168–71.

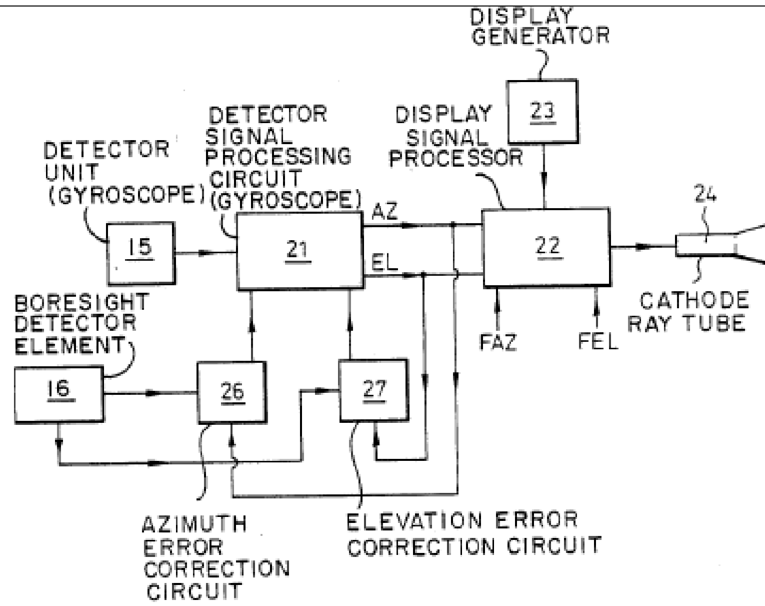
Claim 22	**Combination of McFarlane and Velger**
A method comprising	
determining an orientation of an object relative to a moving reference frame	"This invention relates to apparatus for determining the direction of a line of sight relative to a known reference frame, and is intended particularly though not exclusively, for use with helmet-mounted sighting or display devices. Ex. 1003, 1:5–9. "It is therefore necessary to detect movements of the user's head relative to a predetermined frame of reference." Ex. 1003, 1:25–27.

	Ex. 1003, Claim 1. "[T]he merit of HMDs and HMSs for both fixed-wing aircraft and helicopters is now recognized; undoubtedly, they will become part of the next-generation aircraft . . . ." Ex. 1004, at 259.  **Figure 6.14** Functional block diagram of helmet-pose measurement using strapdown AHRU concept. Ex. 1004, at 168. "The embodiment described above uses one or more gyros to determine the orientation of the helmet and hence of the sight line." Ex. 1003, 3:58–60. "It [sic, if] the **apparatus is to be used with a movable reference frame, such as a ship or an aircraft**, then account has to be taken of the fact that any of the types of position detectors referred to above measure position, or orientation, with respect to free space. . . . **If the frame is moving, however, then allowance has to be made for such movement. Hence it is necessary to apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit**. Such signals are indicated in FIG. 2 as FAZ (frame azimuth) and FEL

	(frame elevation) inputs." Ex. 1003, 4:8–21. "Most head-coupled systems incorporate some type of device that measures the pose of the head, that is, the angular orientation and the linear translations of the head." Ex. 1004, at 143. "As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion." Ex. 1004, at 168. "The inertial rate data is corrected for the effects of Earth rotation and the vehicle motion over the Earth's surface to obtain the head rates relative to the local level coordinate frame. Those rates are utilized to derive the direction cosine matrix (DCM) and the associated helmet attitude and azimuth angles. . . . The attitude with respect to the navigation frame of coordinates is determined from the DCM, C_H^N . . . . The navigation coordinate frame is related to the Earth coordinate frame by the transformation matrix, C_N^E . . . . The helmet attitude and azimuth angle are finally computed from the DCM (6.50). The DCM matrix is related to the Euler angles . . . . **The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. They easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required**." Ex. 1004, at 168–71.
based on signals from two inertial sensors mounted respectively on the object and	"The sighting unit carries a detector unit 15 which determines the movements of the helmet 10 without reference to apparatus external to the helmet, and preferably comprising some form of gyroscopic apparatus . . . ." Ex. 1003, Abstract. "According to the present invention there is provided apparatus for determining the direction of a line of sight

	relative to a predetermined frame of reference, which includes a sighting unit defining said direction, a detector unit mounted on the sighting unit and operable to detect movements of the sighting unit without reference to apparatus external to the sighting unit . . . ." Ex. 1003, 1:58–64. "**Also carried on the helmet is the detector unit 15 which indicates the position of the helmet in the reference frame**. . . . The . . . detector unit 15 . . . [is] connected to external electronic circuitry by a cable 17." Ex. 1003, 2:12–18. "**[T]he detector unit 15 of FIG. 1 comprises an arrangement of gyroscopes arranged to detect movements of the helmet about the axiumuth [sic] and elevation axes**. It is possible to use either two single-axis gyros or a single two-axis gyro as preferred." Ex. 1003, 2:39–43. "Referring to FIG. 2, the detector unit 15, which comprises the gyro or gyros just mentioned applies signals to a detector (gyro) signal processing circuit 21. This determines changes in the azimuth and elevation angles of the line of sight from the output signals produced by the gyro or gyros. **These azimuth and elevation angles are applied to a display signal processor 22** controlling the cathode ray tube display. The display itself is produced by a display generator 23, whilst the actual position of the display on the screen of the cathode-ray tube 24 is controlled by the display signal processor 22." Ex. 1003, 2:43–54. Ex. 1003, Claims 1, 3, 4. "Head-orientation measurement using inertial sensors is mechanized by . . . using an IMU to measure the 6-DOF head position and orientation relative to the inertial space." Ex. 1004, at 166.

	"The second method utilizes a strapdown inertial attitude and heading reference unit (AHRU) concept. A miniature IMU, composed of three miniature gyroscopes and three accelerometers, is mounted on the helmet. The gyroscopes of the IMU measure the angular increments of the head motion while the accelerometers measure the increments of the linear velocities of the head. . . . **The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and three accelerometers**." Ex. 1004, at 168.
on the moving reference frame.	"The reference frame may be stationary, as in the case of a land-based missile tracking system, or may itself be movable, such as a ship or an aircraft." Ex. 1003, 2:33–36. "[T]he larger and more accurate gyros commonly used on inertial platforms." Ex. 1003, 2:62–64. "It [sic, if] the apparatus is to be used with a movable reference frame, such as a ship or an aircraft, then account has to be taken of the fact that any of the types of position detectors referred to above measure position, or orientation, with respect to free space. . . . **If the frame is moving, however, then allowance has to be made for such movement. Hence it is necessary to apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit. Such signals are indicated in FIG. 2 as FAZ (frame azimuth) and FEL (frame elevation) inputs**." Ex. 1003, 4:8–21.

	 *Fig. 2.* Ex. 1003, Fig. 2. "The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. They **easily can be converted to the vehicle coordinate frame** by using the vehicle-orientation measurements obtained by the vehicle master navigator, if measurements relative to the vehicle are required." Ex. 1004, at 171.

C. Ground II: Claims 2–7, 10–13, 20, 23–28, 31–34 and 41 are invalid under 35 U.S.C. § 103 as obvious over McFarlane and Velger and further in view of Streit.

McFarlane and Velger provide extensive information on the design, structure, and implementation of an orientation tracker for an HMD, especially as it relates to the specifics of the HMD itself. Combined, they disclose an HMD that consists of an IMU with three gyroscopes to measure angular rate and three accelerometers to measure linear acceleration. These references also disclose an optical drift corrector, which employs a non-inertial subsystem to mitigate the effects of inertial drift. Likely due to its well understood nature by a POSITA at the time, Ex. 1006, ¶ 40, however, neither McFarlane nor Velger contain extensive disclosure of the specifics of the IMU associated with the moving reference frame, *i.e.*, the ship or aircraft. Such specifics are recited in the dependent claims addressed below. Streit discloses the specifics of the navigation IMU contemplated by both McFarlane and Velger.

Streit's disclosure relates generally to the tracking of vehicle motion. Ex. 1005, 1:5–6. Streit explains that "[v]ehicle tracking and navigation systems provide an abundance of useful information related to the vehicle state," most of which is derived from the integrated IMU. Ex. 1005, 1:26–27; Ex. 1006, ¶ 62. The IMU disclosed in Streit consists of a full set of strapdown inertial instruments including three orthogonally oriented gyros and three orthogonally oriented accelerometers. Ex. 1005, 3:34–3:37; Ex. 1006, ¶ 63. The gyros measure angular velocity, and hence the angular orientation may be obtained by integrating the output of those gyros with respect to time. Ex. 1005, 1:55–2:1; Ex. 1006, ¶ 64. The accelerometers measure linear acceleration, and hence the position can be obtained by twice integrating the output of those accelerometers with respect to time. Ex. 1005, 2:1–5, 3:51–56; Ex. 1006, ¶ 64.

A POSITA would have reason to implement the navigation system of Streit in the combined system of McFarlane and Velger. Ex. 1006, ¶¶ 69–71. For example, McFarlane contemplates an "inertial platform" that consists of large and accurate gyros, among other things. Ex. 1003, 2:62–64. Likewise, Velger identifies a "vehicle master navigator" and explains that "the motion of the vehicle itself is subtracted from the computed head motion." Ex. 1004, at 168. In particular, Velger teaches that computed head orientation can be converted to the vehicle coordinate frame using vehicle-orientation measurements obtained by the aforementioned vehicle master navigator. Ex. 1004, at 171. Due to the well understood nature of vehicle navigation units at the time, however, neither McFarlane nor Velger elaborate further on their contents beyond indicating that they contain gyroscopes. Ex. 1006, ¶ 40.

Streit directly states that a "vehicle tracking system may include an inertial measurement unit for providing inertial vehicle state characteristics of the vehicle." Ex. 1005, Abstract. Note that Streit is titled, "Apparatus and Method for Tracking a Vehicle." Furthermore, Streit includes extensive description of not only what is contained in a vehicle navigation unit—preferably three gyroscopes and three accelerometers—but also how the data obtained by those sensors is processed. Data from the gyroscopes are integrated once to obtain orientation, and data from the accelerometers are integrated twice to obtain position. Ex. 1005, 1:55–2:1, 3:34–3:37, 3:51–56; Ex. 1006, ¶¶ 63–64.

A POSITA would understand that the ship or aircraft's "own inertial platform" in McFarlane or the "vehicle master navigator" in Velger, would be an IMU like the one disclosed in Streit. Ex. 1006, ¶ 59. In addition, a POSITA would expect to successfully implement the specific structures and methods disclosed in Streit in the combination of McFarlane and Velger. Ex. 1006, ¶¶ 69–71. In so doing, a POSITA would expect to obtain the predictable result of a working system to track the orientation of an object with respect to a moving reference frame about the three axes of rotation. Ex. 1006, ¶ 71.

For example, McFarlane discloses that the inertial platform uses "larger and more accurate gyros," Ex. 1003, 2:62–64, while Velger contemplates determining the motion of the vehicle, including vehicle-orientation measurements obtained by the vehicle master navigator. Ex. 1004, at 168, 171. A POSITA looking to implement a "vehicle master navigator" would understand that Streit discloses the most common form of a vehicle navigation system, an IMU. In Streit, a POSITA would find a description of the IMU including the hardware commonly used in sea-, air-, and land-based navigation systems (e.g., orthogonally-oriented gyros and accelerometers—*see* Ex. 1005, Abstract; 1:5–6, 1:26–27, 1:50–52, 2:32–35, 3:31–37, 3:45–3:47; Ex. 1006, ¶¶ 61–63—used to measure angular rate and linear acceleration, as well as an inertial converter used to obtain the angular orientation and position of a vehicle—Ex. 1005, 1:55–2:5, 2:42–44, 2:35–39, 3:51–56; Ex. 1006, ¶ 64). Armed with this disclosure from Streit, combined with the teachings of McFarlane and Velger, a POSITA would have no trouble fully implementing the systems and methods found in the dependent claims as follows:

Claims 2, 11 and 23, 32: Velger discloses a first inertial sensor in the form of a helmet-mounted IMU composed of three miniature gyroscopes and three accelerometers that sense "inertial angular rates" and "specific forces" (which is actually a type of acceleration, having the units of m/s^2), Ex. 1006, ¶¶ 50–51, of the HMD. Ex. 1004, at 168. Likewise, Streit discloses a second inertial sensor in the form of an IMU attached to the vehicle that consists of three orthogonally oriented gyroscopes and three orthogonally oriented accelerometers that sense the angular velocity (*i.e.*, rate) and linear acceleration, respectively, of the vehicle. Ex. 1005, 3:34–3:37. Because the gyros disclosed in McFarlane, Velger, and Streit all measure angular rate, they necessarily are all angular rate sensors, as required by the *Markush* group recited in claims 2 and 23. Ex. 1006, ¶¶ 11, 39, 49, 67, 70. One skilled in the art would readily recognize that the tracked object IMU disclosed by the combination of McFarlane and Velger would thus include three angular rate sensors (the gyroscopes) and three linear accelerometers. Ex. 1006, ¶ 67. Similarly, a POSITA would understand that the moving reference frame IMU disclosed by Streit includes three angular rate sensors and three linear accelerometers. Ex. 1006, ¶¶ 64, 70.

Claims 3, 6 and 24, 27: As stated in the prior paragraph, the combination of McFarlane, Velger, and Streit discloses two sets of angular inertial sensors that are angular rate sensors. Velger also discloses that, based on those angular rate sensors, the orientation of the HMD can be determined by computing the orientation of the HMD relative to "inertial space" and using the direction cosine matrix (DCM) to relate that orientation to the navigation frame. Ex. 1004, at 168–70. Ex. 1006, ¶¶ 13, 51, 67–68. McFarlane likewise discloses that the HMD's orientation is determined relative to "free space" when using gyroscopes. Ex. 1003, 4:8–12. One skilled in the art would readily appreciate from the combination of McFarlane and Velger that it would be necessary to integrate the gyroscope outputs to obtain the orientation of the vehicle. Ex. 1006, ¶¶ 64, 67. Streit expressly discloses that the orientation of the vehicle can be determined by computing the orientation of the vehicle relative to the same "inertial space" by integrating the output of the gyroscopes. Ex. 1005, 1:55–2:1. Velger and McFarlane both disclose that the orientation of the HMD relative to the vehicle can "easily" be determined by offsetting the computed orientation for the HMD with the computed orientation for the vehicle. Ex. 1003, 4:15–21; Ex. 1004, at 171. This is a process Velger refers to as converting the head orientation Euler angles into the vehicle coordinate frame using vehicle-orientation measurements. Ex. 1004, at 171. A POSITA would understand that the steps recited by claims 6 and 27—integrating two functions before relating them—is mathematically equivalent to the process of claims 2 and 24—integrating two functions that have already been related—due to a well understood property of integrals:

$$\int f(x) \pm g(x)\,dx = \int f(x)\,dx \pm \int g(x)\,dx$$

Ex. 1006, ¶¶ 67–68. A POSITA would thus understand that, when computing the orientation of the head relative to the vehicle in the combined system of McFarlane and Velger, the integration of the angular rate data from Velger's helmet IMU and Streit's vehicle IMU could either be performed before (as in claims 6 and 27) or after (as in claims 3 and 24) relating the motion of the helmet to the vehicle. Ex. 1006, ¶¶ 67–71.

Claims 4–5, 7, 10, 25–26, 28, and 31: McFarlane discloses an optical, and therefore non-inertial, boresight detector 16 on the HMD, which is distinct from the detector unit 15 and acts to automatically correct for inertial drift that arises from integration of the gyros in the detector unit 15. Ex. 1003, Abstract, 1:64–66, 2:60–3:53; Ex. 1006, ¶¶ 44–45. When the HMD moves through a reference direction from time-to-time, an optical component on the HMD (e.g., an emitter) and a corresponding optical component on the vehicle (e.g., a receiver) provide an independent measurement of the orientation of the HMD relative to the vehicle, which can be used to correct any errors—including drift errors—that have accumulated in the inertial sensors. Ex. 1003, 2:60–3:53; Ex. 1006, ¶ 44. McFarlane also explains that other non-inertial drift correctors could be employed, such as those relying on ultrasonic (*i.e.*, acoustic) or microwave energy. Ex. 1003, 3:54–56; Ex. 1006, ¶ 45. While McFarlane discloses a drift corrector that corrects errors that arise from the inertial sensors in the HMD based on the determined orientation of the

HMD relative to the vehicle, Velger and Streit disclose drift correctors that improve the inertial measurements of the gyroscopes and vehicle, respectively. Specifically, Velger discloses a Kalman filter that relies on inputs form the vehicle master navigator and the HMD accelerometers to improve the determination of the HMD relative to the inertial reference frame. Ex. 1006, ¶ 54. Similarly, Streit discloses a drift corrector that relies on, among other things, a Global Positioning System 32 (a Radio Frequency-based system), clinometer(s) 28, and a Kalman filter 50 for reducing errors that arise in the computation of the position and orientation of the vehicle relative to inertial reference frame when the position and orientation are determined by the IMU 26. Ex. 1005, 5:52–6:39; Ex. 1006, ¶ 65. A POSITA would thus have reason to implement Velger or Streit's drift corrector in the combined system of McFarlane and Velger to further improve the accuracy of the system by eliminating any errors in the HMD or vehicle's inertial position and orientation calculations. Ex. 1006, ¶ 65.

<u>*Claims 12–13 and 33–34*</u>: Velger discloses three linear accelerometers as well as equation (6.53) to provide the acceleration of an HMD relative to a navigation frame:

$$\dot{V}^N = C_H^N f^H - (2\omega_{IE}^N + \omega_{EN}^N) \cdot V^N + g^N$$

Ex. 1004, at 169. It is a well known mathematical fact that acceleration is the second derivative of position, Ex. 1006, ¶ 53, and while Velger leaves that fact implicit, Streit makes clear that integrating acceleration twice would result in position. Ex. 1005, 1:55–2:5, 3:51–56; Ex. 1006, ¶ 70. Therefore, equation 6.53 from Velger, when integrated twice according the methods disclosed in Streit, and related to the vehicle coordinate system according to further disclosure in Velger using the DCM, would yield the position of the HMD relative to the vehicle. Ex. 1004, at 169–71; Ex. 1006, ¶¶ 53, 64, 68–70. And as before, double integrating before the HMD's acceleration is related to the vehicle's acceleration is mathematically equivalent to double integrating the relative acceleration, as required by claims 13 and 34. Additionally, both Velger and McFarlane each disclose two or more known acoustic, magnetic, or optical systems that are capable of determining the position and orientation of a tracked object relative to a moving reference frame. Ex. 1003, 1:33–39, 1:42–43, 2:30–36; Ex. 1004, at 143–44, 147, 161, 165. Using a known acoustic, magnetic, or optical position tracker or the double integration methodology taught by Streit in the combined system of McFarlane and Velger to determine the position of both the head and vehicle would be a routine selection of known alternatives to a POSITA. Ex. 1006, ¶¶ 36–37, 54, 70.

Claims 20 and 41: Both McFarlane and Velger disclose a moving reference frame that is a vehicle, such as a ship or aircraft, Ex. 1003, 4:8–9, as well as a pre-existing navigation unit referred to as an "inertial platform" and "master vehicle navigator," respectively. Ex. 1003, 2:62–64, 4:15–19; Ex. 1004, at 168, 171. One skilled in the art would recognize that the navigation systems of McFarlane and Velger contained IMUs Ex. 1006, ¶¶ 40, 47, 59. Streit confirms the specifics of the inertial navigation system mentioned by McFarlane and Velger, and in particular, that such navigation systems contained IMUs. Therefore, Streit explicitly discloses a second inertial sensor that is an IMU associated with the vehicle, which is used for navigation. Ex. 1005, 1:17–2:5, 2:32–35, 3:28–4:2. A POSITA would have reason to use the IMU of Streit in the combined system of McFarlane and Velger because Streit's IMU and GPS systems would provide the vehicle operator more than adequate information to successfully navigate the vehicle.

The claim charts below show how the combination of McFarlane, Velger and Streit meet each and every limitation of the dependent claims here in issue:

Claims 2 and 23	**Combination of McFarlane, Velger and Streit**
[The system of claim 1 in which the first and second inertial sensors --OR-- The method of claim 22 in which the two inertial sensors] each comprise[s] three angular inertial sensors selected from the set of angular accelerometers, angular rate sensors, and angular position gyroscopes.	"A miniature IMU, composed of **three miniature gyroscopes and three accelerometers**, is mounted on the helmet. The gyroscopes of the IMU measure the angular increments of the head motion while the accelerometers measure the increments of the linear velocities of the head. . . . The **inertial angular rates and specific forces of the head are sensed by the IMU**, which consists of three gyroscopes and three accelerometers." Ex. 1004, at 168. "The inertial measurement units generally consist of various combinations of **inertial sensors including one to three gyros and one to three accelerometers**." Ex. 1005, 1:50–52. "The **gyros used in the inertial measurement unit measure the angular velocity of the vehicle** with respect

	to inertial space and the **accelerometers measure the linear acceleration of the vehicle**." Ex. 1005, 1:55–58. "Preferably, the inertial measurement unit 26 consists of a full set of strapdown inertial instruments including **three orthogonally oriented gyros and three orthogonally oriented accelerometers**." Ex. 1005, 3:34–3:37. "The **accelerometer of the inertial measurement unit 26 provides the linear velocity of the vehicle 10 while the gyros provide angular rotational rates of the vehicle**. The gyros are preferably oriented to provide attitude information including roll, pitch and heading of the vehicle 10." Ex. 1005, 3:42–47.

Claims 3 and 24	**Combination of McFarlane, Velger and Streit**
[The system of claim 2 --OR-- The method of claim 23], in which the angular inertial sensors comprise angular rate sensors, and the orientation of the object relative to the moving reference frame is determined by integrating a relative angular rate signal determined from the angular rate signals measured by the first and second inertial sensors.	"A miniature IMU, composed of three miniature gyroscopes and three accelerometers, is mounted on the helmet. The gyroscopes of the IMU measure the angular increments of the head motion while the accelerometers measure the increments of the linear velocities of the head. **As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion**. . . . **The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and three accelerometers**." Ex. 1004, at 168. "The angular orientation of the vehicle may be obtained **by integrating the output of the gyros** with respect to time." Ex. 1005, 1:58–2:1. "The **attitude module may integrate the rotational rate measured by each gyro to provide an instantaneous angular orientation of the vehicle 10**. However, the initial orientation of the vehicle must be known in order to obtain accurate information from the gyros." Ex. 1005, 3:57–4:2.

Claims 4 and 25	**Combination of McFarlane, Velger and Streit**
[The system of claim 3, further comprising a non-inertial measuring subsystem for making independent measurements --OR-- The method of claim 24, further comprising making independent measurements with a non-inertial measuring subsystem] related to the orientation of the object relative to the moving reference frame, and [for] using those measurements for correcting drift that may occur in the inertial orientation integration.	"The sighting unit carries a detector unit 15 which determines the movements of the helmet 10 without reference to apparatus external to the helmet, and preferably comprising some form of gyroscopic apparatus. **The helmet also carries a boresight detector 16 which forms part of correction means operable to correct automatically from time to time for errors in the output of the detector unit**." Ex. 1003, Abstract. "According to the present invention there is provided apparatus for determining the direction of a line of sight relative to a predetermined frame of reference, which includes **a sighting unit defining said direction, a detector unit mounted on the sighting unit and operable to detect movements of the sighting unit without reference to apparatus external to the sighting unit, and correction means arranged to correct automatically from time to time for any errors in the output of the detector unit**." Ex. 1003, 1:57–66. "Also carried on the helmet is . . . **a boresight detector 16 which forms part of the correction mean**s." Ex. 1003, 2:12–16. "For a gyro to be suitable for mounting on a helmet it must be of small size and weight. It is therefore likely to be more susceptible to errors, such as drift, than the larger and more accurate gyros commonly used on inertial platforms." Ex. 1003, 2:60–64. "In FIG. 2 a boresight detector element 25, which, as is explained below, may correspond to the active portion of the boresight detector indicated at 16 in FIG. 1 detects the passing of the sight line through the predetermined orientation and applies signals to azimuth and elevation error correction circuits 26 and 27 respectively. **These circuits sample the azimuth and elevation outputs of the gyro signal processing circuit 21, and are able to**

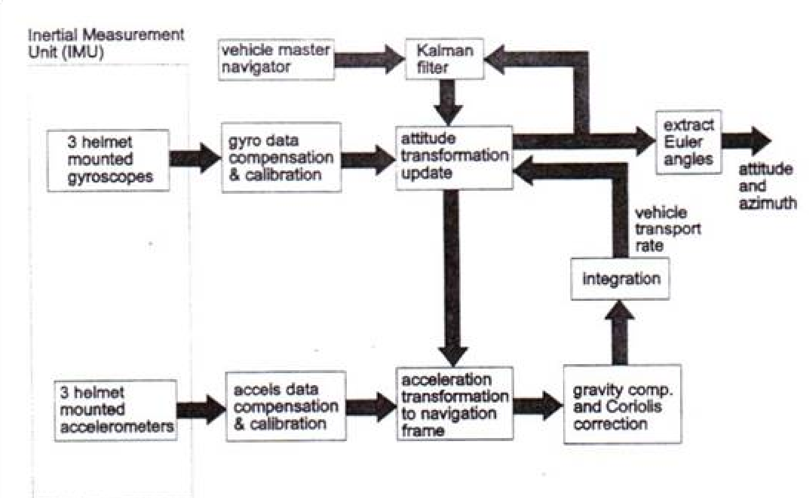
	apply appropriate corrections to that circuit." Ex. 1003, 3:16–25. "The **boresight lock detector is, in one form, an optical device** having one part mounted on the helmet and the other part on the reference frame." Ex. 1003, 3:26–28. "**Other boresight alignment techniques may be used using, for example, narrow beams of ultrasonic or microwave energy** in place of the optical arrangement described above." Ex. 1003, 3:54–56. Ex. 1003, Claims 1, 6. "The main drawback of using inertial sensors is their bias or drift, which causes measurement error to grow with time. For that reason, some scheme of calibration or drift compensation must be employed. Sometimes the error growth can be limited by external information from, for instance, the master navigator of the vehicle." Ex. 1004, at 166. "The inertial body axis accelerations are transformed to the local level frame, are compensated for the local gravity acceleration and Coriolis acceleration, and are integrated to obtain the local level velocities. The velocity is divided by the local radius of the Earth to obtain the angular transport rates for compensation of the inertial angular rates." Ex. 1004, at 168–69. "Each redundant sensor 30 may introduce error into the vehicle tracking system (e.g. error in odometer/tachometer data due to vehicle wheel slippage). Therefore, the vehicle tracking system preferably includes a recursive estimation filter for removing error from the vehicle state information provided by the Global Positioning System 32, map database 34, tag receiver 36, odometer\tachometer 38, inertial measurement unit 26, and inertial converter 27. The clinometers 28 may additionally provide vehicle state information to the

	Kalman filter 50 during vehicle acceleration. The recursive estimation filter can be a Kalman filter 50." Ex. 1005, 5:52–6:4. "As shown in Figure 2, the Kalman filter 50 integrates the vehicle state information from the inertial converter 27 and each redundant sensor 30 and provides an output 52 of corrected position, velocity and attitude information. **In addition, the Kalman filter 50 may feedback biases of the inertial measurement unit 26 to correct future output from the inertial converter 27**." Ex. 1005, 6:27–39.

Claims 5 and 26	**Combination of McFarlane, Velger and Streit**
[The system of claim 4 --OR-- The method of claim 25], in which the non-inertial measuring subsystem is selected from the set of optical, acoustic, magnetic, RF, or electromagnetic technologies.	"**The boresight lock detector is, in one form, an optical device** having one part mounted on the helmet and the other part on the reference frame." Ex. 1003, 3:26–28. "**Other boresight alignment techniques may be used using, for example, narrow beams of ultrasonic or microwave energy** in place of the optical arrangement described above." Ex. 1003, 3:54–56. "The redundant sensors 30 may include an absolute tracking system such as a Global Positioning System (GPS) 32. The vehicle can be equipped with a Global Positioning System receiver 31 as shown in Figure 1 for receiving position data of the vehicle 10 from the Global Positioning System 32." Ex. 1005, 4:24–29. "Each redundant sensor 30 may introduce error into the vehicle tracking system . . . Therefore. the vehicle tracking system preferably includes a recursive estimation filter for removing error from the vehicle state information provided by the Global Positioning System 32, . . . inertial measurement unit 26, and inertial converter 27." Ex. 1005, 5:52–6:1 "As shown in Figure 2, the Kalman filter 50 integrates the vehicle state information from the inertial converter 27

	and each redundant sensor 30 and provides an output 52 of corrected position, velocity and attitude information. In addition, the Kalman filter 50 may feedback biases of the inertial measurement unit 26 to correct future output from the inertial converter 27." Ex. 1005, 6:27–39.

Claims 6 and 27	**Combination of McFarlane, Velger and Streit**
[The system of claim 2 --OR-- The method of claim 24], in which the determination of relative orientation includes	
computing the orientation of the object with respect to a fixed inertial reference frame using the signals from the first inertial sensor,	"**As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion**. A functional block diagram of an AHRU is shown in Figure 6.14. The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and three accelerometers." Ex. 1004, at 168. "The inertial rate data is corrected for the effects of Earth rotation and the vehicle motion over the Earth's surface to obtain the head rates relative to the local level coordinate frame. Those rates are utilized to derive the direction cosine matrix (DCM) and the associated helmet attitude and azimuth angles. . . . The attitude with respect to the navigation frame of coordinates is determined from the DCM, C_H^N . . . . The navigation coordinate frame is related to the Earth coordinate frame by the transformation matrix, C_N^E . . . . **The helmet attitude and azimuth angle are finally computed from the DCM (6.50)**. The DCM matrix is related to the Euler angles . . . ." Ex. 1004, at 168–70.
computing the orientation of the moving reference frame with respect to	"As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, **the motion of the vehicle itself is subtracted from the computed head motion**."

the same fixed inertial reference frame using the signals from the second inertial sensor. and	Ex. 1004, at 168. "The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. **They easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator**, if measurements relative to the vehicle are required." Ex. 1004, at 171. "The **angular orientation of the vehicle may be obtained by integrating the output of the gyros** with respect to time." Ex. 1005, 1:58–2:1. "The **attitude module may integrate the rotational rate measured by each gyro to provide an instantaneous angular orientation of the vehicle 10**. However, the initial orientation of the vehicle must be known in order to obtain accurate information from the gyros." Ex. 1005, 3:57–4:2.
computing the relative orientation based on the two orientations.	"As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion." Ex. 1004, at 168.  **Figure 6.14** Functional block diagram of helmet-pose measurement using strapdown AHRU concept.

	Ex. 1004, at 168. “**The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. They easily can be converted to the vehicle coordinate frame by using the vehicle-orientation measurements obtained by the vehicle master navigator**, if measurements relative to the vehicle are required.” Ex. 1004, at 171.

Claims 7 and 28	**Combination of McFarlane, Velger and Streit**
[The system of claim 6 --OR-- The method of claim 27], further comprising a drift corrector [for/to] correct[ing] inertial drift in the determined orientation of the object with respect to the inertial reference frame or of the moving reference frame with respect to the inertial reference frame.	“The sighting unit carries a detector unit 15 which determines the movements of the helmet 10 without reference to apparatus external to the helmet, and preferably comprising some form of gyroscopic apparatus. The helmet also carries a bore sight detector 16 which forms part of correction means operable to correct automatically from time to time for errors in the output of the detector unit.” Ex. 1003, Abstract. “According to the present invention there is provided apparatus for determining the direction of a line of sight relative to a predetermined frame of reference, which includes a sighting unit defining said direction, a detector unit mounted on the sighting unit and operable to detect movements of the sighting unit without reference to apparatus external to the sighting unit, and correction means arranged to correct automatically from time to time for any errors in the output of the detector unit.” Ex. 1003, 1:57–66. “Also carried on the helmet is . . . a boresight detector 16 which forms part of the correction means.” Ex. 1003, 2:12–16. “For a gyro to be suitable for mounting on a helmet it must be of small size and weight. It is therefore likely to be more susceptible to errors, such as drift, than the larger and more accurate gyros commonly used on inertial platforms.” Ex. 1003, 2:60–64.

	"In FIG. 2 a boresight detector element 25, which, as is explained below, may correspond to the active portion of the boresight detector indicated at 16 in FIG. 1 detects the passing of the sight line through the predetermined orientation and applies signals to azimuth and elevation error correction circuits 26 and 27 respectively. These circuits sample the azimuth and elevation outputs of the gyro signal processing circuit 21, and are able to apply appropriate corrections to that circuit." Ex. 1003, 3:16–25. "The boresight lock detector is, in one form, an optical device having one part mounted on the helmet and the other part on the reference frame." Ex. 1003, 3:26–28. "Other boresight alignment techniques may be used using, for example, narrow beams of ultrasonic or microwave energy in place of the optical arrangement described above." Ex. 1003, 3:54–56. Ex. 1003, Claims 1, 6. "The main drawback of using inertial sensors is their bias or drift, which causes measurement error to grow with time. For that reason, some scheme of calibration or drift compensation must be employed. Sometimes the error growth can be limited by external information from, for instance, the master navigator of the vehicle." Ex. 1004, at 166. "The inertial body axis accelerations are transformed to the local level frame, are compensated for the local gravity acceleration and Coriolis acceleration, and are integrated to obtain the local level velocities. The velocity is divided by the local radius of the Earth to obtain the angular transport rates for compensation of the inertial angular rates." Ex. 1004, at 168–69. "Therefore, **the vehicle tracking system may include**

	one or more clinometers 28 for initializing the gyros, and additionally providing vehicle state information. Operating in a static mode, the clinometers 28 measure the angle between the gravity vector and an axis of orientation of the clinometer 28. **Preferably, two clinometers 28 are utilized by the vehicle tracking system for measuring the roll and pitch of the vehicle 10 while the vehicle is not accelerating**. The output of the clinometers 28 in the static mode may thereafter be forwarded to the inertial converter 27 for initializing the roll and pitch gyros of the inertial measurement unit 26." Ex. 1005, 4:3–14. "Each redundant sensor 30 may introduce error into the vehicle tracking system (e.g. error in odometer/tachometer data due to vehicle wheel slippage). Therefore, the vehicle tracking system preferably includes a recursive estimation filter for removing error from the vehicle state information provided by the Global Positioning System 32, map database 34, tag receiver 36, odometer\tachometer 38, inertial measurement unit 26, and inertial converter 27. . . . The recursive estimation filter can be a Kalman filter 50." Ex. 1005, 5:52–6:4. "As shown in Figure 2, the Kalman filter 50 integrates the vehicle state information from the inertial converter 27 and each redundant sensor 30 and provides an output 52 of corrected position, velocity and attitude information. In addition, the Kalman filter 50 may feedback biases of the inertial measurement unit 26 to correct future output from the inertial converter 27." Ex. 1005, 6:27–39.

Claims 10 and 31	**Combination of McFarlane, Velger and Streit**
[The system of claim 6 --OR-- The method of claim 27], further comprising [using] a drift corrector [for/to] correct[ing] inertial drift in the determined	"The sighting unit carries a detector unit 15 which determines the movements of the helmet 10 without reference to apparatus external to the helmet, and preferably comprising some form of gyroscopic apparatus. **The helmet also carries a bore sight detector 16 which forms part of correction means operable to correct automatically from time to time** for errors in the

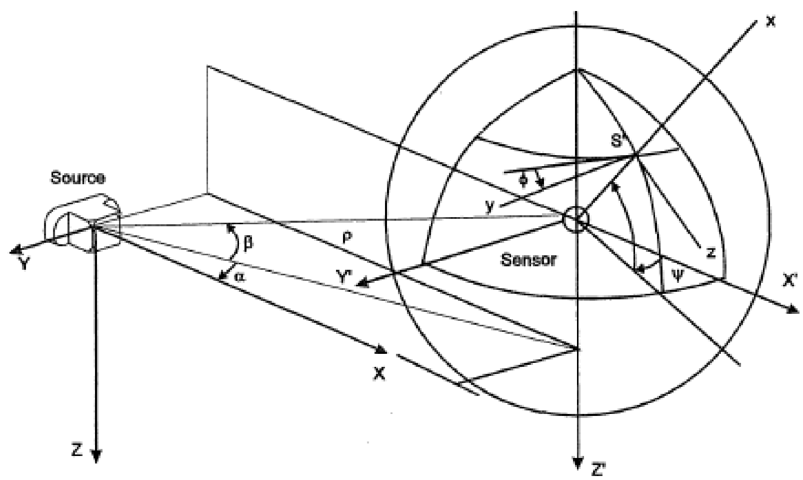
orientation of the object with respect to the moving reference frame by using non-inertial sensors to independently measure the relative orientation.	output of the detector unit." Ex. 1003, Abstract. "According to the present invention there is provided apparatus for determining the direction of a line of sight relative to a predetermined frame of reference, which includes a sighting unit defining said direction, a detector unit mounted on the sighting unit and operable to detect movements of the sighting unit without reference to apparatus external to the sighting unit, and **correction means arranged to correct automatically from time to time for any errors in the output of the detector unit**." Ex. 1003, 1:57–66. "Also carried on the helmet is . . . **a boresight detector 16 which forms part of the correction means**." Ex. 1003, 2:12–16. "For a gyro to be suitable for mounting on a helmet it must be of small size and weight. It is therefore likely to be more susceptible to errors, such as drift, than the larger and more accurate gyros commonly used on inertial platforms." Ex. 1003, 2:60–64. "In FIG. 2 a boresight detector element 25, which, as is explained below, may correspond to the active portion of the boresight detector indicated at 16 in FIG. 1 detects the passing of the sight line through the predetermined orientation and applies signals to azimuth and elevation error correction circuits 26 and 27 respectively. **These circuits sample the azimuth and elevation outputs of the gyro signal processing circuit 21, and are able to apply appropriate corrections to that circuit.**" Ex. 1003, 3:16–25. "**The boresight lock detector is, in one form, an optical device** having one part mounted on the helmet and the other part on the reference frame." Ex. 1003, 3:26–28. "**Other boresight alignment techniques may be used**

	using, for example, narrow beams of ultrasonic or microwave energy in place of the optical arrangement described above." Ex. 1003, 3:54–56. Ex. 1003, Claim 1, 6. "The main drawback of using inertial sensors is their bias or drift, which causes measurement error to grow with time. For that reason, some scheme of calibration or drift compensation must be employed. Sometimes the error growth can be limited by external information from, for instance, the master navigator of the vehicle." Ex. 1004, at 166. "The inertial body axis accelerations are transformed to the local level frame, are compensated for the local gravity acceleration and Coriolis acceleration, and are integrated to obtain the local level velocities. The velocity is divided by the local radius of the Earth to obtain the angular transport rates for compensation of the inertial angular rates." Ex. 1004, at 168–69. "Each redundant sensor 30 may introduce error into the vehicle tracking system (e.g. error in odometer/tachometer data due to vehicle wheel slippage). Therefore, the vehicle tracking system preferably includes a recursive estimation filter for removing error from the vehicle state information provided by the Global Positioning System 32, map database 34, tag receiver 36, odometer\tachometer 38, inertial measurement unit 26, and inertial converter 27. . . . The recursive estimation filter can be a Kalman filter 50." Ex. 1005, 5:52–6:4. "As shown in Figure 2, the Kalman filter 50 integrates the vehicle state information from the inertial converter 27 and each redundant sensor 30 and provides an output 52 of corrected position, velocity and attitude information. In addition, the Kalman filter 50 may feedback biases of the inertial measurement unit 26 to correct future output from the inertial converter 27." Ex. 1005, 6:27–39.

Claims 11 and 32	Combination of McFarlane, Velger and Streit
[The system of claim 2 --OR-- The method of claim 23], in which the first and second inertial sensors each further comprises three linear accelerometers.	"A miniature IMU, composed of three miniature gyroscopes and **three accelerometers**, is mounted on the helmet. The gyroscopes of the IMU measure the angular increments of the head motion while t**he accelerometers measure the increments of the linear velocities of the head**. . . . The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and **three accelerometers**." Ex. 1004, at 168. "The inertial measurement units generally consist of various combinations of inertial sensors including one to three gyros and **one to three accelerometers.**" Ex. 1005, 1:50–52. "The gyros used in the inertial measurement unit measure the angular velocity of the vehicle with respect to inertial space and **the accelerometers measure the linear acceleration of the vehicle**." Ex. 1005, 1:55–58. "Preferably, the inertial measurement unit 26 consists of a full set of strapdown inertial instruments including three orthogonally oriented gyros and **three orthogonally oriented accelerometers**." Ex. 1005, 3:34–3:37. "The accelerometer of the inertial measurement unit 26 provides the linear velocity of the vehicle 10 while the gyros provide angular rotational rates of the vehicle. The gyros are preferably oriented to provide attitude information including roll, pitch and heading of the vehicle 10." Ex. 1005, 3:42–47.

Claims 12 and 33	Combination of McFarlane, Velger and Streit
[The system of claim 11 --OR-- The method of claim 32], further comprising [an element for] calculating the position of the object	"It is known to use an electromagnetic system in which some form of radiator is carried by the reference frame and a number of sensor coils are carried on the user's helmet. **The radiator and the sensor are arranged such that the orientation and position of the helmet in the magnetic field produced by the radiator is determined**

relative to the moving reference frame.	**by the voltages induced in the sensor coils**." Ex. 1003, 1:33–39. "**Alternative arrangements use optical means for determining the position** and orientation of the helmet." Ex. 1003, 1:42–43. "**Arrangements for doing this are well known, as discussed above, using optical or electromagnetic means to determine position of the helmet relative to the reference frame**. The reference frame may. . . itself be moveable, such as a ship or an aircraft." Ex. 1003, 2:30–36. "Other position detectors may also be used which do not require other cooperating components. One such device is the laser ring gyroscope. This is a single axis device, and hence two of these would have to be attached to the helmet in the correct relative positions." Ex. 1003, 3:62–4:2. "It [sic, if] the apparatus is to be used with a movable reference frame, such as a ship or an aircraft, then account has to be taken of the fact that any of the types of position detectors referred to above measure position, or orientation, with respect to free space. . . . Hence it is necessary to apply to the processor 22 of FIG. 2 inputs from the ship or aircraft's own inertial platform so that movements of the reference frame may be off set against movements indicated by the helmet detector unit. Such signals are indicated in FIG. 2 as FAZ (frame azimuth) and FEL (frame elevation) inputs." Ex. 1003, 4:8–19. "The third category includes all self-contained systems, which use a sensor mounted on the helmet to measure a certain global physical property from which the head position and orientation are resolved." Ex. 1004, at 143. "In some applications, mainly if the system is to be used in fighter aircraft, the exact position of the helmet in the

	cockpit is desired. . . . That can be achieved only if the head position relative to the canopy is known." Ex. 1004, at 144. "Magnetic sensors use a small transmitter in the vehicle and a similar receiver mounted on the helmet [7,8]. Both units have three mutually orthogonal magnetic coils. . . . **The relative position and orientation between the transmitter and the receiver and their respective coordinate frames are depicted in Figure 6.3**." Ex. 1004, at 147.  **Figure 6.3** Definition of the transmitter and receiver frames of coordinates. "Having reconstructed the positions of the **LED triad** relative to the sensing camera, **it remains to compute the position and the orientation of the helmet**." Ex. 1004, at 161. "Acoustic head-position measurement devices have been implemented using two basic approaches: time-of-flight measurement and phase coherence measurement [6]. **Both methods measure distances between emitters and receivers and implement triangulation principles to compute the head position** and orientation." Ex. 1004, at 165. "The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three

	gyroscopes and three accelerometers. . . . The inertial body axis accelerations are transformed to the local level frame, are compensated for the local gravity acceleration and Coriolis acceleration, and are integrated to obtain the local level velocities. . . . The helmet velocity in the navigation coordinate frame is updated by $\dot{V}^N = C_H^N f^H - (2\omega_{IE}^N + \omega_{EN}^N) \cdot V^N + g^N$ where f^H= helmet axes specific forces as measured by the accelerometers; g^N= the gravity vector in the navigation coordinate frame." Ex. 1004, at 168–69. "The gyros used in the inertial measurement unit measure the angular velocity of the vehicle with respect to inertial space and the accelerometers measure the linear acceleration of the vehicle. . . . . **The linear velocity and position of the vehicle may be obtained by integrating the accelerometer output with respect to time and performing appropriate coordinate transformations.**" Ex. 1005, 1:55–2:5. "The vehicle tracking system according to the present invention provides an apparatus and a method for determining vehicle state information including position, velocity, acceleration, and attitude." Ex. 1005, 3:10–13. "The vehicle tracking system preferably includes an inertial measurement unit 26 for providing vehicle state information including position, velocity, acceleration and attitude of the vehicle 10. The inertial measurement unit 26 can include a plurality of inertial sensors including one or more gyros and one or more accelerometers." Ex. 1005, 3:28–33. "The velocity module of the inertial converter 27 may obtain velocity information of the vehicle 10 by integrating the accelerometer output with respect to time. **Further, the position of the vehicle 10 may be approximated by integrating the velocity** information with respect to time." Ex. 1005, 3:51–56.

Claims 13 and 34	Combination of McFarlane, Velger and Streit
[The system of claim 12, in which the calculating element --OR-- The method of claim 33, in further comprising] double-integrate[s/ing] a relative linear acceleration signal computed from the linear accelerometer signals measured by the first and second inertial sensors.	"The inertial angular rates and specific forces of the head are sensed by the IMU, which consists of three gyroscopes and three accelerometers. . . . The inertial body axis accelerations are transformed to the local level frame, are compensated for the local gravity acceleration and Coriolis acceleration, and are integrated to obtain the local level velocities. . . . The helmet velocity in the navigation coordinate frame is updated by $\dot{V}^N = C_H^N f^H - (2\omega_{IE}^N + \omega_{EN}^N) \cdot V^N + g^N$ where f^H= helmet axes specific forces as measured by the accelerometers; g^N= the gravity vector in the navigation coordinate frame." Ex. 1004, at 168–69. "The gyros used in the inertial measurement unit measure the angular velocity of the vehicle with respect to inertial space and the accelerometers measure the linear acceleration of the vehicle. . . . . **The linear velocity and position of the vehicle may be obtained by integrating the accelerometer output** with respect to time and performing appropriate coordinate transformations." Ex. 1005, 1:55–2:5. "The velocity module of the inertial converter 27 may obtain **velocity information of the vehicle 10 by integrating the accelerometer output** with respect to time. Further, **the position of the vehicle 10 may be approximated by integrating the velocity information** with respect to time." Ex. 1005, 3:51–56.

Claims 20 and 41	Combination of McFarlane, Velger and Streit
[The system of claim 1 --OR-- The method of claim 22], in which the moving reference frame is associated with a vehicle, and the second inertial sensor comprises a pre-	"[T]he larger and more accurate gyros commonly used on **inertial platforms**." Ex. 1003, 2:62–64. "Hence it is necessary to apply to the processor 22 of FIG. 2 inputs from **the ship or aircraft's own inertial platform** so that movements of the reference frame may be off set against movements indicated by the helmet detector unit. Such signals are indicated in FIG. 2 as FAZ

existing inertial measurement unit on a vehicle that was installed for the purpose of navigation.	(frame azimuth) and FEL (frame elevation) inputs." Ex. 1003, 4:15–21. "As the inertial sensors measure angular and linear velocity increments relative to the inertial space rather than relative to the vehicle, the motion of the vehicle itself is subtracted from the computed head motion." Ex. 1004, at 168. "The Euler angles from (6.58) measure the head orientation and azimuth relative to the navigation frame of reference. They easily can be converted to the vehicle coordinate frame by using the **vehicle-orientation measurements obtained by the vehicle master navigator**, if measurements relative to the vehicle are required." Ex. 1004, at 171. "**Vehicle tracking and navigation systems provide an abundance of useful information related to the vehicle state.**" Ex. 1005, 1:26–27. "Inertial measurement units or guidance systems were developed in Germany during the Second World War. These initial inertial systems were generally utilized for determining desired flight attitude in aircraft and measuring acceleration or thrust along a longitudinal axis." Ex. 1005, 1:40–45. "**More recently, inertial measurement units have been utilized to assist with the tracking and navigation of land vehicles**. Specifically, inertial measurement units can monitor the acceleration vector of a land vehicle in motion. The inertial measurement units generally consist of various combinations of inertial sensors including one to three gyros and one to three accelerometers." Ex. 1005, 1:46–52.

VII. CONCLUSION

Petitioner respectfully submits that, for the reasons set forth above, there is a reasonable likelihood that Petitioner will prevail on at least one claim. Accordingly, Petitioner respectfully requests that this Petition be granted and Claims 1–7, 10–13, 20, 22–28, 31–34, and 41 of the '159 Patent be found to be unpatentable.

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Respectfully submitted,

By ______________________

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CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. §§ 42.6 and 42.105, I hereby certify that on this 23rd day of April 2015, the foregoing Petition for *Inter Partes* Review of U.S. Patent No. 6,474,159 Under 35 U.S.C. §§ 311–319 and 37 C.F.R. § 42.100 *et seq.*, together with Petitioner's Exhibits Nos. 1001–1026, was served by FedEx, a means at least as fast and reliable as Priority Mail Express®, on the following correspondence address of record for patent owner:

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Date: April 23, 2015

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