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Maranville et al.

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(45) **Date of Patent: Aug. 14, 2018**

(54) **SENSOR APPARATUS**

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(22) Filed: **Jan. 4, 2016**

(65) **Prior Publication Data**

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(51) **Int. Cl.**

B60R 11/00	(2006.01)
B60R 9/04	(2006.01)
B62D 25/06	(2006.01)
G01S 13/93	(2006.01)

(52) **U.S. Cl.**

CPC ***B60R 11/00*** (2013.01); ***B60R 9/04*** (2013.01); ***B62D 25/06*** (2013.01); *B60R 2011/0028* (2013.01); *G01S 2013/9367* (2013.01); *G01S 2013/9382* (2013.01)

(58) **Field of Classification Search**

CPC G01S 17/93; G01S 13/93; B62D 25/06; B60R 11/00

USPC 296/216.01–224, 210

See application file for complete search history.

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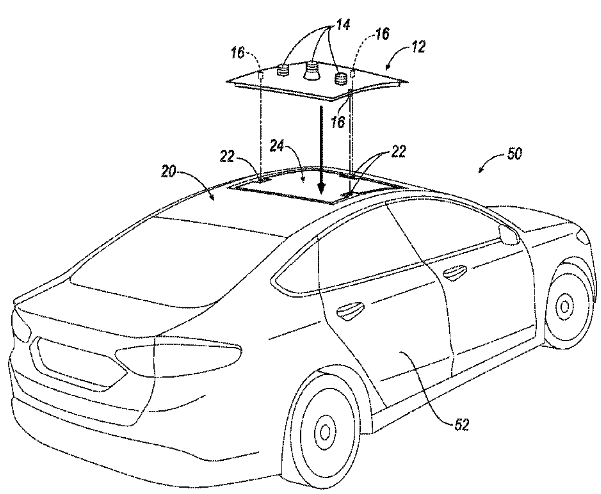
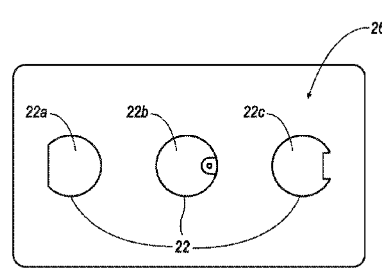
(57) **ABSTRACT**

A vehicle roof mount includes at least one datum feature. The datum feature is provided according to at least one datum. The at least one datum is determined according to a specified orientation of a sensor included in a sensor frame. The sensor frame is mateable to the roof mount.

14 Claims, 7 Drawing Sheets





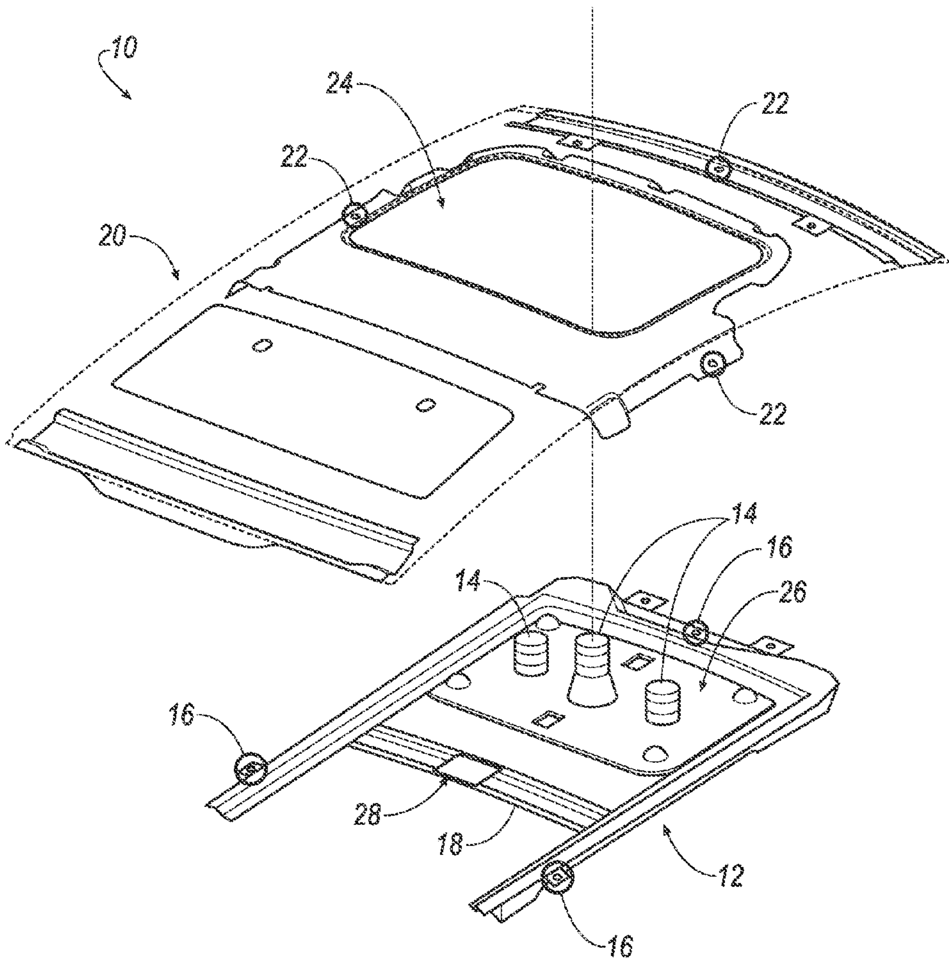


FIG. 1

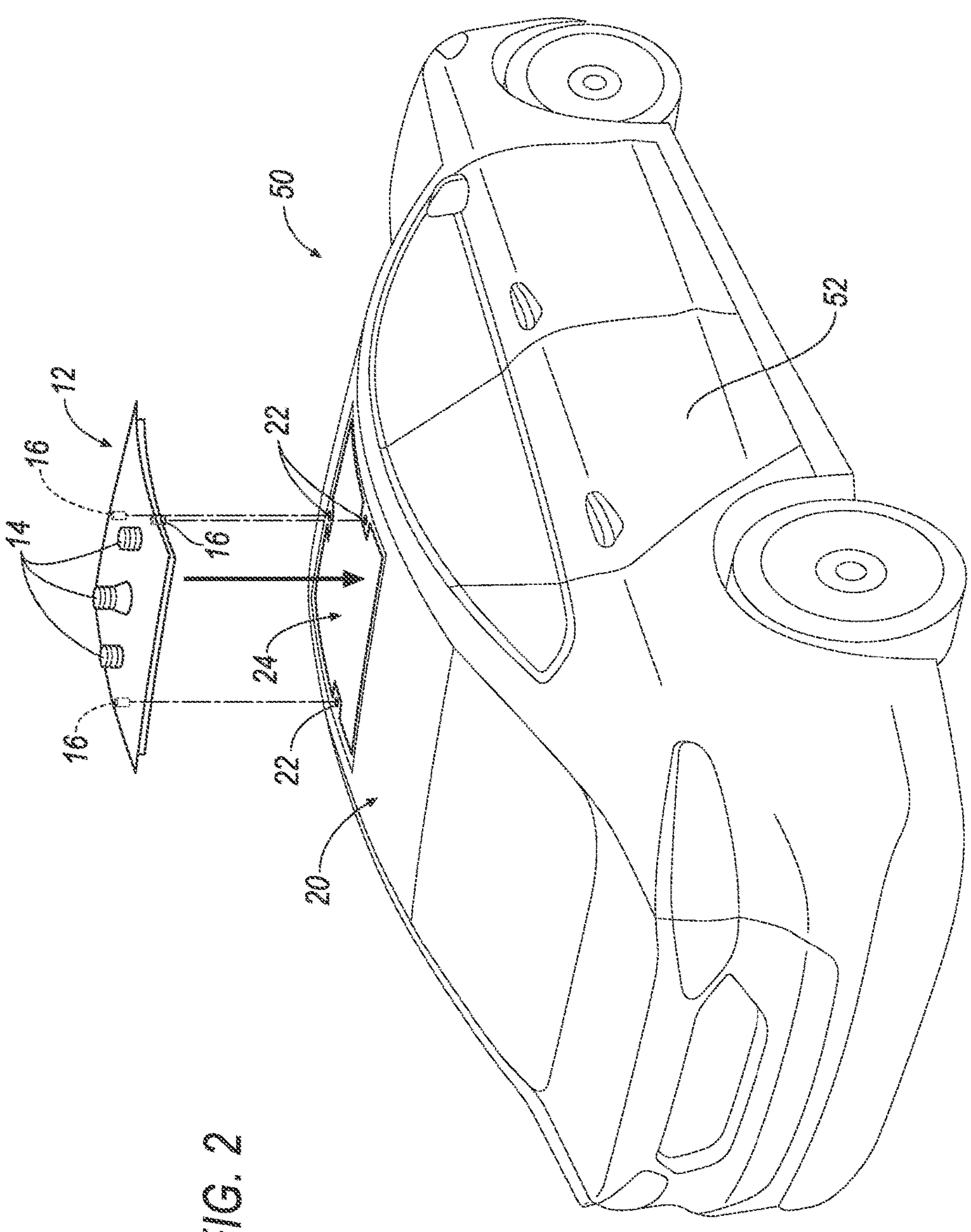


FIG. 2

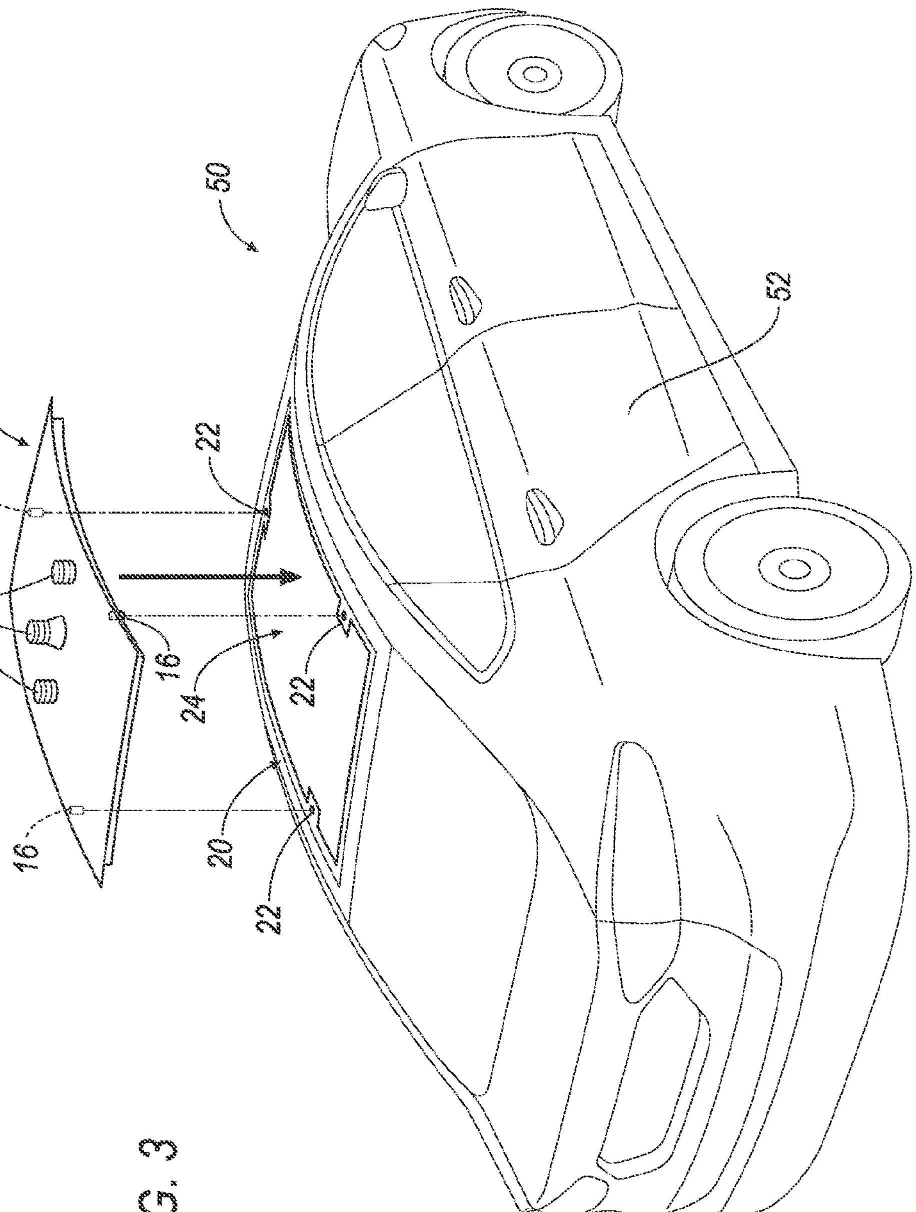


FIG. 3

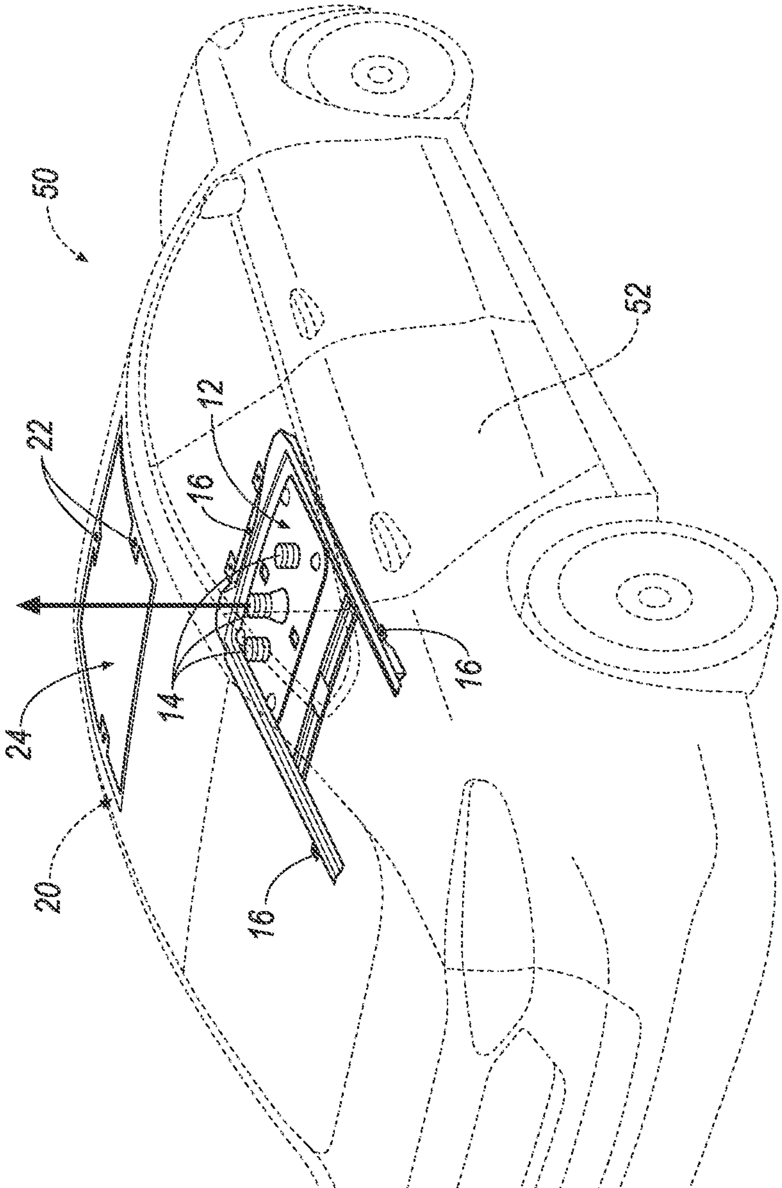


FIG. 4

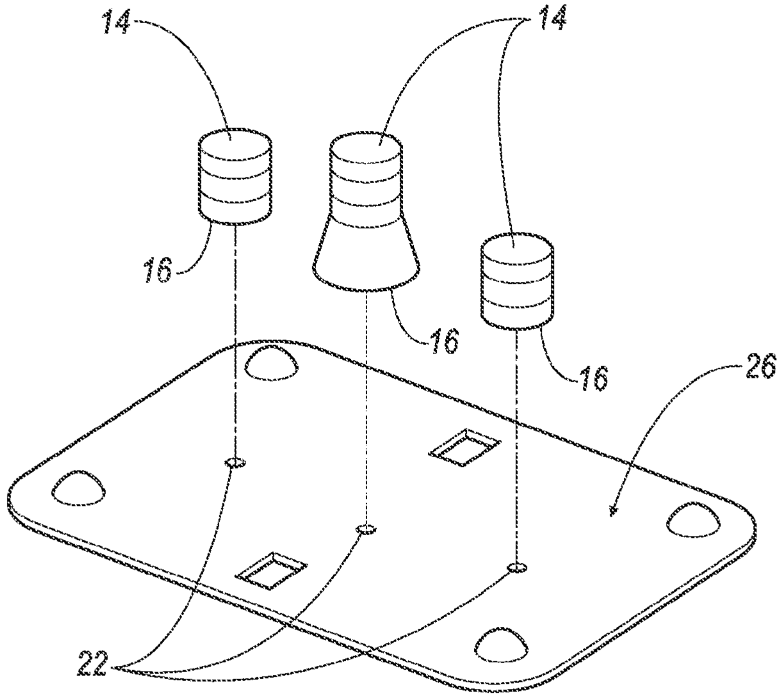


FIG. 5

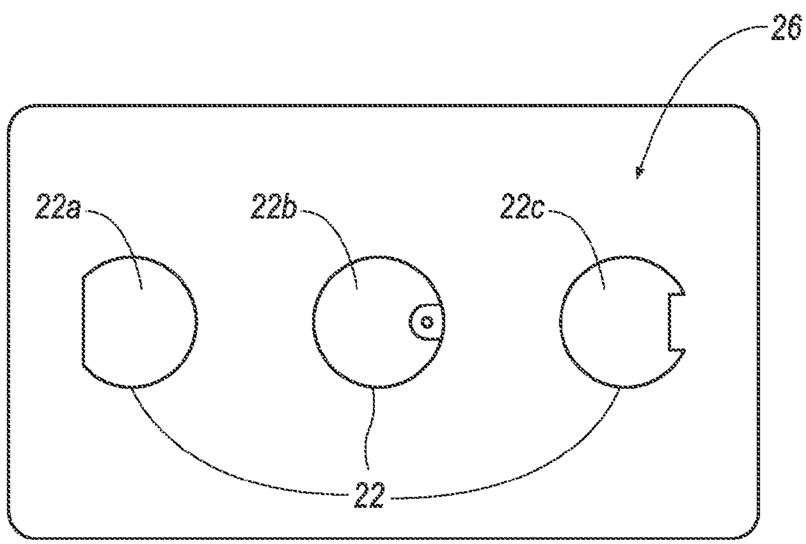


FIG. 6

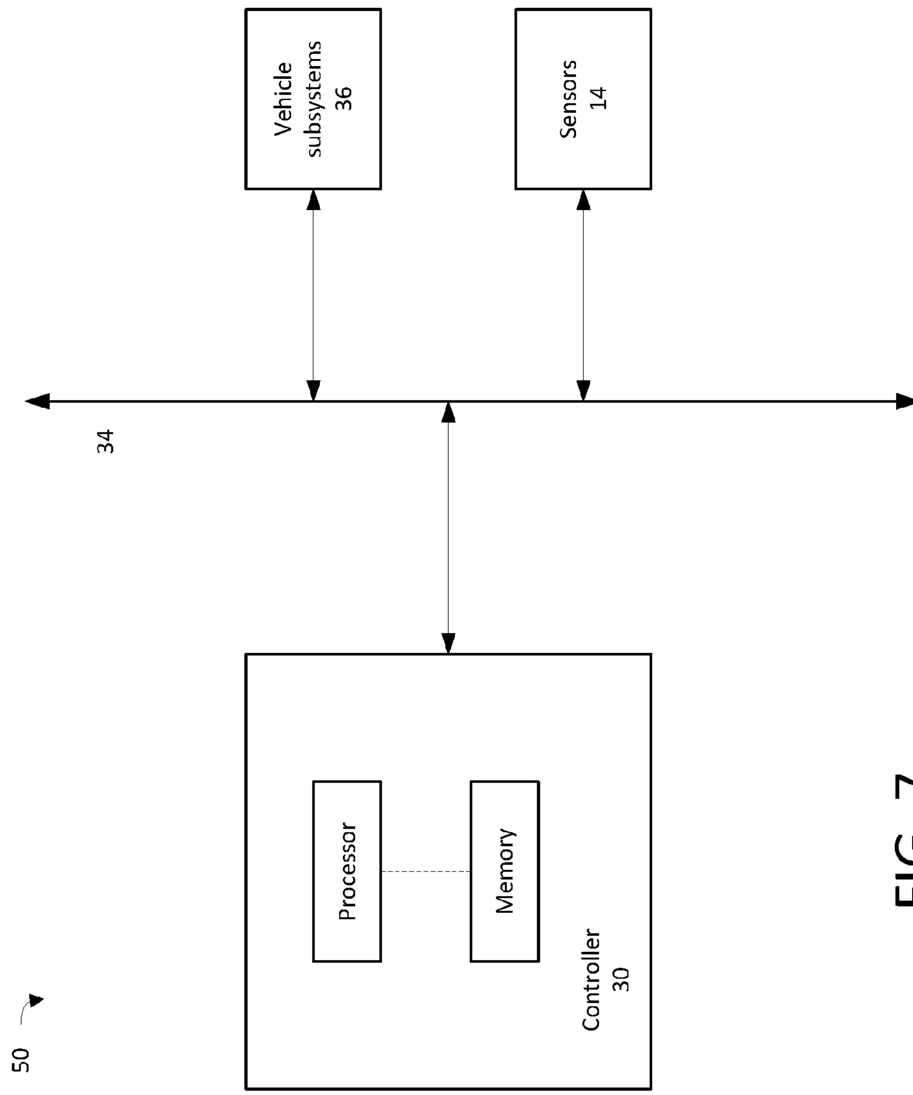
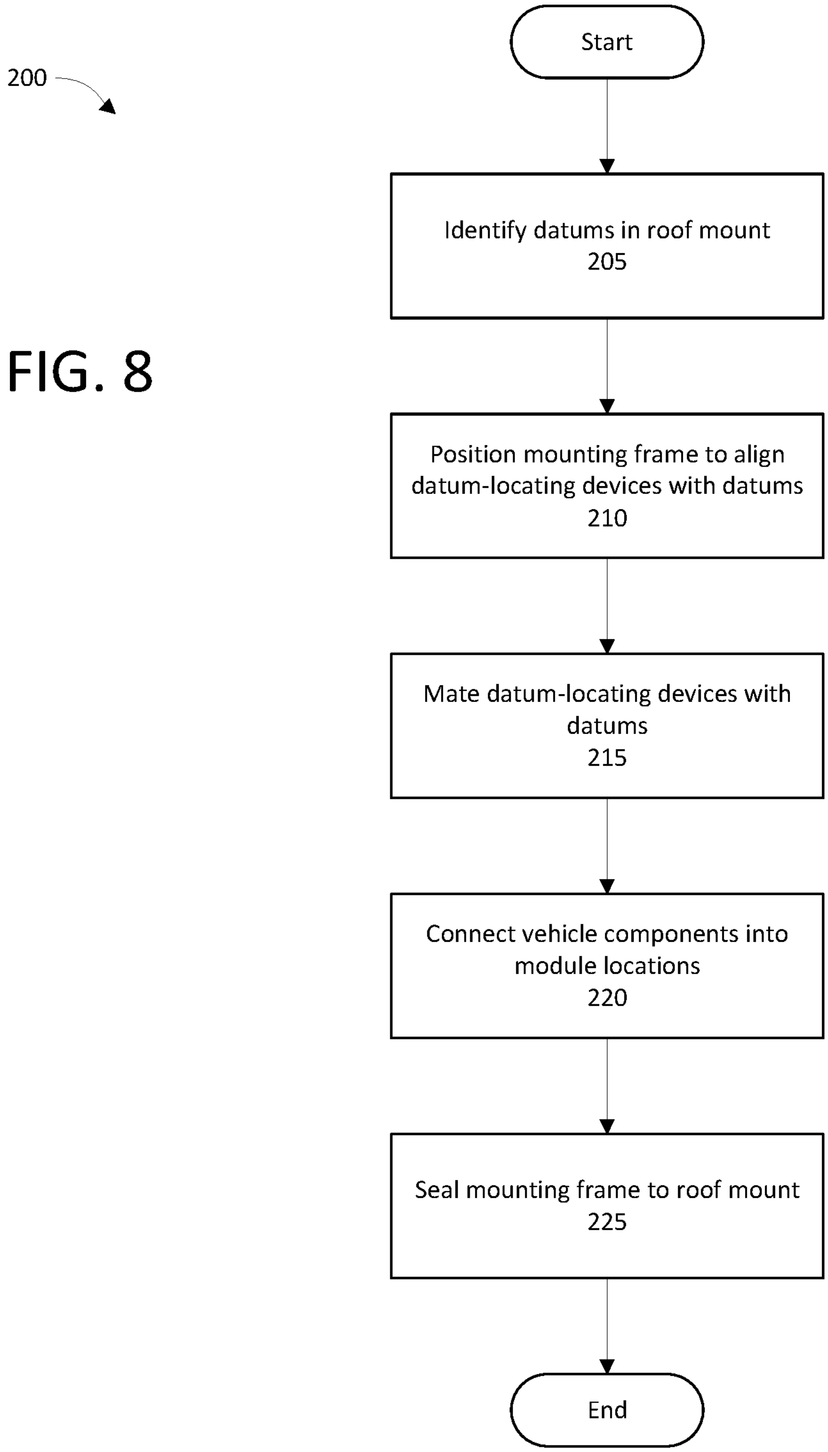

Vehicle subsystems 36
Sensors 14
34
Processor
Memory
Controller 30
50

FIG. 7

FIG. 8


200
Start
Identify datums in roof mount
205
Position mounting frame to align datum-locating devices with datums
210
Mate datum-locating devices with datums
215
Connect vehicle components into module locations
220
Seal mounting frame to roof mount
225
End

SENSOR APPARATUS

BACKGROUND

Vehicles include sensors to support various operations. Often, sensors must be aligned in a specific orientation for accuracy and/or proper operation. For example, vehicle sensors typically depend on a predetermined location and/or orientation, e.g., one or more angles with respect to horizontal and/or vertical axes, a position one the vehicle and/or with respect to vehicle parts, e.g., a distance from a bumper, pillar, roofline, beltline, etc. Due to variability of sensor assembly and/or component tolerance, the location of sensors may vary in conventional manufacturing and assembly processes. For example, a sensor may require a specific location with respect to 3-dimensional axial coordinates, e.g., X, Y, and Z axes, and an orientation at three angles with respect to the axes, e.g., θ, ϕ, ψ, i.e., there are 6 degrees of freedom. A vehicle includes several components, each with its own tolerance for location error. These tolerances add up as more components are included in the vehicle. Therefore, sensors may have significant variation of their location upon installation. As such, alignment of the sensors is typically difficult. Sensors that are installed and calibrated individually require additional time for installation, calibration, assurance of correct orientation, etc., during manufacture.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view of an example system for aligning sensors in a roof mount.

FIG. **2** is a view of the system of FIG. **1** top-loading the sensors into an example roof mount.

FIG. **3** is a view of the system of FIG. **1** top-loading the sensors into another FIG. **1** roof mount.

FIG. **4** is a view of the system bottom-loading the sensors into yet another FIG. **1** roof mount.

FIG. **5** is a view of a sensor mount as shown in FIG. **1**.

FIG. **6** is a view of datum features in the sensor mount of FIG. **5**.

FIG. **7** is a block diagram of an example vehicle.

FIG. **8** is an example process diagram of a method for installing the sensors into the roof mount.

DETAILED DESCRIPTION

Sensors in a vehicle such as an autonomous vehicle may require a specific alignment with a vehicle body. Aligning the sensors may be difficult and expensive. By prefabricating an assembly with precalibrated sensors that fits into a vehicle roof mount, the sensors may be easily installed and aligned with the vehicle body. The assembly generally limits some of this variability in sensor location and/or orientation. The assembly may be constructed to fit within existing vehicle roof mounts, allowing for retro-fitting of current vehicles and easier installation into new vehicles.

FIG. **1** illustrates an exemplary system **10** in a vehicle **50**. The system **10** includes a sensor frame **12** having sensors **14**, feature-locating elements **16**, a support rail **18**, a sensor mount **26**, and module locations **28**. The system **10** further includes a roof mount **20** having datum features **22** and a cavity **24**. The system **10** is configured to align the sensors **14** with a vehicle body **52**.

The sensor frame **12** is fittable into the roof mount **20** in an orientation that is aligned with the vehicle body **52**. The sensor frame **12** may be manufactured prior to installation in the roof mount **20**, which is a structure that can be provided in a roof location of the vehicle body **52** to receive and/or support various elements of a vehicle roof, including the sensor frame **12**.

The sensor frame **12** includes at least one sensor **14**. The sensors **14** may include, e.g., radar, lidar, and a vision system. The sensors **14** may be communicatively coupled, e.g., via a wired and/or wireless connection such as is known, with a communications bus in the vehicle **50**. The sensors **14** may be arranged to be aligned with the vehicle body **52** or otherwise oriented in a specific manner when the sensor frame **12** is installed into the roof mount **20**. Examples of sensors **14** that should be oriented in a specific manner include, e.g., lidar sensors, which as is known typically require a specified the position and orientation of the vehicle body to avoid interference during operation of the vehicle **50** and/or to provide useful data. The sensors **14** may include, by way of example and not limitation, lidar, radar, vision systems, microphones, radio-frequency directional antennas, and directional ultrasonic sensors. The sensors **14** may be supported by the sensor mount **26** and/or the support rail **18**.

The sensor frame **12** includes at least one feature-locating element **16**. The roof mount **20** includes at least one datum feature **22** aligned with a datum, and the feature-locating elements **16** are mateable with the datum features **22** to align the sensor frame **12** with the rest of the vehicle body **52**. The term "datum" as used herein is intended to have the meaning used in the known Y14.5-2009 standard promulgated by the American Society of Mechanical Engineers (ASME), published in Dimensioning and Tolerancing, ASME y14.5-2009; NY: American Society of Mechanical Engineers (2009). According to that standard, a "datum" is "a theoretically exact point, axis, or plane derived from the true geometric counterpart of a specified datum feature. A datum is the origin from which the location or geometric characteristics of features of a part are established." In the present context, a datum typically defines a point, line or shape (i.e., portion of a plane) that defines a location in and/or orientation according to which the sensor frame **12** attaches, or is to attach, to the roof mount **20**. The sensor frame **12** may be aligned with the vehicle body **52** via respective datum features **22** and feature-locating elements **16**. That is, the roof mount **20** may have predetermined datums arranged to align the roof mount **12** with the vehicle body **52**, which aligns the sensors **14** with the vehicle body **52**.

The datum is indicated by datum features **22** on the roof mount **20** that, as discussed below, can receive a feature-locating element **16**, which allows for controlled, fine-tolerance positioning of the sensor frame **12** in the roof mount **20**. The feature-locating elements **16** may be physical structures arranged to mate with the datum features **22**, e.g., a pin and/or a flat, a "flat" being a pin with a flattened side to, e.g., receive a set screw. A datum feature **22** and a feature-locating element **16** are typically mateable by, e.g., a press fit, a threaded fastener, etc. The sensor frame **12** may include at least three feature-locating elements **16**. The feature-locating elements **16** align the sensor frame **12** to the roof mount **20**, securing the alignment of the sensors **14** and easing installation of the sensor frame **12**.

The sensor frame **12** includes at least one support rail **18**. The support rails **18** may protect the sensors **14** and the feature-locating elements **16**. The support rails **18** may house the module locations **28**. The support rails **18** may be, e.g., longitudinal rails and/or cross-rails.

The sensor mount **26** houses the sensors **14**, and, additionally or alternatively to the roof mount **20**, can include one or more datum features **22**. The sensor mount **26** may be, e.g., a structure configured to house the sensors **14** to retain their alignment upon installation of the sensor frame **12**. The sensor mount **26** may be constructed of, e.g., metal, acrylic, polycarbonate, glass, etc. The sensor mount **26** may be supported by and/or attached to the support rails **18**.

The sensor frame **12** includes at least one module location **28**. The module locations **28** may be located on, e.g., the support rails **18** and/or the sensor mount **26**. The module locations **28** may include receptacles or the like as are known to receive a vehicle component, e.g., a wiring harness and/or a thermal management interface. For example, a wire harness and cooling line may be routed up a vehicle **50** pillar, e.g., the C-pillar, and connect to the sensors **14**. The module locations **28** may face an interior of the vehicle **50**, e.g., a bottom of the sensor frame **12**.

The roof mount **20** is a structure typically attachable to the vehicle body **52** and houses the sensor frame **12**. The roof mount **20** advantageously retains respective orientations, i.e., positions and/or angles, of the sensors **14** when the sensor frame **12** is installed into the roof mount **20**.

The roof mount **20** may include at least one datum feature **22** as stated above. One or more datum features **22** allow the sensor frame **12** to be installed into the roof mount quickly and accurately. The datum features **22** are physical structures in the roof mount **20**, e.g., slots, annuli, circular cavities, cutouts from the structure of the roof mount, etc., arranged to receive the feature-locating elements **16**. For example, a datum feature **22** may be a circular slot arranged to receive a cylindrical feature-locating element in the roof mount **20**. The datum features **22** can receive the feature-locating elements **16** to position the sensor frame **12** in the cavity **24** and with respect to the roof mount **20**.

The roof mount **20** may include at least three datum features **22**. For example, where one of the datum features **22** is a circular slot, the datum feature **22** thereby prevents motion along two of three directional axes and prevents rotation in two of three directions when a feature-locating element **16**, e.g., a cylindrical pin, is placed in the datum feature **22**, i.e., the circular slot. However, a datum feature **22** that is a circular slot may allow for movement along the axis of the circle defining the circular slot, i.e., the datum feature **22**, and may allow rotation around the axis. To prevent such rotation, one of the datum features **22** may include a flat edge or a notch added to the circular slot in the roof mount **20**, e.g., as shown in FIG. **6** as datum features **22***a* (having a flat edge) and **22***c* (having a notch). The flat edge or notch prevents rotation about the axis, resulting in five degrees of freedom constrained, i.e., only vertical movement along the axis of the datum is allowed. Another datum feature **22** may include a slot for a pin, as shown in FIG. **6** as datum feature **22***b*, which would constrain the vertical axial motion, resulting in six degrees of freedom constrained. However, it is generally desired for the datum feature **22** to constrain movement of the roof mount **20** with respect to the sensor frame **12** in at most five of six possible degrees of freedom, the reason being that constraining in six or more degrees of freedom can result in over-constraining and stack-up tolerance errors. In any case, the feature-locating elements **16** may be shaped to mate with the datum features **22**, providing a specific orientation for the sensor frame **12** to attach to the roof mount **20**. When the sensor frame **12** is attached to the roof mount **20** via the datum features **22**, the sensor frame **12** may be sealed to the roof mount **20** with, e.g., an adhesive and/or a rubber seal.

The roof mount **20** includes the cavity **24**. The cavity **24** may be, e.g., a cavity configured to house mechanisms such as are known for a moon roof and/or a panoramic roof. The cavity **24** may house the sensor mount **26** when the sensor frame **12** is installed into the roof mount **20**. The sensor mount **26** may be sized to fit within the cavity **24**.

FIG. **2** illustrates the sensor frame **12** top-loaded into the roof mount **20**, here a moon roof. The term "top-loaded" means that the sensor frame **12** is installed in the roof mount **20** from the top in a vertical direction, i.e., the sensor frame **12** is lowered from above into the roof mount **20**. The feature-locating elements **16** may be located toward the bottom of the sensor frame **12**, and the datum features **22** may be arranged along the top of the roof mount **20** to receive the feature-locating elements **16**. When the feature-locating elements **16** mate with the datum features **22**, the sensor mount **26** and the sensors **14** may be aligned with the vehicle body **52**. The mounting plate **12** may then be attached to the roof mount with, e.g., an adhesive seal, e.g., urethane. The sensor frame **12** may be arranged to top-load into the roof mount **20** based on, e.g., the datums, the orientation of the sensors **14**, manufacturing techniques, etc.

The mounting plate **12** may be installed in a vehicle **50** that has the moon roof removed, creating the cavity **24** in which the sensor mount **26** is placed. Thus, the sensor frame **12** may be retro-fitted into existing vehicles. The sensor frame **12** may also be installed into existing roof mounts **20** designed for a moon roof, and thus special manufacturing may not be required.

FIG. **3** illustrates the sensor frame **12** top-loaded into another exemplary roof mount **20**, here a panoramic roof. The panoramic roof may create a larger cavity **24** than the moon roof of FIG. **2**. The sensor frame **12** may be similarly top-loaded, i.e., lowered into the cavity **24** from above and sealed to the roof mount **20**. Because the cavity **24** is larger for a panoramic roof than for the moon roof of FIG. **2**, the sensor mount **26** must be constructed to the larger cavity, and the mounting plate **12** may be arranged so that the sensors **14** are calibrated and aligned upon installation. Similarly, the datum features **22** and the feature-locating elements **16** are located to preserve the calibration and alignment of the sensors **14** upon installation of the sensor frame **12**. Because the panoramic roof has a larger cavity **24**, the sensor frame **12** may include more sensors **14**.

FIG. **4** illustrates the sensor frame **12** bottom-loaded into the roof mount **20**. The term "bottom-loaded" means that the sensor frame **12** is installed in the roof mount **20** from the bottom in a vertical direction, i.e., the sensor frame **12** is raised from beneath the roof mount **20** and installed from below the roof mount **20**. The feature-locating elements **16** may be arranged on the top of the sensor frame **12** to mate with the datum features **22** located on the bottom of the roof mount **20**. The sensor frame **12** may be attached to the roof mount **20** with, e.g., a rubber seal. The sensor frame **12** may be arranged to bottom-load into the roof mount **20** based on, e.g., the datums, the orientation of the sensors **14**, manufacturing techniques, etc.

FIG. **5** illustrates an example sensor mount **26**. The sensor mount **26** includes the sensors **14**. The sensors **14** are mateable with the sensor mount **26** via datum features **22** in the sensor mount **26** and feature-locating elements **16** in the sensors **14**. The datum features **22** and feature-locating elements **16** may be selected to ensure proper orientation of the sensors **14** when installed in the vehicle **50**.

FIG. **6** illustrates datum features **22** in the sensor mount **26**, but may also be used in the roof mount **20**. As described above, the datum features **22** include, e.g., a feature **22***a* having a substantially circular shape with a flattened edge, a feature **22***b* having a circular slot for a cylindrical pin, and a feature **22***c* having a rectangular notch included in the substantially circular shape. In this example, the feature **22***a* may prevent rotation of the sensor **14**, but allows for axial motion along the axis of the feature **22***a*. The feature **22***b* may receive a pin from the sensor **14**, preventing motion in all directions except for vertical axial motion out from the feature **22***b*. The feature **22***c* may prevent rotation of the sensor **14**, and may ensure that the sensor **14** designed to mate with the feature **22***a* is not improperly placed in the feature **22***c*. That is, the sensor mount **26** and the roof mount **20** may include any combination of the features **22***a*, **22***b*, **22***c* to ensure that the sensors **14** are aligned upon installation and that the sensors **14** are fitted to their respective datum features **22** and only their respective datum features **22**.

FIG. **7** illustrates a block diagram of the vehicle **50**. The sensors **14** are communicatively coupled to a controller **30** including a processor and a memory, and vehicle subsystems **36** via a communications bus **34**, such as a controller area network (CAN) bus, of the vehicle **50**.

The controller **30** may be programmed to receive information collected by the sensors **14** and transmitted over the communications bus **34** to actuate the vehicle subsystems **36** to operate the vehicle in an autonomous mode. The memory may store instructions executable by processor to actuate the vehicle subsystems **36**.

The vehicle subsystems **36** may include, e.g., data collectors, throttle, braking, steering, entertainment, human-machine interface, etc. The vehicle subsystems **36** may receive instructions from the controller **30** and/or a vehicle operator to operate the vehicle. The vehicle subsystems **36** may be operated in an autonomous mode.

FIG. **8** illustrates an example process **200** for installing the sensor frame **12** into the roof mount **20**. The process **200** begins in a block **205**, in which the datum features **22** in the roof mount **20** are identified. For example, this identification could be done by an installer that is, e.g., a robot arranged to manufacture the vehicle **50**, a human worker, etc.

Next, in a block **210**, the installer positions the sensor frame **12** to align the feature-locating elements **16** with the datum features **22**. The datum features **22** are arranged to receive the feature-locating elements **16** and to allow the installer to orient the sensor frame **12** within the roof mount **20** so that the sensors **14** are aligned with the vehicle body **52**. The installer may position the sensor frame **12** above the roof mount **20** in a top-load, as shown in FIGS. **2-3**, or may position the sensor frame **12** beneath the roof mount **20** in a bottom-load, as shown in FIG. **4**.

Next, in a block **215**, the installer mates the feature-locating elements **16** with the datum features **22**. The mating may be, e.g., press-fitting the feature-locating elements **16** into the cavities of the datum features **2**, installing threaded fasteners securing the feature-locating elements **16** to the datum features **22**, etc. Upon mating of the feature-locating elements **16** with the datum features **22**, the sensors **14** are aligned with the vehicle body **52**.

Next, in a block **220**, the installer connects vehicle components to the module locations **28**. The roof mount **12** may include module locations **28** for various vehicle components, e.g., a wiring harness and/or a thermal management interface, and the installer may install the components into the module locations **28**.

Next, in a block **225**, the installer seals the sensor frame **12** to the roof mount **20**, and the process **200** ends. The seal may be a urethane seal and/or a rubber seal. The seal secures the sensor frame **12** to the roof mount **20**, maintaining the alignment of the sensors **14** with the vehicle body **52**.

As used herein, the adverb "substantially" modifying an adjective means that a shape, structure, measurement, value, calculation, etc. may deviate from an exact described geometry, distance, measurement, value, calculation, etc., because of imperfections in materials, machining, manufacturing, sensor measurements, computations, processing time, communications time, etc.

Accordingly, it is to be understood that the present disclosure, including the above description and the accompanying figures and below claims, is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be apparent to those of skill in the art upon reading the above description. The scope of the invention should be determined, not with reference to the above description, but should instead be determined with reference to claims appended hereto and/or included in a non-provisional patent application based hereon, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the arts discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the disclosed subject matter is capable of modification and variation.

The invention claimed is:

1. An assembly, comprising:

a vehicle roof mount including a plurality of first physical structures, each first physical structure provided according to a respective specified location on the vehicle roof mount;

a sensor frame mateable to the vehicle roof mount including a plurality of second physical structures, each second physical structure of the sensor frame mateable to a respective one of the first physical structures of the vehicle roof mount, and a sensor;

wherein each specified location is determined to preserve a predetermined orientation of the sensor with respect to a vehicle body when the first physical structures are mated with the second physical structures.

2. The assembly of claim **1**, wherein the second physical structures are arranged to position the sensor frame on the roof mount and to constrain one or more degrees of freedom.

3. The assembly of claim **1**, wherein the sensor frame includes a sensor mount, and the sensor mount includes a first physical structure disposed on the sensor mount, and the sensor includes a second physical structure, the first physical structure of the sensor mount provided to preserve a specified orientation of the sensor with respect to the sensor mount when the first physical structure is mated with the second physical structure.

4. The assembly of claim **1**, wherein the sensor frame is arranged to top-load into the roof mount.

5. The assembly of claim **1**, wherein the sensor frame is arranged to bottom-load into the roof mount.

6. The assembly of claim **1**, wherein the roof mount further includes a cavity, and the sensor frame is fittable within the cavity.

7. The assembly of claim **1**, the sensor frame further comprising at least one module location.

8. The assembly of claim **7**, wherein the module location is arranged to receive at least one of a thermal management interface and a wiring harness.

9. The assembly of claim **1**, wherein the sensor is at least one of radar, lidar, and a vision system.

10. A vehicle roof, comprising:

a roof mount including a plurality of first physical structures, each first physical structure provided according to a respective specified location on the vehicle roof mount;

a sensor frame including at least one sensor mount;

a plurality of second physical structures disposed on the sensor frame, each second physical structure of the sensor frame mateable to a respective one of the first physical structures of the roof mount; and

at least one sensor supported by the sensor mount;

wherein each specified location is determined to preserve a specified orientation of the sensor with respect to a vehicle body when the first physical structures are mated with the second physical structures.

11. The roof of claim **10**, wherein the sensor frame is arranged to top-load into the roof mount.

12. The roof of claim **10**, wherein the sensor frame is arranged to bottom-load into the roof mount.

13. The roof of claim **10**, wherein the sensor frame further includes at least one module location arranged to receive at least one of a thermal management interface and a wiring harness.

14. The roof of claim **10**, wherein the roof frame further includes a cavity, and the sensor mount is fittable within the cavity.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,046,713 B2
APPLICATION NO. : 14/986841
DATED : August 14, 2018
INVENTOR(S) : Clay Wesley Maranville et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 7, in Lines 24-25, replace "wherein the roof frame further includes a cavity, and the sensor mount is fittable" with -- wherein the roof mount further includes a cavity, and the sensor frame is fittable --.

Signed and Sealed this
Eighteenth Day of June, 2019

Andrei Iancu
Director of the United States Patent and Trademark Office