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Vehicular alignment for sensor calibration

Abstract

A system and method of calibrating an ADAS sensor of a vehicle by aligning a target with the sensor using a target adjustment stand that includes a base frame and a movable target mount configured to support a target, with the target adjustment stand including one or more actuators for adjusting the position of the target mount. The position of the target mount is adjusted based on the orientation of the vehicle relative to the target adjustment stand. Upon properly orienting the target mount, and the target supported thereon, a calibration routine is performed whereby the sensor is calibrated using the target.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) The present application is a continuation of U.S. patent application Ser. No. 16/398,404, filed Apr. 30, 2019, now U.S. Pat. No. 11,624,608, which claims priority of U.S. provisional application Ser. No. 62/664,323 filed Apr. 30, 2018, and claims priority of U.S. provisional application Ser. No. 62/798,268 filed Jan. 29, 2019, all of which are hereby incorporated herein by reference in their entireties.

BACKGROUND AND FIELD OF THE INVENTION
(1) The present invention is directed to a vehicle alignment/calibration method and system, and in particular to a method and system for aligning a vehicle and sensors of a vehicle to one or more calibration targets for calibration of the sensors.
(2) The use of radar, imaging systems, and other sensors, such as LIDAR, ultrasonic, and infrared (IR) sensors, to determine range, velocity, and angle (elevation or azimuth) of objects in an environment are important in a number of automotive safety systems, such as an Advanced Driver Assistance System (ADAS) for a vehicle. A conventional ADAS system will utilize one or more sensors. While these sensors are aligned and/or calibrated by the manufacturer during production of the vehicle whereby they are able to provide accurate driver assistance functionality, the sensors may need realignment or recalibration periodically, such as due to the effects of wear and tear, or misalignment due to driving conditions or through mishap, such as a collision
SUMMARY OF THE INVENTION
(3) The present invention provides a method and system for calibrating and/or aligning a vehicle-equipped sensor by aligning the vehicle and thereby the vehicle equipped sensor with one or more calibration targets. In aligning the vehicle-equipped sensor(s) to the one or more calibration targets, a target is aligned to the vehicle by way of determining the vehicle's vertical center plane. As discussed herein, once the vehicle's vertical center plane is determined, a lateral center point of a

target may be aligned coincident with the vehicle's ADAS sensors with respect to the vertical center plane. In particular, a controller issues control signals for controlling the driven motion of a target adjustment frame to which a target, such as a target panel, may be mounted such that the target panel is aligned to the vehicle's ADAS sensors

(4) According to an aspect of the present invention, a system and method of calibrating a sensor of a vehicle by aligning a target with the sensor includes nominally positioning a vehicle in front of a target adjustment stand, where the target adjustment stand includes a stationary base frame and a target mount configured to support a target with the target adjustment stand including one or more actuators for adjusting the position of the target mount. An orientation of the vehicle relative to the target adjustment stand is then determined, with the target mount, and thereby the target, being positioned relative to a sensor of the vehicle based on the determined orientation of the vehicle relative to the target adjustment stand, including such as based on a known location of the sensor on the vehicle. Upon positioning the target relative to the sensor a calibration routine is performed whereby the sensor is calibrated using the target.

(5) In a particular embodiment, the base frame of the target adjustment frame is configured to be mounted to a floor, with the target adjustment frame including a base member movably mounted to the base frame and a tower joined to the base member, and with the target mount supported by a tower. The target adjustment frame further includes a base member actuator configured to selectively move the base member relative to the base frame and tower actuators configured to selectively move the tower relative to the base member. A computer system is operable to selectively actuate the base member actuator and tower actuators to position the target relative to a vehicle positioned in front of the target adjustment frame, and in particular relative to a sensor of the vehicle. The computer system is configured to determine the orientation of the vehicle relative to the target adjustment frame and to actuate the base member actuator and tower actuators responsive to the determination of the orientation of the vehicle relative to the target adjustment frame.

(6) Still further, the system may utilize two rearward wheel clamps and two forward wheel clamps, wherein the rearward wheel clamps each include a light projector and are configured for mounting to the opposed wheel assemblies of the vehicle furthest from the target adjustment frame, with the forward wheel clamps each including an aperture plate and being configured for mounting to the opposed wheel assemblies of the vehicle closest to the target adjustment frame. The light projectors are operable to selectively project light at respective ones of the aperture plates, with each aperture plate including at least one aperture through which the projected light is directed at the target adjustment frame. The target adjustment frame further includes a pair of imagers with each imager operable to image projected light passing through respective ones of the aperture plates, with the computing system being operable to determine the orientation of the vehicle relative to the target adjustment frame based on the images of projected light obtained by the imagers.

(7) According to a particular aspect of the invention, a pair of spaced-apart imager panels are provided on the target adjustment frame, where the projected light passing through the aperture plates is projected onto respective ones of the imager panels to form a light pattern on the imager panel, with the imagers configured to image the light patterns. The imager panels may be translucent with the light patterns formed on a front surface of the panels with the imagers arranged to image the light pattern from a back surface of the imager panels.

(8) The forward wheel clamps may each further include a distance sensor configured to obtain distance information of the forward wheel clamps relative to spaced apart portions of the target adjustment frame, such as the imager panels, with the computer system determining the orientation of the vehicle relative to the target adjustment frame based at least in part on the distance information from the distance sensors.

(9) In an alternative embodiment according to the present invention non-contact wheel alignment sensors are used to determine the position of the vehicle relative to the non-contact wheel

alignment sensors, with the computer system being operable to determine the orientation of the vehicle relative to the target adjustment frame based at least in part on the determined position.
(10) The computer system may comprise a controller disposed at or adjacent the target adjustment frame, with the controller configured to selectively actuate actuators of the target adjustment frame. The computer system may further comprise a remote computing device that is configured to determine the orientation of the vehicle relative to the target adjustment stand and transmit control signals to the controller for selectively actuating the actuators, such as via an Internet connection.
(11) The computer system, such as the remote computing device, may interface with one or more databases for performing the alignment of the target relative to the sensor of the vehicle, as well as performing the calibration routine. The databases may include information regarding makes and models of vehicles, as well as databases regarding specifics of the ADAS sensors equipped on such vehicles and processes for calibrating the sensors, including for example locations of the sensors on the vehicle, specifics regarding the type of target to use for calibrating the sensor, and calibration program routines for calibrating the sensor. The databases may further include calibration routines, such as OEM calibration routines. The computer system may further include a computing device, such as an operator computing device, that interfaces with ECUs of the vehicle to obtain information from the vehicle and/or perform a calibration routine.
(12) In another alternative embodiment, a system and method for aligning a target to a vehicle for calibration of a sensor equipped on the vehicle comprises a vehicle stand upon which a vehicle is configured to be positioned, a target adjustment frame movably mounted to a rail with the rail extending longitudinally with respect to the vehicle stand and to a longitudinal axis of the vehicle when positioned on the vehicle stand, with the target adjustment frame including a base frame movably mounted to the rail and a target mount moveably mounted on the target adjustment frame with the target mount configured to support a target and the target adjustment frame further including a plurality of actuators configured to selectively move the target mount relative to the base frame. A computer system is provided that is configured to selectively actuate the actuators to position the target relative to the vehicle positioned in front of the target adjustment frame, with the target mount being moveable by the actuators vertically and laterally with respect to the longitudinal axis of the vehicle when positioned in front of the target adjustment frame. The target adjustment frame is moved on the rail into a longitudinal orientation relative to the vehicle and the computer system selectively actuates the actuators to position the target based on a known orientation of the vehicle on the vehicle stand to position the target relative to a sensor of the vehicle whereby the sensor is able to be calibrated using the target.
(13) The present invention provides a system and method for accurately positioning a calibration target relative to a sensor of a vehicle and calibrating the sensor, such as in accordance with OEM specifications. The accurate positioning and calibration of the sensor thus aids in optimizing the performance of the sensor to in turn enable the sensor to perform its ADAS functions. These and other objects, advantages, purposes and features of this invention will become apparent upon review of the following specification in conjunction with the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective view of a vehicle target alignment system in accordance with the present invention;
(2) FIG. **2** is a side perspective view of the vehicle of FIG. **1** to which wheel mounted alignment tools in accordance with the present invention are affixed;
(3) FIG. **3** is a perspective view of the wheel mounted laser tool clamp of FIG. **2**;
(4) FIG. **3**A is a close-up perspective view of the wheel clamp of FIG. **3** shown removed from the

wheel assembly;
(5) FIG. **4** is a perspective view of the wheel mounted aperture plate tool clamp of FIG. **2**;
(6) FIG. **4**A is a close-up perspective view of the wheel clamp of FIG. **4** shown removed from the wheel assembly;
(7) FIG. **5** is a front perspective view of the target adjustment frame or stand of FIG. **1**;
(8) FIG. **6** is a rear perspective view of the target adjustment frame or stand of FIG. **1**;
(9) FIG. **7** is a perspective view of an alignment housing of the target adjustment frame of FIG. **1** illustrating an imager disposed therein;
(10) FIG. **8** is an interior view of the imager panel of the alignment housing of FIG. **7**;
(11) FIG. **9** is an interior perspective view of the alignment housing of FIG. **7** for calibration of the imager;
(12) FIG. **10** illustrates an exemplary flow chart of the operation of a vehicle target alignment system in accordance with the present invention;
(13) FIG. **11** is a schematic illustration of remote processes operations of a vehicle target alignment system in accordance with the present invention;
(14) FIG. **12** is a perspective view of the vehicle target alignment system of FIG. **1** equipped with an adjustable floor target assembly illustrating the vehicle in a reversed orientation relative to the target adjustment frame;
(15) FIG. **13** is a close-up perspective view of the system and orientation of FIG. **12** disclosing the adjustable floor framework for positioning of the floor mat relative to the vehicle;
(16) FIG. **14** is an overhead view of the vehicle target alignment system and orientation of FIG. **12**;
(17) FIG. **15** is a perspective view of a non-contact alignment system that may be used with a target adjustment frame in accordance with an embodiment of the present invention; and
(18) FIG. **16** is a perspective view of an alternative vehicle target alignment system in accordance with a further aspect of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(19) The present invention will now be described with reference to the accompanying figures, wherein the numbered elements in the following written description correspond to like-numbered elements in the figures.
(20) FIG. **1** illustrates an exemplary vehicle target alignment and sensor calibration system **20** in accordance with the present invention. In general, upon a vehicle **22** being nominally positioned or located in front of a target adjustment frame or stand **24**, the system **20** is configured to align one or more targets, such as a target or target panel **26** mounted to target adjustment frame **24**, or targets on floor mat **28**, or other targets, relative to vehicle **22**, and in particular to align targets relative to one or more ADAS sensors **30** of the vehicle **22**. Sensors **30** may thus be radar sensors for adaptive cruise control (“ACC”), imaging systems such as camera sensors for lane departure warning (“LDW”) and other ADAS camera sensors disposed about vehicle, as well as other sensors, such as LIDAR, ultrasonic, and infrared (“IW”) sensors of an ADAS system, including sensors mounted inside the vehicle, such as forward facing cameras, or exterior mounted sensors, with the targets supported on stand **24** constructed for calibration of such sensors, including grids, patterns, trihedrals, and the like. Upon aligning the target with the sensor of the vehicle, a calibration routine is performed whereby the sensor is calibrated or aligned using the target.
(21) As discussed in detail below, in order to align the targets relative to the vehicle sensors **30**, in one embodiment wheel clamps are mounted to the wheel assemblies **32** of vehicle **22**, where the wheel clamps include a pair of rearward clamps or light projector clamps **34***a*, **34***b* and a pair of forward clamps or aperture plate clamps **36***a*, **36***b*. Light projected from projector clamps **34***a*, **34***b* passes through respective aperture plate clamps **36***a*, **36***b* and is received by an imager or camera **38** (FIG. **7**) within housings **40***a*, **40***b* located on target adjustment frame **24**. As discussed in more detail below, a computer system, such as a controller **42** that may be configured as a programmable logic controller (PLC) of system **20**, is then configured to adjust the target relative to sensors **30**

upon acquisition of data related to the orientation of vehicle **22**, including based on the projected light from projector clamps **34***a*, **34***b* received by imagers **38**. Upon the targets being aligned with a sensor of the vehicle **22**, calibration of the sensor may be performed, such as in accordance with OEM specifications. In a particular embodiment the computer system includes a remote computing device that interfaces with controller **42**, such as over an internet connection, for both providing an operator of system **20** with instructions as well as for processing and controlling movement of target adjustment frame **24**. The following discussion provides details regarding the construction and operation of the illustrated embodiment of vehicle target alignment system **20**. As used herein, references to calibration of the sensor encompass alignment of the sensor.

(22) Light projector clamps **34***a*, **34***b* and aperture plate clamps **36***a*, **36***b* will be discussed with initial reference to FIGS. **2-4**. As there shown, a left side projector clamp **34***a* is mounted to the rear wheel assembly **32** of vehicle **22** and a left side aperture plate clamp **36***a* is mounted to the front wheel assembly **32**. Although not shown in detail, it should be appreciated that the right side clamps **34***b*, **36***b* are substantially similar to the left side clamps **34***a*, **36***a*, but in mirror arrangement. Due to their similarity not all of the details of the right side clamps are discussed herein. Moreover, the left and right side are referenced with respect to the target adjustment frame **24** relative to the orientation in which the light is projected at frame **24** by the projector clamps **34***a*, **34***b*. As discussed below with reference to FIGS. **10-12**, vehicle **22** may be alternatively oriented with regard to system **20** for calibration of other vehicle sensors whereby clamps **34**, **36** would be mounted to different wheel assemblies. That is, projector clamp **34***a* would be mounted to the passenger side front wheel assembly **32** and projector clamp **34***b* would be mounted to the driver side front wheel assembly **32**.

(23) In the illustrated embodiment the clamps **34***a*, **36***a* are modified from a conventional wheel clamp. The clamps **34***a*, **36***a*, include multiple adjustable arms **44** having extendable and retractable projection arms **46** to which are mounted claws **47**, where claws **47** are configured for engaging to the wheel flange **48** of the wheel **54** of the wheel assembly **32**. Also provided are optional retention arms **50** that engage with the tire of the wheel assembly **32**. In use, claws **47** may be disposed about the wheel flange **48** with a spacing of approximately 120 degrees, with projection arms **46** being drawn in, such as by the rotatable handle **52** shown, to securely fix the clamp to the wheel flange **48** of the wheel **54** of the wheel assembly **32**. When so mounted, clamps **34***a*, **36***a* are co-planar with a plane defined by the wheel **54** and are centered on wheel **54**, where wheel **54** is mounted to the hub of the vehicle, which establishes the axis of rotation such that the clamps **34***a*, **36***a* are mounted about the axis of rotation of wheel **54**. The clamps **34***a*, **36***a* further include a central hub **56**, which when mounted to wheel **54** is centered on the wheel **54** and is aligned about the axis of rotation of wheel **54**.

(24) The projector clamps **34**, with reference to the projector clamp **34***a* shown in FIGS. **2** and **3**, are modified to include a projection assembly **60**. Projection assembly **60** includes a post or shaft **62**, a bearing assembly or mount **64** mounted coaxially to shaft **62**, a bearing block **65** connected with bearing mount **64** so as to be disposed perpendicularly to shaft **62** and be able to rotate on shaft **62** via gravity, a light projector that in the illustrated embodiment is configured as a laser **66** attached to bearing block **65**, and a projector controller assembly **68** that is also attached to bearing block **65**. Shaft **62** is inserted into a hub **56** to thereby extend normal to a plane defined by wheel **54**. Bearing mount **64** in turn pivots on shaft **62** such that due to gravity it will naturally rotate into a vertical orientation.

(25) As understood from FIGS. **2-4**, laser **66** is configured to project a pair of light planes **70***a*, **70***b* (see FIGS. **3**A, **7** and **8**) that are oriented perpendicularly to each other in a cross pattern **71**. In a situation in which shaft **62** is parallel to the surface upon which vehicle **22** rests, light plane **70***a* would be planar to the surface upon which vehicle **22** rests and light plane **70***b* would be perpendicular to the surface.

(26) Projector controller assembly **68** includes a controller, such as a microprocessor, and software

for selective operation of laser **66**, as well as includes an internal battery and a transmitter/receiver for wireless communication with controller **42**, such as by way of a Wi-Fi, Bluetooth, or other wireless communication format, which are contained within a housing, as shown in FIG. **3**. As also shown in FIG. **3**, assembly **68** may be provided with a control switch **72** for selectively powering the projector assembly **60** on and off.

(27) The aperture plate clamps **36**, with reference to the aperture plate clamp **36***a* shown in FIGS. **2** and **4**, are modified to include an aperture assembly **76**. Aperture assembly **76** includes a post or shaft **78**, a bearing assembly or mount **80** mounted coaxially to shaft **78**, a bearing block **81** connected with bearing mount **80** so as to be disposed perpendicularly to shaft **78** and be able to rotate on shaft **78** via gravity, an aperture plate **82** mounted to bearing block **81**, a controller assembly **84** mounted to bearing block **81**, and a distance sensor **86**. Shaft **78** is inserted into a hub **56** to thereby extend normal to a plane defined by wheel **54**. Bearing mount **80** in turn pivots on shaft **78** such that due to gravity it will naturally rotate into a vertical orientation.

(28) Aperture plate **82** is configured to include pairs of parallel opposed apertures. In the illustrated embodiment these include a pair of vertically oriented elongate apertures **88***a*, **88***b* and a pair of horizontally oriented elongate apertures **90***a*, **90***b* (see FIG. **4**A), where the pairs of elongate apertures are oriented perpendicularly with respect to each other and are disposed about a central aperture **92** that in the illustrated embodiment is square. In a situation in which shaft **78** was parallel to the surface upon which vehicle **22** rests, apertures **90***a*, **90***b* would be aligned parallel to the surface and apertures **88***a*, **88***b* would be aligned perpendicular to the surface.

(29) In the illustrated embodiment distance sensors **86** are configured as time-of-flight ("ToF") sensors that are used to determine distances to features of the target adjustment frame **24**, as discussed in more detail below. Controller assembly **84** includes a controller, such as a microprocessor, and software for selective operation of sensor **86**, as well as includes an internal battery and a transmitter/receiver for wireless communication with controller **42**, such as by way of a Wi-Fi, Bluetooth, or other wireless communication format, which are contained within a housing, as shown in FIG. **4**. As also shown in FIG. **4**, assembly **84** may be provided with a control switch **94** for selectively powering the aperture assembly **76** on and off. Although distance sensors **86** are disclosed as ToF sensors, it should be appreciated that alternative distance sensors may be employed, such as laser distance sensors, or other conventional distance sensors.

(30) Referring now to FIGS. **5** and **6**, as previously noted target adjustment frame **24** movably supports target **26** and includes alignment housings **40***a*, **40***b* and controller **42**. Target adjustment frame **24** includes a base frame **96** having wheels **98** and leveler stops **100**. Base frame **96** in the illustrated embodiment is generally rectangular with various cross members, with wheels **98** being mounted to frame **96**. Leveler stops **100** are configured to be lowered to raise and level base frame **96** such that wheels **98** are no longer in contact with the floor surface whereby target adjustment frame **24** may remain stationary and level.

(31) Target adjustment frame **24** further includes a base member **102** that is moveable forwards and backwards via an actuator **104** along an X-axis, where base member **102** is mounted for sliding movement in rails **106** of base frame **96** and the X-axis is thus parallel to rails **106** for movement longitudinally relative to vehicle **22** when in the orientation of FIG. **1**. A tower assembly **108** and an imager housing support **110** are rotatably mounted to base member **102** via a bearing (not shown), with imager housings **40***a*, **40***b* being supported distally from one another on opposed ends of support **110**. The pivoting or rotatable mounting on base member **102** enable tower assembly **108** and imager housing support **110** to be simultaneously rotated about the vertical or Z-axis by way of actuator **112**, as well as translated or moved longitudinally by actuator **104** via movement of base member **102**. Due to imager housings **40***a*, **40***b* being mounted to support **110**, rotation of support **110** via actuator **112** will in turn cause housings **40***a*, **40***b* to rotate about the vertical axis. Moreover, in the illustrated embodiment the imager housings **40***a*, **40***b* are located equidistant from the rotational Z-axis.

(32) Tower assembly **108** in turn includes an upright frame member configured as a vertically oriented tower **114** with vertically oriented rails **116**, with a target support assembly **118** being mounted to rails **116** whereby the assembly **118** is moveable up and down in the vertical or Z-axis, where assembly **118** is moveable by way of actuator **120**. Target support assembly **118** is mounted to rails **116** for vertical movement, with a target mount **124** in turn being mounted to horizontal rail **122**. Target mount **124** is configured to hold target **26** and is horizontally moveable along rail **122** by way of actuator **126**.
(33) Target adjustment frame **24** further includes holders **128***a*, **128***b* for retaining the pairs of projector clamps **34** and aperture plate clamps **36** for respective sides of a vehicle when the clamps **34**, **36** are not in use. In particular, holders **128***a*, **128***b* comprise battery charging stations for recharging the batteries of clamps **34**, **36**, such as between uses.
(34) Actuators **104**, **112**, **120** and **126** are operably connected, such as by control wires, with controller **42** whereby controller **42** is able to selectively activate the actuators to move their associated components of target adjustment frame **24**. It should be appreciated that various constructions or types of actuators may be used for actuators **104**, **112**, **120** and **126** for movement of the various components of target adjustment frame **24**. In the illustrated embodiment, actuators **104**, **112**, **120** and **126** are constructed as electrical linear actuators. Alternatively, however, the actuators may be constructed as geared tracks, adjustment screws, hydraulic or pneumatic piston actuators, or the like. Still further, it should be appreciated that alternative arrangements of target adjustment frame and actuators may be employed for positioning of a target within the scope of the present invention. For example, base member **102** may be configured for lateral movement relative to base frame **96** and/or tower **108** may be configured for lateral movement relative to base member **102**.
(35) Details of imager housings **40***a*, **40***b* will now be discussed with reference to FIGS. **7-9**, where each imager housing **40***a* and **40***b* are substantially similar such that only one housing **40** is shown in FIGS. **7-9** and discussed herein. As understood from FIG. **7**, a digital imager or camera **38** is mounted to a rear wall **132** of housing **40**, where camera **38** comprises a CMOS device or the like. Housing **40** further includes a translucent or semitransparent front panel or image panel **134** having a front surface **136** and a back surface **138**, with camera **38** being directed at back surface **138**. As discussed in more detail below, the light planes **70***a*, **70***b* projected by laser **66** from projector clamps **34** pass through the apertures **88***a*, **88***b*, **90***a*, **90***b* and **92** of the aperture plates **82** of aperture plate clamps **36** and project onto front surface **136** of panel **134**, with camera **38** then imaging the projected light pattern **73** viewable by camera **38** on back surface **138** of panel **134** (FIG. **8**). Camera **38** in turn transmits signals regarding the images to controller **42**.
(36) Housing **40** further includes sides **140** and a moveable lid **142**, with panel **134** being configured to pivot downward about support **110**. Panel **134** is also connected to a calibration panel or grid **144**, whereby when panel **134** is rotated outwardly, calibration panel **144** is disposed in the fixed upright position in which panel **134** was previously disposed. (See FIG. **9**.) Calibration panel **144** may thus be used for calibrating camera **38**, such as with respect to the vertical and horizontal orientations and geometric spacings. As discussed in more detail below, this is then used in determining the orientation of the light projected on panel **134** from projector clamps **34**, which in turn is used in determining the orientation of vehicle **22** relative to target adjustment frame **24** whereby a target **26** mounted on target adjustment frame **24** may be oriented for calibration of sensors **30** on vehicle **22**.
(37) Descriptions of exemplary use and operation of vehicle target alignment system **20** may be understood with reference to FIG. **10**, which illustrates a process **146** including various steps for aligning a target held by target mount **124**, such as target **26** or another or additional target, relative to vehicle **22**, and in particular relative to sensors **30** of the vehicle **22** such that one or more sensors **30** of vehicle **22** may be calibrated/aligned.
(38) In an initial vehicle setup step **148** vehicle **22** may be prepared, such as by ensuring that tire

pressures are nominal and that the vehicle is empty. Step **148** may further include supplying or inputting information to an operator computer device **166** (FIG. **11**), such as by being input into a desktop, laptop or tablet by an operator or being obtained directly from a computer of vehicle **22**, such as an electronic control unit (ECU) of vehicle **22**. Such information may include information regarding specifics of the vehicle **22**, such as its make, model and/or other information regarding sensor systems on vehicle **22**, and/or include specific information regarding sensors **30** of vehicle **22**, the wheelbase dimensions of vehicle **22**, or other relevant information for performing calibration/alignment of sensors **30**. Still further, operator computer device **166** may prompt an operator as to which target to mount to target mount **124** for calibration of a given vehicle sensor **30**.

(39) As discussed herein, an operator may be provided a series of instructions for performing the ADAS calibration process **146** via operator computing device **166** provided with an operator interface, such as a graphical user interface ("GUI"). The instructions may be based on a flow chart that both requests information from the operator regarding the vehicle, such as make, model, VIN and/or details regarding equipment of the vehicle, such as tire and wheel size, types of vehicle options, including sensor options, as well as provides information to the operator regarding the system and vehicle setup for calibration of ADAS sensors. The provided instructions may also inform the operator how to mount and position equipment, as well as provide adjustments to the target adjustment frame **24**.

(40) At step **150** vehicle **22** and target adjustment frame **24** are nominally positioned with respect to each other such that vehicle **22** is generally longitudinally oriented relative to frame **24**, such as shown in either FIG. **1** in which vehicle **22** is facing forward toward frame **24** or in FIG. **10** in which vehicle **22** is directed rearward toward frame **24**. This nominal position may also include, for example, positioning vehicle **22** at a coarse alignment distance relative to frame **24**, such as by using a tape measure or other measuring device to obtain a coarse alignment of the target frame **24** to vehicle **22**, or by way of pre-established markings on a floor surface. In a particular aspect, this may include nominally positioning the target adjustment frame **24** relative to an axle of the vehicle **22** that is closest to target adjustment frame **24**. This step also includes orienting the front wheels of vehicle **22** in a straight-driving position. Sill further, distance sensors **86** of aperture wheel clamps **36***a*, **36***b* may be used to establish a nominal distance, as also referenced below.

(41) At step **152** projector clamps **34***a*, **34***b* are mounted to the wheel assemblies **32** of vehicle **22** that are furthest from target adjustment frame **24** and aperture plate clamps **36***a*, **36***b* are mounted to the wheel assemblies **32** that are closet to target adjustment frame **24**. Accordingly, in the orientation of FIG. **1** projector clamps **34***a*, **34***b* are mounted to the rear wheel assemblies **32** of vehicle **22**, and in the orientation of FIGS. **12-14** projector clamps **34***a*, **34***b* are mounted to the front wheel assemblies **32**, with aperture plate clamps **36***a*, **36***b* being mounted to the other wheel assemblies in each case.

(42) At step **154**, ToF sensors **86** of aperture plate clamps **36***a*, **36***b* on either side of vehicle **22** are activated, such as by way of a signal from controller **42** or by an operator manually activating assemblies **76**, such as by way of switches **94**. Sensors **86** are directed to generate and acquire signals regarding the distance between each of the aperture plate clamps **36***a*, **36***b* and the respective panels **134** of imager housings **40***a*, **40***b*, with distance information for both sides then being transmitted by the respective controller assemblies **84**, such as back to controller **42**.

(43) At step **156**, based on the acquired distance information of step **154**, controller **42** is operable to activate actuator **112** to rotate support **110** and thereby adjust the rotational orientation of imager housings **40***a*, **40***b* as required in order to square the housings **40***a*, **40***b* to the longitudinal orientation of vehicle **22**. Controller **42** is additionally operable to activate actuator **104** to adjust the longitudinal position of tower assembly **108** relative to the longitudinal orientation of vehicle **22** to a specific distance specified for the sensors **30** of vehicle **22** undergoing calibration, where this distance may be specified, for example, by the OEM procedures for calibration, such as

including based on the front axle distance to the target. As such each of the aperture plate clamps **36***a*, **36***b* will be at a predefined equidistance from its respective associated imager housing **40***a*, **40***b*, to thereby align the particular vehicle sensor **30** at issue to the target. It should be appreciated that distance measurements acquired via distance sensors **86** may be continuously acquired during the adjustments of support **110** and tower assembly **108** until the desired position is achieved in a closed-loop manner. Moreover, upon adjusting into the desired position the distance sensors **86** may be deactivated.

(44) At step **158**, lasers **66** of projector clamps **34***a*, **34***b* are activated, such as by way of a signal from controller **42** or by an operator manually activating projection assemblies **60**, such as by way of switches **72**. Each laser **66** generates a cross shaped pattern of light planes **70***a*, **70***b* directed at the aperture plates **82** of the respective aperture plate clamps **36***a*, **36***b*. When so aligned, the horizontal light planes **70***a* pass through the vertical apertures **88***a*, **88***b* to form light points or dots A**1** and A**2** on each panel **134**. Likewise, the vertical light planes **70***b* pass through the horizontal apertures **90***a*, **90***b* to form light points or dots B**1** and B**2** on each panel **134**. Moreover, a portion of the intersecting light planes **70***a*, **70***b* of each laser **66** pass through the central aperture **92** of the respective aperture plates **82** to form a cross pattern **71**. The dots A**1**, A**2** and B**1**, B**2**, as well as the cross pattern **71**, thus form a light pattern **73** on the panels **134**, which is viewable by camera **38** on surface **138** (FIG. **8**). It should be appreciated that alternative light patterns may be employed, such as may be generated by alternative light projectors and/or different aperture plates, for determining the orientation of the vehicle **22** relative to target adjustment frame **24**.

(45) At step **160**, the cameras **38** of each of the imager housings **40***a*, **40***b* image the back surfaces **138** of the respective panels **134** to obtain images of the light pattern formed on the panels **134** by the lasers **66** as the light planes **70***a*, **70***b* pass through the aperture plates **82**. The images taken by cameras **38** are transmitted to controller **42**, with controller **42** thus being able to define a proper orientation for the target mount **124**, and associated target **26**, relative to the current position of the vehicle. For example, controller **42** is able to determine the location of the vertical center plane of vehicle **22** relative to target adjustment frame **24** via the respective light patterns **73**. The controller **42** may first identify the dots A**1**, A**2** and/or B**1**, B**2**, including via use of the cross pattern **71** as a reference for identifying the imaged dots. Controller **42** may then resolve the relative location of dots A**1**, A**2** and/or B**1**, B**2** on each of the panels **134** based on the predetermined known calibration of camera **38** established via calibration panel **144**. For example, controller **42** may determine the center line location of vehicle **22** based on the known spacing of housings **40***a*, **40***b* relative to the Z-axis and the determination of the relative location of the dots A**1**, A**2** formed on panels **134**.

(46) In particular, various vehicle alignment parameters may be determined via light patterns **73**. For example, a rolling radius may be determined via the dots B**1**, B**2** and the known symmetrical spacing of apertures **90***a*, **90***b* relative to each other about the axis defined by shaft **78**, which is in alignment with the axis of the associated wheel assembly **32** to which the clamp **36** is mounted, thus enabling determination of the vertical radial distance from the floor to the axes of the front wheel assemblies **32** of vehicle **22**. The rolling radius value from both sides of the vehicle **22** may be obtained and averaged together. Rear toe values may also be obtained from dots B**1**, B**2** with respect to A**1**, A**2** via the vertical laser planes **70***b* passing through the horizontal apertures **90***a*, **90***b*, where a single measurement would be uncompensated for runout of the rear wheel assemblies **32**. In addition, the vehicle centerline value may be obtained via the dots A**1**, A**2** formed by laser planes **70***a* passing through the vertical apertures **88***a*, **88***b* on each side of the vehicle **22**.

(47) At step **162**, based on the acquired vehicle position or center plane information of step **160**, controller **42** is operable to activate actuator **126** to adjust the lateral orientation of the target mount **124**, and thus the target **26** mounted thereon, to a desired lateral position relative to vehicle **22**, and in particular relative to a particular sensor **30** of vehicle **22**. For example, a sensor **30** positioned on vehicle **22** may be offset from the vehicle centerline, with system **20** taking this into account, such as based on the vehicle make, model and equipped sensors by way of the information obtained at

process step **148** discussed above, whereby target **26** may be positioned in a specified position relative to the sensor **30**, such as specified by OEM calibration procedures. As such, system **20** may thus not only align the target **26** with respect not to the XYZ axis of the vehicle, but with respect to a sensor mounted on the vehicle.

(48) In addition to the above, the vertical height of target mount **124** is positioned via actuator **120** to be in a predefined height for a given sensor **30** of vehicle **22**, such as specified by an OEM calibration procedure. This height may be based on, for example, a vertical height above the floor surface upon which target adjustment frame **24** and vehicle **22** are positioned. Alternatively, a chassis height or fender height of vehicle **22** may be determined to further aid in orientating the target **26**. For example, the chassis or fender height may be determined, such as at multiple locations about vehicle **22**, such that an absolute height, pitch, and yaw of a vehicle mounted sensor may be determined, such as a LDW or ACC sensor. Any conventional method for determining a chassis or fender height of vehicle **22** may be used. For example, one or more leveled lasers may be aimed at targets magnetically mounted to vehicle **22**, such as to the fenders or chassis. Alternatively, a non-contact system may be used that does not utilize mounted targets, but instead reflects projected light off of portions of the vehicle itself.

(49) Finally, at step **164**, the calibration of sensors **30** of vehicle **22** may be performed, such as in accordance with the OEM calibration procedures. This may involve, for example, operator computing device **166** communicating signals to one or more ECUs of vehicle **22** to activate an OEM calibration routine, where the particular target required for calibration of a given vehicle sensor **30** has thus been properly positioned with respect for the sensor **30** in accordance with the calibration requirements.

(50) It should be appreciated that aspects of process **146** may be altered, such as in order, and/or combined and still enable calibration/alignment of sensors **30** in accordance with the present invention. For example steps **148** and **150**, or aspects thereof, may be combined. Still further, simultaneous operation of various steps may occur. This includes, as noted, the use of distance sensors **86** for determining a nominal distance, in which case wheel clamps **34**, **36** would be mounted to wheel assemblies **32**, whereby at least steps **150** and **152** may be combined.

(51) Further with regard to steps **160** and **162**, additional procedures and processing may be performed in situations in which it is desired or required to account for a thrust angle of the vehicle **22** during calibration of vehicle sensors. In particular, with regard to the orientation of FIG. **1**, with vehicle **22** facing forward toward target adjustment frame **24**, the rear axle thrust angle of the non-steering rear wheels may be addressed. To do so, in like manner as discussed above, camera **38** takes initial images of the light pattern formed on the back surfaces **138** of panels **134** by the lasers **66** as the light planes **70***a*, **70***b* pass through the aperture plates **82**, with the image data being transmitted to controller **42**. Subsequently, vehicle **22** is caused to move either forward or backward such that the wheel assemblies **32** rotate by 180 degrees. After vehicle **22** is moved, camera **38** takes additional images of the light pattern formed on the back surfaces **138** of panels **134** by the lasers **66** as the light planes **70***a*, **70***b* pass through the aperture plates **82**, with the image data also being transmitted to controller **42**. The runout-compensated thrust angle of vehicle **22** can be determined and accounted for by controller **42** based on the orientation of the vertically disposed dots B**1**, B**2** between the first and second images for each of the cameras **38** on either side of vehicle **22** based on the runout of the wheels **32** with respect to A**1**, A**2**.

(52) Accordingly, after the vehicle has been moved, a second vehicle centerline value is obtained via the horizontal laser planes **70***a* passing through the vertical apertures **88***a*, **88***b* from each of the left and right sides of the vehicle **22**. The second alignment measurement values additionally include determining second rear toe values via the vertical laser planes **70***b* passing through the horizontal apertures **90***a*, **90***b*, which values are uncompensated for runout of the rear wheel assemblies. Based on the first and second vehicle centerline values, runout-compensated alignment values are determined. This includes rear runout-compensated rear toe and thrust angles.

(53) Upon obtaining the alignment values the vehicle **22** is rolled into or back into the original starting calibration position such that wheel assemblies **32** rotate 180 degrees opposite to their original rotation, with cameras **38** again taking images of the light pattern. Controller **42** is thereby able to confirm that dots B**1**, B**2** have returned to the same position on panels **134** as in the original images. Alternatively, vehicle **22** may be located in an initial position and then rolled into a calibration position, such as to have 180 degrees of rotation of the wheel assemblies **32**, with the vehicle **22** thrust angle compensation determination being made based on images being taken in the initial and calibration positions. Upon determination of the thrust angle, the determined thrust angle may be used by controller **42** to compensate the specific position at which target **26** is positioned via controller **42** activating one or more of the actuators of target adjustment frame **24**. For example, the yaw of tower assembly **109** may be adjusted to compensate for the rear thrust angle. With the vehicle **22** properly aligned with the target frame **80**, and the rear thrust angle thus determined, calibration and alignment procedures may be carried out.
(54) Vehicle **22** may be rolled forward and backward, or vice versa, by an operator pushing the vehicle. Alternatively, target adjustment frame **24** may be provided with a carriage having arms engaged with conventional cradle rollers located on either side of the forward wheel assemblies, with such arms being extendable and retractable to move the vehicle the required distance, such as based on the tire size.
(55) Alignment and calibration system **20** may be configured to operate independently of external data, information or signals, in which case the computer system of the embodiment comprises the controller **42** that may be programmed for operation with various makes, models and equipped sensors, as well as may include the operator computer device **166**. In such a standalone configuration, as illustrated in FIG. **11**, operator computer device **166** may interface with vehicle **22**, such as via one or more ECUs **168** of vehicle **22** that may be interfaced via an on-board diagnostic (OBD) port of vehicle **22**, as well as with controller **42** to provide step-by-step instructions to an operator. Alternatively, operator computer device **166** may receive information input by an operator regarding vehicle **22**, such as make, model, vehicle identification number (VIN) and/or information regarding the equipped sensors, with device **166** communicating such information to controller **42**.
(56) Alternative to such a standalone configuration, FIG. **11** also discloses an exemplary embodiment of a remote interface configuration for system **20** where system **20** is configured to interface with a remote computing device or system **170**, such as a server, and one or more remote databases **172**, such as may be accessed via an Internet **174**, whereby the computer system thus further comprise the remote computing device **170**. For example, remote computing device **170** incorporating a database **172** accessed via the Internet, may be used to run a calibration sequence through one or more engine control units ("ECUs") of the vehicle **22** to calibrate one or more ADAS sensors pursuant to pre-established programs and methodologies, such as based on original factory-employed calibration sequences or based on alternative calibration sequences. In such a configuration, controller **42** need not contain programs related to setup parameters for particular makes, models and equipped sensors, nor is controller **42** required to perform data analysis from distance sensors **86** or cameras **38**. Rather, an operator may connect operator computer device **166** to an ECU **168** of vehicle **22**, with computer device **166** then transmitting acquired vehicle specific information to computing system **170**, or alternatively an operator may enter information directly into operator computer device **166** without connecting to vehicle **22** for transmitting to computing system **170**. Such information may be, for example, make, model, vehicle identification number (VIN) and/or information regarding the equipped sensors. Computing system **170** may then provide the necessary instructions to the operator based on specific procedures required to calibrate sensors as set forth in databases **172** and specific processing performed by computing system **170**, with control signals then transmitted to controller **42**. For example, computing system **170** may provide instructions to operator regarding the nominal position at which to locate vehicle **22** from target

adjustment frame **24** and regarding installation of the wheel clamps **34**, **36**.

(57) Computing system **170** may further send control signals to perform the alignment procedure. For example, computing system **170** may send control signals to controller **42** to activate actuator **120** to position the target mount **124** at the desired vertical height for the particular sensor **30** that is to be calibrated. Computing system **170** may also send control signals to controller **42**, with controller **42** selectively wirelessly activating distance sensors **86**, with the information obtained from distance sensors **86** in turn transmitted back to computing system **170**. Computing system **170** may then process the distance information and send further control signals to controller **42** for activating the actuators **104** and **112** for the yaw and longitudinal alignment, in like manner as discussed above. Upon confirmation of that alignment step, computing system **170** may then transmit control signals to controller **42** for activating lasers **66**, with controller **42** in turn transmitting image data signals to computing system **170** based on images of the light patterns formed on panels **134** detected by cameras **38**. Computing system **170** in turn processes the image data signals to determine a lateral alignment, and sends control signals to controller **42** for activating actuator **126** to achieve the predefined lateral positioning of the target held by target mount **124**.

(58) Databases **172** may thus contain information for performing calibration processes, including, for example, information regarding the specific target to be used for a given vehicle and sensor, the location at which the target is to be positioned relative to such a sensor and vehicle, and for performing or activating the sensor calibration routine. Such information may be in accordance with OEM processes and procedures or alternative processes and procedures.

(59) In either embodiment various levels of autonomous operation by system **20** may be utilized, such as with regard to automatically activating distance sensors **86** and/or light projectors **66** as compared to system **20** providing prompts to an operator, such as by way of operator computing device **166**, to selectively turn distance sensors **86** and/or light projectors **66** on and off. This applies to other steps and procedures as well.

(60) Referring now to FIGS. **12-14**, system **20** may additionally include an adjustable floor target assembly **180** integrated with target adjustment frame **24**. Floor target assembly **180** includes a mat **28** that is adjustably positionable about vehicle **22**, where mat **28** may include various targets **184** disposed directly on mat **28**, such as may be used for calibration of sensors configured as exterior mounted cameras on vehicle **22** that are disposed about vehicle **22**, such as cameras used for a conventional surround view system mounted in the bumpers and side view mirrors. In the illustrated embodiment, mat **28** of floor target assembly **180** additionally includes mounting locations or indicators **186** for locating targets that may be disposed on mat **28**, such as targets **188** that are configured as trihedrals mounted on posts for calibration of rear radar sensors on vehicle **22**.

(61) In the illustrated embodiment, floor target assembly **180** includes a pair of arms **190** that are securable to the imager housing support **110**, with arms **190** extending outwards toward vehicle **22** and being connected to and supporting a lateral rail **192**. A moveable rail **194** is disposed in sliding engagement with rail **192**, with rail **194** including a bracket **196** for selective connection with target mount **124** when target mount **124** is in a lowered orientation, as shown in FIG. **13**. Mat **28** in turn is connected to rail **194**, such as via fasteners or pegs. In the illustrated embodiment mat **28** is constructed of a flexible material such that it may be rolled up when not in use, and surrounds vehicle **22** and has an opening **198** wherein vehicle **22** is supported on the floor at opening **198**. Mat **28** may be constructed as a single integrated piece, or may be constructed as separate segments that are secured together.

(62) Accordingly, the above discussed process for aligning target mount **24** may be used to position mat **28** about vehicle **22** for calibration of sensors disposed on vehicle **22**, including based on known dimensions of mat **28** and locations of targets **180** on mat **28**. For example, vehicle **22** is initially nominally positioned relative to target frame **24** and wheel clamps **34**, **36** are attached to

vehicle **22**, with process **146** being employed to position arms **190** and rail **194** as required for calibration of a given sensor on a vehicle **22**, including via longitudinal and rotational movement of support **110** by actuators **104** and **112**, and laterally with respect to the longitudinal orientation of vehicle **22** by way of actuator **126** that moves target mount **124** along rail **122**, where movement of target mount **124** will in turn cause rail **194** to slide along rail **192**. Mat **28** may then be secured to rail **194** and rolled out around vehicle **22**. Alternatively, mat **28** may be moved by being dragged along the floor into a desired orientation. Upon mat **28** being positioned into a desired orientation, mat **28** may also be checked, such as by an operator, to be sure its sides disposed on either side of vehicle **22** are parallel to each other. For example, as understood from FIG. **13**, lasers **187** may be mounted to rail **192** and/or rail **194**, with lasers **187** being square thereto. Lasers **187** may be configured for alignment with a straight edge of mat **28** whereby an operator may activate lasers **187** to check and adjust as necessary that mat **28** is properly square relative to target adjustment frame **24**.

(63) As noted, mat **28** may also include locators **186** for positioning of targets, such as targets **188**. Locators **186** may comprise receptacles in the form of cutouts in mat **28** or printed markings on mat **28** for indicating the correct positional location for placement of targets **188**. Still further, locators **186** may comprise embedded receptacles in the form of fixtures, such as pegs, or grooves, or the like, to which targets **188** may connect. Still further, instead of mat **28**, or in addition to mat **28**, a target assembly may be equipped with rigid arms **189** (FIG. **14**), with the arms **189** extending between a moveable rail, such as rail **194**, and a target, such as target **188**. As such, the alignment and calibration system **20** may be used to position alternative targets about vehicle **22**.

(64) An alternative floor target assembly as compared to assembly **180** may be employed within the scope of the invention. For example, a sliding rail such as sliding rail **194** may be provided with telescoping ends to increase its length, such as to accommodate differently sized mats. Still further, a sliding rail may be configured for lateral movement in an alternative manner than by way of connection to target mount **124** and actuator **126**. For example, an actuator may alternatively be mounted to arms **190** extending from support **110**.

(65) FIGS. **12-14** additionally illustrate that system **20** may be used in connection with calibration of non-forward facing sensors, whereby a vehicle such as vehicle **22** may be oriented rearwardly relative to target adjustment frame **24**. In such an orientation projector wheel clamps **34***a*, **34***b* are mounted to the front wheel assemblies **32** of vehicle **22**, and aperture plate wheel clamps **36***a*, **36***b* are mounted to the rear wheels, with the light projectors **66** oriented to project toward imager housings **40***a*, **40***b* on target adjustment frame **24**. This orientation may be used for the calibration of ADAS sensors configured as rear cameras, rear radar, and the like.

(66) With reference to FIG. **15**, in another aspect of the present invention, an ADAS calibration system may be employed with a non-contact wheel alignment system **250**, such as supplied by Burke E. Porter Machinery Co. of Grand Rapids, Michigan, for determining the vehicle position as well as wheel alignment information, with such data supplied to controller **42** or a remote computing system **170** for controlling the target position to a target adjustment frame, such as frame **24**. In such an embodiment, the target adjustment frame **24** need not include imager housings **40***a*, **40***b* or camera **38**, and likewise wheel clamps **34**, **36** would not be employed.

(67) Non-contact wheel alignment system **250** is positioned adjacent a target adjustment frame, where vehicle **260** may either face the target adjustment frame forwardly or rearwardly depending on the specific sensor to be calibrated. In the illustrated embodiment of FIG. **15** non-contact wheel alignment system **250** is constructed in accordance with U.S. Pat. Nos. 7,864,309, 8,107,062 and 8,400,624, which are incorporated herein by reference. As shown, a pair of non-contact wheel alignment ("NCA") sensors **252***a*, **252***b* are disposed on either side of a tire and wheel assembly **258** of vehicle **260**. NCA sensors **252***a*, **252***b* project illumination lines **264** onto either side of the tire, with left side **266***a* shown. NCA sensors **252***a*, **252***b* receive reflections of illumination lines **264**, by which system **250** is able to determine the orientation of the tire and wheel assembly **258**.

Although not shown, corresponding NCA sensors **252***a*, **252***b* would be positioned about all four tire and wheel assemblies **258** of vehicle **260** whereby vehicle position information can be determined by system **250**, which may be based on a known orientation of the sensors NCA sensors **252***a*, **252***b* disposed about vehicle **260** in a stand of the system **250**. As noted, the wheel alignment and vehicle position information is provided to a controller, such as controller **42**, or to a remote computing device, such as computing device **170**, such as via the Internet. In response to the wheel assembly alignment and vehicle position information, the controller or remote computing device may then operatively in response send signals to the controller **42** for activating the various actuators **104**, **112**, **120** and **126** to position a target relative to a sensor of a vehicle. It should be appreciated that alternative NCA sensors relative to sensors **252***a*, **252***b* may be employed.

(68) In the illustrated embodiment non-contact wheel alignment system **250** comprises a stand having rollers **269** disposed at each of the wheel assemblies **258** of vehicle **260**, whereby wheel assemblies **258** may be rotated during the alignment and position analysis while vehicle **260** remains stationary. It should be appreciated, however, that alternative non-contact wheel alignment systems may be employed, including systems utilizing stands upon which a vehicle remains stationary and the wheel alignment and vehicle position information is measured at two separate locations, as well as drive-through non-contact alignment systems in which the vehicle position is determined. For example, alignment of a target in front of a vehicle for calibration of vehicle sensors may be performed using a system for determining wheel alignment and vehicle position based on movement of a vehicle past a vehicle wheel alignment sensor, which systems are known in the art. Based on vehicle orientation and alignment information from such sensors a controller may determine a location for placement or positioning of a target adjustment frame, as disclosed above. For example, the vehicle may be driven along or by such sensors located on either side of the vehicle and come to a stop within the sensor field whereby the controller is able to position the target frame at the appropriate location relative to the vehicle. Such drive-through systems are known in the art.

(69) With reference to FIG. **16**, a vehicle target alignment system **300** is illustrated employing alternative NCA sensors **550** attached to a lift **321**. A target adjustment frame is schematically illustrated at **324**, where target adjustment frame **324** may be configured in like manner to target adjustment frame **24** discussed above. As shown, target adjustment frame **324** is mounted to rails **325** for longitudinal movement relative to lift **321** and to vehicle **322** disposed on lift **321**. FIG. **16** additionally illustrates the inclusion of a combined controller and operator computing device **345** for use by an operator **347**. In use, vehicle **322** is driven onto stand **349** of lift **321** when lift **321** is in a lowered orientation. Vehicle **322** is then positioned into an initial position and NCA sensors **550** are used to determine wheel alignment of vehicle **322** as well as position of vehicle **322** on stand **349**. Vehicle **322** may then be positioned into a second position or calibration orientation, such as by rolling vehicle **322** whereby the wheels turn 180 degrees. NCA sensors **550** are then again used to determine wheel alignment of vehicle **322** as well as position of vehicle **322** on stand **349**. The two sets of determinations enable system **300** to determine runout-compensated thrust angle of vehicle **322**, where by a target on target adjustment frame **324** may be positioned into a desired orientation for calibration. It should be appreciated that the mounting of frame **324** on rails **325** enables frame **324** to have greater movement relative to vehicle **322** when used with lift **321**, which is beneficial due to the fixed orientation of vehicle **322** on lift **321** whereby frame **324** may be positioned as required based on the particular sensor and vehicle make and model procedures specified therefor, such as specified by an OEM. It should be further understood that although lift **321** is shown in an elevated orientation in FIG. **16**, lift **321** would be lowered to be generally planar with target adjustment frame **324** when used for calibration of sensors on vehicle **321**. Lift **321** may be used, for example, in a repair facility whereby an operator **347** may be able to conveniently perform additional operations on vehicle **321**, such as adjustment of the alignment of vehicle **321** based on the alignment information from NCA sensors **550**.

(70) Accordingly, the target alignment and sensor calibration system of the present invention may employ alternative vehicle orientation detection systems, including NCA sensors, such as sensors **252***a*, **252***b* or cooperative wheel clamps with light projectors, such as clamps **34**, **36** and imagers **38**, with the vehicle orientation detection systems providing information regarding the orientation of a vehicle relative to a target adjustment frame whereby the target adjustment frame selectively positions a target relative to the vehicle, and in particular relative to a sensor of the vehicle.
(71) It should further be appreciated that system **20** may include variations in the construction and operation within the scope of the present invention. For example, target mount **124** or an alternatively constructed target mount may simultaneously hold more than one target, in addition to being able to hold different targets at separate times. Still further, target mount **124** may hold a target configured as a digital display or monitor, such as an LED monitor, whereby such a digital monitor may receive signals to display different target patterns as required for specific sensor calibration processes. Moreover, target adjustment frame may optionally or alternatively include a passive ACC radar alignment system configured for aligning the ACC radar of a vehicle. This may comprise, for example, a modified headlight alignment box having a Fresnel lens mounted to the target stand or frame, with the alignment box configured to project light onto a reflective element of an ACC sensor of the vehicle, with the projected light being reflected back to the alignment box. Alternatively configured wheel clamp devices may be used relative to wheel clamps **34** and **36**. For example, projection assembly **60** and aperture assembly **76** may be incorporated into a known conventional wheel clamp, or other wheel clamp specifically constructed to mount in a known orientation to a wheel assembly.
(72) Still further, although system **20** and vehicle **22** are shown and discussed as being disposed on a floor in the illustrated embodiment, such as a floor of a repair facility or vehicle dealership, system **20** may alternatively employ a rigid plate, such as a steel plate upon which the target adjustment frame **24** and vehicle **22** are disposed to promote a flat, level surface for alignment and calibration. Moreover, in the illustrated embodiment of FIG. **1**, the target adjustment frame **24** is shown to be approximately of the same width as vehicle **22**. In an alternative embodiment, a target adjustment frame may be configured to have extended lateral movement, such as by being mounted to the floor via lateral rails to enable the frame to traverse across or relative to multiple vehicles. For example, an ADAS alignment system may be disposed within a repair facility having multiple bays with the extended lateral movement thereby enabling a target to be selectively positioned in front of multiple vehicles. Such a configuration may also aid in throughput of the vehicles through a facility, with one vehicle being readied for ADAS calibration while another is undergoing calibration. In another alternative embodiment, a base frame of a target adjustment frame is mounted to the floor on longitudinal rails to enable greater longitudinal positioning of the target adjustment frame, with such longitudinal rails being used for nominal longitudinal adjustment relative to a vehicle.
(73) Further changes and modifications in the specifically described embodiments can be carried out without departing from the principles of the present invention which is intended to be limited only by the scope of the appended claims, as interpreted according to the principles of patent law including the doctrine of equivalents.

Claims

1. A system for aligning a target to a vehicle for calibration of a sensor equipped on the vehicle, said system comprising: a vehicle stand upon which a vehicle is configured to be positioned; a target adjustment frame movably mounted to a rail with said rail extending longitudinally with respect to said vehicle stand and to a longitudinal axis of the vehicle when positioned on said vehicle stand, said target adjustment frame including a base frame movably mounted to said rail, a target mount moveably mounted on said target adjustment frame with said target mount configured

to support a target, said target adjustment frame further including a plurality of actuators configured to selectively move said target mount relative to said base frame; a computer system, said computer system configured to selectively actuate said actuators to position said target relative to the vehicle positioned in front of said target adjustment frame, with said target mount being moveable by said actuators vertically and laterally with respect to the longitudinal axis of the vehicle when positioned in front of said target adjustment frame; wherein said target adjustment frame is moved on said rail into a longitudinal orientation relative to the vehicle and said computer system selectively actuates said actuators to position said target based on a known orientation of the vehicle on said vehicle stand to position said target relative to a sensor of the vehicle whereby the sensor is able to be calibrated using the target.

2. The system of claim 1, wherein said rail comprises a pair of rails to which said target adjustment frame is movably mounted for longitudinal movement relative to the longitudinal axis of the vehicle when positioned on said vehicle stand.

3. The system of claim 1, wherein said base frame comprises a base member and said target adjustment frame comprises a tower coupled to said base member with said target mount supported by said tower, and wherein said actuators are configured to move said target mount vertically and laterally relative to said tower.

4. The system of claim 3, further including a target mount rail disposed on said tower and wherein said actuators comprise a first target mount actuator and a second target mount actuator, wherein said first target mount actuator is operable to move said target mount laterally along said target mount rail and said second target mount actuator is operable to adjust the vertical orientation of said target mount.

5. The system of claim 4, wherein said computer system comprises a controller configured to selectively actuate said first target mount actuator and said second target mount actuator.

6. The system of claim 1, further comprising non-contact wheel alignment sensors disposed on said vehicle stand, wherein said non-contact wheel alignment sensors are operable to determine the position of the vehicle relative to said non-contact wheel alignment sensors.

7. The system of claim 1, wherein said vehicle stand comprises a lift configured to selectively raise and lower the vehicle.