Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3045999 C 2023/10/10

(11)(21) **3 045 999**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2019/06/11
(41) **Mise à la disp. pub./Open to Public Insp.:** 2020/01/12
(45) **Date de délivrance/Issue Date:** 2023/10/10
(30) **Priorité/Priority:** 2018/07/12 (US16/033,438)

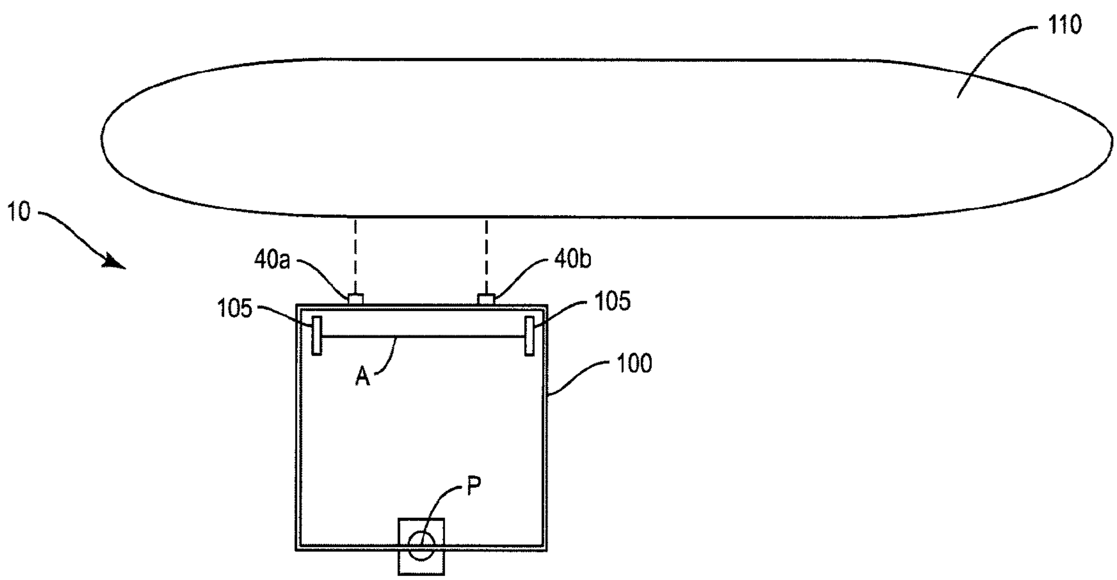
(51) **Cl.Int./Int.Cl.** *E04G 1/24* (2006.01), *B64F 1/315* (2006.01), *E04G 1/15* (2006.01), *E04G 1/18* (2006.01)

(72) **Inventeurs/Inventors:**
RICHARDS, CHARLES M., US;
TROY, JAMES J., US;
MOORE, STEPHEN G., US;
WEBSTER, KURT F., US

(73) **Propriétaire/Owner:**
THE BOEING COMPANY, US

(74) **Agent:** SMART & BIGGAR LP

(54) Titre : SYSTEME DE DEPLACEMENT DE LA PLATE-FORME DE TRAVAIL
(54) Title: WORK PLATFORM MOVER SYSTEM



(57) **Abrégé/Abstract:**
A mover system that moves a work platform relative to a target object. The mover system includes a drive vehicle configured to be attached to the work platform. Sensors are attached to the work platform that detect a distance between the sensors and the target object. Signals from the sensors are used to determine an alignment angle used for the operation of the drive vehicle to move the work platform into alignment and spacing relative to the work object.

ABSTRACT

A mover system that moves a work platform relative to a target object. The mover system includes a drive vehicle configured to be attached to the work platform. Sensors are attached to the work platform that detect a distance between the sensors and the target object. Signals from the sensors are used to determine an alignment angle used for the operation of the drive vehicle to move the work platform into alignment and spacing relative to the work object.

WORK PLATFORM MOVER SYSTEM

TECHNOLOGICAL FIELD

The present application is directed to a system for moving a work platform relative to a target object and, more particularly, to a system with a drive vehicle that is controlled based on real-time sensor feedback to calculate a distance and alignment of a work platform relative to a target object.

BACKGROUND

Many industrial settings use a work platform to position operators and/or equipment relative to a target object, such as a work piece. The work platform is often large to support multiple operators and/or equipment. Further, the platform can have large dimensions to position the operators and/or equipment relative to a large target object. One use is a work platform for use with a large commercial aircraft. The work platform can have a height in excess of twenty feet to perform various operations on the aircraft.

Current methods of moving and positioning a work platform include workers manually pushing and pulling the work platform. Because of the large size and weight of the work platform, this movement is often difficult and requires multiple of

CA 3045999 2019-06-11

workers. Workers can potentially become injured due to the large forces necessary to move and position the work platforms.

It is often difficult for workers to accurately position the work platform relative to the target object. If the work platform is not properly positioned relative to the target object such as being too far away or spaced away from the desired position, it may be difficult for the workers and/or equipment to work on the target object. Another issue with manually moving the work platforms is the potential for damaging the target object. The work platforms can accidentally run into the target object during the movement. This is particularly likely when the work platform is required to be in very close position relative to the target object which is often required during various manufacturing processes.

SUMMARY

In one embodiment, there is provided a method of aligning a work platform relative to a stationary target object, the method comprises: attaching a drive vehicle to the work platform; receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object; and moving the work platform with the drive vehicle based on the signals and aligning the work platform relative to the target object and reducing a distance between the work platform and the target object.

The method may further comprise calculating based on the signals a target object angle between the work platform and the target object.

The method may further comprise sensing an angle of a forward motion of the drive vehicle relative to a longitudinal centerline of the work platform and adjusting a position of the drive vehicle relative to the work platform based on the angle.

The method may further comprise storing in a memory circuit on the drive vehicle distance variables of the first and second sensors and dimensional aspects of the work platform and an attachment location of the drive vehicle relative to the work platform.

The method may further comprise operating the drive vehicle and moving the work platform through a control unit prior to receiving signals from the first and second sensors.

The method may further comprise after attaching the drive vehicle to the work platform, elevating a section of work platform and limiting a number of wheels of the work platform that remain in contact with a work surface, the wheels remaining in contact with the work surface forming a wheel rotation axis about which the work platform turns while being moved by the drive vehicle.

CA 3045999 2019-06-11

The method may further comprise receiving the signals from the first and second sensors with the signals comprising raw sensor data.

The method may further comprise adjusting an angular position of the drive vehicle relative to the work platform while moving the work platform with the drive vehicle with respect to the target object.

The method may further comprise stopping the drive vehicle when the work platform is aligned with the target object and is spaced a predetermined distance away from the target object.

In another embodiment, there is provided a method to align a work platform relative to a stationary target object, the method comprising: attaching a drive vehicle to the work platform at a pivot point (P); receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object; calculating based on the signals a target object angle (α) between the work platform and the target object; calculating based on rotational sensor signals a drive vehicle angle (ß) between a forward movement direction of the drive vehicle and a longitudinal centerline of the work platform; and calculating the target object angle (α) and the drive vehicle angle (ß) while moving the work platform with the drive vehicle towards the target object and based on the target object angle (α) and the drive vehicle angle (ß) completing a rotational aspect of a motion path of the work platform prior to reaching a zero offset distance between the work platform and the target object.

The method may further comprise, based on the rotational sensor signals, adjusting an angular position of the drive vehicle relative to the work platform at the pivot point (P) while moving the work platform with respect to the target object.

The method may further comprise stopping the drive vehicle based on sensor data when the work platform reaches the zero offset distance.

The method may further comprise elevating a section of the work platform above a work surface such that a limited number of wheels of the work platform remain in contact with the work surface.

The method may further comprise extending a lift mechanism on the drive vehicle relative to a body of the drive vehicle and elevating the section of the work platform.

In another embodiment, there is provided a system to align a work platform relative to a stationary target object, the system comprises a drive vehicle. The drive vehicle comprises: a body; drive members attached to the body; a mount pivotally attached to the body, the mount configured to attach to the work platform; a processing circuit configured to control movement of the drive vehicle; a first sensor attached to the work platform at a first position, the first sensor configured to detect a first distance

CA 3045999 2019-06-11

at the first position between the work platform and the target object; a second sensor attached to the work platform at a second position that is spaced away from the first position, the second sensor configured to detect a second distance at the second position between the work platform and the target object; a rotation sensor to sense an angle of the work platform relative to the drive vehicle; and the processing circuit configured to receive signals from the first and second sensors and the rotation sensor and based on the signals to control movement of the drive vehicle to adjust a spacing and alignment between the work platform and the target object.

The system may further comprise a lift mechanism attached to the body and to the mount, the lift mechanism configured to elevate the mount relative to the body to lift a section of the work platform. The lift may transfer a load from the work platform onto the drive vehicle to increase traction of the wheels of the drive vehicle.

The processing circuit may calculate based on the signals from the first and second sensors a target object angle that is an angle between the work platform and the target object.

The processing circuit may calculate based on readings from the rotation sensor on the drive vehicle a drive vehicle angle that is an angle between a first line extending in a forward movement direction of the drive vehicle from a pivot point with the work platform and a second line extending from the pivot point and being perpendicular to a wheel rotation axis of the work platform and parallel to a longitudinal centerline of the work platform.

The system may further comprise a display mounted to the work platform and comprising at least one row of lights, the display illuminates one or more of the lights based on the signals received from the first and second sensors.

The system may further comprise a control unit that communicates with the processing circuit and control the drive vehicle based on signals received from the control unit.

In one embodiment, there is provided a method of aligning a work platform relative to a stationary target object. The method comprises: attaching a drive vehicle to the work platform; receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object; moving the work platform with the drive vehicle based on the signals; sensing an angle of a vector indicating a forward motion of the drive vehicle relative to a line extending along a longitudinal centerline of the work platform from a pivot point; and adjusting the drive vehicle relative to the work platform based on the angle to align the work platform relative to the target object and reduce a distance between the work platform and the target object.

Date Reçue/Date Received 2022-12-16

In another embodiment, there is provided a method to align a work platform relative to a stationary target object. The method comprises: attaching a drive vehicle to the work platform at a pivot point (P); receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object; calculating, based on the signals, a target object angle (α) between the work platform and the target object while moving the work platform with the drive vehicle; calculating, based on rotational sensor signals, a drive vehicle angle (ß) between a forward movement direction of the drive vehicle and a longitudinal centerline of the work platform while moving the work platform with the drive vehicle; and completing, based on the target object angle (α) and the drive vehicle angle (ß), a rotational aspect of a motion path of the work platform prior to reaching a zero offset distance between the work platform and the target object.

In another embodiment, there is provided a system to align a work platform relative to a stationary target object. The system comprises a drive vehicle comprising: a body; at least one drive member attached to the body; and a mount pivotally attached to the body, the mount configured to attach to the work platform. The system further comprises: a first sensor attached to the work platform at a first position, the first sensor configured to detect a first distance at the first position between the work platform and the target object; a second sensor attached to the work platform at a second position that is spaced away from the first position, the second sensor configured to detect a second distance at the second position

Date Reçue/Date Received 2022-12-16

between the work platform and the target object; a rotation sensor to sense an angle between a longitudinal centerline of the work platform relative to a forward movement direction of the drive vehicle; and a processing circuit configured to receive signals from the first sensor, the second sensor and the rotation sensor and to control movement of the drive vehicle to adjust a spacing and alignment between the work platform and the target object based on the signals.

In another embodiment, there is provided a system to align a work platform relative to a stationary target object. The system comprises: a drive vehicle comprising a body, a mount configured to attach to the work platform, and a lift mechanism to elevate the mount relative to the body; sensors that are spaced apart and configured to detect distances between the work platform and the target object; a rotation sensor to detect an angle between a longitudinal centerline of the work platform relative to a forward movement direction of the drive vehicle; and a processing circuit configured to receive signals from the sensors and the rotation sensor and to control movement of the drive vehicle based on the signals while the lift mechanism elevates the mount above the body to adjust a spacing and alignment between the work platform and the target object.

The features, functions and advantages that have been discussed can be achieved independently in various aspects or may be combined in yet other aspects further details of which can be seen with reference to the following description and the drawings.

Date Reçue/Date Received 2022-12-16

BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1** is a schematic diagram illustrating a top view of a mover system to position a work platform relative to a target object.

Figure **2** is a rear perspective view of a drive vehicle attached to a work platform.

Date Reçue/Date Received 2022-12-16

Figure **3** is a schematic diagram of a drive vehicle.

Figure **4** is a schematic side view of a drive vehicle attached to and elevating a work platform.

Figure **5** is a schematic diagram of a mover system.

Figure **6** is a schematic diagram of a display with lights.

Figures **7**A-**7**B are schematic diagrams of a display with lights.

Figures **8**A-**8**C are schematic diagrams of a display with lights.

Figure **9** is a schematic diagram illustrating a top view of a mover system positioning a work platform relative to a target object.

Figure **10** is a schematic diagram illustrating a top view of a mover system positioning a work platform relative to a target object.

Figure **11** is a schematic diagram illustrating a top view of a mover system positioning a work platform relative to a target object.

CA 3045999 2019-06-11

Figure **12** is a flowchart diagram of a method of using a mover system to align and position a work platform relative to a target object.

Figure **13** is a perspective view of a work platform.

Figure **14** is a top view of work platforms located at an aircraft.

Figure **15** is a schematic diagram illustrating a top view of multiple drive vehicles attached to a work platform to position and align the work platform relative to a target object.

DETAILED DESCRIPTION

The present application is directed to a mover system that moves a work platform relative to a stationary target object. The mover system includes a drive vehicle configured to be attached to the work platform. Sensors are attached to the work platform and detect a distance between the sensors and the target object. Signals from the sensors are used to determine the alignment angle used for the operation of the drive vehicle to align and move the work platform relative to the work object.

Figure **1** schematically illustrates a mover system **10** for moving a work platform **100** relative to a stationary target object **110**. The mover system **10** includes a drive vehicle **20** that attaches to the work platform **100**. The drive vehicle **20** is configured

CA 3045999 2019-06-11

to move the work platform **100** about a pivot point along a wheel rotation axis A of the work platform **100** that extends between wheels **105** on the platform **100**. The drive vehicle **20** is further configured to receive signals from sensors **40** indicating distances that the work platform **100** is spaced away from the target object **110**. The drive vehicle **20** processes the distance information to determine spacing and alignment to steer the work platform **100** relative to the stationary target object **110**.

Figure **2** illustrate a drive vehicle **20** attached to a work platform **100**. Figure **3** schematically illustrates the components of the drive vehicle **20**. The drive vehicle **20** includes a body **21** with a mount **22** configured to pivotally attach to the work platform **100**. Fasteners **103** can attach the mount **22** to the work platform **100**. In one design, the mount **22** includes a pair of plates that are pivotally connected together. Another design includes the mount **22** pivotal about a fastener that attaches the mount **22** to the body **21**. Yet another design includes a gimbal connection between the mount **22** and the body **21**. The pivoting connection forms a pivot point P that provides for the drive vehicle **20** to be positioned at different angular orientations relative to the work platform **100**. This provides for the drive vehicle **20** to adjust the angular position of the work platform **100** relative to the target object **110**. A rotation sensor **28** such as an absolute encoder or a potentiometer senses an angle at the pivot point P formed between the mount **22** and/or work platform **100** and the body **21**. The angle can include a yaw axis angle which is the rotation about a vertical axis that extends through the pivot point P.

Date Reçue/Date Received 2022-12-16

A lift mechanism **27** on the drive vehicle **20** can selectively adjust a vertical position of the mount **22** relative to the body **21**. The lift mechanism **27** provides for lifting a section of the work platform **100** above the work surface **99**. As illustrated in Figure **4**, this can elevate one or more wheels **104** of the work platform **100** above the work surface **99**. One or more wheels **105** of the work platform **100** remain in contact with the work surface **99** and form the wheel rotation axis A of the work platform **100** used for steering the work platform **100**. The lift mechanism **27** can include an extendable arm with a telescoping, scissor, and/or pivoting configuration to move between a retracted position and an extended position. In the retracted position, the drive vehicle **20** can be moved underneath the work platform **100** to align and connect the mount **22**. In the extended position, the mount **22** and section of the work platform **100** are elevated. The lift mechanism **27** can be pneumatically powered for movement between the extended and retracted positions.

The drive vehicle **20** also includes drive members **23** for movement across the work surface **99**. The drive members **23** can include wheels or can include continuous tracks that are configured to directly contact against the work surface **99**. The drive members **23** equipped with wheels can be configured as omni wheels, mecanum wheels, and swerve drive wheel modules for multi-axis movement.

The drive vehicle **20** includes one or more motors **25** to provide power to one or more of the drive members **23**. This power drives the drive vehicle **20** to move the work platform **100** across the work surface **99**. A gear train can extend between the motor **25** and the drive members **23**. The drive vehicle **20** can include a single motor **25** that powers one or more of the drive members **23**, or two or more motors **25** that each power one or more of the drive members **23**. A power source **26** such as a rechargeable battery provides power to the motor **25** and other components on the drive vehicle **20**. Power source **26** can also include a solar panel to recharge the power source **26**.

The drive vehicle **20** also includes one or more processing circuits (shown as processing circuit **31**) that can include one or more microprocessors, Application Specific Integrated Circuits (ASICs), or the like, configured with appropriate software and/or firmware. A computer readable storage medium (shown as memory circuit **32**) stores data and computer readable program code that configures the processing circuit **31** to implement the techniques used to align the work platform **100**. Memory circuit **32** is a non-transitory computer readable medium, and may include various memory devices such as random access memory, read-only memory, and flash memory.

An operator interface **33** includes one or more user input devices such as a keypad, touchpad, function keys, scroll wheel, gamepad, joystick, or other type of computer input device. The operator interface **33** can include a display screen, such as a conventional liquid crystal display (LCD) or touch screen display which also functions as a user input device.

A system interface **34** is configured to communications with a remote control unit **60** that is used by an operator to control the drive vehicle **20**. The system interface **34** includes a transceiver configured to wirelessly communicate with the remote control unit **60**. The system interface **34** can also provide for hardwire connection with the remote control unit **60**. The system interface **34** can also communicate with other remote components, such as a system control unit that oversees multiple different aspects of the manufacturing process. The system interface **34** can also provide for the supply of power from a remote source. This power supply can be used to recharge the power source **26** and/or provide power to one or more the components on the drive vehicle **20**.

Figure **4** illustrates the drive vehicle **20** attached to the work platform **100**. The mount **22** is attached to the work platform **100** and is elevated above the body **21** by the lift mechanism **27**. This positioning elevates one or more wheels **104** of the work platform **100** above the work surface **99**. This positioning maintains the wheels **105** on the work surface **99** and provides the wheel rotation axis A of the work platform **100** that provides for moving the work platform **100** by the drive vehicle **20**. Lifting the work platform **100** also applies a load to the drive vehicle **20**. This load can increase the traction of the drive members **23**against the work surface **99**.

The mover system **10** also includes sensors **40** that detect the distance between the work platform **100** and the target object **110**. One design includes a pair of sensors

CA 3045999 2019-06-11

40 spaced apart along the work platform **100** to detect distances at different sections of the work platform **100**. Other designs can include three or more sensors **40**.

As illustrated in Figures **1** and **4**, the sensors **40** are configured to be positioned along an edge **109** of the work platform **100** that faces the target object **110**. Each sensor **40** can include an attachment member **41** to attach to the work platform **100**. The attachment members **41** can receive fasteners to secure the sensors **40** to the work platform **100**. The sensors **40** are further configured to be attached to different locations along the edge **109** of the work platform **100**. This spacing provides for each sensor **40** to detect the distance of different sections of the work platform **100** away from the target object **110**.

A variety of different sensors **40** can be used to detect the distance between the work platform **100** and the target object **110**. Sensors **40** can include Lidar sensors with an emitter and a receiver. The emitters emit a pulsed laser light with the receiver configured to receive reflected pulses. The sensors **40** can also use various other sensing technologies, including but not limited to ultrasonic distance sensors or radar-based distance measurement sensors. The different sensors **40** that are attached to the work platform **100** can include the same or different sensing technologies.

As illustrated in Figure **5**, a processing circuit **42** can be associated with each sensor **40**. The processing circuits **42** can include one or more microprocessors, Application Specific Integrated Circuits (ASICs), or the like, configured with appropriate software and/or firmware. A computer readable storage medium (shown as memory circuit **43**) stores data and computer readable program code that configures the processing circuit **42** to implement the techniques used during the functioning of the sensors **40**. Each memory circuit **43** is a non-transitory computer readable medium, and may include various memory devices such as random access memory, read-only memory, and flash memory. Each processing circuit **42** receives signals from their respective sensor **40** and determines a distance between the sensor **40** and the target object **110**. This information is then signaled to the processing circuit **31** to control the movement of the drive vehicle **20**. The processing at the sensors **40** increases the response rate of the drive vehicle **20** to adjust the position and/or speed of the drive vehicle **20** during movement of the work platform **100**. Additionally or alternatively, the processing circuit **31** at the drive vehicle **20** can receive raw sensor data and calculate a distance between the sensors **40** and the target object **110**. In one design, there are no processing circuits **42** or memory circuits **43** associated with the sensors **40** as the raw sensor signals are received by the processing circuit **31** that performs the distance calculations. In one design, the sensors **40** provide a limited amount of processing of the sensor data. Processing circuit **31** performs additional processing on the data.

A control unit **60** can be used by an operator to remotely control the drive vehicle **20**. The control unit **60** can include on/off, direction control, speed control, positioning of the lift mechanism **27**, and other functions. The control unit **60** can include one or

CA 3045999 2019-06-11

more user input devices such as a keypad, touchpad, function keys, scroll wheel, gamepad, joystick, or other type of computer input device. The control unit **60** can also include a display screen, such as a conventional liquid crystal display (LCD) or touch screen display which also functions as a user input device. The control unit **60** can provide a wireless transceiver for communication with the processing circuit **31** through the system interface **34**. Additionally or alternatively, the control unit **60** can be hardwired to communicate with the drive vehicle **20**.

The mover system **10** provides for operator control of the drive vehicle **20** and automatic control of the drive vehicle **20**. Operator control occurs through the control unit **60**. Automatic control provides for the processing circuit **31** to control the drive vehicle **20** in a real-time basis based on inputs from the sensors **40**.

To facilitate operator control, a display **50** provides a visual indication of the alignment and/or proximity of the work platform **100** to the target object **110**. As illustrated in Figure **6**, the display **50** includes a number of separate lights **51** that are aligned in a horizontal row. Each of the lights **51** can be individually illuminated to indicate the alignment of the work platform **100** relative to the target object **110**. The display **50** is controlled based on signals received from the processing circuits **42** of the sensors **40**. In one design, the display **50** is controlled by the processing circuits **42**. Additionally or alternatively, the display **50** can include a processing circuit and associated memory circuit to process the signals from the sensors **40** and determine the illumination of the various lights **51**.

CA 3045999 2019-06-11

The display **50** is positioned for viewing by the operator that is controlling the drive vehicle **20** with the control unit **60**. As illustrated in Figure **4**, the display **50** can include an attachment member **52** to attach to the work platform **100**. The display **50** can also be positioned at other locations, including but not limited to the target object **110**, and on a stand in proximity to the work platform **100** and/or the target object **110**.

The lights **51** are individually controlled and adjustable between an on state (i.e., illuminated state) and an off state (i.e., non-illuminated state). The lights **51** can be illuminated in various configurations to provide a visual indication to the user of the relative position of the work platform **100** and the target object **110**.

Figure **7**A includes a lighting configuration with just limited number of lights **51** being in the on state within a central section **53** of the display. Lights **51** away from the central section **53** are in the off state. This provides a visual indication that the work platform **100** is aligned with the target object **110**. Figure **7**B includes a lighting configuration visually indicating that the work platform **100** is not aligned with the target object **110**. This includes a limited number of illuminated lights **51** that are away from the central section **53** of the display **50**. The remainder of the lights **51** are not illuminated, including the lights at the central section **53**. The extent of misalignment can be visually indicated by the distance the illuminated lights **51** are away from the central section **53**. Illumination of lights **51** adjacent to the central section **53** can indicate a relatively small amount of misalignment. Illumination of lights **51** at the outer edges of the display **50** can include a greater amount of misalignment.

The various lights **51** can also include different colors to provide an additional visual indication of the positioning. This can include the lights **51** at the central section **53** being a first color, and lights **51** away from the central section **53** being one or more different colors. In one design, the lights have different colors based on the distance away from the central section **53**. The lights **51** can progressively change the farther away from the central section **53** to visually indicate the extent of misalignment. By way of example, the lights **51** of the central section **53** can be green. Lights **51** adjacent to the central section **53** can be yellow indicating a slight amount of misalignment. Lights **51** on the outer side of the yellow lights are orange indicating a greater amount of misalignment. Lights **51** on the outer periphery of the display **50** can be red indicating an extreme amount of misalignment.

Figure **8**A includes another display **50** to visually indicate the alignment of the work platform **100** relative to the target object **110**. The display **50** includes a first section **57** with a horizontal row of lights **51**, a second section **58** that with a vertical column of lights **51**, and a third section **59** with another vertical column of lights **51**. The second and third sections **58**, **59** can be perpendicular to the first section **57**. The first section **57** can visually indicate the alignment of the work platform **100** relative to the target object **110**. The second section **58** visually indicates the distance the first sensor **40**a is away from the target object **110**, and the third section **59** visually indicates the distance the second sensor **40**b is away from the target object **110**.

Figure **8**A includes the display **50** illuminated when the work platform **100** is not aligned with the target object **110**. Lights **51** away from the central section **53** are illuminated (and the lights **51** of the central section **53** are not illuminated). A comparison of the second and third sections **58**, **59** visually indicates that the first sensor **40**a corresponding to the second section **58** is farther away from the target object **110** than the second sensor **40**b (that corresponds to the third section **59**). This is because fewer lights **51** are illuminated in the second section **58** than the third section **59**.

Figure **8**B includes the display **50** with the work platform **100** being aligned with the target object **110**. Lights **51** within the central section **53** of the first section **57** are illuminated with the other lights **51** being off. The second and third sections **58**, **59** indicate that the work platform **100** is still spaced away from the target object **110**. Lights **51** along a lower portion of the second and third sections **58**, **59** are illuminated with the lights along upper portions being off. This visually indicates the extent of the distance remaining between the work platform **100** and the target object **110**. Further, the second and third sections **58**, **59** indicate that the work platform **100** is aligned with the target object **110** since the same lights **51** are illuminated in each of the first and second sections **58**, **59**.

CA 3045999 2019-06-11

Figure **8C** illustrates the display **50** with the work platform **100** aligned with and at the desired distance away from the target object **110**. The lights **51** within the central section **53** of the first section **57** are illuminated with the other lights **51** being off. This indicates that the work platform **100** is aligned with the target object **110**. Further, each of the lights **51** along the second and third sections **58**, **59** are illuminated. This visually indicates that the work platform **100** is aligned and is the desired distance away from the target object **110**.

In some designs, a single display **50** is used for visual observation by the operator. Other designs can include two or more displays **50**. This can include a separate display **50** associated with each sensor **40**. In one specific design, two displays **50** are used with each connected to one of the sensors **40**. Individually connecting each display **50** to a sensor **40** can be more straight-forward to configure.

The desired distance away from the target object **110** can vary depending upon the context of use. This can include the sensors **40** being located against the target object **110** or being spaced various distances away from the target object **110**. The desired distance can be pre-programmed into the memory circuits **32**, **42**. Additionally or alternatively, the desired distance can be input by an operator.

As illustrated in Figure **9**, the drive vehicle **20** turns relative to the work platform **100** about the pivot point P where the drive vehicle **20** is attached to the work platform **100**. The work platform **100** turns about a rotation point W which is located at the

CA 3045999 2019-06-11

intersection of the wheel rotation axis A of the work platform **100** and a line V that extends from the pivot point P and is perpendicular to a vector R. The wheel rotation axis A of the work platform **100** provides for the point of rotation because the wheels **105** are locked in their angular position (i.e., the orientation of the wheels **105**, which can be lockable caster wheels **105**, are fixed relative to the work platform **100**). Further, additional wheels **104** on the work platform **100** can be slightly elevated above the work surface **99** by the drive vehicle **20** (see Fig. **4**).

The processing circuit **31**uses various data items to perform the automated alignment of the work platform **100**. As illustrated in Figure **9**, this includes the distance "a" measured between the sensors **40**. A distance "b" is the distance between the wheel rotation axis A of the work platform **100** and the pivot point P. A distance "s" is the distance between the sensors **40** at the edge **109** of the work platform **100** and the wheel rotation axis A of the work platform **100**. A distance "d_1" is the sensed distance between the first sensor **40a** and the target object **110**. Distance "d_2" is the sensed distance between the second sensor **40b** and the target object **110**.

The drive vehicle **20** includes a forward motion indicated by vector R that extends from the pivot point P. A line H extends along the longitudinal centerline of the drive vehicle **20** from the pivot point P and is perpendicular to the wheel rotation axis A of the work platform **100**. The line V extends from the pivot point P and is perpendicular to the forward motion vector R. The point W is the intersection of line

V and the wheel rotation axis A of the work platform **100**. A line T extends along the edge of the target object **110**.

The processing circuit **31** calculates the positioning of the work platform **100** based on the readings from the two sensors **40**a, **40**b that are spaced apart along the work platform **100**. Using the distance readings and the geometry of the work platform **100**, the processing circuit **31** calculates an angle between the work platform **100** and the target object **110**. This target object angle α is the angle between the wheel rotation axis A of the work platform **100** and line T that aligns with the front of the target object **110**. The target object angle α is defined in equation (**1**):

$$\alpha = \operatorname{atan}(d_1 - d_2/a) \qquad \text{(Eq. 1)}$$

A drive vehicle angle ß is measured by the rotation sensor **28** and is an angle of the work platform **100** relative to the drive vehicle **20**. This angle ß is formed by vector R indicating the forward motion of the drive vehicle **20** and the line H that extends from the pivot point P and is perpendicular to the wheel rotation axis A and is the longitudinal centerline H of the work platform **100**.

The processing circuit **31** uses feedback of the drive vehicle angle ß, along with the geometry of the work platform **100** including the location of the wheels **105**, the longitudinal centerline H of the work platform **100**, the wheel rotation axis A, the sensor separation distance a, and the pivot point P, to calculate a required vector for

CA 3045999 2019-06-11

the drive vehicle **20** to follow to achieve the target object angle α for alignment. After angle alignment is achieved, the processing circuit **31** adjusts angle ß to maintain the target object angle α while moving the work platform **100** towards he target object **110**. The processing circuit **31** uses feedback from the sensors **40** until the desired offset distance between the work platform **100** and the target object **110** is achieved. At this point, the processing circuit **31** stops the drive vehicle **20**. Continuous feedback based on the readings from the sensors **40** provides for the necessary adjustments in the drive vehicle angle ß to allow for the necessary alignment.

The rotational alignment of the work platform **100** is accomplished by determining the rotation point of the work platform **100** that is needed for alignment of the target object **110** without colliding with the target object **110**. The processing circuit **31** sets a platform pivot point W at an intersection of the vector V and the wheel rotation axis A of the work platform **100**. In order to produce a collision-free path for of the work platform **100** relative to the target object **110**, the rotation aspect of the motion path is to be completed before the desired distance away from the target object **110** is reached. As illustrated in Figure **10**, this means that the rotation point distance D**2** of the work platform **100** is less than or equal to the distance D**1** of the intersection point of the boundary edge line of the target object **110** and wheel rotation axis A of the work platform **100**.

CA 3045999 2019-06-11

Figure **10** illustrates a positioning in which the work platform **100** can be aligned prior to contacting against the target object **110**. The distance D**2** is less than or equal to the distance D**1**. Figure **11** illustrates a positioning in which the work platform **100** will not achieve alignment before contacting against the target object **110**. This contact occurs because D**2** is greater than D**1**. In Figure **11**, the drive vehicle **20** is adjusted to change the drive vehicle angle ß (which would involve increasing angle ß from the situation shown here) to allow for the necessary alignment.

The processing circuit **31** can continuously calculate the various distances and alignments during movement of the drive vehicle **20**. A minimum drive vehicle angle ß is determined based on the initial target object angle α and the desired approach offset distance. The minimum drive vehicle angle ß is defined in equation (**2**):

$$ß_{min} = \text{atan}\,(b / ((s + (d_1 + d_2)/2)/\tan(\alpha)\,)) \qquad \text{(Eq. 2)}$$

In practice, the initial drive vehicle angle ß can be set to be greater than the minimum drive vehicle angle ß to achieve alignment before the desired offset distance is achieved. The processing circuit **31** continuously computes the target object angle α while moving towards the target object **110** until the target object angle α becomes zero.

The processing circuit **31** can also control the speed of the drive vehicle **20** as it moves towards the target object **110**. The speed can be continuously computed

CA 3045999 2019-06-11

during the time that the target object angle α is not equal to zero. The speed can be calculated based on equation (**3**):

$$\text{Speed} = K_p * \alpha + \sin(\alpha) * (K_{min\_yaw\_rate}) \qquad \text{(Eq. 3)}$$

The processing circuit **31** is provided with the various data points and dimensions to correctly determine the various calculations for movement of the work platform **100**, such as the target object angle α, pivot point P, and sensor offsets. Motion control equations with kinematic dimension variables integrated into them can be pre-programmed with the processing circuit **31** and memory circuit **32**. This can include setting the variables (such as a, b, and s).

The kinematics variables can be set in various manners, such as hard coding them into a motion control app, having the operator enter them manually through the control unit **60** or inputs on the drive vehicle **20**, and having the operator select an ID number associated with the work platform **100** that loads a file containing the variables at run time, or having some type of automated selection process. One design can load the data based on RFI tags on the work platform **100** scanned by the drive vehicle **20** and/or control unit **60**.

Figure **12** illustrates a method of aligning a work platform **100** relative to a target object **110**. The drive vehicle **20** and sensors **40** are activated (block **200**). This can be completed at the components themselves, or remotely such as through the

CA 3045999 2019-06-11

control unit **60**. The drive vehicle **20** can be positioned relative to the work platform **100** and attached to the work platform **100** (block **202**).

Once attached, the mount **22** can be lifted through the lift mechanism **27** (block **203**). This can elevate a section of the work platform **100**. This can include elevating the work platform **100** such that just the wheels **105** on and/or towards the edge **109** remain in contact with the work surface **99**. This can also place a load on the drive vehicle **20** to increase its traction with the work surface **99**. At this stage, the movement of the work platform **100** occurs along the wheel rotation axis A of the work platform **100** that extends through the wheels **105** that are in contact with the work surface **99**, and the mount **22** that is pivotally connected to the body **21** of the drive vehicle **20**.

The drive vehicle **20** receives signals from the sensors **40** indicating the distance from the target object **110** (block **204**). Signals from the sensors **40** can begin to be received once the drive vehicle **20** is attached to the work platform **100**. The processing circuit **31** can signal the sensors **40** and/or processing circuits **42** to begin sending the signals. In one design, activation of the lift mechanism **27** to elevate the work platform **100** causes the sensors **40** to begin sending the signals. The signals from the sensors **40** are also sent to the display **50**. This causes the applicable lights **51** to be illuminated for the visual indication of the aligning and/or positioning for the operator that is controlling the drive vehicle **20**.

CA 3045999 2019-06-11

Commands can continue to be received from the operator to control the drive vehicle **20** and thus the movement of the work platform **100** (block **206**). These commands can be received from the control unit **60** from the operator who is located remotely away from the drive vehicle **20**. The operator through the control unit **60** moves the work platform **100** into an approximated offset location away from the target object **110**.

The operator determines whether to use the automatic alignment process to control the movement of the work platform **100** (block **208**). If the automatic alignment process is not to be used, the movement can be controlled by the operator through the control unit **60** (block **210**). The operator can observe the physical location of the work platform **100** relative to the target object **110** in controlling the movement. Additionally or alternatively, the operator can also observe the display **50** to determine the alignment and/or position.

If automatic alignment process is to be used (block **208**), the operator can input a command through the control unit **60** indicating that the automatic alignment process is to take over the movement (block **212**). Once activated, the processing circuit **31** controls the movement based on the sensor data feedback.

The designs above include the processing circuit **31** positioned in the drive vehicle **20**. The processing circuit **31** can also be located away from the drive vehicle **20**.

CA 3045999 2019-06-11

A variety of different work platforms **100** can be used with the mover system **10**. Figure **13** illustrates a work platform **100** with an elevated work surface to position workers and/or equipment. The work platform **100** can also include steps to provide for egress to and from the elevated work surface.

The mover system **10** can be used in a variety of different environments to work on a variety of different target objects. Figure **14** includes one use in the target object **110** is an aircraft. One or more work platforms **100** can be used to work on different sections of the aircraft **110**. The mover system **10** can be used with a variety of vehicles. One vehicle includes a commercial aircraft that includes rows of seats each configured to accommodate a passenger. Other vehicles include but are not limited to manned aircraft, unmanned aircraft, manned spacecraft, unmanned spacecraft, manned rotorcraft, unmanned rotorcraft, satellites, rockets, missiles, manned terrestrial aircraft, unmanned terrestrial aircraft, manned surface water borne vehicles, unmanned surface water borne vehicles, manned sub-surface water borne vehicles, unmanned sub-surface water borne vehicles, ships, and combinations thereof.

The examples above include a single drive vehicle **20** attached to a work platform **100**. The mover system **10** can also include multiple drive vehicles **20** attached to a work platform **100**. The multiple drive vehicles **20** can act in concert to move and align the work platform **100**. Figure **15** illustrates a pair of drive vehicles **20**a, **20**b attached to a work platform **100**. The wheels **105** on the work platform **100** are castors and able to rotate through various angular positions. Each of the drive vehicles **20**a, **20**b receives signals from the sensors **40**a, **40**b. Based on these signals, the drive vehicles **20**a, **20**b can determine the applicable directional positioning. In addition, the drive vehicles **20**a, **20**b can communicate between themselves to further determine movements to steer the work platform **100**. In one mover system **10**, one of the drive vehicles **20**a, **20**b is a master and determines the movements and directs the other drive vehicle **20**a, **20**b. Other mover systems **10** include both drive vehicles **20**a, **20**b calculating their movements based on the signals from the sensors **40**a, **40**b.

While specific embodiments have been described and illustrated, such embodiments should be considered illustrative of the subject matter described herein and not as limiting the claims as construed in accordance with the relevant jurisprudence.

CA 3045999 2019-06-11

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of aligning a work platform relative to a stationary target object, the method comprising:

attaching a drive vehicle to the work platform;

receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object;

moving the work platform with the drive vehicle based on the signals;

sensing an angle of a vector indicating a forward motion of the drive vehicle relative to a line extending along a longitudinal centerline of the work platform from a pivot point; and

adjusting the drive vehicle relative to the work platform based on the angle to align the work platform relative to the target object and reduce a distance between the work platform and the target object.

2. The method of claim **1**, further comprising calculating, based on the signals, a target object angle between the work platform and the target object.

Date Reçue/Date Received 2022-12-16

3. The method of claim **1** or **2**, further comprising storing, in a memory circuit on the drive vehicle, distance variables of the first and second sensors and dimensional aspects of the work platform and an attachment location of the drive vehicle relative to the work platform.

4. The method of any one of claims **1**-**3**, further comprising operating the drive vehicle and moving the work platform through a control unit prior to receiving the signals from the first and second sensors.

5. The method of any one of claims **1**-**4**, further comprising, after attaching the drive vehicle to the work platform, elevating a section of the work platform and limiting a number of wheels of the work platform that remain in contact with a work surface, the wheels remaining in contact with the work surface forming a wheel rotation axis about which the work platform turns while being moved by the drive vehicle.

6. The method of claim **5**, wherein the longitudinal centerline of the work platform is perpendicular to the wheel rotation axis.

7. The method of any one of claims **1**-**6**, wherein the signals from the first and second sensors comprise raw sensor data.

8. The method of any one of claims **1**-**7**, wherein adjusting the drive vehicle relative to the work platform based on the angle comprises adjusting an

Date Reçue/Date Received 2022-12-16

angular position of the drive vehicle relative to the work platform while moving the work platform with the drive vehicle with respect to the target object.

9. The method of any one of claims **1**-**8**, further comprising stopping the drive vehicle when the work platform is aligned with the target object and is spaced a predetermined distance away from the target object.

10. A method to align a work platform relative to a stationary target object, the method comprising:

attaching a drive vehicle to the work platform at a pivot point (P);

receiving signals from first and second sensors that are spaced apart on the work platform, the signals indicating a first distance between the first sensor and the target object and a second distance between the second sensor and the target object;

calculating, based on the signals, a target object angle (α) between the work platform and the target object while moving the work platform with the drive vehicle;

calculating, based on rotational sensor signals, a drive vehicle angle (ß) between a forward movement direction of the drive vehicle and a longitudinal centerline of the work platform while moving the work platform with the drive vehicle; and

Date Reçue/Date Received 2022-12-16

completing, based on the target object angle (α) and the drive vehicle angle (ß), a rotational aspect of a motion path of the work platform prior to reaching a zero offset distance between the work platform and the target object.

11. The method of claim **10**, further comprising adjusting, based on the rotational sensor signals, an angular position of the drive vehicle relative to the work platform at the pivot point (P) while moving the work platform with respect to the target object.

12. The method of claim **10** or **11**, further comprising stopping the drive vehicle when the work platform reaches the zero offset distance.

13. The method of any one of claims **10**-**12**, further comprising elevating a section of the work platform above a work surface such that a limited number of wheels of the work platform remain in contact with the work surface.

14. The method of claim **13**, wherein elevating the section of the work platform comprises extending a lift mechanism on the drive vehicle relative to a body of the drive vehicle.

15. A system to align a work platform relative to a stationary target object, the system comprising:

a drive vehicle comprising:

Date Reçue/Date Received 2022-12-16

a body;

at least one drive member attached to the body; and

a mount pivotally attached to the body, the mount configured to attach to the work platform;

a first sensor attached to the work platform at a first position, the first sensor configured to detect a first distance at the first position between the work platform and the target object;

a second sensor attached to the work platform at a second position that is spaced away from the first position, the second sensor configured to detect a second distance at the second position between the work platform and the target object;

a rotation sensor to sense an angle between a longitudinal centerline of the work platform relative to a forward movement direction of the drive vehicle; and

a processing circuit configured to receive signals from the first sensor, the second sensor and the rotation sensor and to control movement of the drive vehicle to adjust a spacing and alignment between the work platform and the target object based on the signals.

Date Reçue/Date Received 2022-12-16

16. The system of claim **15**, the drive vehicle further comprising a lift mechanism attached to the body and to the mount, the lift mechanism configured to elevate the mount relative to the body to lift a section of the work platform.

17. The system of claim **15** or **16**, wherein the processing circuit is further configured to calculate a target object angle that is an angle between the work platform and the target object based on the signals from the first and second sensors .

18. The system of any one of claims **15**-**17**, wherein the longitudinal centerline of the work platform is perpendicular to a wheel rotation axis of the work platform.

19. The system of any one of claims **15**-**18**, further comprising a display mounted to the work platform and comprising at least one row of lights, the display illuminates one or more of the lights based on the signals received from the first and second sensors.

20. The system of any one of claims **15**-**19**, further comprising a control unit that communicates with the processing circuit and control the drive vehicle based on signals received from the first and second sensors.

21. A system to align a work platform relative to a stationary target object, the system comprising:

Date Reçue/Date Received 2022-12-16

a drive vehicle comprising a body, a mount configured to attach to the work platform, and a lift mechanism to elevate the mount relative to the body;

sensors that are spaced apart and configured to detect distances between the work platform and the target object;

a rotation sensor to detect an angle between a longitudinal centerline of the work platform relative to a forward movement direction of the drive vehicle; and

a processing circuit configured to receive signals from the sensors and the rotation sensor and to control movement of the drive vehicle based on the signals while the lift mechanism elevates the mount above the body to adjust a spacing and alignment between the work platform and the target object.

22. The system of claim **21**, wherein the drive vehicle comprises wheels that are rotated to adjust an angular position between the body and the mount.

23. The system of claim **21** or **22**, wherein the mount is pivotally attached to the body.

24. The system of any one of claims **21**-**23**, wherein the lift mechanism comprises an extendable arm that is movable between a retracted position in proximity to the body and an extended position away from the body.

Date Reçue/Date Received 2022-12-16

25. The system of any one of claims **21**-**24**, wherein each sensor of the sensors comprises an emitter configured to emit a pulsed laser light and a receiver configured to receive reflected pulses.

26. The system of any one of claims **21**-**25**, further comprising a control unit configured to remotely control the movement of the drive vehicle.

27. The system of any one of claims **21**-**26**, wherein the processing circuit is further configured to calculate, based on the distances detected by the sensors, a target object angle between the work platform and the target object.

28. The system of any one of claims **21**-**27**, wherein the processing circuit is further configured to adjust, based on the angle detected by the rotational sensor, a position of the drive vehicle relative to the work platform.

29. The system of any one of claims **21**-**28**, further comprising a display configured to provide a visual indication of a position of the work platform relative to the target object, the display comprising a plurality of lights aligned in a horizontal row.

Date Reçue/Date Received 2022-12-16

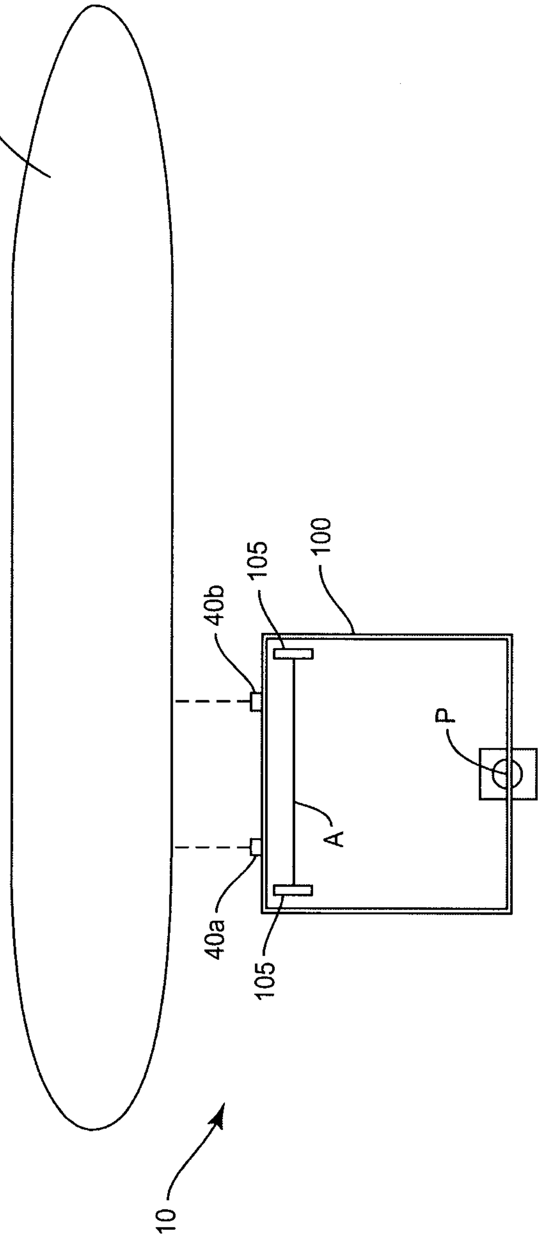


FIG. 1

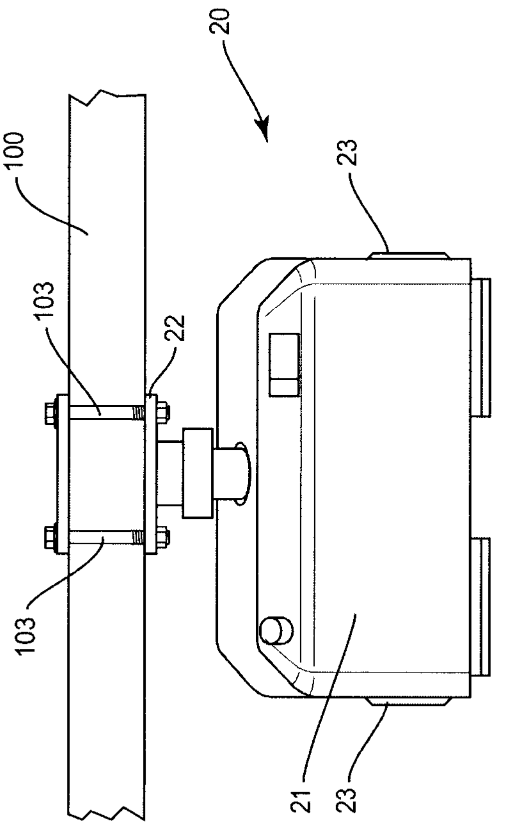


FIG. 2

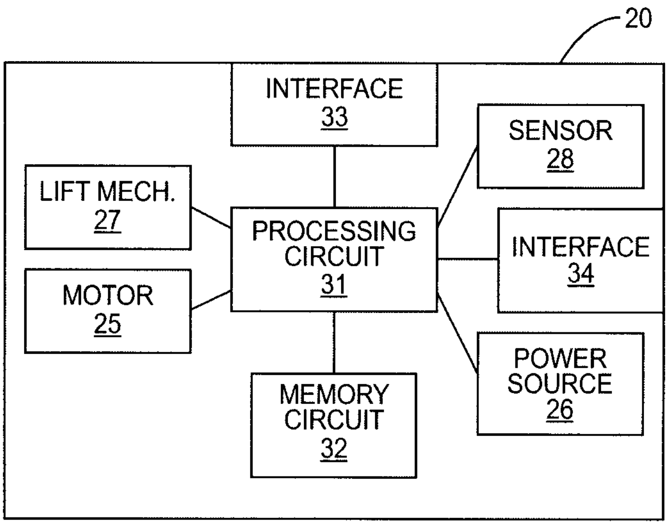

20
INTERFACE
33
SENSOR
28
LIFT MECH.
27
PROCESSING
CIRCUIT
31
INTERFACE
34
MOTOR
25
POWER
SOURCE
26
MEMORY
CIRCUIT
32

FIG. 3

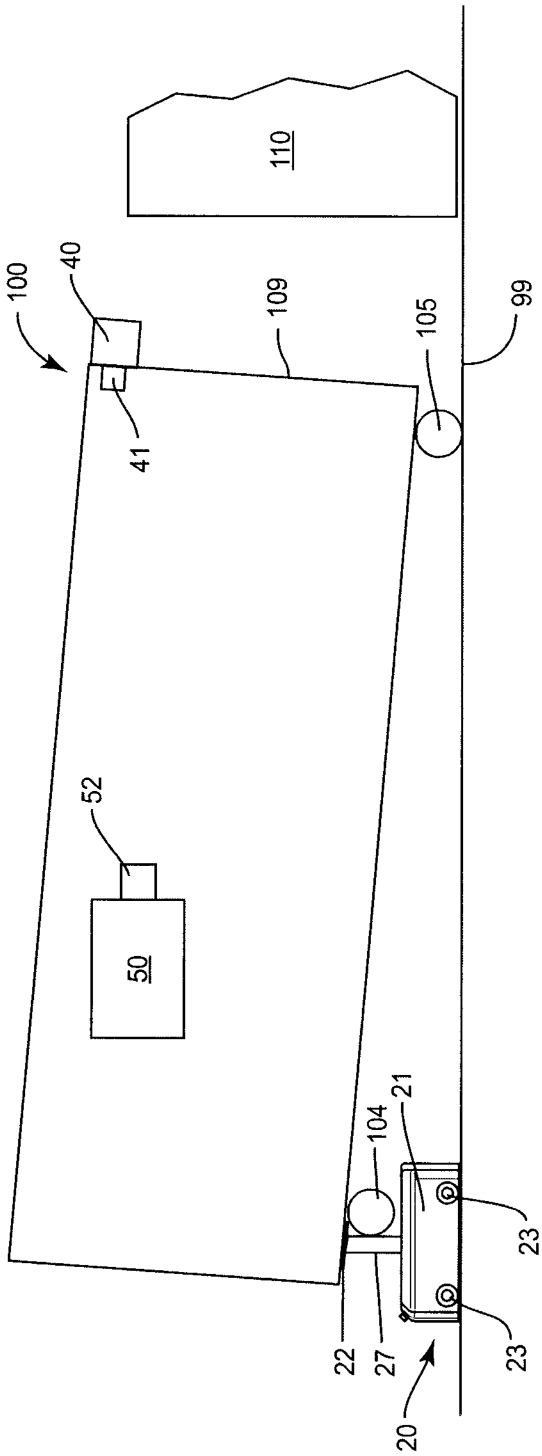


FIG. 4

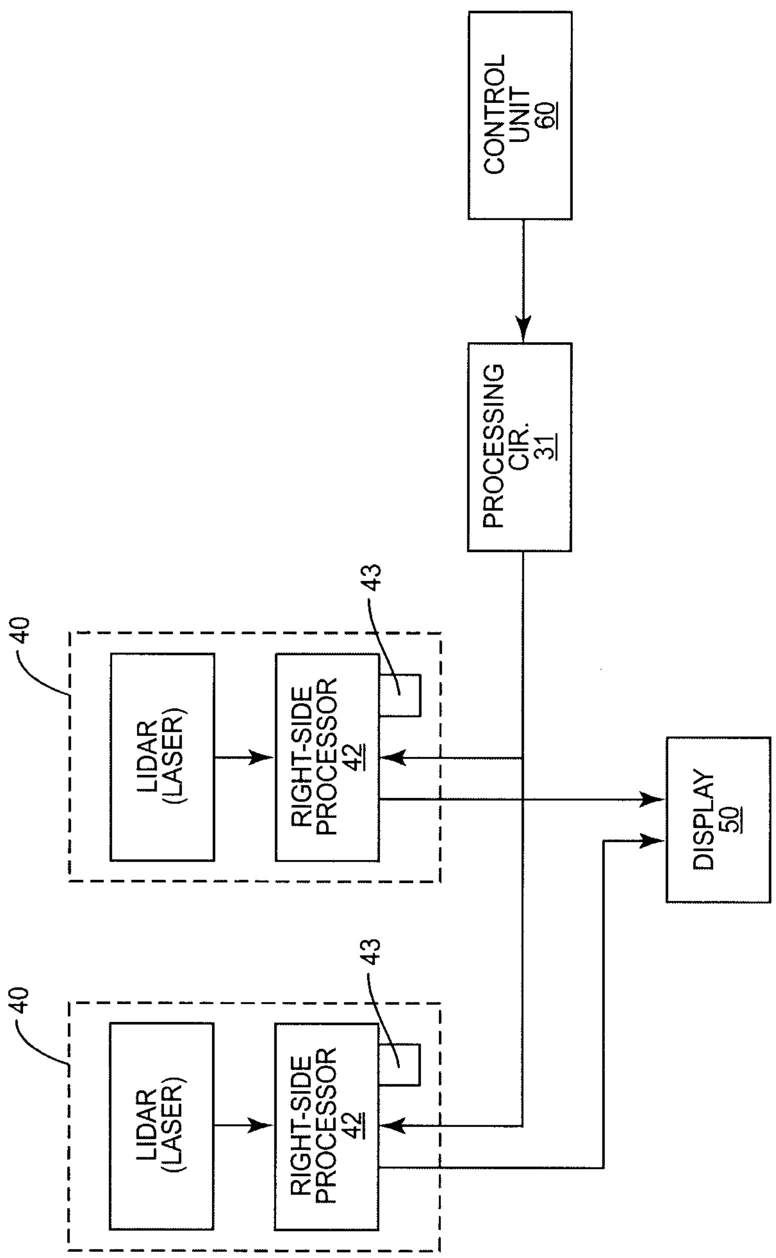

CONTROL UNIT 60
PROCESSING CIR. 31
40
LIDAR (LASER)
RIGHT-SIDE PROCESSOR 42
43
DISPLAY 50
40
LIDAR (LASER)
RIGHT-SIDE PROCESSOR 42
43

FIG. 5

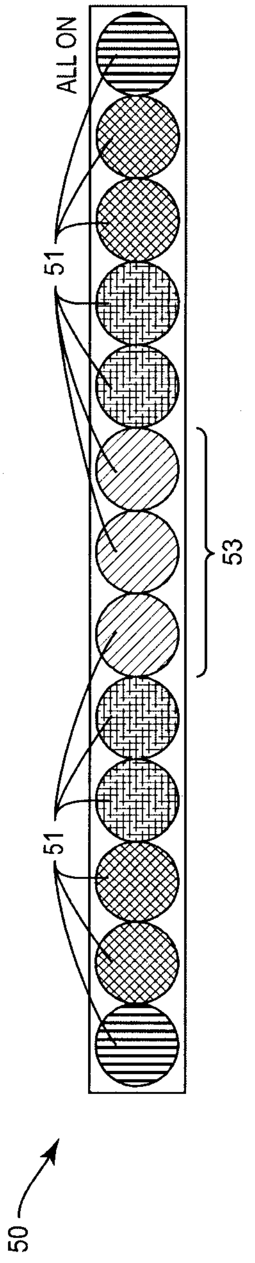


FIG. 6

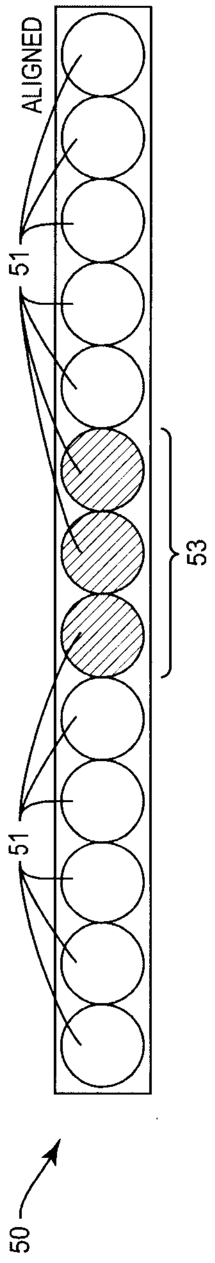


FIG. 7A

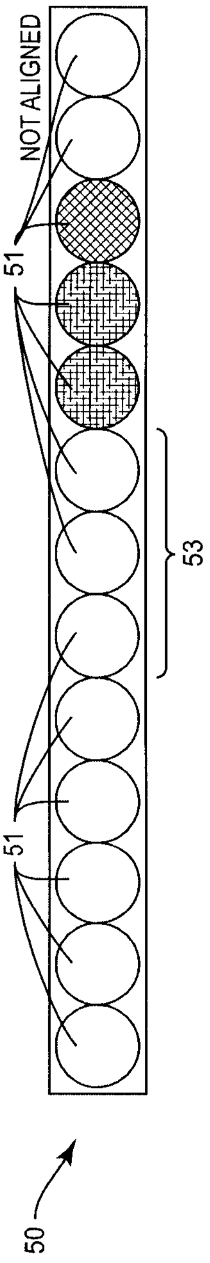


FIG. 7B

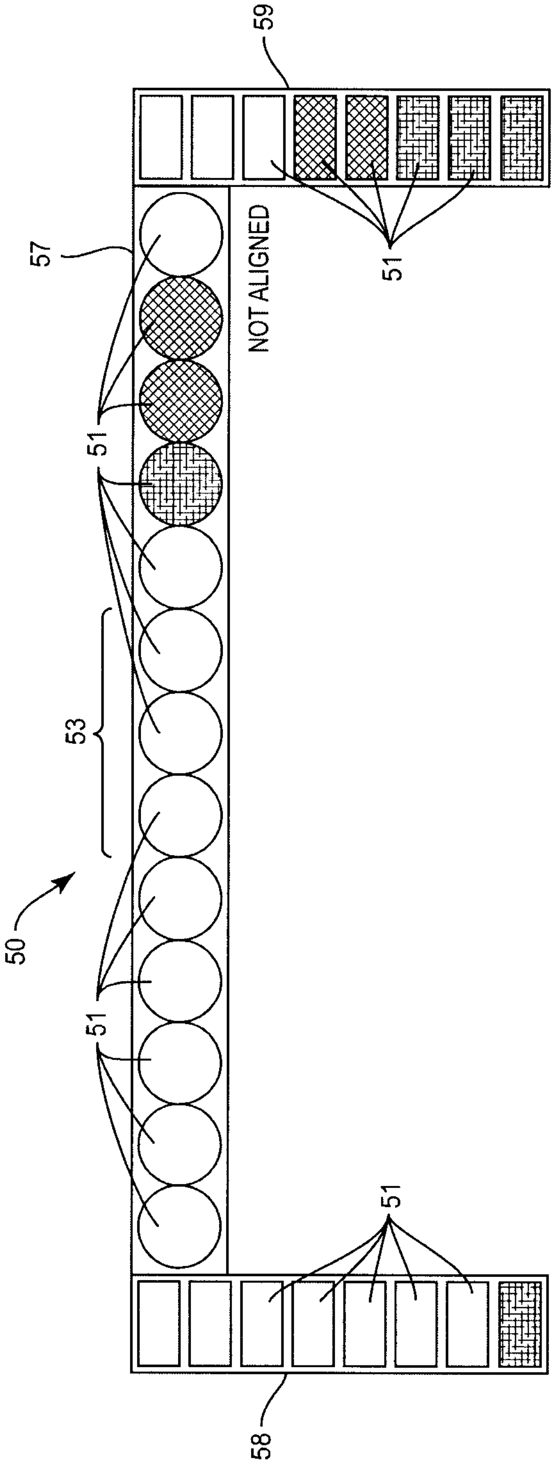


FIG. 8A

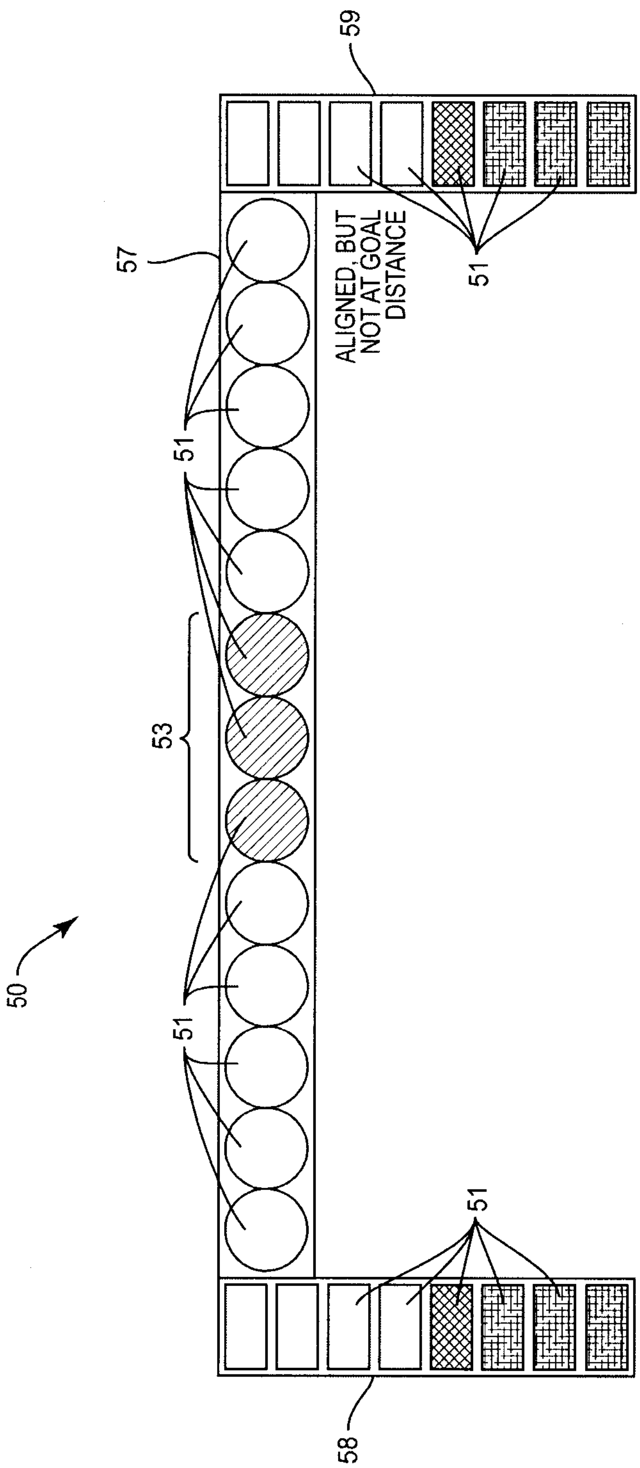


FIG. 8B

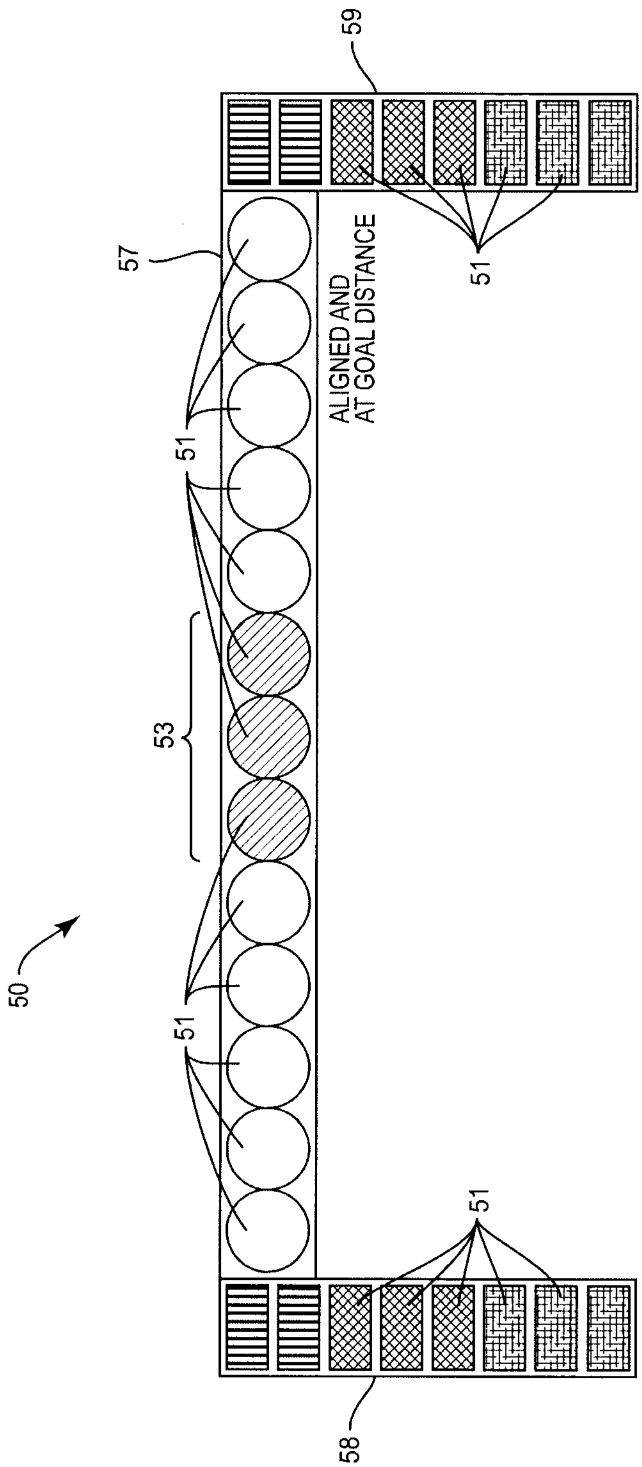


FIG. 8C

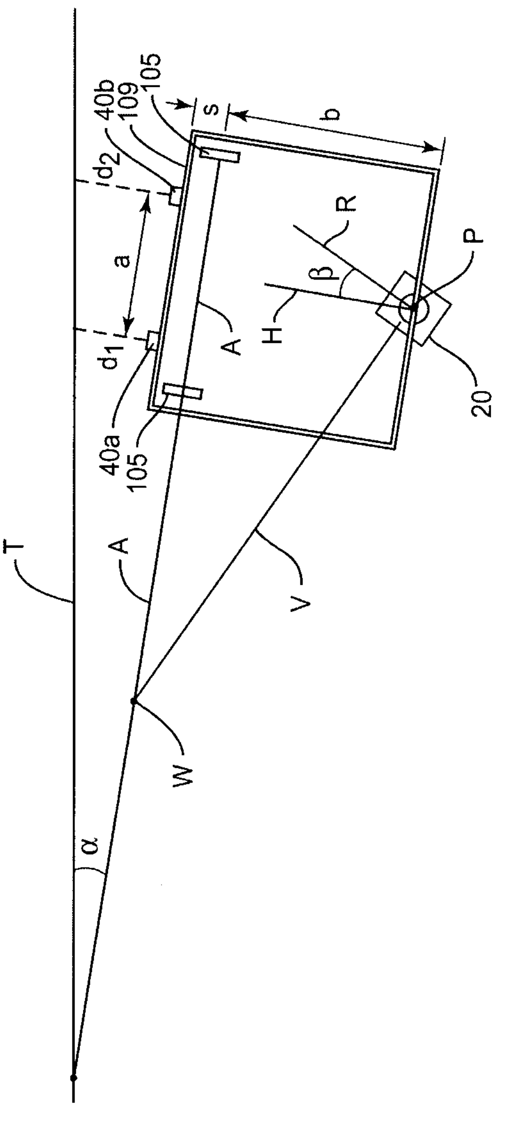


FIG. 9

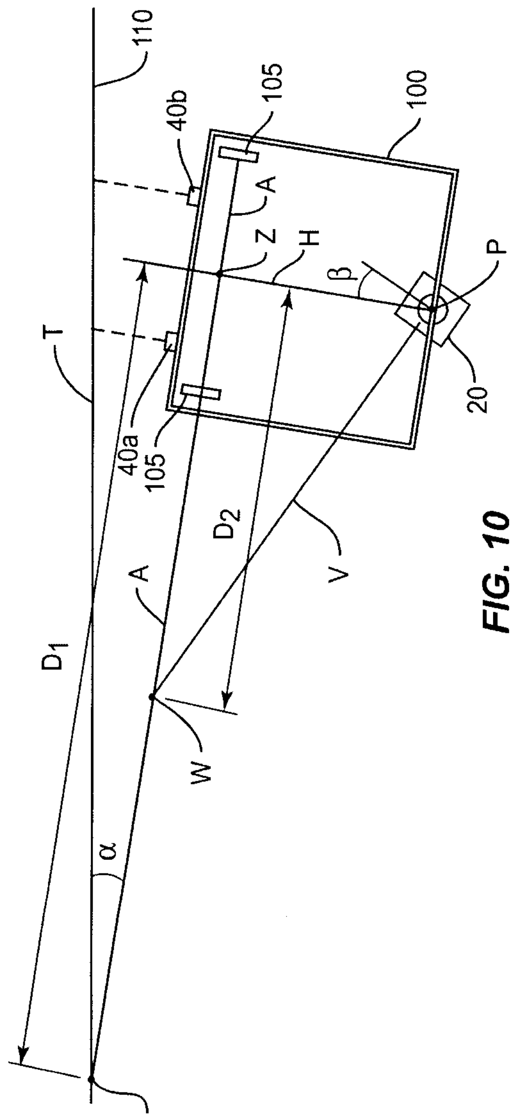

110
T
40b
105
100
A
Z
H
β
P
20
40a
105
D1
D2
A
V
W
α
C

FIG. 10

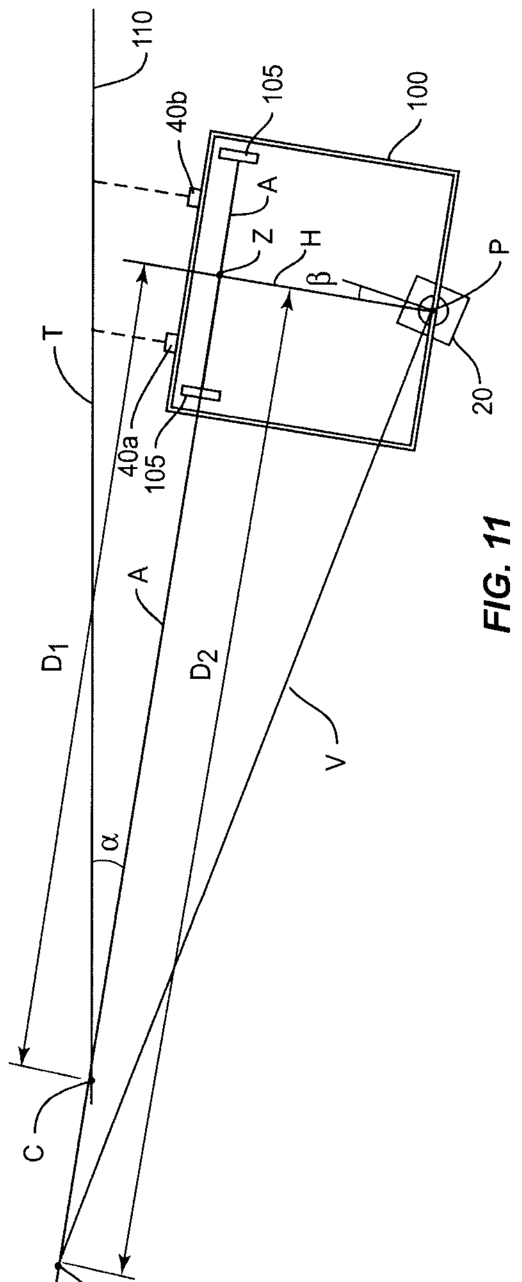

110
T
40b
105
100
A
Z
H
β
P
20
40a
105
D1
D2
A
V
W
α
C

FIG. 11

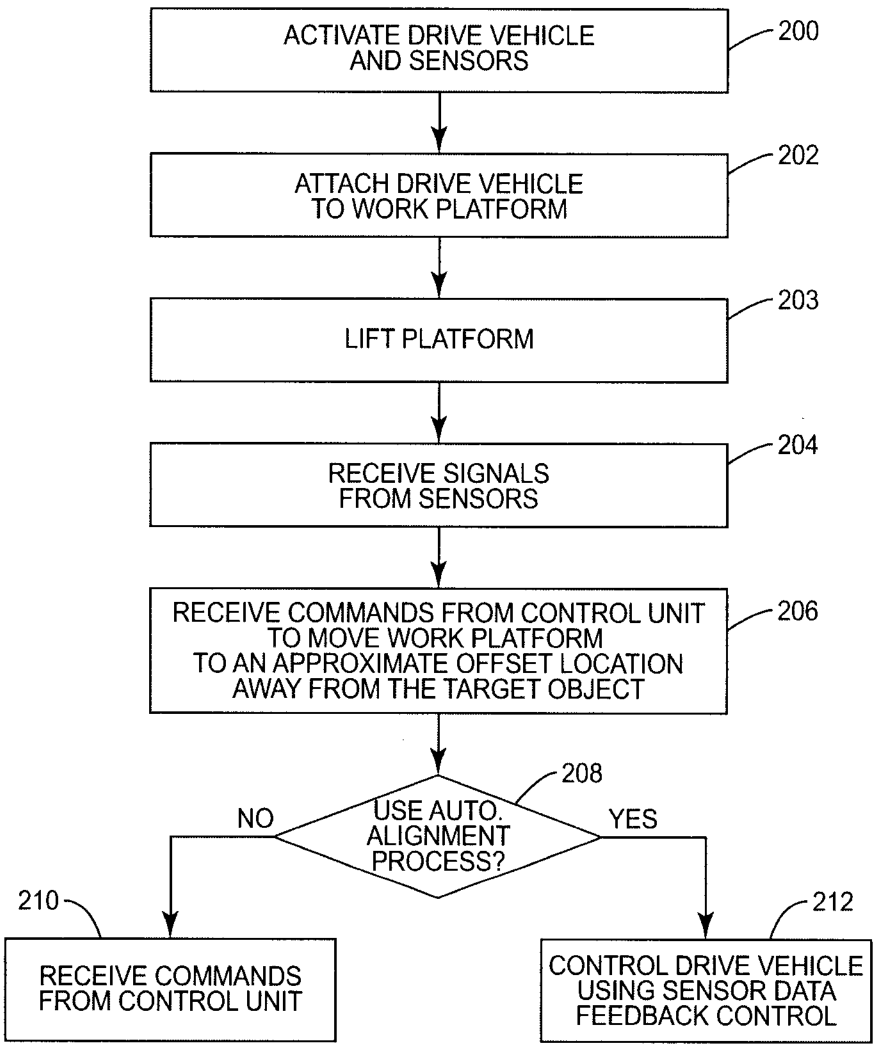

ACTIVATE DRIVE VEHICLE AND SENSORS
200
ATTACH DRIVE VEHICLE TO WORK PLATFORM
202
LIFT PLATFORM
203
RECEIVE SIGNALS FROM SENSORS
204
RECEIVE COMMANDS FROM CONTROL UNIT TO MOVE WORK PLATFORM TO AN APPROXIMATE OFFSET LOCATION AWAY FROM THE TARGET OBJECT
206
USE AUTO. ALIGNMENT PROCESS?
208
NO
YES
210
RECEIVE COMMANDS FROM CONTROL UNIT
212
CONTROL DRIVE VEHICLE USING SENSOR DATA FEEDBACK CONTROL

FIG. 12

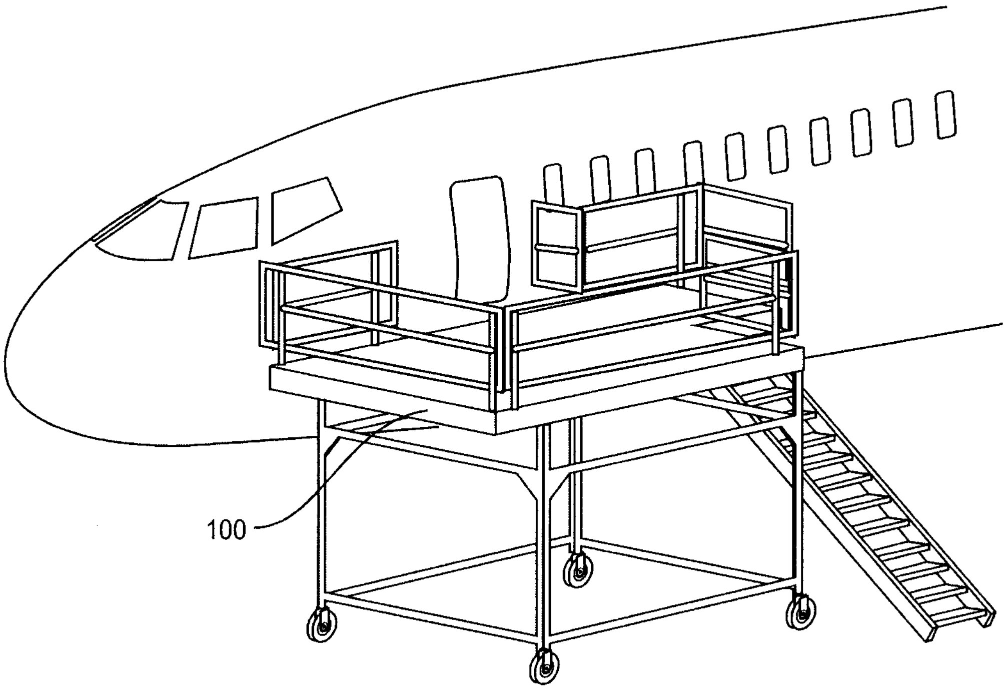


FIG. 13

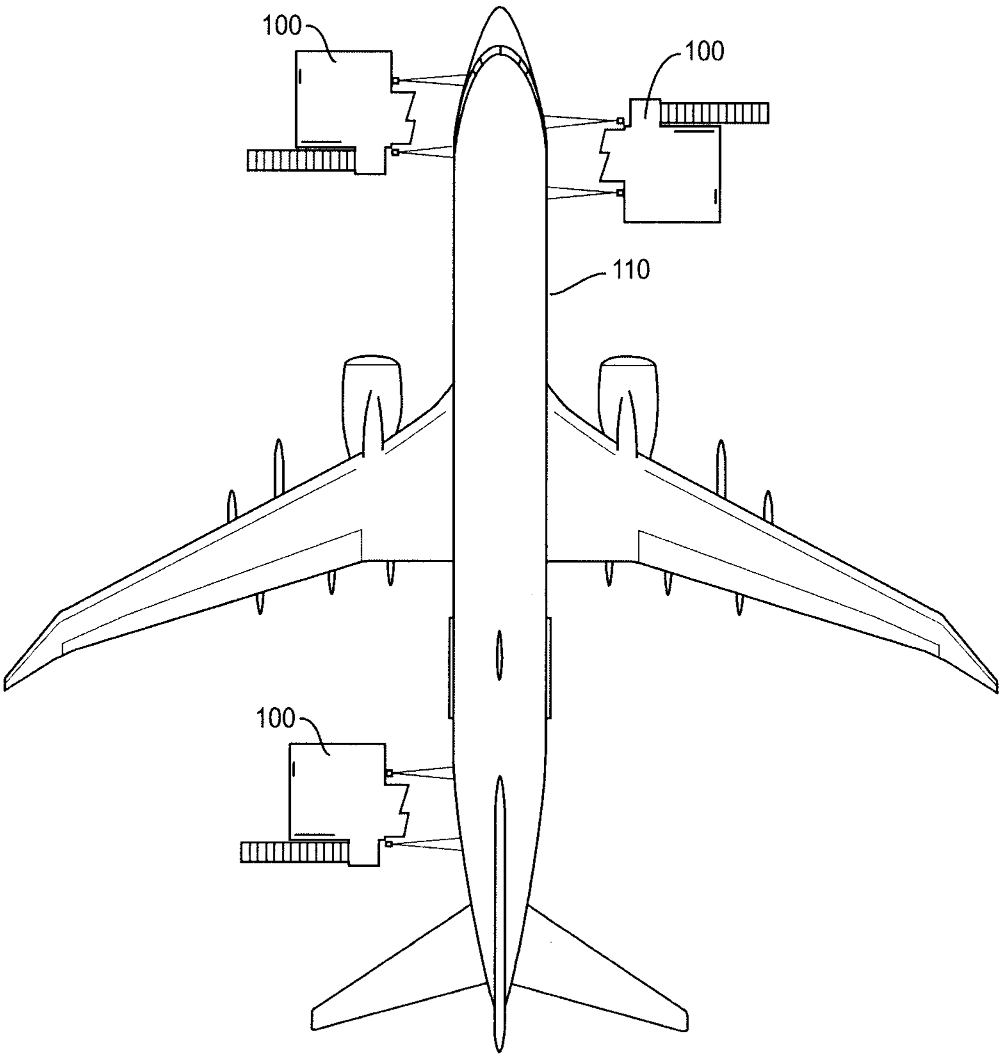


FIG. 14

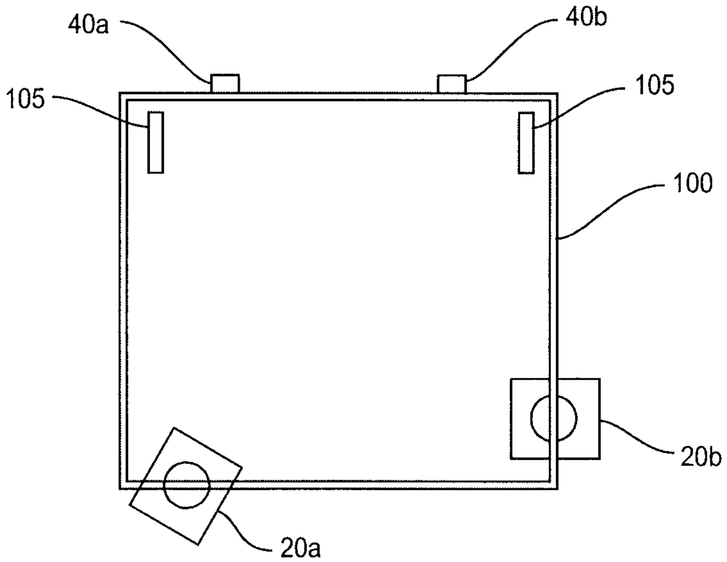
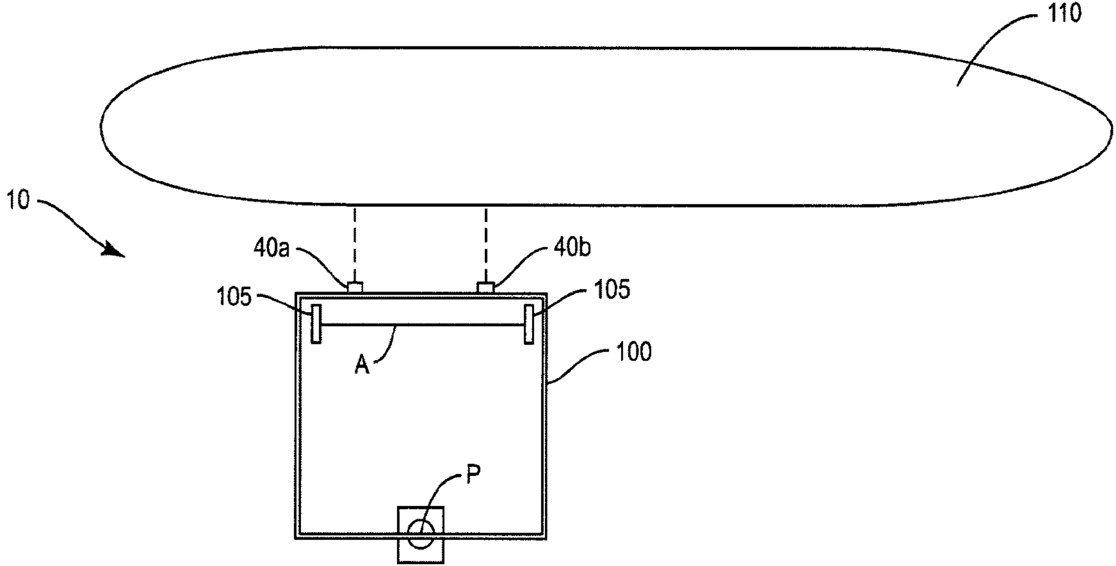


FIG. 15


110
10
40a
40b
105
105
A
100
P