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Zahdeh et al.

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(54) **AUTONOMOUS TRANSPORT VEHICLE**

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B65G 1/04 (2006.01)
B65G 1/137 (2006.01)
G05D 1/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B65G 1/0492*** (2013.01); ***B65G 1/1373*** (2013.01); ***G05D 1/0088*** (2013.01)

(58) **Field of Classification Search**
CPC B65G 1/0492
See application file for complete search history.

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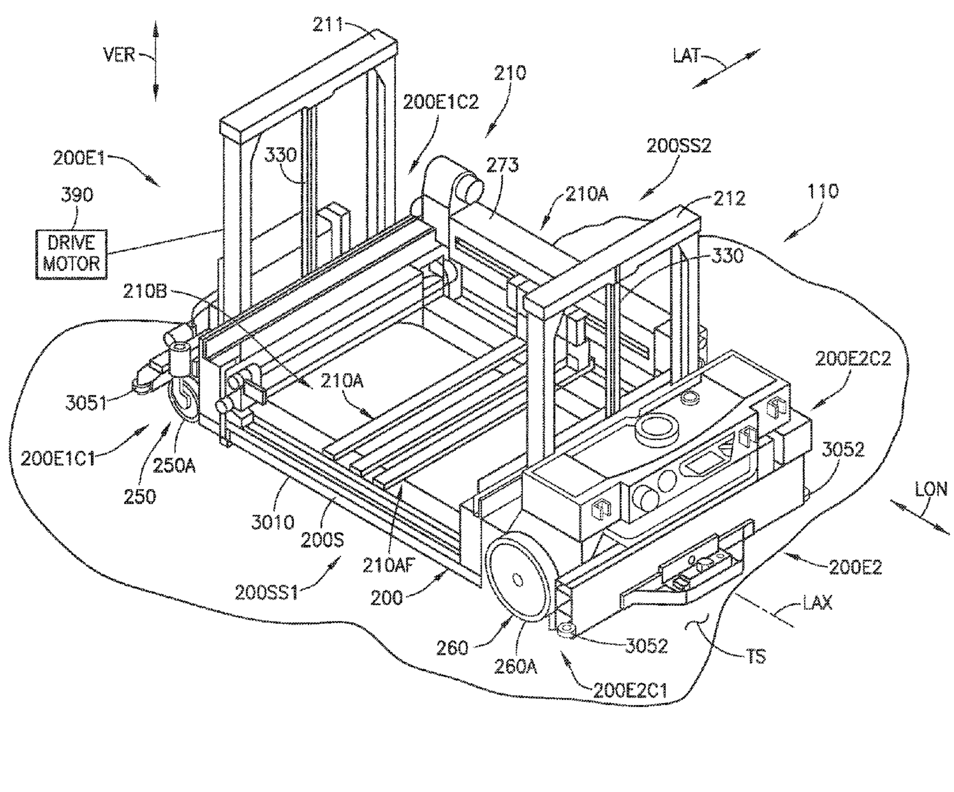
(74) *Attorney, Agent, or Firm* — Perman & Green, LLP

(57) **ABSTRACT**

An autonomous transport robot vehicle for transporting a payload, includes a chassis that is a space frame formed of longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and respective front and rear lateral beams closing opposite ends of the space frame. A payload support is connected to the chassis. Ride wheels depend from the chassis. The ride wheels and chassis in combination form a low profile height from the traverse surface to atop the chassis, where chassis height and ride wheel height are overlapped at least in part and the payload support is nested within the ride wheels. The space frame has predetermined modular coupling interfaces, each disposed for removably coupling, as a module unit, a corresponding predetermined electronic or mechanical component module of the autonomous transport robot vehicle to the chassis.

22 Claims, 11 Drawing Sheets



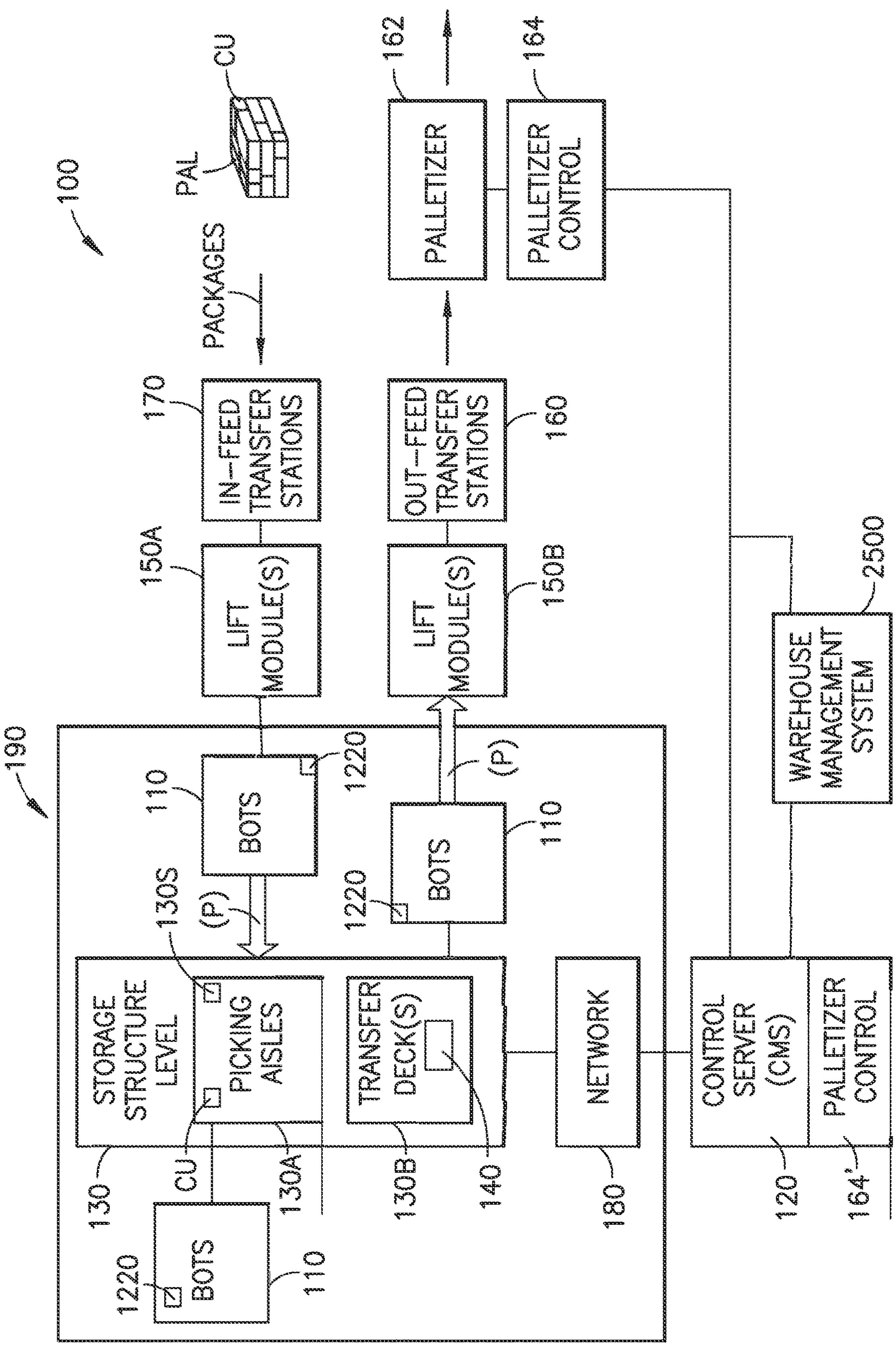

100
PAL
CU
PACKAGES
162
164
PALLETIZER
PALLETIZER CONTROL
170
IN-FEED TRANSFER STATIONS
OUT-FEED TRANSFER STATIONS
160
150A
LIFT MODULE(S)
LIFT MODULE(S)
150B
2500
WAREHOUSE MANAGEMENT SYSTEM
190
110
BOTS
1220
(P)
130S
STORAGE STRUCTURE LEVEL
PICKING AISLES
TRANSFER DECK(S)
NETWORK
CONTROL SERVER (CMS)
PALLETIZER CONTROL
130
130A
130B
140
180
120
164'

FIG. 1

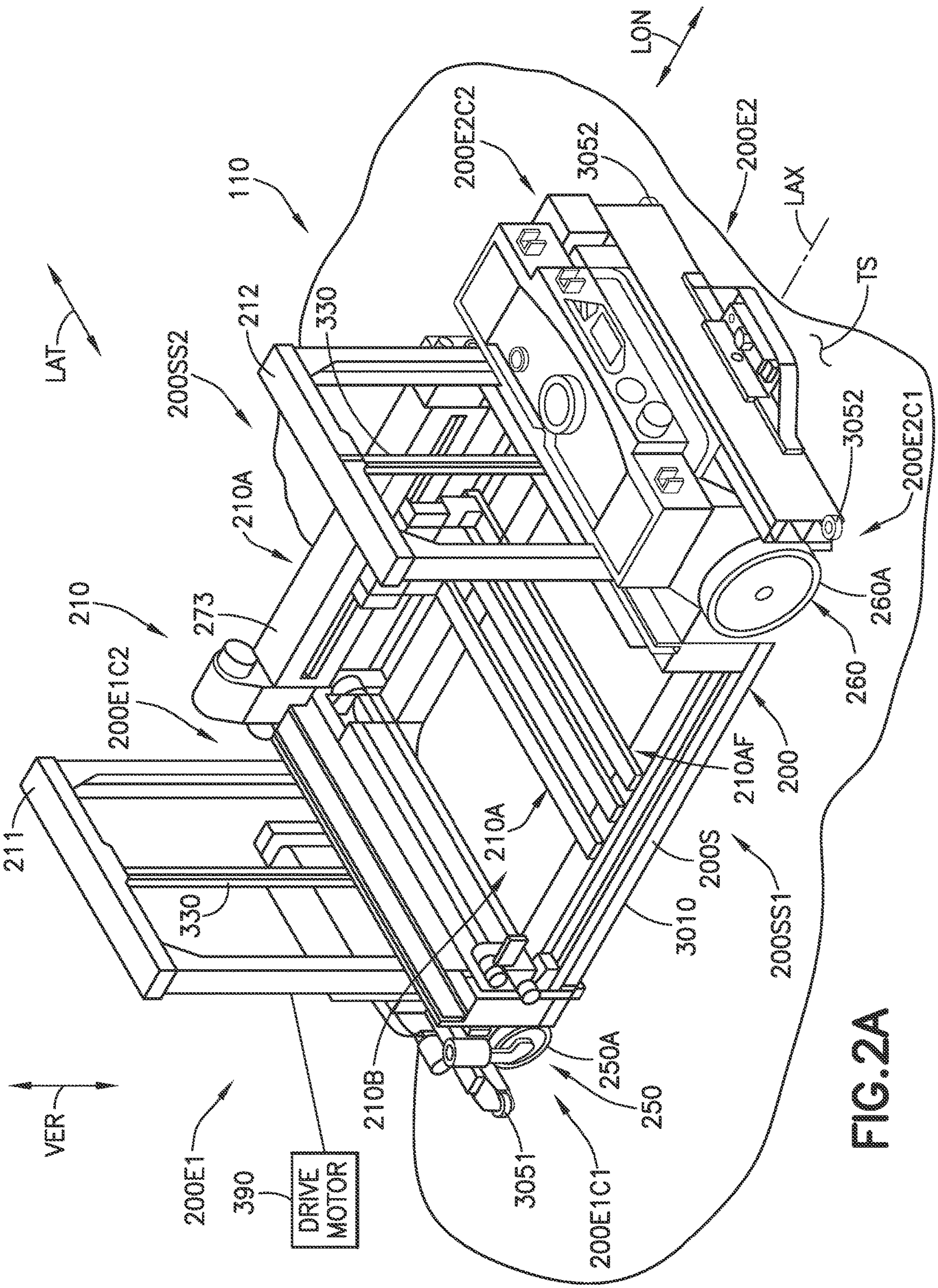
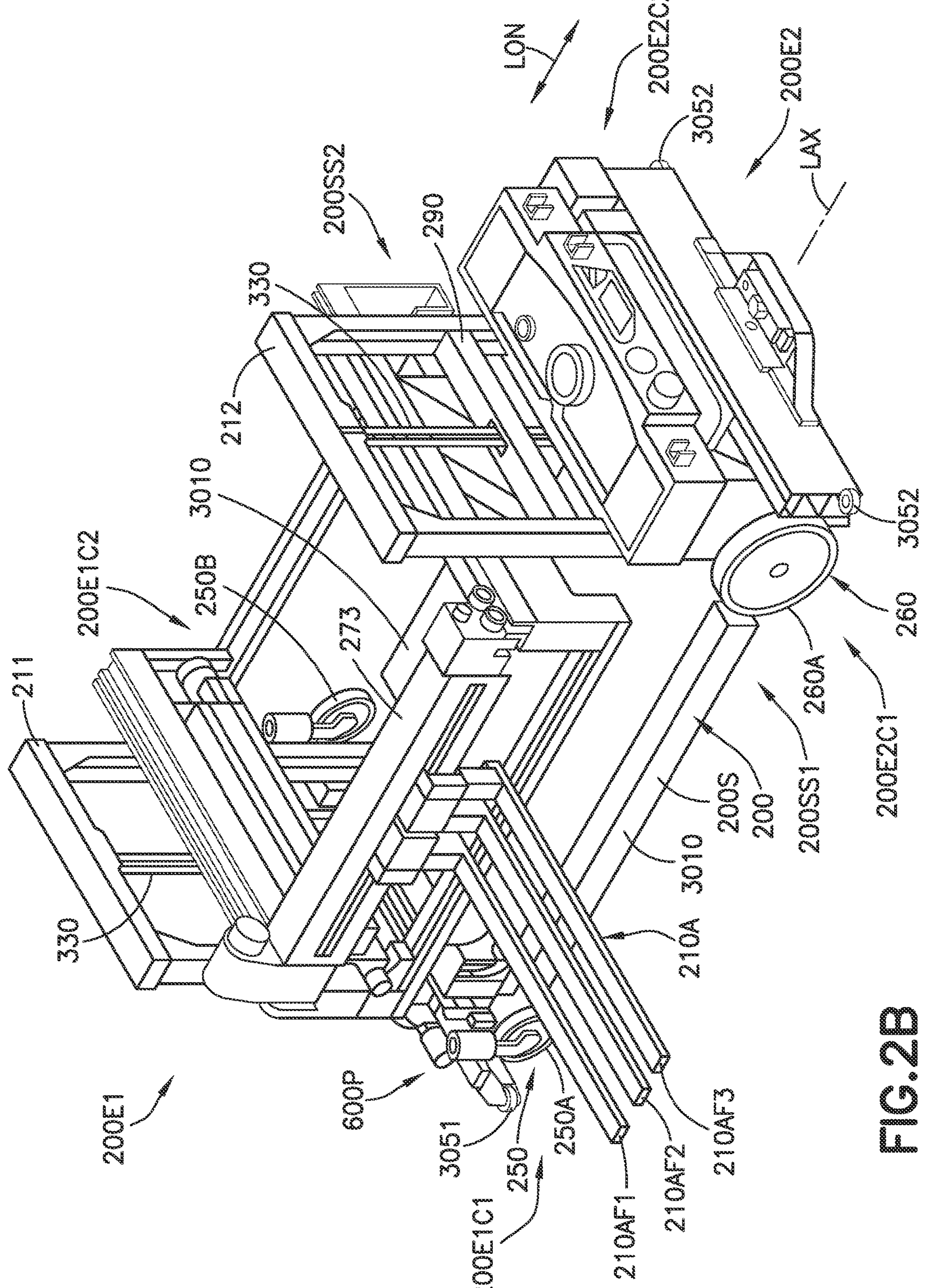

LON
LAT
LAX
TS
110
200E2C2
3052
200E2
212
330
200SS2
210A
210
273
200E1C2
211
3052
200E2C1
260A
260
200
210AF
210A
200S
200SS1
3010
330
210B
250A
250
3051
200E1C1
VER
200E1
390
DRIVE MOTOR

FIG.2A



LON
200E2C2
200E2
3052
LAX
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290
330
212
3010
3052
200E1C2
250B
273
260
260A
200E2C1
200SS1
200S
200
3010
211
330
210A
200E1
600P
3051
250
250A
210AF1
210AF2
210AF3
200E1C1

FIG.2B

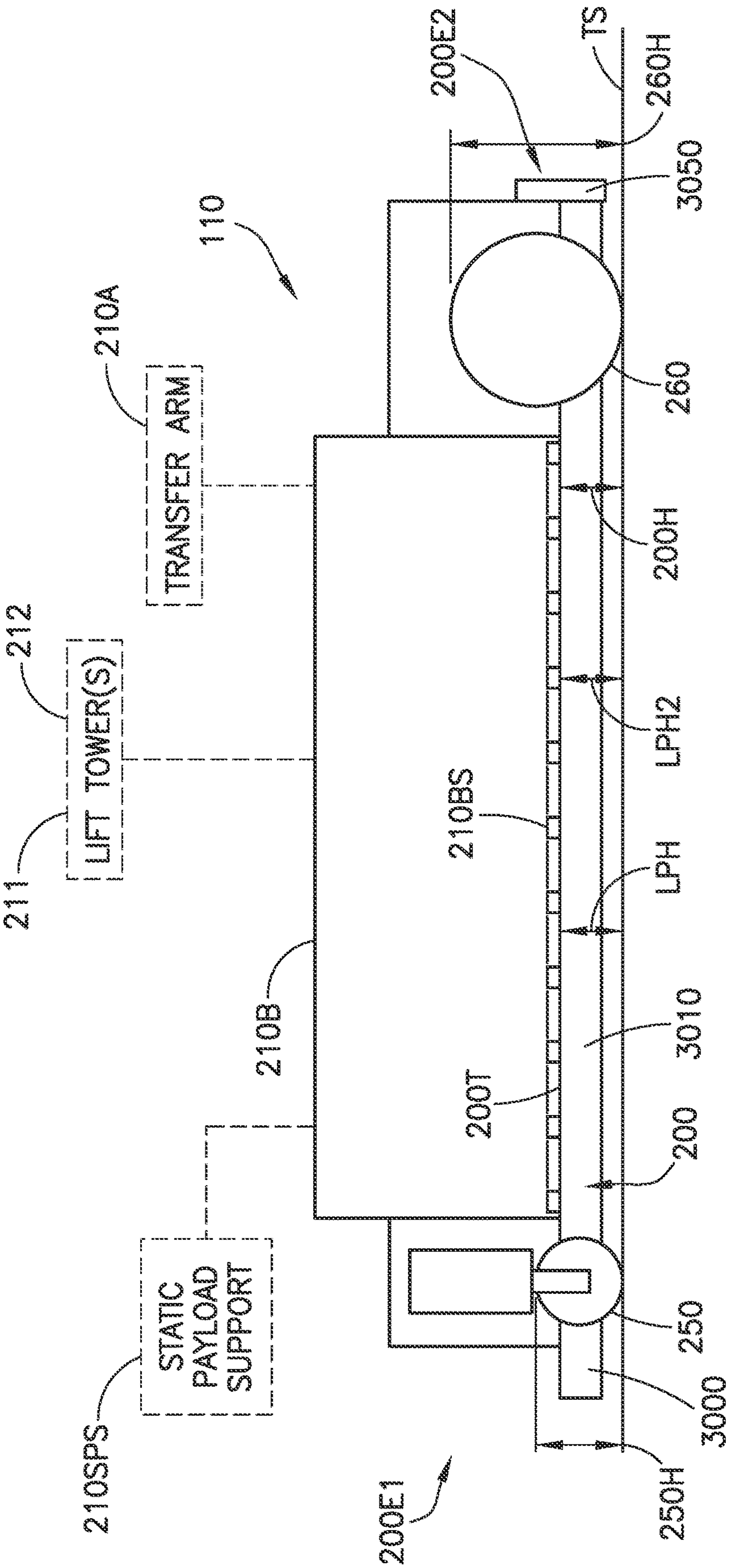

110
200E2
TS
260H
3050
210A
TRANSFER ARM
260
200H
212
LIFT TOWER(S)
211
LPH2
210BS
LPH
210B
3010
200T
200
STATIC PAYLOAD SUPPORT
250
3000
210SPS
200E1
250H

FIG.2C

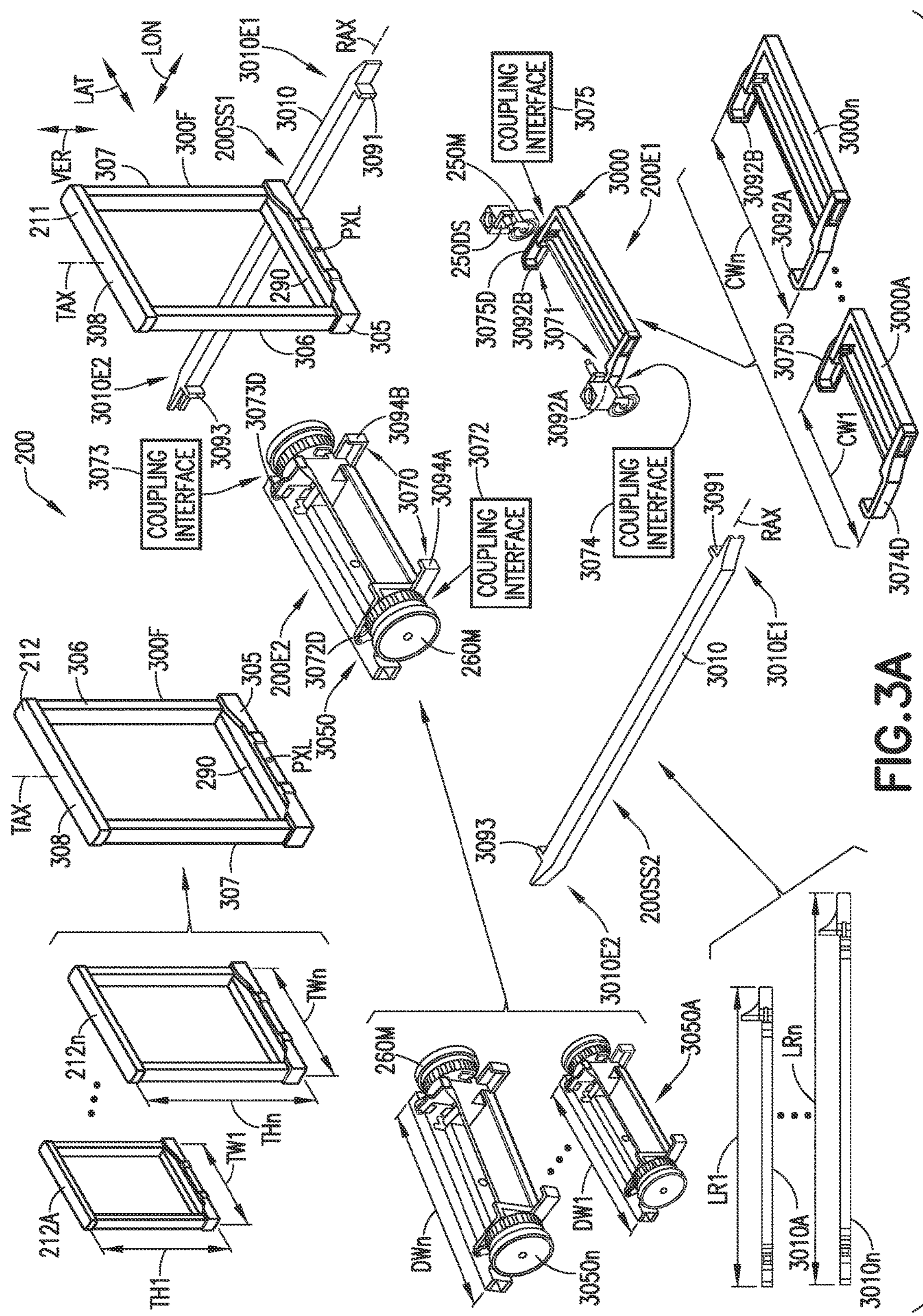

200
211
212
212A
212n
TH1
THn
TW1
TWn
TAX
VER
LAT
LON
RAX
PXL
290
300F
305
306
307
308
200SS1
200SS2
200E1
200E2
3010
3010E1
3010E2
3091
3093
COUPLING INTERFACE
3073
3073D
3072
3072D
3074
3074D
3075
3075D
3070
3071
3094A
3094B
3050
3050A
3050n
260M
250M
250DS
3000
3000A
3000n
3092A
3092B
CW1
CWn
DW1
DWn
LR1
LRn
3010A
3010n

FIG.3A

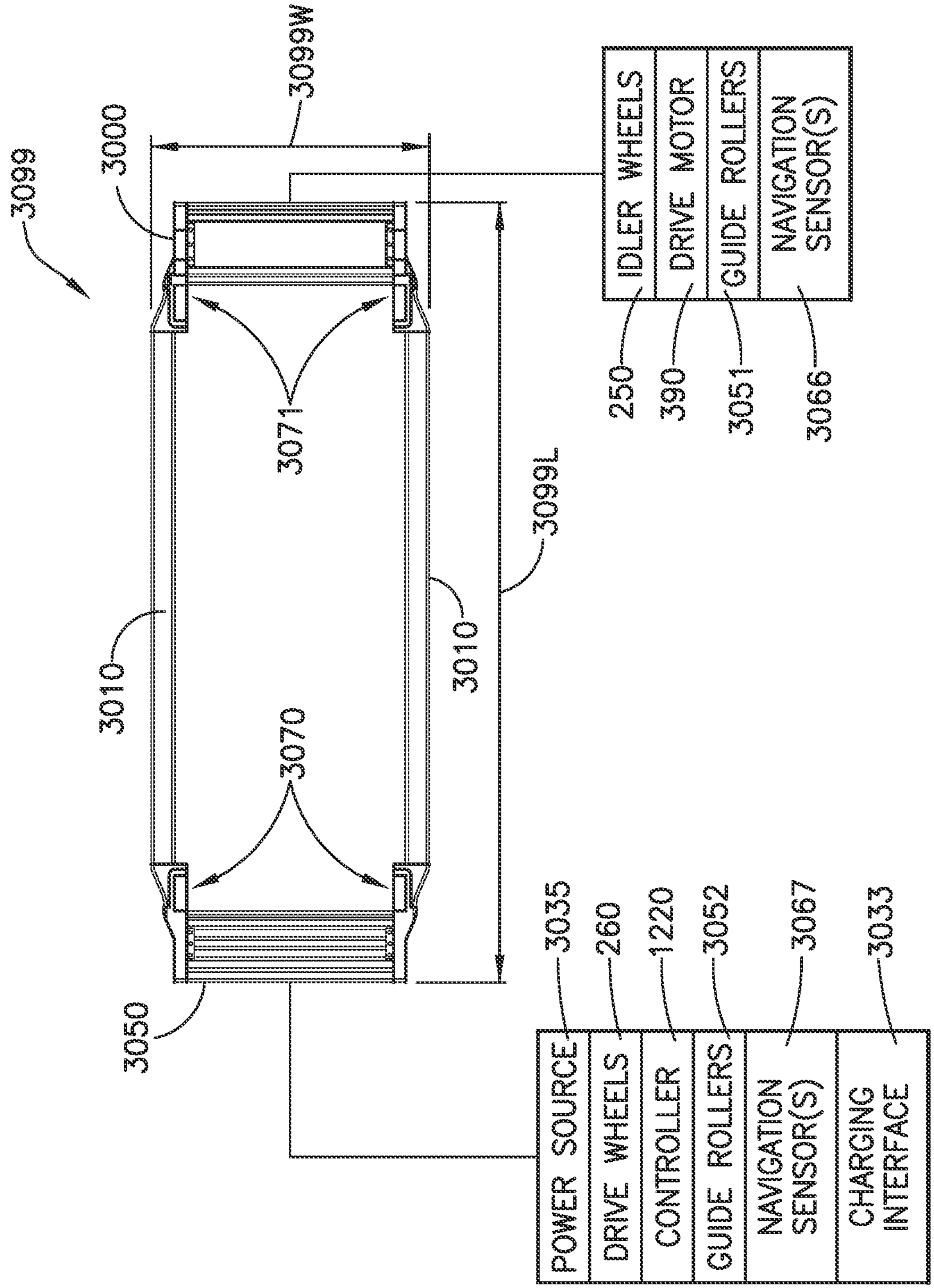
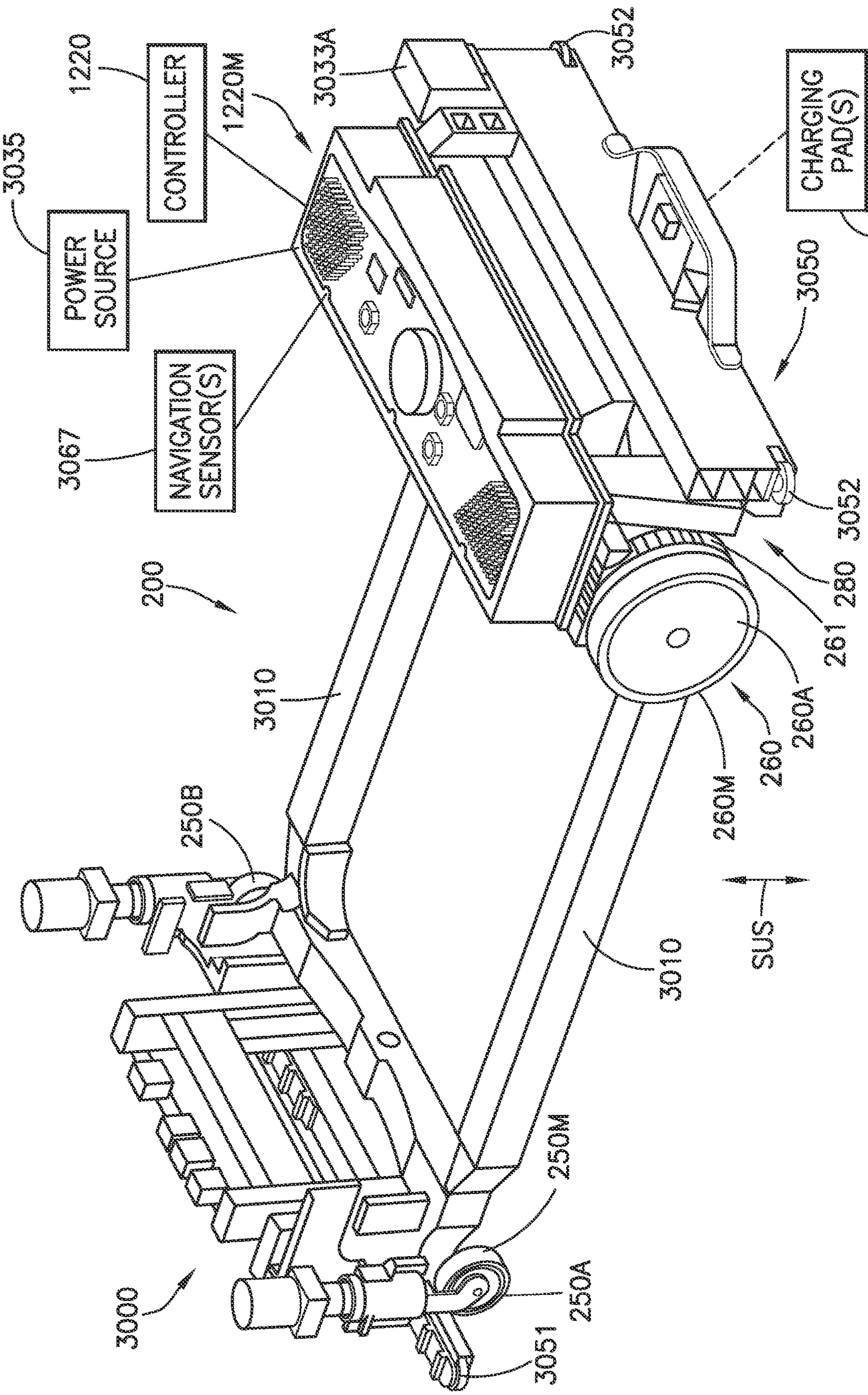
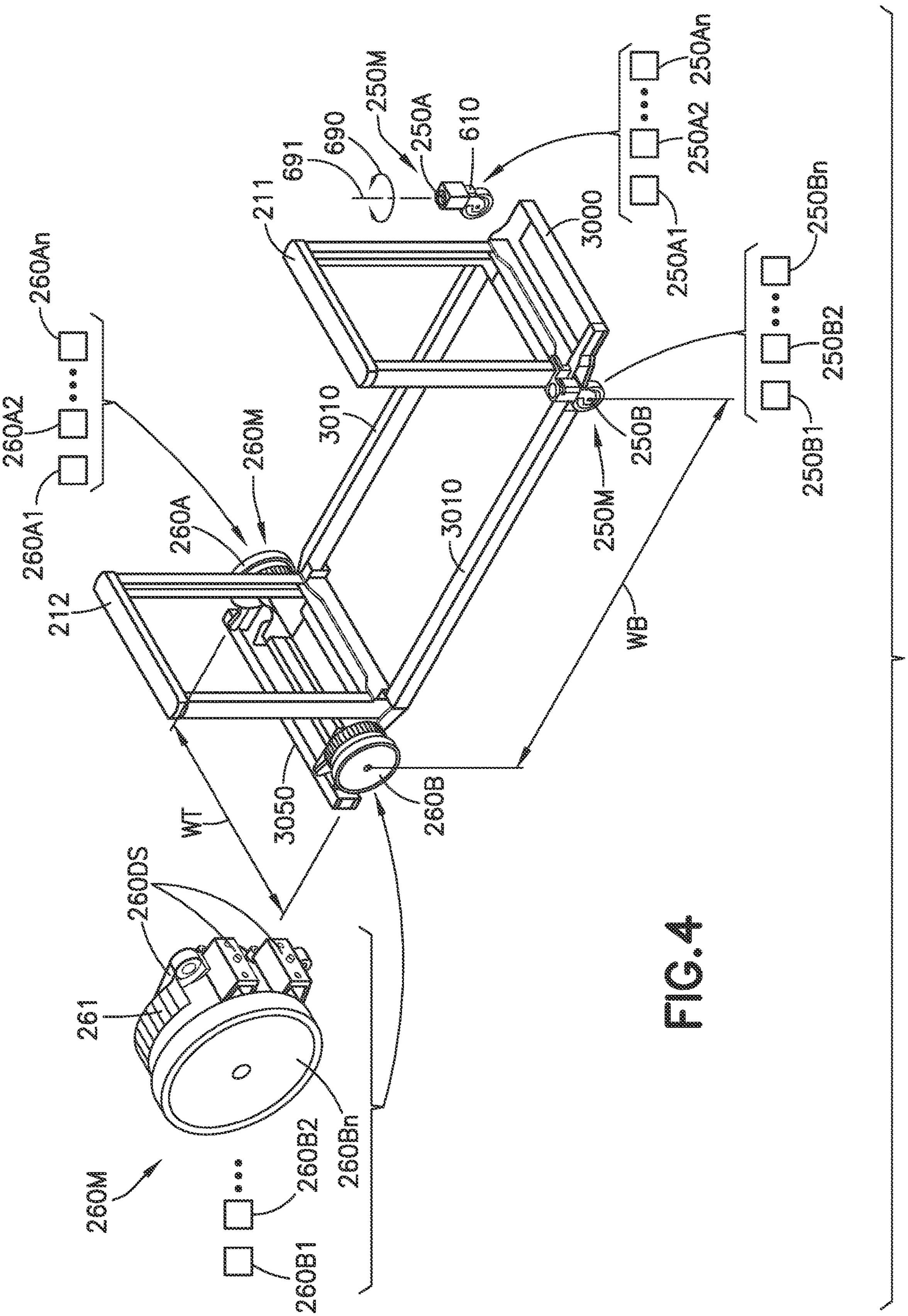

3099
3000
3099W
IDLER WHEELS
DRIVE MOTOR
GUIDE ROLLERS
NAVIGATION SENSOR(S)
250
390
3051
3066
3071
3099L
3010
3010
3070
3050
3035
260
1220
3052
3067
3033
POWER SOURCE
DRIVE WHEELS
CONTROLLER
GUIDE ROLLERS
NAVIGATION SENSOR(S)
CHARGING INTERFACE

FIG.3B



1220
CONTROLLER
1220M
3035
POWER SOURCE
3067
NAVIGATION SENSOR(S)
3033A
3052
CHARGING PAD(S)
3033B
3050
3052
280
261
260A
260
260M
200
3010
250B
SUS
3010
250M
250A
3000
3051

FIG.3C


211
212
3000
3010
3010
3050
691
690
250M
250A
610
250A1
250A2
250An
250B
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250Bn
250M
260A
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260An
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WB
WT
260DS
261
260M
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260B2
260Bn

FIG. 4

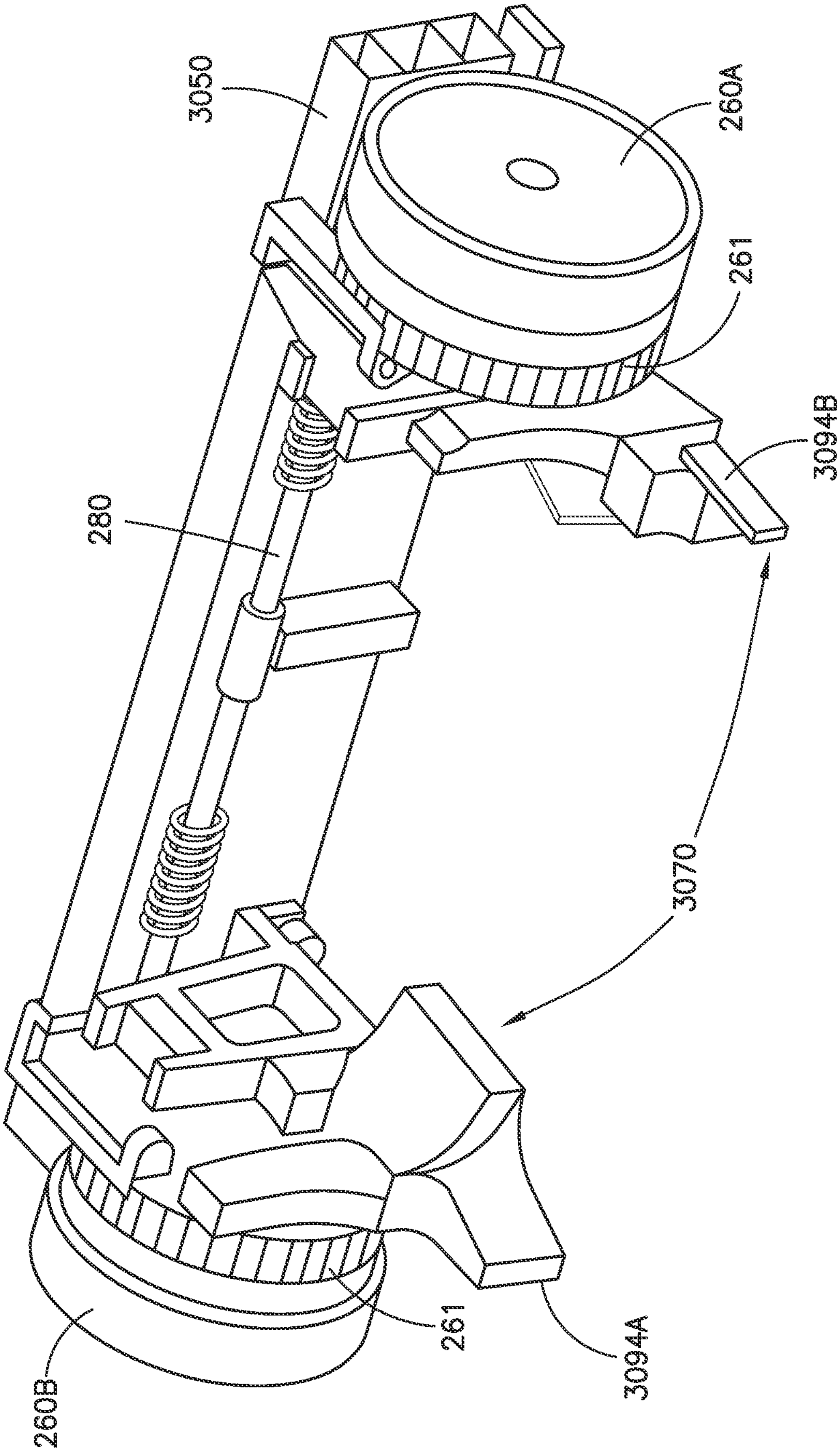
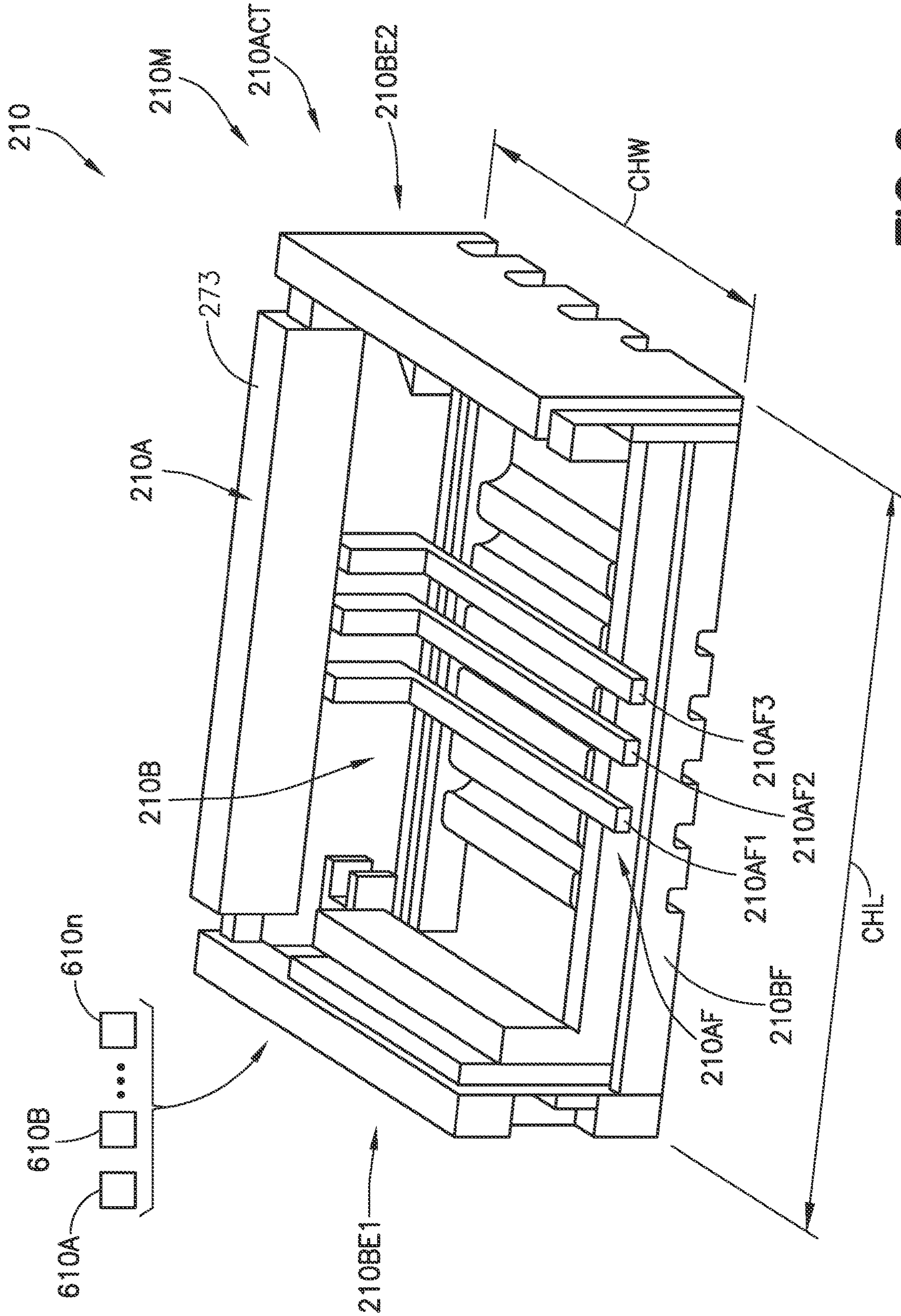


FIG.5


210
210M
210ACT
210BE2
CHW
273
210A
210B
210AF3
210AF2
210AF1
210AF
210BF
CHL
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610A
210BE1

FIG.6

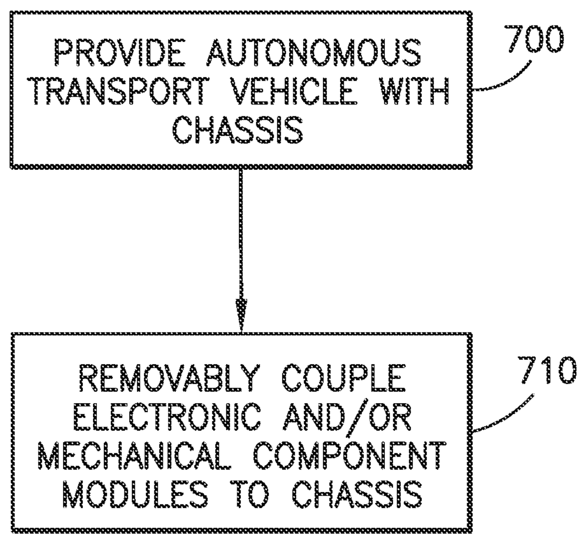
PROVIDE AUTONOMOUS TRANSPORT VEHICLE WITH CHASSIS
700
REMOVABLY COUPLE ELECTRONIC AND/OR MECHANICAL COMPONENT MODULES TO CHASSIS
710

FIG.7

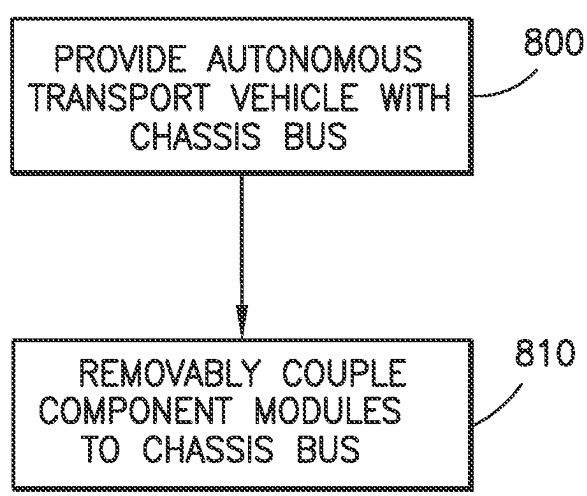
PROVIDE AUTONOMOUS TRANSPORT VEHICLE WITH CHASSIS BUS
800
REMOVABLY COUPLE COMPONENT MODULES TO CHASSIS BUS
810

FIG.8

AUTONOMOUS TRANSPORT VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a non-provisional of and claims the benefit of U.S. provisional patent application No. 63/241,893 filed on Sep. 8, 2021, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field

The disclosed embodiment generally relates to material handling systems, and more particularly, to transports for automated storage and retrieval systems.

2. Brief Description of Related Developments

Generally, autonomous transport vehicles in logistics/warehouse facilities are manufactured to have a predetermined form factor for an assigned task in a given environment. These autonomous transport vehicles are constructed of a bespoke cast or machined chassis/frame that is generally heavy and costly to produce. The other components (e.g., wheels, transfer arms, etc.) are mounted to the frame and are carried with the frame as the autonomous transport vehicle traverses along a traverse surface. The mass of the autonomous transport vehicle, in part from the cast or machined frame, calls for appropriately sized motors and suspension components to drive and carry the mass of the autonomous transport vehicles. These motors and suspension components may also increase the cost and weight of the autonomous transport vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other features of the disclosed embodiment are explained in the following description, taken in connection with the accompanying drawings, wherein:

FIG. **1** is an exemplary schematic block diagram of an automated storage and retrieval system incorporating aspects of the disclosed embodiment;

FIG. **2**A is a schematic perspective illustration of an exemplary autonomous transport vehicle of the automated storage and retrieval system of FIG. **1** in a first configuration in accordance with aspects of the disclosed embodiment;

FIG. **2**B is a schematic perspective illustration of the exemplary autonomous transport vehicle of FIG. **2**A in a second configuration in accordance with aspects of the disclosed embodiment;

FIG. **2**C is a schematic elevation illustration of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **3**A is a schematic exploded illustration of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **3**B is a schematic plan view of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **3**C is a schematic perspective illustration of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **4** is a partial exploded illustration of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **5** is a perspective illustration of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **6** is a perspective illustration of a portion of the exemplary autonomous transport vehicle of FIG. **2**A in accordance with aspects of the disclosed embodiment;

FIG. **7** is an exemplary block diagram of a method in accordance with aspects of the disclosed embodiment; and

FIG. **8** is an exemplary block diagram of a method in accordance with aspects of the disclosed embodiment.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary automated storage and retrieval system **100** in accordance with aspects of the disclosed embodiment. Although the aspects of the disclosed embodiment will be described with reference to the drawings, it should be understood that the aspects of the disclosed embodiment can be embodied in many forms. In addition, any suitable size, shape or type of elements or materials could be used.

The aspects of the disclosed embodiment provide an automated storage and retrieval system with a modular autonomous transport robot vehicle **110** (referred to herein as an autonomous transport (or guided) vehicle or bot). The autonomous transport vehicle **110** includes selectable modular chassis, motor, and case unit handling components, the selection of which configures (or reconfigures) the autonomous transport vehicle **110** with different case handling characteristics (e.g., chassis length, chassis width, payload area size, case unit lift height, suspension spring preload, suspension spring rate, chassis rigidity characteristics, etc.) that may depend on a size/weight of the case units being handled and/or storage characteristics (e.g., shelf height, multiple shelves serviced from a common rolling surface/deck) of the automated storage and retrieval system **100** storage structure **130**. The modular chassis components (described herein) may be fabricated at least in part from readily available bar stock, tubing stock, channel stock, etc. so as to reduce manufacturing/machining costs compared to conventional autonomous transport vehicles having bespoke chassis/frames. At least the modular chassis components contribute to a reduced weight compared to the conventional autonomous transport vehicles having bespoke chassis/frames. The reduced weight may provide for less wear on the rolling surfaces along which the autonomous transport vehicle **110** travels as well as less wear on the wheels of the autonomous transport vehicle **110**.

The automated storage and retrieval system **100** in FIG. **1**, in which the autonomous transport vehicle **110** operates, may be disposed in a retail distribution center or warehouse, for example, to fulfill orders received from retail stores for replenishment goods shipped in cases, packages, and or parcels. The terms case, package and parcel are used interchangeably herein and as noted before may be any container that may be used for shipping and may be filled with case or more product units by the producer. Case or cases as used herein means case, package or parcel units not stored in trays, on totes, etc. (e.g. uncontained), and/or a tote of individual goods that are of a common or mixed goods type. It is noted that the case units CU (also referred to herein as mixed cases, cases, shipping units, or payload) may include cases of items/unit (e.g. case of soup cans, boxes of cereal, etc.) or individual item/units that are adapted to be taken off of or placed on a pallet. In accordance with the exemplary embodiments, shipping cases or case units (e.g. cartons, barrels, boxes, crates, jugs, shrink wrapped trays or groups or any other suitable device for holding case units) may have variable sizes and may be used to hold case units in shipping and may be configured so they are capable of being palletized for shipping. Case units may also include totes, boxes, and/or containers of one or more individual goods, unpacked/decommissioned (generally referred to as breakpack goods) from original packaging and placed into the tote, boxes, and/or containers (collectively referred to as totes) with one or more other individual goods of mixed or common types at an order fill station. It is noted that when, for example, incoming bundles or pallets (e.g. from manufacturers or suppliers of case units arrive at the storage and retrieval system for replenishment of the automated storage and retrieval system **100**, the content of each pallet may be uniform (e.g. each pallet holds a predetermined number of the same item—one pallet holds soup and another pallet holds cereal). As may be realized, the cases of such pallet load may be substantially similar or in other words, homogenous cases (e.g. similar dimensions), and may have the same SKU (otherwise, as noted before the pallets may be "rainbow" pallets having layers formed of homogeneous cases). As pallets leave the storage and retrieval system, with cases or totes filling replenishment orders, the pallets may contain any suitable number and combination of different case units (e.g. each pallet may hold different types of case units—a pallet holds a combination of canned soup, cereal, beverage packs, cosmetics and household cleaners). The cases combined onto a single pallet may have different dimensions and/or different SKU's.

The automated storage and retrieval system may be generally described as a storage and retrieval engine **190** coupled to a palletizer **162**. In greater detail now, and with reference still to FIG. **1**, the storage and retrieval system **100** may be configured for installation in, for example, existing warehouse structures or adapted to new warehouse structures. As noted before the system **100** shown in FIG. **1** is representative and may include for example, in-feed and out-feed conveyors terminating on respective transfer stations **170**, **160**, lift module(s) **150**A, **150**B, a storage structure **130**, and a number of autonomous transport vehicles **110** (also referred to herein as "bots"). It is noted that the storage and retrieval engine **190** is formed at least by the storage structure **130** and the bots **110** (and in some aspect the lift modules **150**A, **150**B; however in other aspects the lift modules **150**A, **150**B may form vertical sequencers in addition to the storage and retrieval engine **190** as described in U.S. patent application Ser. No. 17/091,265 filed on Nov. 6, 2020 and titled "Pallet Building System with Flexible Sequencing," the disclosure of which is incorporated herein by reference in its entirety). In alternate aspects, the storage and retrieval system may also include robot or bot transfer stations (not shown) that may provide an interface between the bots **110** and the lift module(s) **150**A, **150**B. The storage structure **130** may include multiple levels of storage rack modules where each level includes respective picking aisles **130**A, and transfer decks **130**B for transferring case units between any of the storage areas of the storage structure **130** and a shelf of the lift module(s) **150**A, **150**B. The picking aisles **130**A are in one aspect configured to provide guided travel of the bots **110** (such as along rails) while in other aspects the picking aisles are configured to provide unrestrained travel of the bot **110** (e.g., the picking aisles are open and undeterministic with respect to bot **110** guidance/travel). The transfer decks **130**B have open and undeterministic bot support travel surfaces along which the bots **110** travel under guidance and control provided by bot steering (as will be described herein). As used herein, "open and undeterministic" denotes the travel surface of the picking aisle and/or the transfer deck has no mechanical/physical restraints/guides (such as guide rails) that delimit the travel of the autonomous transport vehicle **110** to any given path along the travel surface. In one or more aspects, the transfer decks have multiple lanes between which the bots **110** freely transition for accessing the picking aisles **130**A and/or lift modules **150**A, **150**B. The picking aisles **130**A, and transfer decks **130**B also allow the bots **110** to place case units CU into picking stock and to retrieve ordered case units CU. In alternate aspects, each level may also include respective bot transfer stations **140**. It is noted that while the aspects of the disclosed embodiment are described with respect to a multilevel storage array, the aspects of the disclosed embodiment may be equally applied to a single level storage array that is disposed on a facility floor or elevated above the facility floor.

The bots **110** may be configured to place case units, such as the above described retail merchandise, into picking stock in the one or more levels of the storage structure **130** and then selectively retrieve ordered case units for shipping the ordered case units to, for example, a store or other suitable location. The in-feed transfer stations **170** and out-feed transfer stations **160** may operate together with their respective lift module(s) **150**A, **150**B for bi-directionally transferring case units CU to and from one or more levels of the storage structure **130**. It is noted that while the lift modules **150**A, **150**B may be described as being dedicated inbound lift modules **150**A and outbound lift modules **150**B, in alternate aspects each of the lift modules **150**A, **150**B may be used for both inbound and outbound transfer of case units from the storage and retrieval system **100**.

As may be realized, the storage and retrieval system **100** may include multiple in-feed and out-feed lift modules **150**A, **150**B that are accessible by, for example, bots **110** of the storage and retrieval system **100** so that one or more case unit(s), uncontained (e.g. case unit(s) are not held in trays), or contained (within a tray or tote) can be transferred from a lift module **150**A, **150**B to each storage space on a respective level and from each storage space to any one of the lift modules **150**A, **150**B on a respective level. The bots **110** may be configured to transfer the case units between the storage spaces **130**S (e.g., located in the picking aisles **130**A or other suitable storage space/case unit buffer disposed along the transfer deck **130**B) and the lift modules **150**A, **150**B. Generally, the lift modules **150**A, **150**B include at least one movable payload support that may move the case unit(s) between the in-feed and out-feed transfer stations **160**, **170** and the respective level of the storage space where the case unit(s) is stored and retrieved. The lift module(s) may have any suitable configuration, such as for example reciprocating lift, or any other suitable configuration. The lift module(s) **150**A, **150**B include any suitable controller (such as controller **120** or other suitable controller coupled to controller **120**, warehouse management system **2500**, and/or palletizer controller **164**, **164'**) and may form a sequencer or sorter in a manner similar to that described in U.S. patent application Ser. No. 16/444,592 filed on Jun. 18, 2019 and titled "Vertical Sequencer for Product Order Fulfillment" (the disclosure of which is incorporated herein by reference in its entirety).

The automated storage and retrieval system may include a control system, comprising for example one or more control servers **120** that are communicably connected to the in-feed and out-feed conveyors and transfer stations **170**, **160**, the lift modules **150**A, **150**B, and the bots **110** via a suitable communication and control network **180**. The communication and control network **180** may have any suitable architecture which, for example, may incorporate various programmable logic controllers (PLC) such as for commanding the operations of the in-feed and out-feed conveyors and transfer stations **170**, **160**, the lift modules **150**A, **150**B, and other suitable system automation. The control server **120** may include high level programming that effects a case management system (CMS) **120** managing the case flow system. The network **180** may further include suitable communication for effecting a bi-directional interface with the bots **110**. For example, the bots **110** may include an on-board processor/controller **1220**. The network **180** may include a suitable bi-directional communication suite enabling the bot controller **1220** to request or receive commands from the control server **180** for effecting desired transport (e.g. placing into storage locations or retrieving from storage locations) of case units and to send desired bot **110** information and data including bot **110** ephemeris, status and other desired data, to the control server **120**. As seen in FIG. **1**, the control server **120** may be further connected to a warehouse management system **2500** for providing, for example, inventory management, and customer order fulfillment information to the CMS **120** level program. A suitable example of an automated storage and retrieval system arranged for holding and storing case units is described in U.S. Pat. No. 9,096,375, issued on Aug. 4, 2015 the disclosure of which is incorporated by reference herein in its entirety.

Referring now to FIGS. **2**A, **2**B, and **2**C, the autonomous transport vehicle or bot **110** includes a chassis or chassis bus **200** having a front end **200**E**1** and a back end **200**E**2** that define a longitudinal axis LAX of the autonomous transport vehicle **110**. The chassis **200** is a space frame **200**S and may be constructed (e.g., formed) of any suitable material including but not limited to steel, aluminum, and composites. As will be described herein, the space frame **200**S has predetermined modular coupling interfaces (see, e.g., interfaces **3070**-**3075**—FIG. **3**A) that have known locations relative to each other and include datums for positioning/locating components of the autonomous transport vehicle relative to each other as described herein. Each of the modular coupling interfaces is disposed for removably coupling, as a modular unit, a corresponding predetermined electronic and/or mechanical component module of the autonomous transport vehicle **110** to the chassis **200** so that the autonomous transport robot vehicle **110** has a modular construction. The predetermined modular coupling interfaces include at least one of at least one caster wheel module coupling interface **3074**, **3075**, at least one drive wheel module coupling interface **3072**, **3073**, and at least one payload support module coupling interface **3070**, **3071**. As described herein, the corresponding predetermined electronic and/or mechanical component modules include, but are not limited to, ride wheel modules (e.g., at least one drive wheel module **260**M and at least one caster wheel module **250**M), payload support module **210**M, control module **1220**M, etc. The drive wheel module **260**M has a drive wheel **260**A, **260**B removably coupled as a module unit to the chassis **200** with a corresponding drive wheel module coupling interface **3072**, **3073**. The caster wheel module **250**M has a caster wheel **250**A, **250**B removably coupled as a module unit to the chassis **200** with a corresponding caster wheel module coupling interface **3074**, **3075**. The payload support module **210**M has a payload support contact surface **210**BS removably coupled as a module unit to the chassis **200** with a corresponding payload support module coupling interface **3070**, **3071**.

The autonomous transport vehicle **110** also includes a case handling assembly or payload support **210** configured to handle cases/payloads transported by the autonomous transport vehicle **110**. The payload support **210** may be provided as the payload support module **210**M and is removably connected to the chassis **200** (e.g., with mechanical fasteners) and is dependent therefrom. The payload support **210** includes at least any suitable payload support contact surface **210**B on which payloads are placed for transport. In one or more aspects, the payload support also includes any suitable transfer arm **210**A configured to transfer payloads between the autonomous transport vehicle **110** and a payload holding location (such as any suitable payload storage location, a shelf of lift module **150**A, **150**B, and/or any other suitable payload holding location). The transfer arm **210**A may be configured to extend laterally in direction LAT and/or vertically in direction VER to transport payloads to and from a payload area of the payload support **210**. Examples of suitable payload support contact surfaces **210**B and transfer arms **210**A and/or autonomous transport vehicles to which the aspects of the disclosed embodiment may be applied can be found in United States pre-grant publication number 2012/0189416 published on Jul. 26, 2012 (U.S. patent application Ser. No. 13/326,952 filed on Dec. 15, 2011) and titled "Automated Bot with Transfer Arm"; U.S. Pat. No. 7,591,630 issued on Sep. 22, 2009 titled "Materials-Handling System Using Autonomous Transfer and Transport Vehicles"; U.S. Pat. No. 7,991,505 issued on Aug. 2, 2011 titled "Materials-Handling System Using Autonomous Transfer and Transport Vehicles"; U.S. Pat. No. 9,561,905 issued on Feb. 7, 2017 titled "Autonomous Transport Vehicle"; U.S. Pat. No. 9,082,112 issued on Jul. 14, 2015 titled "Autonomous Transport Vehicle Charging System"; U.S. Pat. No. 9,850,079 issued on Dec. 26, 2017 titled "Storage and Retrieval System Transport Vehicle"; U.S. Pat. No. 9,187,244 issued on Nov. 17, 2015 titled "Bot Payload Alignment and Sensing"; U.S. Pat. No. 9,499,338 issued on Nov. 22, 2016 titled "Automated Bot Transfer Arm Drive System"; U.S. Pat. No. 8,965,619 issued on Feb. 24, 2015 titled "Bot Having High Speed Stability"; U.S. Pat. No. 9,008,884 issued on Apr. 14, 2015 titled "Bot Position Sensing"; U.S. Pat. No. 8,425,173 issued on Apr. 23, 2013 titled "Autonomous Transports for Storage and Retrieval Systems"; and U.S. Pat. No. 8,696,010 issued on Apr. 15, 2014 titled "Suspension System for Autonomous Transports", the disclosures of which are incorporated herein by reference in their entireties.

As will be described in greater detail herein, the chassis **200** includes ride wheels dependent from the chassis **200**, proximate opposite end corners **200**E**1**C**1**, **200**E**1**C**2**, **200**E**2**C**1**, **200**E**2**C**2** of the chassis **200**, on which the autonomous transport vehicle **110** rides so as to traverse a traverse surface TS of the storage and retrieval system **100** storage structure level **130** on which the autonomous transport vehicle **110** is disposed. The ride wheels **250**, **260** include at least one idler or caster wheel **250**A, **250**B and at least one drive wheel **260**A, **260**B supporting the chassis **200** from the traverse surface TS. For example, one or more idler wheels **250**A, **250**B are disposed adjacent the front end **200**E**1** (e.g., a pair of caster wheels **250**A, **250**B are illustrated in the figures for exemplary purposes) and one or more drive wheels **260**A, **260**B (e.g., a pair of drive wheels **260**A, **260**B are illustrated in the figures for exemplary purposes) are disposed adjacent the back end **200**E**2**. In other aspects, the position of the idler wheels **250** and drive wheels **260** may be reversed (e.g., the drive wheels **260** are disposed at the front end **200**E**1** and the idler wheels **250** are disposed at the back end **200**E**2**). It is noted that in some aspects, the autonomous transport vehicle **110** is configured to travel with the front end **200**E**1** leading the direction of travel or with the back end **200**E**2** leading the direction of travel. In one aspect, idler wheels **250**A, **250**B (which are substantially similar to idler wheel **250** described herein) are located at respective front corners of the chassis **200** at the front end **200**E**1** and drive wheels **260**A, **260**B (which are substantially similar to drive wheel **260** described herein) are located at respective back corners of the chassis **200** at the back end **200**E**2** (e.g., a support wheel is located at each of the four corners **200**E**1**C**1**, **200**E**1**C**2**, **200**E**2**C**1**, **200**E**2**C**2** of the chassis **200**) so that the autonomous transport vehicle **110** stably traverses the transfer deck(s) **130**B and picking aisles **130**A of the storage structure **130**.

As will be described herein, the ride wheels **250**, **260** and chassis **200** in combination form a low profile height LPH (FIG. **2**C) that is a minimum height from the traverse surface TS to atop **200**T the chassis **200**, where chassis height **200**H and ride wheel height (e.g., one or more of ride wheels heights **250**H, **260**H) are overlapped (coextensive) at least in part and a payload support contact surface **210**BS of the payload support **210**B (on which contact surface **210**BS a payload, e.g., such as case unit CU, resting on the payload support **210**B is seated) is nested within (e.g., between and within the height of at least one of) the ride wheels **250**, **260** (see FIG. **2**C). Here, the payload support contact surface **210**BS disposed atop the chassis **200**. The payload support contact surface **210**BS may be disposed at a height LPH2 from the traverse surface TS that is substantially the same as the low profile height LPH, while in other aspects the height LPH2 may be greater than the low profile height LPH while still being nested within the ride wheels **250**, **260** (see FIG. **2**C).

Referring to FIGS. **2**A, **2**B, **2**C, **3**A, and **3**B, the chassis **200**, as noted herein, is a space frame **200**S having a modular configuration/construction such that selection of chassis components from a number of different selectable chassis components configures and/or reconfigures the autonomous transport vehicle **110** for one or more of case transfer operations, employment in different storage and retrieval systems having different physical requirements for the autonomous transport vehicles **100**, and/or different operational requirements of the autonomous transport vehicles **100** (e.g., suspension travel, case lift heights, ground clearance, automated charging configurations, etc.). The modular configuration of the chassis **200** also facilitates modular repair and/or maintenance of the autonomous transport vehicle **110** so as to reduce downtime (i.e., increase in-service time) of the autonomous transport vehicle **110**. The space frame **200**S is configured so that the chassis **200** is substantially rigid with predetermined rigidity characteristics, with a shape and form that provide the minimum low profile height LPH from the traverse surface TS to atop **200**T the chassis **200**. Examples of predetermined rigidity characteristics include, but are not limited to, generating a predetermined transient response of the chassis/payload support contact surface **210**BS from one or more of bot traverse transient loads (as described in U.S. provisional patent application No. 63/213,589 filed on Jun. 22, 2021) and titled "Autonomous Transport Vehicle with Synergistic Vehicle Dynamic Response," the disclosure of which is incorporated herein by reference in its entirety), static and dynamic loads generated by actuation of the transfer arm/end effector **210**A, and loading/unloading payloads to/from the payload bed **21**B and payload transfers. The space frame **200**S configuration resolves both predetermined rigidity characteristics (as to imparted loads) and the minimum low profile height LPH of the chassis **200** from the traverse surface TS to atop **200**T the chassis **200**. As described herein, the chassis **200** has a selectably variable configuration, selectable from different configurations each having different chassis form factors (e.g., selectably variable lengths and/or widths). The predetermined rigidity characteristics include torsional rigidity of the space frame **200**S along the longitudinal axis (e.g., twisting of the chassis about the longitudinal axis), bending rigidity of the space frame **200**S along the lateral direction (e.g., from side to side), and bending rigidity of the space frame **200**S along the longitudinal direction (e.g., from front to back). The predetermined rigidity characteristics result in deflection, with respect to the payload carried by vehicle **110**, that is negligible/indiscernible for a given payload weight (e.g., such as payloads of up to about 60 lbs or more). The deflection is negligible/indiscernible with respect to the seating of the payload across a contact surface between the payload bed (or transfer arm) of the vehicle **110** and the payload such that the payload remains in substantially contact with the contact surface throughout travel of and/or a range of motion of the vehicle **110**.

Referring also to FIGS. **3**A and **3**B, the chassis **200** includes longitudinal hollow section beams **3010** that are arrayed to form longitudinally extended sides (or lateral sides) **200**SS**1**, **200**SS**2** of the space frame **200**S. The chassis **200** also includes a respective front lateral beam or cross-member **3000** and a respective rear lateral beam or cross-member **3050** closing opposite ends **200**E**1**, **200**E**2** of the space frame **200**S. As described herein, at least one of the longitudinal hollow section beams **3010**, the front lateral beam **3000**, and the rear lateral beam **3050**, is/are selectable from a number of different selectably interchangeable respective longitudinal hollow section beams **3010**A-**3010***n*, front lateral beams **3000**A-**3000***n*, and rear lateral beams **3050**A-**3050***n*, each with different predetermined mechanical characteristics. Examples of the difference predetermined mechanical characteristics include, but are not limited to, material, cross-section, etc. Here, selection of the at least one of the longitudinal hollow section beams **3010**, the front lateral beam **3000**, and the rear lateral beam **3050** from the number of different selectably interchangeable respective longitudinal hollow section beams **3010**A-**3010***n*, the front lateral beams **3000**A-**3000***n*, and the rear lateral beams **3050**A-**3050***n* determines the selected variable configuration of the chassis **200**.

In one or more aspects the chassis includes the transfer arm **210**A that extends/retracts laterally relative to the payload support **210**B where the transfer arm **210**A may be movable in the vertical direction VER in any suitable manner by any suitable distance so that the transfer arm **210**A is above/clears the chassis **200** when the transfer arm **210**A is extended/retracted. The transfer arm **210**A may be provided as a part of the payload support module **210**M as described herein. In some aspects, the payload support **210**B and transfer arm **210**A are coupled to at least one payload support stanchion module **211**, **212** (also referred to as a payload support stanchion) as described herein, where in some aspects the payload support stanchions **211**, **212** are configured to move one or more of the payload support **21**B and transfer arm **210**A in vertical direction VER. In other aspects, the payload support **210**B may be a static payload support **210**SPS (FIG. **2**C) without an actuated transfer arm

210A (and without vertical movement provided by the payload support stanchions 211, 212, although in some aspects vertical movement may be provided). In some aspect, the payload support stanchion modules 211, 212 may also be provided as a part of the payload support module 210M or as separate modules to which the payload support module 210M is coupled.

The front lateral beam 3000 and the rear lateral beam 3000 extend laterally in direction LAT. The longitudinal hollow section beams 3010 extend longitudinally in direction LON. The longitudinal hollow section beams 3010 are substantially similar to each other so that either longitudinal hollow section beam 3010 can be installed on either lateral side of the autonomous transport vehicle by reorienting (e.g., rotating by about 180 degrees) the longitudinal hollow section beams 3010 about a respective longitudinal axis RAX; however, in other aspects the longitudinal hollow section beam 3010 may be differently configured depending on which lateral side of the autonomous transport vehicle 110 the longitudinal hollow section beams 3010 are installed. Each longitudinal hollow section beam 3010 includes a first end 3010E1 configured to couple to the front lateral beam 3000 in any suitable manner (such as mechanical fasteners). The first end 3010E1 includes at least one datum surface 3091 that is configured to seat against a corresponding datum surface 3092A, 3092B of the front lateral beam 3000. Each longitudinal hollow section beam 3010 also includes a second end 3010E2 configured to couple to the rear lateral beam 3050 in any suitable manner (such as mechanical fasteners). Each second end 3010E2 has at least one datum surface 3093 that is configured to seat against a corresponding datum surface 3094A, 3094B of the rear lateral beam 3050. The longitudinal distance between the datum surface 3091 and the datum surface 3093 of each longitudinal hollow section beam 3010 is predetermined so that with the front lateral beam 3000 and the rear lateral beam 3050 coupled to the longitudinal hollow section beams 3010, e.g., to form the chassis 3099 having a longitudinal length 3099L and a lateral width 3099W, the components (e.g., sensors, actuators, etc.) of the front lateral beam 3000 and the rear lateral beam 3050 have a known positional/spatial relationship relative to each other. The chassis 3099 is illustrated in FIG. 3B without sub-components (e.g., wheels, electronics, etc.) thereon for clarity. In some aspects, the longitudinal hollow section beams 3010 include identifying indicia (radio frequency identification tags, etc.) that inform the controller 1220 of the length (between datum surfaces 3091, 3093) of the respective longitudinal hollow section beam 3010. The identifying indicia are read by suitable sensors of the controller 1220 of the autonomous transport vehicle 110 to effect a plug and play positional/spatial relationship between the autonomous vehicle components by the controller 1220 as described herein. In other aspects, the length (between datum surfaces 3091, 3093) of the respective longitudinal hollow section beam 3010 may be input to the controller 1220 manually through any suitable user interface of the autonomous transport vehicle 110.

In one or more aspects, the length 3099L and/or width 3099W of the chassis 3099 is selectable from a number of different lengths and/or widths (e.g., effected through a selection of different longitudinal hollow section beam 3010A-3010*n* having different lengths LR1-LRn and/or a selection of different front and rear lateral beams 3000A-3000*n*, 3050A-3050*n* having different widths CW1-CWn, DW1-DWn) so as to enlarge or reduce payload capacity of the autonomous transport vehicle 110. For example, the length 3099L is increased or decreased depending on, for example, a maximum length of case units handled by the autonomous transport vehicle 110. Similarly, the width 3099W is increased or decreased depending on, for example, a maximum width of case units handled by the autonomous transport vehicle 110. The length 3099L and/or width 3099W may also be increased or decreased so as to increase the wheel base WB and/or wheel track WT (see FIG. 4) depending one or more of, for example, structural size constraints imposed on the autonomous transport vehicle 110 by structure of the storage and retrieval system 100 (e.g., picking aisle width, turning radius, etc.), ride quality of the autonomous transport vehicle (e.g., longer wheel base provides less jostling of goods being transported), and transport speeds (e.g., wider wheel track provides greater stability in turns). In other aspects, the length 3099L and/or width 3099W may be increased or decreased for any suitable reasons. The length 3099L of the chassis 3099 is selected through a selection of a number of different longitudinal hollow section beam 3010A-3010*n* each having a respective length LR1-LRn (where "n" is an integer denoting a maximum number for the selection).

The width 3099W of the chassis 3099 is selected through a selection of a number of different front lateral beams 3000A-3000*n* each having a respective width CW1-CWn and a corresponding one of a number of different rear lateral beams 3050A-3050*n* each having a respective width DW1-DWn. In some aspects, the front and rear lateral beams 3000, 3050 each include identifying indicia (radio frequency identification tags, etc.) that inform the controller 1220 of at least the width (between datum surfaces 3072D, 3073D or 3074D, 3075D—FIG. 3A) of the respective front and rear lateral beams 3000, 3050. The identifying indicia are read by suitable sensors of the controller 1220 of the autonomous transport vehicle 110 to effect a plug and play positional/spatial relationship between the autonomous vehicle components by the controller 1220 as described herein. In other aspects, the width (between datum surfaces 3072D, 3073D or 3074D, 3075D) of the respective front and rear lateral beams 3000, 3050 may be input to the controller 1220 manually through any suitable user interface of the autonomous transport vehicle 110.

While the rear lateral beams 3050A-3050*n* are illustrated as having the drive wheels 260A, 260B installed thereon, in one or more aspects the drive wheels 260A, 260B may be installed, as drive wheel modules 260M, on the rear lateral beams 3050A-3050*n* prior to coupling of the rear lateral beams 3050A-3050*n* to the longitudinal hollow section beam 3010. In other aspects, the drive wheels 260A, 260B may be installed, as drive wheel modules 260M, on the rear lateral beams 3050A-3050*n* post coupling of the rear lateral beams 3050A-3050*n* to the longitudinal hollow section beam 3010.

In one or more aspects, the rear lateral beams 3050A-3050*n* are provided as selectable modular assemblies that include the drive wheels 260 (which may themselves be provided as drive wheel module 260M sub-assemblies that are selected from a number of different modular drive wheel assemblies 260A1-260An, 260B1-260Bn and installed to the selectable modular rear lateral beam assembly), electronics (controllers, electronic busses, wire harnesses, sensors, etc.), and auxiliary equipment (e.g., charging interfaces, switches, interface ports, etc.). For example, as can be seen in FIGS. 2A, 2B and 3C the rear lateral beam 3050 includes one or more of any suitable power source 3035 (e.g., ultra-capacitor, battery, etc.), drive wheels 260, any suitable controller 1220 (and associated electronics), guide rollers 3052, one or more suitable navigation sensors 3067 (e.g., line following sensors, vision sensors, sonic sensors, etc.), and charging interface **3033** (e.g., side-mount bus bar contact pad **3033**A and/or under-mount charging pads **3033**B). The longitudinal hollow section beam **3010** and/or payload support stanchions **211**, **212** are mechanically coupled to the cross member **3050** assembly as described herein.

The front lateral beam **3000** is, in one or more aspects, provided as an assembly that includes one or more of the caster wheels **250** (which may themselves be provided as modular sub-assemblies that are selected from a number of different modular caster wheel assemblies **250**A**1**-**250**An, **250**B**1**-**250**Bn), electronics (sub-controllers, electronic busses, wire harnesses, motors, sensors, etc.), and/or auxiliary equipment (e.g., charging interfaces, switches, interface ports, etc.) For example, as can be seen in FIGS. **2**A, **2**B and **3**C the front lateral beam **3000** includes idler wheels **250**, a drive motor **290** for moving a carrier **290** of the payload support stanchions **211**, **212** in direction VER (such as where the payload support **210**B is an actuated payload support), guide rollers **3051**, one or more suitable navigation sensors **3066** (e.g., line following sensors, vision sensors, sonic sensors, etc.), and/or any suitable couplings that facilitate a substantially plug-and-play connection of the components of the front lateral beam **3000** to at least the controller **1220** of the rear lateral beam **3050**. In other aspects, the front lateral beam **3000** may also include a charging interface substantially similar to charging interface **3033**. In still other aspects, the caster wheels **250**, electronics, and/or auxiliary equipment may be coupled to the front lateral beam **3000** after the front lateral beam **3000** is coupled to the longitudinal hollow section beam **3010** and/or payload support stanchions **211**, **212**. While the front lateral beam **3000** is described above as a module including the caster wheels **250**A, **250**B, in one or more aspects the drive caster wheels **250**A, **250**B may be installed on the front lateral beam **3000** prior to or post coupling of the front lateral beam **3000** to the longitudinal hollow section beam **3010**.

The at least one payload support stanchion **211**, **212** is/are coupled to chassis **3099** so that each payload support stanchion **211**, **212** is removed from and installed to the chassis **3099** in a modular manner. In the example illustrated in FIGS. **2**A, **2**B, there is one payload support stanchion **212** disposed at or adjacent end **200**E**2** of the chassis **200** and another payload support stanchion **211** disposed at or adjacent end **200**E**1** of the chassis **200**; however, in other aspects there may be one payload support stanchion or more than two payload support stanchions. Referring to FIGS. **2**A, **2**B, **3**A, and **3**B, the payload support stanchions are substantially similar to each other such that payload support stanchion **212** may be coupled to the chassis **3099** at or adjacent end **200**E**1** and payload support stanchion **211** may be coupled to the chassis **3099** at or adjacent end **200**E**2**. In one or more aspects, rotation of the payload support stanchions about a respective (vertical) axis TAX facilitates placement of the either payload support stanchion **211**, **212** at either one of ends **200**E**1**, **200**E**2**. The payload support stanchions **211**, **212** are coupled to the chassis **3099** by inserting the payload support stanchions **211**, **212** into corresponding receptacles/interfaces **3070**, **3071** of a respective front lateral beam **3000** and rear lateral beam **3050**. The receptacles **3070**, **3071** of the front lateral beam **3000** and the rear lateral beam **3050** form datum surfaces that are in a known spatial relationship with one or more of the datum surfaces **3091**, **3093** so as to position the respective payload support stanchion **211**, **212** (and payload support contact surface **210**BS coupled thereto) in a known predetermined location relative to the components (e.g., actuators, sensors, etc.) of the front lateral beam **3000** and the rear lateral beam **3050**. As may be realized, the receptacles **3070**, **3071** position the payload support contact surface **210**BS at the height LPH2 described herein. The receptacles **3070**, **3071** are configured to orient the respective payload support stanchion **211**, **212** so that the payload support stanchions **211**, **212** extend substantially parallel with each other in the lateral direction LAT and so that the payload support stanchions **211**, **212** extend substantially parallel with each other in the vertical direction VER. The payload support stanchions **211**, **212** are coupled to a respective one of the front lateral beam **3000** and rear lateral beam **3050** in a removable manner, such as by mechanical fasteners; however, in other aspects, the payload support stanchions **211**, **212** are coupled to the longitudinal hollow section beam **3010** and serve as additional frame cross members (e.g., increasing torsional stiffness of the chassis **200**); while in still other aspects the payload support stanchions **211**, **212** are coupled to both the respective one of the front lateral beam **300** and the rear lateral beam **3050** and the longitudinal hollow section beam **3010**.

The payload support stanchions **211**, **212** are selectable from a number of different payload support stanchions **212**A-**212***n* each having a respective height TH**1**-THn and width TW**1**-TWn, where the widths TW**1**-TWn of the payload support stanchions **212** correspond with (and are selected depending on) the widths of the number of different front lateral beams **3000**A-**3000***n* and the number of different rear lateral beams **3050**A-**3050***n*. The height TH**1**-THn of the number of different payload support stanchions **212**A-**212***n* is selected depending on, for example, heights of case unit holding locations/shelves of the storage and retrieval system **100** at which the autonomous transport vehicle **110** transfers case units.

The payload support stanchions **211**, **212** are, in one or more aspects, provided as modular assemblies. For example, referring to FIGS. **2**A, **2**B, and **3**A, each payload support stanchion includes a tower frame **300**F. The tower frame **300**F includes a base **305**, vertical guides **306**, **307**, and a cross brace or brace **308**. The carrier **290** extends laterally between and is guided in vertical movement by the vertical guides **306**, **307**. The carrier **290** moves vertically in direction VER between the base **305** and brace **308** under motive force of any suitable drive motor **390** that is coupled to the carrier **290** by any suitable flexible transmission **330** (e.g., such as a drive shaft, gear box, belts, chains, and/or cables and associated pulleys/sprockets, etc.) where the transmission is coupled to an axle PXL tower frame **300**F. In one aspect, the drive motor **390** is a rotary motor coupled to the carrier **290** through the flexible transmission **330**; while in other aspects the drive motor **390** may be a linear motor (e.g., any suitable electric, hydraulic, and/or pneumatic linear actuator) coupled to the carrier **290** for moving the carrier **290** in direction VER. As described herein, the carrier **290** is coupled to and supports the payload support **210** and the transfer arm **210**A of the payload support **210** for movement in direction VER.

Referring to FIGS. **2**A, **2**B, and **6** the payload support **210** is a modular unit/assembly (e.g., the payload support module **210**M) that includes at least the payload bed **210**B. Where the payload support **210** comprises the static payload support **210**SPS the payload support **210** is coupled substantially directly to the chassis **200** in a manner similar to that described above with respect to the payload support stanchions **211**, **210** (e.g., where the static payload support is received into the receptacles **3070**, **3071**) or statically coupled to the payload support stanchions **210**, **211** (e.g., the payload support stanchions do not include vertical actuation). In other aspects, the static payload support **210**SPS may be coupled to the payload support stanchions **211**, **212** for vertical travel in direction VER in a manner substantially similar to that described herein with respect to active payload support **210**ACT. The static payload support **210**SPS is configured for a passive transfer of case units CU to and from the payload bed **210**B. For example, the passive transfer, in one or more aspects, is with respect to the payload bed **210**B (e.g., no lateral extension of the payload bed/arm to effect a transfer of the payload). The passive transfer with respect to the payload bed **210**B is effected with an extending support (e.g., extendable slatted shelf that is separate and distinct from the vehicle **110**) that interfaces with the raised payload bed so that lowering of the payload bed transfers the payload to the extending support (e.g., the payload bed is configured so that the extending support, or a portion thereof, passes through (such as in an interdigitated manner) the payload bed **210**B upon lowering of the payload bed **210**B. Here, the raised payload bed may be positioned relative to extended support in any suitable manner, such as with a traverse motion of the vehicle **110** in direction LON along a picking aisle or transfer deck so that the extendable support extends to intervene between the raised payload bed **210**B and the chassis **200** (where lowering the payload bed passively transfers the payload to the extended support). In one or more aspects, the drive wheels of the vehicle **110** may be omnidirectional wheels that are configured (in combination with rotation or yawing of the caster wheels) to move the vehicle **110** in a lateral traverse motion (e.g., in direction LAT). Here, the lateral traverse motion of the vehicle **110** provides for the raised payload bed **210**B to be positioned over a static support (i.e., the support is fixed in place and does not move) by at least the lateral traverse motion of the vehicle **110** in direction LAT such that the static support intervenes between the raised payload bed **210**B and the chassis **200** (where lowering the payload bed passively transfers the payload to the extended support). As may be realized, passive transfer of payload to the vehicle **110** may occur in an opposite manner to that described above.

Where the payload support **210** is an active payload support **210**ACT (FIG. **6**), the payload support **210** includes transfer arm **210**A. In this aspect, the payload bed **210**B is coupled to the at least one payload support stanchion **211**, **212**. The at least one payload support stanchion is configured to move the payload bed **210**B and/or transfer arm **210**A in direction VER; while in other aspects substantial vertical movement of the payload bed **210**B and/or transfer arm **210**A may not be provided in direction VER. The transfer arm **210**A is movably coupled to the payload bed **210**B for lateral movement in direction LAT.

The payload bed **210**B includes a payload bed frame **210**BF that forms a payload area in which case units CU carried by the bot **110** are disposed for transport throughout the storage and retrieval system **100**. The payload bed frame **210**BF includes longitudinal ends **210**BE**1**, **210**BE**2** that are each coupled to a respective one of the at least one payload support stanchion **211**, **212**. Here the at least one payload support stanchion **211**, **212** includes payload support stanchion **211** disposed at or adjacent the front end **200**E**1** of the chassis **200** and payload support stanchion **212** disposed at or adjacent the back end **200**E**2** of the chassis **200**. Here, each payload support stanchion **211**, **212** includes the movable carrier **290** to which a respective one of the longitudinal ends **210**BE**1**, **210**BE**2** is fixedly coupled in any suitable manner such as mechanical or chemical fasteners (i.e., so that as the movable carrier **290** moves the payload bed frame **210**BF moves with the movable carrier **290**). The payload support **210** is coupled to and removed from the carriers **290** of the payload support stanchions **211**, **212** in any suitable manner, such as by any suitable mechanical fasteners.

As noted herein, the payload support **210** is provided as a modular assembly (e.g., payload support module **210**M) that is selected from a number of different interchangeable payload support modules **610**A-**610***n* (it is noted that while FIG. **6** illustrates an active payload support **210**ACT assembly it should be realized different modular static payload support **210**SPS may also be provided), each payload support module having a different predetermined payload support module characteristic (e.g., active case transfer (payload bed with end effector/transfer arm), passive case transfer (payload bed without actuated end effector/transfer arm as described herein), lift capability, length, width, different size payload actuators for different sized payload, etc.). The different payload support modules **610**A-**610***n* have longitudinal lengths CHL and lateral widths CHW that correspond with the longitudinal length **3099**L and a lateral width **3099**W of the chassis **3099** (as effected through selection of the front lateral beams **3000**A-**3000***n*, the rear lateral beams **3050**A-**3050***n*, the longitudinal hollow section beams **3010**A-**3010***n*, and the payload support stanchions **212**A-**212***n*). In this manner one of the payload support modules **610**A-**610***n* is selected depending on a predetermined chassis configuration for installation to the chassis **3099** in a modular manner (i.e., the selected payload support **210** is coupled to the carriers **290** substantially without modification to either the payload support **210**, the payload support stanchions **211**, **212**, and the chassis **3099**). The different payload support modules **610**A-**610***n* may also be selected depending on whether the autonomous transport vehicle **110** is to be configured for active or passive case transfer CU to and from the payload bed **210**B. In one or more aspects, the payload support stanchions **211**, **212** form a portion of a respective different interchangeable payload support modules **610**A-**610***n*, where the payload support stanchions **211**, **212** are pre-assembled to the longitudinal ends **210**BE**1**, **210**BE**2** (see FIG. **6**) of the payload bed frame **210**BF so that the payload support stanchions **211**, **212** form a modular unit with the payload support **210**. Here, the modular combination of the payload support stanchions **211**, **212** and the payload support **210** are selected from the different interchangeable payload support modules **610**A-**610***n* and coupled to the chassis **3099** as a payload support modular unit.

The transfer arm **210**A includes one or more fingers **210**AF that are each cantilevered from a finger support rail **273** of the transfer arm **210**A. It is noted that while three fingers **210**AF**1**-**210**AF**3** are illustrated for exemplary purposes only, in other aspects there may be more or fewer than three fingers spaced apart from one another (with any suitable spacing) along the finger support rail **273**. The finger support rail **273** of the transfer arm **210**A is movably coupled to the payload bed frame **210**BF in any suitable manner so that the transfer arm **210**A (inclusive of the finger support rail **273** and the one or more fingers **210**A**1**-**210**A**3**) moves relative to the payload bed frame in direction LAT. Movement of the transfer arm **210**A in direction LAT extends and retracts the one or more fingers **210**AF for picking and placing payloads to and from the payload bed **210**B.

Referring to FIGS. **2**A, **2**B, **3**A, **3**C and **4**, as described above, the ride wheels **250**, **260** include the drive wheels **260**A, **260**B and idler wheels **250**A, **250**B. Each of the drive wheels **260**A, **260**B and idler wheels **250**A, **250**B are provided as modular components (e.g., drive wheel modules **260**M and idle/caster wheel modules **250**M) that can each be independently removed from and installed to the chassis **200** as respective modular units in a plug-and-play manner so as to be swapped with other selectable drive wheels **260** and idler wheels **250**. For example, idler wheel **250**A is selectable from a number of different idler wheels **250**A**1**-**250**An each having a different characteristic or combination of characteristics (e.g., wheel diameter, ride height, wheel tread pattern, wheel material, motorized (steerable) casters, non-motorized (passive) casters, suspension preload (which may be preset at different levels before mounting to configure the vehicles **110** with different payload capacities), etc.). Idler wheel **250**B is similarly selectable. Drive wheel **260**B is selectable from a number of different drive wheels **260**B**1**-**260**Bn each having a different characteristic or combination of characteristics (e.g., wheel diameter, ride height, wheel tread pattern, wheel material/friction coefficient, motor horsepower, motor operational speed, suspension preload (which may be preset at different levels before mounting to configure the vehicles **110** with different payload capacities), etc.).

The idler wheels **250**A, **250**B are coupled to the front lateral beam **3000** at a respective coupling interface **3074**, **3075** in a removable manner such as with mechanical fasteners. Each of the coupling interfaces **3074**, **3075** include a datum surfaces **3074**D, **3075**D at which the idler wheels **250**A, **250**B are coupled to the space frame **200**S in a repeatable and known location relative to the sensors, actuators, etc. of the front and rear crossmembers **3000**, **3050** (and the components of the interchangeable payload support modules **610**A-**610**n). For example, the datum surfaces **3074**D, **3075**D of the space frame **200**S seat against and locate mating datum surfaces **250**DS of the respective idler wheel **250**A, **250**B relative to the space frame **200**S (see FIG. **3**A) so that the idler wheels **250**A, **250**B can be coupled to and removed from the space frame **200**S in a plug-and-play manner.

The drive wheels **260**A, **260**B are coupled to the rear lateral beam **3000** at a respective coupling interface **3072**, **3073** in a removable manner such as with mechanical fasteners. Here, there are separate and distinct interfaces **3072**, **3073** for respective separate and distinct drive wheel modules **260**M of each different drive wheel **260**A, **260**B of a pair of drive wheels. Each of the coupling interfaces **3072**, **3073** include a datum surfaces **3072**D, **3073**D at which the drive wheels **260**A, **260**B are coupled to the space frame **200**S in a repeatable and known location relative to the sensors, actuators, etc. of the front and rear crossmembers **3000**, **3050** (and the components of the interchangeable payload support modules **610**A-**610**n). For example, the datum surfaces **3072**D, **3073**D of the space frame **200**S seat against and locate mating datum surfaces **260**DS of the respective drive wheel **260**A, **260**B so as to locate the drive wheels **260**A, **260**B in the known predetermined location relative to the space frame **200**S (see FIGS. **3**A and **4**) so that the drive wheels **260**A, **260**B can be coupled to and removed from the space frame **200**S in a plug-and-play manner. It is noted that while the drive wheel module **260**M is illustrated in FIG. **4** as being sans suspension components, in other aspects the drive wheel module **260**M may include at least part of suspension system **280** (e.g., control arm(s) and shock absorber mounted to a datum plate that is coupled to the rear crossmember **3050**).

Here, the chassis **200** includes one or more idler wheels **250** disposed adjacent the front end **200**E**1**. In one aspect, an idler wheel **250** is located adjacent each front corner of the chassis **200** so that in combination with the drive wheels **260** (the drive wheels **310** being disposed at each rear corner of the chassis **200**) the chassis **200** stably traverses the transfer deck **130**B and picking aisles **130**A of the storage structure **130**. Each idler wheel **250** comprises any suitable unmotorized/passive caster or a motorized caster that is configured to actively pivot the wheel **610** in direction **690** about caster pivot axis **691** (see FIG. **4**) to at least assist in effecting a change in the travel direction of the autonomous transport vehicle **110**. Each drive wheel **260** comprises a drive unit **261** (see, e.g., FIG. **4**) that is independently coupled to the chassis **200** by a respective independent suspension system **280** (see FIGS. **3**C and **5**), so that each drive wheel **260** is independently movable (e.g., independently driven by a respective drive motor of a respective drive unit) in a wheel travel direction SUS relative to the chassis **200** and any other drive wheel(s) **260** that is/are also coupled to the chassis **200**.

As described herein the drive wheels **260**, the idler wheels **250**, and payload support **210** are provided as modular components (e.g., the drive wheel modules **260**M, the idler/caster wheel modules **250**M, and the payload support module **210**M) that can each be independently removed from and installed to the chassis **200** as respective modular units in a plug-and-play manner so as to be swapped with other selectable the drive wheels **260**, the idler wheels **250**, and payload support **210**. For example, the autonomous transport vehicle **110** includes any suitable onboard communications backbone such as a controller area network (CAN) that communicably couples the controller **1220** to the electronic components (e.g., sensors, motors, and other suitable sensors/actuable components) of the autonomous transport vehicle **110**. The controller area network is configured such that each of the modular drive wheels **260**, the modular idler wheels **250** (such as where the idler wheels include actuable components such as steering motors, locks, etc.), and modular payload support **210** releasably plug into the controller area network (e.g., so that electronic components thereof are in communication with the controller **1220**) and include any suitable identification protocol (e.g., digital signature) that is communicated to the controller **1220** over the controller area network upon connection of the modular drive wheels **260**, the modular idler wheels **250**, and modular payload support **210** to the controller area network. The identification protocol may identify types of sensors, motors specifications, actuator travel limits (such as for lifting case units), and/or any other suitable operation specifications that effect operation of the respective one of the modular drive wheels **260**, the modular idler wheels **250**, and modular payload support **210** coupled to the controller **1220** through the controller area network. The identification protocol also identifies the position at which the modular drive wheels **260**, the modular idler wheels **250**, and modular payload support **210** are coupled to the chassis, where the controller **1220** determines the location of the sensors, actuators, etc. of the modular components based on the location of the respective datum surfaces of the respective coupling interfaces **3070**, **3071**, **3072**, **3073**, **3074**, **3075** and data obtained from the modular components in the identification protocol. The controller **1220** is configured (e.g., through suitable non-transitory computer program code) to receive the identification protocol from the modular drive wheels **260**, the modular idler wheels **250**, and/or modular payload support **210** and effect operation of the modular drive wheels **260**, the modular idler wheels **250**, and/or modular payload support **210** based, at least in part, on the operational data embodied in the identification protocol.

Referring to FIGS. **2**A-**2**C, **3**A-**3**C, **6**, and **7** an exemplary method will be described in accordance with aspects of the disclosed embodiment. In the method the autonomous transport vehicle **110** is provided with the chassis **200** (forming the space frame **200**S), payload support **210**, and ride wheels **250**, **260** (FIG. **7**, Block **700**). As described herein, the ride wheels **250**, **260** and chassis **200** in combination form the low profile height LPH from the traverse surface TS to atop **200**T the chassis **200**, where chassis height **200**H and ride wheel height **250**H, **260**H are overlapped at least in part and the payload support **210** is nested within the ride wheels **260** (e.g., between the ride wheels **250**, **260** such that the low profile height LPH is smaller than one or more of the ride wheel height **250**H, **260**H). A corresponding electronic and/or mechanical component module (e.g., ride wheel modules (e.g., at least one drive wheel module **260**M and at least one caster wheel module **250**M), payload support module **210**M, control module **1220**M, etc., as described herein) are removably coupled, as a modular unit, to the space frame **200**S (FIG. **7**, Block **710**) with the predetermined modular coupling interfaces **3070**, **3071**, **3072**, **3073**, **3074**, **3075** described herein.

Referring to FIGS. **2**A-**2**C, **3**A-**3**C, **6**, and **8** another exemplary method will be described in accordance with aspects of the disclosed embodiment. In the method the autonomous transport vehicle **110** is provided with the chassis bus (also referred to as chassis) **200** (FIG. **8**, Block **800**), where the chassis bus **200** includes the predetermined modular coupling interfaces **3070**, **3071**, **3072**, **3073**, **3074**, **3075** described herein. Corresponding predetermined component modules of the autonomous transport vehicle **110** are removably coupled, as a module unit, to the chassis bus **200** (FIG. **8**, Block **810**) so that the autonomous transport vehicle **110** has a modular construction. Here, the predetermined component modules include at least one of: a payload support module **210**M with a payload support contact surface **210**BS removably coupled as a module unit to the chassis bus **200** with a corresponding payload support module coupling interface **3070**, **3071**; a caster wheel module **250**M with a caster wheel **250**A, **250**B removably coupled as a module unit to the chassis bus **200** with a corresponding caster wheel module coupling interface **3074**, **3075**; and a drive wheel module **260**M with a drive wheel **260**A, **260**B removably coupled as a module unit to the chassis bus **200** with a corresponding drive wheel module coupling interface **3072**, **3073**.

In accordance with one or more aspects of the disclosed embodiment, an autonomous transport robot vehicle for transporting a payload is provided. The autonomous transport robot vehicle comprises:

a chassis that is a space frame formed of:

longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and

respective front and rear lateral beams closing opposite ends of the space frame;

a payload support connected to the chassis and dependent therefrom; and

ride wheels dependent from the chassis, proximate opposite end corners of the chassis, on which the autonomous transport robot vehicle rides so as to traverse a traverse surface, the ride wheels include at least one caster wheel and a pair of drive wheels supporting the chassis from the traverse surface, and

wherein the ride wheels and chassis in combination form a low profile height from the traverse surface to atop the chassis, where chassis height and ride wheel height are overlapped at least in part and the payload support is nested within the ride wheels; and

wherein the space frame has predetermined modular coupling interfaces, each disposed for removably coupling, as a module unit, a corresponding predetermined electronic or mechanical component module of the autonomous transport robot vehicle to the chassis.

In accordance with one or more aspects of the disclosed embodiment, the predetermined modular coupling interfaces include at least one of at least one caster wheel module coupling interface, at least one drive wheel module coupling interface, and at least one payload support module coupling interface.

In accordance with one or more aspects of the disclosed embodiment the at least one caster wheel is selectable from a number of different selectably interchangeable caster wheel modules, each with a different predetermined caster wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, drive wheels of the pair of drive wheels are selectable from a number of different selectably interchangeable drive wheel modules, each with a different predetermined drive wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, the payload support is selectable from a number of different interchangeable payload support modules, each with a different predetermined payload support module characteristic.

In accordance with one or more aspects of the disclosed embodiment the at least one drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules of each different drive wheel of the pair of drive wheels.

In accordance with one or more aspects of the disclosed embodiment, the longitudinal hollow section beams and the respective front and rear lateral beams of the space frame are mechanically fastened to each other.

In accordance with one or more aspects of the disclosed embodiment the payload support comprises a payload support contact surface on which a payload resting on the payload support is seated, the payload support contact surface is disposed atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the space frame is configured so that the chassis is substantially rigid with predetermined rigidity characteristics, with a shape and form that provides a minimum height from the traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the space frame configuration resolves both predetermined rigidity characteristics and a minimum low profile height of chassis from the traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment the chassis has a selectably variable configuration, selectable from different configurations each having different chassis form factors.

In accordance with one or more aspects of the disclosed embodiment at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam, is selectable from a number of different selectably interchangeable respective longitudinal hollow section beams, front lateral beams, and rear lateral beams each with different predetermined mechanical characteristics.

In accordance with one or more aspects of the disclosed embodiment selection of the at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from the number of different selectably interchangeable respective longitudinal hollow section beams, the front lateral beams, and the rear lateral beams determines the selected variable configuration of the chassis.

In accordance with one or more aspects of the disclosed embodiment, an autonomous transport robot vehicle for transporting a payload is provided. The autonomous transport robot vehicle comprises:

a chassis bus with predetermined modular coupling interfaces, each disposed for removably coupling, as a module unit, corresponding predetermined component modules of the autonomous transport robot vehicle to the chassis bus so that the autonomous transport robot vehicle has a modular construction; and

wherein the corresponding predetermined component modules include at least one of:

a payload support module with a payload support contact surface removably coupled as a module unit to the chassis bus with a corresponding payload support module coupling interface;

a caster wheel module with a caster wheel removably coupled as a module unit to the chassis bus with a corresponding caster wheel module coupling interface; and

a drive wheel module with a drive wheel removably coupled as a module unit to the chassis bus with a corresponding drive wheel module coupling interface.

In accordance with one or more aspects of the disclosed embodiment, the caster wheel module is selectable from a number of different selectably interchangeable caster wheel modules, each with a different predetermined caster wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, the drive wheel module is selectable from a number of different selectably interchangeable drive wheel modules, each with a different predetermined drive wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, the corresponding drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules.

In accordance with one or more aspects of the disclosed embodiment, the payload support module is selectable from a number of different interchangeable payload support modules, each with a different predetermined payload support module characteristic.

In accordance with one or more aspects of the disclosed embodiment the chassis bus is a space frame formed of:

longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and

respective front and rear lateral beams closing opposite ends of the space frame.

In accordance with one or more aspects of the disclosed embodiment, the longitudinal hollow section beams and the respective front and rear lateral beams of the space frame are mechanically fastened to each other.

In accordance with one or more aspects of the disclosed embodiment, the space frame is configured so that the chassis bus is substantially rigid with predetermined rigidity characteristics, with a shape and form that provides a minimum height from a traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the space frame configuration resolves both predetermined rigidity characteristics and a minimum low profile height of chassis from a traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam, is selectable from a number of different selectably interchangeable respective longitudinal hollow section beams, front lateral beams, and rear lateral beams each with different predetermined mechanical characteristics.

In accordance with one or more aspects of the disclosed embodiment selection of the at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from the number of different selectably interchangeable respective longitudinal hollow section beams, the front lateral beams, and the rear lateral beams determines the selected variable configuration of the chassis.

In accordance with one or more aspects of the disclosed embodiment the autonomous transport robot vehicle includes at least one caster wheel module and at least one drive wheel module, the at least one caster wheel module and the at least one drive wheel module are dependent from the chassis bus, proximate opposite end corners of the chassis, where the autonomous transport robot vehicle rides on at least a caster wheel of the at least one caster wheel module and at least one drive wheel of the at least one drive wheel module so as to traverse a traverse surface.

In accordance with one or more aspects of the disclosed embodiment the at least one caster wheel, the at least one drive wheel, and the chassis bus in combination form a low profile height from the traverse surface to atop the chassis, where:

the at least one drive wheel comprises a pair of drive wheels and the at least one caster wheel comprises a pair of caster wheels,

a chassis height and a height of the at least one drive wheel are overlapped at least in part, and

the payload support contact surface, on which a payload resting on the payload support module is seated, is nested within the pair of drive wheel and the pair of caster wheels.

In accordance with one or more aspects of the disclosed embodiment the payload support contact surface, on which a payload resting on the payload support module is seated, is disposed atop the chassis bus.

In accordance with one or more aspects of the disclosed embodiment the chassis bus has a selectably variable configuration, selectable from different configurations each having different chassis form factors.

In accordance with one or more aspects of the disclosed embodiment a method comprises:

providing the autonomous transport robot vehicle with:

a chassis that is a space frame formed of:

longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and

respective front and rear lateral beams closing opposite ends of the space frame,

a payload support connected to the chassis and dependent therefrom, and

ride wheels dependent from the chassis, proximate opposite end corners of the chassis, on which the autonomous transport robot vehicle rides so as to traverse a traverse surface, the ride wheels include at least one caster wheel and a pair of drive wheels supporting the chassis from the traverse surface, and

wherein the ride wheels and chassis in combination form a low profile height from the traverse surface to atop the chassis, where chassis height and ride wheel height are overlapped at least in part and the payload support is nested within the ride wheels; and removably coupling as a module unit, with predetermined modular coupling interfaces of the space frame, a corresponding predetermined electronic or mechanical component module of the autonomous transport robot vehicle to the chassis.

In accordance with one or more aspects of the disclosed embodiment, the predetermined modular coupling interfaces include at least one of at least one caster wheel module coupling interface, at least one drive wheel module coupling interface, and at least one payload support module coupling interface.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting the at least one caster wheel from a number of different selectably interchangeable caster wheel modules, each with a different predetermined caster wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting drive wheels of the pair of drive wheels from a number of different selectably interchangeable drive wheel modules, each with a different predetermined drive wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises selecting the payload support from a number of different interchangeable payload support modules, each with a different predetermined payload support module characteristic.

In accordance with one or more aspects of the disclosed embodiment the at least one drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules of each different drive wheel of the pair of drive wheels.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises mechanically fastening the longitudinal hollow section beams and the respective front and rear lateral beams of the space frame to each other.

In accordance with one or more aspects of the disclosed embodiment the payload support comprises a payload support contact surface on which a payload resting on the payload support is seated, the payload support contact surface is disposed atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the chassis is substantially rigid with predetermined rigidity characteristics, with a shape and form that provides a minimum height from the traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the space frame resolves both predetermined rigidity characteristics and a minimum low profile height of chassis from the traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting a selectably variable configuration of the chassis from different configurations each having different chassis form factors.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises selecting at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from a number of different selectably interchangeable respective longitudinal hollow section beams, front lateral beams, and rear lateral beams each with different predetermined mechanical characteristics.

In accordance with one or more aspects of the disclosed embodiment selection of the at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from the number of different selectably interchangeable respective longitudinal hollow section beams, the front lateral beams, and the rear lateral beams determines the selected variable configuration of the chassis.

In accordance with one or more aspects of the disclosed embodiment a method comprises:

providing the autonomous transport robot vehicle with a chassis bus with predetermined modular coupling interfaces; and

removably coupling as a module unit, with the predetermined modular coupling interfaces, corresponding predetermined component modules of the autonomous transport robot vehicle to the chassis bus so that the autonomous transport robot vehicle has a modular construction;

wherein the predetermined component modules include at least one of:

a payload support module with a payload support contact surface removably coupled as a module unit to the chassis bus with a corresponding payload support module coupling interface,

a caster wheel module with a caster wheel removably coupled as a module unit to the chassis bus with a corresponding caster wheel module coupling interface, and

a drive wheel module with a drive wheel removably coupled as a module unit to the chassis bus with a corresponding drive wheel module coupling interface.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting the caster wheel module from a number of different selectably interchangeable caster wheel modules, each with a different predetermined caster wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting the drive wheel module from a number of different selectably interchangeable drive wheel modules, each with a different predetermined drive wheel module characteristic.

In accordance with one or more aspects of the disclosed embodiment, the drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises selecting the payload support module from a number of different interchangeable payload support modules, each with a different predetermined payload support module characteristic.

In accordance with one or more aspects of the disclosed embodiment the chassis bus is a space frame formed of:

longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and

respective front and rear lateral beams closing opposite ends of the space frame.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises mechanically fastening the longitudinal hollow section beams and the respective front and rear lateral beams of the space frame to each other.

In accordance with one or more aspects of the disclosed embodiment, the space frame is configured so that the chassis is substantially rigid with predetermined rigidity characteristics, with a shape and form that provides a minimum height from a traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the space frame configuration resolves both predetermined rigidity characteristics and a minimum low profile height of chassis from a traverse surface to atop the chassis.

In accordance with one or more aspects of the disclosed embodiment, the method further comprises selecting at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from a number of different selectably interchangeable respective longitudinal hollow section beams, front lateral beams, and rear lateral beams each with different predetermined mechanical characteristics.

In accordance with one or more aspects of the disclosed embodiment selection of the at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from the number of different selectably interchangeable respective longitudinal hollow section beams, the front lateral beams, and the rear lateral beams determines the selected variable configuration of the chassis.

In accordance with one or more aspects of the disclosed embodiment the autonomous transport robot vehicle includes at least one caster wheel module and at least one drive wheel module, the at least one caster wheel module and the at least one drive wheel module are dependent from the chassis bus, proximate opposite end corners of the chassis, where the autonomous transport robot vehicle rides on at least caster wheel of the at least one caster wheel module and at least one drive wheel of the at least one drive wheel module so as to traverse a traverse surface.

In accordance with one or more aspects of the disclosed embodiment the caster wheel, the drive wheel, and the chassis bus in combination form a low profile height from the traverse surface to atop the chassis, where:

- the at least one drive wheel comprises a pair of drive wheels and the at least one caster comprises a pair of caster wheels,
- a chassis height and a height of the at least one drive wheel are overlapped at least in part, and
- the payload support contact surface, on which a payload resting on the payload support module is seated, is nested within the pair of drive wheel and the pair of caster wheels.

In accordance with one or more aspects of the disclosed embodiment the payload support contact surface, on which a payload resting on the payload support module is seated, is disposed atop the chassis bus.

In accordance with one or more aspects of the disclosed embodiment the method further comprises selecting a selectably variable configuration of the chassis bus from different configurations each having different chassis form factors.

It should be understood that the foregoing description is only illustrative of the aspects of the disclosed embodiment. Various alternatives and modifications can be devised by those skilled in the art without departing from the aspects of the disclosed embodiment. Accordingly, the aspects of the disclosed embodiment are intended to embrace all such alternatives, modifications and variances that fall within the scope of any claims appended hereto. Further, the mere fact that different features are recited in mutually different dependent or independent claims does not indicate that a combination of these features cannot be advantageously used, such a combination remaining within the scope of the aspects of the disclosed embodiment.

What is claimed is:

1. An autonomous transport robot vehicle for transporting a payload, the autonomous transport robot vehicle comprising:

- a chassis that is a space frame formed of:
  - longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and respective front and rear lateral beams closing opposite ends of the space frame;
- a payload support connected to the chassis and dependent therefrom; and
- ride wheels dependent from the chassis, proximate opposite end corners of the chassis, on which the autonomous transport robot vehicle rides so as to traverse a traverse surface, the ride wheels include at least one caster wheel and a pair of drive wheels supporting the chassis from the traverse surface, and
- wherein the ride wheels and chassis in combination form a low profile height from the traverse surface to atop the chassis, where a chassis height and a ride wheel height are overlapped at least in part so that a payload support contact surface of the payload support is nested between and within the ride wheel height of the ride wheels; and
- wherein the space frame has predetermined modular coupling interfaces, each disposed for removably coupling, as a module unit, a corresponding predetermined electronic or mechanical component module of the autonomous transport robot vehicle to the chassis.

2. The autonomous transport robot vehicle of claim **1**, wherein the predetermined modular coupling interfaces include at least one caster wheel module coupling interface, at least one drive wheel module coupling interface, and at least one payload support module coupling interface.

3. The autonomous transport robot vehicle of claim **2**, wherein the at least one caster wheel is selectable from a number of different selectably interchangeable caster wheel modules, each with a different predetermined mechanical or electrical caster wheel module characteristic.

4. The autonomous transport robot vehicle of claim **2**, wherein drive wheels of the pair of drive wheels are selectable from a number of different selectably interchangeable drive wheel modules, each with a different predetermined mechanical or electrical drive wheel module characteristic.

5. The autonomous transport robot vehicle of claim **2**, wherein the payload support is selectable from a number of different interchangeable payload support modules, each with a different predetermined mechanical or electrical payload support module characteristic.

6. The autonomous transport robot vehicle of claim **2**, wherein the at least one drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules of each different drive wheel of the pair of drive wheels.

7. The autonomous transport robot vehicle of claim **1**, wherein the longitudinal hollow section beams and the respective front and rear lateral beams of the space frame are mechanically fastened to each other.

8. The autonomous transport robot vehicle of claim **1**, wherein the payload support comprises the payload support contact surface on which a payload resting on the payload support is seated, the payload support contact surface is disposed atop the chassis.

9. The autonomous transport robot vehicle of claim **1**, wherein the space frame is configured so that the chassis is substantially rigid with predetermined rigidity characteristics, with a shape and form that provides a minimum height from the traverse surface to atop the chassis.

10. The autonomous transport robot vehicle of claim **1**, wherein a configuration of the space frame resolves both predetermined rigidity characteristics and a minimum low profile height of chassis from the traverse surface to atop the chassis.

11. The autonomous transport robot vehicle of claim 1, wherein the chassis has a selectably variable configuration, selectable from different configurations each having different chassis form factors.

12. The autonomous transport robot vehicle of claim 1, wherein at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam, is selectable from a number of different selectably interchangeable respective longitudinal hollow section beams, front lateral beams, and rear lateral beams each with different predetermined mechanical characteristics.

13. The autonomous transport robot vehicle of claim 12, wherein selection of the at least one of the longitudinal hollow section beams, the front lateral beam, and the rear lateral beam from the number of different selectably interchangeable respective longitudinal hollow section beams, the front lateral beams, and the rear lateral beams determines a selected variable configuration of the chassis.

14. An autonomous transport robot vehicle for transporting a payload, the autonomous transport robot vehicle comprising:

a chassis bus with predetermined modular coupling interfaces, each disposed for removably coupling, as a module unit, corresponding predetermined component modules of the autonomous transport robot vehicle to the chassis bus so that the autonomous transport robot vehicle has a modular construction, the predetermined modular coupling interfaces include datum surfaces at which a respective predetermined component module is coupled to the chassis bus in a known and repeatable position relative to at least the chassis bus; and

wherein the corresponding predetermined component modules include at least one of:

a payload support module with a payload support contact surface removably coupled as a module unit to the chassis bus with a corresponding payload support module coupling interface;

a caster wheel module with a caster wheel removably coupled as a module unit to the chassis bus with a corresponding caster wheel module coupling interface; and

a drive wheel module with a drive wheel removably coupled as a module unit to the chassis bus with a corresponding drive wheel module coupling interface.

15. The autonomous transport robot vehicle of claim 14, wherein the caster wheel module is selectable from a number of different selectably interchangeable caster wheel modules, each with a different predetermined mechanical or electrical caster wheel module characteristic.

16. The autonomous transport robot vehicle of claim 14, wherein the drive wheel module is selectable from a number of different selectably interchangeable drive wheel modules, each with a different predetermined mechanical or electrical drive wheel module characteristic.

17. The autonomous transport robot vehicle of claim 16, wherein the corresponding drive wheel module coupling interface includes separate and distinct interfaces for respective separate and distinct drive wheel modules.

18. The autonomous transport robot vehicle of claim 14, wherein the payload support module is selectable from a number of different interchangeable payload support modules, each with a different predetermined mechanical or electrical payload support module characteristic.

19. The autonomous transport robot vehicle of claim 14, wherein the chassis bus is a space frame formed of:

longitudinal hollow section beams, arrayed to form longitudinally extended sides of the space frame, and

respective front and rear lateral beams closing opposite ends of the space frame.

20. The autonomous transport robot vehicle of claim 14, wherein the autonomous transport robot vehicle includes at least one caster wheel module and at least one drive wheel module, the at least one caster wheel module and the at least one drive wheel module are dependent from the chassis bus, proximate opposite end corners of the chassis, where the autonomous transport robot vehicle rides on at least a caster wheel of the at least one caster wheel module and at least one drive wheel of the at least one drive wheel module so as to traverse a traverse surface.

21. The autonomous transport robot vehicle of claim 14, wherein the payload support contact surface, on which a payload resting on the payload support module is seated, is disposed atop the chassis bus.

22. The autonomous transport robot vehicle of claim 14, wherein the chassis bus has a selectably variable configuration, selectable from different configurations each having different chassis form factors.

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