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# Double-Deep Automated Storage and Retrieval System

## Abstract

An automated sorting and packing system is described. A system may include a mobile vehicle body including a first mobile conveyor that moves with the mobile vehicle body. A system may include an item handling mechanism coupled with the mobile vehicle body and including one or more extendable members that move between a retracted position and an extended position to retrieve one or more items from one or more external shelves and move the one or more items onto the first mobile conveyor. A system may include one or more driving wheels coupled with a drive motor that cause the mobile vehicle body, mobile conveyor, and the item handling mechanism to move in an aisle.

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## Background/Summary

## BACKGROUND

[0001] This application relates to warehouse fulfillment systems. For example, this application relates to an automated, efficient automated storage and retrieval system that includes various automated guided mobile vehicles that move items to or from a storage area.

[0002] Existing systems for fulfilling orders pick items into cartons one-by-one, often using human pickers that seek out items in a warehouse and then place them into shipping cartons. Human based systems result in errors, fatigue, and increased task completion time.

[0003] Some fulfillment systems use robots to transport shelves holding a plurality of items from a storage area to a picking station where a human places picks items from the shelves. Unfortunately, some of these systems transport entire shelving units of items, thereby resulting in significant wasted movement of robots and shelving units, thus being an inefficient use of space and resources. Other systems transport single items or move a single item per trip of the robot, which causes significant movement of robots, bottlenecks in space and other resource utilization, and other inefficiencies. These automated systems typically use just-in-time transportation of the shelves to the picking station, which results in downtime, increased quantities or conflicts for robots, and many other issues. Furthermore, these systems tend to be inflexible, are only useful in limited situations, and only useful for single item picks. These previous systems required human picking and/or high complexity, and the quantity of robots required were expensive, deployed slowly, and required substantial amounts of maintenance.

[0004] Furthermore, the shelving and robot layouts used by these systems tend to be inefficient due to the limitations of these robots, which reduces the amount and variety of items that may be stored and/or retrieved in a warehouse or fulfillment center.

## SUMMARY

[0005] An automated sorting and packing system can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. In some aspects, the techniques described herein relate to a system including: a mobile vehicle body including a first mobile conveyor that moves with the mobile vehicle body; an item handling mechanism coupled with the mobile vehicle body and including one or more extendable members that move between a retracted position and an extended position to retrieve one or more items from one or more external shelves and move the one or more items onto the first mobile conveyor; and one or more driving wheels coupled with a drive motor that cause the mobile vehicle body, mobile conveyor, and the item handling mechanism to move in an aisle.

[0006] In some aspects, the techniques described herein relate to a system, wherein the mobile vehicle body includes: one or more guide wheels oriented horizontally to contact one or more external guide rails extending down a length of the aisle, the one or more external guide rails aligning the mobile vehicle body in the aisle.

[0007] In some aspects, the techniques described herein relate to a system, wherein the system further includes: one or more vertical support rails coupled with and extending vertically from the mobile vehicle body; a vertical carriage coupled with and moving vertically along the one or more vertical support rails, the vertical carriage holding the item handling mechanism; and a second motor mounted to the mobile vehicle body and adapted to drive a belt extending along the one or more vertical support rails, the vertical carriage coupled with the belt.

[0008] In some aspects, the techniques described herein relate to a system, wherein the mobile vehicle body includes: two or more mobile conveyors coupled with a frame of the mobile vehicle body, each of the two or more mobile conveyors being accessible to the item handling mechanism, the two or more mobile conveyors including the first mobile conveyor and a second mobile conveyor, the first mobile conveyor being located vertically above the second mobile conveyor.

[0009] In some aspects, the techniques described herein relate to a system, wherein the item

handling mechanism is configured to remove an item from the second mobile conveyor and place the item on the first mobile conveyor.
[0010] In some aspects, the techniques described herein relate to a system, wherein: the one or more extendable members include one or more grasping fingers at an end of the one or more extendable members, the one or more grasping fingers pivoting between a vertical position and a horizontal position, the horizontal position providing contact with the one or more items handled by the item handling mechanism, the contact pulling the one or more items from the one or more external shelves when the item handling mechanism moves into the retracted position.
[0011] In some aspects, the techniques described herein relate to a system, wherein: the one or more extendable members include one or more linear rails supporting one or more telescoping side members, a belt, and a motor engaging with the belt, the one or more telescoping side members being coupled with the belt so that when the motor rotates the belt, the belt causes the one or more telescoping side members to extend along the one or more linear rails and move the item handling mechanism into the extended position.
[0012] In some aspects, the techniques described herein relate to a system, further including: a vertical carriage moving vertically along a vertical support rail, the vertical support rail extending vertically upward from the mobile vehicle body, the vertical carriage including a horizontal platform extending horizontally away from the vertical support rail, the horizontal platform providing vertical support to the item handling mechanism.
[0013] In some aspects, the techniques described herein relate to a system, further including: a first horizontal gear coupled with the horizontal platform and mounted in a horizontal orientation, the item handling mechanism including a motor that engages with the first horizontal gear to cause the item handling mechanism to rotate relative to the first horizontal gear, the rotation of the item handling mechanism allowing the one or more extendable members to extend in along two or more different directions.
[0014] In some aspects, the techniques described herein relate to a system, further including: wherein a second horizontal gear is mounted to the motor and interacts with a belt, the belt extending around the first horizontal gear and the second horizontal gear, the motor being coupled with and rotating with the item handling mechanism, the motor causing the item handling mechanism to rotate relative to the horizontal platform when the motor rotates the second horizontal gear, the first horizontal gear being rigidly mounted to the horizontal platform.
[0015] In some aspects, the techniques described herein relate to a system, wherein: the one or more extendable members of the item handling mechanism have a reach length configured to extend into one or more external storage shelves, the one or more external storage shelves including a front storage shelf and a back storage shelf, the one or more extendable members being adapted to access both the front storage shelf and the back storage shelf, the back storage shelf including the one or more external shelves from which the one or more items are retrieved by the item handling mechanism.
[0016] In some aspects, the techniques described herein relate to a system, wherein: the one or more driving wheels are configured to move the mobile vehicle body to an unloading zone at which the first mobile conveyor rotates to transfer the one or more items off from the first mobile conveyor.
[0017] In some aspects, the techniques described herein relate to a method including: retrieving a first item from a first location on one or more external storage shelves using an item handling mechanism coupled with a mobile vehicle; transferring the first item from the item handling mechanism to a first mobile conveyor coupled with the mobile vehicle; navigating the mobile vehicle to a transfer location; and transferring the first item from the first mobile conveyor including rotating the first mobile conveyor at the transfer location.
[0018] In some aspects, the techniques described herein relate to a method, further including: retrieving a second item from a second location on the one or more external storage shelves using

the item handling mechanism; and transferring the second item from the item handling mechanism to the first mobile conveyor, the first mobile conveyor holding the first item and the second item simultaneously.

[0019] In some aspects, the techniques described herein relate to a method, further including: transferring the second item with the first item from the first mobile conveyor including rotating the first mobile conveyor at the transfer location.

[0020] In some aspects, the techniques described herein relate to a method, further including: transferring a second item from a second mobile conveyor coupled with the mobile vehicle to the first mobile conveyor using the item handling mechanism.

[0021] In some aspects, the techniques described herein relate to a method, wherein transferring the second item from the second mobile conveyor to the first mobile conveyor includes: moving the item handling mechanism to a first height of the second mobile conveyor; rotating the second mobile conveyor to position the second item within reach of the item handling mechanism; extending the item handling mechanism to interact with the second item on the second mobile conveyor; retracting the item handling mechanism holding the second item; moving the item handling mechanism to a second height of the first mobile conveyor; and extending the item handling mechanism to move the second item onto the first mobile conveyor.

[0022] In some aspects, the techniques described herein relate to a method, further including: retrieving a second item from a second location on the one or more external storage shelves using the item handling mechanism; and transferring the second item from the item handling mechanism to a second mobile conveyor coupled with the mobile vehicle.

[0023] In some aspects, the techniques described herein relate to a method, wherein: the second item is retrieved from a front storage shelf and the first item is retrieved from a back storage shelf of the one or more external storage shelves; the first item is an assigned item for retrieval by the item handling mechanism and the second item is an unassigned item; and the second item is retrieved by the item handling mechanism prior to the first item being retrieved by the item handling mechanism.

[0024] In some aspects, the techniques described herein relate to a method, further including: retrieving the second item from the second mobile conveyor using the item handling mechanism; moving the item handling mechanism holding the second item to a height of the front storage shelf; rotating the item handling mechanism to face the item handling mechanism toward the front storage shelf; and extending the item handling mechanism and the second item to place the second item on the front storage shelf.

[0025] Other implementations of one or more of these aspects include corresponding systems, apparatus, and computer programs, configured to perform the actions of the methods, encoded on computer storage devices.

[0026] It should be understood that the language used in the present disclosure has been principally selected for readability and instructional purposes, and not to limit the scope of the subject matter disclosed herein.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The disclosure is illustrated by way of example, and not by way of limitation in the figures of the accompanying drawings in which like reference numerals are used to refer to similar elements.

[0028] FIG. **1** depicts an example system and data communication flow for implementing an automated robotic fulfillment system, which may use technologies, such as a double-deep automated storage and retrieval system.

[0029] FIG. **2** illustrates an example layout of a portion of a fulfillment center used in the automated robotic fulfillment system.
[0030] FIG. **3**A is a flowchart of an example method for retrieving items for one or more orders from a storage area using an ASRS vehicle.
[0031] FIG. **3**B is a flowchart of an example method for retrieving an item, for example, from a back shelf in a double-deep shelving configuration.
[0032] FIGS. **3**C, **3**D, and **3**E depict a flowchart of an example method for retrieving an item using an ASRS vehicle with a telescoping, rotating item handling head.
[0033] FIGS. **4**A-**4**C illustrate various views of an example ASRS vehicle.
[0034] FIGS. **5**A-**5**C illustrate perspective views of an example ASRS vehicle with its vertical carriage and item handling mechanism in different positions.
[0035] FIGS. **6**A-**6**E illustrate various views of an ASRS body and other portions of an ASRS vehicle.
[0036] FIGS. **7**A-**7**F illustrate various views and configurations of a vertical carriage.
[0037] FIGS. **8**A-**8**H illustrate various views of an example implementation of an item handling mechanism, which may be coupled with a vertical carriage.
[0038] FIGS. **9**A-**9**F illustrate various views of an item handling mechanism **444** in a retracted and extended position as well as various components that facilitate its extension functionality.
[0039] FIG. **10** is a block diagram illustrating an example computing system.

## DESCRIPTION

[0040] The technology described herein may be used in an automatic, robotic replenishment, organizing, or fulfillment system in a warehouse. For instance, the technology described herein may be applied in various contexts to move items between storage and fulfillment areas in a warehouse or fulfillment center. For instance, items of one or more types or SKUs (stock keeping units) may be stored in a mobile storage unit, which may be retrieved from a high-density storage area by technologies described herein and conveyed to other areas of a fulfillment center where other mechanisms (e.g., diverters, pickers, robotic arms, etc.) may be used to pick the items into shipping cartons in order to fulfill orders for those items. Additionally, technologies described herein may be used to replace, replenish, or otherwise store items in the high-density storage area. This technology improves the efficiency of storage and retrieval of items, among other benefits described below. It should be noted that the configurations may take various forms and have various materials without departing from the scope of this disclosure.
[0041] Depending on the implementation, the technology may include automated guided vehicles or AGVs, which may be mobile vehicles that move within an operating environment to perform operations. While there are multiple types of AGVs that may be used in the same environment or in coordination to perform operations, some implementations are described herein. Implementations of AGVs may also be referred to as automated storage and retrieval (ASRS) vehicles.
[0042] The technology is designed to increase the picking capacity in a fulfillment center by making various improvements over previous technologies, such as those described in the Background. For instance, the example ASRS vehicle(s) described may increase the storage and picking capacity by increasing the robot picking unit reach length to reach up to two items (e.g., totes, mini-pallets, mobile storage units, etc.) deep in a shelving area, which reduces the number of aisles required by half. Similarly, the example ASRS vehicles are designed to increase the stability and vertical reach of the ASRS vehicle (e.g., up to sixteen feet or more), which increases the density of items that can be stored in a given area of a building.
[0043] In some implementations of the technology, the ASRS vehicle may use an item handling device or mechanism (also referred to as item handling head) to retrieve items from external storage units and place them on a conveyor coupled with the ASRS vehicle. For instance, the conveyor may be coupled or integrated with the ASRS vehicle's body in order to move with the vehicle and receive items from the item handling head. Accordingly, the ASRS vehicle may retrieve

items from external storage shelving and place them on a mobile conveyor that moves with the ASRS vehicle (e.g., down a length of an aisle).

[0044] The ASRS vehicle, upon completing an assigned set of picks/retrievals from the aisle (e.g., where a set of items or totes are placed by the item handling head onto the mobile conveyor(s)), may travel to a unloading point or transfer station at which it may stop or dock to unload the set of items. In some implementations, the ASRS vehicle may rotate the conveyor to cause the set of items to be unloaded at the unloading points. The items may be conveyed onto an external conveyor, chute, cart, or another mechanism that allows them to be processed elsewhere in the facility. Accordingly, because multiple items may be moved simultaneously on a conveyor, they may be unloaded more quickly than where an item handling mechanism individually unloads them, for instance, from portable shelves. This process may be reversed in order to quickly transfer items on to the mobile conveyor and then onto storage shelves by the ASRS vehicle.

[0045] Example implementations of the ASRS vehicle are described herein that provide benefits of both track-mounted and completely free-standing robots. For instance, the technology allows the ASRS vehicle to be very stable in its direction of movement thereby reducing the probability that it will tip over. Accordingly, the ASRS vehicle may move quickly and reach greater heights, for example, due to its long body (e.g., including one or more conveyors). In some implementations, while the ASRS vehicle may be guided by external rails or other structures, it may be decoupled from top or bottom rails, which allows the vehicle to be easily removed from an aisle or guides (e.g., by merely navigating it beyond the limits of the aisle or rails) to allow maintenance, replacement, etc. Accordingly, using the technologies described herein, some implementations of the ASRS vehicle may be more easily maintained than mounted, crane robots while being more stable and efficient than free-moving robots.

[0046] Among other benefits described herein, the technology provides for an item handling head that, due in part to its telescoping and rotating design (and in part due to the stability of the ASRS vehicle), allows it to reach double deep shelves. The technology may include one or more mobile conveyors on which items may be placed, thereby providing increased carrying and buffering capacity to the ASRS vehicle and allowing it to move items more efficiently. For example, the double-deep reach of the item handling head and quick-loading and unloading buffering capacity of the mobile conveyors improves overall performance of the fulfillment center, for instance, by providing the improved mobile buffer, the technology improves the speed, timeliness, and efficiency of the automated storage and retrieval system.

[0047] This technology substantially improves the picking process as multiple items (e.g., in totes/mobile storage units) from the system can be transported at one time and the effort (e.g., by automatic guided vehicles, conveyors, or other equipment) required to move the items into or out of the storage area is reduced.

[0048] Various operations, features, and components for implementing the technology are described throughout this disclosure, such as in reference to the examples illustrated in the figures.

[0049] The technology described herein relates to an automated system comprising various software and hardware devices, for example, an automated robotic picking system, an automated storage and retrieval system, or other technology. The technology may include beneficial configurations, operations, features, and interactions. Among other benefits, the technology described herein improves upon that described in the Background Section. For instance, the technology provides robotic devices, systems, methods, and other aspects that can more efficiently retrieve items from or place items in a storage area.

[0050] In some implementations, the technology may provide integration, coordination, and control of various systems to intelligently move items and reduce human interaction, which increases speed and accuracy.

[0051] In some instances, the technology may include various computing devices or controllers coupled with equipment, such as the robotic arm(s), optical sensors or cameras, AGV(s), motors,

consolidation area transfer mechanisms, conveyors, other equipment, sensors (e.g., optical sensors, scanners, etc.) human interface system(s), and other devices. In some implementations, the components may communicate with each other directly, for instance, via a network or communication bus. In some implementations, a central control system, such as a warehouse management system (WMS) **104** or other system may receive signals, perform computations, and issue commands to other devices.

[0052] Features of the technology described herein can be integrated into any logistics system, dispatch system, warehouse execution system, warehouse management system, a robot execution server, etc., to coordinate the operations of various systems, information, and devices in a fulfillment system. The technology described herein may provide a fully or partially automated system that provides redundancy, reduces the number of operations, and provides many other benefits described herein. The technology beneficially improves productivity and throughput, increases asset utilization, increases space utilization, and lowers cycle time and labor costs. These benefits, in turn, lead to shorter delivery times and result in significant time and resource savings along with reduced error rates.

[0053] With reference to the figures, reference numbers may be used to refer to components found in any of the figures, regardless of whether those reference numbers are shown in the figure being described. Further, where a reference number includes a letter referring to one of multiple similar components (e.g., component 000a, 000b, and 000n), the reference number may be used without the letter to refer to one or all of the similar components.

[0054] FIG. **1** depicts an example system **100** and data communication flow for implementing an automated robotic fulfillment system, which may use the technologies, such as the double-deep automated storage and retrieval system, described in further detail herein. The system **100** includes a warehouse execution system (WES) **102**. The WES **102** is coupled to equipment controller(s) **110**, a warehouse management system (WMS) **104**, a data store **120** storing various data, a human interface system **108** (e.g., pick-to-voice, pick-to-light, graphical user interface(s), etc.), a robot execution server (REX) **118**, a dispatch system **106**, and other systems. For instance, the system **100** may include picking station component(s) or other systems, ASRS vehicle controller(s) **142**, and/or other equipment **144**, such as optical sensors or cameras, conveyors, printers, conveyors, robots, or other devices.

[0055] The WES **102** may, in some implementations, include one or more hardware and/or virtual servers programmed to perform operations, acts, and/or functionality described herein. For instance, the components of the WES **102** may comprise software routines storable in one or more non-transitory memory devices and executable by one or more computer processors of the WES **102** to carry out operations, acts, and/or functionality described herein. In further implementations, these routines, or a portion thereof, may be embodied in electrical hardware that is operable to carry out the operations, acts, and/or functionality described herein.

[0056] For example, the WES **102** may be communicatively coupled with scanner(s), carton conveyor(s), item conveyor(s), diverter(s), picking station component(s), camera(s), robotic arms, and other equipment **144** either directly or via the equipment controller(s) **110**, which may be programmable logic controllers (e.g., conveyor controllers, conveyor scanner controllers, automated induction equipment controllers, other warehouse equipment controllers, or other computing devices for controlling equipment).

[0057] In some implementations, the WES **102** may receive, process, and transmit data to control software and hardware interactions, for example, by consolidating and controlling information across systems, as described herein. For instance, the WES **102** may serve as a decision point or control software that processes data streams for receiving data, processing the data, instructing devices, and other computations, as noted herein. For example, the WES **102** may communicate with equipment controller(s) **110**, ASRS vehicle controller(s) **142**, and/or other systems to perform operations respective to the technology described herein. One or more of these operations may be

performed via communication with various equipment of the system **100**, as described in further detail herein. Accordingly, the WES **102** may provide unified communication that coordinates various systems.

[0058] The WES **102** and/or WMS **104** (together or separately) may communicate with various other systems and devices to perform its operations, as described herein, such as equipment controller(s) **110**, ASRS vehicle controller(s) **142**, REX server **118**, dispatch system **106**, and/or other equipment. The WES **102** or WMS **104** may communicate with equipment or a human-interface system **108**, which may provide instructions for picking items or correcting errors, for instance.

[0059] The other equipment **144** may include an item handling station, other box erectors, label applicators, scanners, picking equipment, or other devices for inducting or moving items, mobile storage units, cartons, or other objects in the system; scanners that may include optical, radio, or other scanners or sensors that scan items, containers, totes, mobile storage units, or cartons to identify them; conveyors that may include one or more conveyor belts or other devices that convey objects (e.g., items, mobile storage units, cartons, or other objects), for instance, as described herein Other equipment **144** may include various other devices, such as label applicators, carton-closing equipment, control systems, printers, actuators, motors; or various other devices.

[0060] The REX server **118** may, in some implementations, include one or more hardware and/or virtual servers programmed to perform operations, acts, and/or functionality described herein. The REX server **118** may generate a schedule that defines the route for one or more AGVs **114** and/or one or more ASRS vehicle **116**. For a given AGV **114** or ASRS vehicle **116**, the REX server **118** may generate a schedule and transmit it to the dispatch system **106**, equipment controller(s) **110**, and/or an ASRS vehicle controller **142**, which may, in turn, deploy an AGV **114** or ASRS vehicle **116** according to the schedule or instruction. In some implementations, the dispatch system **106** instructs the ASRS vehicle **116** to proceed to various locations in an aisle or perform various other operations described herein according to the schedule/instruction. The schedule of each of the AGVs **114** and/or ASRS vehicles **116** may be coordinated such that an optimal flow of items in a warehouse or fulfillment center can be achieved. For example, as described elsewhere herein, the REX server **118**, WES **102**, or other component of the system **100** may instruct an ASRS vehicle **116** to retrieve a defined mobile storage unit or tote from a storage area and transport it to a transfer location at which it may be unloaded, for instance, from the mobile conveyor on the ASRS vehicle **116**.

[0061] In some implementations, the REX server **118** may include or may communicate with a routing engine, which may route ASRS vehicles **116** and/or objects (e.g., items, mobile storage units, etc.) in a fulfillment center.

[0062] The dispatch system **106** may be electronically communicatively coupled to a plurality of automated guided vehicles (AGVs) **114** or **116**, directly or via ASRS vehicle controllers **142**, for example. In some implementations, the dispatch system **106**, or elements thereof, may be integrated with or communicatively coupled with the REX server **118**. The dispatch system **106** includes hardware and software configured to dispatch automated vehicles and is coupled for communication the components of the system **100** to receive instructions and provide data.

[0063] The AGVs **114** may be robotic vehicles including drive units providing motive force for moving the AGVs **114** (and, in some instances, items, storage units, etc.), guidance systems for determining position of the AGVs **114** within the distribution facility, and equipment for carrying items. Some AGVs **114** may be attached to, include, or carry carts, which, in turn, carry items or storage units. Various configurations of AGVs **114** may be used, such as those with forklifts, robotic arms, or other mechanisms for manipulating items. In some implementations, in addition to or in lieu of AGVs **114**, conveyors or other conveyance mechanisms may be used to transport mobile storage units (e.g., pallets, totes, etc.) or other objects.

[0064] An ASRS vehicle **116** may include a robotic, mobile vehicle that allows automated storage

and retrieval of items, such as mobile storage containers, to/from a storage area of an operating environment, such as a warehouse or fulfillment center. An ASRS vehicle **116** may be fully or partially automated based on certain instructions or triggers, such as an instruction to navigate to, retrieve, and/or deliver a defined item to a transfer point, where the item may be removed or moved to another device for downstream processing (e.g., transferred to a picking station at which items may be picked from a mobile storage container).

[0065] Depending on the implementation, the ASRS vehicle **116** may include a mobile vehicle body that moves within an operating environment, such as between shelves in an aisle. An ASRS vehicle **116** may include one or more conveyors, which may facilitate storage while the vehicle is moving, transfer of items onto/off of the vehicle, buffering of operations (e.g., where an item is stored while a second-deep item is being retrieved, where items are stored to allow multiple items to be retrieved in a single trip in the aisle), or other functionality. Although implementations described herein describe mobile conveyors as being integrated with the vehicle body, they may be integrated with an item handling head (e.g., an item handling head may include a vertical carriage and an item handling mechanism), or attached to the vehicle body, such as where the mobile conveyors are on a separate, couplable cart, although other implementations are possible and contemplated herein.

[0066] In some implementations, the ASRS vehicle **116** may include various item handling mechanisms, such as the examples described herein, that allow it to retrieve items from externals shelves and place items on an internal storage or transfer device, such as the example mobile conveyors described. While various example systems are shown and described, it should be noted that others are possible and contemplated herein. For example, while a rotating, telescoping item handling head is described being coupled with a vertical carriage that travels vertically along one or more vertical support rails, other implementations, such as a robotic arm, actuatable forklift, sliding platform, or other devices are possible and contemplated. In some implementations, the item handling mechanism may include a telescoping mechanism that rotates on a platform, the configuration of which allows a more densely packed shelving in a storage area, such as by allowing the item handling mechanism to access one, two, three, or another quantity deep of shelves. The configuration of the ASRS vehicle **116** and other components allow improved range of motion and stability of the item handling head to provide these and other benefits, as described in further detail throughout this disclosure.

[0067] The ASRS vehicle controllers(s) **142** may include computing devices or programmable logic controllers (e.g., conveyor controllers, motor controllers, etc.) that provides control, communication, and/or other interaction with ASRS vehicles **116** and/or their components. For instance, an ASRS vehicle controller **142** may be mounted to an ASRS vehicle **116** or communicatively coupled therewith to receive sensor data (e.g., guidance sensors that sense guidance markers, optical scanners that scan item identifiers, position sensors that detect conveyor, carriage, motor, or other positions, or otherwise), provide instructions (e.g., to a motor to perform certain movements), or other execute other operations, as described elsewhere herein. The ASRS vehicle controller(s) **142** may be communicatively coupled with the equipment controller(s) **110**, WES **102**, REX server **118**, dispatch system **106**, or other devices of the system **100**.

[0068] The WMS **104** may, in some implementations, include one or more hardware and/or virtual servers or software routines storable in one or more non-transitory memory devices and executable by one or more processors to perform operations, acts, and/or functionality described herein. The WMS **104** may be configured to store and maintain data in the data store **120**. In some implementations, the WMS **104** may be configured to communicate with the WES **102**, the human interface system **108**, dispatch system **106**, and/or other systems in real time, in batches, as requested by these components, etc. For example, the WMS **104** may receive data from an e-commerce or other server, process the data, and update various data in the data store **120** based on the order data. Similarly, the WMS **104** may detect and update inventory and other data.

[0069] It should be noted that operations described herein in reference to the WMS **104** or ASRS vehicle controller(s) **142** may be performed by other devices or by other components of the system **100**. Similarly, it should be noted that the operations described in reference the WMS **104** and the other components of the system **100** may be distributed or shifted among the components of the system without departing from the scope of this disclosure. For instance, some operations described in reference to the WES **102** or WMS **104** may be performed by the equipment controller(s) **110**, ASRS vehicle controller(s) **142**, or REX server **118**, or some operations described in reference to the equipment controller(s) **110**, ASRS vehicle controller(s) **142**, REX server **118**, or picking station component(s) may be performed by the WMS **104** or WES **102**.
[0070] The human interface system **108** may, in some implementations, include one or more hardware and/or virtual servers or software routines storable in one or more non-transitory memory devices and executable by one or more processors to perform operations, acts, and/or functionality, such as interaction by humans with machinery or to receive instructions to perform operations relative to items or machinery. The human interface system **108** may provide instructions and/or receive data (e.g., scan data, user input, confirmations), for example, from human agents or operators (e.g., using barcode scanners, NFC, RFID or radio-frequency identification chips, or other sensors or input methods), as described in further detail below. An example human interface system **108** may include audio, illumination, or a graphical user interface system that receives inputs and/or provides instructions to human agents. The human interface system **108** may be configured to communicate the data with the WES **102**, WMS **104**, or other components of the system in real time, in batches, as requested by the components of the system, etc.
[0071] The human interface system **108** may receive scan data from a client device based on a user scanning a barcode or other identifier of an item, conveyance device, tote, etc. The human interface system **108** may provide instructions to users indicating to place certain items, totes, containers, mobile storage units, etc., at certain locations, remedy errors or exceptions, or perform other actions. For instance, the human interface system **108** may instruct a user to place an item on a consolidation tray, clear a clog in a chute or transfer area of a picking station, correct an error at the buffer system, or perform other actions.
[0072] In some implementations, for example, an equipment controller **110** may detect that an error has occurred with an ASRS vehicle **116**. The equipment controller **110** or ASRS vehicle controller **142** may communicate with the human interface system **108** directly or via a WES **102** or other component to issue instructions to a human agent to clear the error.
[0073] The data store **120** is an information source for storing and providing access to data. The data stored by the data store **120** may be organized and queried using various criteria including any type of data stored by it. The data store **120** may include data tables, databases, or other organized collections of data. An example of the types of data stored by the data store **120** may include, but is not limited to map data **122**, pallet data, AGV data **126**, item data **128**, MSU (mobile storage unit) data **130**, carton data **132**, order data **134**, picking station data **136**, ASRS data **138**, or other data. In some instances, the data store **120** may also include system attributes, sensor data, labels, system health, etc.
[0074] The data store **120** may be included in the WES **102**, WMS **104**, equipment controller(s) **110**, REX server **118**, or in another computing system and/or storage system distinct from but coupled to or accessible by the WES **102**, WMS **104**, REX server **118**, equipment controller(s) **110**, ASRS vehicle controller(s) **142**, or other components of the system **100**. The WES **102**, WMS **104**, human interface system **108**, REX server **118**, equipment controller(s) **110**, and/or dispatch system **106**, for example, may store and maintain data in the data store **120**. The data store **120** can include one or more non-transitory computer-readable mediums for storing the data. In some implementations, the data store **120** may store data associated with a database management system (DBMS) operable on a computing system. For example, the DBMS could include a structured query language (SQL) DBMS, a NoSQL DMBS, various combinations thereof, etc. In some

instances, the DBMS may store data in multi-dimensional tables comprised of rows and columns, and manipulate, e.g., insert, query, update and/or delete, rows of data using programmatic operations.

[0075] The map data **122** may include data reflecting the 2- or 3-dimensional layout of the facility including example locations of storage units, shelves, totes, or other items, automated picking station(s), carton receiving areas/spaces, mobile storage unit receiving area/spaces, conveyors, equipment, storage shelving units, buffer shelves, items, AGVs **114**, ASRS vehicles **116**, conveyors, etc. Map data **122** may indicate the attributes of the distribution facility, including attributes of zones/areas of a warehouse. For example, attributes of zones may include the number, quantity, and location of shelving units or bays, storage units, items, boxes/cartons, guidance system locators or markers, etc.

[0076] The AGV data **126** may describe the state of an AGV **114**, such as operational state, health, location, battery life, storage capacity, objects (e.g., items, mobile storage units, totes, pallets, etc.) being carried, cartons, whether a picker is assigned to it, etc.

[0077] The item data **128** may describe items in a distribution facility. The item data **128** may include unique identifiers for these items, the item volume (e.g., the total amount picked in given window (e.g., in an hour, day, etc.)), the item velocity (e.g., number of different times item picked in given window (e.g., per hour, day etc.), the location of the items within the distribution facility (aisle, shelf, shelf position, mobile storage unit, mobile storage unit partition, tote, conveyance device, pallet, shipping carton, etc.), other attributes of the item (e.g., size, description, weight, quantity of items in a package, color, quantity of packages in a container, etc.), item inventory, or mapping of items to storage units, orders, conveyor locations, picking station(s), trays in a picking station, pallets, totes, etc. In some implementations, the item data **128** may include the quantity of particular items a mobile storage unit contains, the current location of a storage unit, a storage location of items and/or storage units, and other data. For instance, the item data **128** may include visual aspects, labels, QR codes, identifying markers, etc., that may be used by the WES **102**, WMS **104**, or equipment controller(s) **110**, etc., to identify items, for example, based on a scan of an item.

[0078] The MSU data **130** may include information about mobile storage units and/or containers in the system, such as a unique identifier or license plate number for each mobile storage unit or container, a mobile storage unit or container type, the zones a mobile storage unit will visit, the current or assigned location of a mobile storage unit, and the priority for the mobile storage unit. For instance, the MSU data **130** (or map data **122**) may indicate an aisle, distance into an aisle, side of an aisle, shelving unit, shelf height, shelf depth (e.g., whether it is in a front shelf or a back shelf where double deep or other depths of shelves are used), or other information. The MSU data **130** may include a list indicating the items, item types, and/or the quantity of items a mobile storage unit (or a partition thereof) contains or should contain (e.g., its maximum or assigned capacity).

[0079] The carton data **132** may include various attributes describing box formers, available box sizes, box sizes associated with a box former, box size(s) associated with an order, the state of each box former, box former queues, or other data described herein. For example, the carton data **132** may include license plate numbers or other identifiers on cartons, status and locations of cartons in the systems (e.g., on conveyors), orders or items assigned to cartons, and other data.

[0080] Order data **134** may include data pertaining to orders to-be-fulfilled, being fulfilled, and/or already fulfilled in the fulfillment center. For example, the order data **134** may include tables or other files indicating which items are associated with orders, attributes of the items, attributes of the orders, shipping information, box size needed for the items, picking stations to which orders are assigned, status information, or other information for orders.

[0081] Picking station data **136** may include various data describing a picking station, such as its location, status, orders assigned to the station, mobile storage unit assigned to or at the station, cartons assigned to or at the station, or other data. For example, as described below, orders and

associated items may be assigned to be picked at a station.
[0082] ASRS data **138** may include data describing the locations, storage state, items, or other attributes of ASRS vehicles **116**. The ASRS data **138** may additionally or alternatively describe the current state, health, location, battery life, storage capacity, items being carried, pending task, position of the item handling head, position of each mobile conveyor, or other attributes of an ASRS robot/vehicle **116**, its components, or its sensors, for example. For instance, the ASRS data **138** may indicate a current or assigned position of each item on the ASRS vehicle, such as where or whether it is on each mobile conveyor, the item handling head, staging conveyor, or otherwise.
[0083] The components of the system **100** may be coupled to exchange data via wireless and/or wired data connections. The connections may be made via direct data connections and/or a computer network. The computer network may comprise any number of networks and/or types of networks, such as wide area networks, local area networks, virtual private networks, cellular networks, close or micro proximity networks (e.g., Bluetooth, NFC, etc.), etc. In some implementations, one or more of these components may be coupled via a data communications bus.
[0084] FIG. **2** illustrates an example layout **200** of a portion of a fulfillment center used in the automated robotic fulfillment system. For instance, the layout **200** illustrates a top-down view of an operating environment in which multiple ASRS vehicles **116** operate between storage shelves **204**. It should be noted that the layout **200** is provided as an illustrative example of the technology described herein and that other layouts, configurations, and uses may be used. Additionally, the other figures herein illustrate example configurations and implementations of this technology. While certain examples are described, the operations, components, and features described herein may be modified, interchanged, omitted, or augmented without departing from the scope of this disclosure. It should be noted that while certain movements, interactions, paths, locations, and devices are illustrated, other implementations are possible and contemplated herein.
[0085] It should be understood that various facilities may include different configurations. For instance, a fulfillment center, distribution facility, or another location may use some or all of the aspects of the example layout. It should be noted that other configurations, components, or layouts are possible and contemplated herein, and the examples are provided by way of illustration.
[0086] In the illustrated example, two ASRS vehicles **116***a* and **116***b* are illustrated in two separate aisles, for example, where the aisles extend between storage shelves **204**. In the illustrated example, the storage shelves **204** are in a double deep configuration (e.g., where there are four shelves or shelving unit bays between aisles), so that an item handling head **214** that is configured to access two shelves deep may reach beyond a front shelf to access a back shelf, although other implementations are possible and contemplated herein, such as single or triple deep shelves.
[0087] In the illustrated example, the shelves are shown to the right and left of an ASRS vehicle **116** in an aisle but, in some implementations, shelves may also be at an end of an aisle and the item handling head **214** may be adapted to rotate to access the shelves at the end of the aisle/in front of the ASRS vehicle **116**.
[0088] The shelves may be flat, open at the bottom, or have various other configurations to allow them to hold items **206**. In some implementations, as illustrated, the items **206** may include mobile storage units where each shelf holds a single mobile storage unit. Although other implementations are possible, a mobile storage unit may include a tote with a bottom and four sides in which objects may be stored. The mobile storage unit may include one or more internal dividers, a lid, one or more access doors in the top or side(s), handling mechanism interface mechanisms, or other components. The mobile storage units may have a bar code, QR code, RFID chip, or other ID that allows it to be identified and tracked in a fulfillment center, for example, by a scanner coupled with an ASRS vehicle **116** (e.g., on an item handling head **214**). In some implementations, the shelves may extend vertically well beyond the reach of a human and, potentially, limited by a ceiling in a building, such as 8, 10, 16, or other feet from the floor. Accordingly, the shelves **204** may provide high density storage area for items **206**, such as the mobile storage units (which may hold one or

more types of items **206** or objects).
[0089] In the illustrated example layout, an ASRS vehicle **116** may be positioned between two guide rails **210** that that extend into the aisle and improve guidance and/or stability of the ASRS vehicle **116**. The rails **210** may be mounted to shelves **204** or may be mounted to a floor and may support and/or guide an ASRS vehicle **116**. Although not shown in the illustrated examples, in some implementations, the rails **210** may couple the ASRS vehicle **116** to the floor to prevent it from tipping, guide it, locate it, move it, or otherwise, so that it may move more quickly and accurately than would be possible with other systems. Additionally, or alternatively, one or more power and/or other rails may be disposed along the support rails and/or shelves. The power rails may, for instance, provide power via brushes, etc., to the ASRS vehicle **116**.
[0090] In the depicted example, the ASRS vehicle **116** includes one or more mobile conveyors **212** coupled with or integrated with the body of the vehicle. The mobile conveyors **212** may store items **206** during movement of the ASRS vehicle **116** in an aisle or elsewhere. In some implementations, one or more of the mobile conveyors **212** may rotate to allow additional items **206** to be stored thereon and/or transferred thereto/therefrom.
[0091] The ASRS vehicle **116** may include a vertical rail **216** or mast that allows an item handling head **214** to move upward or downward and access external shelves at various heights. As described in further detail below, some implementations of the ASRS vehicle **116** may be configured to allow the item handling head **214** to access multiple mobile conveyors **212** on the vehicle body.
[0092] The item handling head **214** may include various mechanisms that allow it to pull items **206** from shelves **204**, place items **206** on mobile conveyors **212**, move items **206** between multiple mobile conveyors **212**, move items **206** from a mobile conveyor **212** to an external shelf **204**, or perform other operations. In some implementations, the item handling head **214** may include one or more telescoping members or arms that extend into a shelf **204** thereby allowing the item handling head **214** to retrieve or place items **206** deeper into shelves, such as into double-deep shelves, as illustrated in the example. Various example configurations of the item handling head **214** (as well as other components of the ASRS vehicle **116**) are described throughout this disclosure, such as in reference to FIGS. **4**A-**9**F.
[0093] Depending on the implementation, the ASRS vehicle **116** may be configured to navigate to a transfer point at which it transfers one or more items **206** or storage units **206** from the mobile conveyor **212** to an external device, such as an external conveyor **208**, an AGV **114**, a shelf of a picking station, a chute, a robotic arm, a diverter station, or other component of a fully or partially automated warehouse or fulfillment center. For instance, through rotation of one or more of the conveyors **208** and **212**, or using a diverter mechanism, items **204** may be transferred to or from the mobile conveyor **212**. While the transfer points for the ASRS vehicles **116***a* and **116***b* are illustrated being external to or at the end of the aisle, other locations or configurations are possible, such as midway in an aisle, at another location in a facility, etc.
[0094] In some implementations, the transfer point/location may include a docking station that receives an ASRS vehicle **116**. The docking station may include a guide that assists placement, a trigger/sensor that confirms that the ASRS vehicle **116** is in place, an electrical charger, a communication port for transmitting instructions, a diverter or arm to move items **206** off the mobile conveyor(s) **212**, or other devices. Each ASRS vehicle **116** may use a single transfer point or docking station or each ASRS vehicle **116** may have their own transfer point (e.g., at the end of each aisle).
[0095] In some implementations, multiple ASRS vehicles **116** may be used to retrieve items **206** from separate aisles in order to fulfill a single order. The WES **102**, for instance, may coordinate their movements and task lists in order to retrieve all items **206** listed in the order, which may be transferred from the storage area by the ASRS vehicles **116** to other areas in the fulfillment center where they are picked in to shipping cartons.

[0096] Although other operations, paths, and features are possible, FIG. **2** illustrates certain operations being performed in the layout **200**. For instance, a first ASRS vehicle **116***a* is shown navigated to an end of an aisle where its double-deep item handling head **214** is able to access two shelves deep on each side of the aisle. The item **206***a* is shown at a single bay or reach distance deep while item **206***b* is shown at a double-deep bay or each distance. The item handling head **214***a* may access item **206***a* directly, while it may have to reach past a first shelf and into a second, back shelf to access another item **206***b*. The improved stability of the ASRS vehicle **116***a* and configuration of the item handling mechanism **214***a* allow this increased range of motion.
[0097] In some instances, an ASRS vehicle **116** may have multiple mobile conveyors **212** or a mobile conveyor and a staging location/conveyor, which allows the ASRS vehicle **116** to shuffle a first item **206** from a front shelf **204***b* out of the way (e.g., on to the staging location/conveyor or second mobile conveyor **212**), so the item handling head **214** can access a second item **206** on a back shelf **204***a* and then replace the first item on the front shelf **204***b*.
[0098] Once the item handling mechanism **214***a* removes the item **206***b* from its shelf **204**, it may travel down the vertical rail **216***a* until it reaches a height of the mobile conveyor **212***a* at which point the item handling mechanism **214***a* may rotate until its telescoping members or arms face the mobile conveyor **212***a*. The item handling head **214** may then extend the arms to push the item **206***b* onto the mobile conveyor **212***a*. In some instances, the conveyor **212***a* may rotate to move the item **206***b* to a different location on the conveyor **212***a* and/or prepare for a subsequent item **206**. It should be noted that other mechanisms and processes are possible, such as where the item handling head **214***a* rotates at a different time or performs other operations.
[0099] As illustrated in the example of FIG. **2**, a second ASRS vehicle **116***b* may be located in a second aisle. As illustrated, the second ASRS vehicle **116***b* has moved toward a transfer point at the end of the second aisle. The second ASRS vehicle **116***b* also includes a mobile conveyor **212***b*, vertical support rail **216***b*, and item handling head **214***b*. As illustrated in the example, the item handling head **214***b* is shown rotated toward the mobile conveyor **212***b* and its arms are extended to place an item **206***c* on the mobile conveyor **212***b*. Additionally, two other items **206***d* and **206***e* are shown on the mobile conveyor **212***b*. The mobile conveyor **212***b* may rotate to move items **206** onto the external conveyor **208**. In some instances, this movement may be assisted by external robotic arms, chutes, diverters, or other mechanisms.
[0100] In implementations where the ASRS vehicle **116** includes multiple mobile conveyors **212** (e.g., as illustrated in the example of FIG. **4**A), the item handling head **214** may move items **206** between the multiple mobile conveyors **212** to shuffle items on external shelves (e.g., to allow access to a back shelf, as described elsewhere herein), to increase the number of items **206** carried by the ASRS vehicle **116** or improve the rate at which the items **206** are unloaded. For instance, where items **206** are unloaded from a top mobile conveyor **212** (e.g., where a transfer point or docking station unloads from only the top mobile conveyor **212**), the item handling head **214** may move items **206** from bottom mobile conveyor **212** onto the top mobile conveyor **212**, so that they may also be unloaded. When the ASRS vehicle **116** arrives at the transfer point (e.g., the unloading station, docking station, etc.), it may rotate the main conveyor **212** first to unload and also rotate the bottom conveyor **212** while using the item handling head **214** to move the items one by one from the bottom conveyor **212** to the top/main conveyor **212**, which may also rotate to move the moved items **206** to unload them. In some implementations, both or all of the mobile conveyors **212** may be loaded and/or unloaded simultaneously.
[0101] FIG. **3**A-**3**E are flowcharts of example methods **300**, **320**, and **350** for automated storage and retrieval using a system, such as the ASRS system, such as those described elsewhere herein. The operations described in reference to FIGS. **3**A-**3**E may be used with components and features described throughout this description, such as in reference to FIGS. **1**, **2**, and **4**A-**10**. It should be noted that the operations of the methods **300**, **320**, and **350** may respectively be used interchangeably or with the other operations and features used herein. Furthermore, it should be

noted that operations of the methods **300**, **320**, and **350** (as well as other operations of this description) may be augmented, reordered, omitted, or modified while still using technologies described in this disclosure. Similarly, the example hardware features and configurations described in this disclosure may be used with different operations, methods, contexts, etc.

[0102] It should be noted that, although the operations of the methods **300**, **320**, and **350** are described as being performed by the ASRS vehicle controller(s) **142** (e.g., in conjunction with the WES **102**, equipment controller(s) **110**, or other components), other implementations are possible, such as where another system, machine, computer, server, process, engine, etc., performs all or a portion of the operations. The WES **102**, REX **118**, ASRS vehicle controller(s) **142**, other equipment, etc., may be communicatively coupled and may also be coupled with various sensors, motors, actuators, and devices, such as those described throughout this disclosure. For instance, an ASRS vehicle **116**, AGVs **114**, etc., may be controlled by a WES **102**, human agent, or other device, such as those of the system **100**.

[0103] Although described in reference to the ASRS vehicle controller(s) **142**, some operations may be performed directly by the WES **102**, by the equipment controller(s) **110**, by the controller(s) **110** or **142** based on communications between these and other components, or otherwise. For example, it should be noted that some or all of the operations may be performed automatically by an equipment controller **110** or ASRS vehicle controller **142**. In some implementations, operations may be controlled by a human user, such as by applying physical force via levers, by pressing buttons, or otherwise.

[0104] The operations and features described in reference to FIGS. **3**A-**3**E, for example, may be described in additional detail throughout this disclosure, both in terms of the operations and mechanical components.

[0105] FIG. **3**A is a flowchart of an example method **300** for retrieving items for one or more orders from a storage area using an ASRS vehicle **116**.

[0106] At **302**, the ASRS vehicle controller(s) **142** may determine a set of items for a set of orders. For instance, the WES **102** or WMS **104** may receive orders each including one or more items and may determine a time frame at which to fulfill those orders based on available resources in a fulfillment center, priority of the orders, or other criteria. The WES **102** may split the tasks for retrieving items for the orders up among various resources, such as among one or more ASRS vehicles **116** in aisles at which the items are stored. Accordingly, the WES **102** may generate a set of tasks for each of one or more ASRS vehicles **116** to retrieve or replace items or perform other operations. The WES **102** may transmit those tasks to an ASRS vehicle controller **142**, as described elsewhere herein.

[0107] At **304**, the ASRS vehicle controller(s) **142** may determine locations of each item **206** in the set of items in a storage area. For example, the ASRS vehicle controller(s) **142** or WES **102** may access the data store **120** to determine the locations of each item in the storage area. In some implementations, the items may be stored inside mobile storage units or totes sitting on shelves in the storage area.

[0108] At **306**, the ASRS vehicle controller(s) **142** or WES **102** may assign one or more ASRS vehicles **116** to retrieve the set of items based on their determined locations (e.g., in aisles), aisles associated with the locations, and ASRS vehicles **116** associated with the aisles. For instance, the WES **102** may divide tasks in a set of orders to multiple ASRS vehicles **116** to retrieve items from their respective locations and/or balance ASRS vehicle **116** utilization (e.g., where a certain item/SKU is located in multiple aisles, or where tasks are assigned at varying time periods to balance workload).

[0109] At **308**, the ASRS vehicle controller(s) **142** or WES **102** may instruct each ASRS vehicle **116** to retrieve the subset of items, for example, those items stored in an aisle associated with each respective ASRS vehicle **116**. In some implementations, the WES **102**, when assigning the tasks, may also transmit locations, specific operations, storage unit or tote identification codes, or other

details to the ASRS vehicle controller(s) **142** to perform the assigned tasks, or the ASRS vehicle controller(s) **142** may access the data store **120** to determine information needed to perform the tasks.

[0110] At **310**, the ASRS vehicle controller(s) **142** may instruct an ASRS vehicle **116** to transfer the subset of items to mobile conveyor(s) **212** coupled with the ASRS vehicle **116**. For example, the WES **102** may transmit an instruction to one or more ASRS vehicle controllers **142** that cause the sensors, motors, and other components of the ASRS vehicle **116** to complete the tasks of retrieving the item from a determined or defined location. For example, the ASRS vehicle **116** may navigate down an aisle using one or more drive and one or more sensors reading navigation markers (e.g., QR codes on a floor, markers on a rail, markers on a shelf, lasers, or other guidance system components) or otherwise locate itself in the aisle. The ASRS vehicle **116** may then vertically move the item handling mechanism to a height of the assigned item, rotate toward the item, if necessary, and extend one or more grasping members or arms that remove the item from the shelf and onto the item handling head **214**. The ASRS vehicle **116** may then move the item handling head **214** to a height of the mobile conveyor **212** and use it to place the item on the conveyor.

[0111] The ASRS vehicle controller(s) **142**, WES **102**, and/or ASRS vehicle **116** may repeat these operations to add additional items to the vehicle's mobile conveyor(s) **212**, for example, by moving the items on the conveyor(s) **212**.

[0112] These and other example operations and associated mechanisms are described in further detail throughout this disclosure, such as in reference to the methods in FIGS. **3**B-**3**E.

[0113] At **312**, the ASRS vehicle controller(s) **142** or WES **102** may instruct the ASRS vehicle **116** to transfer the subset of items at a transfer zone or point via the mobile conveyor(s) **212**. For example, the ASRS vehicle **116** may navigate to an end of the aisle at which a transfer point is located in response to completion of a single or set of tasks where the assigned subset of items are retrieved. At the transfer point, the mobile conveyor **212** may rotate to shift the item(s) on the conveyor (e.g., on a belt or rollers), which, in some instances, may push the items off the conveyor onto another device, such as an external conveyor.

[0114] When items are stored on a second conveyor of the ASRS vehicle **116**, the second conveyor may rotate and/or the item handling head **214** may retrieve items therefrom and move them to the main conveyor, which dispenses them from the ASRS vehicle **116**.

[0115] At **314**, the ASRS vehicle controller(s) **142** may transfer a second set of items at the transfer station onto the mobile conveyor **212** of the ASRS vehicle **116**. For example, the WES **102** may determine and use the ASRS vehicle **116** to place items in the storage area, for example, after picks have been completed, to replenish storage of items (e.g., where items are stored in a mobile storage unit), or to store new items in the storage area. Accordingly, at the transfer point, items to be stored in the storage area may be transferred onto the mobile conveyor(s) **212** of the ASRS vehicle **116**.

[0116] At **316**, the ASRS vehicle controller(s) **142** or WES **102** may instruct an ASRS vehicle **116** to transfer the second set of items to assigned location(s) in the storage area. For example, based on the instruction(s), the ASRS vehicle **116** may navigate from the transfer point to the storage location(s) of the second set of items. The item handling head **214** may then actuate to move the item from the mobile conveyor **212** to the storage location. For instance, these operations may be performed in the reverse of the operations for retrieving items from the external shelves.

[0117] FIG. **3**B is a flowchart of an example method **320** for retrieving an item, for example, from a back shelf in a double-deep shelving configuration. Beneficially, this configuration allows increased storage density thereby allowing more items and/or SKUs to be stored in a given area of a fulfillment center. As discussed in further detail elsewhere herein, the simplicity and configuration of the item handling head **214** may allow items to be retrieved and/or placed in double-deep external shelves and retrieved and/or placed on one or more mobile conveyors **212** of the ASRS vehicle **116**. Additionally, or alternatively, the length and low center of gravity of the ASRS vehicle's **116** body (and/or potentially the guide rails) allows additional storage space, buffer

shelves or conveyors, improved stability, increased speed, and other benefits that further allow items to be placed or retrieved quickly and potentially in a double-deep shelf configuration.
[0118] At **322**, the ASRS vehicle controller(s) **142** may navigate the ASRS vehicle **116** in an aisle to a location of a storage shelf holding an assigned item, for example, based on an instruction or information received from the WES **102**. The ASRS vehicle controller(s) **142** may receive sensor data that allows localization of the vehicle.
[0119] At **324**, the ASRS vehicle controller(s) **142** may raise or lower a vertical carriage holding an item handling mechanism or head **214** to a shelf height of the item. For instance, the vertical carriage may position a floor or carrying surface of the item handling head **214** at the shelf height (and/or telescoping arms at or above the shelf to interact with the item). In some implementations, the height may be stored in the data store **120** and/or scanned by a sensor on the item handling head **214**.
[0120] At **326**, the ASRS vehicle controller(s) **142** may determine that an unassigned item is between an item handling head **214** and the assigned item (e.g., and/or that the assigned item is on a back or second deep shelf). For example, the WES **102** may determine the storage locations of items (e.g., mobile storage units) on the shelves and thereby determine that an unassigned item is currently between the item handling head **214**/aisle and the assigned item on a back shelf. Additionally, or alternatively, an optical scanner of the item handling head **214** may detect an item in the way of the assigned item.
[0121] At **328**, the ASRS vehicle controller(s) **142** may retrieve the unassigned item using the item handling head **214** and transfer the unassigned item to a first mobile conveyor **212** of the ASRS vehicle **116**. As described in further detail below, the item handling head **214** may extend a telescoping component to or into the shelf to couple with the unassigned item, pull the unassigned item from the external shelf, rotate toward the first mobile conveyor **212**, and extend the telescoping component to push the unassigned item onto the first mobile conveyor **212**.
[0122] At **330**, the ASRS vehicle controller(s) **142** may retrieve the assigned item using the item handling head **214** and transfer the assigned item to a second mobile conveyor **212** of the ASRS vehicle **116**. The vertical carriage or item handling head **214** may move to the height of the shelf, extend the telescoping component to the assigned item (e.g., on a back shelf), pull the assigned item from the shelf, rotate toward the second conveyor, and extend the telescoping component to push the assigned item onto the second mobile conveyor **212**.
[0123] At **332**, the ASRS vehicle controller(s) **142** may retrieve the unassigned item from the first mobile conveyor **212** using the item handling head **214** and transfer to the external storage shelf. For instance, the item handling head **214** may reverse the operations at **328** to replace the unassigned item on the shelf. In some instances, it may replace the unassigned item on the same shelf (e.g., the front shelf) where it was previously stored while in other instances it may move the unassigned item to the back shelf and update the file associated with the item in the data store **120** to indicate its new location. Accordingly, the assigned item may more easily be returned to the location or approximate location in the aisle.
[0124] FIGS. **3**C, **3**D, and **3**D depict a flowchart of an example method **350** for retrieving an item using an ASRS vehicle **116** with a telescoping, rotating item handling head **214**, such as the example illustrated in FIG. **4**A.
[0125] At **352**, the ASRS vehicle controller(s) **142** may drive the ASRS vehicle **116** along a first horizontal axis using one or more first motors until the ASRS vehicle **116** reaches a defined position in the aisle. As described below, the first motor(s) may be a drive motor coupled with drive wheels directly or via a chain, belt, or gears.
[0126] At **354**, the ASRS vehicle controller(s) **142** may position a vertical carriage holding an item handling mechanism or head **214** along a vertical axis using a second motor to move it to a defined position/height, such as to that of a shelf on which an assigned item is located. For example, as described below the second motor may be coupled with a belt or chain extending upward along a

vertical support rail to move the vertical carriage along the vertical axis. The motor may be a servo or stepper motor that remembers its position, or the position may be determined using another sensor. In some instances, once the vertical position is reached, it may be locked in place using a lock, such as a rachet mechanism to prevent slippage in a power off or motor failure situation.
[0127] At **356**, the ASRS vehicle controller(s) **142** may extend the telescoping component or arms of the item handling head **214** along a second horizontal axis (e.g., perpendicular to the direction of movement of the ASRS vehicle **116**) using a third motor until the arm(s) are in a defined position (e.g., matching a depth of the item). The third motor may be coupled with the telescoping arms using various mechanisms, such as those described and illustrated elsewhere herein. The telescoping arm(s) may have one or more members at the sides, bottom, or top of the item to lift, pull, or push it.
[0128] At **358**, the ASRS vehicle controller(s) **142** may actuate one or more item grasping mechanisms of the telescoping arm(s) to grasp the first item. For instance, the grasping mechanism may include rotatable fingers, a suction cup, a lifting mechanism or fork, or various other mechanisms that keep the item with the telescoping arm(s), as described elsewhere herein.
[0129] At **360**, the ASRS vehicle controller(s) **142** may retract the telescoping arm(s) along the second horizontal axis to remove the item from the external shelf. For example, by rotating the third motor, the telescoping arm(s) may be retracted along with the item.
[0130] At **362**, the ASRS vehicle controller(s) **142** may select a first mobile conveyor **212** of the ASRS vehicle **116** to which to transfer the first item. The first mobile conveyor **212** may be selected from a plurality of mobile conveyors **212** based on availability of locations on the conveyors, task order, randomly, or based on other criteria.
[0131] At **364**, the ASRS vehicle controller(s) **142** may position the vertical carriage or item handling head **214** at a defined position or height adjacent to the selected first conveyor.
[0132] At **366**, the ASRS vehicle controller(s) **142** may rotate the item handling head **214** relative to the vertical carriage or ASRS vehicle **116** using the fourth motor to face it toward the first mobile conveyor **212**. For example, a fourth motor may rotate the item handling head **214** relative to the vertical carriage so that the telescoping arm(s) or other components face toward the first mobile conveyor **212**. In some implementations, as the item handling head **214** rotates, it may also rotate the item that it is holding.
[0133] At **368**, the ASRS vehicle controller(s) **142** may extend the telescoping arm(s) of the item handling head **214** along the first horizontal axis to push the first item onto the first mobile conveyor **212**. For instance, in some implementations the first mobile conveyor **212** is in line with the movement of the ASRS vehicle **116**, and the item handling head **214** rotates to allow the telescoping arms to push the item onto the first mobile conveyor **212**.
[0134] At **370**, the ASRS vehicle controller(s) **142** may retract the telescoping arm(s) to allow the item handling head **214** to rotate and/or move vertically.
[0135] In some instances, the first item may be positioned on a first conveyor with one or more additional items that have previously been retrieved by the ASRS vehicle **116**. The ASRS vehicle **116** may also include one or more additional mobile conveyors **212** storing additional items.
[0136] At **372**, the ASRS vehicle controller(s) **142** may drive the ASRS vehicle **116** along the first horizontal axis (e.g., using the first motor) to position it at a transfer point, such as at a docking station at the end of the aisle.
[0137] At **374**, the ASRS vehicle controller(s) **142** may rotate the first mobile conveyor **212** using a fifth motor to position the first item on the first mobile conveyor **212**. The conveyor may move the item to an end to push it off the conveyor and/or where a diverter, robotic arm, chute, or other mechanism removes the item from the conveyor. Similarly, the conveyor may rotate to move one or more other held items off the conveyor at the transfer point.
[0138] At **376**, the ASRS vehicle controller(s) **142** may transfer the first item (and/or other items) off the first mobile conveyor **212**, for example, by further rotating the first mobile conveyor **212** or

actuating a diverter or other mechanism to move it onto an external device, such as an external conveyor that may move it to a picking station or other location in a warehouse or fulfillment center.

[0139] At **378**, the ASRS vehicle controller(s) **142** may position the vertical carriage or item handling head **214** along the vertical axis at a defined position or height adjacent to a second mobile conveyor **212** of the ASRS vehicle **116**. The ASRS vehicle controller(s) **142** may determine that there are additional items that were retrieved from the storage area and that are located on the second mobile conveyor **212**.

[0140] At **380**, the ASRS vehicle controller(s) **142** may rotate the second mobile conveyor **212** using a sixth motor coupled with the second mobile conveyor **212** to position a second item on the second mobile conveyor **212**, for example, at an end proximate to the item handling head **214**.

[0141] At **382**, the ASRS vehicle controller(s) **142** may extend the one or more telescoping arm(s) along the first horizontal axis until the arm(s) reach a defined position at the end proximate to the item handling head **214**.

[0142] At **384**, the ASRS vehicle controller(s) **142** may actuate the item grasping mechanism of the telescoping arm(s) to grasp the second item, for example, as described above.

[0143] At **386**, the ASRS vehicle controller(s) **142** may retract the telescoping arm(s) to remove the second item from the second mobile conveyor **212**, for example, by pulling it onto the item handling mechanism.

[0144] At **388**, the ASRS vehicle controller(s) **142** may position the vertical carriage or item handling head **214** at a defined position or height adjacent to the first mobile conveyor **212**.

[0145] At **390**, the ASRS vehicle controller(s) **142** may extend the telescoping arm(s) along the first horizontal axis to move the second item onto the first mobile conveyor **212**. The ASRS vehicle controller(s) **142** may deactivate the grasping mechanism and, in some instances, retract the telescoping arm(s).

[0146] At **392**, the ASRS vehicle controller(s) **142** may rotate the first mobile conveyor **212** to position the second item on the first mobile conveyor **212**, for example, at an end at the transfer point.

[0147] At **394**, the ASRS vehicle controller(s) **142** may transfer the second item off the first mobile conveyor **212**, for example, as described above. Additionally, where other items are on the first or second mobile conveyors **212**, they may accordingly be positioned by the conveyor(s) and/or item handling head **214** and transferred off the ASRS vehicle **116**.

[0148] As discussed above, the operations of the methods described in reference to FIGS. **3**B-**3**E may be reversed to place items on storage shelves.

[0149] FIGS. **4**A-**9**F illustrate various example implementations of an ASRS vehicle **402** and/or example components, which may be used, for instance, in conjunction or in alternative with the other features and operations described herein. The example ASRS vehicle **402** may represent example implementations of the ASRS vehicle **116** (and/or its components) described above, although other configurations are possible and contemplated. Additionally, it should be noted that its features may be used separately or together with each other and others described herein. Similarly, they may be used with or without the operations described herein.

[0150] FIGS. **4**A-**4**C illustrate various views of an example ASRS vehicle **402**. Example features and components of the ASRS vehicle **402** are described in reference to FIGS. **5**A-**9**F below. FIG. **4**A illustrates a perspective view of the example ASRS vehicle **402**, FIG. **4**B illustrates a right-side view of the example ASRS vehicle **402**, and FIG. **4**C illustrates a top-down view of the example ASRS vehicle **402**. Although certain implementations and configurations are shown and described, it should be noted that they are provided by way of example and that others are possible and contemplated herein.

[0151] Although other implementations are possible, an ASRS vehicle **402** may include a cart or body **412** that moves along one or more guide rails **410**, which provide guidance, support, rigidity,

power, communication, or other services to the ASRS vehicle **402**. A vertical mast **416** may be coupled with the body **432** (e.g., at an end thereof) and extend upward therefrom. An item handling head **414** may include a vertical carriage **442** and an item handling mechanism **444**, for instance. A vertical carriage **442** may be movably coupled with the vertical support rail(s) **434** to move upward or downward along the vertical rail(s) **434**. The vertical carriage **442** may lift and lower an item handling mechanism **444** to access external shelves of various heights and/or mobile conveyors at various heights. In some implementations, power, communications, controller (e.g., an ASRS vehicle controller **142**), or other components may be mounted to the ASRS vehicle **402**, for example, in a box **438** on the mast **416**.

[0152] The ASRS body **412** may include drive wheels that contact a floor or external guide rails **410** and/or guide wheels that align the ASRS body **412** along the guide rails **410**. The ASRS body **412** may include a frame **432** that provides structure to its motors, wheels, the mast **416**, and one or more mobile conveyors **452** and **454**, which may be stacked vertically, positioned at the same level next to one another, or otherwise.

[0153] The mast **416** may include one or more vertical support rails **434**, which may include side frames, tracks, a chain or belt path, pulleys, or other components. The ASRS vehicle **402** may include one or more buttresses **436** that stabilize the vertical support rails **434**.

[0154] In the illustrated example, the ASRS body **412** may provide support for a bottom conveyor **452** and a top conveyor **454**. Depending on the implementation, each of these conveyors may couple with internal or external motors to allow them to rotate and position items thereon. In some instances, both conveyors may transfer items therefrom or thereto simultaneously or only a single conveyor (e.g., the top conveyor **454**) may transfer items at a transfer point while the second conveyor (e.g., the bottom conveyor **452**) may transfer items to the first conveyor using the item handling mechanism **444**. As illustrated numerous items **406**, such as mobile storage units or totes may be carried on the conveyors **452** and **454**.

[0155] The length of the body **412**, its low center of gravity, and its other features improve its stability so that a tall mast **416** may be used, the ASRS vehicle **402** may move quickly, and a double-deep item handling mechanism **444** may be used.

[0156] Additional details of the ASRS body **412** are described in further detail elsewhere herein, such as in reference to FIGS. **6**A-**6**E.

[0157] The item handling mechanism **444** may be carried on the vertical carriage **442** along the vertical support rail(s) **434**. For instance, a motor may be located in the ASRS body **412** and coupled with belts or chains (e.g., a chain on each side or support rail and coupled together using a driveshaft) extending up the mast **416**, over a top pulley or sprocket, and back down to the motor-drive gear. The vertical carriage may be coupled with the belt/chain. This configuration allows a heavy motor to remain low while moving the vertical carriage **442**. Accordingly, an ASRS vehicle controller **142** may instruct the mast motor to move the vertical carriage **442** to a defined height.

[0158] An item handling mechanism **444** may be carried by the vertical carriage **442**. Although various configurations are possible and contemplated, it may be configured to rotate in place and/or extend in one or more directions. For instance, the item handling mechanism **444** may extend horizontally perpendicular (and/or parallel) to the movement of the ASRS vehicle **402** to access external shelves. The item handling head, depending on the implementation, may also be configured to rotate, which allows it to extend toward the conveyors **452** and **454** to place or retrieve items.

[0159] Example configurations of the item handling mechanism **444** and support carriage are described in further detail below, for example, in reference to FIGS. **7**A-**9**F.

[0160] Although other configurations are possible, illustrated example configurations are provided. In some figures, certain elements have been omitted from illustration to improve clarity. The features described in reference to the various figures herein may be omitted, changed, interchanged, or augmented without departing from the technology. For instance, aspects of some example

implementations may be used with other implementations.
[0161] FIGS. **5**A-**5**C illustrate perspective views of an example ASRS vehicle **402** with its vertical carriage **442** and item handling mechanism **444** in different positions. It should be noted that these views are provided by way of example and that other operations and positions are possible and contemplated. Additionally, example mechanisms for these movements are described in further detail below, although others are possible and contemplated herein.
[0162] FIG. **5**A illustrates the vertical carriage **442** in a partially raised position, as if it were at the elevation of an external storage shelf (not shown) to retrieve an item **406** therefrom. The item handling mechanism **444** is shown in a fully extended position, such as where it would reach a back shelf in a double-deep shelving arrangement. The item handling mechanism **444** may include one or more structures, which are referred to herein as extendable or telescoping members or arms, and that extend outward from the vertical carriage **442** to interact with items on an external shelf or internal mobile conveyor (e.g., **454**). It should be noted that although the extendable structure is described as a member or arm, it may take various shapes or configurations. Example implementations of the item handling head are described in further detail elsewhere herein, for example, in reference to FIGS. **7**A-**9**F. For example, pulleys, belts, and motors may be connected with extendible portions of the item handling head to cause some or all of it to extend or retract, as described elsewhere herein. Additionally, other implementations, such as robotic arms, multi-directional sliding platforms, or other devices are possible and contemplated.
[0163] FIG. **5**B illustrates the item handling mechanism **444** in a retracted position and holding an item **406**, for example, where the item handling mechanism **444** has retracted from the extended position shown in FIG. **5**A.
[0164] FIG. **5**C illustrates the vertical carriage **442** moved vertically downward to be at a height matching the mobile conveyor **454**, for example, to place an item on the conveyor **454**. The item handling mechanism **444** is also shown rotated toward the mobile conveyor **454** to place the item **406** thereon. The vertical carriage **442** and item handling mechanism **444** may repeat this process to add items to mobile conveyors. In some cases, where the mobile conveyor(s) **454** have no remaining capacity, the item handling mechanism **444** may hold an item **406** during transportation and may transfer the item **406** onto the conveyor **454**, for example at a transfer point.
[0165] FIGS. **6**A-**6**E illustrate various views of an ASRS body **412** and other portions of an ASRS vehicle **402**. For example, the ASRS body may be a lower portion of an ASRS vehicle **402**.
[0166] As illustrated in FIG. **6**A, an ASRS body **412** may include one or more frame members **432** that support and transport conveyors **452** and **454**, which may, in turn, hold one or more items **406**. The ASRS body **412** may have a generally rectangular shape in which the mobile conveyors **452** and **454** extend away from an end of the body **412** where the item handling mechanism **444** (not shown in FIG. **6**A) is mounted. Depending on the implementation, the transfer point may be at an opposing end to the item handling mechanism **444**.
[0167] As illustrated, an ASRS body **412** may include a frame and/or body that provides structure to the ASRS body **412**. The frame may be constructed of aluminum extrusions, stamped plates, or otherwise.
[0168] FIG. **6**B illustrates the example ASRS body **412** from a bottom-up perspective view. As shown in the example, the ASRS body **412** may include four wheels **608***a*, **608***b*, **608***c*, and **608***d* that provide vertical support to the body **412**, although other quantities and positions are possible. Depending on the implementation, one or more of the wheels **608** may be a drive wheel coupled with a motor that causes the ASRS body **412** to move. For instance, wheels **608***a* and **608***b* are illustrated being coupled with a driveshaft and drive motor while wheels **608***c* and **608***d* are free moving.
[0169] For instance, FIG. **6**C shows a cut away bottom perspective view of the ASRS body **412** where the drive wheels **608***a* and **608***b* are coupled together via a driveshaft, which is in turn coupled with a geared motor via a gear and chain (not shown).

[0170] Returning to FIG. **6**B, the ASRS body **412** may also include four guide wheels **610***a*, **610***b*, **610***c*, and **610***d*, which contact shelves or a guide rail to keep the ASRS body **412** aligned as it moves, although other implementations are possible. The guide wheels **610** may be mounted horizontally to contact sides of guide rails mounted to a floor. The guide rails may be bolted directly to a floor of the fulfillment center and/or may include locating markers that may be scanned by the ASRS vehicle **402**, although many other types of locating mechanisms are possible.
[0171] In some implementations, the ASRS body **412** may include brushes that contact the power rail(s) (which may be combined or separate from the guide rails, etc.) and provide power to the ASRS vehicle's **402** components. It should be noted that other means of providing power are possible, such as where the ASRS vehicle **402** includes a rechargeable battery or where it is continuously coupled with an external power source using wire(s) (e.g., in a wire chase and/or drag chain).
[0172] FIG. **6**D illustrates a bottom-up perspective view of a portion of an ASRS vehicle **402**. In the depicted illustration, a portion of the ASRS body **412**, including frame members are omitted to expose certain components. For example, as illustrated, a first and second belt (or chain, etc.) **632***a* and **632***b* extend upward into vertical support rails (only one rail is shown) **434**. The belts **632** may wrap around sprockets or gears, which are coupled together via a driveshaft **634**. Another gear on the driveshaft **634** may couple the driveshaft **634** to a motor **636** via a chain (not shown), and/or one or more other gears.
[0173] The vertical carriage **442** (not shown in FIG. **6**D) may be coupled with the belts **632***a* and **632***b*, so that when the belt(s) **632** move upward or downward, the vertical carriage **442** also move upward or downward. For instance, the motor **636** is mounted low inside the ASRS body **412** to lower the center of gravity while the belt position and geared linkage allows a full vertical range of motion of the vertical carriage **442** (e.g., where it may access a low shelf or conveyor).
[0174] In some implementations, a locking mechanism may also be included on the motor **636**, driveshaft **634**, belt(s) **632**, gears, a top pulley or sprocket, vertical carriage **442** to prevent the vertical carriage **442** from falling if power is lost to the motor **636**. For instance, the brake may include a ratcheting mechanism, automatically actuated friction brake, automatically inserted locking pin, motor shorting for increased resistance, or other mechanism to prevent the vertical carriage **442** from falling if there is a failure or electrical power is lost.
[0175] FIG. **6**E illustrates a top perspective view of a mast **416** where a top driveshaft **642** extends between vertical support rails **434**. The top driveshaft **642** may couple a gear, sprocket, or pulley on each end to keep belts **632** (only one belt **632***b* is visible in FIG. **6**E) in alignment and allow them to remain in a loop to facilitate vertical carriage **442** movement. Although not shown in FIG. **6**E, in some implementations, the vertical support rail(s) **434** may include a wire chase or drag chain that provides power to motors on the vertical carriage **442** and/or item handling mechanism **444**.
[0176] FIGS. **7**A-**7**F illustrate various views and configurations of a vertical carriage **442**. The vertical carriage **442** may carry an item handling mechanism **444** vertically along one or more vertical support rails **434**. The vertical carriage **442** may be coupled with a chain (and/or belt, etc.), as described above, which causes it to move vertically, although other mechanisms, such as drive wheels, pneumatics, linear actuators, or other mechanisms may raise or lower the vertical carriage **442**. It should also be noted that, depending on the implementation, the vertical carriage **442** may be integrated with or may be separate from the item handling mechanism **444**.
[0177] In the illustrated example, the vertical carriage **442** may include frame member(s) **702** that extend vertically partially along the vertical support rail(s) **434** to provide rigidity and support to the vertical carriage **442**. Frame member(s) **702** may be held apart by other structures or cross frames. In some implementations, the frame member(s) **702** may include or couple with a track and/or various wheels or bearings **704**, which may be on the front, inside, back, and/or outside of the vertical support rail(s) **434**. For instance, the bearings **704** keep the vertical carriage **442** aligned with the vertical support rail(s) **434** while also allowing it to easily slide upward or downward. The

bearings **704** may be spaced apart (e.g., vertically) to prevent the frame member(s) **702** from binding on the vertical support rail(s) **434**. The bearings **704** may have various orientations, for example, some bearings **704** may be on an inside of the vertical support rail(s) **434** (or track thereof) perpendicular to those shown in FIG. **7**A.

[0178] In some implementations, the vertical carriage **442** may include one or more adjustment mechanisms **706** that allows it to be tightened, loosened, its angle to be moved, or other adjustments to be made.

[0179] The vertical carriage **442** may include a platform **708** that extends horizontally from the frame member(s) **702** and away from the vertical support rail(s) **434**. The platform **708** may include frames, mounting plates, reinforcing structures, and other devices that allow it to securely support an item handling mechanism **444**. For example, the frame member(s) **702** may be shaped to extend to the platform **708** to buttress its strength. Other mechanisms, such as wires, buttresses, etc., may also be used to increase strength depending on loads being lifted in a particular application.

[0180] FIG. **7**D illustrates the platform **708** of a vertical carriage **442**. As shown, a large gear **710** or sprocket may be mounted horizontally to the platform **708** with a recess or groove in the center, which may hold an item handling mechanism **444** (not shown) and allow it to turn about an axis formed by the center of the gear **710**. The gear **710** may include radially or axially oriented teeth that interact with one or more external mechanisms to allow the item handling mechanism **444** to rotate relative to the platform **708**. In the depicted example, the gear **710** is rigidly connected (e.g., via bolts or other fasteners) with the platform **708** so that the gear does not rotate relative to the platform. In other implementations, the gear may rotate to cause the item handling mechanism **444** to rotate.

[0181] Returning to FIG. **7**A, an example rotatable platform **712** is shown with a pivot point at the center of the gear **710**. The rotatable platform **712** may form a bottom or may be coupled with a bottom surface of the item handling mechanism **444**, as shown elsewhere herein, but it is shown in FIG. **7**A without the item handling mechanism **444** for illustration purposes. In the depicted example, a vertically mounted motor **714** may be mounted to the rotatable platform **712**, although it may be mounted in various positions or orientations. The motor **714** may include a gear that interacts with a belt **716** or chain extending around the gear **710**, so that when the motor **714** rotates the gear, the rotatable platform **712** rotates about the gear **710** and relative to the platform **708**. In this configuration, the belt **716** may remain stationary on some of the teeth of the gear **710**. For instance, the platform **708** and/or **714** may include protrusions or stops that prevent the platform **712** from rotating more than a defined angle (e.g., 90, 180, or 270 degrees), although other implementations are possible.

[0182] In some implementations, the gear of the motor **714** may interact directly with the gear **710** or the motor **714** may be mounted horizontally or may be coupled instead with the platform **708**.

[0183] In some implementations, the rotatable platform **712** extends away from an axis of rotation and the motor **714** interacts with the gear **710** via a belt **716**, which allows the motor **714** to be easily accessible and mounted at a side of the item handling mechanism **444** while also avoiding potentially contacting the platform **708** or other components of the vertical carriage **442** or item handling mechanism **444**. Thus, the vertical range of motion and horizontal range of motion are improved by this configuration.

[0184] FIG. **7**B illustrates another view of the rotatable platform **712** mounted to the platform **708** via the center of the gear **710**. As illustrated, the motor **714** has rotated the belt **716**, which has caused the rotatable platform **712** to rotate ninety degrees, which would, correspondingly, rotate other components of the item handling mechanism **444**, as described elsewhere herein.

[0185] FIG. **7**C illustrates the belt **716** extending around the gear **710** with the rotatable platform **712** omitted. As shown, the belt **716** may loop around a second gear **722** and along a tensioning gear/pulley **724** that provides tension to the belt **716**. The second gear **722** may be coupled with the motor **714** (not shown in FIG. **7**C) to interact with the belt **716**. The tensioning pulley **724** may be

adjustable and/or spring loaded to increase or decrease tension in the belt **716**.
[0186] FIG. **7**C also illustrates a center portion **726** of an item handling mechanism **444**, which may extend into the center of the gear **710**, so that the item handling mechanism **444** may rotate about the gear **710**. The center portion **726** may be bolted to the rotatable platform **712**, for instance, and may include ball, liquid, or other bearings that decrease friction during rotation.
[0187] The platform **708** in FIG. **7**C also illustrates one or more stops **728** protruding from the platform **708**, which may interact with corresponding structures on the item handling mechanism **444** to prevent it from rotating beyond a defined point and/or locate the head **444** rotationally, although other mechanisms are possible and contemplated, such as different stops, sensors/triggers, etc.
[0188] FIGS. **7**E and **7**F illustrate bottom-up views of the platform **708** of an example vertical carriage **442** coupled with an example item handling mechanism **444**. FIG. **7**E illustrates the item handling mechanism **444** in a first orientation (e.g., where it would extend perpendicularly to the direction of motion of the ASRS vehicle **402**) and FIG. **7**F illustrates the item handling mechanism **444** in a second orientation (e.g., where it would extend parallel with the direction of motion of the ASRS vehicle **402**). As shown, the rotatable platform **712** may rotate relative to the platform **708** of the vertical carriage **442**.
[0189] In some implementations, as depicted in FIG. **7**F, the item handling mechanism **444** may be oriented, so that it may extend (e.g., via extendable members or arms thereof) between the vertical support rails **434** to access a mobile conveyor (not shown).
[0190] FIGS. **8**A-**8**H illustrate various views of an example implementation of an item handling mechanism **444**, which may be coupled with a vertical carriage **442**.
[0191] FIG. **8**A illustrates a right (when facing an item handling mechanism **444**) perspective view of an example implementation of an item handling head **414**, such as an item handling mechanism **444** held by a vertical carriage **442** and holding an item **406**, which may be a tote or mobile storage unit. FIG. **8**B illustrates a left perspective view of an example implementation of an item handling mechanism **444** held by a vertical carriage **442** and holding an item **406**. FIG. **8**C illustrates a back perspective view of an example implementation of an item handling mechanism **444** held by a vertical carriage **442** and holding an item **406**.
[0192] FIGS. **8**A, **8**B, and **8**C illustrate various views of an item handling mechanism **444** and a vertical carriage **442** in a first orientation, for example, where the item handling mechanism **444** is rotated to extend into an external shelf to the side of an ASRS vehicle **402** (not shown). FIG. **8**D also illustrates a side view of an item handling mechanism **444** and vertical carriage **442** and FIG. **8**E illustrates a top-down view in this sideways orientation, but the item handling mechanism **444** is not holding an item.
[0193] As illustrated, an item handling mechanism **444** may include one or more internal side members **802***a* and **802***b*, which may be coupled together using one or more cross braces **804**. The internal side members **802** may also be coupled with a floor or other support that may support an item. The internal side members **802** and/or associated structures may represent an example implementation of one or more extendable arm(s). For instance, the internal side members **802** may telescope outward from a base **808** of the item handling mechanism **444**. A base **808** may couple with a rotatable platform **712** (not visible), so that the external sides **806** and the internal sides **802** extend therefrom, as illustrated and described elsewhere herein. In some implementations, the internal side members **802** may be slidably coupled with one or more external side members **806***a* and **806***b* via belts, linear rails, or other structures, as described in further detail in reference to FIGS. **9**A-**9**F below.
[0194] The internal side members **802** may be vertical plates or other structures frames that extend outward to interact with an item. In some instances, the internal side members **802** may include or hold one or more grasping mechanisms. For instance, a grasping mechanism may include a suction cup, grasping clamp, or fingers **812**, such are illustrated in the examples of FIGS. **8**A-**8**D, or other

device. For instance, as shown in FIG. **8**D, the fingers **812***a* and **812***b* may pivot between a vertical, open position and a horizontal closed (e.g., actuated or grasping) position. FIG. **8**D shows the fingers **812***a* and **812***b* in a horizontal closed position that allows them to keep an item with the interior side members **802**, thereby pulling it off a shelf. Depending on the implementation, the fingers **812** may be coupled with a motor **814** that slides with (e.g., coupled with a cross brace **804**) the internal side members **802** and actuates the fingers **812**. For instance, one or more driveshafts and gears couple the motor **814** with one or more of the fingers **812**. Advantageously, the fingers **812** are reliable, slim, and may travel with telescoping components of the item handling mechanism **444**.

[0195] In some implementations, as shown in FIG. **8**D, one or more pushing members **816** may be coupled with a cross support **804** and/or internal side members **802** and used to contact a surface of an item and push it as the internal side members **802** are extended.

[0196] FIGS. **8**F, **8**G, and **8**H illustrate the item handling mechanism **444** rotated relative to the vertical carriage **442**, for example, so that it faces the vertical support rail(s) **434** and/or may access a mobile conveyor.

[0197] FIG. **8**F illustrates a perspective view of an example item handling mechanism **444** coupled with an example vertical carriage **442**. As shown, a rotating platform **712** coupled with a base **808**, has rotated the base and other components of the item handling mechanism **444**. As illustrated, the motor **714** may extend through the rotating platform **712** to interact with a belt **716** and may be coupled with the platform **712** vertically, so that it is positioned to a side of an external side member **806**. Accordingly, because the motor **714** may rotate with the rest of the item handling mechanism **444**, it is accessible while not impeding its movement.

[0198] For example, FIG. **8**G illustrates a perspective view of the vertical carriage **442** mounted to a mast **416** and positioned at a height to match a top mobile conveyor **454** to place items thereon or retrieve items therefrom. FIG. **8**H also shows a perspective view of the vertical carriage **442** mounted to vertical support rails **434** and carrying the item handling mechanism **444** in a rotation toward the vertical support rails **434***a* and **434***b*, so that the item handling mechanism **444** may extend between the vertical support rails **434***a* and **434***b* to place an item on **406** on a mobile conveyor (not shown in FIG. **8**H).

[0199] FIGS. **9**A-**9**F illustrate various views of an item handling mechanism **444** in a retracted and extended position as well as various components that facilitate its extension/telescoping functionality. Although other components and features are possible, the illustrated examples provide stability and significant range of motion to allow the item handling mechanism **444** to access a back shelf (and/or front shelf) in a double-deep shelving/storage arrangement.

[0200] FIG. **9**A illustrates a perspective view of an example item handling mechanism **444** holding an item **406** in a retracted state. As shown, the external side member(s) **806** and internal side member(s) **802** are retracted to be adjacent to/above a base **808**.

[0201] FIGS. **9**B and **9**C illustrate a top perspective view and bottom perspective view, respectively, of the item handling mechanism **444** in a fully extended position. As illustrated, the base **808**, which may include one or more frames, plates, wire chases, or other devices is illustrated in a non-extended position because it may be attached with the rotatable platform **712**.

[0202] The external side member(s) **806** may be extended relative to the base **808**. For instance, the external side member(s) **806** may be coupled with the base **808** via one or more linear rails **906** along which they may slide to allow the external side member(s) **806** to extend outward. In some implementations, a motor **902** may be coupled with the external side member(s) **806** and move with the member(s) **806**. For example, the motor **902** may turn one or more belts **904** (e.g., coupled together using a driveshaft) that extend along the external side member(s) **806** and couple with both the base **808** and the internal side member(s) **802**. For instance, a base **808** may be coupled on a bottom side of a belt **904** while an internal side member **802** may be coupled on a top side of the belt **904**, so that when the belt is rotated in a first direction, they move apart, and when the belt **904**

is rotated in the opposite direction, they move toward one another.
[0203] For example, the internal side member(s) **802** may be coupled with the external side member(s) **806** via one or more second linear rails **908**. The internal side member(s) **802** may be coupled with the belt **904**, as noted above and in further detail below to cause it to extend or retract as the belt **904** is rotated by the motor **902**.
[0204] FIG. **9**D illustrated an end-on view of an extended item handling mechanism **444**. As shown, internal side members **802***a* and **802***b* are shown in a fully extended position. Cross supports **804***a*, **804***b*, and **804***c* are illustrated coupling the side members **802***a* and **802***b* together, supporting a motor **814** and one or more pushing member **816**. In the illustrated implementation, the motor **814** may move with the internal side members **802** into an extended position to allow the motor **814** to drive the fingers **812***a* and **812***b*, for example, via one or more gears and/or driveshafts (e.g., extending horizontally and then longitudinally along the side members **802**).
[0205] As shown, the base **808** may house various components, such as wire chases and drag chains that allow the motors **814** and **902** to remain plugged in while the item handling mechanism **444** moves between a retracted and extended position.
[0206] FIG. **9**E illustrates a perspective view of an example item handling mechanism **444** in an extended position with various components hidden to display example action of the belt **904** and other components. For instance, a motor **902** is shown coupled via a set of gears and a belt/chain to a driveshaft **932**, which allows the motor **902** to drive multiple belts **904***a* and **904***b*, so that the telescoping mechanism is less likely to bind or become out of alignment. The motor **902** may be attached to a cross support **804***d* that couples the external side members **806** together, so that it moves with the external side members **806** along with the belt(s) **904** and other hardware, as shown in the example.
[0207] Each of the belts **904***a* and **904***b* may include a gear, a tensioning pulley, and an end pulley, so that the motor **902** may rotate both belts **904***a* and **904***b* together. It should be noted that although the term belt or chain are used herein, they may be interchanged or replaced with similar mechanisms, such as a driveshaft, worm gear, hydraulics, or otherwise.
[0208] In the illustrated example, the base **808** may be coupled with the belt(s) **904** via one or more belt clamps **936** to cause the belt(s) **904** to move relative to the base **808**. Similarly, the internal side member(s) **802** may be coupled with the belt(s) **904** via one or more second belt clamps **938**.
[0209] FIG. **9**F illustrates a perspective view of an example item handling mechanism **444** in a retracted position with various components hidden to display an example configuration of the belt **904** and other components. As shown, the belt **904***a* has rotated to pull the side members **802** and **806** backward, as described in further detail above. When in a retracted state, the interior side member(s) **802** and external side member(s) **806** may be nested next to and/or above one another and the base **808** to allow the item handling mechanism **444** to fit in a compact space.
[0210] It should be noted that these configurations, for example, of the item handling mechanism **444** and/or vertical carriage **442** are provided by way of examples and that configurations are possible and contemplated herein. For instance, vertical carriage may travel up/down four posts and may include one or more staging shelves or conveyors (e.g., traveling with the vertical carriage) to which items may be placed by an item handling head or other mechanism to allow additional items to be carried or staged while shuffling from deeper shelves. Similarly, other mechanisms for rotating the item handling head or extending it/its arms may alternatively be used.
[0211] FIG. **10** is a block diagram illustrating an example computing system **1000**. The example computing system **1000** may correspond to a WES **102**, a WMS **104**, a dispatch system **106**, a human interface system **108**, equipment controller(s) **110**, ASRS vehicle controller(s) **142**, REX server **118**, a client device, a computing device of a picking station, a computing device of a robotic arm, a computing device/controller of an AGV or ASRS, or other component of the system **100**, for example.
[0212] The code and routines **1012** may include computer logic executable by the processor **1004**

on a computing system **1000** to provide for the functionality described in reference to one or more of the components of the system **100**. For instance, in some implementations, the code and routines may include one or more of the components of the WES **102**, equipment controller(s) **110**, ASRS vehicle controller **142**, or other system(s) for controlling the ASRS and/or components thereof.
[0213] As depicted, the computing system **1000** may include a processor **1004**, a memory **1006**, a communication unit **1002**, an output device **1016**, an input device **1014**, and database(s) **1008**, which may be communicatively coupled by a communication bus **1010**. The computing system **1000** depicted in FIG. **10** is provided by way of example and it should be understood that it may take other forms and include additional or fewer components without departing from the scope of the present disclosure. For instance, various components of the computing devices may be coupled for communication using a variety of communication protocols and/or technologies including, for instance, communication buses, software communication mechanisms, computer networks, etc. While not shown, the computing system **1000** may include various operating systems, sensors, additional processors, and other physical configurations. Although, for purposes of clarity, FIG. **10** only shows a single processor **1004**, memory **1006**, communication unit **1002**, etc., it should be understood that the computing system **1000** may include a plurality of one or more of these components.
[0214] The processor **1004** may execute software instructions by performing various input, logical, and/or mathematical operations. The processor **1004** may have various computing architectures to process data signals including, for example, a complex instruction set computer (CISC) architecture, a reduced instruction set computer (RISC) architecture, and/or an architecture implementing a combination of instruction sets. The processor **1004** may be physical and/or virtual, and it may include a single core or plurality of processing units and/or cores. In some implementations, the processor **1004** may be capable of generating and providing electronic display signals to a display device, supporting the display of images, capturing and transmitting images, performing complex tasks including various types of feature extraction and sampling, etc. In some implementations, the processor **1004** may be coupled to the memory **1006** via the bus **1010** to access data and instructions therefrom and store data therein. The bus **1010** may couple the processor **1004** to the other components of the computing system **1000** including, for example, the memory **1006**, the communication unit **1002**, the input device **1014**, the output device **1016**, and the database(s) **1008**.
[0215] The memory **1006** may store and provide access to data to the other components of the computing system **1000**. The memory **1006** may be included in a single computing device or a plurality of computing devices. In some implementations, the memory **1006** may store instructions and/or data that may be executed by the processor **1004**. For example, the memory **1006** may store the code and routines **1012**. The memory **1006** is also capable of storing other instructions and data, including, for example, an operating system, hardware drivers, other software applications, databases, etc. The memory **1006** may be coupled to the bus **1010** for communication with the processor **1004** and the other components of computing system **1000**.
[0216] The memory **1006** may include a non-transitory computer-usable (e.g., readable, writeable, etc.) medium, which can be any non-transitory apparatus or device that can contain, store, communicate, propagate or transport instructions, data, computer programs, software, code, routines, etc., for processing by or in connection with the processor **1004**. In some implementations, the memory **1006** may include one or more of volatile memory and non-volatile memory (e.g., RAM, ROM, hard disk, optical disk, etc.). It should be understood that the memory **1006** may be a single device or may include multiple types of devices and configurations.
[0217] The bus **1010** can include a communication bus for transferring data between components of a computing device or between computing devices, a network bus system including a network or portions thereof, a processor mesh, a combination thereof, etc. The software communication mechanism can include and/or facilitate, for example, inter-method communication, local function

or procedure calls, remote procedure calls, an object broker (e.g., CORBA), direct socket communication (e.g., TCP/IP sockets) among software modules, UDP broadcasts and receipts, HTTP connections, etc. Further, any or all of the communication could be secure (e.g., SSH, HTTPS, etc.).

[0218] The communication unit **1002** may include one or more interface devices (I/F) for wired and wireless connectivity among the components of the system **100**. For instance, the communication unit **1002** may include various types of connectivity and interface options. The communication unit **1002** may be coupled to the other components of the computing system **1000** via the bus **1010**. The communication unit **1002** may be electronically communicatively coupled to a network (e.g., wiredly, wirelessly, etc.). In some implementations, the communication unit **1002** can link the processor **1004** to a network, which may in turn be coupled to other processing systems. The communication unit **1002** can provide other connections to a network and to other entities of the system **100** using various standard communication protocols.

[0219] The input device **1014** may include any device for inputting information into the computing system **1000**. In some implementations, the input device **1014** may include one or more peripheral devices. For example, the input device **1014** may include a keyboard, a pointing device, microphone, an image/video capture device (e.g., camera), a touch-screen display integrated with the output device **1016**, optical scanner, barcode reader, QR™ code reader, RFID (radio-frequency identification) tag reader, etc. In some implementations, the input device **1014** may receive sensor data from one or more sensors.

[0220] The output device **1016** may be any device capable of outputting information from the computing system **1000**. The output device **1016** may include one or more of a display (LCD, OLED, etc.), a printer, a **3**D printer, a haptic device, audio reproduction device, touch-screen display, etc. In some implementations, the output device is a display which may display electronic images and data output by the computing system **1000** for presentation to a user, such as a picker or associate in the order fulfillment center. In some implementations, the computing system **1000** may include a graphics adapter (not shown) for rendering and outputting the images and data for presentation on output device **1016**. The graphics adapter (not shown) may be a separate processing device including a separate processor and memory (not shown) or may be integrated with the processor **1004** and memory **1006**. In some implementations, the output device **1016** may provide signals to control various motors, actuators, or other devices.

[0221] The database(s) are information source(s) for storing and providing access to data. The data stored by the database(s) **1008** may be organized and queried using various criteria including any type of data stored by them, such as the data in the data store **120** and other data discussed herein. The database(s) **1008** may include file systems, data tables, documents, databases, or other organized collections of data. Examples of the types of data stored by the database(s) **1008** may include the data described herein, for example, in reference to the data store **120**.

[0222] The database(s) **1008** may be included in the computing system **1000** or in another computing system and/or storage system distinct from but coupled to or accessible by the computing system **1000**. The database(s) **1008** can include one or more non-transitory computer-readable mediums for storing the data. In some implementations, the database(s) **1008** may be incorporated with the memory **1006** or may be distinct therefrom. In some implementations, the database(s) **1008** may store data associated with a database management system (DBMS) operable on the computing system **1000**. For example, the DBMS could include a structured query language (SQL) DBMS, a NoSQL DMBS, various combinations thereof, etc. In some instances, the DBMS may store data in multi-dimensional tables comprised of rows and columns, and manipulate, e.g., insert, query, update and/or delete, rows of data using programmatic operations.

[0223] It should be noted that the components described herein may be further delineated or changed without departing from the techniques described herein. For example, the processes described throughout this disclosure may be performed by fewer, additional, or different

components.
[0224] It should be understood that the methods described herein are provided by way of example, and that variations and combinations of these methods, as well as other methods, are contemplated. For example, in some implementations, at least a portion of one or more of the methods represent various segments of one or more larger methods and may be concatenated or various steps of these methods may be combined to produce other methods which are encompassed by the present disclosure. Additionally, it should be understood that various operations in the methods are iterative, and thus repeated as many times as necessary generate the results described herein. Further the ordering of the operations in the methods is provided by way of example and it should be understood that various operations may occur earlier and/or later in the method without departing from the scope thereof.
[0225] In the above description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it should be understood that the technology described herein can be practiced without these specific details in various cases. Further, various systems, devices, and structures are shown in block diagram form in order to avoid obscuring the description. For instance, various implementations are described as having particular hardware, software, and user interfaces. However, the present disclosure applies to any type of computing device that can receive data and commands, and to any peripheral devices providing services.
[0226] In some instances, various implementations may be presented herein in terms of algorithms and symbolic representations of operations on data bits within a computer memory. An algorithm is here, and generally, conceived to be a self-consistent set of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.
[0227] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout this disclosure, discussions utilizing terms such as “processing,” “computing,” “calculating,” “determining,” “displaying,” or the like, refer to the action and methods of a computer system that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.
[0228] A data processing system suitable for storing and/or executing program code, such as the computing system and/or devices discussed herein, may include at least one processor coupled directly or indirectly to memory elements through a system bus. The memory elements can include local memory employed during actual execution of the program code, bulk storage, and cache memories that provide temporary storage of at least some program code in order to reduce the number of times code must be retrieved from bulk storage during execution. Input or I/O devices can be coupled to the system either directly or through intervening I/O controllers. The data processing system may include an apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer.
[0229] The foregoing description has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the specification to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the disclosure be limited not by this detailed description, but rather by

the claims of this application. As will be understood by those familiar with the art, the specification may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Likewise, the particular naming and division of the modules, routines, features, attributes, methodologies and other aspects may not be mandatory or significant, and the mechanisms that implement the specification or its features may have different names, divisions, and/or formats.

[0230] Furthermore, the modules, routines, features, attributes, methodologies, and other aspects of the disclosure can be implemented as software, hardware, firmware, or any combination of the foregoing. The technology can also take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by or in connection with a computer or any instruction execution system. Wherever a component, an example of which is a module or engine, of the specification is implemented as software, the component can be implemented as a standalone program, as part of a larger program, as a plurality of separate programs, as a statically or dynamically linked library, as a kernel loadable module, as firmware, as resident software, as microcode, as a device driver, and/or in every and any other way known now or in the future. Additionally, the disclosure is in no way limited to implementation in any specific programming language, or for any specific operating system or environment. Accordingly, the disclosure is intended to be illustrative, but not limiting, of the scope of the subject matter set forth in the following claims.

## Claims

**1**. A system comprising: a mobile vehicle body including a first mobile conveyor that moves with the mobile vehicle body; an item handling mechanism coupled with the mobile vehicle body and including one or more extendable members that move between a retracted position and an extended position to retrieve one or more items from one or more external shelves and move the one or more items onto the first mobile conveyor; and one or more driving wheels coupled with a drive motor that cause the mobile vehicle body, mobile conveyor, and the item handling mechanism to move in an aisle.

**2**. The system of claim 1, wherein the mobile vehicle body includes: one or more guide wheels oriented horizontally to contact one or more external guide rails extending down a length of the aisle, the one or more external guide rails aligning the mobile vehicle body in the aisle.

**3**. The system of claim 1, wherein the system further comprises: one or more vertical support rails coupled with and extending vertically from the mobile vehicle body; a vertical carriage coupled with and moving vertically along the one or more vertical support rails, the vertical carriage holding the item handling mechanism; and a second motor mounted to the mobile vehicle body and adapted to drive a belt extending along the one or more vertical support rails, the vertical carriage coupled with the belt.

**4**. The system of claim 1, wherein the mobile vehicle body includes: two or more mobile conveyors coupled with a frame of the mobile vehicle body, each of the two or more mobile conveyors being accessible to the item handling mechanism, the two or more mobile conveyors including the first mobile conveyor and a second mobile conveyor, the first mobile conveyor being located vertically above the second mobile conveyor.

**5**. The system of claim 4, wherein the item handling mechanism is configured to remove an item from the second mobile conveyor and place the item on the first mobile conveyor.

**6**. The system of claim 1, wherein: the one or more extendable members include one or more grasping fingers at an end of the one or more extendable members, the one or more grasping fingers pivoting between a vertical position and a horizontal position, the horizontal position providing contact with the one or more items handled by the item handling mechanism, the contact pulling the one or more items from the one or more external shelves when the item handling

mechanism moves into the retracted position.
**7**. The system of claim 6, wherein: the one or more extendable members include one or more linear rails supporting one or more telescoping side members, a belt, and a motor engaging with the belt, the one or more telescoping side members being coupled with the belt so that when the motor rotates the belt, the belt causes the one or more telescoping side members to extend along the one or more linear rails and move the item handling mechanism into the extended position.
**8**. The system of claim 1, further comprising: a vertical carriage moving vertically along a vertical support rail, the vertical support rail extending vertically upward from the mobile vehicle body, the vertical carriage including a horizontal platform extending horizontally away from the vertical support rail, the horizontal platform providing vertical support to the item handling mechanism.
**9**. The system of claim 8, further comprising: a first horizontal gear coupled with the horizontal platform and mounted in a horizontal orientation, the item handling mechanism including a motor that engages with the first horizontal gear to cause the item handling mechanism to rotate relative to the first horizontal gear, the rotation of the item handling mechanism allowing the one or more extendable members to extend in along two or more different directions.
**10**. The system of claim 9, further comprising: wherein a second horizontal gear is mounted to the motor and interacts with a belt, the belt extending around the first horizontal gear and the second horizontal gear, the motor being coupled with and rotating with the item handling mechanism, the motor causing the item handling mechanism to rotate relative to the horizontal platform when the motor rotates the second horizontal gear, the first horizontal gear being rigidly mounted to the horizontal platform.
**11**. The system of claim 1, wherein: the one or more extendable members of the item handling mechanism have a reach length configured to extend into one or more external storage shelves, the one or more external storage shelves including a front storage shelf and a back storage shelf, the one or more extendable members being adapted to access both the front storage shelf and the back storage shelf, the back storage shelf including the one or more external shelves from which the one or more items are retrieved by the item handling mechanism.
**12**. The system of claim 1, wherein: the one or more driving wheels are configured to move the mobile vehicle body to an unloading zone at which the first mobile conveyor rotates to transfer the one or more items off from the first mobile conveyor.
**13**. A method comprising: retrieving a first item from a first location on one or more external storage shelves using an item handling mechanism coupled with a mobile vehicle; transferring the first item from the item handling mechanism to a first mobile conveyor coupled with the mobile vehicle; navigating the mobile vehicle to a transfer location; and transferring the first item from the first mobile conveyor including rotating the first mobile conveyor at the transfer location.
**14**. The method of claim 13, further comprising: retrieving a second item from a second location on the one or more external storage shelves using the item handling mechanism; and transferring the second item from the item handling mechanism to the first mobile conveyor, the first mobile conveyor holding the first item and the second item simultaneously.
**15**. The method of claim 14, further comprising: transferring the second item with the first item from the first mobile conveyor including rotating the first mobile conveyor at the transfer location.
**16**. The method of claim 13, further comprising: transferring a second item from a second mobile conveyor coupled with the mobile vehicle to the first mobile conveyor using the item handling mechanism.
**17**. The method of claim 16, wherein transferring the second item from the second mobile conveyor to the first mobile conveyor includes: moving the item handling mechanism to a first height of the second mobile conveyor; rotating the second mobile conveyor to position the second item within reach of the item handling mechanism; extending the item handling mechanism to interact with the second item on the second mobile conveyor; retracting the item handling mechanism holding the second item; moving the item handling mechanism to a second height of

the first mobile conveyor; and extending the item handling mechanism to move the second item onto the first mobile conveyor.

**18**. The method of claim 13, further comprising: retrieving a second item from a second location on the one or more external storage shelves using the item handling mechanism; and transferring the second item from the item handling mechanism to a second mobile conveyor coupled with the mobile vehicle.

**19**. The method of claim 18, wherein: the second item is retrieved from a front storage shelf and the first item is retrieved from a back storage shelf of the one or more external storage shelves; the first item is an assigned item for retrieval by the item handling mechanism and the second item is an unassigned item; and the second item is retrieved by the item handling mechanism prior to the first item being retrieved by the item handling mechanism.

**20**. The method of claim 19, further comprising: retrieving the second item from the second mobile conveyor using the item handling mechanism; moving the item handling mechanism holding the second item to a height of the front storage shelf; rotating the item handling mechanism to face the item handling mechanism toward the front storage shelf; and extending the item handling mechanism and the second item to place the second item on the front storage shelf.