White Paper

Robotic Order Picking and Packing Concepts

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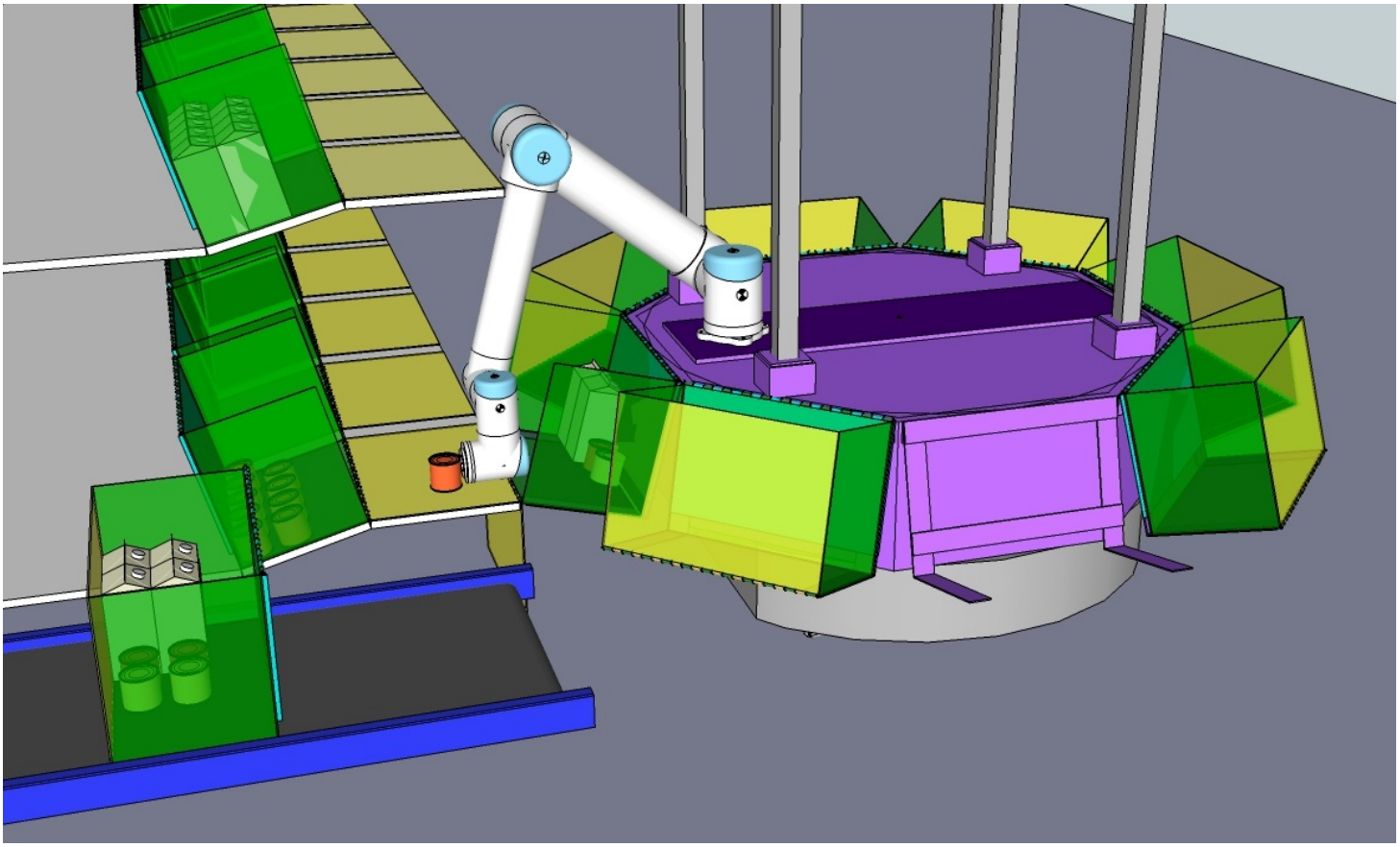

Patent Pending

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Executive Summary

An innovative product storage and automation system has been designed to address the changing needs for robotic order picking and packing found in today's warehouses. A key element is the addition of a container's folding side wall that allows for easier transfer of items from the supply container into the customer's delivery container. The folding side wall allows easier egress for both humans and automation when loading and unloading these containers. Both the supply container and the delivery container can be a mix of a novel reusable totes and custom designed corrugated cases.

A robot arm can then glide the product from the supply container to the delivery container without having to perform the traditional lifting and packing motion. The requirements for the robotic picking vision system are also significantly more straightforward than traditional top only bin picking. Also within this document is a description of one embodiment of the many potential automation options where the system moves a collection of delivery containers near to the racks of supply containers holding multiples of the same product.

1.0] Container Design

The robotic order picking described here does not use traditional standard shipping totes or RSC corrugated cases with its top flaps open or removed. One of the sides of these containers can be opened by folding a side wall to gain access. The "up – over – down" motion of manual packing is replaced by a sliding or flowing of the items in a more efficient manner. And equally as important is the access to the supply container's contents for robotic vision systems. Traditional robotic item bin picking has not changed significantly since the first experiments in the mid 1970's. Recently has stereo vision been implemented but it is still hampered by top-only access to the container.

The innovative approach presented here can use a mix of several different container types:

- A novel plastic tote with a folding side wall and single piece folding top cover
- A similar plastic supply tote transporting a RSC corrugated case with both its top and one side removed
- A novel corrugated cardboard case with a folding side wall and wrap-around top lid
- A combination of novel plastic tote transporting a novel corrugated cardboard case with a folding side wall and wrap-around top lid

Each type will now be discussed in detail.

1.1] Folding Side Wall Tote Design

The standard tote used today by many stores and their Distribution Centers (DC's) as a reusable container to ship a collection of items. These items are usually either an individual product or a limited number grouped together (i.e. six pack of soda). The store's staff restocks the items onto their specific shelf to resupply what the previous customer recently purchased. Most totes have a 2 piece top lid with an interlocking portion to offer reasonable support for several totes on top of the lid. These 2 piece lids can pinch fingers of even experienced stock people and present a barrier to customers if these totes are used for home delivery.

The Folding Side Wall Tote (FSW Tote) is a novel variation of the standard tote by adding 2 specific new features. Figure 1 shows the side view of the FSW Tote, with the folding side wall of the tote removed for clarity.

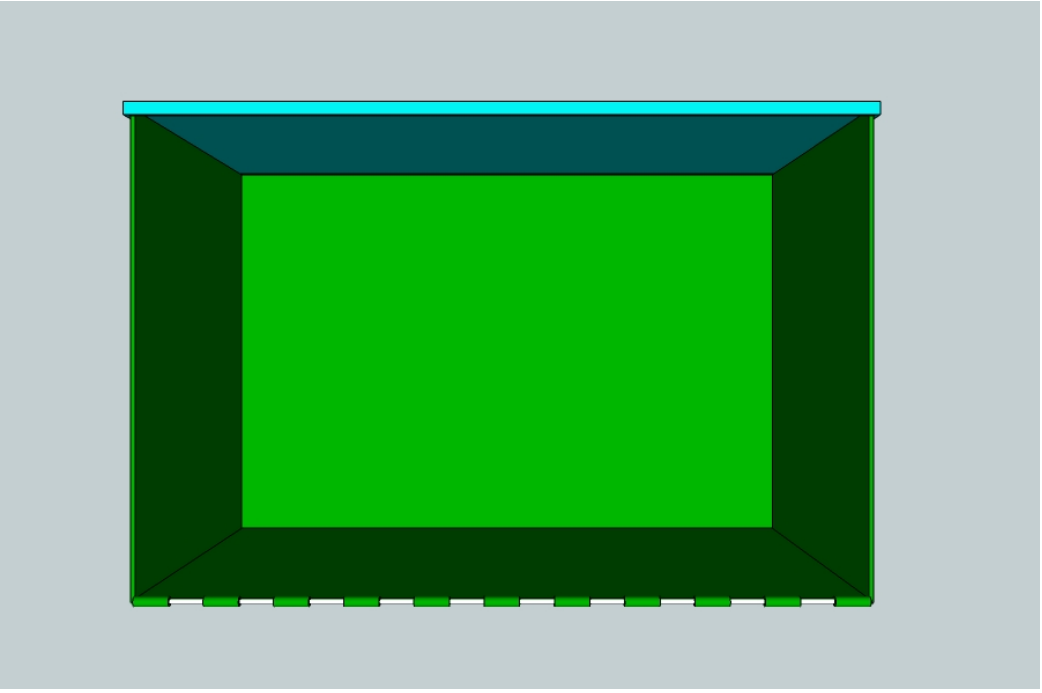

Figure 1 The Folding Side Wall Tote (FSW Tote) – Side View with Folding Side Removed

The yellow folding side wall pivots at the bottom of the tote and the blue lid has lip to hold the folding side wall in place for transit. The yellow folding side wall may also have several magnets and the interface to the tote body have several metal plates. This will allow the folding side wall to remain in place when the lid has been lifted. The tote has handle on each end but they are not shown in these figures. The totes are design to hold a variety of consumer products (Figures 2 and 3) for transit from the local store or DC for delivery to homes. These FSW Totes can also be used as supply containers for transportation from the manufacturer to the DC, or from one DC to another.

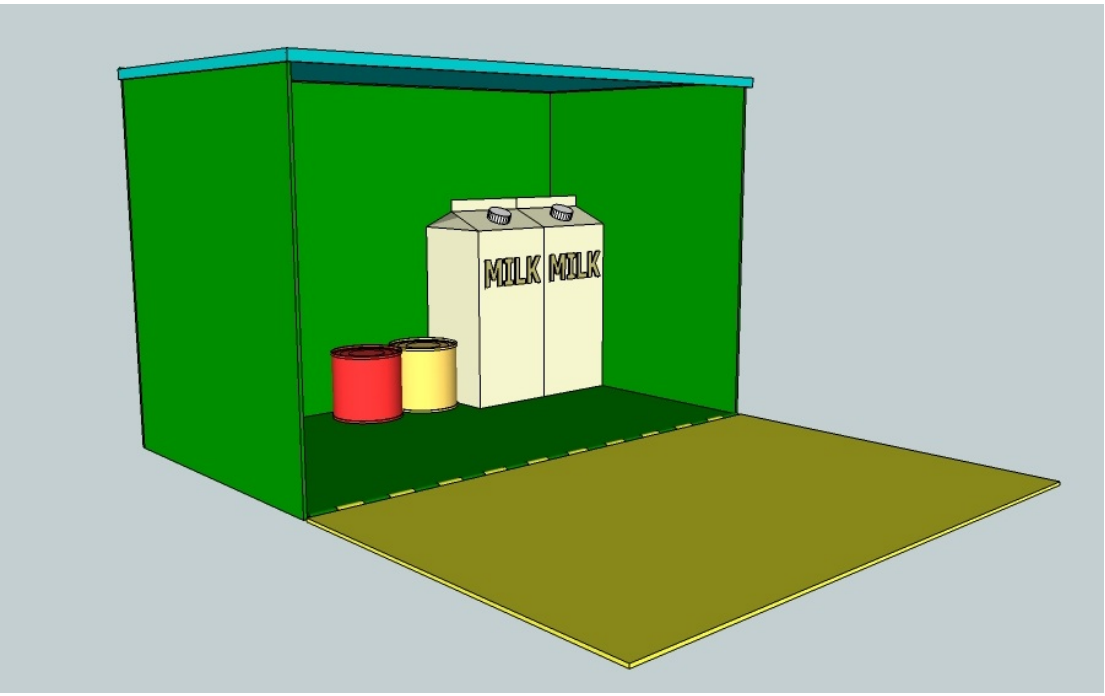

Figure 2 The FSW Tote Carrying Products – With Side Wall Folded Down

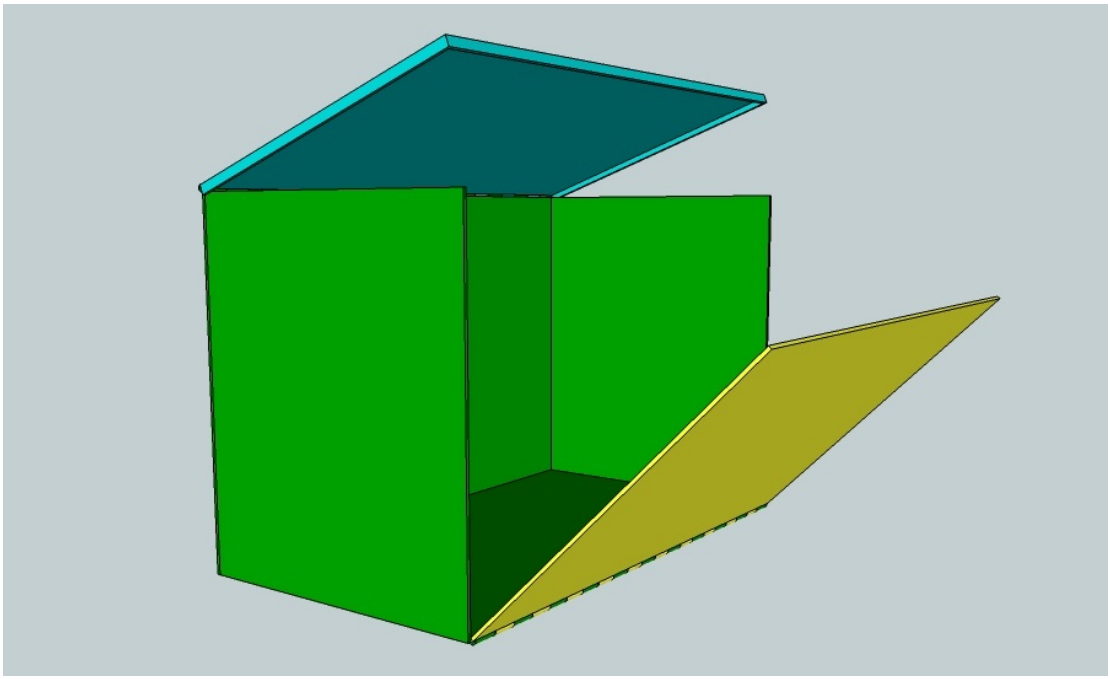

Figure 3 The FSW Tote Lid Folding Back and Side Wall Folding Down

The FSW Tote also allows for better use at home by the ability for the side wall to lay on a table top or to drop over a countertop edge (Figure 4).

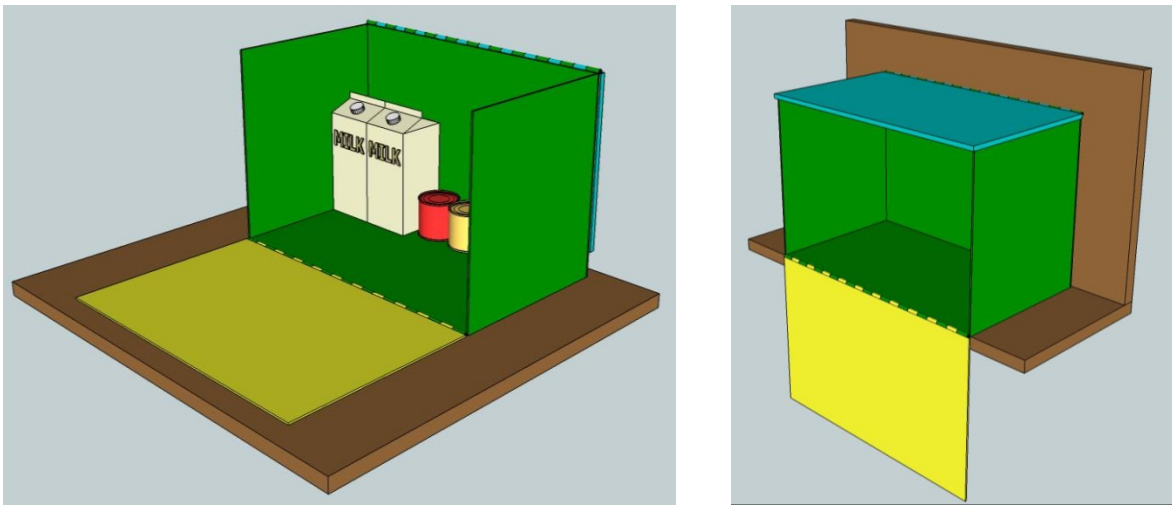

Figure 4 The FSW Tote Side Wall Adapts to Better Access at Home

1.2] Tote Usage and the Picking/Loading Process

One method of using the FSW Tote in all modes within the DC is to keep the tote tilted at all times. This helps to keep product somewhat organized when product is being picked and to create better alignment when filling a delivery tote with mixed items. Figure 5 shows a supply tote with similar product on the right connected to the delivery tote being filled. Here the product can flow from one tote to another without ever lifting the product more than 1 inch off of the surface. Figures 5 - 10 shows a robot picker transferring the product. The picker would first face the product to pull it from the supply tote, then would spin the product 180 degrees, and finally push the product into the delivery tote. The robot picker has a member (or thumb) with a roller that can bear most of the weight along the totes' folded side walls.

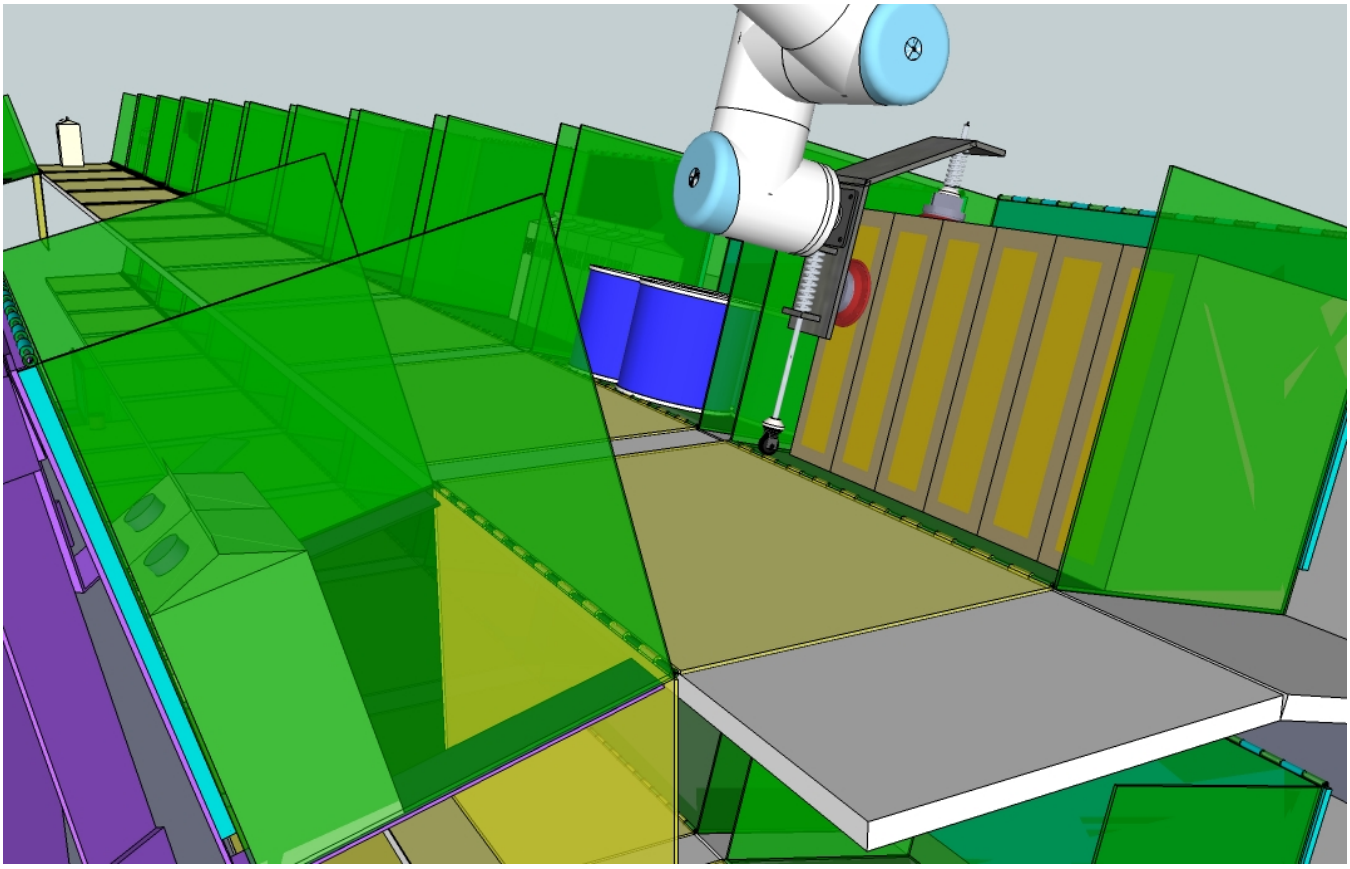

Figure 5 Delivery Tote (on left) with Folding Side Wall Lowered and Supply Tote (on right)

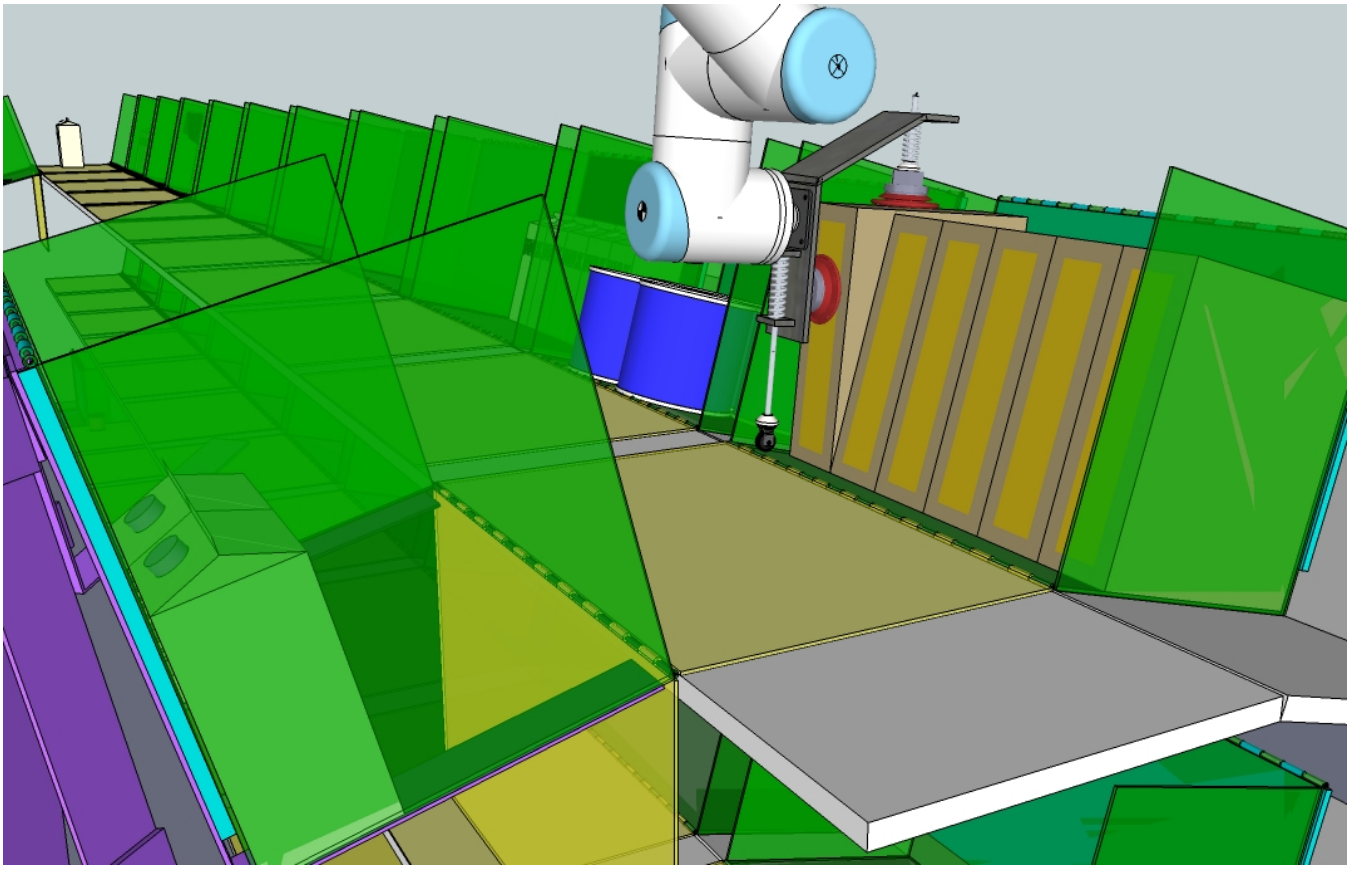

Figure 6 Robot Picker Tilts Product to Aid the Removal from Supply Tote

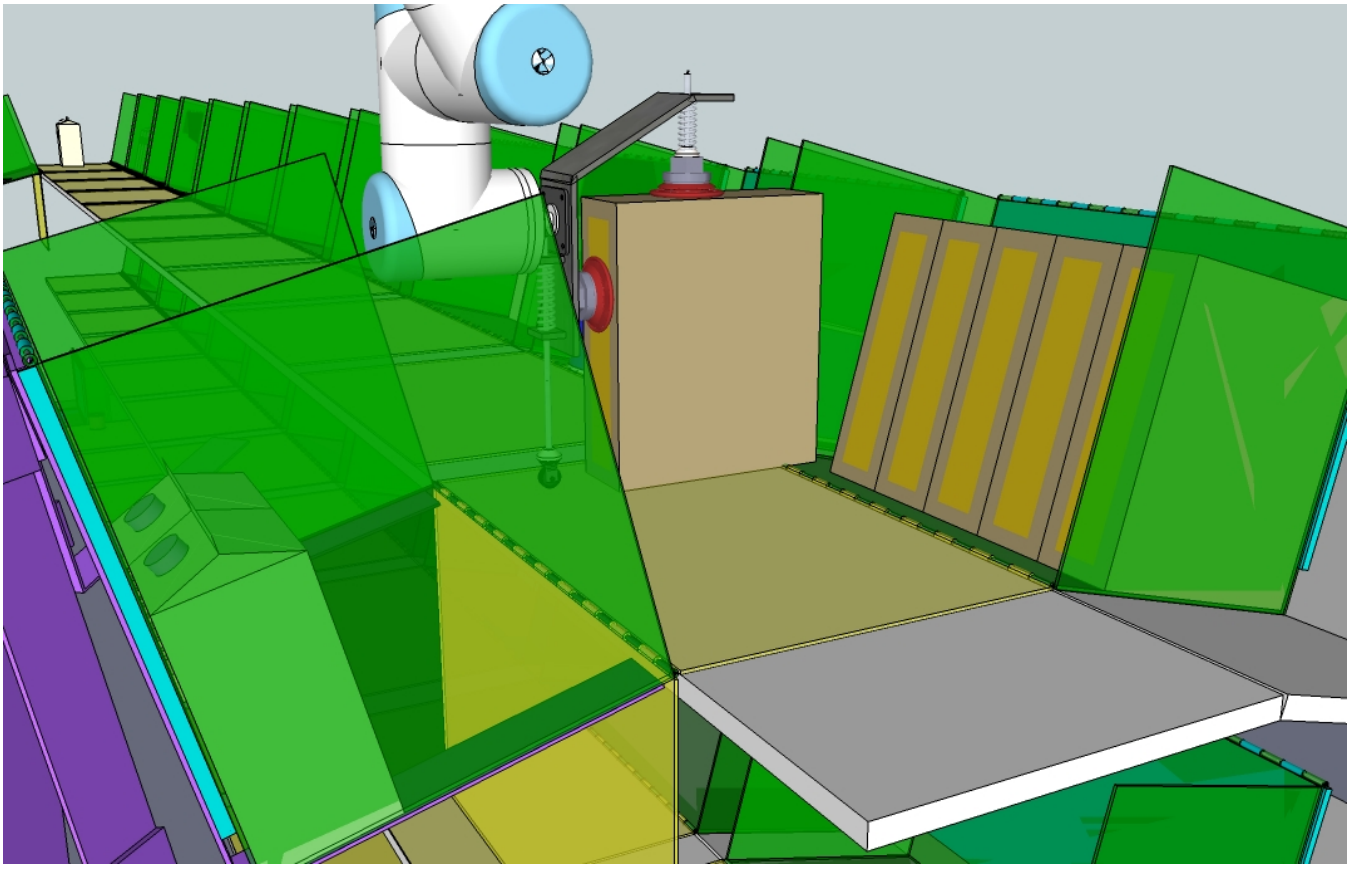

Figure 7 Product Picked from Delivery Tote

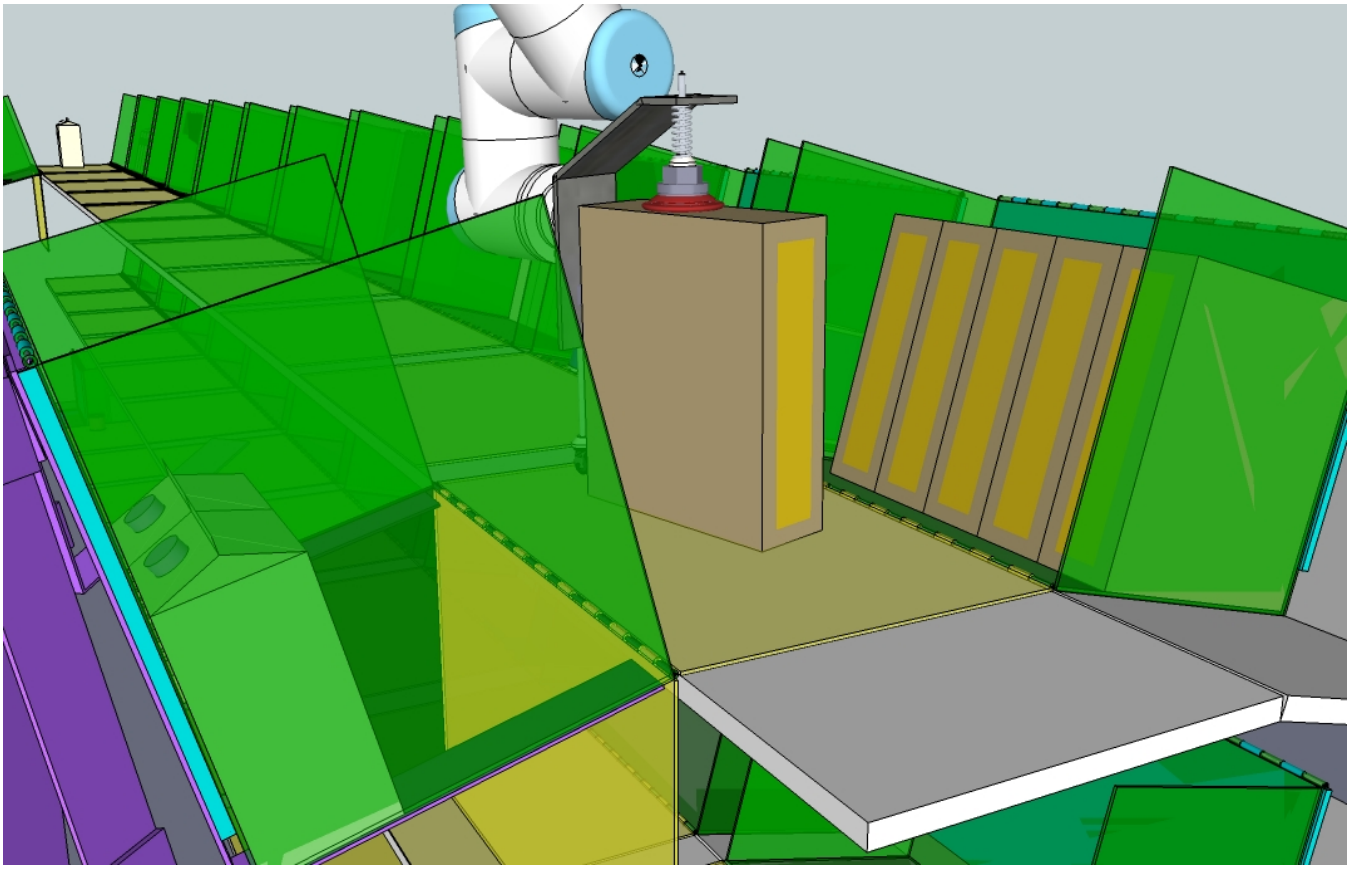

Figure 8 Product is Turned

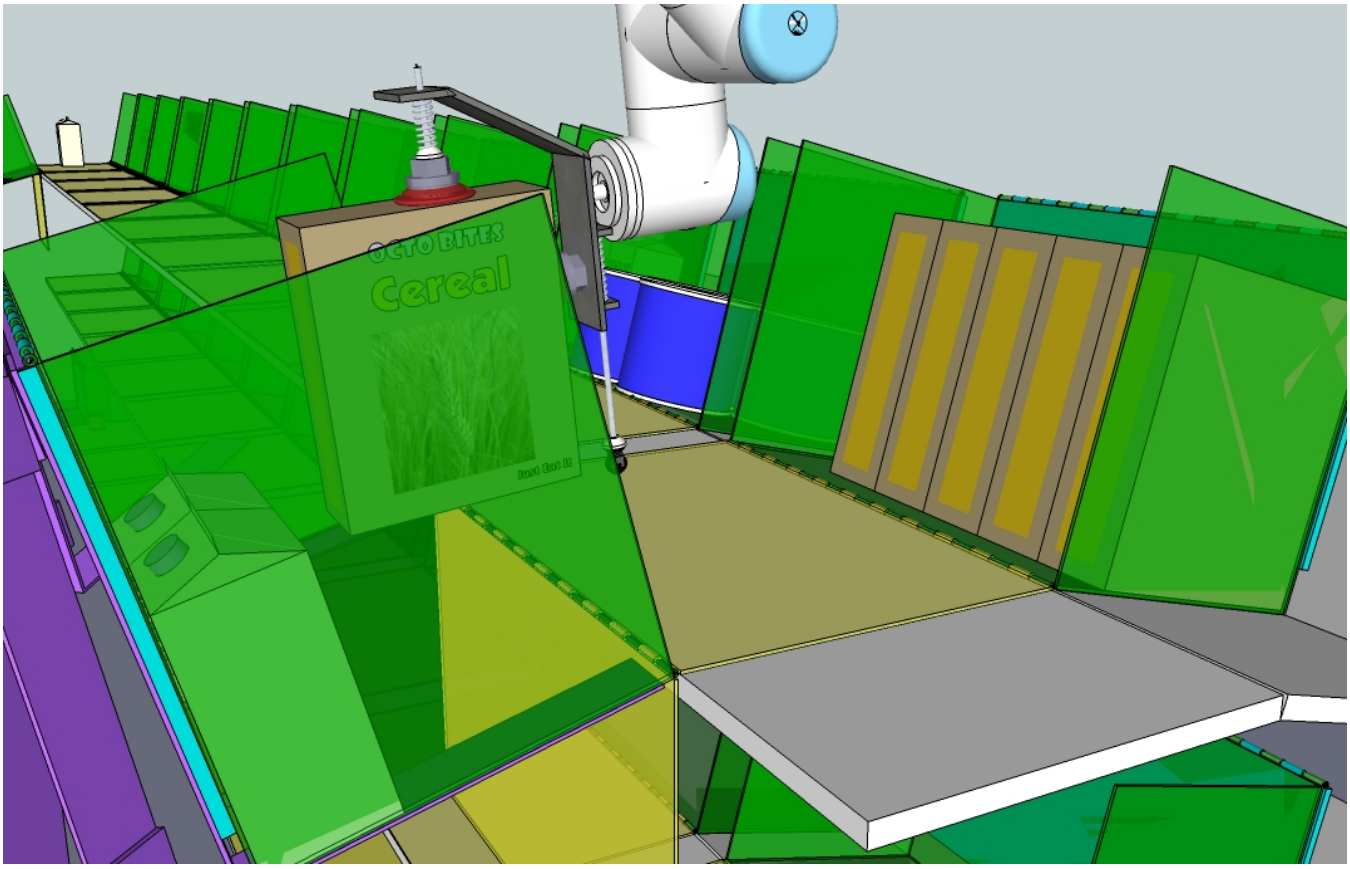

Figure 9 Robot Picker Member with Roller Bears Weight of Product

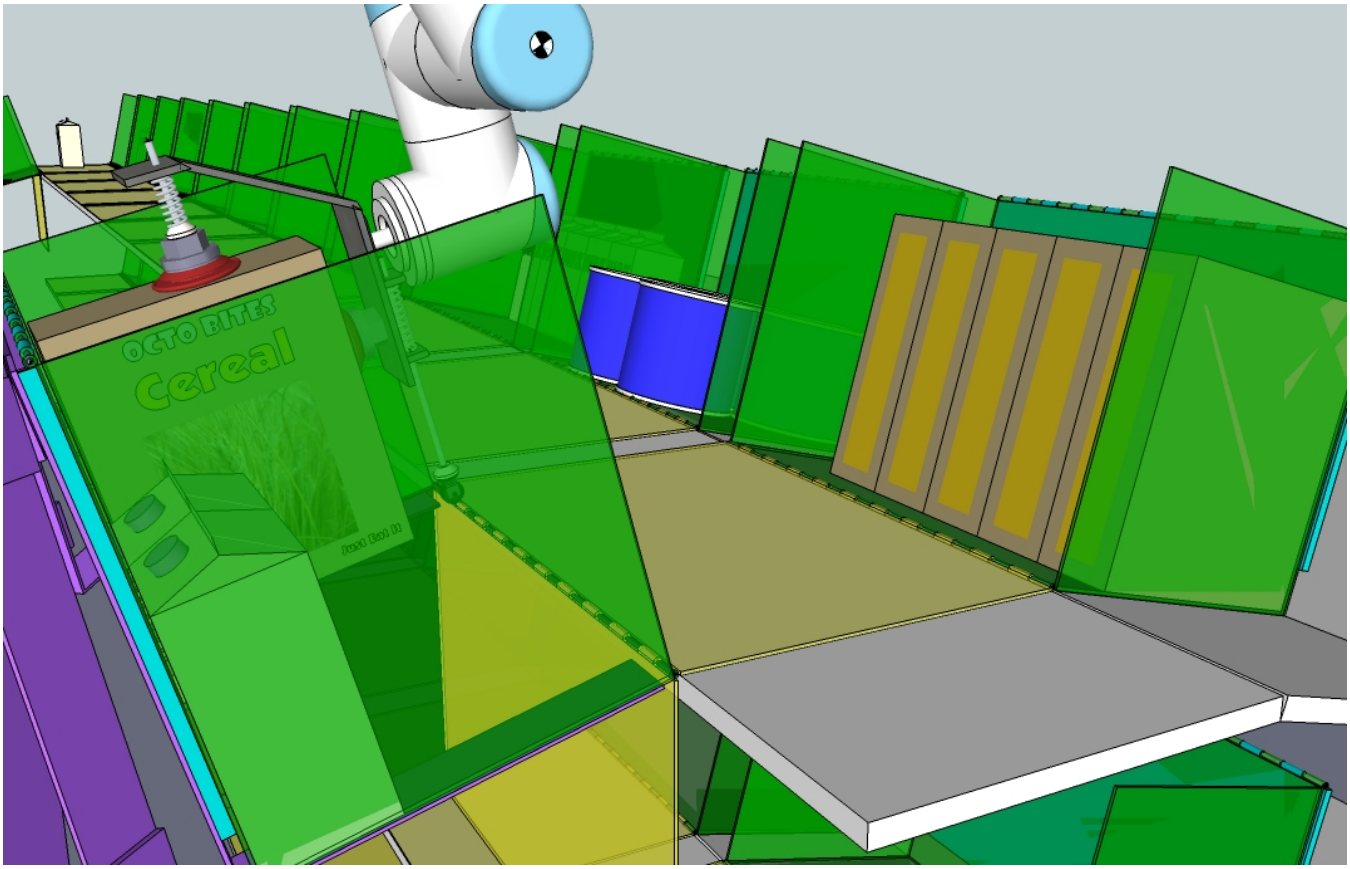

Figure 10 Robot Picker Has Placed Product in Delivery Tote

1.3] Picking Strategies

Picking product from the supply container will rely on both knowing the contents of the supply container beforehand and the use of sensor technology. There are many families of product families and associated methods to handle that include:

1) Rectangular Cartons
2) Round Bottles or Cans
3) Shelf Ready Pouches or Containers in Racks
4) Randomly Located Bulk Items

The computer vision and robotic picking grippers and strategies will be different for each product family, yet there will be much commonality. Since the products to be picked are not mixed, a specifically designed gripper for each product family can be used. Depending on the range of product SKU's there may not be a single general purpose gripper that will suffice. Picking robots can either function within a dedicated product family or quick exchange wrists can be used to allow for multiple grippers.

The first key to this solution is the openness of the FSW Tote on the top and the side. Many grocery products are designed to be displayed on a shelf and this tote design allows the vision system to both see and grip the product as it was designed to be gripped by a human shopper.

The second key to the solution is due to FSW Tote creating a surface that the randomly located bulk items can be temporarily pulled out onto the folded side wall or the transfer surface. The vision system can more easily find an individual product when they are not multiple layers deep and the robot gripper has a significantly easier process of gripping the product. Then the remaining product is transferred back into the supply tote by the robot.

The method used here mimics a pharmacist counting pills. A pharmacist pours some pills on the counting tray, moves the pills in groups to the transfer well with a narrow spatula, returns the excess pills to the larger pill shipping bottle and then pours the pills in the transfer well into the customer's bottle.

Smaller products will likely be stored in sub compartments in the supply tote. Lighter products will likely not have to use the roller thumb for transferring and can be picked in the traditional method.

1.4] RSC Corrugated Cases within the Supply Folding Side Wall Tote Design

Before the robotic system can pick the contents of a supply FSW Tote, the contents need to have been transferred either at the product manufacturing site (perhaps a future vision) or more likely at the DC's receiving department. Manual transferring of product is time consuming and the level of automation to transfer product from the RSC corrugated case to the FSW Tote may be expensive depending on the products' material handing requirements.

So one alternative is to use existing automation to cut and remove the top of the corrugated case and to also remove the front of the case. Then the modified case can be inserted into a plastic FSW Tote for transporting and proper control of product.

The picking and packing of RSC corrugated cases with a folding side wall acting without a plastic FSW Tote to keep product from spilling out is a challenge. This concept is shown in Figure 11 but needs additional constraints not currently shown

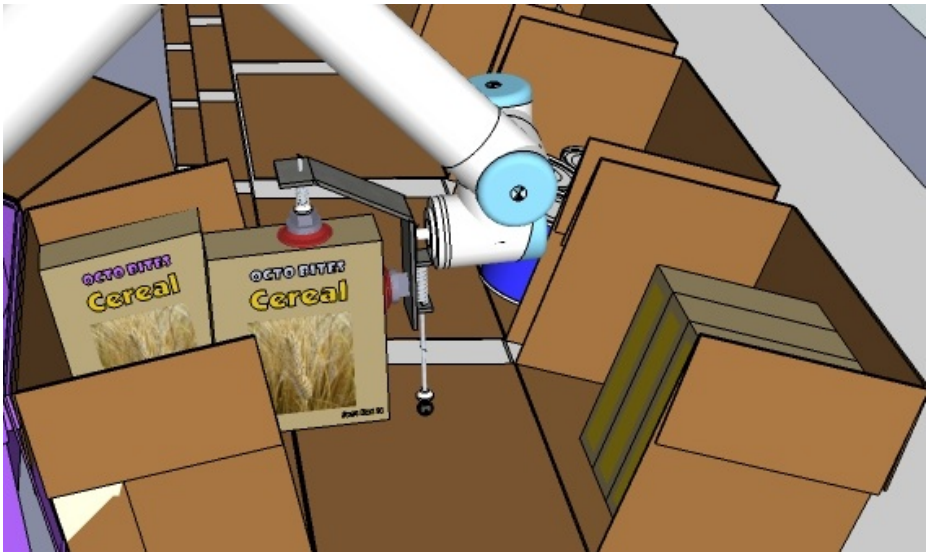

Figure 11 Corrugated Case Folding Side Wall Tote Concept – Not Recommended as Shown

1.5] Corrugated Cardboard Case with a Folding Side Wall and Wrap-around Top Lid Design

So as to pack a corrugated case for delivery with the gliding approach detailed in this document, a novel design was established. The case has a short folding side wall attached to the case bottom, and the opposite side wall has attached to it the case lid and a short side wall flap that is glued to the short folding side wall. Figure 12 shows this case design. The wrap-around top lid and short side wall flap do need to be folded backwards out of the way of the picking robot to work correctly.

Figure 12 Corrugated Cardboard Case with a Folding Side Wall and Wrap-around Top Lid Design

1.6] Combination of Novel Plastic Tote Transporting a Novel Corrugated Cardboard Case with a Folding Side Wall and Wrap-around Top Lid Design

As shown in Figure 12 (left hand photo) the partially erected corrugated case does not offer much structural integrity. It is recommended that such a case be transported internal to a FSW Tote within the DC operations. Then after the completion of order picking and packing, the case is slid out of the FSW Tote and the top lid and side wall and flap are all sealed.

2.0] Robot Order Picking on AGV's

One strategy for this operation of robotic order picking and packing is to have a larger mobile robot or AGV move the picking robot and delivery case/tote to the storage racks where supply containers hold the products. The AGV can move in front of the supply container, lower the side wall, and glide product into the delivery container. It is likely that this mobile robot or AGV will carry multiple delivery containers in order to have some meaningful efficiency.

3.0] The OctoPicker

The OctoPicker is the term used to describe a particular AGV designed to carry 8 containers. This same AGV design can be used for a range of number of containers, where the choice of 8 containers here has not been optimized. It is used to both transfer supply containers of product to and from a rack and to move a collection of delivery containers close to a supply container. Then its robotic arm can pick an individual item from the supply container and transfer it to pack the delivery container (Figure 13). The transfer motion is a gliding motion as opposed to the traditional bin picking and case loading found in most other automation systems.

The racks of supply containers can be a single layer of containers deep (which gives the quickest access to all containers at an expense of maximum rack face area – more racks) or multiple layers of containers deep (which gives the least rack face area but at the expense of time to move the containers in front of the desired container). The OctoPicker concept presented here can function with either design, but the multiple layer pick/place process will add additional cycle time. The OctoPicker can service both sides of an aisle (though the figures show a single side).

The OctoPicker (Figures 14 and 15) has the following components:

- Rotating ring with 8 container holders on vertically lifted platform
- Robot arm mounted on linear slide, also mounted on vertically lifted platform
- Robot gripper can pick an item from the supply container and transfer it to the delivery container
- Robot arm can also slide a supply container from/to the container holder to/from the storage rack locations
- Auxiliary linkage to move a container side wall up or down
- Vision system to determine location of products in supply and delivery containers

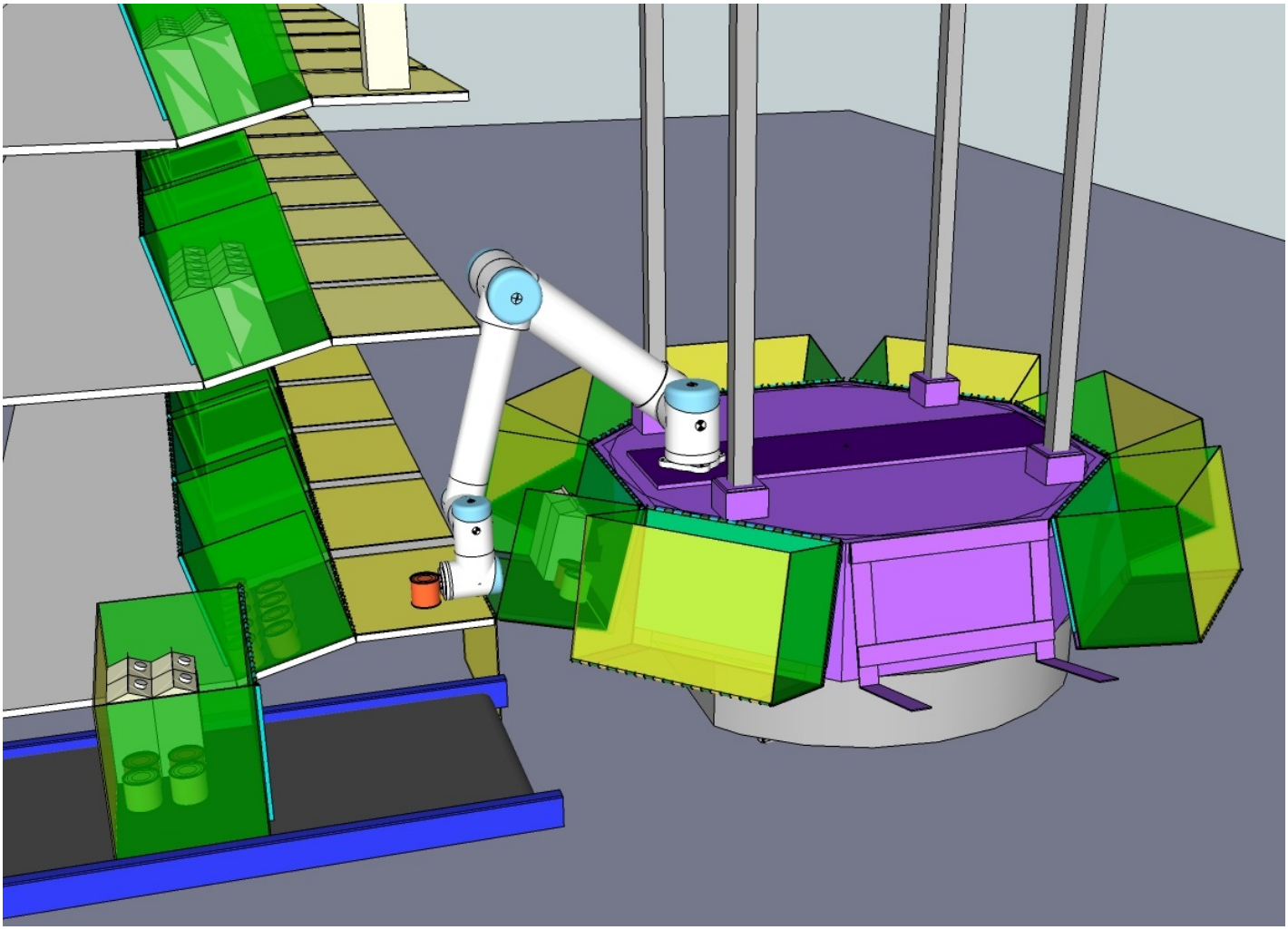

Figure 13 OctoPicker Picking from Lowest Rack

One possible mode of operation of the OctoPicker in the warehouse application would be:

- A warehouse row has empty locations on both sides of the aisle for a single layer of supply containers
- The OctoPicker moves to the end of the aisle and picks up 8 supply containers
- The OctoPicker moves to empty rack locations and uses its robot arm to slide supply containers into locations
- When racks are filled OctoPicker proceeds to end of aisle to get delivery containers
- OctoPicker moves to correct supply container and rotates ring of 8 container holders to match correct delivery container
- OctoPicker vision system identifies item in supply container and uses robot to slide product into delivery container
- When all delivery containers have been filled as much as possible with the items from that aisle, OctoPicker moves to end of aisle to unload filled delivery containers and to load next set of delivery containers to service

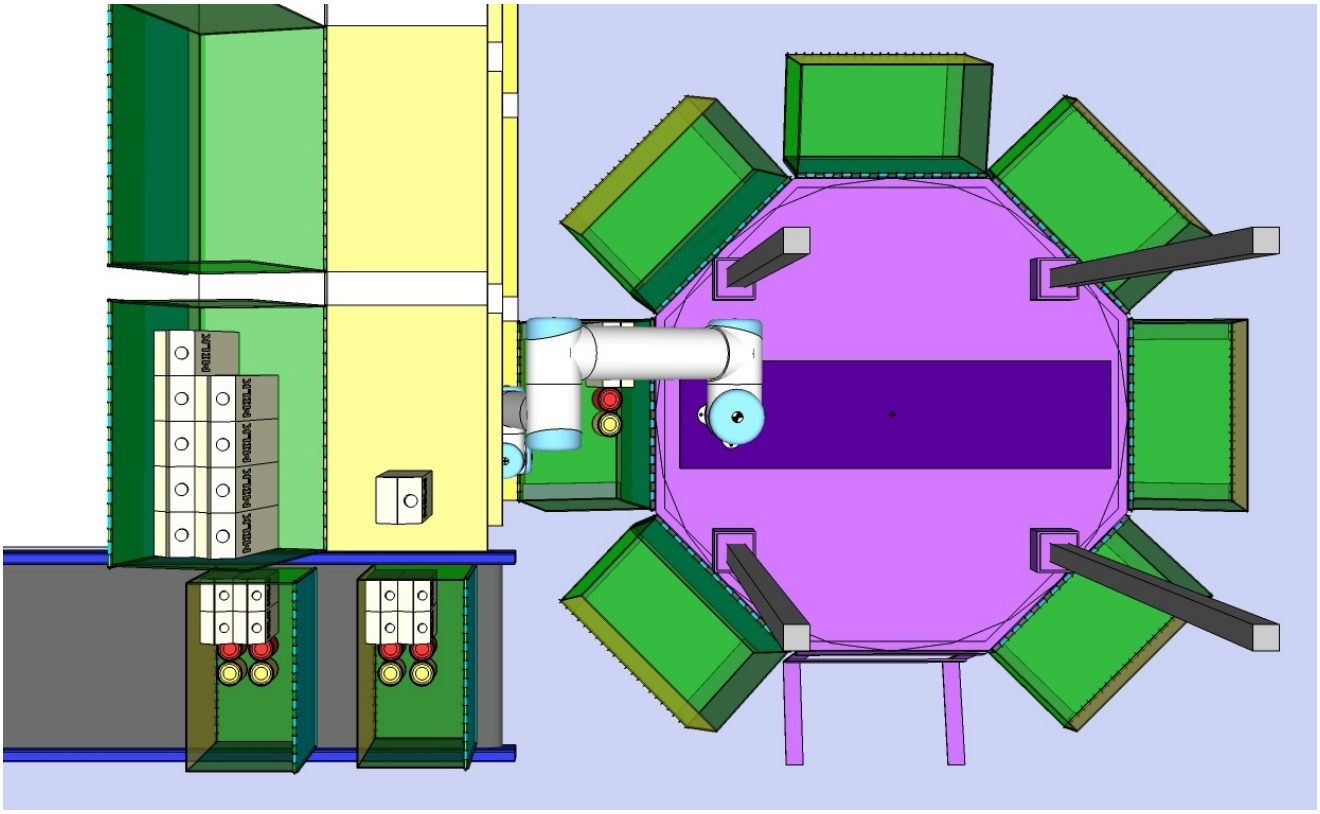

Figure 14 OctoPicker Components – Top View

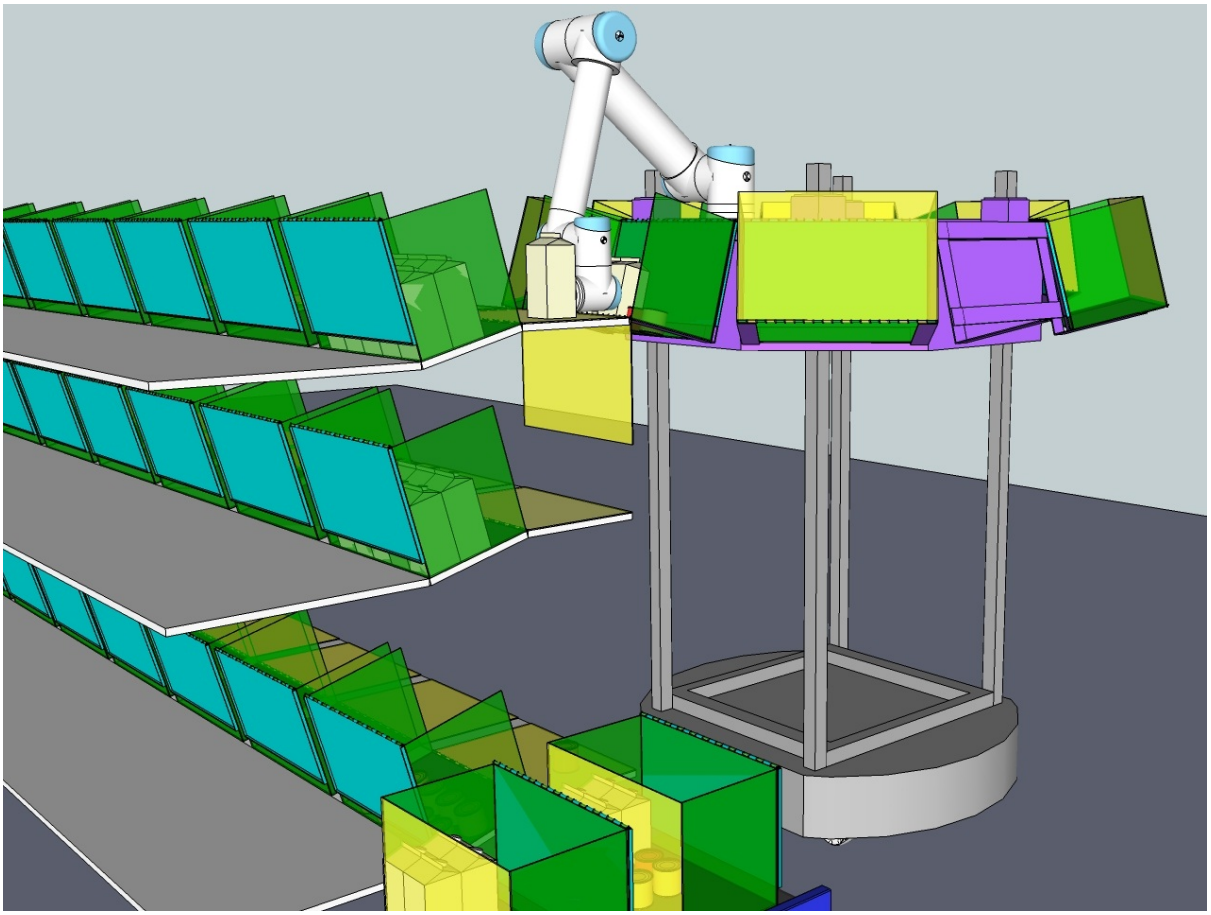

Figure 15 OctoPicker Raised to Upper Rack

Options include:

- OctoPicker can be mounted on an AGV, a rail based cart or a hybrid AGV with guide rails
- Layers of supply containers can be 1, 2 or 3 layers deep
- OctoPicker can use 1 or 2 empty container holders on the container holder ring to temporarily store supply containers to gain access to the second or third layer of supply containers.
- 1 or 2 OctoPickers can be used per aisle
    - Both can service supply containers and item picking
    - One can be dedicated for item picking, the other supply container servicing
    - A supply AGV can be used to move delivery containers to/from OctoPicker
    - A conveyor system along the aisle can be used to move delivery containers to/from OctoPicker
- OctoPicker can be serviced 1 or 2 containers at a time at the end of the aisle
- Robot arm can folded so as to pivot between support pillars (Figure 16)

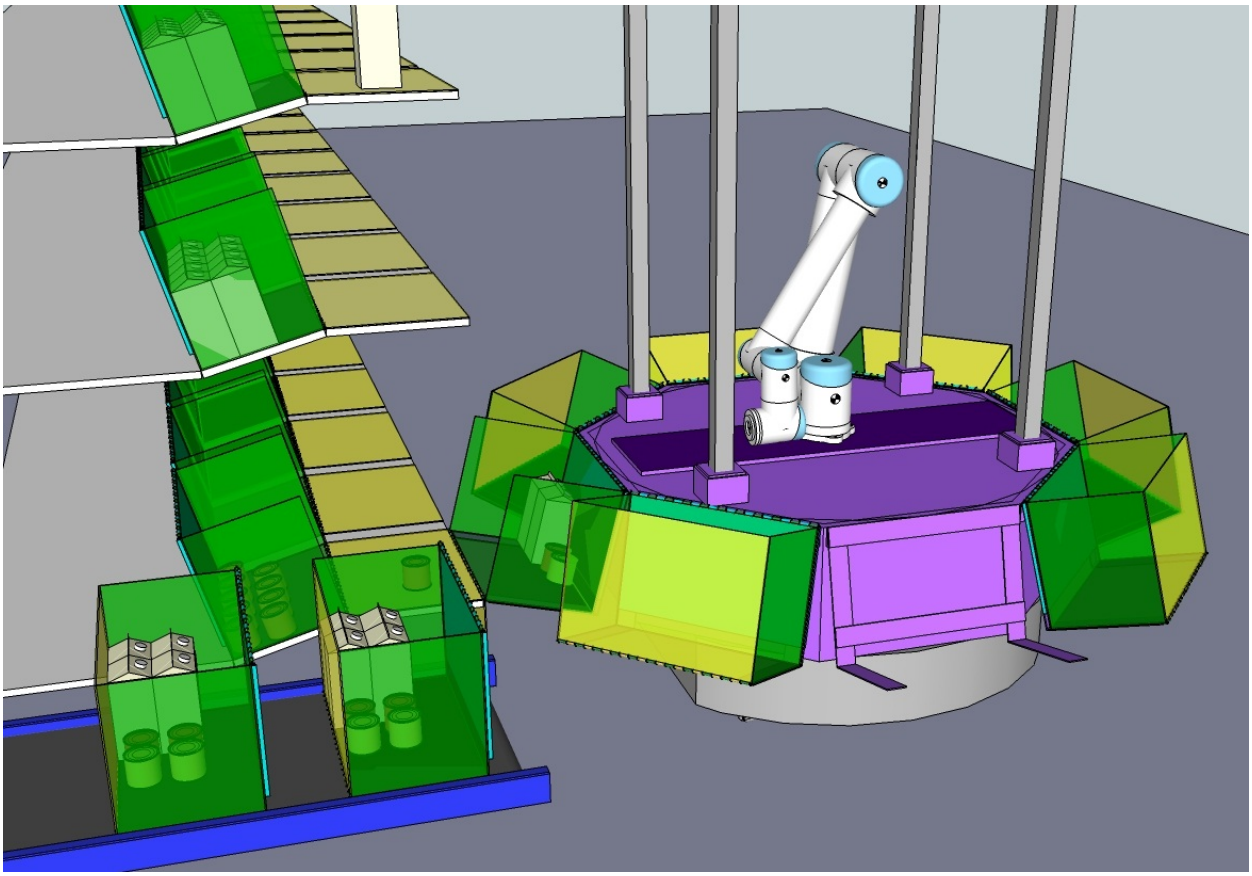

Figure 16 Robot Arm Can Be Folded So As To Pivot Between Support Pillars

Conclusions

A novel warehouse automation system has been developed that allows for both the picking of product and the packing the product for delivery with a single operation. The enabling technologies of the Patent Pending reusable totes with their folding side walls or the Patent Pending corrugated case design combined with the Patent Pending tote automation concepts that use innovative methods to see and transfer the products from a supply container to a delivery container create a new paradigm. This approach will provide distribution centers a more cost effective answer to the current challenges.