WHITE PAPER

Designing Packaging for Automated Material Handling

A practical guide to totes, dunnage, and dividers that work with AS/RS, goods-to-person, conveyors, and mobile robots

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Executive Summary

Automated material handling does not forgive sloppy packaging. A returnable tote that fits a manual workflow may not fit an Autostore grid. A divider system that survives a forklift may not survive a robot arm. The geometry, the surface, the stack-up, and the weight all matter in ways that a manual program would absorb without noticing.

This paper is for the packaging engineer or buyer scoping reusable packaging for an AS/RS, goods-to-person, conveyor, or AMR system. It covers what makes automation different, the five system types your packaging will encounter, the seven jobs automated packaging has to do, the dimensional and mechanical design rules that drive performance, and the RFQ inputs that turn a vague conversation into a quotable program.

The short version: automation raises the stakes on every packaging variable. Cost-per-trip math gets better because cycle counts go up. Failure modes get less forgiving because there is no human in the loop catching problems. The packaging that works in an automated environment is not the packaging that works in a manual one with extra rivets.

1. Why Automation Is Different

Three things change when packaging moves into an automated environment.

Cycle counts go up by an order of magnitude. A manual returnable program runs each tote 100 to 500 times over its life. An automated program runs the same tote 1,000 to 5,000 times, sometimes more. That changes the material spec, the tooling investment, and the cost-per-trip math in a way that favors durability over unit price.

Tolerances go down by a factor of three to five. AS/RS grids hold totes in slots with millimeter-level clearances. Conveyor merges and sortation lines have a tight envelope for how a tote can ride. A 5 mm oversize tote that nobody noticed in a manual program will jam a shuttle in an automated one.

There is no human in the loop. In manual handling, a worker catches the warped tote, the cracked corner, the missing handle, and works around it. In automated handling, nobody catches it. Throughput drops, error rates rise, and the first signal is a maintenance ticket. Packaging in an automated environment has to be right by design, not right by intervention.

2. The Five Automation System Types

Most packaging programs interact with one or more of the five system types below. Each puts different demands on the packaging.

System type	Examples	Packaging implication
AS/RS (mini-load and unit-load)	Dematic Multishuttle, Knapp OSR Shuttle, SSI Schaefer, TGW, Witron	Tote dimensions, weight, and lip geometry must match the shuttle and grid spec exactly. Outer tolerance typically ±1 to 2 mm.
Goods-to-person (G2P)	Autostore, Exotec Skypod, Geek+ PopPick, Kardex AutoStore	Most systems use a proprietary tote standard. Custom dunnage and inserts go inside the standard tote. Outer tote is fixed by the system, not the part.
Conveyor and sortation	Honeywell Intelligrated, Dematic, Vanderlande, Daifuku	Base geometry, foot or skid design, and flatness drive ride quality. A warped base sorts wrong or jams.
AMRs and AGVs	Locus, 6 River Systems, MiR, Otto, Geek+	Variable load size and sometimes stacked. Tote must hold geometry on a moving robot deck. Center of gravity matters.
Robotic pick and place	Berkshire Grey, RightHand Robotics, Boston Dynamics Stretch, Covariant	Dunnage presents parts in known, repeatable positions. Vision system reads pocket location and orientation. Matte surfaces and color contrast matter.

> *If the system has a proprietary tote standard (Autostore, Exotec, Kardex), the outer tote is fixed and the engineering work happens inside. Custom dunnage, dividers, and inserts go in the standard tote. If the system uses a generic conveyor with a custom tote (most AS/RS), the outer tote is the engineering opportunity.*

3. The Seven Jobs Automated Packaging Has to Do

Strip away the system specifics and automated packaging has seven jobs. Get any one wrong and the system slows down.

Job 1: Hold Its Geometry

No warp, no sag, no creep over the program life. Corrugated polypropylene and thermoformed sheet are the right materials. Cardboard is not. Wood is not. Material that absorbs moisture or fatigues under cyclic load will lose dimension somewhere in the program and start failing the system clearance.

Job 2: Match the System Spec

Every automated system has a defined envelope. Outer dimensions, weight limit, lip geometry, base footprint, stacking accuracy. The packaging meets the spec or the packaging does not run. There is no "close enough" in an automated cell.

Job 3: Stay Light Without Losing Rigidity

Robot energy cost and cycle time both scale with the load being moved. A heavy tote slows the system. A flimsy tote sags under part load and loses geometry. The design problem is finding the gauge and structure that gives the lightest possible tote without compromising dimensional stability. Corrugated polypropylene with wire reinforcement is often the answer for heavy programs. Thermoformed PP or ABS handles the lighter ones.

Job 4: Survive Impact

Robots do not soft-touch. AMRs hit racks. Shuttles drop totes by design at end of cycle. AS/RS grids see lateral impact from rapid acceleration. Packaging in an automated environment has to take that hit thousands of times without cracking, deforming, or shedding.

Job 5: Present Parts Repeatably

Robot picks happen at known pocket positions. Dunnage that lets a part rotate, slide, or sit cocked in the pocket fails the pick. Pocket geometry should hold the part in one orientation without ambiguity. For dense pick patterns, mold or die-cut the pocket to match the part contour.

Job 6: Cooperate With Vision

Vision systems read surface contrast, edges, and color. Matte surfaces produce clean images. Gloss creates highlights that confuse cameras. Light colored totes show dark parts well. Dark colored totes show light parts well. Picking a color that contrasts with the part the system is reading is the difference between a 99 percent first-pick rate and an 85 percent rate.

Job 7: Identify Itself

Every automated tote ties to a record. Barcode, RFID, or both. Barcode zones need a flat surface, light background, and quiet zone on all sides. RFID needs a pocket that does not block RF. Corrugated polypropylene is RF-transparent. Aluminum is not. Foam liners can absorb RF depending on density. Build the ID location into the design, not as an afterthought.

4. Dimensional and Mechanical Design Rules

Automated systems demand tighter tolerances than manual ones across every variable. The table below shows how the spec tightens when a program moves into automation.

Variable	Manual handling target	Automated handling target
Outer dimension tolerance	±3 to 5 mm	±1 to 2 mm. AS/RS grid clearances are tight enough that a 4 mm oversize tote will not clear.

Variable	Manual handling target	Automated handling target
Base flatness	Functional flatness	Flat to within 1 to 2 mm across the base. Warped bases jam on conveyors and sortation merges.
Stack and nest accuracy	Eyeball alignment	Stacking lips must interlock without lateral play. Tolerances stack across the column.
Weight	Whatever the part needs	Optimize down. Every kg of empty tote weight slows the robot and adds energy cost over the program life.
Surface finish	Whatever forms cleanly	Matte preferred for vision systems. Gloss creates highlights that confuse cameras. Color drives contrast against the part.
Cycle count target	100 to 500 cycles typical	1,000 to 5,000+ cycles common. Higher cycle counts amortize tooling and materials further.
Identification	Stick a label on it	Designed-in barcode zone, RFID pocket, or color coding tied to the WMS or WCS.

> *The single most common failure mode in automated packaging is a tote that meets the spec on the first article and drifts out of spec at cycle 500. Material selection, gauge, and structural reinforcement are the levers that prevent drift. Spec the program for cycle count, not first article.*

5. Vision, Identification, and the WMS Tie-In

Automated handling depends on identifying every tote and every part. The packaging is part of that identification system whether the design treats it that way or not.

VISION-SYSTEM DESIGN NOTES

- Matte finish on the outer surface. Avoid gloss, avoid clear unless required.
- Color chosen for contrast against the part the camera is reading.
- Pocket geometry that holds the part in one known orientation, with surface features the camera can see (no shadows, no glare hot-spots).
- Fiducial marks (printed or molded) where the robot needs a reference point.

IDENTIFICATION DESIGN NOTES

- Designated barcode zone, flat, oriented for the scanner geometry, with quiet zone.
- RFID pocket positioned away from foam, metal, or other RF absorbers.
- Color coding tied to the WMS or WCS class (different SKUs, different routings, different priority).
- Serialization integrated at fabrication if the program needs unit-level traceability.

6. Cost-per-Trip in an Automated Environment

Cost-per-trip math gets more favorable in automation. A tote that runs 250 cycles in a manual program runs 1,500 in an automated one. The fixed costs (tooling, design, qualification) amortize across six times the trips. Per-trip cost drops by a factor of four to six versus the same packaging in a manual workflow.

That changes the buy-versus-build calculus. A $40 corrugated polypropylene tote that costs $0.16 per trip at 250 cycles costs $0.027 per trip at 1,500 cycles. The same program in a one-way corrugated cardboard box runs $4 to $6 per trip. The reusable program wins by a factor of 150 or more.

> *Two failure modes erase the savings. Lost totes (no return path, no tracking) and damaged totes (no repair or replacement plan). An automated returnable program has to include both: a closed return loop and a maintenance and replacement cycle. Build them before tooling lock.*

7. What to Send a Vendor for an Automation RFQ

Automation RFQs are different from manual RFQs in two places: the system spec is non-negotiable, and the cycle count is much higher. Both have to be in the package.

1	**Automation system make and model.** Autostore Black Line, Exotec Skypod, Dematic Multishuttle, Knapp OSR, AMR fleet model, robot arm and gripper. The system spec drives the outer tote envelope.
2	**Tote and dunnage envelope.** Maximum outer dimensions, weight limit per loaded tote, stack height, nesting requirement. If the system has a tote standard, send the spec sheet.
3	**Part drawing or 3D file.** STEP or IGES preferred. Include orientation, pick face, and any surface-critical zones.
4	**Cycle count and program life.** Cycles per tote over the program life. This drives material, gauge, and tooling decisions.
5	**Vision and identification spec.** Barcode position and quiet zone, RFID tag pocket and frequency, fiducial marks for robot vision, color requirements.
6	**Conveyor and shuttle interface.** Conveyor type (belt, roller, chain), shuttle pickup style, lip geometry, foot or skid design.
7	**Tolerance requirements.** Outer dimension tolerance, base flatness, stacking accuracy. Tighter than manual programs.
8	**Material and environmental.** Standard PP, ESD grade, cleanroom, FDA, chemical resistance, temperature range.
9	**Hardware and assembly.** Handles, lids, RFID inserts, dividers, foam liners. Field-serviceable or production-assembled.

10	**Lead time and ramp.** First-article date, pilot quantity, full ramp schedule. Automation programs often need a pilot lot before tooling lock.

> *Send the system spec sheet with the RFQ. "It runs on Autostore" is not enough. The vendor needs the tote standard, the load class, and the conveyor or shuttle interface drawing. Without it, the quote is a guess.*

About Kiva Container Corporation

Kiva Container Corporation is a custom thermoforming and corrugated plastic shop in Anaheim, California. Founded in 1986. AS9100D and ISO 9001:2015 certified. Women-owned. All design, tooling, and production in-house at a single facility.

CAPABILITIES RELEVANT TO AUTOMATION PROGRAMS

- Pioneer flatbed die-cutter, 78 by 150 inch, for large corrugated polypropylene totes and dunnage
- Gerber M3000 turbo router and cutting table, 75 by 120 inch, for prototypes and short-run validation
- 4 sheet-fed thermoformers, max 46 by 54 inch, for thermoformed totes and dunnage
- Wire bending and structural fabrication for high cycle count programs
- Sonic and proprietary flat welding for assembled tote and divider geometry
- Materials including standard PP, ESD and conductive grades, FDA grades, cleanroom-compatible sheet
- In-house screen and digital printing for barcode zones, fiducials, and color coding
- Aluminum CNC tooling and steel rule dies fabricated in-house
- Full design through production cycle, no outsourcing

Most customers are packaging engineers and buyers in aerospace, medical, and material handling. Order profile runs from short prototype runs to repeat production. Custom engineering is the default, not the exception.

> *Have an automation program coming up? Send the system spec, the part drawing, and the cycle count. We will tell you what we would build before we quote.*

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