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PC-based control and EtherCAT are driving foundational change across the intralogistics industry

A new wave of automation investment has arrived – but the blueprint has changed

Doug Schuchart, Global Material Handling & Intralogistics Manager, Beckhoff

Following the disruption ignited by the COVID-19 pandemic and the subsequent global supply chain crisis, operating conditions across many industries, including intralogistics, have largely stabilized. As a result, major retailers and parcel carriers have regained confidence and are resuming capital expenditure programs. A significant portion of the investments is being allocated to warehouse and distribution automation.

This shift reflects the structural labor challenges made worse by pandemic era events. During the COVID-19 period, labor availability contracted dramatically, while the later supply chain disruptions and subsequent softening of demand actually led to labor overcapacity in some areas. In parallel, the physically intensive nature of manual material handling operations in distribution and fulfillment centers has continued to drive high employee turnover, injuries, and inefficiencies. As capital spending resumes, automation is increasingly viewed as a strategic mechanism to improve labor resilience, operational consistency, and long-term cost efficiency, while also ensuring the highest level of employee safety.

This significant investment in automation is occurring at a pivotal moment, as the industry undergoes a fundamental shift in the standardization of controls technology. With artificial intelligence (AI) taking center stage in next-generation automation equipment, many of the world's intralogistics and material handling industry leaders are moving away from traditional PLC architectures in favor of modern PC-based control platforms. These architectures are specifically designed to fully leverage machine learning (ML) and other AI-enabled technologies to support advanced system optimization, as well as predictive and prescriptive maintenance strategies.

Although modern PLCs are often built on hardware architectures similar to industrial PCs (IPCs), they retain inherent limitations that are not typical of true PC-based control platforms. In contrast, hardened Beckhoff IPCs can fully utilize all cores of multi- and many-core processors. Leveraging the multi-threading capabilities of Beckhoff's TwinCAT 3 automation software platform, workloads can be distributed across multiple cores or assigned to dedicated cores for independent yet synchronized tasks, such as robot arm kinematics. TwinCAT 3 further extends this advantage through more recent advances such as TwinCAT Core Boost, which can increase the computing performance of individual real-time or user-mode cores by up to 50% to maximize overall system performance. As a result, the need to add separate edge computing devices – introducing additional cost, complexity, and lifecycle constraints – for AI-driven data collection and analytics is eliminated. Instead, PLC execution and AI workloads can coexist on the same IPC.

A second critical enabler for AI-driven automation is EtherCAT. To allow a single IPC to handle both real-time PLC execution and high-volume data analytics with immediate system response, the underlying communication network must support both deterministic real-time traffic and extensive data collection. EtherCAT's unique functional principle delivers exceptionally high bandwidth for data transmission without compromising real-time performance.

For this reason, EtherCAT has achieved significant milestones and continues to experience rapid global adoption. The timing of EtherCAT's growth aligns closely with the large capital investments in automation currently underway by major retailers and parcel handling companies. The EtherCAT Technology Group (ETG)—the world's largest fieldbus and industrial Ethernet organization, with more than 8,500 member companies – reported approximately 88 million EtherCAT nodes in the field worldwide as of last year. In addition, Grand View Research projects continued strong growth, with EtherCAT expected to expand at a compound annual growth rate (CAGR) of 9.8% from 2025 through 2033.

Several of the world's largest global retailers have already adopted EtherCAT, driving a sustained acceleration of its adoption within the intralogistics sector. Parcel handling companies are similarly leveraging EtherCAT to achieve higher performance, simplified cabling, and enhanced system diagnostics. This global expansion of EtherCAT – particularly within intralogistics – comes at an ideal time, as major retail and parcel organizations prepare for substantial automation investments beginning in 2026.

Another transformative technology is also arriving at precisely the right time: Beckhoff's MX-System. This complete, decentralized, and cabinet-free automation platform is built on the same powerful TwinCAT 3 automation software and EtherCAT communication architecture found across the Beckhoff ecosystem. Available today, the MX-System represents the next generation of automation technology, eliminating traditional control cabinets and integrating control components directly onto the automation equipment. The result is increased flexibility and modularity, significantly reduced installation and commissioning times, and improved system uptime enabled by the combined diagnostics of EtherCAT and the advanced diagnostic capabilities of the MX-System.

In this year's intralogistics special edition of Beckhoff's PC-Control magazine, you will see how companies across the industry are leveraging Beckhoff's PC-based control platform with TwinCAT 3 and EtherCAT to lock in a competitive advantage. These benefits extend across virtually every type of equipment found in distribution and fulfillment operations, including sortation systems, singulators, automated storage and retrieval systems, conveyors, and mobile robots. Importantly, these advantages are realized regardless of equipment size or complexity – from compact machines to large-scale sortation and conveyor systems – thanks to TwinCAT 3 and EtherCAT's ability to break through the limitations imposed by traditional PLCs and fieldbus technologies.

We invite you to explore the many exciting applications featured in this year's intralogistics special edition. And be sure to scan the QR codes at the end of each article to see the equipment in action and hear directly from Beckhoff users. If you are ready to join the next wave of automation as retailers and parcel organizations accelerate their investment cycles, contact your local Beckhoff representatives and get started today.

More information:
www.beckhoff.com/intralogistics

Advancements in motor-driven roller (MDR) control technology continue at full speed

The evolution of conveyor technology continues in modern distribution and fulfillment operations

As the already booming e-commerce sector continues to expand, the demands placed on distribution and fulfillment operations increase in parallel. Skyrocketing order volumes, growing SKU diversity, and the expectations for rapid delivery have pushed logistics systems to their limits. At the same time, the availability of qualified labor – especially during seasonal peaks – remains a persistent challenge for operations.

> EtherCAT remains the fastest open fieldbus in the world and offers an ideal foundation for the next generation of warehouse automation.

To address these pressures, automation has become essential across the industry. Modern automated systems improve operational flexibility, enhance fulfillment accuracy, and enable facilities to scale performance efficiently to match changing demand.

Automated fulfillment centers, whether parcel or retail focused, rely on a variety of automated systems: sortation equipment, singulators, gappers, and automated storage and retrieval systems (AS/RS). Additional solutions, such as robotic picking, automated truck unloaders, and stow systems, also play critical roles.

Yet one technology remains central to tying these elements together – the ubiquitous conveyor system. Of course, conveyors are not exclusive to distribution; they are used across manufacturing, assembly, and logistics wherever goods need to be moved efficiently from one point to another. Despite over a century of use, conveyors remain a foundational component of modern automation.

From centralized drives to zone control: A brief history

The conveyor's significance dates back to Henry Ford's 1913 reimagining of the assembly line for the automotive industry, where products were brought to workers via powered belts. Early conveyors, however, were inefficient, driven by a single motor powering a long line shaft or chain system and ran at a constant speed.

Advancements in electric motor control led to the invention of the variable frequency drive (VFD) in the 1960s, which was then commercialized and refined in subsequent decades. These allowed variable-speed operation and offered significant advantages for large-scale, continuous systems, such as those used in mining or bulk material handling.

However, as distribution and fulfillment centers demanded more modular, compact, flexible and efficient systems, a new generation of conveyor technology emerged — the motor-driven roller (MDR) conveyor.

The emergence of motor-driven roller (MDR) conveyors

Modern MDR conveyors utilize rollers with integrated 24 V or 48 V Brushless DC (BLDC) motors. Each powered roller drives a short group of passive rollers, forming a zone that can operate independently. These zones start, stop, and vary speeds based on product presence, controlled via local MDR controllers networked along the conveyor.

Proximity sensors wired to the MDR controllers or other networked I/O devices detect items entering a zone, activating it only as needed. When no product is present, the motor rollers are not activated. This approach can reduce energy consumption by 50 – 70% compared to continuously running conveyors. Integration with barcode scanners, diverters, and routing logic improves overall system accuracy. Further logic for zero pressure accumulation (ZPA) minimizes carton damage, avoids conveyor jams, and maximizes throughput.

Because each conveyor section operates independently, MDR systems are inherently modular and scalable, offering safer low-voltage DC motors which are inherently more efficient than large AC motors, particularly for intermittent loads. Building the conveyor via individual zone modules simplifies reconfiguration for evolving warehouse layouts. These qualities make MDR technology ideal for high-speed, high-accuracy distribution environments.

Historically, MDR controllers were proprietary, supplied only by motor roller manufacturers, and only worked with that vendor's motors. Differences in motor feedback types and electrical specifications often required multiple controller models within the same facility, creating challenges for engineering, maintenance, and spare parts management. This lack of standardization also complicated supply chains and system scalability.

Enter EtherCAT: The ideal network for conveyor automation

Conveyors are inherently linear systems, making line topology an ideal network architecture. However, traditional Ethernet-based fieldbuses, such as EtherNet/IP and PROFINET, rely on switch-based communication, which introduces latency as each frame passes through successive devices. In a line topology, these cumulative delays can degrade communication timing and cause operational errors such as missed diverts or routing faults.

EtherCAT, in contrast, is not IP-based. It operates below the IP layer and eliminates the need for switches and IP addresses while still supporting flexible network topologies. This design prevents cumulative latency, making EtherCAT exceptionally well-suited for linear material handling systems such as conveyors and sorters.

With support for over 65,000 devices per segment and sub-millisecond update rates, EtherCAT removes the limits on conveyor length and the need for proprietary sub-bus architectures otherwise needed in traditional switch-based fieldbuses. EtherCAT remains the fastest open fieldbus in the world and offers an ideal foundation for the next generation of warehouse automation.

The EtherCAT-enabled approach to MDR control

Building on the success of Beckhoff's first EtherCAT-based MDR controller, the new EP741x-9071 EtherCAT Box series introduces enhanced functionality and industry-leading safety capabilities. Like the proven EP7402 EtherCAT MDR controller, the EP741x-9071 can control any 24 – 48 V BLDC motor with high precision – regardless of manufacturer – simplifying engineering, procurement, and spare parts management.

The new series also maintains Beckhoff's fully pluggable, IP54+ rated design, eliminating wiring errors and reducing installation labor. Available in two- and four-channel variants (EP7412-9071 and EP7414-9071), the controllers enable flexible zone configurations and cost-efficient operation. The unique 4-channel MDR controllers provide additional cost savings with the higher density.

While automation delivers major gains in productivity and reliability, it also introduces new safety risks. Beckhoff brings deep expertise in functional safety and integrates Safety over EtherCAT (FSoE) into many of our IEC 61784-3-12 compliant products, which unlocks new functions and higher performance for our customers.

End users have been demanding smaller and more granular safety zones, which adds cost and complexity when using traditional MDR controllers. The EP741x-9071 MDR controller addresses these challenges by integrating FSoE with Safe Torque Off (STO) and Safe Stop 1 (SS1) directly within the device – an industry first for MDR systems. This functionality ensures the conveyor achieves a safe state without removing control power. Instead, the drive's internal circuitry de-energizes the motor power stage, safely disabling motor torque while diagnostic communication remains active. This allows operators and maintenance systems to retain full visibility during an E-stop condition. Also, individually controlled safety zones for a conveyor section as small as two MDR zones can be achieved without additional power supplies, wiring, or safety components, unlocking flexibility that was unachievable or impractical before.

> Beckhoff's new EP741x-9071 EtherCAT MDR controllers set a new benchmark for conveyor safety, efficiency, and modularity in automated material handling environments.

In 2006, NFPA 79 introduced new standards for emergency stopping of powered conveyors, requiring that power to motors be safely removed during an E-stop. Many conventional MDR controllers lack the ability to separate motor power from logic power, resulting in total loss of system visibility during shutdown. The dual-circuit design in the EP7402, with separate power feeds for motors and control electronics, and the new EP741x-9071 with STO/SS1 fully meet this requirement while preserving system communication.

Beckhoff's integration of STO and SS1 via Safety over EtherCAT enhances diagnostic transparency, simplifies safety wiring, and reduces power supply complexity. This results in a safer, more efficient, and more maintainable conveyor control platform.

Distributed safety, modular flexibility

Many Beckhoff devices with integrated FSoE, including the new EP741x-9071 series MDR controllers, also incorporate local safety logic, enabling distributed safety zoning across a single EtherCAT network. This flexible architecture allows independent, zone-level safety operation for maintenance or reconfiguration.

Additional improvements – such as reduced installation depth for integration into conveyor side rails and integrated cordsets with standardized M8/M12 connectors – further streamline installation and service while minimizing costs and spare parts inventory.

Beckhoff's new EP741x-9071 EtherCAT MDR controllers set a new benchmark for conveyor safety, efficiency, and modularity in automated material handling environments. By combining high-performance EtherCAT communication, integrated FSoE safety, and universal MDR compatibility, Beckhoff delivers a controller platform that aligns with the evolving safety standards, flexibility, and performance expectations of modern distribution and fulfillment centers.

Doug Schuchart
Global Material Handling & Intralogistics Manager, Beckhoff

More information:
www.beckhoff.com/ep7402
www.beckhoff.com/intralogistics

Ensuring safe material handling and distribution workspaces for humans and robots alike with TwinSAFE

Mobile robot advancements

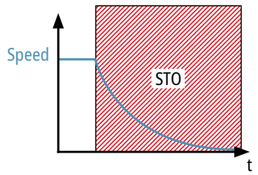
Hinge on programmable safety

Beckhoff provides the necessary engineering framework for mobile robot OEMs, integrators, and end users to keep people and assets safe while getting the job of material handling and logistics done.

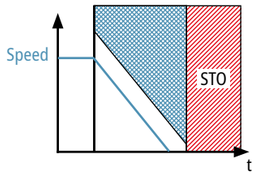
In his 1989 book, On Becoming a Leader, Warren Bennis popularized an old industrial joke. “The factory of the future will have only two employees, a man and a dog. The man will be there to feed the dog. The dog will be there to keep the man from touching the equipment.” Until that day arrives, engineered safety solutions will continue to be a critical part of industrial systems.

TwinSAFE logic is fully integrated into nearly all Beckhoff safety capable devices. This means logic may be centralized or distributed in whatever way makes the most sense for a particular application.

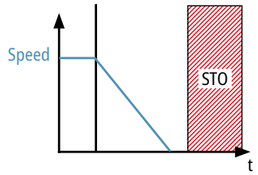
Stop functions



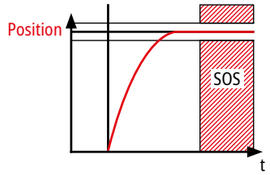
STO – Safe Torque Off



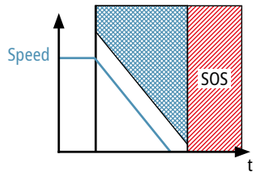
SS1(r) – Safe Stop 1 ramp



SS1(t) – Safe Stop 1 time

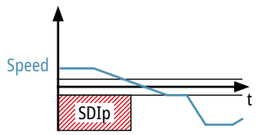


SOS – Safe Operating Stop

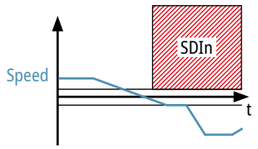


SS2 – Safe STop 2

Rotating direction functions

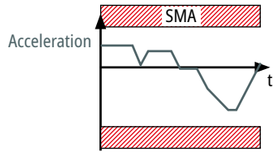


SDIp – Safe Direction Positive

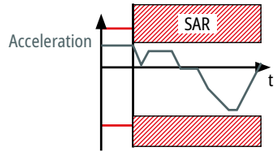


SDIn – Safe Direction Negative

Accelerations functions

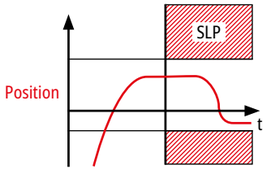


SMA – Safe Maximum Acceleration

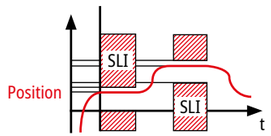


SAR –Safe Acceleration Range

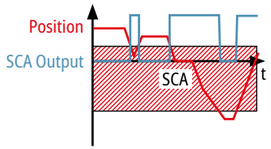
Position functions



SLP – Safe Limited Position

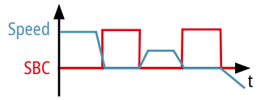


SLI – Safe Limizted Increment

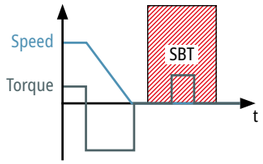


SCA – Safe CAM

Brake functions

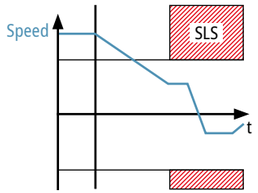


SBC – Safe Brake Control

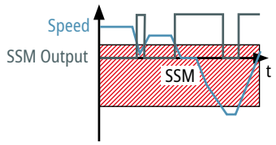


SBC – Safe Brake Control

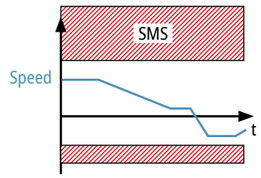
Speed functions



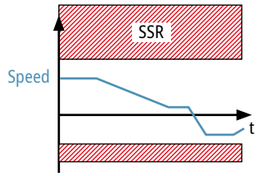
SLS – Safe Limited Speed



SSM – Safe Speed Monitor



SMS – Safe Maximum Speed



SSR – Safe Speed Range

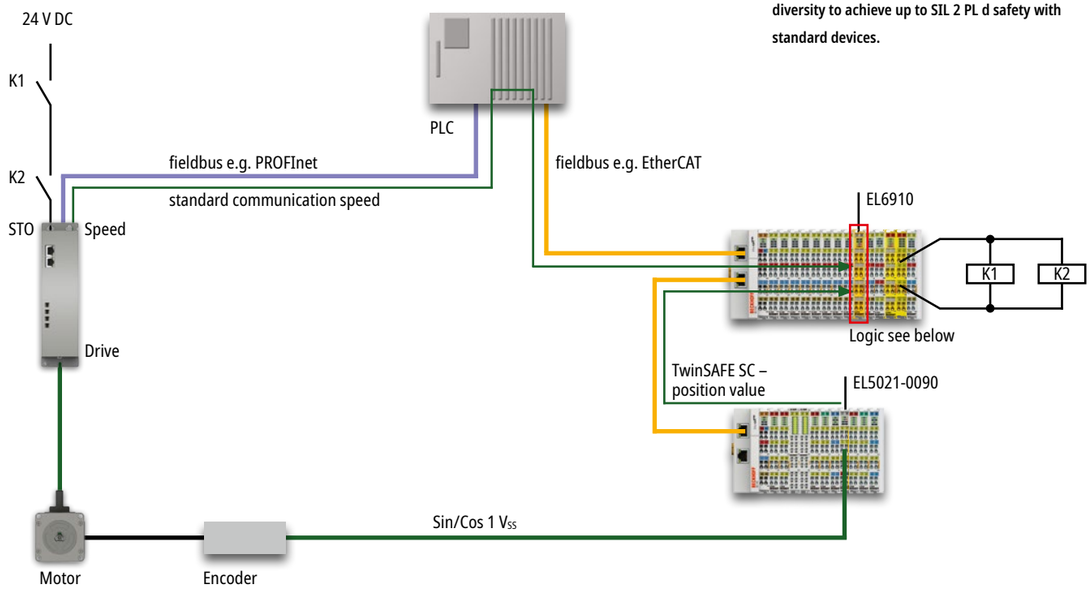
TwinSAFE logic is available in Beckhoff drives and motors with 17 different safe motion functions built right into these devices with more features being released on a regular basis.

Some of the largest and most complex automated systems today live in distribution centers common to the intralogistics industry. What was once defined by miles of conveyors, diverters, sorters, and forklift pickup points is moving squarely to the realm of mobile robots. The risks associated with these nomadic, autonomous machines lies at the point of human or machine interaction, be it intended or not. TwinSAFE programmable safety technology from Beckhoff provides the necessary engineering framework for mobile robot OEMs, integrators, and end users to keep people and assets safe while getting the job of material handling and logistics done.

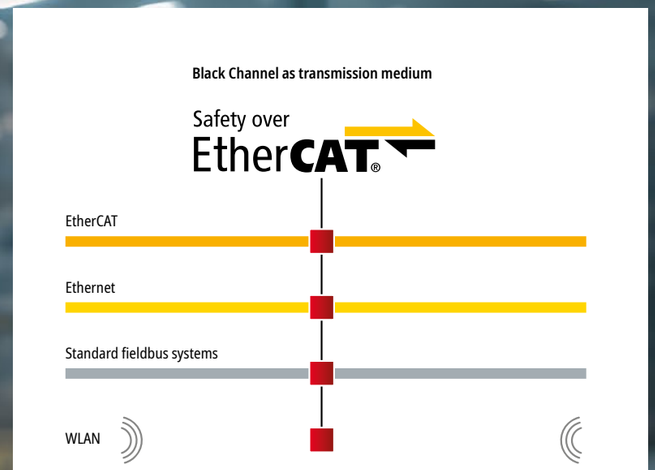
TwinSAFE streamlines safety implementations

Let's start by looking at the robot itself. In traditional designs, navigation, control and safety processors are all separate devices that take up valuable space and must be integrated to share data across vendor platforms. Our TwinCAT automation software fully integrates all three into a compact solution perfect for the confined spaces aboard a mobile robot. The TwinSAFE logic itself is fully integrated into nearly all Beckhoff safety capable devices. This means logic may be centralized or distributed in whatever way makes the most sense for a particular application.

TwinSAFE logic is even available in our drives and motors! Today, we offer 17 different safe motion functions built right into these devices with more features being released all the time. And depending on the drive/encoder combination selected, every function shown may be executed up to SIL 3, PL e. Whether the robot is traveling, or an articulated arm is picking a product, there are a whole range of possibilities for to humans to safely work side by side with mobile robots in fast-paced distribution centers.



TwinSAFE SC offers redundancy and technology diversity to achieve up to SIL 2 PL d safety with standard devices.



Safety over EtherCAT uses a 'black channel' approach to transmit safety-relevant data from TwinSAFE logic device to I/O and beyond.

What about using standard components in a mobile for robot safety functionality? TwinSAFE SC (Single Channel) links standard I/O hardware with a special firmware that secures the communication channel directly to a TwinSAFE logic device. By using redundancy and technology diversity, paired with a well-executed failure mode effects analysis (FMEA), safety functions may achieve up to SIL 2 performance level d with less expensive standard sensors and encoders and "standard" I/O. The TwinSAFE Application Guide is an excellent resource providing step by step instructions.

The importance of EtherCAT, FSoE, and EAP

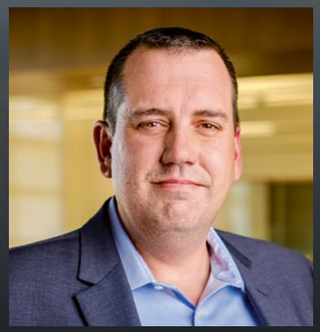
The communication backbone of TwinSAFE is Safety over EtherCAT, or FSoE. The EtherCAT safety technology was developed according to IEC 61508, is approved by TÜV SÜD Rail, and standardized in IEC 61784-3. The protocol is suitable for safety applications with a safety integrity level up to SIL 3. Safety over EtherCAT uses a 'black channel' approach to transmit safety-relevant data from TwinSAFE logic device to I/O and beyond. This means the safety containers do not depend on the underlying communication technology and aren't restricted to EtherCAT.

Safety containers can travel through fieldbus systems, ethernet or similar technologies, and can make use of copper cables, fiber optics, and even wireless connections. This provides important flexibility when selecting sensors such as scanners, radar, and other equipment. Connection to TwinSAFE may be handled via I/O or the sensor may be fully integrated into the Safety over EtherCAT network. Actuators such as drives may also be added to the safety network. While Beckhoff invented EtherCAT and FSoE, there are over 60 different FSoE device manufacturers at the time of this article. For more information on these vendors and Safety over EtherCAT, be sure to check out the EtherCAT Technology Group (ETG).

With so much communication flexibility, what if we look outside the mobile robot to the distribution center environment itself? What if robots aren't confined to one room? What if they can move freely throughout a facility resulting in a variable combination of robots in each space? Enter FSoE over EAP. The EtherCAT Automation Protocol (EAP) enables the cyclic, highly deterministic exchange of any desired variables between PCs that are connected by Ethernet. Communication between EAP devices takes place according to the Publisher/Subscriber principle and is specified by the ETG. As an IP-based protocol, standard Ethernet and wireless devices may be used. Each logic device is capable of up to 212 safe connections and may be cascaded, permitting simple safety commands such as an E-stop to be routed to the appropriate mobile robots. Looking to the future, the new TwinSAFE logic runtime, based on the EL6910 TwinSAFE Logic Terminal, will be capable of safe connections to over 2,000 devices!

A whole world of machine safety tools awaits

Finally, complementary tools help to quickly adopt TwinSAFE projects to new applications. The TwinSAFE editor is able import and export XML configuration files that have been built or modified outside the TwinSAFE editor environment. The TwinSAFE Loader enables you to download safety programs or customize program group settings quickly and efficiently. User management may be administered via TwinSAFE User, a command line tool for setting up user administration of a TwinSAFE safety controller without TwinCAT. All of these tools are designed to be incorporated into your own custom deployment toolset. Together, they provide maximum flexibility to increase the overall safety of your equipment and facility.



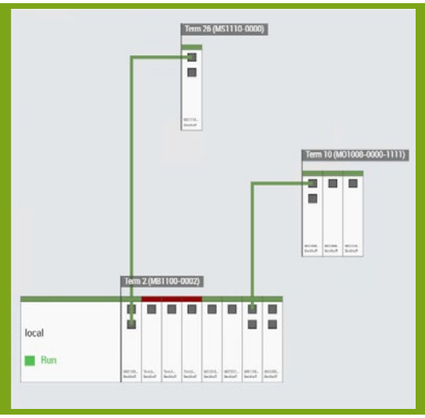
Christopher Woller,
Safety Product Manager, Beckhoff USA

More information:
www.beckhoff.com/twinsafe
www.ethercat.org
www.youtube.com/@TwinSAFE

Built-in diagnostics – and a change in mindset – help intralogistics operations run at optimum efficiency

It’s time to empower your maintenance teams

As in many other industries, intralogistics operations have little tolerance for surprises, particularly during peak seasons. When a sorter, shuttle, or conveyor line goes down, orders slip, labor gets misallocated, and short shipping windows quickly close. For e-commerce in particular, a major factor in a customer's decision to click the "place order" button is based on delivery speed. When shipments slip due to down equipment, so does customer confidence in that online retailer – even for well established brands.



TwinCAT’s built-in EtherCAT diagnostics enhance the maintenance of all Beckhoff systems with a drag and drop tool for real-time visualization in the TwinCAT HMI software with no engineering and requires no specialized tools.

Rethinking the maintenance philosophy

If every minute of downtime translates directly to lost productivity and lost revenue, why do material handling operations still rely on maintenance approaches that seem stuck in the past? Why are technicians still hunting for laptops, deciphering cryptic error codes, and spending precious time troubleshooting issues that should be immediately obvious?

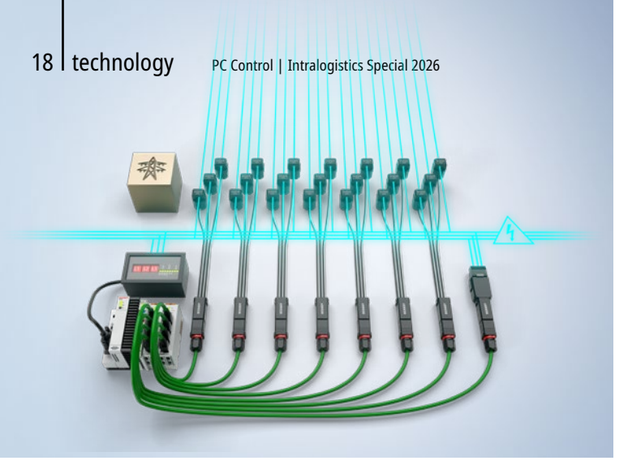
Maintenance teams should be treated as skilled professionals – not as a last-minute scramble force whenever issues arise. They’re the critical first line of defense when profitability is on the line and should be respected accordingly.

The fundamental question is this: Why should a maintenance technician need to be a PLC programming and Ethernet networking expert to diagnose common machine problems? Leading equipment builders are embracing a different philosophy – one that builds comprehensive diagnostic capabilities directly into the HMI, making critical information accessible at a glance and enabling faster resolution without specialized tools or deep platform expertise. The TwinCAT automation software platform, along with extensive EtherCAT diagnostics and analytics tools, provide a basis for a more modern machine maintenance philosophy.

Power and network monitoring:
A foundation for success

Effective diagnostics start with the basics. Modern HMIs provide real-time visibility into incoming power and power supply health, displaying voltage levels, over/under current conditions, and temperature data in intuitive formats. Built-in IPC diagnostics display CPU

The TwinCAT automation software platform, along with extensive EtherCAT diagnostics and analytics tools, provide a basis for more modern machine maintenance philosophies.



EtherCAT power measurement devices provide much needed visibility into incoming power and power supply health, voltage levels, and over/under current conditions impacting automation systems.

workload, memory and disk drive utilization, internal temperature readings, and fan status. Historical values further help technicians identify patterns – such as systems running hot during specific shifts, memory spikes during certain operations, or poor facility power causing random machine behaviors. All this data can be made freely available for maintenance teams and other technicians to access via the TwinCAT HMI.

EtherCAT has become the nervous system of modern automation – especially in the intralogistics industry. With traditional Ethernet fieldbuses, communication failures meant maddeningly time-consuming troubleshooting with specialized tools and software such as Wireshark. EtherCAT's built-in diagnostic data are made fully available in TwinCAT, combined with the TwinCAT HMI graphical EtherCAT network topology view, show the health of every device in real time at the touch of a button. Simple color-coded visual indicators identify the health of communication paths. Green indicates healthy network operation, while orange or red indicators pinpoint exact locations of cabling issues, power failures, or CRC communication issues – no laptop or deep engineering training required. And with the intuitive multi-touch capability of Beckhoff's Control Panels, even the diagnostics of large networks can be easily visualized by swiping around the screen, pinching, and zooming to zero in on a problem area in the network.

Rather than vague "network errors," each EtherCAT device can be deeply interrogated directly on the HMI and can identify the exact port of the device where the communication problem exists – immediately narrowing the root cause to a cable issue, power failure, or interference at that exact location. With EtherCAT's self-healing capabilities, remedying the problem restores the network automatically and is updated on the HMI.

Event video playback: See what actually happened

One of the most frustrating scenarios is returning to a stopped machine with no clear understanding of what went wrong, particularly knowing that the clock is ticking to restore the flow of orders. Traditional alarm logs provide timestamps and error codes but leave technicians guessing the actual sequence of events.

Combining two features of TwinCAT solves this dilemma elegantly. First, TwinCAT Vision software directly integrated into the PLC enables you to gather images and create video files when events trigger. The optimal solution then is to utilize video playback integrated with the TwinCAT event viewer control withing TwinCAT HMI. Technicians can simply double-click an alarm and immediately watch exactly what happened – product jams, inadvertent safety triggers, or procedural errors.

This proves particularly valuable in high-speed intralogistics applications. Instead of examining the aftermath and reconstructing events, maintenance teams see the actual incident. Was it a damaged box? Downstream backups? An operator error? The video evidence makes root causes immediately apparent, enabling faster, more confident decisions for resolution of the immediate issue and how to optimize the system to prevent the error in the future.

From cryptic alarms to plain language guidance

Too many systems still throw out vague alarms – "Drive fault," "Zone blocked," "Error 4312" – that send techs hunting through manuals or calling the OEM to solve the mystery.

Modern, AI-driven approaches pull detailed status from drives, MDR zones, safety devices, and sensors over common fieldbuses and turn it into human-readable diagnostics: "Right divert MDR overcurrent – likely jammed tote" or "Zone 14 accumulation sensor blocked – clear path and press reset." This is the fastest path to reduced downtime without making every technician a PLC expert – making the machine a better communicator. With AI, the goal should be to create a machine that can not only self-diagnose but also communicate with the operator and maintenance staff with clear actionable instructions for fast resolution. This is possible via AI agents which can be accessed via the engineering tools or operator interface via TwinCAT CoAgent.

Embedded maintenance resources

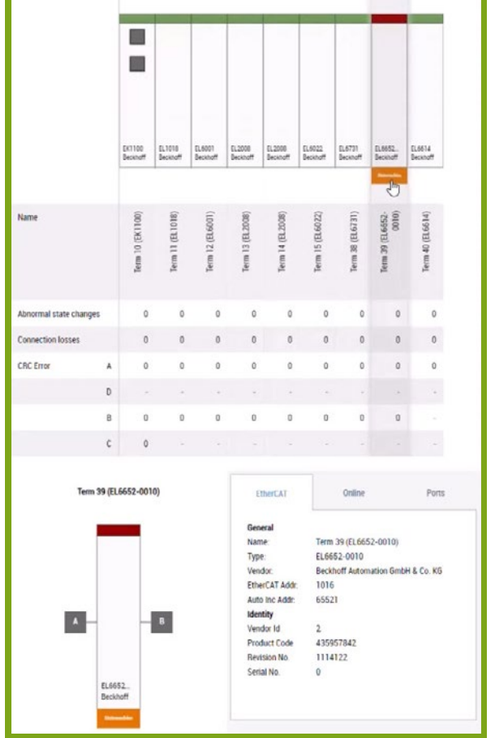
Progressive equipment builders embed maintenance videos, wiring diagrams, and configuration information directly into the HMI. Need to replace a worn conveyor roller? Pull up a maintenance page and play a step-by-step video. The same interface provides connector identification, wiring color schemes, and specific PLC parameters for different roller types.

This approach recognizes that maintenance documentation isn't just about having information available somewhere – it's about putting the right information in front of technicians at the exact moment they need it in user-friendly formats.

Flight recorder for your equipment

Traditional data logging approaches that sample at one-second intervals fall woefully short when diagnosing modern high-speed material handling systems running PLC cycles in the millisecond – or even microsecond – range. TwinCAT Analytics Logger acts as a true "black box logger" or flight recorder for equipment, continuously capturing data at every PLC execution if needed, creating a comprehensive record of everything that happens during equipment operation.

This high-fidelity data can be stored locally on the controller, or on network-based storage, using configurable ring buffers – perhaps retaining the last 24 or 48 hours of operation – ensuring that when intermittent problems occur or machines exhibit unexpected behavior, the evidence is already captured and waiting for analysis. When issues arise, maintenance teams or remote support engineers can retrieve this recorded data and analyze it using the TwinCAT Analytics Service Tool, which provides powerful algorithms



Integrated EtherCAT diagnostics on the HMI visually pinpoint the exact locations of cabling issues, power failures, or CRC communication issues – no laptop, no Wireshark, no meter, or deep engineering training required.

Scope tools integrated into TwinCAT are available to provide even greater insights into the performance of EtherCAT networks and diagnostic data.

for identifying patterns, correlating events, and pinpointing root causes that would otherwise be invisible in traditional low-resolution logs. Whether troubleshooting random faults that don't make sense, investigating inconsistent cycle times, or optimizing machine performance, having access to microsecond-level historical data transforms maintenance from reactive guesswork into data-driven problem solving.

The tools within TwinCAT Analytics Service Tool, combined with equipment data logged via Analytics Storage Provider, enable technicians at end-user facilities and OEMs to identify unwanted equipment behaviors and analyze machine timing. Critically, this can be done without needing deep programming expertise or intimate familiarity with the equipment's PLC code.

Modern control architectures accommodate easy and secure access remotely, enabling technicians to check machine health from anywhere or allowing OEMs to provide remote support without site visits. The same HMI framework accessed through web browsers or mobile devices enables off-hours monitoring, predictive maintenance scheduling, and faster responses to issues.

The bottom line for maintenance time

Equipment builders embracing comprehensive built-in diagnostics aren't just adding features for a spec sheet – they're fundamentally changing the maintenance experience for their end user customers. Systems that enable faster troubleshooting reduce downtime costs, minimize the need for specialized expertise, and help operations run efficiently even as skilled labor becomes scarcer.

This technology exists today. The question for equipment builders is whether they'll continue asking maintenance technicians to needlessly toil away as in years past or embrace the philosophy that diagnostic intelligence belongs in the machine itself, accessible through intuitive interfaces that make every technician more effective.

Beckhoff's TwinCAT automation software, including its intuitive HMI, event video playback via TwinCAT Vision, machine "flight recorder" via TwinCAT Analytics, and the rich diagnostics of EtherCAT make it possible to fundamentally change the traditional approach to machine diagnostics and maintenance as a whole.

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More information:
www.beckhoff.com/twincat
www.beckhoff.com/ethercat
www.beckhoff.com/ai
www.beckhoff.com/analytics

Writing a new script for how medications move

The future of pharmaceutical fulfillment hinges on fully integrated automation and mechatronics

Pharmaceutical fulfillment is entering a period of rapid transformation. The COVID-19 pandemic accelerated the shift toward e-commerce and home delivery across nearly every retail category, and prescriptions were no exception. Consumers now expect medications to arrive at their doorstep with the same ease and speed as a grocery order or household item. Meanwhile, retail pharmacies increasingly rely on centralized fulfillment centers to efficiently handle the growing prescription volume, reduce reliance on overburdened in-store staff, and allow pharmacists to focus more on patient care.

At the same time, the industry faces mounting pressures: chronic labor shortages, increasing order complexity, more stringent regulatory expectations, and near zero tolerance for errors. A single miscounted bottle or mislabeled medication can have severe financial implications and, more importantly, represent a potentially life-threatening risk for the patient. Because pharmaceuticals simply cannot be returned to inventory or repackaged, the cost of mistakes is exceptionally high. As a result, fulfillment operations are searching for technologies that offer not just improved throughput, but also higher levels of accuracy, traceability, and adaptability that were previously impossible with conventional machinery.

These challenges make the case for next-generation automation technologies like Beckhoff's XPlanar and XTS intelligent transport systems exceptionally compelling. Especially as more pharmaceutical fulfilment operations seek scalable solutions, from compact micro-fulfillment inside hospitals to massive central fill and direct-to-consumer hubs that can support integrated quality checks, robust traceability, and new individualized packaging. The shift has made flexible, software-defined automation the new standard, and Beckhoff's portfolio of mechatronics, controls, and integrated software is proving to be an ideal foundation for this new world of pharma.

Rethinking automation in pharmaceutical fulfillment

Traditional conveyors and fixed automation systems were never designed for the variability or complexity of modern pharmaceutical fulfillment order profiles. Historically, these systems moved one type of package through sequential linear processes taking up significant floor space with complex mazes of conveyors that presented significant maintenance challenges. One point of failure can bring all upstream processes to a costly standstill. Today, a single customer order may include a prescription bottle, a box of pre-packaged "unit-of-use" medication, and even a customized roll of multi-dose strip pouches that combine the patient's daily prescriptions and supplements into pre-sorted pouches for the month.

This level of variation demands material handling systems that behave less like rigid machinery and more like orchestrated fleets of independent, intelligent carriers. Facilities need transport platforms that can route products dynamically, change workflows through software rather than mechanical rework, and merge different product types into a single shipping container with precision timing.

Beckhoff's XPlanar and XTS mechatronic transport systems, combined with TwinCAT Vision software, machine learning, integrated robotic control, and secure enterprise connectivity make this vision a reality. Rather than designing the process around mechanical limitations, engineers can now design around

the ideal workflow and trust the automation platform to adapt instantly to product variability, order prioritization, and new packaging formats.

XPlanar's Flying Motion elevates automation

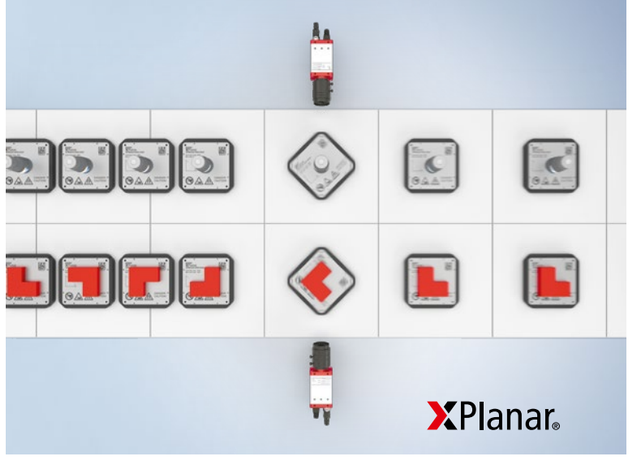
One of the most transformative technologies enabling this shift is XPlanar, Beckhoff's magnetically levitating transport system. XPlanar movers glide freely at speeds up to 3 m/s above a planar surface made up of modular tiles that generate contact-free electromagnetic propulsion. This offers each independent mover six degrees of freedom including translation, rotation, and even tilting. This "flying" capability eliminates all mechanical wear and maintenance concerns while delivering precise positioning and exceptionally quiet operation, both invaluable in a clean and tightly regulated pharmaceutical environment.

XPlanar's flexibility shines in pharmaceutical fulfillment because each mover operates independently and can carry a wide variety of payloads, as well as being able to coordinate multiple movers together to move as one for larger items or totes. A bottle held in a puck, for example, can be labelled, travel to a dispensing station for filling, then to a vision verification cell. From there, it can either immediately proceed to capping, or if an issue is detected, it can be diverted to a manual pharmacist verification station without interrupting other product flows. In addition, XPlanar enables parallel processing and duplication of certain slower stations in the process, rather than the entire system being limited to the throughput of the slowest station in a traditional sequential linear operation. Also, the system can intelligently bypass individual stations that are temporarily not functioning due to maintenance or refilling a consumable, without stopping or slowing down the rest of the system. On the same grid, another mover may carry a roll of customized multi-dose strip-pouches, while a third carries a pre-packaged unit-of-use medication retrieved from an automated storage and retrieval system and labeled with patient order data.

This ability to handle different package formats simultaneously allows designers to merge multiple fulfillment processes into a compact, efficient footprint. Orders that once required separate lines with dedicated equipment can now converge on a single XPlanar system, where movers deliver all components to a collation station before sortation and finally outbound shipment. XPlanar's optional ID Bumper technology ensures that every mover is tracked, even across unexpected power loss, minimizing waste, reducing recovery time, and establishing a continuous digital chain-of-custody – a crucial requirement for pharmaceutical traceability.

XTS with NCT: A robotic revolution in linear transport

Where high-speed, linear throughput is needed, the XTS complements XPlanar by providing a linear track system with magnetically propelled movers capable of continuous, precise product transport at up to 4 m/s. With the addition of No Cable Technology (NCT), each XTS mover can run a powered end effector. This essentially turns the mover into a wireless robot with onboard power and communication to control complex actuators. In pharmaceutical fulfilment applications, this enables movers to perform localized functions, from pick and place using pneumatic grippers without worrying about vacuum lines, electromagnetic or motorized actuators, or even weighing by integrating a load cell directly on the mover.



XPlanar movers glide freely at up to 3 m/s and offer six degrees of freedom, including translation, rotation, and tilting using electromagnetic propulsion.

Combined with XTS Track Management, which enables XTS movers to dynamically divert from one track to another, this dramatically simplifies the system architecture. Instead of slowly transporting products at a constant speed between sequential stations and relying on slow pneumatic diverts and gates to manage traffic flow, XTS movers can quickly and intelligently race to their destination asynchronously with delicate and precise control of each individual product without worrying about pucks and pill bottles crashing into each other and spilling medications. Such capabilities help pharma fulfillment centers increase output within existing floor space, which is critical at a time when end users are demanding more throughput in a smaller footprint.

Integrated machine vision and AI

The highest priority in pharmaceutical fulfillment remains in accuracy, and automated inspection is fundamental to achieving it. Beckhoff's TwinCAT Vision integrates camera control, image processing, and decision logic directly into a standard PLC environment. This native integration eliminates the complexity of external vision systems and ensures high-speed coordination with the motion control and robotics run on the same platform.

A compelling use case is bottle inspection. After a dispensing machine counts and drops medication into a bottle, an XPlanar mover can position the bottle beneath a TwinCAT Vision Camera Unit equipped with a liquid lens. The lens adjusts automatically to the correct focal depth to capture a crisp image inside the bottle, regardless of fill level. Machine learning algorithms could then compare the pill shapes and colors to a central database, confirming its identity and potentially skipping manual pharmacist verification to help ease the worsening skilled labor shortages. What once required human eyes and significant labor overhead can now occur automatically, reliably, and with fully auditable data logging.

In addition to pill verification, the same vision platform handles barcode reading, label and cap quality inspection, etc. This centralizes quality control into a single cohesive software environment that is fully synchronized with your transport system.

Regulatory compliance and secure operation built into the control layer

Pharmaceutical operations must meet strict regulatory requirements, particularly around data integrity, user access, and traceability. Beckhoff's TwinCAT 3 HMI Audit Trail module (TF2400) provides secure, FDA 21 CFR Part 11-compatible electronic records and electronic signatures. Every critical action, from dispensing counts to vision inspection to label printing and HMI user inputs, is logged with a timestamp and user identity. Integration with Lightweight Directory Access Protocol (LDAP) allows centralized management of user roles and permissions, simplifying compliance across large fulfillment operations.

Cybersecurity is equally essential. Beckhoff's EtherCAT fieldbus technology, the communication protocol behind XPlanar and XTS, provides unrivaled cybersecurity resilience. Further evidence of this is the recent announcement that EtherCAT has already met the new EU Cyber Resilience Act (CRA) requirements for digital devices, without requiring any modifications. We offer several modern encryption protocols for secure communication to the enterprise natively in TwinCAT software.

Integrated robotics:
Perfect synchronization with intelligent transport technology

Robots play a central role in modern fulfillment, whether performing high-precision picking, labeling, or final de-pucking and collation. Beckhoff's universal automation platform allows all robot kinematics to run directly within the same environment that controls XPlanar, XTS, standard conveyors, and vision systems. This eliminates the need for large, proprietary robot controllers and reduces both cost and system complexity.

Because everything is synchronized through a unified control platform, robots can pick from XPlanar and XTS movers with micrometer accuracy or place bottles, boxes, and pouch rolls into outbound containers with intelligent buffering. This tight integration ensures smoother product flow, smaller footprints, and significantly higher throughput.

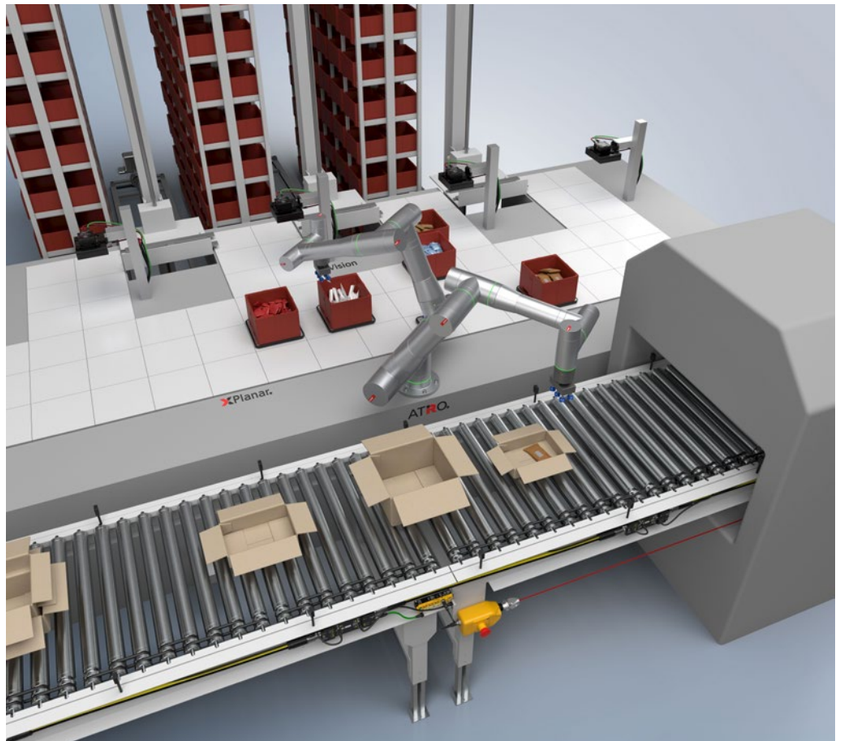
Flexible, scalable, software-defined automation

Pharmaceutical fulfillment is only becoming more complex, personalized, and tightly regulated, all at a time when skilled labor is in short supply. Meeting these challenges requires automation that is not only fast and accurate but scalable and adaptable to changing product formats, order profiles, and regulatory expectations.

Beckhoff's XPlanar Flying Motion, XTS NCT, TwinCAT Vision, integrated robotics, secure connectivity, and compliance-ready HMI environment form a cohesive platform that elevates pharmaceutical fulfillment from rigid mechanical systems to intelligent, software-defined automation. These technologies deliver the flexibility, precision, and reliability the industry demands, while providing a long-term scalable platform to fit any size fulfillment operation from small backroom microfulfillment to sprawling central fill facilities and anything in-between.

The future of pharmaceutical fulfillment is built on higher throughput, smaller footprints, and easily maintained systems which are adaptable to ever-changing market trends – without compromising order accuracy. With Beckhoff, the future is here today.

XPlanar's Flying Motion is an ideal pairing with robotics and conveyance systems in complex material handling applications such as pharmaceutical fulfillment.



Nathan Hibbs,
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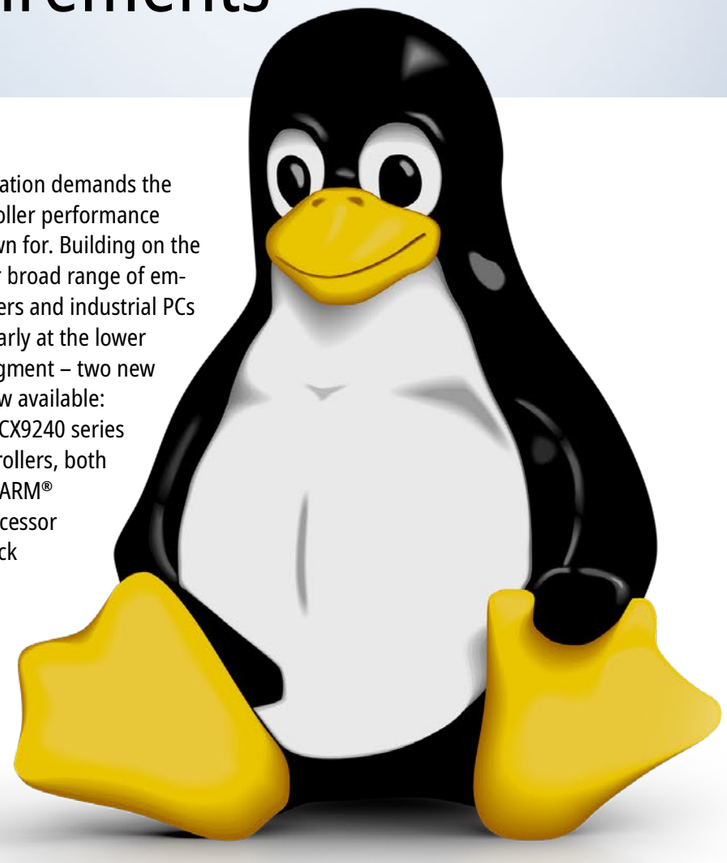
More information:
www.beckhoff.com/xts
www.beckhoff.com/xplanar

With the TwinCAT runtime for real-time Linux®, Beckhoff is expanding the possibilities for real-time control.

Beckhoff's scalable controller portfolio empowers fulfillment operations to meet today's demands and capitalize on tomorrow's opportunities

Entry-level controls offer cost-effective automation for less demanding control requirements

Not every application demands the ultra-high controller performance Beckhoff is known for. Building on the scalability of our broad range of embedded controllers and industrial PCs (IPCs) – particularly at the lower performance segment – two new offerings are now available: the CX82x0 and CX9240 series embedded controllers, both powered by the ARM® Cortex®-A53 processor with 1.2 GHz clock frequency.



With TwinCAT automation software's ability to fully leverage all available cores, multi-core processors take on even greater importance. The CX82xx provides 2 CPU cores for compact control tasks, while the CX9240 offers 4 cores for more demanding applications, delivering significantly higher power than its predecessor, the CX9020. Both devices feature 1 Gbit Ethernet interfaces, which enable significantly higher transfer rates, along with a built-in capacitive 1-second UPS. Memory is also greatly enhanced: the CX82x0 includes 1 GB LPDDR4 RAM, while the CX9240 doubles that with 2 GB, offering twice the capacity of both the CX82x0 and the CX9020.

The C6043 Industrial PC with NVIDIA® GPU handles applications with higher demands for 3D graphics or deeply integrated vision and AI program blocks with minimal cycle times.

The CX82x0 fills the performance gap between the CX7000 (Arm® Cortex®-M7) and the CX9240, giving users a broad range of cost-optimized options for compact controls that are well suited to less demanding applications. TwinCAT automation software can transform both devices into a high-performance PLC and motion control system. The CX9240 can be used with or without visualization and includes a DisplayPort for connecting to Beckhoff's new cost-optimized CP49xx and CP59xx Next multi-touch panels.

For warehouse integrators, machine builders, and end users in intralogistics, scalability ensures that every application gets the right level of performance at the right price. Seamless integration into the Beckhoff ecosystem also guarantees lifecycle protection: all embedded controllers and industrial PCs (IPCs) are programmed with TwinCAT, and existing projects can be executed on these next-generation devices without modification. Performance is further extended by EtherCAT (E-bus) which is integrated into the devices and supports unlimited connectivity to Beckhoff's EtherCAT I/O portfolio.

Both the CX82x0 and CX9240 are delivered with the new Beckhoff RT Linux® operating system, ensuring modern performance and long-term availability.

Linux®-based real-time control opens new application possibilities

With the TwinCAT runtime for real-time Linux®, Beckhoff is expanding the possibilities for real-time control. Multiple TwinCAT runtimes can now be executed on a single IPC, enabling users to consolidate system components onto one high-performance platform for simplified programming and diagnostics. In addition, real-time access to a GPU allows hardware acceleration for demanding applications such as machine vision and beyond.

The TwinCAT runtime for real-time Linux® is based on Beckhoff's own Linux® distribution, which expands the existing spectrum of operating systems beyond Windows and TwinCAT/BSD. This distribution was developed using the free Debian operating system and includes a Linux® real-time kernel as standard for real-time execution of the runtime. The Debian package system also makes it easy to install additional software on the same device.

This all combines to provide a TwinCAT runtime for stable real-time control on a Linux® platform. Using container technologies such as Docker®, Podman, or LXC, several TwinCAT runtimes can be executed on a single IPC to achieve modularity in machine control and other automation applications. The individual execution of several TwinCAT runtimes on a single IPC facilitates hardware consolidation with corresponding cost advantages due to the improved utilization of the available computing capacity.

Linux® users can take advantage of a whole new world of automation possibilities, while the familiar TwinCAT application programming remains unchanged. Benefits include the optimized execution of several real-time applications on a single CPU, increased user flexibility thanks to the modular control code, simplified addition or replacement of application modules, and the targeted execution of updates for individual applications. There is even a reduced overall investment in terms of both time and costs for engineering.

TwinCAT runtime for real-time Linux® is initially available for the new Arm®-based CX82x0 and CX9240 embedded controllers. The Beckhoff Linux® distribution will then be successively rolled out for all Beckhoff's other industrial and embedded PCs.

For high-performance control applications

Beckhoff also continues to extend the mid- and high-performance controller offering of industrial and embedded PCs. The scalable ultra-compact C60xx series industrial PCs, which combine maximum computing power in the most compact format available, includes Intel Atom®, Celeron®, Pentium® and a wide selection of 11th/12th/and 13th generation Intel® Core™ processors up to 24 cores. This represents a broad performance range that's able to support all distribution center requirements.

C6043 | Ultra-compact Industrial PC with NVIDIA® GPU

Smart distribution and fulfillment centers are embracing the latest technologies such as robotics, vision systems, and AI to stay competitive and optimize operations with state-of-the-art automation solutions.

The C6043 Industrial PC with NVIDIA® GPU handles applications with higher demands for 3D graphics or deeply integrated vision and AI program blocks with minimal cycle times. It extends the series of ultra-compact IPCs to include a high-performance device with a built-in slot for powerful graphics cards. With the latest Intel® Core™ processors and highly parallelizing NVIDIA® graphics processors, this IPC becomes the perfect central control unit for ultra-sophisticated applications. The Beckhoff TwinCAT 3 control software is capable of mapping this as a fully integrated solution without any additional software or interfaces. With the additional freely assignable PCIe® compact module slot, the C6043 can be flexibly expanded with supplementary functions.

The use of Intel® Core™ processors in the 12th and 13th generations gives the C6043 enormous computing power, with the Intel® Core™ i5, i7, and i9 processors built in a hybrid architecture for the very first time. As with previous generations, Intel® Celeron®, Pentium®, and Core™ i3 are equipped exclusively with classic performance cores. Four additional efficiency cores are added to the Core™ i5, eight to the Core™ i7, and 16 to the Core™ i9 processors. This combination of performance and efficiency cores allows applications to be implemented on a total of up to 24 real cores.

While performance cores are primarily suitable for high-performance, single-thread applications, many additional threads can be executed in real time or in user mode on the additional efficiency cores. Each individual core can be individually configured in clock frequency, just as it can with the 11th generation of Intel® Core™ processors. The power supply and the cooling have sufficient reserves to utilize the available computing power of the processors and the external graphics card. Depending on the graphics performance, the system is balanced in terms of available CPU power to always get the maximum out of the application. Measuring 132 x 202 x 127 mm (W x H x D), the device remains incredibly compact despite its computing power and represents yet another milestone in terms of power density.

The C6043 unlocks new potential for intralogistics equipment. For example, high-speed singulation systems running advanced algorithms can achieve greater throughput while the same device also powers high-speed sorters. With multiple TwinCAT runtimes in separate Linux® containers, multiple machines can be modularized on a single IPC. Robotics applications that rely on advanced vision for handling objects of varying shapes and sizes are also supported through the optional NVIDIA® GPU extension. By combining multi-core computing, GPU acceleration, Linux® containers, and the TwinCAT Linux® runtime, the C6043 delivers the scalability and performance to handle even the most complex warehouse operations.

Scalable for every application

With the powerful TwinCAT automation platform and a broad hardware portfolio—from compact embedded PCs to mid-range and ultra-compact systems, all the way to extreme high-performance industrial PCs – Beckhoff equips customers to tackle today's toughest intralogistics challenges and prepare for the future. Supporting PLC, motion, vision, robotics, HMI, speech, communication, machine learning, and analytics, TwinCAT provides a foundation for success as AI continues to drive competitive advantages for leading warehouse and distribution center operators.

TwinCAT runtime for real-time Linux® is initially available for the new Arm®-based CX82x0 and CX9240 embedded controllers.

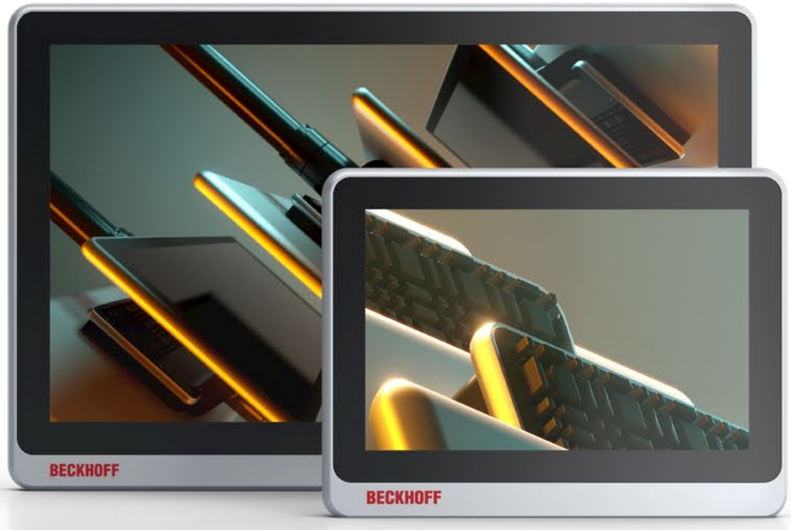
Doug Schuchart
Global Material Handling & Intralogistics Manager, Beckhoff

More information:
www.beckhoff.com/embedded-pc
www.beckhoff.com/ipc

Advanced, cost-optimized series of multi-touch industrial displays offers more efficient operator interface concepts

Beckhoff introduces Next multi-touch control panel generation in a smart design

Following over 25 years of successful in-house production of control panels and panel PCs, and 12 years of expertise in multi-touch screen design, Beckhoff is releasing a new smart panel design: the Next panel generation. With its improved electronics concept and standardized connection solution, this new hardware platform builds on a technological lead in multi-touch-enabled HMIs. The consistently high quality of Beckhoff Control Panels and Panel PCs is combined with an improved price/performance ratio.



Doug Schuchart
Global Material Handling & Intralogistics Manager, Beckhoff

The cost-optimized Next panel series further expands the diversity of Beckhoff's broad portfolio of industrial display hardware. As usual, this generation of operator panels and panel PCs offers user-friendly operation thanks to advanced multi-touch technology, a high-quality design, and a wide choice of formats and options. These devices are characterized by a smart, sleek electronics and device design, EtherCAT communication, including FSoE (Safety over EtherCAT) at the push of a button, and high-quality industrial-grade displays with multi-finger touch functionality. The new designs also align with growing requirements in the intralogistics market to improve safety standards and address continuing cost pressures.

EtherCAT has continued its impressive growth worldwide over the last few years even during some challenging global economic conditions. This growth is due in part to the increasing acceptance and adoption of EtherCAT in intralogistics where the benefits of EtherCAT and FSoE present clear advantages over other fieldbuses and safety systems. Over this period, some of the largest end users that shape the intralogistics industry have adopted EtherCAT and FSoE. This means integrating EtherCAT into control panels with an FSoE e-stop button simplifies the safety architecture and adds even further value to the cost- optimized units.

The Next multi-touch panels with IP20 or IP65 protection ratings are high-quality and are resilient in demanding environments. Like all products introduced into the Beckhoff ecosystem, they will be available over the long-term and integrate easily with all other Beckhoff technologies, including the TwinCAT HMI software platform. A wide range of display sizes are available from 7 to 24-inches in various formats, as cabinet installation and support arm variants. This includes a variety of accessories and mechanical extensions. The latest standards have been integrated to provide a future-proof control panel platform that makes it easy to optimize costs without changing the system design and provides tried-and-tested touch technology with anti-glare and anti-ghosting effects.

In addition to the new line of multi-touch panel displays, Beckhoff is also introducing a new line of multi-core Panel PCs with Arm® processors in a built-in format for installation into a cabinet door, as well as a series for pendant or swing arm mounting. The new CP4xxx and CP5xxx Panel PCs offer a complete real-time control solution with HMI for lean Linux®-based applications and are ideal as thin clients, edge solutions, or as just an HMI. The high-performance Arm® processors have six cores, consisting of two 2.0 GHz Arm Cortex®-A78 and four 2.0 GHz Arm® Cortex®-A55 cores, striking an excellent balance between performance and efficiency. This provides new cost-effective solutions for a wide range of automation equipment in fulfillment operations.

As warehouses, distribution centers, and fulfillment operations increasingly adopt automation to handle rising demands for faster deliveries amid limited labor availability, it is essential that operators can interact with equipment in familiar, intuitive ways. Multi-touch operator interfaces address this need by providing the same type of interaction people use daily on smartphones and tablets. In large facilities, it can be challenging to visualize an entire machine – such as a sorter – or the broader operation in a single view. Multi-touch displays solve this by highlighting problem areas when alarms or bottlenecks occur, allowing operators to quickly pinch and zoom, pinpoint the issue, and take corrective action.

The introduction of the Next multi-touch panel generation starts with the CP49xx built-in Control Panel with an IP 20 protection rating and the CP59xx Control Panel with an IP 65 protection rating for mounting arm installation. The latter are intended for direct mounting on a VESA monitor mount by the customer and can optionally be fitted on a mounting arm with a 48 mm round tube.

With the interface versatility, long-term availability, and cost-effectiveness of Beckhoff's Next multi-touch operator interface panels, your fulfillment operation can advance to the next level of automation, achieving greater uptime and enhanced safety integration.

More information:
www.beckhoff.com/next-panel-generation
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How the innovative MX-System is revolutionizing automation in machine and systems engineering

The future of the intralogistics industry is cabinet-free

Intralogistics and material handling equipment OEMs are under increasing pressure to innovate. To compete successfully, you need to automate your products quickly and comprehensively, offer more customized solutions, and win over buyers around the globe with an environmentally and economically sustainable system footprint.

1895

The British electrical company Ferranti develops oil switches to minimize the risk of fire and accidents caused by sparks in electrical switchgear.

MX-System fully integrated into the machine: Open mounting directly on the base frame simplifies wiring, improves accessibility, and replaces the control cabinet – a superior solution, especially in terms of design.

Given the current challenges, the concept of the control cabinet – which has remained largely unchanged for decades – is increasingly becoming a bottleneck. This is due to its limited flexibility and modularity in view of the greatly increased demands on the machines. In addition, the engineering and production processes for control cabinet projects are complex and barely automated. Apart from that, maintenance and service require experts, who are both expensive and hard to find. The concept of the control cabinet must be reconsidered and implemented in new ways to ensure that progress is not slowed down. At Beckhoff, we have achieved this by developing a solution for control cabinet-free automation, the MX-System.

Top trends and challenges for equipment manufacturers and system integrators

Whether your company manufactures AS/RS, sortation systems, or innovative conveyor technology, there are a handful of trends[1] that ultimately set the framework conditions for your company internationally. Here is a brief overview of our top five.

1. Pressure to innovate due to digitalization

The pace of automation in machine and systems engineering is accelerating. Following the acceleration of networking brought about by the expansion of the Industrial Internet of Things (IIoT), further milestones are now being achieved on the road to digitalization. The focus is on robotics and AI. Artificial intelligence algorithms require a comprehensive database. The challenges in engineering therefore involve recording and handling process data, including in the form of physical variables such as voltage, current, and temperature. Another challenge lies in creating digital twins for production simulation and modeling. In short, the pressure to achieve digital innovation is increasing and demands flexible, highly customized solutions.

2. Shortage of skilled workers

The latest study[2] by an international personnel service provider confirms that 75 percent of companies worldwide are suffering from an acute shortage of skilled workers. The main driver is demographic change. After Japan, its impact is being felt particularly strongly in Germany. The German Economic Institute (IW)[3] forecasts that the German mechanical engineering industry will lose 296,000 skilled workers by 2034 due to retirement alone. However, only 118,000 new workers are expected to be hired in the same period. The bottom line is that the industry is short by 178,000 skilled workers.

3. Globalization

Globalization continues to advance, not only on the market side but increasingly on the production side as well. A growing number of manufacturers are locating their production process in places where potential new customers can be found or where labor and energy costs are attractive, rather than producing exclusively or primarily in their home market. If you want to realize the potential savings effectively, you need machines and material handling solutions that meet high global standards and that can be used anywhere without major technical adaptations due to regulatory requirements.

4. Sustainability and footprint minimization (ESG)

In the context of machines and systems, sustainability is a decisive competitive factor. This is true in terms of energy consumption and emissions during operation, as well as material and space consumption. This is why the footprint of machines and systems has been a compliance issue for some time. It is also becoming an increasingly important aspect for manufacturing companies due to ESG (Environment, Social, Governance) requirements. When assessing the value and attractiveness of a company, investors and rating agencies now apply ESG criteria rather than examining economic efficiency alone. These criteria are becoming increasingly important due to new political goals, such as those defined in the European Green Deal.

5. Customization and short time-to-market

Off-the-shelf products are now almost impossible to sell in the machine and systems engineering market. Today's users demand solutions that are precisely tailored to their requirements and their spatial and operating conditions on site. For you as a equipment manufacturer or systems engineering company, this means that your products must be designed in such a way that they can be quickly adapted to meet individual requirements. One way to achieve this is through modular, distributed concepts. In addition, new basic requirements are being added at an ever faster rate. The companies that can offer new developments that meet these requirements with a short time-to-market will secure a valuable competitive edge.

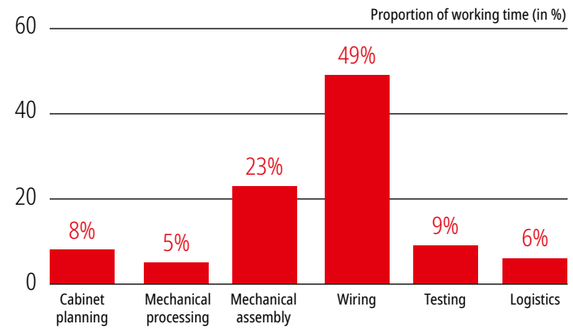
The control cabinet can be a limiting factor when dealing with the top trends

Up to now, for anyone wanting to develop solutions to meet the major challenges in machine and systems engineering, there has been no way to get around the control cabinet – and the way through it is becoming increasingly narrow. This is because the number of devices, relays, and cables that converge within it has been growing dynamically over the years. For quite some time, the control cabinet has been creating a bottleneck for automation and progress.

The following review shows how and why the control cabinet is now hindering progress when it comes to meeting the key challenges.

Digitalization and automation require larger control cabinets

The number of components installed in the control cabinet is growing. These additions range from new devices to the necessary fan and cooling units, as well as supplementary measurement and testing technologies. The latter need to be planned and installed separately when using conventional control cabinets. This is both labor-intensive and costly. What's more, each additional installation requires more space, especially as the defined minimum distances in relation to heat emission and temperature sensitivity must be maintained. As a result, control cabinets are becoming increasingly bulky, complex, and expensive.



Proportion accounted for by the individual work steps in the total time required to manufacture and assemble a control cabinet.

As the complexity of control cabinets increases, so does the workload

The increasing complexity makes control cabinet construction more time-consuming and labor-intensive. For equipment manufacturing companies, this means either accepting longer throughput times and lower productivity in production, or hiring additional skilled workers. In times of a shortage of skilled workers, however, this is hardly feasible on the scale required. The work has to be done with the available resources.

1903

A major fire breaks out at a plant in Bristol. The cause was a defective oil switch. This type of switch is surrounded by an oil-filled housing. Oil extinguishes the arcs that occur during switching. If the housing has a leak, gases can escape and ignite.

1908

The English engineer Henry Clothier develops a closed metal cabinet for switchgear to prevent disasters like the one in Bristol. The experts are not convinced by the new development at first.

1930s

Even though metal-sheathed control cabinets are now increasingly being used, oil switches remain the standard until well into the 1930s.

1960s

The era of custom-made control cabinets is over. New suppliers are entering the market with standard control cabinets.

1980s

In addition to electrical systems, control cabinets are increasingly housing devices for system and machine control as well as the necessary data connections.

2000s

As electrification and digitalization advance, control cabinets face temperature and space issues. Systems are becoming ever larger, more complex, more expensive, and more wiring-intensive.

1 Cf. e.g.: https://www.eit.edu.au/power-ahead-with-mechanical-engineering-trends/ or https://www.mittelstand-heute.com/maschinenbau-2024-4-top-trends-und-herausforderungen
2 Man Power Group, Global Talent Shortage 2024
3 Cf.: https://www.elektroniknet.de/karriere/arbeitswelt/iw-studie-maschinenbau-droht-bis-2034-massiver-personalmangel.221781.html

Take wiring, for example: It accounts for around 50 percent of the total time required to manufacture a control cabinet (see chart on page 33). Attempts to make wiring more efficient with the help of robots are still in their infancy. In addition, these concepts are very capital-intensive and ultimately only address the symptoms. Robots do not change the fact that the effort required to manufacture control cabinets continues to increase.

Lack of international standards makes global marketing difficult

There are no globally applicable standards for the devices and components in the control cabinet. The same also applies to the structure as a whole. As a result, depending on the target market, manufacturers need to constantly adapt their control cabinets and check the product information and data sheets for all installed components individually, for example with regard to electrical and functional safety, as well as electromagnetic compatibility and immunity. Even for standard products, multiple variants of one and the same control cabinet are usually available today – for example, in accordance with UL, CSA, or IEC standards. This is time-consuming and expensive.

Developments in control cabinet design clash with ESG and sustainability goals

ESG and sustainability goals are becoming increasingly important in machine and systems engineering. And it all starts with the supply chain. As they contain a large number of components from different manufacturers, the supply chains for control cabinets are so complex that compliance with all ESG criteria can only be guaranteed with a great deal of effort that does not add value. And this complexity is increasing.

This 14-meter Schirmer machine for the fully automatic processing of PVC window profiles is the first to replace all previously required control cabinets with the MX-System.

© Beckhoff

2010s

Control cabinet manufacturers are increasingly integrating more functions into their systems: devices are being digitally networked while components are becoming more compact and energy- efficient. Intelligent, demand-based cooling systems are replacing conventional air conditioning units, but often only allow limited savings in terms of space, energy, and costs.

2021s

Beckhoff engineers develop and present a completely new approach. This allows the control cabinet system to be completely eliminated. This is proven over the following years in collaboration with pilot customers.

2025

Beckhoff launches the MX-System, a revolutionary hardware platform for control cabinet-free automation.

CSRD reporting and the ESPR Regulation are key concepts in this regard. The Corporate Sustainability Reporting Directive (CSRD), which has been in force since summer 2024, requires companies to disclose ESG aspects, including the sustainability of their own products. The measures will be tightened further from 2026 onwards in line with the Ecodesign for Sustainable Products Regulation (ESPR). This explicitly calls for sustainable product designs.

Another highly relevant aspect of sustainability is the space requirements for control cabinets. This is because the amount of hall space used by a production facility increases its resource consumption while also pushing up production costs. In addition, there is a lack of recyclability: When retrofitting the machine, it is only possible to recycle a small number of selected components at best. This does not include the copper cables used for the internal wiring.

Fixed installation spaces and lack of modularity are limiting factors

For machines and systems with a traditional control cabinet, it is very time-consuming to implement customized features. This is because all of the components that are not pre-assembled and installed as standard in the series control cabinet have to be planned, installed, and wired by hand in a complex and specific way for the relevant application. This takes time and requires human resources, both in development and production.

In addition, the installation space for extensions is limited, even though control cabinets are usually supplied with a space reserve and are therefore larger than necessary. Another stumbling block is the design principle. The control cabinet is not planned as a modular element, but as a central element, even for machine concepts with a modular mechanical design. Although multiple control cabinets are often used in these cases, a one-to-one modularity of control cabinet and machine module is never achieved. The result is merely an increase in the number of control cabinets, which multiplies all the challenges described above.

Conclusion: The control cabinet no longer has a future

In view of the current challenges, the control cabinet has long since reached its conceptual limits. After more than 100 years of continuous development, a fundamentally new and disruptive approach is needed.

At a glance: Benefits of the MX-System throughout the value chain

- Greatly reduced number of components (average of 10 instead of 100)
- 80% reduction in circuit diagrams and parts lists
- Significantly less effort involved in design and project planning
- 100% EtherCAT integration. The system is fully digital, with no passive components
- No additional purchase of control cabinet housings, no design planning work, no outsourcing
- Compliant with all standards and safety requirements worldwide (IP67, EMC, IEC, UL, CSA)
- No additional space required, installation in or on the machine
- No manual mechanical work or assembly work required
- No need for manual wiring – wiring errors are eliminated
- Massively reduced set-up times due to plug-and-play installation, saving you time and money
- Devices and components are connected using hybrid cables
- No special knowledge is required to plug in and screw the modules into place
- No specialist electricians are required for installation
- 100% EtherCAT integration: Users can perform system diagnostics on all modules, at any time
- LED status indicators show the operating status of each individual module
- A dedicated smartphone app reads the DataMatrix codes of the modules and provides all relevant diagnostic data. This means that faults can be identified and rectified by operating personnel themselves, without the need for a qualified electrician
- Reusability: The modules can be easily dismantled and reused in other MX-Systems, even internationally and following relocations, as they are fully compliant with standards
- One function module replaces many conventional components. This means fewer components to purchase and store in the spare parts warehouse.

More information:
www.beckhoff.com/mx-system

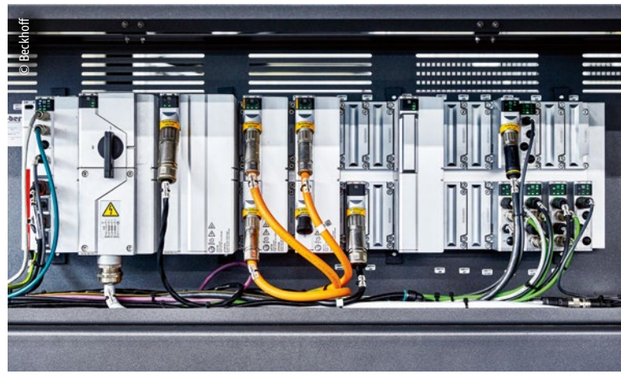
The linear robot from RO-BER handles heavy containers fully automatically, ensuring the safety of Bürkert's logistics staff.

Depalletizing cell with MX-System solves age-old floor space problems in intralogistics

Going control cabinet-free to maximize space savings

Bürkert Fluid Control Systems faced a classic production logistics challenge at its Criesbach Campus in Germany: manually feeding heavy containers into the automated small parts warehouse was slowing down processes and putting strain on personnel. However, there simply wasn't enough floor space for conventional automation solutions. That's when Bürkert commissioned gantry robot and material handling equipment manufacturer RO-BER to deliver an exceptionally compact depalletizing cell that receives pallets from AGVs (Automated Guided Vehicles). Despite this solution, the end user still needed more space savings to satisfy its high demands: the MX-System from Beckhoff, which allows the system to operate entirely without a control cabinet, provided the solution to the limited space constraints.

Floor space is one of the most valuable resources in intralogistics – usually, every single square centimeter counts, and this was certainly true for Bürkert. The supplier of measuring, control, and regulation systems for liquids and gases is on a steady growth trajectory, which means it has to achieve constant improvements in its internal material handling and logistics. Bürkert does not sell standard products but instead focuses on valve designs and materials precisely tailored to each customer. As a result, the company's product range comprises 140,000 sellable items. Frank Landgraf – who is responsible for all logistics processes at Bürkert – described the starting point: "Getting to grips with this kind of diversity in production and intralogistics is a real challenge. While automation used to focus on assembly, today the greatest potential lies in intralogistics." He also believes that it is important to consider ergonomics; "Manually handling heavy crates of 20 kg or more isn't the way we do things now – and given the labor shortage we're experiencing, it isn't a method we can support anymore." The process of feeding material into an automated small parts warehouse with around 27,000 bays was creating a bottleneck at the Criesbach site. The company was looking for an automated solution, but the on-site conditions left little room to maneuver. The system had to fit into an existing niche that would have been too small for conventional robot cells and bulky control cabinets.



Mounted directly in the superstructure of the machine, the MX-System completely replaces the conventional control cabinet and controls all axes and processes.

Less work, less space

With this goal in mind, Bürkert approached RO-BER Industrieroboter, based in the German town of Kamen. As RO-BER specializes in sophisticated gantry robot systems, their team worked with the specific requirements for the Criesbach site to develop a tailor-made cell for depalletizing Euro containers from floor rollers. A linear robot with a multi-functional gripper removes the containers and places them, perfectly aligned, on the conveyor system in the automated small parts warehouse. While RO-BER was able to fall back on its proven range of solutions for the mechanics and robotics, it pursued new paths

© Beckhoff

The operator has access to all functions and process data for the networked system via the custom Beckhoff control panel.

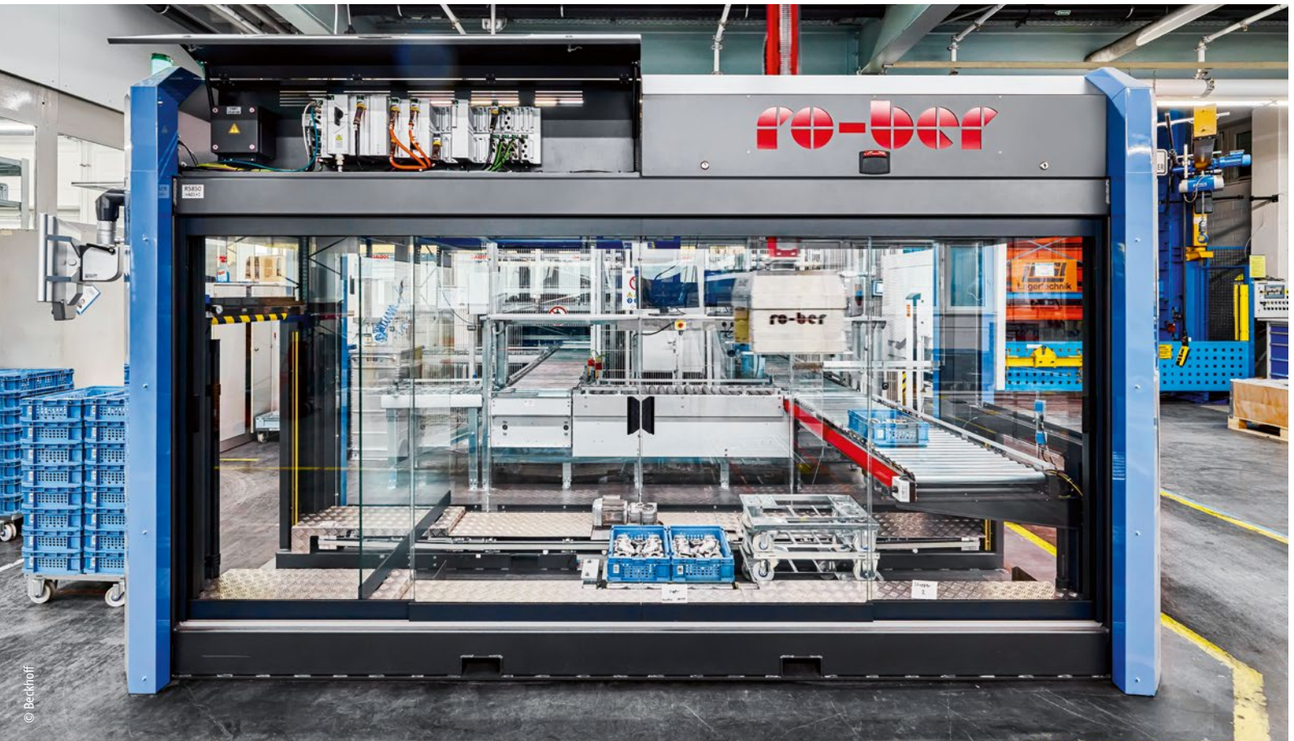
for the automation aspect. To ensure the requisite compactness, RO-BER opted for the MX-System from Beckhoff.

"As a pluggable, modular solution for control cabinet-free automation, it quickly caught our attention," explains Elmar Stöve, Managing Director of RO-BER. The MX-System is a modular automation system that contains all control cabinet functions – from control and drive technology to I/Os, power supply, and fusing. The robust, IP67-protected function modules make it possible to completely eliminate conventional control cabinets in many applications. All the required modules are plugged onto a machine mounted baseplate. For RO-BER, this meant that there was no need to plan any separate space for installing a control cabinet. Instead, the automation was integrated directly into the machine superstructure, which significantly reduced the amount of space and cabling work required while simplifying the design of the entire cell.

Faster assembly and commissioning

"The benefits of the MX-System span the entire life cycle of the equipment, from design and planning to maintenance," explains Antonia Kuhn, who works in sales at Beckhoff. "During assembly, the baseplate's standardized interface concept eliminates the need for manual wiring and complex cable routes. Function modules are simply plugged in and screwed in place, which automatically establishes the electrical connection. All field devices are connected to the MX-System modules with pluggable, connectorized cables, further eliminating any potential wiring errors." This resulted in an enormous gain in efficiency for the machine builder. "A complete MX-System could be installed on the machine in just a few minutes, with an industrial PC, servo drives, main switch, infeed, 48 V power supply, and I/O modules," confirms Elmar Stöve. "That's a huge difference compared to the time required for installing traditional control cabinets – which can be hours or even days." One Cable Automation (OCA) reduces the amount of wiring work required for the motors, as power, data, and feedback are routed in a single cable. This also reduces the potential for errors. In addition, every component from the MX-System portfolio can be diagnosed – a major advantage from a maintenance perspective.

The RO-BER depalletizing cell fits seamlessly into the limited space next to the automated small parts warehouse at Bürkert's Criesbach, Germany site.



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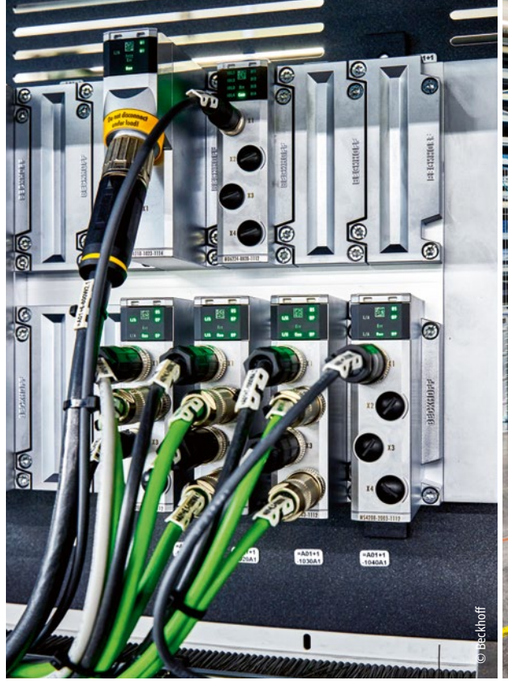


© Beckhoff

The MX-System function modules can simply be plugged onto the baseplate, reducing assembly time from hours to minutes.

© Beckhoff

Think outside the cabinet: Frank Landgraf from Bürkert, Elmar Stöve from RO-BER, Antonia Kuhn from Beckhoff, plus Stefan Keilbach and Marius Mazugo, both from Bürkert (left to right).

Seamless integration and networking

"For us, automatic depalletizing wasn't just about the functions that a new machine would bring – it also had to allow seamless integration into higher-level structures and connection to our automated guided vehicles," states Marius Mazugo, who works in process optimization at Bürkert. This is where open, PC-based control technology and EtherCAT from Beckhoff shows its strengths, as it accommodates all common IT and communication standards, allowing the user to achieve seamless traceability in logistics control, production control systems, and company databases. When an AGV enters the plant, the system automatically recognizes the order, depalletizes the Euro containers, takes them to the automated small parts warehouse, and stacks the empty floor rollers, which the AGV then picks up. This fully automatic cycle eliminates the need for manual intervention and avoids downtime.

Project planning and scalability made easy

In addition to the MX-System, the depalletizing system also features a custom control panel from Beckhoff's CP39xx series, situated on a mounting arm with a compact push-button extension. The HTML5-capable display with TwinCAT 3 HMI is designed for intuitive operation and provides a detailed diagram of the machine and its processes, as well as dynamic real-time graphical monitoring of the EtherCAT network for rapid diagnostics of the system. In addition to servomotors from the AM8000 series, the system uses a number of IP67 EtherCAT Box modules. The entire application was configured in TwinCAT 3 automation software. "For RO-BER, an experienced user of Beckhoff technology, no programming changes were needed in order to use the MX-System," states Elmar Stöve. The flexibility of the software and the high computing power of the industrial PCs can handle and manage extremely complex automation tasks. In principle, RO-BER systems are even able to process mixed pallets or different packages.

Excellent ergonomics and process stability

For Bürkert, investing in the new depalletizing system has paid off. "RO-BER really brought our ideas to life in terms of the functions that it provided and the way the system operates: smooth and error-free," summarizes Stefan Keilbach, team coach in the Warehouse and Logistics department at the Bürkert Campus. "The system also has an advanced look and integrates very well visually." The project underlines the trend toward modular, compact logistics units that can be flexibly integrated into established material flows. The MX-System is a technological catalyst here: machine builders no longer need to design systems around control cabinets and can instead integrate automation into the mechanical system directly. This results in machines that are compact, sleek, and easier to maintain.

Real competitive advantages

The collaboration between Bürkert, RO-BER, and Beckhoff shows that thinking outside the box – or, in this case, outside the cabinet – leads to innovative solutions that can significantly increase efficiency and add value. "We see huge potential in the MX-System and have many ideas for more automation projects," says Elmar Stöve, looking to the future. "For example, at this year's LogiMAT, we're exhibiting a new compact palletizer cell that reflects this approach to equipment." It is yet another sign that control cabinet-free machine building is no longer a far-off vision; it's a reality in today's industrial production, where it is already delivering real competitive advantages.

See a demonstration of RO-BER's cabinet-free piece-picking cell with the MX-System.

More information:

www.buerkert.de/en
www.ro-ber.de/en
www.beckhoff.com/mx-system

With physical AI, Mech superhumanoid robots excel in unpredictable warehouse environments with EtherCAT and PC-based control from Beckhoff.

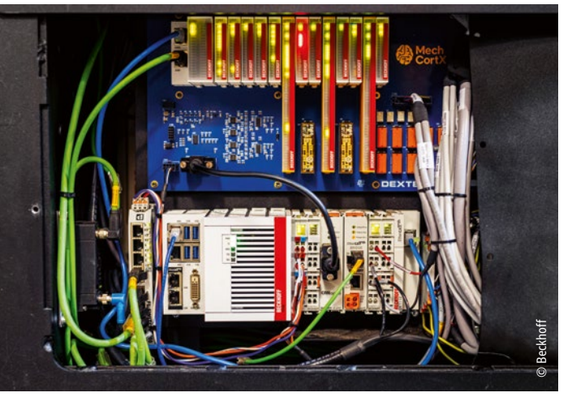
AI acendant: Dexterity redefines robotics in the modern warehouse

The Mech superhumanoid robot features two arms with a unique sense of touch, infusing human-like dexterity through Physical AI.

Robots have been a mainstay in manufacturing for decades, but the intralogistics industry is having its own kinematic moment. New technology providers are rising to meet the occasion with robots geared toward the highly variable and unpredictable tasks common to parcel and package delivery. Based in Redwood City, California, Dexterity is transforming robotics technology for intralogistics by using physical AI to imbue robots with human-like reasoning and agility.

Delivery giant FedEx has already collaborated with Dexterity to optimize trailer loading and unloading, freeing employees for other critical tasks while improving safety and improving already high service levels. With capabilities like machine learning-driven packing algorithms and a "sense of touch" for precise box placement, Dexterity's solutions highlight how robotics can deliver both operational resilience and customer satisfaction in a fast-changing market.

Dexterity's latest groundbreaking invention, named Mech, is the world's first industrial superhumanoid robot designed specifically to transform logistics for a wide range of enterprises. To meet the real-world challenges and complexities of modern warehouses, Dexterity chose to rely on automation technology from Beckhoff, which checked several boxes that traditional PLC-based control systems could not.



Above: Dexterity uses PCB-mounted EJ series EtherCAT I/O terminals in place of traditional wired I/O terminals to minimize Mech's wiring requirements and maximize mass production efficiency.

Below: Mech features a 5+ meter arm span and can handle payloads up to 60kg, allowing the system to manipulate millions of different types of parcels and packages.

"If you go to any warehouse in the world and ask, 'What would you most like to outsource to a robot?', every person in that facility will tell you it's truck loading/unloading," says Michael Perry, Vice President of Marketing and Business Development at Dexterity. The task requires not only physical dexterity, but also skill and planning as workers try to maximize product density and maintain load stability in environments that are often subject to high variability and drastic changes based on the season or even time of day. Add factors like time constraints, the variable temperatures in trailers, the presence of heavy products and fast-moving equipment, and it's no wonder why this environment is at best uncomfortable, and at worst injury prone.

To protect workers, Mech needed to be able to operate safely in dynamic, human-centric environments without compromising throughput, reliability, or performance. With two robot arms mounted on a rover, Mech roves across industrial sites to perform stressful, repetitive tasks that would otherwise require strenuous manual labor, allowing employees to focus on safer, higher-level cognitive work. Each robotic arm can operate independently to greatly boost throughput, or work in coordination to handle heavier and larger loads that would normally require separate automated or manual systems.

Mech doesn't just improve warehouse automation; it redefines how humans and robots will collaborate in the future.

From patchwork to powerhouse tech

For Dexterity, one of the biggest challenges in developing Mech was overcoming system fragmentation. Many traditional automation solutions rely on a patchwork of hardware components, networks, and software platforms that can be difficult to integrate, slowing down development cycles and complicating large-scale deployment. "We needed a solution that simplified integration without sacrificing performance, safety, or reliability," explains Gil Matzliach, Vice President of Hardware Product Engineering at Dexterity. "Beckhoff provided a fully integrated ecosystem for both safety and motion control, meeting all our requirements and, in many cases, exceeding them."

At the beginning of 2025, Dexterity kicked their engineering work with Beckhoff into high gear, collaborating with Beckhoff USA's Special Project Team (SPT) to complete the software development required for this application. This approach allowed Dexterity to streamline everything from initial commissioning to fleet-wide software updates and remote debugging. Instead of having to manage disparate systems that struggled to communicate, Beckhoff's universal and open control architecture created a consistent foundation for

Mech's ultra-compact rover base moves, spins, and climbs ramps with four steerable wheels.

interoperability and the required modularity to scale. Dexterity's engineering team also attended Beckhoff training courses, shortening the learning curve and speeding up commissioning.

The use of EtherCAT also proved pivotal, with its determinism, low latency, almost non-existent jitter, and open communication architecture. By reducing hardware complexity and cabling requirements, Beckhoff helped Dexterity improve system uptime and minimize points of failure. "From day one, Dexterity was heavily invested in EtherCAT," says Avinash Verma, Vice President of Supply Chain at Dexterity. With Beckhoff providing the hardware, software, and networking, integration became seamless across the Mech system architecture. EtherCAT also provides built-in system diagnostics and integrated machine safety that communicates over the main network via a "black channel", even wirelessly, and can be installed in the same line as non-safety equipment.

While EtherCAT heavily factors into the design, the breadth of Beckhoff's communication portfolio to incorporate other networks also played an important role in bringing Mech to life. Dexterity uses CAN bus alongside EtherCAT, overcoming the typical barriers between legacy and next-generation systems. Together, the combination of PC-based control, EtherCAT networking, TwinSAFE functional safety, and modular I/O provided Dexterity with the performance, safety, and scalability needed to bring physical AI-powered robots into production environments.

Under the hood:
Embedded controller brains, one cable magic, and more

In an industry where every second and every movement matters, Mech is built to tackle some of the most grueling logistics challenges, while making warehouse jobs safer and more sustainable. With Dexterity's physical AI platform backed by Beckhoff automation technology, the superhumanoid robot can sense, think, and move with precision in environments where traditional robots fall short.

Dexterity's Mech relies on a tightly integrated Beckhoff control ecosystem that manages everything from overall automation to motion execution to safety-critical functions. By leveraging Beckhoff's broad portfolio of industrial controllers, I/O hardware, safety products and software framework, Dexterity has been able to build a robotic platform that is not only high performing, but also modular, serviceable, and scalable for fleet-level deployment.

At the core of Mech's control architecture is Beckhoff's CX5240 Embedded PC with Intel Atom® x5-E3940 running Windows 10 IoT Enterprise. The space-saving DIN rail-mounted controllers handle motion control and safety logic at the lower machine-control layer, complementing Dexterity's AI-driven decision-making "brain." The DIN rail mountable form factor was chosen for its ability to integrate cleanly into the robot's compact design and improve field serviceability.

Dexterity leverages Beckhoff's PCB-mounted EJ series EtherCAT I/O terminals in place of traditional wired I/O terminals to drive additional labor savings as production scales and larger volumes of superhumanoid robots are built. Terminals plug in quickly and easily, minimizing Mech's wiring requirements and maximizing mass production efficiency.

(From left): Shawn Lange, Beckhoff; Doug Schuchart, Beckhoff; Robert Sun, Dexterity; Gil Matzliach, Dexterity; David Turney, Dexterity; Michael Perry, Dexterity; Nathan Hibbs, Beckhoff; Peng Chen, Beckhoff.

Machine-mountable EtherCAT Box I/O is also vital in minimizing the Mech's wiring and keeping its size manageable. In addition to general data acquisition over multiple networks, these IP67-rated I/O modules add special functions to the mix. "We use the IMU (Inertia Measurement Unit) to track the max position and adjust motion controls accordingly," says Matzliach. For this, Dexterity takes advantage of Beckhoff's EP3751-0260 EtherCAT box which features an accelerometer and gyroscope (IMU) all in one IP67 unit. "That seamless process eliminated additional challenges we had with other devices in the past, and it accelerated our ability to develop mature, production level products."

This full stack approach was integral to reaching the performance, safety, and flexibility standards needed to bring physical AI-powered robots into real-world production environments and ensure that Mech performs at its best in the field for years to come.

Better, faster, stronger warehousing

Dexterity's EtherCAT-enabled Mech delivers marked improvements for teams tasked with integrating the superhumanoid robots. In addition to improved worker safety and reduced risks of injury, Mech brings higher throughput and savings in operational efficiency, commissioning time, and equipment cost. All these benefits are further enhanced with the promise of reduced downtime through advanced diagnostics and remote support capabilities. To improve sustainability, companies are working to eliminate wasted space in trucks. Mech's physical AI optimizes package arrangements, maximizing every inch of available storage capacity.

Doug Schuchart,
Global Intralogistics Industry Manager for Beckhoff

> "Dexterity's strategy – starting with a standard roving base that can be adapted for multiple applications – offers end users a highly flexible and advantageous approach."

With the power of Mech, Dexterity envisions a future where superhumanoid robots become standard in warehouses for the grueling work of truck loading/unloading, palletizing/depalletizing and more. Soon, warehouse teams will include specialists – Mech 'pilots' – dedicated to managing and optimizing robot utilization. These pilots will ensure Mechs are deployed to handle the right tasks and restructure workflows so that the robots can operate at peak efficiency. Meanwhile, fleet captains will oversee performance across an entire warehouse, identifying underutilized robots, redeploying them where needed, and seeking opportunities to expand automation that can increase their location's productivity, all without placing workers at additional safety risk or stress.

Human operators can use Mechs to deliver superhuman feats and increase their productivity. One pilot can manage ten or more Mechs while Fleet Captains oversee entire sites or networks.

Beyond individual warehouses, the real breakthrough comes at the network level. Because Mechs generate streams of high-quality data, such as throughput metrics and operational bottlenecks, organizations will be able to dynamically implement continuous improvement measures and shift capacity across distribution centers. For example, if one facility faces delays due to late shipments, additional capacity can be allocated to nearby sites, ensuring that the overall logistics network remains resilient and efficient. In short, Mech is poised to reshape logistics by unlocking new capabilities and elevating the entire supply chain ecosystem.

Scalable robotics: Mech beyond the warehouse

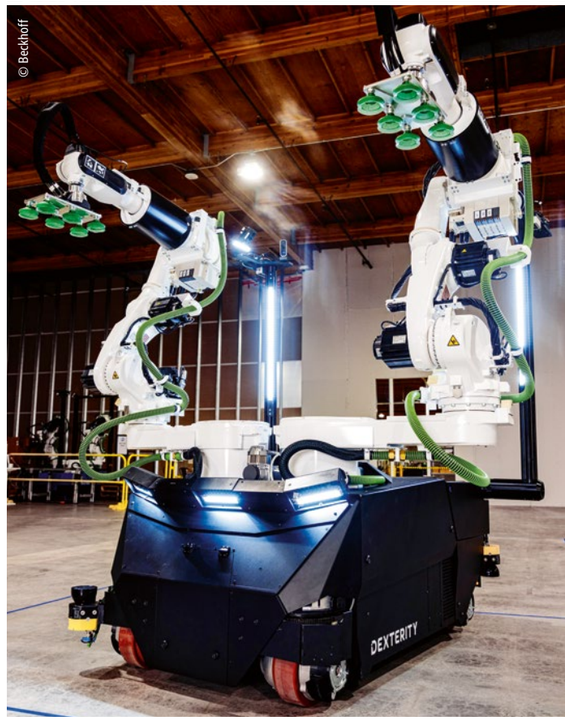
As Dexterity continues to evolve Mech to best fit the intralogistics industry's ever-changing needs, Beckhoff's technology ensures that they have the flexibility to scale solutions across new applications without redesign.

"There are a wide variety of environments where there's a high need for manual work, but low availability of people, or where it's better for the process if people are not involved," explains Perry. One such area is with the production of pharmaceuticals. Decreasing the number of human touches on pharmaceutical products is incredibly important: this increases quality, safety, security, and ultimately, health. "Humans will always be involved in the pharmaceutical industry," Perry adds. "But when you're talking about manipulating pharma products, picking them, packing them, moving them from one clean area to another, having a robot do that work will be very important to protect the supply chain."

As Mech and its physical AI continue to adapt to diverse industries, Beckhoff's scalable automation technology empowers Dexterity to deploy robots that enhance safety and efficiency by reducing human contact in critical, high-risk processes. This approach not only safeguards people and products but also paves the way for expanded automation in environments where precision and safety are paramount.

Dexterity's work with global giants like FedEx, Sagawa Express, and UPS has already proven how its physical AI platform can solve one of today's most pervasive logistical challenges with the power of human-like reasoning and AI-enabled robotics. Now with Mech, Dexterity extends its vision across the warehouse and beyond, offering a scalable solution that not only protects workers but also ensures consistent performance and resilience in demanding applications. In distribution and fulfillment centers, robots are often positioned as solutions to labor shortages and unsafe tasks. "Dexterity's strategy – starting with a standard roving base that can be adapted for multiple applications – offers end users a highly flexible and advantageous approach," says Doug Schuchart, Global Intralogistics Industry Manager for Beckhoff. "The results are already quite apparent for truck loading and unloading, but the future possibilities are limitless for Mech."

By combining their robotics expertise with Beckhoff's integrated automation technology, Dexterity is redefining what's possible in logistics: smarter, AI-driven operations, safer workplaces, and a future where humans and robots work side by side to keep supply chains moving at full speed.



Above: Mech's ultra-compact rover base moves, spins, and climbs ramps with four steerable wheels.

Below: Dexterity's Mech uses PC-based control and EtherCAT from Beckhoff to navigate unpredictable warehouse environments with human-like flexibility and reasoning.

Watch Dexterity unleash the power of physical AI in Mech superhumanoid robots.

More information:
www.dexterity.ai
www.beckhoff.com/intralogistics

Doug Schuchart, Global Intralogistics Industry Manager, Beckhoff; Scott Eisenberg, Regional Sales Manager and Marketing Lead, EuroSort; Matt Bell, VP of Outbound Operations, Mouser Electronics

EuroSort distributes hundreds of machine-mounted EtherCAT Boxes (shown here) and DIN rail mounted high-density EtherCAT Terminals down the sorter lines.

Global electronic components distributor's journey to processing over 30,000 SKUs per hour begins on EtherCAT-enabled sortation systems with over half a mile of track

EuroSort powers new levels of distribution efficiency and precision in massive sortation system installation for Mouser Electronics

It's been said that life is a journey, not a destination – and the same can be said about product distribution and fulfillment. There are thousands of possible processes to move a product from initial warehouse pick to doorstep delivery, but countless things can go right… or wrong along the way. A giant in semiconductor and electronic component distribution, Mouser Electronics operates in a league of its own when managing the complexity of B2B order fulfillment and its customers' supply chains.

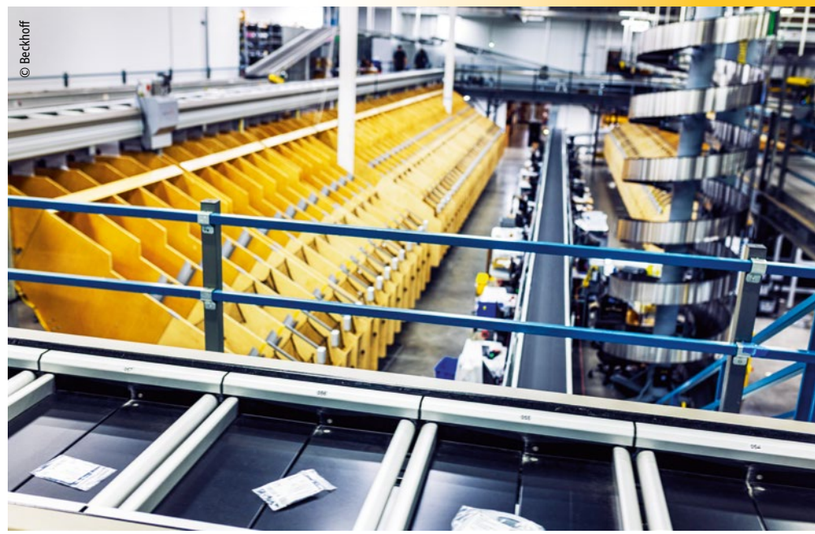
"Mouser distributes products from over 1,200 different manufacturers and specializes in new product introductions with intensive support for research and design engineers, as well as the manufacturing supply chain," says Matt Bell, VP of Outbound Operations at Mouser Electronics. "Our mission is to make sure that our 650,000+ customers can order with confidence through the highest possible order accuracy and on time delivery." The Mansfield, Texas-based Berkshire Hathaway subsidiary is ranked as the #5 electronic components distributor in the 2025 Global Top Distributors List published by Supply Chain Connect and offers over 1.2 million active SKUs with an endless range of product sizes and forms of packaging. Sorting and delivering millions of items with accuracy exceeding 99% and same day shipping with order cutoff times as late as 8:00 PM is an immense challenge.

Traditional sortation systems could not handle the varied, and incredibly small product. Additionally, the technology currently in use reached max capacity, preventing Mouser from continuing their impressive growth streak as they were constructing a new building at their site. That's when Mouser commissioned EuroSort, a leader in bespoke sortation equipment with U.S. headquarters in Owings Mills, Maryland, to deliver a groundbreaking sortation

The sorters are automated by Beckhoff C6030 Industrial PCs with Intel® Core™ i5 processors running TwinCAT software to handle all real time control, multiple fieldbus protocols, and the HMI software all on the same device.

Mouser offers over 1.2 million active SKUs with an endless range of product sizes and forms of packaging.

Mouser Electronics is the #5 electronics component distributor in the world according to the 2025 Global Top Distributors List published by Supply Chain Connect.



solution to meet the multifaceted requirements at Mouser's flagship global distribution hub in Mansfield. "With equipment that can handle almost unlimited sorts, EuroSort stood out among their competitors," Bell says. "The only thing that limits the number of sorts EuroSort can deliver is space. With our new building, we have a lot of space, so we are able to install absolutely massive sortation lines." Accordingly, the resulting EuroSort system was a highly customized suite of sorter technologies spanning four unique sorter types with over half a mile of track combined, all integrated tightly with an advanced, EtherCAT-enabled automation platform from Beckhoff.

A long and winding road to sort items with speed and precision

Mouser's product mix is incredibly diverse. The company distributes everything from large transformers and reels of semiconductors down to individual components in tiny poly bags. Before EuroSort's involvement, Mouser's previous sortation equipment had reached its limits. Handling the more delicate and lightweight items at high speed was especially difficult because they could literally float off the equipment depending on the environmental conditions. "It couldn't go any faster, and lacked the accuracy needed for the smallest items," recalls Scott Eisenberg, Regional Sales Manager and Marketing Lead at EuroSort. "This bottleneck constrained throughput and made it hard for Mouser to scale their operations."

Scott Eisenberg,
Regional Sales Manager and Marketing Lead, EuroSort

> "The parallel induction technology is a first in the world, and the Mouser application was our pilot project."

Adding to the complexity, Mouser's facility posed significant physical constraints. "The largest sorter is actually located on a third-level mezzanine with only 14 feet of clear height," Eisenberg says. "We had to design a system that packed thousands of destinations into this compact vertical space without sacrificing speed or reliability."

Another critical requirement was operational continuity in Mouser's existing building. EuroSort had to install and commission one of the new sorters without any downtime. That meant building this new system over the existing one as it ran in full operation and then transitioning seamlessly to the new sortation system.

To tackle these multifaceted challenges, EuroSort deployed four distinct types of sorters at Mouser, each tailored to specific stages of the operation. For order consolidation, the Single Split Tray Sorter, which integrates with existing goods-to-person (GTP) systems, was a major upgrade and now handles the full range of products offered by Mouser. "With EuroSort technology, we also made significant improvements to our existing equipment," Bell adds. "For example, we were able to improve the performance of our existing GTP system by 100%."

Equally impressive was the Dual Split Tray Sorter, designed specifically for the constrained mezzanine space. "It's the behemoth of the fleet – with thousands of destinations packed into limited vertical clearance," Eisenberg remarked. "This sorter alone can process about 30,000 items per hour and will be a key player in improving overall pick efficiency at the site."

On the receiving side of things, EuroSort's Cross Tray XL and standard Cross Tray sorters manage everything from heavy inbound cases to the small individual items inside them on the same sorter. "This flexibility is crucial given the wide variety of package sizes Mouser processes," Eisenberg notes.

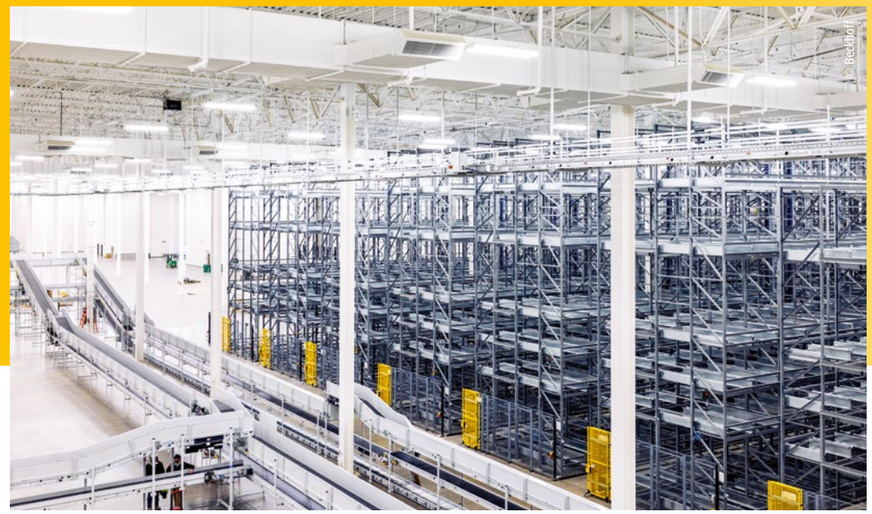
Finally, EuroSort introduced cutting-edge technologies such as the parallel induction, custom designed chutes, and a brand new, multi-destination chute system known as E-Sort, currently in field testing at Mouser. "The parallel induction technology is a first in the world, and the Mouser application was our pilot project," Eisenberg adds. "The new multi-destination chute can also feed 10 different sort destinations from a single drop, dramatically increasing sorter efficiency."

All signs point to EtherCAT

The machine control technology that brings EuroSort's labyrinth of sortation equipment together was backed by Beckhoff's sophisticated controls architecture, which brought all the automation, motion control, networking, safety, and diagnostics capabilities the enormous project demanded. Blake Waybright, Controls Developer at EuroSort, describes the power of Beckhoff's C6030 Industrial PC with capable Intel® Core™ i5 processor: "The fully integrated automation platform powered by TwinCAT software and EtherCAT communication lets us handle not only the real time control but also all of our applications, multiple fieldbus protocols, and the HMI software all on the same device."

The TwinCAT 3 engineering environment supports multi-core task assignment, allowing EuroSort to separate fast real time tasks from slower background processes from core to core to maximize overall CPU bandwidth. "We achieve scan times under 300 microseconds, which is essential when we're detecting items less than two centimeters apart moving at high speed," Waybright says. "TwinCAT's integrated engineering environment and version control supported

The next phase of EuroSort's installation at Mouser is set to go live in 2026 with the goal of handling 100% of Mouser's total distribution volume.



by TFS and Git make it easy for us to manage complex projects and push rapid software improvements. It also boosts our programming, debugging, simulation, and visualization all in one place."

In terms of networking, EtherCAT has already been EuroSort's communication standard for many years. "Before we standardized, we conducted a very open search throughout the industry, interviewing vendors and integrators that are partners, and even customers, and we kept landing on EtherCAT," recalls Jeff Zerr, Advisory Controls Engineer at EuroSort. "Every other protocol had limitations we would reach one way or another, whether it was node count, transmission speeds, scan times, bandwidth issues, etc. Ultimately, it was EtherCAT that brought us to Beckhoff in the first place."

Today, EtherCAT distributed I/O hardware is equally critical in the Mouser application. Because these sorters are so large and have so many I/O points, EuroSort uses hundreds of machine-mounted EtherCAT Boxes and high-density EtherCAT Terminals to minimize space requirements in I/O cabinets. "This distributed approach reduces wiring complexity and lets us design the control system around the mechanical chute layout rather than the other way around," Waybright explains.

Machine safety, too, was handled in a streamlined, fully integrated way with Beckhoff's Safety over EtherCAT (FSoE) and TwinSAFE I/O system. EuroSort integrates safety devices like emergency stop pull cords spanning up to 100 meters directly into the EtherCAT network. "TwinSAFE lets us remotely troubleshoot safety faults and show operators exactly where issues occur to quickly return equipment to a safe state," Waybright says.

The openness of Beckhoff's platform also facilitated integration with various protocols. "We communicate over OPC UA with Mouser's warehouse management system (WMS) to report package dimensions and bar code information in real time," Waybright details. "We also use EtherNet/IP to interface with machine vision cameras and traditional PLCs upstream." EtherCAT also directly integrates with IO-Link to communicate with various encoders on conveyors at the site via an EP6228-0022 EtherCAT Box.

Crucially, Beckhoff's EtherCAT network topology, designed as multiple redundant rings without branching to chutes, ensured both reliability and speed. "We will be handling over 40,000 EtherCAT I/O points on the largest sorter," says Pete Diamonti, EuroSort's Engineering Manager. "Segmenting the network into sync groups and rings lets us commission and troubleshoot the system modularly, which is essential for timely completion of a project of this scale."

Maintenance teams have also benefited from advanced EtherCAT diagnostics. "Without Beckhoff's detailed diagnostics, we wouldn't know if an especially small item floated off its path or if the machine made a mistake," Eisenberg says. "Our logging system records every item's journey for up to 30 days, enabling us to troubleshoot problems long after they occur."

Doubling down on pick rate improvements, energy savings

The results of the collaboration among Mouser, EuroSort, and Beckhoff have been remarkable. The new EuroSort systems are now tasked with handling up to 30,000 items per sorter per hour, with the goal of handling 100% of Mouser's total distribution volume. Additionally, the new sortation stack has created a more predictable and scalable flow across Mouser's Mansfield global distribution center.

EuroSort's Single Split Tray Sorter, integrates with existing goods-to-person (GTP) systems at Mouser.

"Put rates on the existing goods-to-person systems have almost doubled the previous system's, with operators now reaching as many as 600 items per hour during peak times," Bell reports. This dramatic uplift is a direct result of the seamless integration between the GTP systems and the EuroSort Single Split Tray Sorter, enabling faster, more accurate handling of Mouser's highly diverse product mix. The result is a more responsive order fulfillment operation that can adapt to fluctuating demand without sacrificing accuracy.

Energy savings with the new sortation system were also substantial. "Our sorters run on motors typically rated at one horsepower," Eisenberg explains. "That's less than 30 horsepower total for a machine half a mile long. Compared to other technologies like shoe sorters or AGV systems that can draw hundreds of amps for much smaller sections, the energy savings over a 10- to 20-year lifecycle can exceed $1 million."

By all accounts, this ongoing journey has been a fruitful one. Leveraging customized EuroSort sortation solutions powered by Beckhoff's high-performance EtherCAT architecture and flexible TwinCAT software platform, Mouser Electronics has achieved unprecedented rate improvements, energy savings, and operational agility – setting a new benchmark in electronic components distribution. As Waybright summarizes, "Beckhoff isn't just making our solutions possible – they're making them successful."

The combination of higher throughput, real time EtherCAT communication, and tighter control over item destinations has reduced bottlenecks at critical handoffs and unlocked new capacity for growth. Accordingly, Mouser and EuroSort are busy with future plans for the Mansfield distribution center. "EuroSort's team in The Netherlands is working on a new design for high density consolidation which will give us tens of thousands of locations and transform how we fulfill orders yet again," Bell concludes.

See Mouser Electronics deploy EtherCAT-enabled sorters from EuroSort to handle over 30,000 SKUs per hour.

More information:

www.eurosort.com

www.mouser.com

www.beckhoff.com/intralogistics

How Beckhoff technology powers Ocado's Automated Frame Loader

Automation that delivers

As a world leader in online grocery technology, Ocado has long been at the forefront of grocery automation by providing the advanced automation, robotics and software that power some of the most efficient and responsive fulfilment operations globally.

Ocado leverages a variety of Beckhoff's integrated automation and control technologies in the AFL, including a Beckhoff C6017 Industrial PC running TwinCAT automation software, and a variety of EtherCAT and TwinSAFE I/O terminals.

As the enabler behind rapid customer fulfilment for Ocado and Morrisons in the UK, Kroger in the U.S., Sobeys in Canada, and other leading retailers worldwide, Ocado's platform combines cutting-edge engineering with intelligent data systems to deliver faster, more accurate, and more sustainable grocery deliveries.

Its customer fulfilment centers (CFCs) are designed around one simple promise: to deliver every order within a one-hour slot. To maintain its 99% on-time dispatch rate and 99% order accuracy, every process must run like clockwork – from item picking to van loading.

For 20 years, one part of this process remained manual: lifting heavy totes filled with groceries onto van frames for delivery. Each tote can weigh up to 20 kilograms, and every van frame holds four stacks of boxes. Now, that physically demanding, time-critical job has been automated, thanks to Ocado's Automated Frame Loader (AFL), powered by Beckhoff control technology.

"Previously, lifting those heavy totes into one of the multiple positions on a frame could be a really physical, demanding job that didn't suit everyone," explained Cliff Bailey, new propositions director at Ocado Intelligent Automation. "This meant that it was a challenge to find people who wanted to do that role in the facility. The frames aren't always perfectly square because of wear and tear, so the challenge was creating a machine that could look at the frame, identify exactly where each tote needed to go and place it precisely – just like a person would, only faster and more accurately."

Smarter loading

The AFL automates the final stage of grocery dispatch, loading up to 350 totes per hour onto van frames with zero human touch. This innovation not only eliminates one of the most physically demanding and injury prone roles in the warehouse but also ensures consistent accuracy and speed, vital for Ocado's on-time delivery promise.

The machine operates continuously, up to 20 hours a day, and dynamically scales throughput in response to order volumes. "The AFL helps us on our ongoing journey to improve site productivity," added Bailey. "It is a scalable, flexible solution, that responds in real time to the demands of the operation."

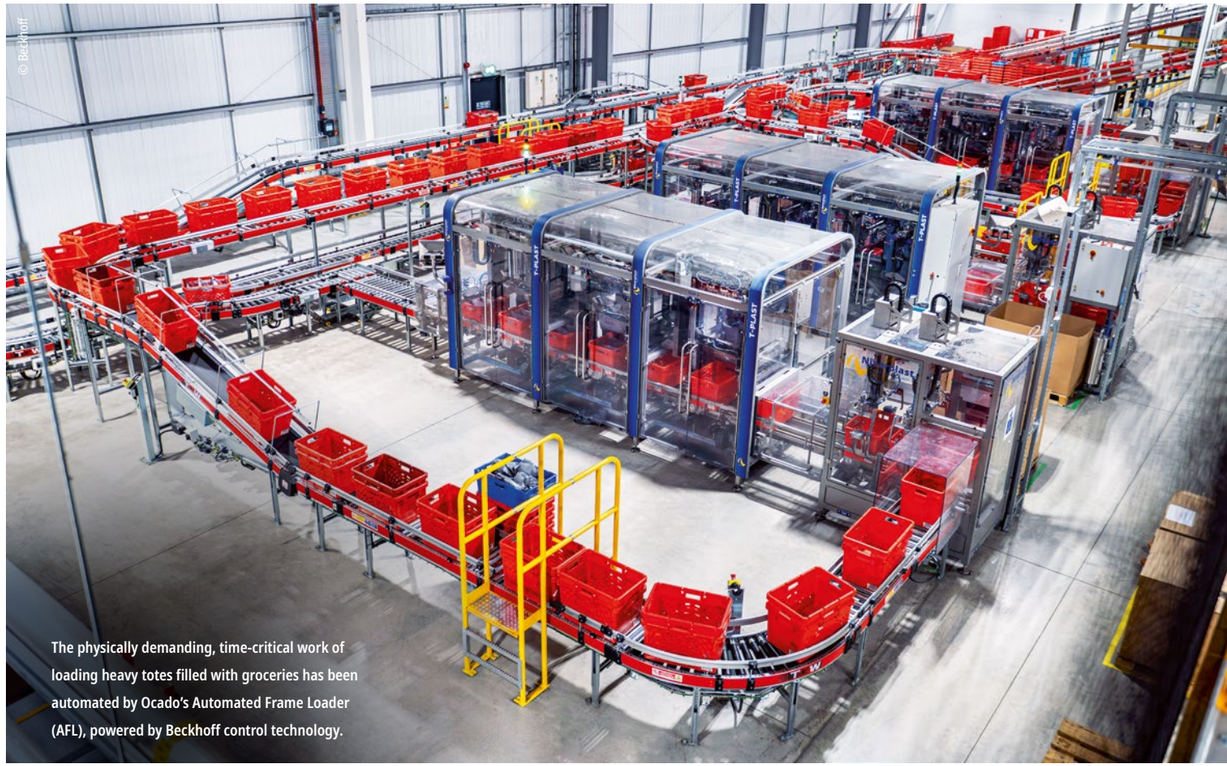
Ocado turned to Beckhoff's integrated automation and control platform to power the AFL. Each AFL is equipped with a Beckhoff C6017 Industrial PC. Compact and powerful, the IPC coordinates all AFL motion, handling both control and functional safety within a single system.

Mounted directly on a DIN rail inside the control cabinet, the C6017 communicates with Beckhoff TwinSAFE I/O terminals – safety-rated components that centralize safety control from multiple sensors and devices across the AFL. This ensures that every movement operates with absolute precision and reliability.

"Ocado needed a compact, high-performance control system that could handle motion, safety and communication in one," explained Bradley McEwan, business development manager at Beckhoff UK. "The C6017 IPC combined with TwinSAFE I/O provides exactly that – integrated functional safety, deterministic control and the ability to expand easily as new features are added."

The IPC and EtherCAT-based I/O architecture allows for seamless integration of vision systems, which can help locate tote positions on imperfect frames. This precision ensures that even if a frame is slightly misaligned, the AFL can still place totes accurately, maintaining the integrity of every load.

Each tote can weigh up to 20 kilograms, and every van frame holds four stacks of boxes.



The physically demanding, time-critical work of loading heavy totes filled with groceries has been automated by Ocado's Automated Frame Loader (AFL), powered by Beckhoff control technology.

When designing the AFL, Ocado evaluated several automation platforms but ultimately selected Beckhoff for the flexibility, scalability, and openness of the system architecture. "The application required us to control multiple motors precisely and integrate a vision system within tight space and cost constraints," Aquiles Calderon Santana, engineering manager at Ocado said. "Beckhoff's platform allowed us to do that. EtherCAT gives us the speed we need for motion control, and TwinCAT provides flexibility in software. It's also cost-effective – we can scale, add I/O easily, and deploy software remotely across global sites."

Aquiles Calderon Santana, Engineering Manager, Ocado

> "The application required us to control multiple motors precisely and integrate a vision system within tight space and cost constraints."

"Beckhoff ensures supply chain resilience through seamless connectivity with virtually any open fieldbus or IT protocol," said Doug Schuchart, global intralogistics manager at Beckhoff. "This openness minimizes engineering effort over the system's lifecycle while enabling straightforward system expansion as facilities evolve."

Remote deployment was a major advantage. Ocado's operations span multiple continents, and its engineering teams must be able to update and support machines worldwide without constant travel.

"Remote software deployment is key for us," continued Calderon Santana. "With Beckhoff, we can push updates and make adjustments from the UK to a site in Japan or the U.S. This remote capability is crucial for reducing downtime and ensuring consistency across every facility."

The TwinCAT software platform enables integration into CI/CD pipelines and allows validated operating system updates, PLC code, and safety logic changes to be administered centrally and automatically rolled out to globally deployed assets.

Collaboration and integration

The partnership began when Ocado's engineers visited Beckhoff's UK technology center to explore live applications and test sample units. From there, Ocado tested Beckhoff hardware and software in-house before standardizing on the platform for the AFL.

The AFL machine operates continuously, up to 20 hours a day, and dynamically scales throughput in response to order volumes.

Ocado's customer fulfilment centers (CFCs) are designed to deliver every order within a onehour slot.

"The Beckhoff team was proactive from the start," said Calderon Santana. "They took the time to understand what we were trying to achieve and provided expert guidance on how to get the best out of their technology. That level of engagement has continued as we look to roll out Beckhoff technology in other machines."

Beckhoff engineers visited Ocado sites to observe the AFL in action and ensure optimal configuration. However, Ocado's internal engineering team handled most of the implementation directly – a testament to the ease of integration.

"It was straightforward to adopt," added Calderon Santana. "Even though it was a new platform for us, the system architecture was intuitive and we didn't need complex co-integration. Beckhoff's support made the transition smooth."

Safety and reliability at scale

In high-throughput facilities, where tens of thousands of orders move each day, safety and uptime are non-negotiable. Beckhoff's TwinSAFE system consolidates all safety functions, from emergency stops to interlocks, into the same EtherCAT network that runs standard I/O, simplifying wiring and reducing latency.

"With TwinSAFE, safety isn't a bolt-on feature – it's fully integrated," explained McEwan. "The TwinSAFE logic is part of the same TwinCAT project environment meaning incorporating functional safety into the machines is seamless. This reduces programming and integration time and improves diagnostics during both commissioning and normal operation."

Bradley McEwan,
business development manager, Beckhoff UK

> "With TwinSAFE, safety isn't a bolt-on feature – it's fully integrated"

For Ocado, reliability is critical. A breakdown in the AFL could delay van departures and disrupt delivery commitments. The Beckhoff hardware and software ensures continuous operation and the Ocado equipment can run all day with minimal intervention. Combined with predictive monitoring via Ocado's own analytics tools, the result is a resilient, self-optimizing system. EtherCAT's efficient bandwidth utilization makes it ideal for collecting large volumes of data to support predictive maintenance strategies.

Because all EtherCAT devices on the network are typically updated within a single frame, ample bandwidth remains available for continuous data acquisition on the fieldbus. Beckhoff controllers further enhance this capability with high memory capacity (RAM) and large, removable media drives, enabling data to be stored and analyzed locally at the edge.

Cybersecurity and connectivity

Given the scale and global reach of Ocado's automation network, cybersecurity is a key consideration for any new technology.

"Cybersecurity is incredibly important for us," said Calderon Santana. "Every piece of technology that enters our system must meet a very high bar. Beckhoff's platform integrates well into our internal cybersecurity framework, which is modular and designed to manage risk across all control systems."

While Ocado's cybersecurity tools are developed internally, Beckhoff's open architecture ensures compatibility with Ocado's monitoring and traceability systems, enabling secure data exchange between the AFL and the wider warehouse management network.

Empowering people

The success of the AFL means Beckhoff and Ocado are already working on future Ocado machines under development within the business.

"Our strategy is to build flexibility into every control system we design," said Calderon Santana. "Beckhoff enables that. Every new machine we're developing is assessed with Beckhoff technology in mind, because it gives us the scalability we need."

Bailey added that Beckhoff's involvement goes beyond hardware: "The team has been genuinely engaged in supporting our growth — not just supplying technology but helping us connect with others and explore new ideas. It's a true partnership."

Looking ahead, Ocado plans to expand its automation technology beyond grocery, applying the same innovations to pharmaceuticals and clothing, among other product areas. The AFL, equipped with Beckhoff technology, provides a modular foundation for these ventures. New technology from Beckhoff is also being tested and considered by Ocado including. PLC++ and TwinCAT for Linux. These developments will allow further integration into Ocado's automated build and verification pipeline, increased programming efficiency and faster execution time in the machine. Furthermore, the support of containerisation with TwinCAT opens the door for more modular and efficient machine design.

At a site in Luton, England, Ocado's most advanced CFC yet, automation has transformed grocery fulfilment. The facility handles up to 65,000 orders per week with 99% on-time dispatch, and its automation allows an order to be picked almost an hour faster than traditional store picking.

With Beckhoff control at the heart of the AFL, Ocado has automated the final stage of its fulfilment process, creating a seamless, fully automated path from supplier to doorstep.

"Beckhoff's technology helps us deliver on our core promise to customers – accuracy, reliability and on-time delivery," concluded Bailey. "It's a critical part of how we make convenient and great-value online grocery deliveries not just possible, but sustainable."

More information:
www.ocadointelligentautomation.com
www.beckhoff.com/intralogistics

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With 100 facilities around the world, the new fleet of Enzo AMRs will help CTDI better control processes and costs across the enterprise.

With Beckhoff technology at its core, the Enzo delivers unmatched mobile robot precision, safety, and adaptability across global operations.

Prototype to production in 60 days: CTDI's Enzo redefines AMR innovation

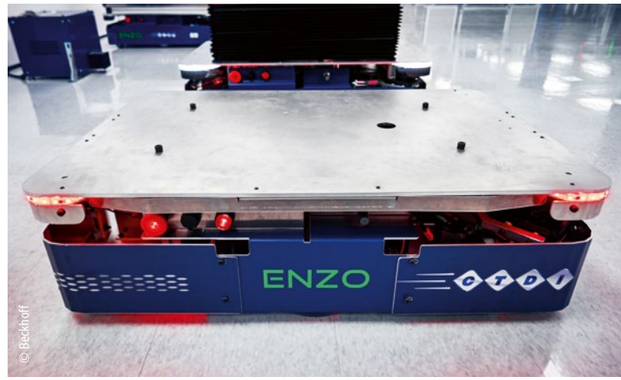
© Beckhoff

The Enzo is powered by Beckhoff's ultra-compact C6032 Industrial PC, which delivers optimum computing power in a rugged housing.

Logistics companies are judged by their ability to move faster and operate smarter. The organizations that are best at this are the ones that convert complexity into flow with new technologies. Autonomous mobile robots (AMRs) offer a rare dual advantage: they boost productivity and workplace safety immediately while laying the foundation for entirely new operational models. What was once seen as a nice-to-have vanity technology has become a competitive mandate, and the companies that fully embrace AMRs today are the ones that are pulling into the pole position.

Based in West Chester, Pennsylvania, CTDI understands how fast AMR technology is evolving and how it can transform material handling and logistics operations. As a leader in the rapidly growing communications, mobility, and consumer device services industries, CTDI specializes in forward and reverse logistics bolstered by industry-leading testing technology and repair/refurbishment services.

Originally founded in 1975 by Don, Jerry, and Richard Parsons in the garage of their family home, the organization has accelerated its growth to encompass locations in 20 countries across the globe. With the expansion of the company's reach, CTDI also needed to expand their automation capabilities to stay competitive. Recognizing the need for greater independence and control over their own material handling automation, CTDI made the decision to design in 2024, build, and support their own AMR. Focusing on goods-to-person systems, CTDI launched its Enzo AMR program in-house with advanced automation and control technologies from Beckhoff.



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By creating a single, adaptable AMR platform, the Enzo from CTDI meets rapidly changing workflow needs across intralogistics operations.

AMR innovation at full speed

Over the course of 2024 and 2025, CTDI has made significant strides in the automation technologies driving their Enzo AMR program. Taking just two weeks to get a working prototype and then two months to deploy a fully functional version in the field, what began as an experimental "version 0" quickly evolved into the current fully autonomous and integrated version 2.2 of the Enzo AMR.

The decision to develop the AMR in-house was driven by CTDI's continued investment to vertically integrate in developing their own flexible, high-impact, automation solutions to support their business growth and their customers' supply chain demands. According to Kirk Whittemore, Director of Automation at CTDI, "We have 100 facilities around the world, and we want to be in full control of those sites. By making our own AMR, we can best control our processes and costs." By owning the development process, CTDI can better adapt the Enzo to rapidly changing workflows, optimize efficiency, and eliminate reliance on external vendors for updates, reconfigurations, or new deployments.

When looking for partners who could tackle their program's unique needs, CTDI chose Beckhoff for an automation platform with unmatched flexibility, integrated safety, and an open architecture. CTDI needed a system that could combine high performance motion control and robust safety functions to operate alongside people in busy testing and warehouse environments. Beckhoff's TwinSAFE programmable safety technologies allowed CTDI to streamline development while still maintaining the company's rigorous standards in a new product category.

Modular by design, intelligent in execution

CTDI focused on three key application areas for the Enzo: goods-to-person operations, dynamic routing, and testing new equipment in development for future innovations.

With this in mind, the Enzo AMR was designed with flexibility at its core. Developers built a versatile base unit that can be customized for a wide range of applications using modular attachments called "toppers." These can include shelves, lifting units, rotation units, tuggers, conveyors, and more. By creating a single, adaptable AMR platform, CTDI can easily tailor the Enzo to meet specific needs for various processes and workflows, maximizing efficiency and scalability across their operations.

The versatile AMR is engineered for deployment across a wide range of warehouse and production environments. Enzo units are used for dynamic routing through warehouse aisles; handling medium to heavy loads depending on order volume and workflow demands. Designed with a hinged center and dual drive wheels, the Enzo maintains stability and maneuverability even over uneven surfaces, ensuring reliable, precise motion control as the AMR surfs across warehouse floors.

Unlike many commercial AMRs that rely on third-party software, CTDI developed 100% of the Enzo's code in-house. Using Beckhoff's TwinCAT automation

The machine-mountable EP3751-0260 EtherCAT Box from Beckhoff features an accelerometer and gyroscope in one compact, IP67-rated device for highly precise tracking and movement.

The Enzo features built-in safety technology (yellow terminal) and precise motion control handled by Beckhoff's ELM7222-9018 servomotor I/O modules (right) which comfortably fit inside AMR housings.

CTDI engineers rapidly accelerated development by creating a digital twin of the Enzo, allowing them to simulate, test, and debug Enzo prior to deployment.

The Enzo AMR drastically cuts down the amount of manual transport within a warehouse, reducing repetitive physical stress and potential accidents for workers.

platform as a development environment, CTDI engineers created a digital twin of the Enzo prior to deployment, allowing them to simulate, test, and debug – all without running the robot in a physical environment. This approach rapidly accelerated development and ensured reliability and responsiveness in the final product.

Enzo was first deployed in goods-to-person operations at CTDI. The AMR transports shelf pods from inventory to picking stations. This cuts down the amount of manual transport within a warehouse space, reduces repetitive physical stress, and eliminates potential sources of accidents for warehouse workers. The Enzo also works alongside CTDI engineers as they test equipment to load and unload telecom equipment.

Engineered precision, inside and out

The Enzo's advanced capabilities are powered by automation technologies from Beckhoff, at the center of which is the C6032-0080 Industrial PC with 11th generation Intel® Core™ i5 processor and Gigabit Ethernet PCIe card running TwinCAT software, including the TwinCAT/BSD operating system. "We use the C6032 because it's a powerhouse controller and it offers unbelievable flexibility," says Shawn Sidelinger, Controls Engineer at CTDI.

(From left): Doug Schuchart, Beckhoff; Michael Parsons, CTDI; Shawn Sidelinger, CTDI; Andrew Elcock, CTDI; Skanda Akkihebbal Prasanna, CTDI; Soham Patwardhan, CTDI; Kirk Whittemore, CTDI; Jay McNeil, Beckhoff.

The C6032 Industrial PC and TwinCAT 3 allowed CTDI to create a hybrid control architecture capable of running both TwinCAT/BSD and Linux operating systems simultaneously through virtualization. This unique platform enables seamless communication between the Robot Operating System (ROS2) and TwinCAT, allowing CTDI engineers to dynamically assign control to the system of their choice based on the specific application, such as QR code guidance or navigation based on Simultaneous Localization and Mapping (SLAM). CTDI also utilizes the CP6706-0001-0070 "Economy" Built-in Panel PC with Intel® Atom™ x6 processor as a secondary controller and HMI for the topper, allowing operators to directly interact with the parts delivery system.

According to CTDI, the Enzo's ability to track its position in real-time further sets it apart in the AMR industry, delivering a level of accuracy and adaptability rarely seen in these systems. Its highly precise motion control comes from ELM7222-9018 servomotor I/O modules in metal housings paired with compact AM8122 servomotors with One Cable Technology (OCT). This combines motor power and feedback into a single cable to minimize wiring complexity, required space, and build time while maximizing flexibility and movement precision.

The system also incorporates an EP3751-0260 EtherCAT Box which offers a 3-axis accelerometer and gyroscope that enable highly precise tracking and movement of the Enzo to help keep the AMR on the planned path. Meanwhile, the WNGV64-25-0B1-F2 right angle planetary gearbox for AGVs enhances torque control for high load capacity in heavy transport, and Beckhoff's comprehensive portfolio of cables and connectors significantly simplified CTDI's wiring setup.

Beckhoff's TwinSAFE safety technology, supported by modules such as the EK1914 EtherCAT coupler and EL1918 TwinSAFE Terminals, delivers integrated, certified safety that simplifies system design while maintaining rigorous performance standards. This combination of safety, flexibility, and openness has enabled CTDI to innovate quickly, unify the Enzo with its warehouse IT and WMS systems, and deploy dozens of highly customized robots across their global locations.

Beckhoff's open platform also empowers CTDI to maintain full ownership of its software and hardware design IP, ensuring complete control over performance, integration, and future scalability. The system's adaptability is epitomized by the Enzo's modular toppers, where EtherCAT I/O with hot connect capability and TwinCAT software's variant management tools make it possible to quickly swap and reconfigure different toppers with minimal software changes.

An AMR platform that's built to last

After its impressive launch, CTDI's AMR program will continue to evolve, with ongoing improvements to the Enzo aimed at increasing flexibility, speeding deployment, and expanding its range of supported workflows. The team has already realized major gains, including dramatically shorter development cycles, reduced reliance on third-party vendors, faster reconfiguration for new programs, and improved safety and motion precision across their facilities. According to Soham Patwardhan, R&D Robotics and Automation, Intralogistics, at CTDI, "Beckhoff's flexibility allows us to select the right equipment without being locked into any particular technology or hardware. In addition to TwinCAT being highly real-time deterministic platform, it also presents several Operating System alternatives like BSD, Linux & Windows, which allow us to integrate into existing test solution, and provide easy integration not just for Engineering, but also from maintenance and operations perspective."

Looking ahead, CTDI is actively developing the next generation of AMR technology with new feature enhancements and targeted reductions in cost and manufacturing time to support wider global rollout. Powered by the Enzo's flexibility, speed, and intelligence, CTDI will continue to transform goods-to-person operations in the telecom industry.

Watch CTDI's Enzo transforms goods-to-person logistics with ultra-compact controls and EtherCAT.

More information:
www.ctdi.com
www.beckhoff.com/intralogistics

The E80 Group relies on TwinCAT 3 and embedded PCs such as the CX5240 with Intel Atom® (1.6 GHz, quad-core) as a control platform in its various LGV series.

© E80 Group

Efficient intralogistics with PC-based control

When a partnership lasts over time: E80 Group and Beckhoff

Since the early 2000s, the E80 Group has been implementing its intralogistics projects with PC-based control from Beckhoff.

© E80 Group

E80 Group, one of the leaders in logistics automation systems, has adopted Beckhoff's PC-based platform for its laser-guided vehicles (LGVs). This choice has helped improve the reliability and efficiency of the solutions offered.

In intralogistics, autonomous laser-guided vehicles (LGVs) are key tools for increasing productivity and flexibility. In this field, E80 Group has stood out from the very beginning for its innovative approach. Founded in 1980 in Viano, Italy, the group has gradually expanded its international presence. With over 1,500 employees and 16 subsidiaries worldwide, it has implemented more than 450 smart factories around the world, installing over 2,800 robotic systems and more than 9,000 laser-guided vehicles. Every day, E80 Group solutions move goods worth more than €1 billion in products around the world.

Transition from PLC to Beckhoff Industrial PC

In the early 2000s, the PLC architecture showed application limitations, as the electronics and associated software were closed environments. In 2004, E80 Group was among the first companies to invest in the use of industrial PCs in mobile applications: "We decided to evaluate alternatives that could respond flexibly to our needs," says Gianluca Clementini, Business Development Manager at E80 Group. "The company was growing, with increasing customer demands. This required greater integration and better data management and processing by the PLC or on-board PC, which controlled all the functions of the laser-guided vehicles."

In terms of performance, cycle times would drop from 100 ms to 800 µs with an industrial PC such as the one proposed by Beckhoff. "Choosing to switch to a new, high-performing system that had yet to be implemented was a challenge, but one that has offered us new opportunities over time," Gianluca Clementini continues. In this scenario, software was central, as was the transition to a new programming mode that Beckhoff provided through its TwinCAT automation platform, which adheres to the IEC 61131 standard.

Doug Schuchart, Global Manager Material Handling & Intralogistics at Beckhoff, describes an additional aspect: "Traditional automated vehicles often require three separate controls – a PLC for the vehicle functions, a PC for navigation and localization algorithms, and a dedicated safety controller. Beckhoff's approach is completely different. TwinCAT eliminates this complicated system and integrates all functions on a single embedded or industrial PC."

TwinCAT, a breakthrough in programming

The TwinCAT platform allowed E80 Group to develop modular functions, facilitating the programming and integration of new features. "With TwinCAT, we were able to develop even complex functions right from the start, with the

LGVs need a flexible, powerful, and open control platform for the convergence of navigation, fleet management, safety, and automation.

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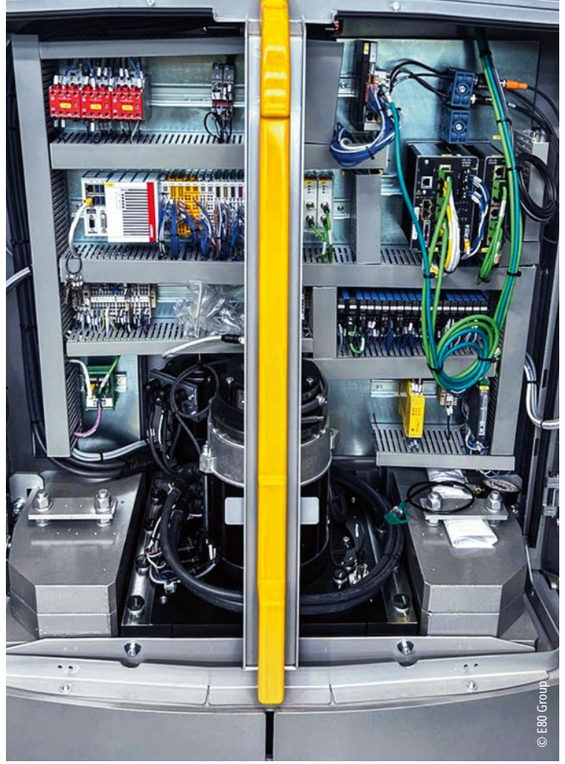

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The small footprint of EtherCAT Terminals and embedded PC enables compact LGVs.

advantage of being able to make them independent of the individual system and, therefore, to use them wherever they were needed, according to the logic of Function Blocks," says Gianluca Clementini.

The further transition from TwinCAT 2 to TwinCAT 3 has allowed E80 Group to take full advantage of multi-core technology to maximize the performance of complex functions, ensuring the use of pre-compiled C++ libraries and the integration of advanced functions, from environmental and mixed navigation. At the same time, there have also been advantages from a safety perspective: whereas a dedicated PLC was once required, today, with TwinSAFE, safety function management is fully integrated within TwinCAT. Doug Schuchart points out: "The black channel principle from Safety over EtherCAT (FSoE) also enables safety communication to be implemented via various transmission media – including EtherCAT, Ethernet, standardized fieldbus systems, and even WLAN. Together with Beckhoff's Single-Channel safety, which supports analog safety, all safety requirements of a mobile robot can be flexibly met. This reduces the overall system complexity."

The hardware reliability of Beckhoff solutions

An industrial PC must withstand the mechanical and thermal stresses typical of integration with mobile devices such as LGVs. For E80 Group, this is a crucial aspect. "Beckhoff Industrial PCs are designed and built to operate in high-stress environments: they have always guaranteed reliability and performance that meets our needs," emphasizes Gianluca Clementini.

This is in reference, for example, to the CX5000 Embedded PCs, fanless units equipped with SSD memory and Intel Atom processors with Hyper-Threading technology. Measuring just 100x100x91 mm and mounted on a DIN rail, they provide everything needed not only in terms of processing power, but also interfaces, including an optional slot for serial communication modules, as well as direct connection to Beckhoff Bus Terminals (K-bus) or EtherCAT Terminals (E-bus), which offer the advantage of simplified cabling. Beckhoff Industrial PCs use a single EtherCAT cable, through which all signals pass, which also translates into greater operational reliability. "In addition, the extended connectivity of Beckhoff PCs has made technical support more efficient," explains Gianluca Clementini. "Today, more than 75% of the reports that come to our service desk are resolved remotely in a short time."

Future prospects

E80 Group continues to develop solutions aimed at making intralogistics operations increasingly efficient. In particular, technologies based on mixed vision and navigation are currently being developed, which have shown great potential recently when applied to autonomous driving and safety, with a significant improvement in the recognition of objects and people.

© E80 Group

Gianluca Clementini,
Business Development Manager of the E80 Group

> "With PC-based control from Beckhoff, we can realize the increasingly diverse requirements of intralogistics projects and driverless transport systems with a single open control platform."

More information:
www.e80group.com
www.beckhoff.com/intralogistics
www.beckhoff.com/embedded-pc

Retrofit of the conveyor technology control system in central dispatch

Open control system reduces maintenance costs and boosts future-proofing

In the extensive central warehouse of Australian office equipment supplier Officeworks, Layer Seven Automation has replaced the proprietary, outdated warehouse logistics control technology with PC-based control.

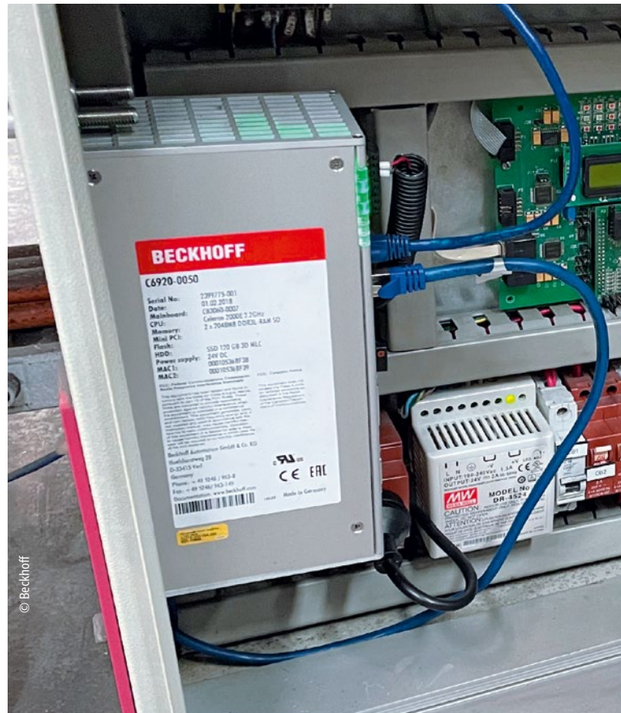
© Beckhoff

For every online retailer, warehouse logistics is part of the critical infrastructure: If the conveyor lines come to a standstill, it generally won't be possible for any more packages to get out. To prevent this, an Australian office equipment supplier has retrofitted the warehouse logistics installation of its central warehouse. In its role as project manager, Layer Seven Automation replaced the proprietary decentralized controllers of the conveyor lines with PC-based control from Beckhoff, based on powerful EtherCAT communication.

The end user is one of Australia's leading office equipment suppliers, with a broad portfolio ranging from office supplies and computers to office furniture. The company operates more than 100 stores across Australia as well as an online store with more than 40,000 products. At main distribution center, the stored goods are removed from shelves and packed into boxes, then transported along various conveyor lines – with a total length of 700 m and 28 distribution stations – and prepared for dispatch.

The conveyor lines had operated reliably for many years but it had become apparent that the systems were reaching the end of their service life. Malfunctions were occurring more and more frequently, and the required spare parts had become increasingly difficult to obtain and more expensive due to the age of the system. As a result, the management of the office equipment supplier commissioned Layer Seven Automation from Bella Vista (in the Sydney metropolitan area), which specializes in warehousing and logistics projects, to develop a concept that would modernize the warehousing system.

The evaluation revealed that the mechanics of the main conveyor belt were still in a usable state, but that the control system needed to be replaced. Lucky Thommadura, co-founder and chief engineer at Layer Seven Automation, says: "One of the disadvantages of the conveyor system was its proprietary structure. Every part had to be purchased from the manufacturer, which would have made it even more difficult to expand the system." As a result, the decision was made to configure an open system based on off-the-shelf products. "This would offer a future-proof solution and reduce maintenance costs," states Thommadura.



The decentralized control technology of the 28 stations in total was replaced by a single C6920 control cabinet Industrial PC (left), which controls all the stations in the extensive logistics system via EtherCAT.

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Barcode scanners with an EtherCAT interface detect incoming packages via integrated I/Os and receive the positioning commands for controlling the switches from the central control computer.

One industrial PC replaces 28 controllers

The original system configuration was based on one controller and one barcode scanner for each distribution station. Layer Seven Automation's aim was to create a centralized control architecture that would increase the efficiency of the system and reduce costs.

The barcode scanners at each station are essential for recording the contents of the boxes. Here, Layer Seven Automation opted for scanners that can be configured via an EtherCAT interface and have integrated I/Os for simple control functions. The inputs are used to detect the boxes via opto sensors, for example, while the outputs are used to switch the switches or pushers according to the destination station.

First, a single distribution station was converted and its scanner was connected to a C6920 control cabinet Industrial PC from Beckhoff via EtherCAT. Following successful tests, all 28 stations were migrated in stages and networked with the C6920 in a linear structure (daisy chain). Lucky Thommadura comments: "The technicians of the logistics company and I were surprised by the compactness of the solution, the fast update rates of the EtherCAT network, and the overall speed of the controller." After all, the barcode on the box has to be scanned and forwarded to the industrial PC via EtherCAT. There, the application determines whether the switch of the corresponding station needs to be switched and sends this information back to the barcode scanner via EtherCAT. "The Beckhoff Industrial PC manages the extensive calculations in around 100 µs, which is phenomenally fast," says Thommadura enthusiastically, "and yet we still have reserves."

Even though there has not yet been a network failure, carelessness can quickly cause a cable break and thus a failure of the entire system. A shutdown of this kind would have a significant impact on productivity, especially in such a large-scale logistics installation. There are therefore concrete plans to implement cable redundancy, which is easy to retrofit with EtherCAT.

Engineering with IT methods

The engineering team at Layer Seven Automation has extensive experience in the general software and computing sector – for example, in setting up databases or creating web servers. Until the project, however, Lucky Thommadura and his team had not yet come into contact with the automation environment: "We knew that all of this would be new to us. But when I discovered how EtherCAT works, what an industrial PC is, and how easily we can combine Windows with a virtual PLC, it all made sense. The virtual machine in particular enabled me to test the program via a laptop from home, at work, or on site." The fact that TwinCAT is integrated in Visual Studio was another reason for the chief engineer to invest in Beckhoff and EtherCAT. "I really believe that this is the way automation technology needs to go – away from closed systems with Ladder Diagram programming and outdated signal processing. We need to take established software design and architecture practices and combine them with automated testing so that we can deliver our solutions more effectively," Thommadura adds.

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Lucky Thommadura, co-founder and chief engineer at Layer Seven Automation, says: "A major advantage of TwinCAT is how easy it is to integrate your own software and incorporate it into existing IT infrastructures."

PC-based control: Secure, open, and flexible

According to Layer Seven Automation, a major advantage of PC-based control is that the control architecture is easy to integrate into existing IT systems. This was another pleasant surprise for Lucky Thommadura: "Many IT departments have very strict security requirements, but Windows is always easy to integrate. The firewall, security settings, and global user administration have made our work here much easier." The option to use Windows has also enabled Layer Seven Automation to combine its own programs with TwinCAT: For example, an SQL database was integrated via TwinCAT 3 Database Server (TF6420), which archives the details of a box every time it is scanned. This action is permanently recorded and logged in the TwinCAT 3 EventLogger. In addition, a dedicated message queue system was created, which uses the ADS protocol to extract data and ultimately link it to the RabbitMQ message broker software. "ADS technology from Beckhoff offers almost unlimited possibilities. We use ADS to collect the recorded volumes of data and distribute them both horizontally and vertically. It can also be used to easily integrate almost any MES or ERP system," adds Thommadura.

More information:
www.layerseven.com.au
www.beckhoff.com/intralogistics

Performance boost in converting with PC-based control and EtherCAT

From film to finished mailer bags in record time

To ensure that an online order arrives in perfect condition, the parcel must be well protected during shipping. CMD Corp. from Appleton, Wisconsin, developed a system producing mailing bags for the fast-paced e-commerce business. Control technology from Beckhoff integrates all stations along the line – regardless of whether for intermittent or continuous operation – into an optimized workflow.

CMD understands that flexible automation and repeatable results are essential in the packaging industry. So the OEM provider strives to meet these requirements by continuously exploring new technologies for use in their highly customized plastic converting solutions. CMD thus lives up to its name, which is an acronym for Custom Machinery Design.

For a contract manufacturer in the e-commerce sector, the company started designing a new mailer packaging machine. A high-throughput machine with an intuitive operator interface was a top priority, according to Scott Fuller, Product Line Manager, Intermittent Motion Products at CMD. “This new machine is much faster and more automated, which was key for our end user customer,” says Fuller. The end customer will produce bags for online retailers primarily to ship e-commerce items in plastic bags. Another customer need: bags that would work with automated product loading.

Next-level automation

In the new streamlined converting process, the 1400-GEC machine unspools two rolls of film, registers the print on those two rolls and applies a continuous longitudinal seal. Then it runs the rolls through a series of cross-directional punches and seals, slits the material in up to five individual lanes of bags,

The new 1400-GEC mailer packaging machine from CMD incorporates a complete Beckhoff control system, offering enhanced flexibility and performance capabilities.

Space-saving EtherCAT Terminals and bus couplers, including the EK1914 coupler with TwinSAFE functionality, combine high-speed real-time communication with functional safety.

The Beckhoff CX2033 Embedded PC functions as the sole machine controller for the 1400-GEC mailer packaging machine and contributes to boosting scan times.

depending on order specifications, and adds perforation for easy separation. Before loading the finished bags into cases, ready for use as specified by the customer, the system performs a vision test while blowing air into the open end of the bag and measuring its shape profile.

"This machine incorporates entirely new automation processes. It transitions from continuous motion to intermittent motion and back to continuous in the outfeed, while handling various tasks in each phase," Scott Fuller explains. "That makes it distinct from the machines we've designed before."

The support of all this functionality in real time required a control system with significant processing power. In addition, the development team faced tight lead times on this project. It was essential to finish on schedule while also delivering a smoothly working, reliable solution.

Powerful programming tools

As an end-to-end engineering and runtime platform, TwinCAT automation software combines everything from PLC and motion control to integrated safety and IoT. When programming the new operator interface, TwinCAT HMI allowed CMD to leverage modern web design standards, such as HTML5, JavaScript and CSS. The resulting responsive interface increases user-friendliness with a more intuitive HMI.

When programming the machine control with TwinCAT, CMD benefited from close cooperation with the software experts in Beckhoff's Special Projects Team (SPT). The SPT framework builds on industry standards such as ISA-TR88 and PackML and the associated libraries in TwinCAT. It simplifies the programming of communication between individual machines within a production line. The advantage for programmers is that they do not have to start from scratch for every project, but can reuse existing code or easily customize it to new requirements.

Efficiency throughout the line

A CX2033 Embedded PC serves as the sole machine controller for the entire line. A dual-core AMD Ryzen™ processor supplies extensive performance capabilities to the DIN rail-mounted controller from Beckhoff with room to grow in the future. "If you're working with a resource-constrained system, your HMI will be laggy to the touch. So, putting the HMI server on a CX2033, which offers ample computing resources, enables the touch panel to operate very responsively," explains Software Engineer Adam Benson from CMD.

EK1914 EtherCAT couplers integrate communication along the entire line with their digital standard and safety I/Os. Besides EtherCAT Terminals for standard signals, the I/O segments of the various stations also include TwinSAFE terminals for functional safety. This allows CMD to conveniently allocate safety functions, such as an e-stop, to each tool in the machine line.

The high level of synchronization provided by EtherCAT also enhanced the powerful drive technology from Beckhoff in CMD's motion-intensive application. The machine features the AX8000 multi-axis servo system and AM8000 servomotors controlling fourteen axes. "The AX8000 drives are very compact for the power they provide," CMD Electrical Engineer Jason Plutz says. "And by using the integrated Safe Torque Off functionality, we eliminated two large contactors, saving significant panel space."

CMD leveraged camming motion control in TwinCAT 3 software with two of the axes on the bag packaging machine. The bag opener, initially positioned in the intermittent movement section, was relocated downstream to enhance efficiency through the camming functionality. Using an extrapolation of continuous web processing, the bag opener is precisely cammed to achieve the desired motion at just the right moment.

Well-positioned for the future

By harnessing the software framework from Beckhoff, CMD boosted their code reusability to 90%. Employing TwinCAT HMI also helped the team create a more intuitive operator interface in a way that supports outstanding customization. "The new operator interface resembles our legacy HMI, but has a much cleaner, more user-friendly design," says Software Engineer Adam Benson.

Running the entire machine with an EtherCAT-networked CX2033 Embedded PC accelerated CMD's cycle times. "Having everything scan at one high speed is a huge benefit. You don't have to worry about communicating between process stations that function at different speeds because everything updates at the same time," Jason Plutz explains. This enabled the CMD team to reach their target throughput rate of 200 feet or approximately 60 m of plastic sheet per minute. This translates to 100 bags per minute per lane, resulting in an impressive total of 300 to 500 bags produced every minute.

Looking ahead, the CMD team intends to scale up to the CX2043 with a quad-core AMD Ryzen™ CPU for even greater machine control horsepower. Beckhoff's nearly endless Industrial PC portfolio is built for scalability, enabling performance adjustments without requiring reengineering.

Beckhoff AM8000 servomotors, including large, air-cooled motors, provide reliable performance for both continuous and intermittent motion axes.

Automation and converting experts combine forces at the CMD Technology Center in Appleton, Wisconsin (from left to right): Mark Lewis (Special Projects Manager at Beckhoff USA) with CMD's Doug Main (R&D Test Technician); Scott Fuller (Product Line Manager, Intermittent Motion Products); Jason Plutz (Electrical Engineer); Nicole Onesti (Corporate Market Manager) and Adam Benson (Software Engineer)

More information:
www.cmd-corp.com
www.beckhoff.com/intralogistics

EP7402 EtherCAT Box modules in warehouse and distribution logistics

Conveyor technology retrofit reduces energy consumption and noise

© Beckhoff

The approximately 250-m long central ring conveyor from Arvato SE was extensively modernized with PC-based control, One Cable Automation, and around 200 EP box modules for roller drives.

© Beckhoff

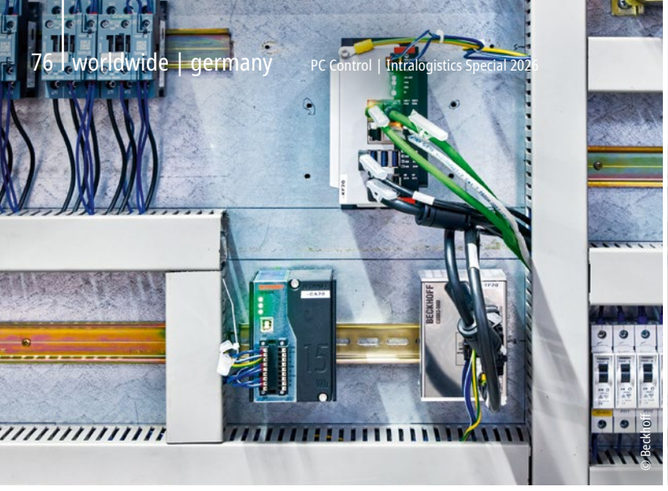
Intralogistics systems such as the central ring conveyor at Arvato SE benefit in particular from One Cable Automation: Power and communication are efficiently distributed to the compact EP7402 MDR controllers using pre-assembled hybrid cables.

Conveyor technology is part of the critical infrastructure of every logistics company. This is why the logistics service provider Arvato SE has completely retrofitted the central conveyor line between several warehouses and the order picking area at its Harsewinkel site. With PC-based control, One Cable Automation, and around 200 EP7402 EtherCAT Box modules with integrated MDR controllers from Beckhoff, the system runs much more efficiently, quietly, and reliably.

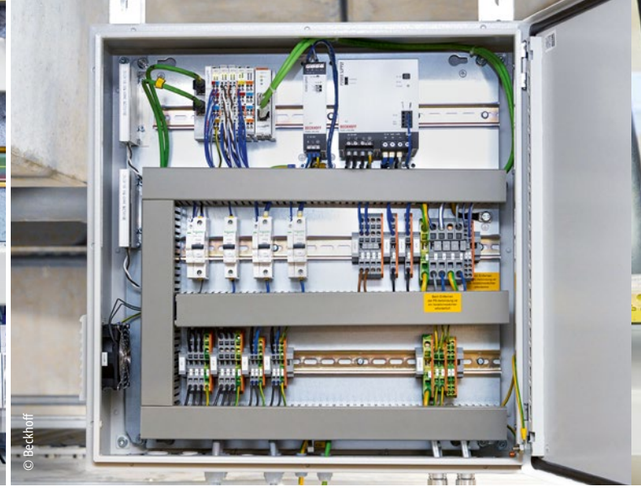
As a global logistics company, Arvato SE, headquartered in Gütersloh, handles all B2C and B2B logistics processes for its customers, from order acceptance and value-added services to returns management. Represented at over 100 locations worldwide, Arvato maintains warehouse capacities of almost 1 million m² at 28 locations in Germany alone, including several halls with high-rack warehouses at the Harsewinkel site near Gütersloh. From here, orders are picked for customers from various industries, then the goods are packed and shipped to the recipients. The high-rack warehouses are connected to the picking area by a central circular conveyor line measuring over 250 m in length.

24-V technology for more efficient operation

The ring's previous conveyor technology was still based on roller drives with three-phase motors. "These drives were very loud, ran continuously along the entire route, and were prone to failure after around 20 years of operation," says Markus Wolharn, Senior Expert Engineering at Arvato. The conveyor technology has therefore been renewed with a mechanical and electrical alternative: 24-V roller motors have now replaced all the old drives. They are controlled via a total of 186 decentralized EP7402 EtherCAT Box modules with integrated MDR controllers (MDR = motor driven roller). At the same time, the existing control hardware was con-



A C6030 ultra-compact Industrial PC controls all roller drives of the central ring conveyor via EtherCAT and EP7402 compact box modules.



The power supply for the EP box modules is decentralized via 27 control cabinets with Beckhoff PS3031-2440 power supply units.

verted to a C6030 ultra-compact Industrial PC, the software was migrated from TwinCAT 2 to TwinCAT 3, and the existing system visualization was adapted.

The mechanical conversion of the conveyor line was designed and realized by Budde Systems in Schloss Holte-Stukenbrock. To speed up the conversion work on site, the conveyor line was divided into 125 individual segments, which were completely pre-fabricated and pre-wired at Budde Systems. “This modular production concept saved us a lot of cabling effort and time during final assembly at Arvato,” explains Maximilian Budde, managing director of Budde Systems.

The advantages of One Cable Automation

The prerequisite for this modular approach is the EtherCAT Box module connection technology using M8 connectors for the sensor technology and roller drives as well as ENP hybrid connectors (B23) for connecting power and EtherCAT communication. “This enables a fast and fail-safe connection,” enthuses Stefan Maßmann from Beckhoff systems engineering, emphasizing one of the advantages of One Cable Automation (OCA). The Budde Systems mechanics only had to lay the pre-assembled hybrid cables between the MDR controllers in the individual segments on site and connect them to one of the power supply control cabinets.

To keep the cable lengths to the EP box modules short, a total of 27 control cabinets are distributed throughout the system to supply power to the roller drives. “Each control cabinet supplies several segments and is positioned in the middle to keep the DC voltage drop low,” emphasizes Stefan Maßmann. The input voltages on the EP box modules were evaluated during commissioning, showing that this approach works. There was only case concerning a roller drive where the output voltage of the corresponding PS3031 power supply had to be adjusted slightly.

Each ring conveyor segment has one or two roller drives and the corresponding sensor technology to activate the drives. The switches also have a barcode scanner to identify the packages. All sensors are recorded via the EP box module I/Os. If required, additional I/O modules or other EtherCAT devices can be connected via the integrated EtherCAT junction. “This was the case, for example, with the switch supplier’s roller drives and the barcode scanners,” explains Stefan Maßmann.

Markus Wolharn, Senior Expert Engineering at Arvato

> “One Cable Automation and the IP67 box modules offer much more flexibility in terms of future system expansions.”

Increased flexibility with PC-based control and OCA

“One Cable Automation and the IP67 box modules offer much more flexibility in terms of future system expansions,” says Markus Wolharn, picking up on another important aspect of the cabling philosophy. If the system needs to be modified, the simple connection technology and pre-assembled cables make this just as easy in terms of control technology as the mechanical conversion. The system also demonstrates its advantages when it comes to maintenance. “The HMI shows the troubleshooting service exactly which segment is blocked and which component may need to be replaced,” explains Markus Wolharn.

When transporting the packages, the individual conveyor segments are switched on or off depending on the destination and whether the next segment is occupied. “When the path is clear, the next two transport segments are always switched on to ensure smooth and fast transportation,” explains Dimitri Kool from Beckhoff systems engineering. By the time the package reaches the next conveyor, it has already reached its target speed and the package moves on without losing time or jerking. In practice, each package creates a zone of active conveyors that moves through the ring.

Efficient engineering through variant management

Logistics operations had to be resumed quickly during the ten-week conversion period. This requirement was met by splitting the project into two sections. To this end, the first part of the modernized conveyor technology – which is a high priority for warehouse logistics – was put into operation with a C6030 ultra-compact Industrial PC and TwinCAT 3. At the same time, the second and larger part of the conveyor technology was automated on an old PC.

Finally, both software projects were merged on the C6030 ultra-compact Industrial PC. “With variant management in TwinCAT 3, we were able to achieve this efficiently and work permanently with an overall project in the Git repository,” says Stefan Maßmann.

The TwinCAT 2 controllers that are still in operation in the connected warehouses presented a challenge. TwinCAT 3 contains prepared data structures that map an EP box module with all variables and significantly speed up configuration. To be able to use this in the configuration of the modernized system parts under TwinCAT 2, this data structure was implemented as a function block for TwinCAT 2 and then migrated back to TwinCAT 3. “This had the advantage of working with identical variable names everywhere and exchanging the program parts between new and existing controllers as required when updating,” emphasizes Stefan Maßmann. “These global data types for TwinCAT 2 and TwinCAT 3 have significantly accelerated the project planning of the approximately 200 MDR controllers with around 50 signals each,” says Jürgen Bolte from Beckhoff systems engineering.

More packages, less energy consumption

The retrofit has not only increased reliability, but also the possible throughput from 2,000 to 3,000 packages or transport containers per hour – with significantly quieter operation and lower energy consumption to boot. “The 24-V technology also ensures greater safety if manual intervention is necessary in the event of a jam,” says Markus Wolharn. As a reference project, the ring conveyor conversion is attracting interest in other Arvato departments and locations due to its energy efficiency and lower noise emissions during operation. For Markus Wolharn, however, the advantages of One Cable Automation and the EP box modules when adapting the conveyor technology and installation are equally valid arguments.

Stefan Maßmann, Jürgen Bolte, and Dimitri Kool (all Beckhoff systems engineering), Maximilian Budde (seated) and Tristan Rodewald (both Budde Systems), and Markus Wolharn (Arvato SE) – from left to right – in front of the ring conveyor mounted under the ceiling with one of the 27 control cabinets for supplying the EP7402.

More information:
www.arvato.com
www.budde-systems.com
www.beckhoff.com/intralogistics
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Special components such as barcode scanners are integrated via the integrated EtherCAT junction of the MDR controller.

EtherCAT and cybersecurity in intralogistics: Integrity, availability, and a risk-based approach

Cybersecurity has become a central concern in industrial automation, and few sectors illustrate this more clearly than intralogistics. Conveyor systems, sorters, automated storage and retrieval systems (AS/RS), and mobile robots form the backbone of modern distribution centers and production supply chains. These systems are highly automated, performance-critical, and increasingly connected – yet they are typically not operated in physically protected environments. Operators, maintenance staff, contractors, and service personnel often have direct physical access to equipment, sensors, drives, and control cabinets. As a result, cybersecurity is not a theoretical concern but a practical requirement.

At the same time, intralogistics places very specific demands on cybersecurity. Availability and deterministic behavior are paramount, and the primary protection goal is usually data integrity – ensuring that commands, setpoints, and feedback data cannot be manipulated – rather than strict confidentiality of process data. A realistic, risk-based approach is therefore essential.

Risk-based cybersecurity as a regulatory and practical foundation

Modern regulations and standards reflect this necessity. Both the EU Cyber Resilience Act (CRA) and the IEC 62443 series for industrial automation and control systems are built on the principle that cybersecurity measures must be proportionate to risk. Risk is defined by the combination of the potential impact of an attack and the likelihood that such an attack can realistically occur under "reasonably foreseeable" conditions.

This approach explicitly avoids exaggerated threat scenarios and blanket requirements that drive up cost and complexity without improving real security. In intralogistics, overengineered cybersecurity can easily backfire: excessive authentication steps, complex certificate handling, or performance-reducing encryption may interfere with commissioning, diagnostics, maintenance, and 24/7 operation. Experience shows that measures that are impractical in daily operation are often bypassed – ultimately reducing, rather than increasing, security.

IEC 62443 therefore allows different ways of meeting its foundational requirements. Integrity, availability, and even confidentiality can be achieved through architectural means, physical measures, and protocol characteristics – not exclusively through cryptography.

EtherCAT in intralogistics automation

EtherCAT is widely used in intralogistics due to its high performance, precise synchronization, flexible topology, and scalability. Long conveyor lines, large numbers of drives and I/O modules, and distributed motion applications benefit from its deterministic behavior and efficient use of bandwidth.

Beyond performance, EtherCAT's functional principle has important cybersecurity implications. EtherCAT operates directly at the Ethernet layer using its own EtherType and does not rely on the Internet Protocol (IP). Process data are processed "on the fly" in hardware by dedicated EtherCAT SubDevice controllers, without the use of switches. This design not only enables short cycle times and precise synchronization but also fundamentally limits the attack surface.

Integrity by design: Protection against data manipulation

In intralogistics environments, where physical access to machines is common and personnel cannot automatically be considered fully trustworthy, preventing manipulation of control data is often the most important security objective. EtherCAT addresses this requirement inherently.

Only valid EtherCAT frames are accepted and processed by SubDevices. Any non-EtherCAT traffic – regardless of its content – is identified in hardware and discarded immediately. Malware, ransomware, or other IP-based attack traffic cannot propagate within an EtherCAT network because such traffic depends on IP and higher-layer protocols that EtherCAT does not use.

Communication follows a strict hierarchical model: All communication is initiated and controlled by the MainDevice, and SubDevices merely insert or extract their data at predefined positions within a frame. SubDevices cannot send frames autonomously, cannot listen to traffic not intended for them, and cannot modify data outside their assigned process data area. Even a compromised or faulty SubDevice firmware cannot violate these rules, as they are enforced by hardware.

For intralogistics systems, this means that unauthorized manipulation of commands or feedback data at the field level is inherently prevented. Attempting to inject or alter process data through standard cyberattack methods is simply not possible within the EtherCAT network.

Physical access does not automatically mean cyber vulnerability

While physical access increases the theoretical attack surface, it does not automatically translate into effective cyberattacks. Adding an unauthorized SubDevice to an EtherCAT network, for example, does not grant any influence over communication unless the MainDevice explicitly configures and enables it. Unused ports can be disabled in hardware, further reducing that threat.

If an attacker has extensive physical access and malicious intent, there are usually far simpler ways to disrupt an intralogistics system than attempting a sophisticated cyberattack at the fieldbus level. From a risk perspective, this reinforces the importance of focusing on realistic threats rather than extreme scenarios.

The system architecture still matters

Cybersecurity is not only about protocol features. System architecture plays a decisive role. EtherCAT supports a clear separation between the real-time automation network and higher-level IT or plant networks. In typical intralogistics architectures, protecting the controller and its northbound interfaces – using established IT security measures such as firewalls, access control, and secure remote access – addresses the dominant attack vectors.

By contrast, architectures in which every field device is directly exposed to IP-based networks require each node to implement complex security mechanisms. This significantly increases system complexity, lifecycle cost, and operational risk. The industry is increasingly returning to structured, compartmentalized architectures that align well with EtherCAT's design philosophy.

Meeting today's – and tomorrow's requirements

From a standards perspective, EtherCAT already meets the requirements typically associated with IEC 62443 Security Level 2, which covers protection against most intentional attacks and is sufficient for the vast majority of intralogistics applications. Importantly, this is achieved without any changes or extensions to the EtherCAT protocol.

For applications with even higher security requirements, the EtherCAT Technology Group is defining additional measures that remain backward compatible. These enhancements focus on software-based solutions in the MainDevice and optional extensions, avoiding technology breaks and protecting existing investments. EtherCAT's history of strict backward compatibility ensures that systems installed years ago remain interoperable with new devices and future security concepts.

Pragmatism as a security strategy

Cybersecurity in intralogistics is not about applying every possible countermeasure, but about making informed, risk-based decisions. EtherCAT demonstrates that a technology designed for deterministic, real-time automation can also provide strong inherent protection against cyber threats – particularly against data manipulation, which is the primary concern in many intralogistics applications.

By combining EtherCAT's built-in characteristics with sound system architecture and proportionate security measures, machine builders and operators can meet regulatory requirements, maintain high availability, and avoid unnecessary complexity. In an industry where downtime is costly and reliability is critical, this pragmatic approach is not just efficient – it is essential.

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