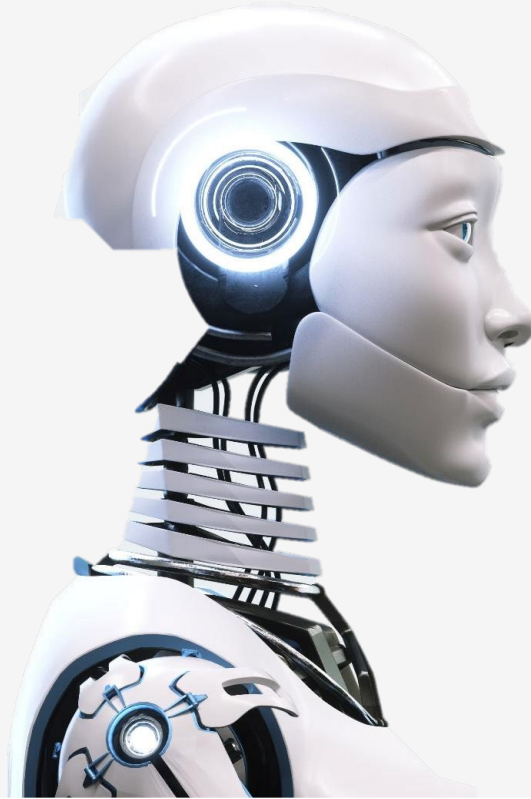


The Future of Factory Automation

**Presenter:**

Elena Dugger, New Market Development Manager, Molex

SEPTEMBER 23, 2026

KEY TAKEAWAYS

- Automation has emerged as a critical strategy to address major industry challenges
- Mobile automation enables greater efficiency, flexibility and visibility.
- Connectors play a foundational role in mobile robot performance.
- Beyond wheeled mobile automation, humanoid robots represent another emerging approach to automating tasks in facilities originally designed around human workers.

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The Future of Factory Automation

OVERVIEW

Manufacturers and logistics providers face growing pressure to boost productivity, overcome labor shortages, and build more flexible operations that can adapt to shifting market demands. Meanwhile, advances in AI, sensing technologies, and robotics are creating opportunities to automate tasks that were once difficult or impractical to scale.

But the advancement of robotics depends on more than AI and software. Every robot still needs a physical infrastructure that can move power, data, and signals reliably. As these systems become smaller, faster, increasingly powerful, and more mobile, the demand placed on their connectors and cable assemblies will continue to grow. It is therefore crucial to consider connectivity early in the design process, when decisions about the system architecture, packaging, thermal performance, motion, assembly, and serviceability can still be optimized.

Molex provides lightweight, mechanically robust connectivity solutions designed to support the transition from prototype systems to production-scale robotic deployments. These solutions can help maintain performance, simplify assembly, and support serviceability. Working with TTI, Inc., manufacturers can evaluate connectivity options suited to the requirements of specific industrial applications.

CONTEXT

Elena Dugger discussed the crucial role of intelligent mobile robots in the transition to autonomous operations.

KEY TAKEAWAYS

Automation has emerged as a critical strategy to address major industry challenges

The industrial manufacturing industry is experiencing significant pressure from multiple fronts, including labor shortages, rising operating costs, supply chain disruptions, and increasing customer expectations. At the same time, global competition is pushing

manufacturers to produce more with fewer resources—most are actively pursuing higher productivity, improved quality, and greater flexibility that will enable rapid response to changing market conditions.

To achieve these goals, manufacturers are expanding factory automation. While automation is not new to manufacturing, recent and forthcoming intelligent mobile automation technology is shifting the industry from isolated, fixed systems toward increasingly autonomous operations.

Automation is already being used for functions such as material movement, inspection, assembly, and logistics, where it can help increase throughput, reduce errors, enhance worker safety, and improve equipment utilization. New advances in sensing, connectivity, artificial intelligence, and robotics technologies are making connected, intelligent automation solutions more capable and accessible than ever before.

Mobile automation enables greater efficiency, flexibility and visibility.

Intelligent mobile automation has become an important component of smart-factory operations. Autonomous mobile robots (AMRs) and automated guided vehicles (AGVs), in particular, are transforming factory operations.

AMRs and AGVs change how materials and components move through manufacturing facilities by enabling:

- **Flexible manufacturing and incremental scaling.** Rather than redesigning an entire facility, manufacturers can deploy these mobile robots into selected workflows and expand the fleet as operational needs evolve.
- **Improved workforce productivity.** These robots can take over repetitive materials handling tasks, allowing employees to focus on work requiring judgment, technical expertise, and problem-solving. AMRs and AGVs can support extended operating schedules, helping reduce reliance on employees for repetitive material-handling tasks.

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Although AMRs and AGVs are often thought of interchangeably, there are key differences that make each suitable for different applications.

Both move materials through the factory, but their navigation and response behaviors differ. AGVs generally follow predetermined fixed routes, using infrastructure, such as tape, wires, tracks, or magnetic guidance. This makes AGVs useful for high-volume, repetitive operations in stable environments, but changing their routes may require modifications to the facility or the guidance infrastructure.

AMRs navigate dynamically, using sensors, cameras, and AI to adjust their paths based on their surroundings. They can adapt to changing layouts without relying on a permanently fixed path. AMRs' flexibility also makes it easier to add robots to the environment without significantly changing the underlying infrastructure. As a result, AMRs are often well suited to dynamic environments with frequent layout changes or mixed operations.

Neither robot is better than the other—the right choice depends on the application.

Figure 1: Understanding the differences between AMRs and AGVs

AMR		AGV			
AUTONOMOUS MOBILE ROBOT		AUTOMATED GUIDED VEHICLE			
	Navigates dynamically using sensors, cameras, and AI.		NAVIGATION		Follows a fixed path using guides like tape, wires, or magnetic strips.
	Highly flexible; adapts to changes in layout and environment.		FLEXIBILITY		Low flexibility; changes require infrastructure modifications.
	Minimal infrastructure required; no fixed paths or guides.		INFRASTRUCTURE		Requires fixed infrastructure (guides, tracks, or wires) and setup.
	Easily scalable; add more robots without major infrastructure changes.		SCALABILITY		Limited scalability; expanding routes can be complex and costly.
	Dynamic environments, frequent layout changes, mixed operations.		BEST APPLICATIONS		Repeatable, high-volume tasks in stable and predictable environments.

Connectors play a foundational role in mobile robot performance.

Mobile robots are an important bridge between conventional automation and autonomous factories, and selecting appropriate connectors is important for supporting robot performance.

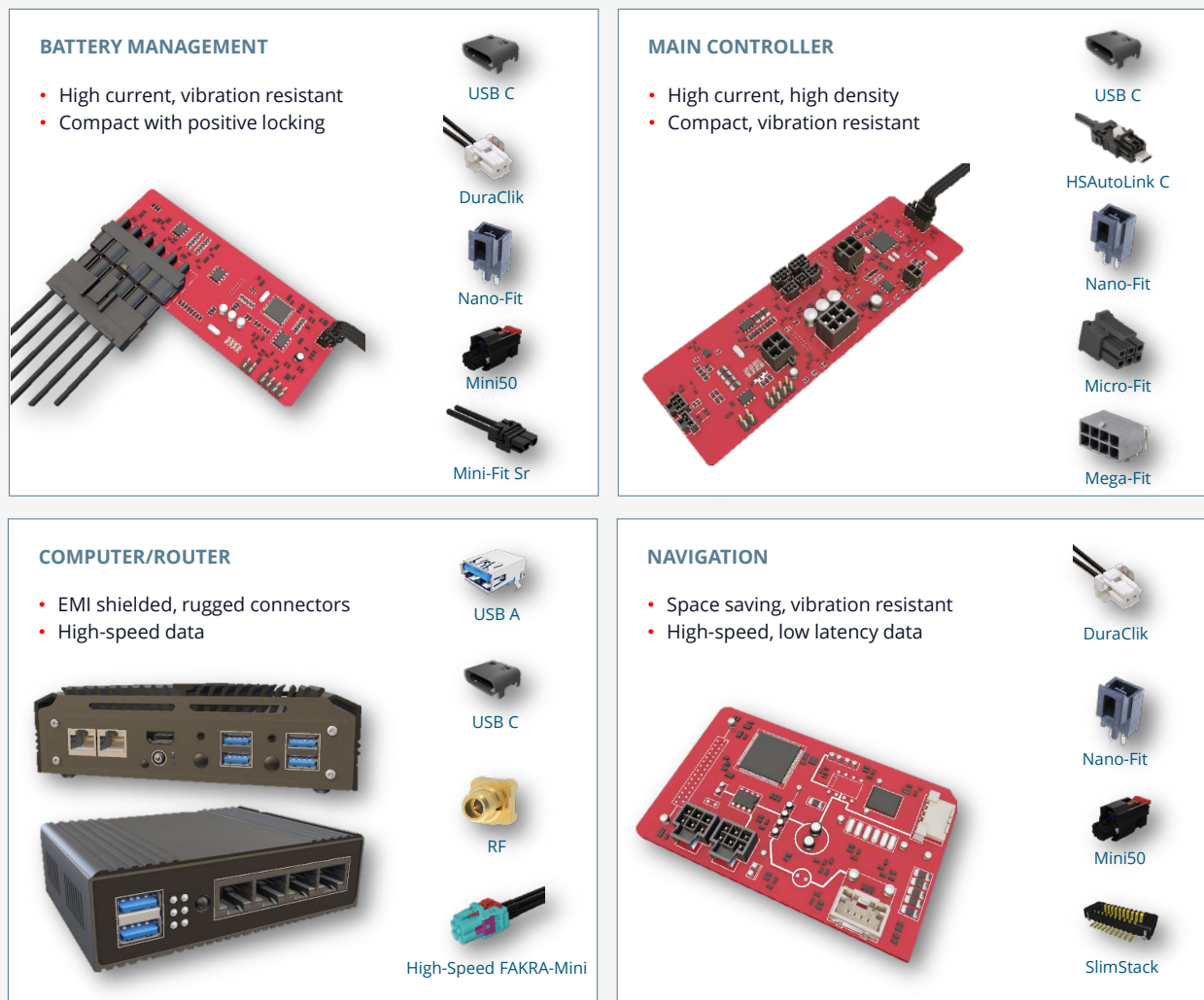
AMRs and AGVs need reliable connections for battery management, controllers, communication, and navigation. These connectors and cable assemblies must reliably transport power, data, and signals while surviving vibration, repeated motion, thermal stress, tight packaging, and industrial environments.

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Key components that require reliable, robust connectors include:

- **Battery management.** Connectors must deliver current securely while tolerating vibration and fitting into increasingly compact designs.
- **Main controller.** Controllers may require high-current and high-density connections within limited space while operating in a system that is constantly moving and vibrating.
- **Communication.** Computers or routers may require high-speed data capability, EMI shielding, and/or ruggedized connections.
- **Navigation.** Systems might require space savings and/or vibration-resistant interconnects that also support high-speed, low-latency data.

Figure 2: Molex solutions supporting key AMR/AGV systems



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Each subsystem has a different combination of mechanical, electrical, space, and serviceability requirements—the best choice of connector depends on the application requirements. At the same time, power and data systems cannot be selected and designed independently. High-speed signals may be routed close to motors and power electronics, creating potential signal integrity and EMI problems. Increasing packaging density also creates thermal and mechanical challenges.

Regardless of the platform, therefore, connectivity should be considered early in system design, when engineers can still optimize packaging, thermal performance, motion, assembly, maintenance, and serviceability together.

“The future of automation is not just about building smarter robots. It is about the seamless integration of power, data, and connectivity that makes intelligent robots possible.”

– Elena Dugger, Molex

Beyond wheeled mobile automation, humanoid robots represent another emerging approach to automating tasks in facilities originally designed around human workers.

Factories were originally designed around people, with human-centric workstations, aisles, tools, shelves, and controls. Tasks still require humans to perform many factory activities.

Humanoid robotics bring human-like mobility and dexterity to tasks that have traditionally resisted automation, such as material handling, machine tending, inspection, and assembly support.

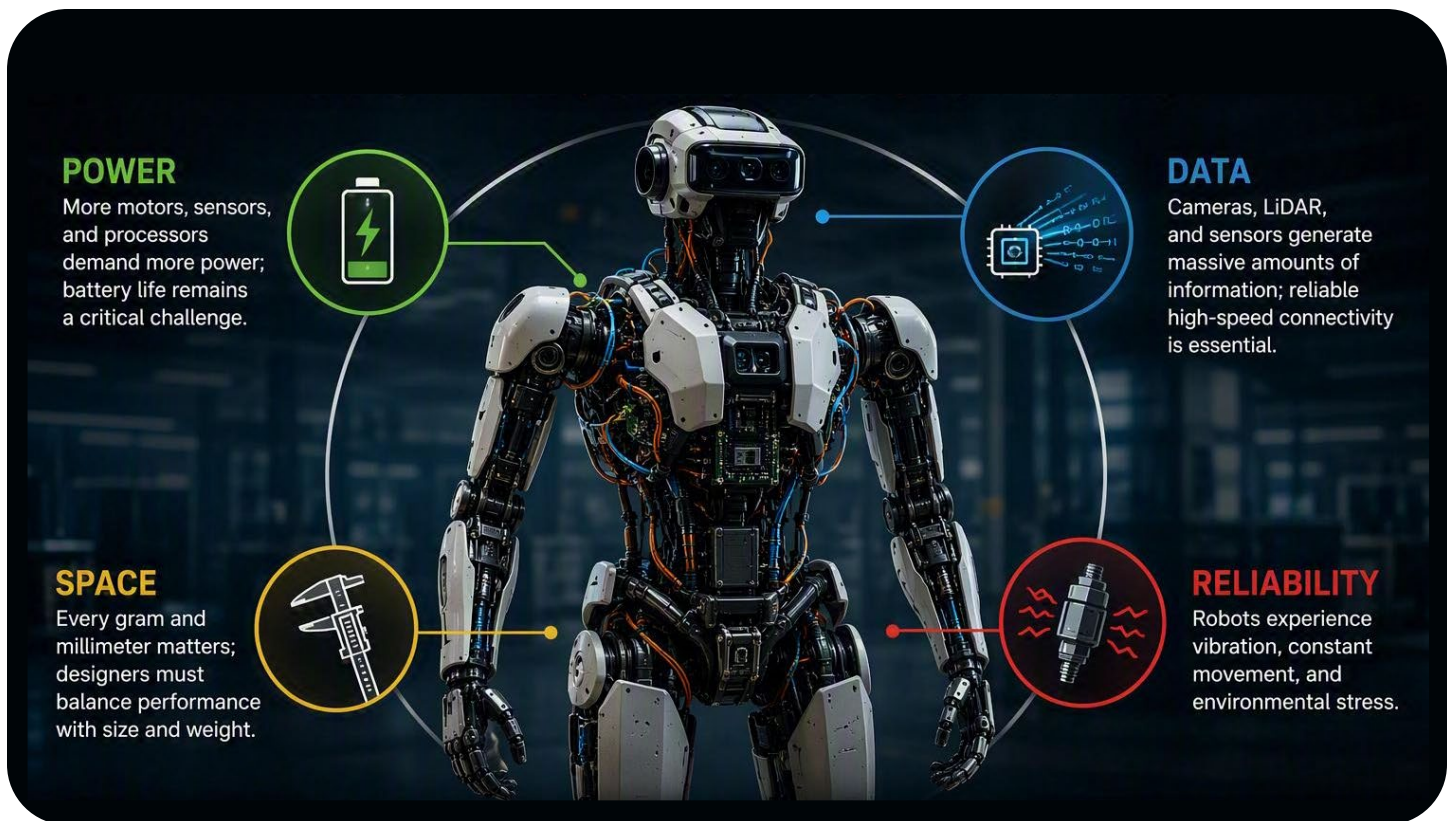
The human form and movement of humanoids enable them to potentially operate in existing facilities with less modification than a specialized automation system; however, a human-like form alone does not make a robot ready for large-scale industrial deployment. They must also meet demanding requirements for power, data, space, and reliability, which requires overcoming various engineering challenges:

- **Micro-miniaturization and thermal routing.** High-current power and high-speed data must pass through narrow actuator channels that can become thermal traps—every millimeter matters.
- **High-motion mechanical fatigue and distal mass.** Multi-axis joints may experience millions of high-speed flex cycles, making conventional wire bundles bulky or prone to failure. And weight located farther from the center of the robot increases the energy required to move a limb.
- **Signal integrity and EMI.** High-speed perception data may be routed adjacent to high-torque motors and power electronics, creating signal-integrity and EMI challenges.

These challenges are interconnected: A larger cable might provide greater current capacity but add weight. Additional shielding might improve EMI performance but consume valuable space. A tighter bend radius might make packaging easier but reduce cable life. Engineers therefore cannot optimize a single characteristic in isolation; they must balance electrical performance, mechanical life, thermal behavior, size, weight, and manufacturability.

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Figure 3: Key power, data, space, and reliability considerations for scalable robotic deployment



Humanoid Robots: A Holistic Connectivity Approach

Achieving scalable robotics deployments often requires a system-level connectivity strategy. Each interface must support not only the prototype's immediate performance, but also assembly, testing, maintenance, and long-term operation.

A wide range of connectors is necessary to power reliable performance in humanoid robotics.

- Mechanical retention is critical to ensure connectors remain secure during vibration and movement.
- Power interfaces must deliver current efficiently while minimizing voltage drop and thermal rise.
- High-speed data and perception interconnects support data rates needed for cameras, lidar, perception systems, and computing.
- Flexible FFC and FPC connectors are especially important in moving joints, where cables must withstand repeated flex cycles.
- Other technologies enable advanced humanoid interaction, extending beyond conventional connections.

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Figure 4: Molex solutions supporting key humanoid robotic systems

PERCEPTION - CAMERA

- High-reliability power and signal connectors
- Compact solutions for motion systems



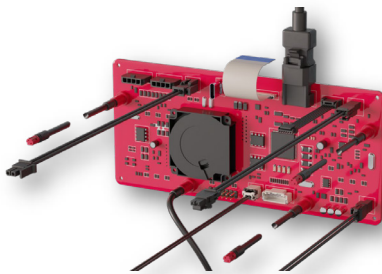
PERCEPTION - LIDAR

- High-speed data connectivity
- Camera and sensor interconnect solutions



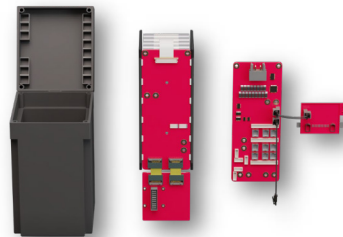
COMPUTING

- High-density interconnect solutions
- High-speed data transmission



POWER

- High-current power connectors
- Reliable battery management interfaces



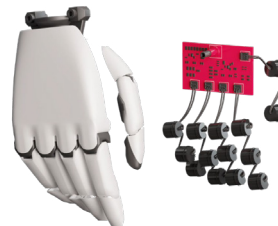
ACTUATION

- High-reliability power and signal connectors
- Compact solutions for motion systems
- Rugged interconnects for dynamic movement



DEXTEROUS HANDS

- Miniaturized connectors
- Flexible cable assemblies
- Space-saving designs for complex joints and sensors



ADDITIONAL INFORMATION

To learn more, visit [TTI & Molex](#)

BIOGRAPHY

**Elena Dugger**

New Market Development Manager
Molex

Elena Dugger earned her engineering degree from Purdue University and joined Molex in 2000. Her career has included roles as a Sales Engineer in Silicon Valley and Product Management Supervisor within the Power and Signal Business Unit, where she has focused on developing connectivity solutions for a wide range of industries.