REPORT

MASTERING MINIATURIZATION INNOVATION: 7 EXPERT PERSPECTIVES

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molex

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INTRODUCTION

When people say the world is getting smaller, they usually mean that technology is shrinking the distance between people, ideas and economies. **But the technologies that bring us together are now also undergoing their own processes of miniaturization as well.** Indeed, the world is getting smaller and so are the devices that make the world go around.

In some industries the trends are obvious. Mobile phones have been packing more features into tight spaces since they were first introduced. Medical wearables are gaining new capabilities even as they become less obtrusive.

In other sectors, miniaturization is driven by more subtle forces. The rise of the electric vehicle (EV) is creating demand for lighter electronics, for example. Massive industrial equipment can benefit from tiny sensors that may reside on weight-sensitive robotic arms. And, in the data center, rising bandwidth is leading to a revolution in fine-pitch interconnects.

Regardless of the industry, squeezing more technology into smaller spaces takes an amazing degree of cross-disciplinary engineering and planning. **In other words, design engineers have to think big to go small.**

To see how engineers can achieve this goal, Molex interviewed seven experts from a variety of disciplines, representing a multitude of key industries. Here are their observations and insights on the ways miniaturization is impacting factories, data centers, automobiles, medical wearables, the evolution of 5G and a nearly endless list of innovation opportunities.

WHAT APPLICATIONS DRIVE ELECTRONICS MINIATURIZATION?

ZACH PETERSON

INDUSTRY EXPERT BIO

Zach Peterson, *printed circuit board (PCB) design expert and electronics design consultant and founder of Northwest Engineering Solutions, works with the biggest brands in PCB design software and simulation. He also supports innovative PCB manufacturers, bringing technological insights and foresight to their product development and digital marketing strategies.*

WHAT APPLICATIONS DRIVE ELECTRONICS MINIATURIZATION?

When the topic of miniaturization arises, microchips are often the focus — for good reason. For decades, the semiconductor industry has followed Moore's law, cutting the size of integrated circuits in half every two years or so. This remarkable feat of miniaturization has brought ever-smarter electronics into all kinds of devices.

But in recent years, this trend has slowed. Instead of going smaller, microchips are getting more specialized. "Just look at all the companies that are focused on novel processors that target intelligence on edge devices," says Zach Peterson, noting artificial intelligence (AI) as a prime example.

This change is putting extraordinary pressure on internal bandwidth, as it leads to proliferation of chips that need to communicate with each other. "All of these specialty devices need high IO counts to get data in and out," Peterson says.

This in turn drives complex requirements for the PCBs. "You've got a lot of data to send over connectors to other systems," he says. "How do you get that data in and out of the system without increasing its overall size? **You can increase pin density, or you can just make the connector smaller."**

Peterson mentions a recent project his company undertook, building a board for a security application. “It had multiple RF protocols. It had multiple cameras. It had high-bandwidth wired connections with power over Ethernet.”

“

You can see how difficult some of these assemblies get,” he explains. “One of the biggest trends is that you need high performance without relying on big field-programmable gate arrays (FPGAs) or single board computers. That means miniaturization and making your Internet of Things (IoT) device smarter without making it bigger.” That requires specialty processors for capabilities like AI, and more complex communications between sub-systems.

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The market for AI will grow by 27.9% between 2023 and 2028. (Source: Global Market for AI in IoT, Mordor Research)

Learn More

ARTIFICIAL INTELLIGENCE IN IOT INDUSTRY OVERVIEW

Source: Mondor Intelligence

Study Period:	2018-2028
Fastest Growing Market:	Asia Pacific
Largest Market:	North America
CAGR:	27.86%

Major Players

Google, IBM, autoplant, SAP, aws

*Disclaimer: Major Players sorted in no particular order

MINIATURIZATION PUTS PRESSURE ON CONNECTORS

PERSPECTIVE: DAVID PIKE

INDUSTRY EXPERT BIO

David Pike, *Content Director at Connector Geek, has more than 30 years of experience with high-reliability connectors in markets that include broadcast, nuclear research, military, automotive and consumer.*

MINIATURIZATION PUTS PRESSURE ON CONNECTORS

Miniturization isn't just about making parts smaller. There's also the question of how to put these parts together. "Can we keep using the same manufacturing techniques?" asks David Pike. Already, many components are too small to place by hand, forcing PCB manufacturers to transition to automated surface-mounting techniques. Now, the connections between boards are facing a similar predicament.

To illustrate the point, Pike highlights the pitch for a typical micro connector — i.e., distance between the centers of two adjacent pins. During his 30-plus-year career, this distance has shrunk from well over a millimeter to 0.35 millimeter. "Are we getting to the point where we can't make them any smaller," he asks, **"and are there any benefits to making them smaller?"**

Eventually the size of pins becomes a constraint in how much power or size of frequency signal they can carry. "At some point you have to make a compromise on size to be able to get the high-speed performance," Pike notes.

Mechanical limits are also a concern. Take the automotive sector as an example. “These connectors have to be robust, waterproof and vibration proof,” Pike says. “Yet they also have to be cheap; they’re designed to be made in huge quantities and available in a multitude of places.”

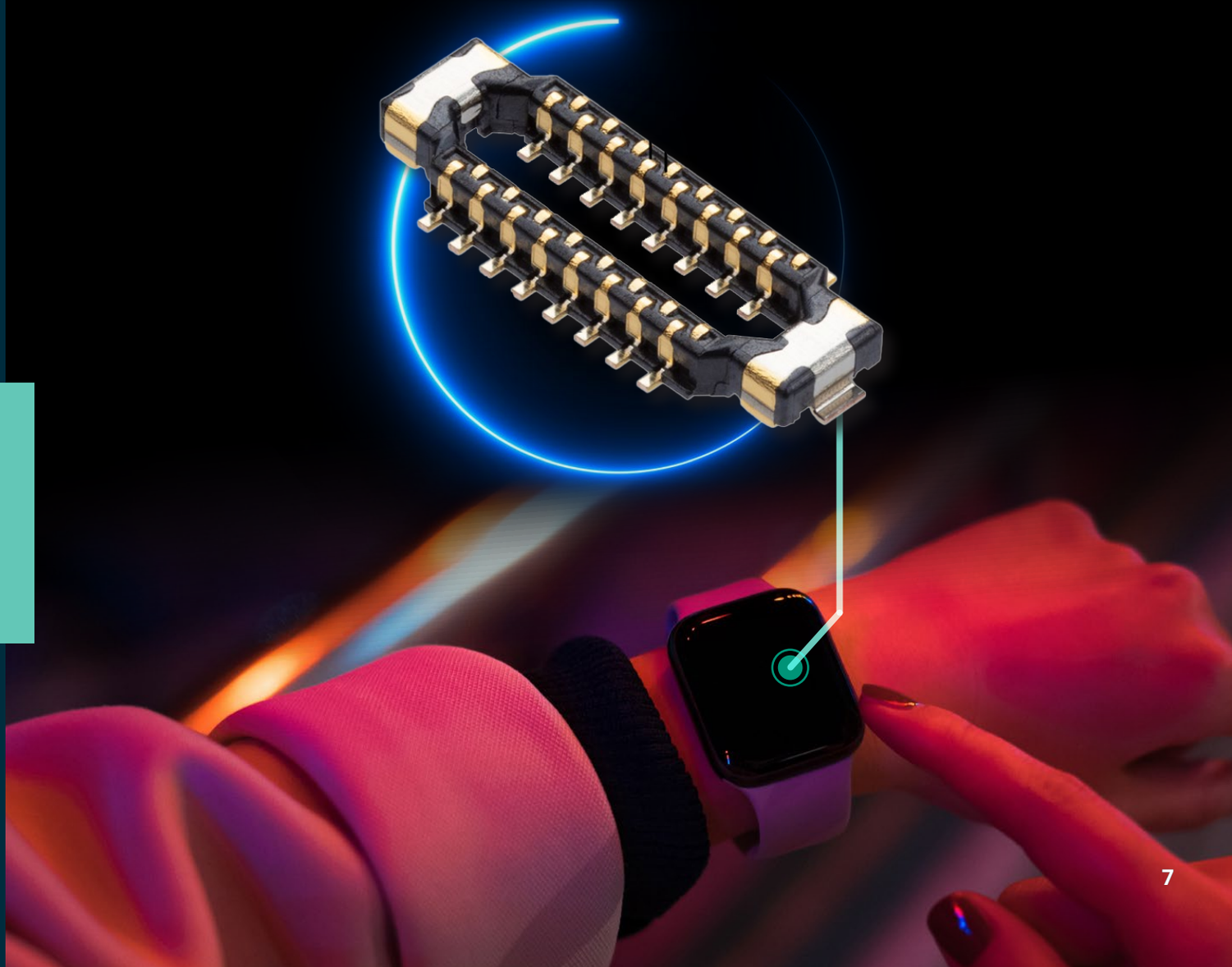
All these constraints point to a need for a more holistic view of product design. Rather than continuing to shrink connector pins, for example, the connector layout can be redesigned — as Molex did with its Quad-Row Board-to-Board Connectors. **This connector staggers pins to reduce board footprint by up to 30%.**

> It’s an innovative way of achieving a much finer pitch without compromising on the physical design, says Pike.

Molex Quad-Row Board-to-Board Connectors achieve a 0.175mm signal pitch while retaining the industry-standard 0.35mm soldering pitch

Learn More

QUAD-ROW BOARD-TO-BOARD CONNECTOR



CAN CARS ADD MORE CONTENT?

PERSPECTIVE: KYLE GLISSMAN

INDUSTRY EXPERT BIO

Kyle Glissman, *Global Product Manager at Molex, specializes in miniaturized products in automotive applications. His 10-year history of miniaturization expertise spans sales and product management across both connector and module suppliers.*

CAN CARS ADD MORE CONTENT?

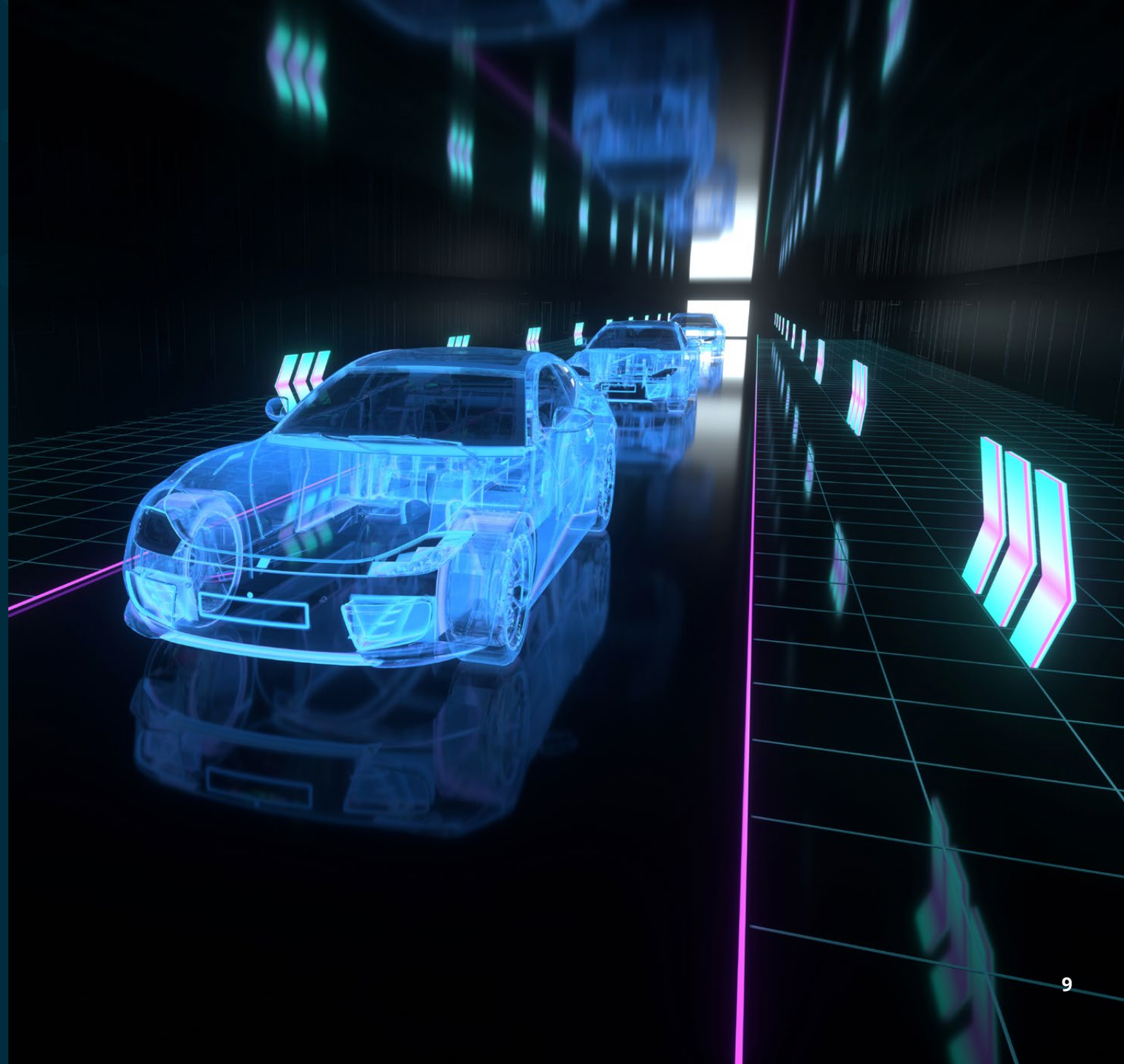
Four key factors are increasing the importance of miniaturization in the automotive industry: connectivity, autonomous driving, shared mobility and electrification, according to Kyle Glissman. And he ought to know. After all, he has been taking on these design challenges for years.

“Consumers go into a dealership saying, ‘I want more. I want a car that can keep itself in its lane. I want a car that has screens in the back for my kids.’” But at the same time, cars need to be more energy efficient.

“Those things are not conducive to each other,” says Glissman. “Something has to give. **That’s where miniaturization comes into play.** We have to shrink the components. We have to shrink the modules. Really, everything needs to get smaller to fit all of that new content in the vehicle.”

Take wiring harness terminals as an example. Traditionally, there were 1.5-millimeter terminals for heavier current and 0.64-millimeter terminals for other uses. The latter is now moving toward 0.5-millimeter terminals, which can substitute for most applications.

“The savings might not sound like a lot, but when you add it all together, **it has a compounding effect.** There’s much better density in terms of fitting all that content in a smaller space.”



Weight and cost are also factors, especially when a full wiring harness in a car is the third heaviest and third most expensive portion of a vehicle.

> When you go to a smaller connector with smaller wires, you then have less weight in the vehicle, which drives the emissions output, Glissman says. You've got more range in your electric vehicle, so you don't need as big of a battery pack.

And it's not about smaller wires — having shorter wires can also make a dramatic difference. **That's why automakers are moving to zonal architectures**, where functions within a vehicle are grouped by location instead of by function. A zonal gateway is responsible for all functions within its designated area. Because the zonal gateway is close to the all devices it controls, the cables are shorter than in a traditional wiring harness.

Communication between zonal gateways and the central computer more closely resembles a computer network than an automotive harness

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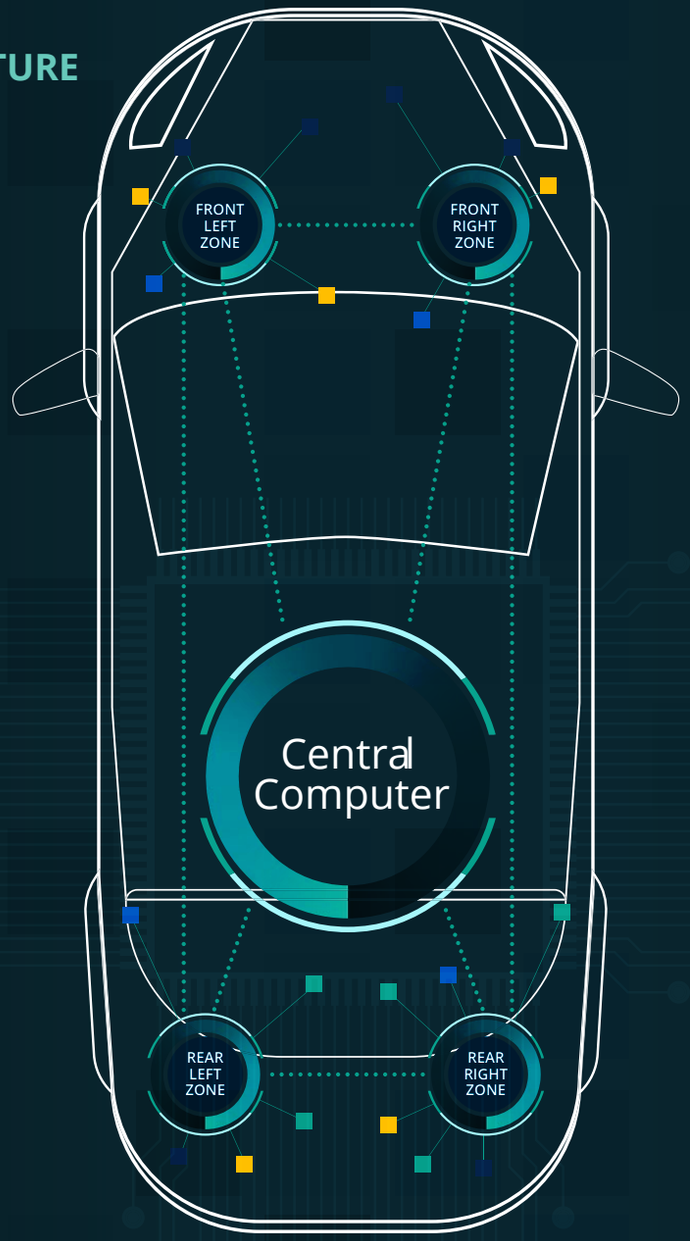
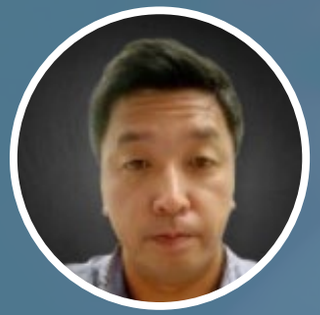
ZONAL ARCHITECTURE



5G: AS WAVELENGTHS GET SMALLER, SO MUST THE DEVICES

PERSPECTIVE: KENJI KIJIMA



INDUSTRY EXPERT BIO

Kenji Kijima, *Director of Mobile Solutions at Molex, brings more than 20 years of experience as an expert on the topic of miniaturization across the electronics industry. At Molex, his primary focus relates to interconnections between small PCBs.*

5G: AS WAVELENGTHS GET SMALLER, SO MUST THE DEVICES

The mobile phone market has been driven by new features — but that may be changing. Now, the challenges of 5G are pushing new needs for miniaturization.

“Five or six years ago, the number of cameras was going up every year,” pushing the requirement to reduce the space components needed, Kijima says. “Recently, it’s been saturated to four or five cameras.”

Now 5G is the biggest factor. “You need more antenna modules and more RF functionality inside the phone.” Plus, all the 5G-related capabilities require more power. “The battery needs to be bigger,” he adds, noting that this creates a pressure to shrink other components.

One example can be seen in RF connectors. “In the past, we used coaxial cables to carry RF signals board to board,” explains Kijima. **“Now we’re changing to smaller RF connectors.”** This evolution presents opportunities for new kinds of miniaturization. Using RF connectors of different heights allows manufacturers to use the Z-axis to optimize placement of components.

But making this transition is no easy feat. Because of the higher frequencies of 5G, the other parts have to be redesigned to avoid signal leakage.

> To address this need, we developed new gap-free manufacturing methods for our connectors, Kijima explains, noting that this illustrates the complex interplay between engineering disciplines required to support next-gen technologies.

Molex 5G25 series connectors deliver industry-leading SI performance. A center shield-in contact within the receptacle or plug isolates each row to boost the overall SI stability even more to meet the toughest 5G connectivity requirements.

Learn More

MOLEX 5G25 SERIES CONNECTORS

MINIATURIZATION IN MEDICAL DEVICES

PERSPECTIVE: BRETT LANDRUM

INDUSTRY EXPERT BIO

Brett Landrum, *Vice President, Global Innovation & Design at Phillips-Medisize, a Molex Company, which partners with medical device customers to provide R&D services.*

MINIATURIZATION IN MEDICAL DEVICES

Medical devices, particularly wearables, have become a proving ground for miniaturization that must work reliably every time — because people's lives depend on them. The prominence of diabetes and the need to monitor blood sugar levels has led to significant advancements in testing and monitoring technologies. For instance, continuous glucose monitors (CGMs) are now available to be attached to the body and provide continuous monitoring and remote connectivity. For large-scale adoption of these technologies, the devices must be unobtrusive — driving miniaturization.

"I worked for a startup where we made one of the first wireless electrocardiogram (ECG or EKG) monitors," Landrum says. "It was very large; it spanned the entire chest. You wound up with a device that was functional, but not very palatable to users."

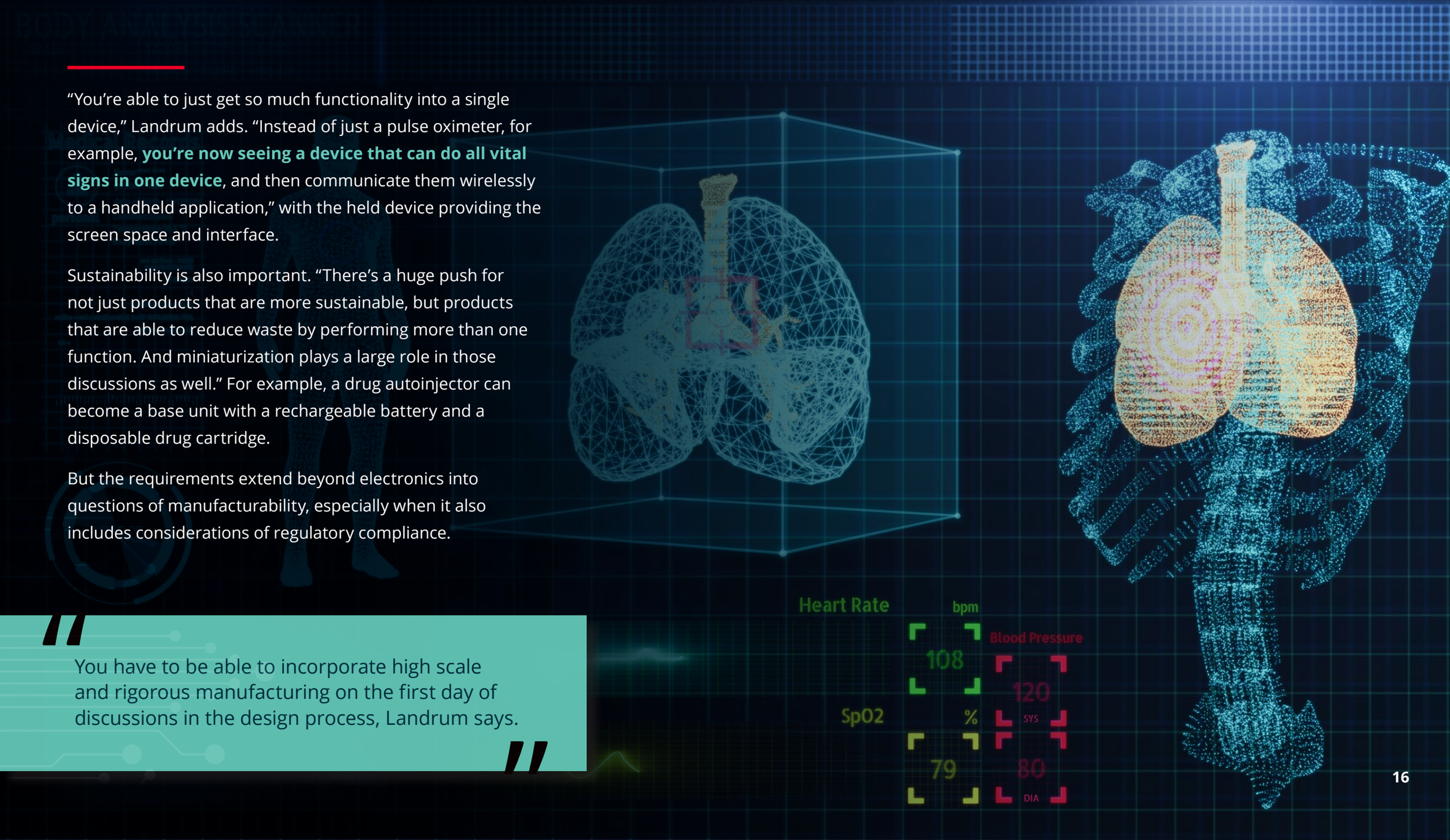
Miniaturization in wearable medical devices has been driven by the need to "develop and design things that people can discreetly wear. And these things are all as a result of being able to fit a lot more functionality on a smaller footprint," Landrum says.

"You're able to just get so much functionality into a single device," Landrum adds. "Instead of just a pulse oximeter, for example, **you're now seeing a device that can do all vital signs in one device**, and then communicate them wirelessly to a handheld application," with the held device providing the screen space and interface.

Sustainability is also important. "There's a huge push for not just products that are more sustainable, but products that are able to reduce waste by performing more than one function. And miniaturization plays a large role in those discussions as well." For example, a drug autoinjector can become a base unit with a rechargeable battery and a disposable drug cartridge.

But the requirements extend beyond electronics into questions of manufacturability, especially when it also includes considerations of regulatory compliance.

> "You have to be able to incorporate high scale and rigorous manufacturing on the first day of discussions in the design process, Landrum says."



SMARTER MANUFACTURING WITH SOPHISTICATED SENSORS

PERSPECTIVE: JAKE HALL

INDUSTRY EXPERT BIO

Jake Hall, *"The Manufacturing Millennial," is an advocate for manufacturing, automation, digital transformation and skilled trades. He is the co-founder of Manufacturing Champions, a consulting group helping manufacturers connect with their audience.*

SMARTER MANUFACTURING WITH SOPHISTICATED SENSORS

As a manufacturing expert, Jake Hall focuses on the factory floor. But advances there can have broader implications for all industries. He points to something as seemingly simple as sensors.

“With the miniaturization of electronics, we’re able to fit a lot more technology into a smaller device,” he says. **“Now I have a sensor the size of a breath mint container that has temperature and vibration sensors,”** Hall says. Factor in the built-in Wi-Fi and onboard computing, and the simple sensor becomes a powerful tool for gaining visibility into factory operations.

As another example, Jake points to the evolution of the photo eye. **Thanks to miniaturization, photo eyes are being replaced by cameras** that can not only tell when a box on a conveyor belt passes by, but also check if the box was damaged. The sensor can even track the time since the last box passed by — and, if too much time elapses, it will alert operators that there might be a jam on the conveyor system.

The same principles allow companies to add processing and artificial intelligence almost anywhere.

> Miniaturization of electronics has allowed for a lot more comfortable wearable devices for workers, Hall adds.

Warehouse workers, aircraft mechanics, maintenance workers and more can all have quick access to information critical to how they perform. **And this leads to better performance for the line, product, division, and company over time.**

MINIATURIZATION PUTS PRESSURE ON DATA CENTERS

PERSPECTIVE: GUS PANELLA

INDUSTRY EXPERT BIO

Gus Panella, *Director of Interconnect Technology in the Data Specialty Solutions group at Molex, develops road maps of technologies to achieve the best channel performance for industry interconnect architectures.*

MINIATURIZATION PUTS PRESSURE ON DATA CENTERS

Data centers might not be the first example most people would think of when asked about miniaturization. But, according to Gus Panella, “Making things smaller within server racks has become an important design consideration.”

Thanks to chip integration advancements, **IO needs have considerably increased.** “Five years ago, the industry was happy with 128 differential pairs; today 1024 differential pairs is a noble goal,” says Panella. What’s more, the bandwidth on each line is also rising. “The trend has been from 10 Gbps-NRZ per data lane from about 20 years ago to 224 Gbps-PAM4 per lane emerging today.”

PCB trace losses are driving different decisions. “We’re at the limits of the material physics for the PCB,” explains Panella. **That’s why more chip-to chip interconnects are moving to cables.** “Cables are going to be important for 224G as there is less signal loss when compared to a PCB. Unless, of course, there are other advancements in semiconductor signal processing.”

It is important to consider how to connect the cables. Signals need to travel from the silicon through the chip substrate, through the PCB and finally through a connector before they reach the cable, and each transition involves signal degradation.

As one example of innovation, Molex developed a way to put the connector directly on the chip substrate. Doing so was a major multidisciplinary engineering challenge including mechanical, electrical, thermal and process engineering. To aid its chipmaker partners, Molex created a cleanroom logistics chain that brings cleanroom connectors into the chip manufacturer's facilities. Now Molex applies its connector expertise to the same process as unpackaged silicon — an industry first, to help meet the advanced engineering needs of data center customers around the globe.

To move connectors onto the silicon substrate, Molex created a cleanroom logistics chain that brings cleanroom connectors into the chip manufacturer's facilities — an industry first.

MOLEX:
A MINIATURIZATION PARTNER

MINIATURIZATION PUTS PRESSURE ON DATA CENTERS

IoT, one of many drivers of miniaturization, permeates all industries and an ever-increasing number of applications: a trend that doesn't appear to be slowing. By 2029, the IoT market is expected to reach $2,465.26 billion, up from $478.36 billion in 2022 (Source: IoT Market Size, Share & COVID-19 Impact Analysis, Fortune Business Insights, **https://www.fortunebusinessinsights.com/industry-reports/internet-of-things-iot-market-100307**.

This growth will likely be further fueled by very recent advancements in generative AI: machine learning algorithms that can output seemingly human-made content such as text, images and audio. Although generative AI isn't new, its popularity in the public is. Released in November 2022, OpenAI's ChatGPT became the talking point of January 2023. Tech companies and manufacturers around the world are now seeking ways to incorporate similar capability, inevitably leading to the development of new and previously unheard-of devices.

While significant, the IoT market is just a fraction of what drives miniaturization. And this demand to go smaller poses a suite of challenges to product development. Design engineers in industries like automotive, consumer devices, medical and data centers must balance competing factors such as power and thermal management, component density and signal integrity, mechanical stress and manufacturability, and all of the above and all balanced against cost. A reliable partner is necessary to navigate this landscape of competing needs, and Molex is there to help. Our industry-leading engineering team is specialized in the complete product development lifecycle across industries and is backed by a breadth of products including connectors, sensors, antennas and more. We look forward to helping you take your products to new, even smaller heights that will drive advantage for OEMs designing the future of innovation.

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