Fischer CONNECTORS

TREND PAPER

EMERGING TRENDS IN WEARABLE TECHNOLOGY ACROSS SEVERAL MARKETS

REIMAGINING CONNECTIVITY TOGETHER

FISCHER CONNECTORS' CEO JONATHAN BROSSARD EXPLAINS WHY THE SWITZERLAND-HEADQUARTERED MULTINATIONAL IS PARTNERING WITH RESEARCHERS AND CUSTOMERS WORLDWIDE TO REIMAGINE THE CONNECTIVITY THAT WILL POWER THE WEARABLE TECHNOLOGY REVOLUTION.

INNOVATION IN CONNECTIVITY

Our new trend paper reflects Fischer Connectors' innovation strategy and our goal of reimagining connectivity in close partnership with our customers. It focuses on the current trends that characterize wearable technologies across different sectors – trends that answer existing and emerging customer needs. We keep these needs in the front of our minds to keep pushing the limits of connectivity forward by exchanging and collaborating with customers, partners and renowned research institutions like the Swiss Federal Institute of Technology in Lausanne (EPFL), AUVSI (Association for Unmanned Vehicle Systems International), and the Swiss Center for Electronics and Microtechnology (CSEM), to name just a few. We also innovate through collaboration on projects like SolarStratos – the first solar manned plane to fly to the stratosphere, for which we provide mission-critical connectivity for the pilot and the plane – and the TWIICE exoskeleton – for which we designed ultra-light, easy-to-wear and easy-to-use connectivity to enable paraplegic people to walk again.

At Fischer Connectors, we're committed to changing the perception of connectors as the 'weakest technological link' to 'human performance-enhancer'. By putting our creativity, entrepreneurial spirit and engineering expertise at our customers' disposal, we're helping them bring breakthrough human-focused wearables to market – saving lives, monitoring health and making workers' lives safer. Together, we're accelerating the development of new technologies, designing wearable solutions that are seamlessly integrated, easy to use and truly ease the burden on the end user.

In this trend paper, you can also discover our new product family, the Fischer Freedom™ Series, specifically designed to meet customers' and end users' needs in terms of wearability, usability and performance. The connectors in the Fischer Freedom™ Series, starting with the LP360™, set a new standard in usability, offering easy mating, easy cleaning and easy integration into wearable and portable textiles and devices for any sector – including medical, industrial, defense and security. Innovating together, we're making peoples' lives better and easier – by making connectivity seamless, fully customizable and easy to use.

Reimagining connectivity like we've shown with this new series allows our customers to turn their ambitions into solutions that fit their markets, and helps them break into new ones, too.

I wish you happy reading. Let us know if you'd like to explore wearable technology in more depth, or partner with us on a new venture.

Jonathan Brossard
CEO, Fischer Connectors

CONTENTS

INTRODUCTION BY THE AUTHOR

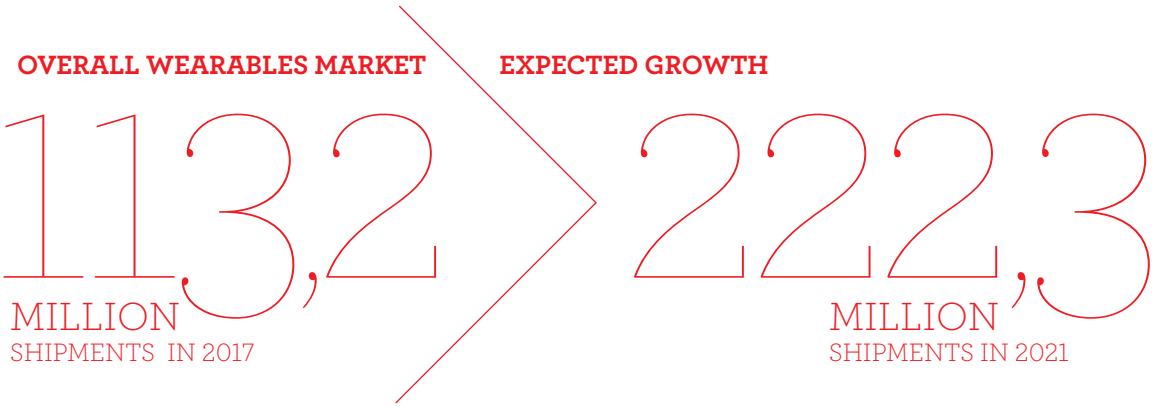
WE'RE ON THE CUSP OF AN EXPLOSION IN WEARABLE TECHNOLOGIES – A NEW CATEGORY THAT WILL REVOLUTIONIZE B2C (BUSINESS-TO-CONSUMER) AND B2B (BUSINESS-TO-BUSINESS) MARKETS. THIS TREND PAPER WILL GIVE YOU AN OVERVIEW OF CURRENT TRENDS IN WEARABLE TECHNOLOGIES, AND DIVE DEEPER INTO EMERGING APPLICATIONS IN DIVERSE MARKETS WITH A SPECIAL FOCUS ON B2B AND COMMERCIAL APPLICATIONS: HEALTHCARE, INDUSTRY, ROBOTICS, DEFENSE AND SPORT. WE'LL PRESENT EXCITING EXAMPLES OF HOW WEARABLES ARE IMPACTING USERS' AND DESIGNERS' LIVES – IMPROVING HEALTH AND SAFETY, CONVENIENCE AND PERFORMANCE, WITH CONNECTIVITY PLAYING A CRUCIAL ROLE.

JEAN-MARIE BUCHILLY
Research & Innovation Manager, Fischer Connectors

Jean-Marie and his team are exploring ways in which Fischer Connectors can reimagine connectivity. He is dedicated to making a major difference in the lives of users in our fast-changing world. His team is working in close collaboration with high-class partners and customers.

01 APPLICATIONS OF WEARABLE TECHNOLOGIES

As an innovator and a thought leader, Fischer Connectors naturally focuses its R&D and activities on the most promising and innovative fields. Wearability represents a particularly exciting and challenging field that is embracing cutting-edge technologies like smart textiles and robotics. The overall wearables market is expected to grow from 113.2 million shipments in 2017 to 222.3 million in 2021 with a compound annual growth rate (CAGR) of 18.4%, according to the International Data Corporation (IDC). The growth includes the development and design of new wearables that are more fully featured and multi-functional, spanning health, communication and productivity.



Wearables are smart electronic devices and accessories worn in or on the body that can sense the person who is wearing them and/or their environment. There are different types, categorized by their proximity to the body. The International Electrotechnical Committee (IEC) Standardization Management Board Strategic Group 10 distinguishes among the following categories of wearables:

- Near-body electronics
- On-body electronics
- In-body electronics
- Electronic textiles

Wearables are key players in the Industrial Internet of Things (IIoT). They enable objects to exchange data through the Internet with a manufacturer, operator and/or other connected devices, without requiring any human intervention. They communicate either directly through embedded wireless connectivity, or through another device, such as a smartphone. Data about the user or his/her environment is processed in a processing unit located locally or on an external server.

Driven by the continuous miniaturization of electronics, as well as by advances in sensor technology, computing power and connectivity, and by an ever-stronger capability to embed intelligence in electronic and photonic components and systems, the use of smart wearables is becoming increasingly widespread. The price of components has also been falling. Moreover, the use of new materials, designs, energy storage and scavenging technologies,

and of new production techniques, is driving improvements in performance, functionality and usability.

Smart wearables can monitor, document and augment our lives, as well as assist people in specialized personal and professional activities. Their capabilities include control, communication, storage and actuation. Thanks to the embedded intelligence and connectivity, they offer unique opportunities for condition/activity monitoring, feedback and actuation/delivery services (e.g. drug delivery or stimulation), localization, identification, personal contextual notifications, information display and virtual assistance. The range of applications is potentially limitless.

Some commercial sectors, particularly healthcare, industrial, defense and sport will be transformed by wearability. These all need human-focused smart wearable devices designed specifically for these varied contexts and conditions of use. Factors such as weight, size, power density, ruggedness, durability, reliability and ease of use are key considerations when seeking ways of easing burdens on end users in these contexts. There is mounting frustration with the current piecemeal approach, whereby different manufacturers make individual pieces of the puzzle, so end-to-end wearable solutions that offer seamless integration into existing systems and processes will certainly add value here. Robotics and smart textiles will also play a significant role in spreading wearable devices across these sectors.

As the IIoT connects more and more devices – including wearable ones –, security and data privacy is now more than ever a critical part of the design and information flow. There are risks inherent to any technology, but they can be reduced through a proactive systemic approach and "security by design".

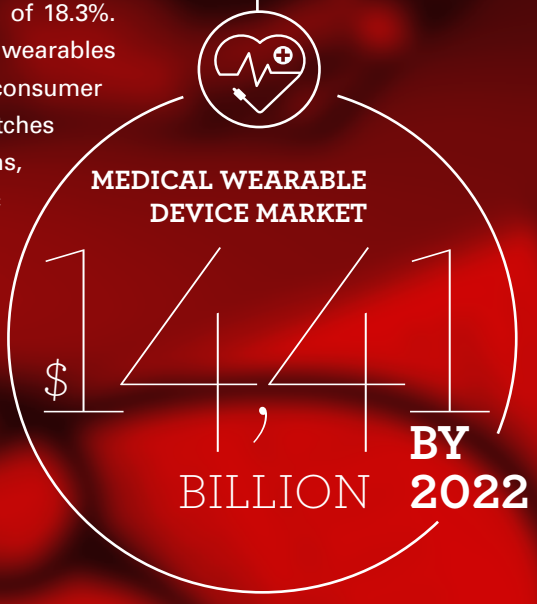
INDUSTRY	APPLICATIONS
Healthcare & Medical	• Blood pressure monitors • Electrocardiogram monitors • Defibrilators • Drug delivery products • Insulin pumps • Smart glasses
Industrial	• Smart PPE (Personal Protective Equipment) • Smart watches and glasses • Exoskeletons • Body-worn terminals
Defense	• Exoskeletons • Smart tactical vests • Body-worn terminals
Sports	• Activity monitors • Fitness & heart rate monitors • Foot pods & pedometers • Sleep sensors • Smart glasses, clothing, watches

02 WEARABLES IN HEALTHCARE

Tremendous progress has been made in medical diagnosis and treatment, yet care delivery has not fundamentally changed. People who are sick or acutely ill consult and are treated by medically trained professionals. That is all rapidly changing, and we are heading towards a future in which doctors and patients are connected.

Wearability lies at the heart of this trend, as patient-worn devices are increasingly being used for monitoring and round-the-clock care. Surgical and therapeutic devices are following the same trend, as wearable connected devices become ubiquitous.

According to a new market research study by MarketsandMarkets published on January 2018 (*Wearable Medical Devices Market by Device, Therapeutic, Application, Type, Distribution Channel - Global Forecast to 2022*), the wearable device market is expected to reach USD 14.41 billion by 2022 from USD 6.22 billion in 2017, at a CAGR of 18.3%. What might be surprising, however, is that wearables are having an impact far beyond typical consumer uses – like activity tracking and smart watches – and moving into medical applications, especially for people managing chronic conditions.



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1
MEDICAL WEARABLE TO MONITOR SLEEP AND ACTIVITY LEVELS.

2, 3
MEDICAL WEARABLES FOR MONITORING MEDICAL CONDITIONS.

MEDICAL VS. CONSUMER APPLICATIONS

Medical wearables differ from those on the consumer market. While they are based on the same premise – the products need to be comfortable, easy to use, and not cumbersome – their functions serve a different purpose. Medical wearables are of vital importance: they can detect life-threatening conditions, collect biometric data to help with patient diagnoses, and even administer medicine to alleviate pain.

Another differentiator, which is delaying the adoption of wearable medical devices, is their need to comply with stringent safety and accuracy standards. For medical wearables to be used more broadly, they first need to overcome regulatory obstacles and compliance issues, plus negotiate medical insurance reimbursement in the various countries where they are to be used. Wearable medical products must be approved by regulatory authorities, such as the U.S. Food and Drug Administration, and be certified as being in compliance with ISO or national standards, and their accuracy and reliability must be strictly monitored.

KEY MARKET DRIVERS

Medical wearables are being developed to provide support to users with specific conditions, e.g. epilepsy, chronic obstructive pulmonary disease, asthma, heart arrhythmia, chronic pain, and breast cancer. The huge quantities of data collected by medical devices are useful not only for consumers to manage their own health, but also for healthcare organizations to improve their healthcare facilities. The data are analyzed by clinicians and other healthcare professionals, to offer a diagnosis, advise on treatment, monitor patient compliance, or aid research. Remote patient monitoring systems also save time and help reduce the cost of care. Moreover, individuals' personal data are also used by employers and insurance companies to manage wellness and healthcare costs.

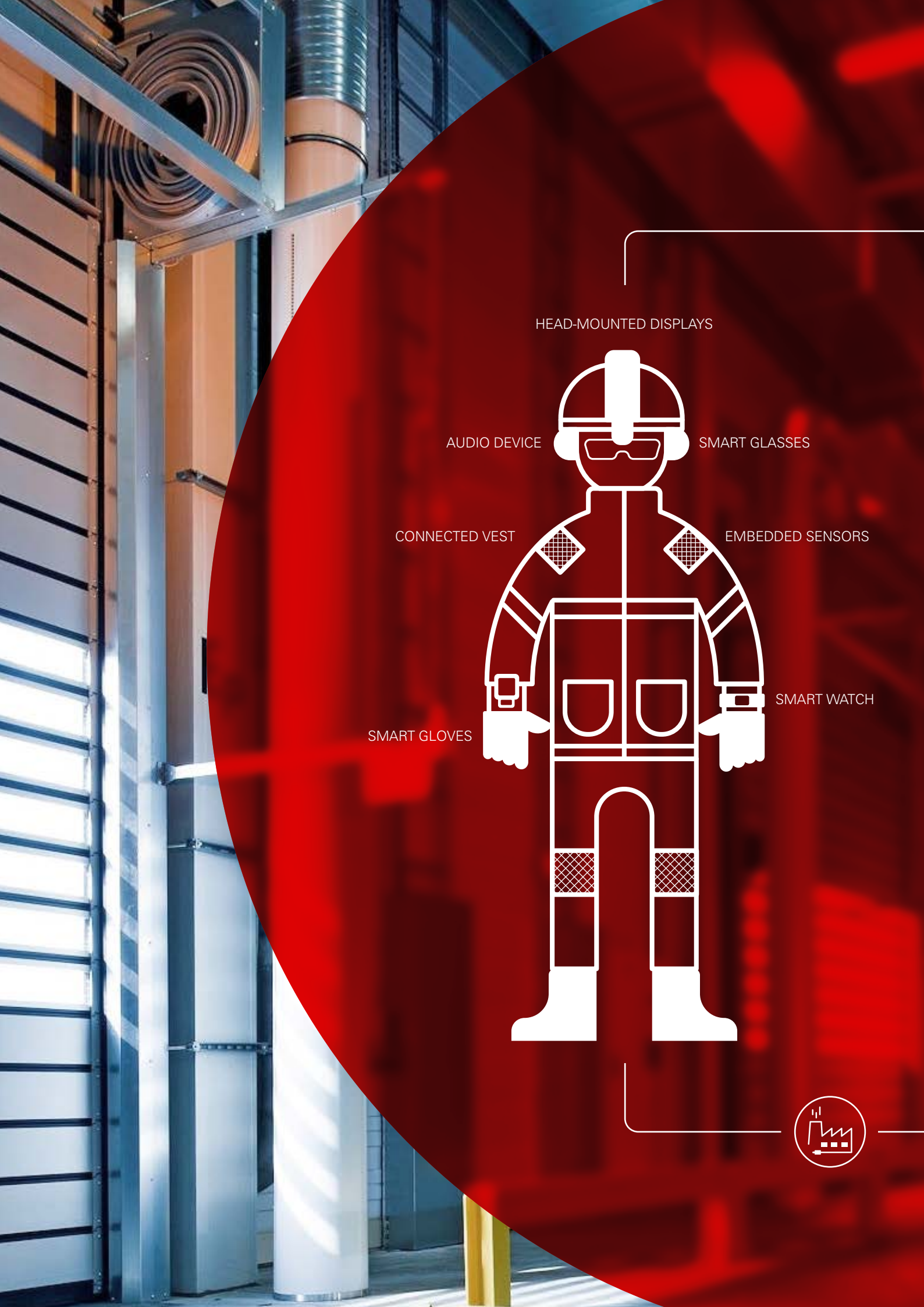
PREFERRED HARDWARE

When designing safe and accurate medical wearables, it is crucial to consider all components used in a product. Any substandard part can render the entire product unreliable or dangerous. Engineers need to consider several key factors in designing the hardware that powers these devices, including product lifecycle, size, weight, reliability, resistance to body fluids, and haptics (sound and feel).

Patients do not want to carry bulky attachments, especially on a wearable device that is constantly with them. Adding communication capabilities to support growing trends like telehealth means adding potentially bulky components like antennae, transmitters, and additional circuitry. That means less room for traditional components like switches that enable users to interact with the products. Even though switches now need to take up less space than before, they still have to meet specific performance requirements if they are to operate reliably for many years. Like all other components in medical wearables, switches also have to withstand harsh environmental conditions, such as body fluids and sterilization chemicals.

New wearable e-textile products are currently being developed and tested in the medical field. They could improve diagnostics and the treatment of several diseases. Some can detect a variety of biological signals, such as electrocardiogram (ECG), to measure body impedance and skin conductance. With ECG detection, it is possible to diagnose heart diseases earlier, which can prevent sudden deaths. You can read more about e-textiles in the Sport section of this paper.

4
WEARABLE BLOOD PRESSURE VEST.


HEAD-MOUNTED DISPLAYS
AUDIO DEVICE
SMART GLASSES
CONNECTED VEST
EMBEDDED SENSORS
SMART WATCH
SMART GLOVES

03 WEARABLES IN INDUSTRY

Industrial wearables (e.g. smart glasses and gloves, head-mounted displays, cameras, audio devices, sensors embedded into clothes) are transforming most industrial sectors. Whereas first-wave industrial wearables were adapted from consumer devices, the current second-wave wearables are being specifically designed for industrial users (e.g. headsets with augmented reality (AR) and smart bands with longer battery life, suitable for shift work).

Internet of Things (IoT) technology is increasingly being integrated into wearables to improve workers' safety, reduce error rates and thereby raise both productivity and the quality of work. Smart wearables establish connections between workers and a digital platform at a central point (e.g. site office), thus increasing visibility. The use of wearable devices can drastically improve occupational safety and health management in physically demanding and hazardous occupations by, for example, tracking workers' locations in dangerous working areas and monitoring workers' physiological status – like fatigue or stress.

KEY MARKET DRIVERS

With the IIoT, wearables are expected to bring high growth opportunities in the industrial sector. The development of smart wearables and sensors designed specifically for industrial environments is being driven by quantifiable results, such as the decrease in worker injury and mortality, improved worker productivity, and falling costs. The ability of wearables to provide real-time data, as well as perform monitoring and tracking functionalities will support further growth.

As connectivity and sensor technology improve, companies in industries as diverse as energy, utilities, manufacturing, construction, and mining are adopting sensors and connectivity to yield greater value. The use of sophisticated sensors, networks, data sciences, and analytics is resulting in quantum improvements in safety, productivity, and decision making, which bode well for the future.

PERSONAL PROTECTIVE EQUIPMENT

This disruptive force is slowly entering personal protective equipment (PPE). Workers rely on PPE to ensure their safety in potentially dangerous working environments. End users, employers and purchasers share a strong common interest: to obtain PPE and other safety equipment that complies with regulations and increases protection by preventing workplace injuries and avoiding the ensuing costs. It is up to employers to request "smart" safety equipment, and to manufacturers to meet their needs.

Among the many applications of wearables and sensors in PPE, some of the most common are:

1. **Environmental protection from invisible risks** – Smart protective clothing with gas, chemical, heat, sound, UV, impact and pulse sensors monitors both the external environment and the user. It alerts wearers to danger in time for them to take preventative steps, and alerts supervisors so that they can intervene if workers get into trouble.
2. **Smart communication systems** – Smart helmets, ear muffs and face masks provide fast, effective communication in loud or low-visibility environments.
3. **Safer equipment** – Smart lockout/tagout, backing cameras and warning devices, smart automation on machines and other automated safety measures keep workers safer.

These applications all require electronic elements to be embedded in the protective equipment. Smart systems also require a wireless link to external equipment. This allows a manager to intervene whenever an operator needs to be warned of a risky situation or is in need of assistance.

The traditional role of PPE in protecting workers and preventing risks is changing. PPE components are now used as carriers for sensors that monitor working environment parameters, workers' health status and their exact locations on the job site.

Another trend is to incorporate signalization systems and Augmented Reality modules into PPE. These provide warnings to users on the occurrence of hazards, and instructions on how to avoid them. They may also include automatic detection of accidents and near misses that can trigger immediate notification of managers and emergency services in case an accident occurs.

Moreover, as IIoT monitoring and analytical services become more widespread, it will also be possible to detect in real-time any anomalies in data streams, which could be caused by failures or malfunctions of sensors, data transmitting nodes, and other IoT devices. IIoT platforms and data analytics applications may also enable smart PPE systems to pave the way for more advanced Occupational Safety and Health (OSH) management processes.

wearin'

Technical Director Alvaro Goncalves on Wearin's industrial solution: "*Our aim at Wearin' is to ensure smarter workplace safety and efficiency by informing and protecting people, and preventing workplace accidents. Connected wearables and portable sensors are now coming of age. Wearin' enables operators in a wide range of industries to integrate plug-and-play sensors into field-proof, rugged, and lightweight PPE (personal protective equipment) garments, among other things. Data coming from the sensors are collected securely to enable real-time alerts, monitoring and visualization, and, more importantly, data are processed in a way that allows for predictive safety and efficiency. This increases adoption and comfort, enhances performance and productivity and, most importantly, protects more human lives.*"

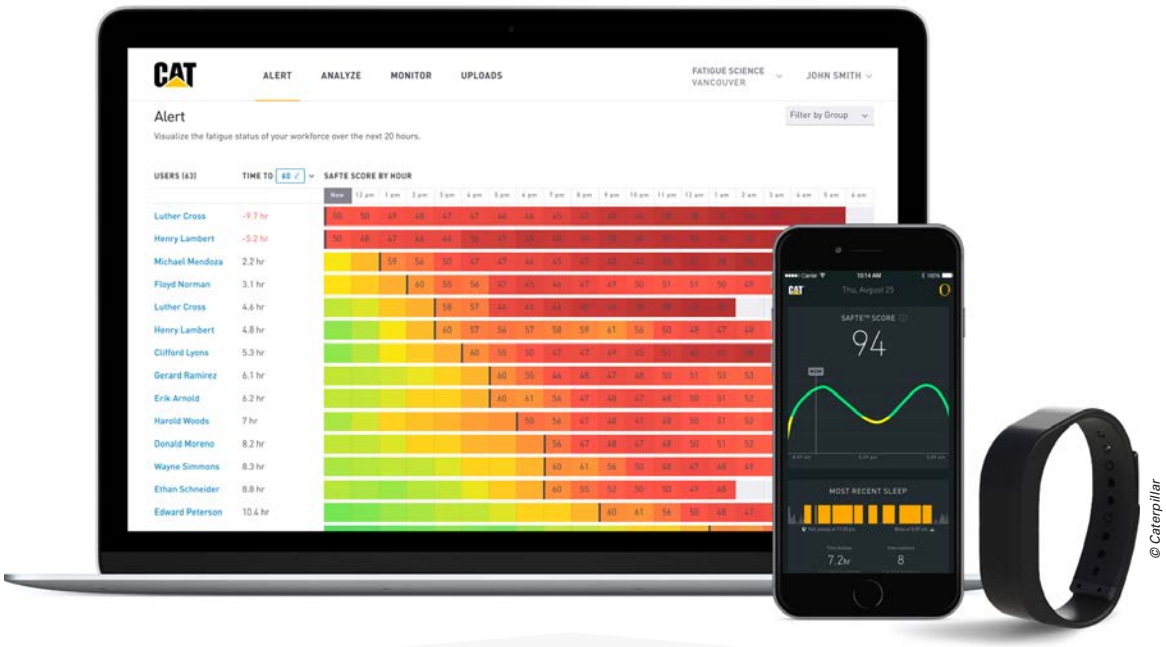
2.3 million

lives are lost to work-related accidents every year.

160 million
victims of illnesses per year

340 million
occupational accidents per year

Wearin' designs and develops wearable connectivity solutions that maximize the safety and performance of connected humans. Through its worldwide network of specialized partners in connectivity, data, gear, user adoption and human factors engineering & technology, Wearin' acts as a catalyst breaking product silos to co-create holistic wearable solutions for professional communities operating in demanding, and data-rich, environments such as construction, industry, defense & security, aerospace, extreme sports and healthcare. As part of the Fischer Connectors Group, Wearin' combines the agility of a start-up with the expertise of one of the world's leading manufacturers of rugged connectivity solutions for harsh environments. **www.wearin.tech**



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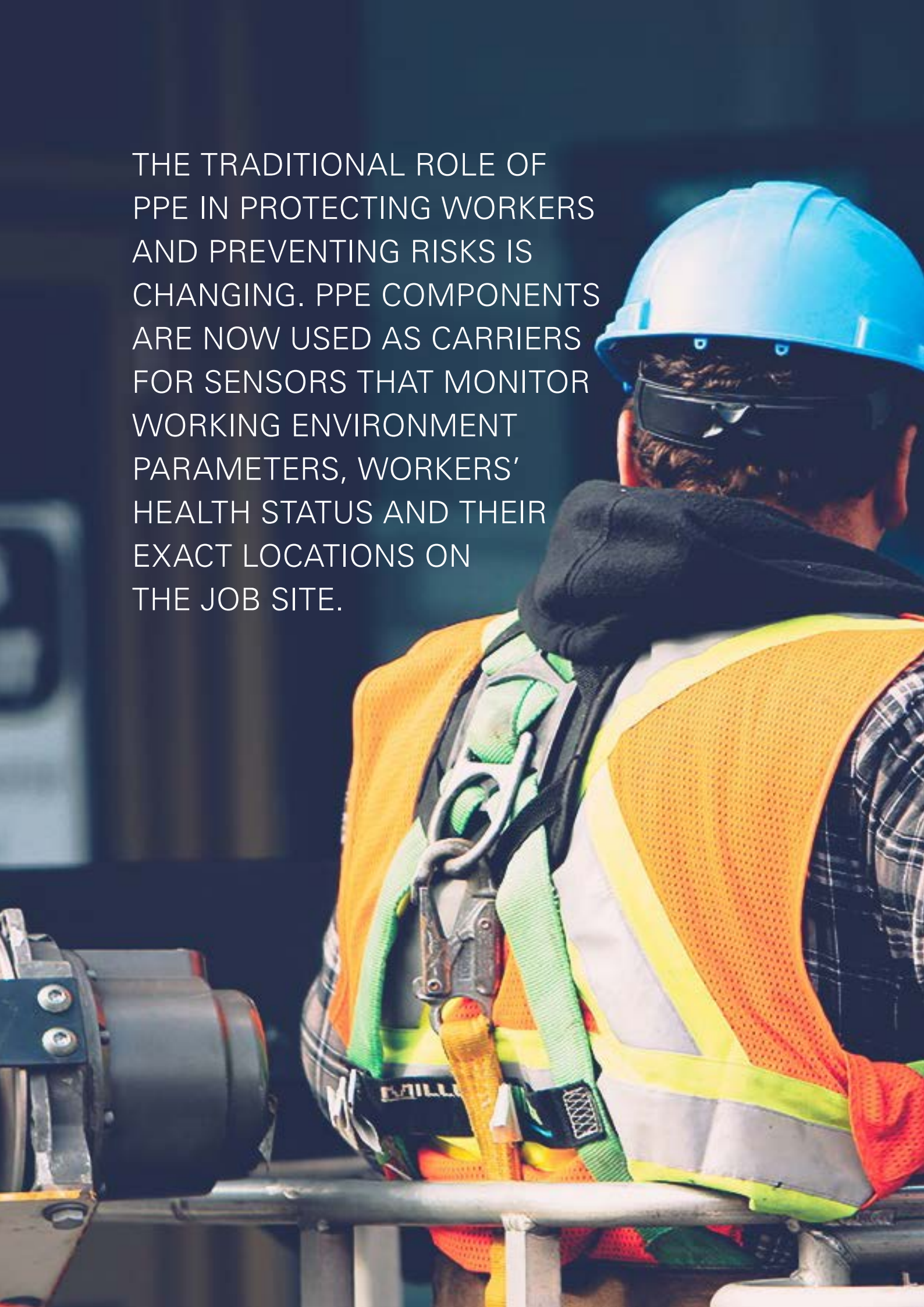
MITIGATING RISK AND MANAGING FATIGUE WITH THE CAT® SMARTBAND.

An example of a company using wearables to mitigate risk and manage fatigue on a job site is Caterpillar. The Cat® Smartband is an actigraphy watch, used in mining and potentially other sectors. It is worn by mining equipment operators to monitor sleep quantity and quality, and the level of alertness on the job. Sleep and alertness levels are closely linked and are critical from a health and safety perspective, as well as for operational performance.

The Cat® Smartband's design features include a battery life of one month for added convenience and ease of use. Shorter battery life necessitates more effort for recharging, making operators less likely to use the bands. One benefit for employees is to give them a tool to personally monitor fatigue. This wearable technology helps manage fatigue by automatically detecting the employee's sleep and wake periods and converts data into an effectiveness score – viewable by the employee at any time with the push of a button. If a score is approaching 70%, the employee is considered to be fatigue-impaired.

This is a useful tool for schedulers to optimize shift schedules, making them more flexible and fitting to individual biorhythms, thereby minimizing accident risk. Data from the smartband is transferred to a Web application that can generate fatigue reports; data can be filtered by specific groups and dates for further analysis. The data can be leveraged to build a robust fatigue management system.

THE TRADITIONAL ROLE OF PPE IN PROTECTING WORKERS AND PREVENTING RISKS IS CHANGING. PPE COMPONENTS ARE NOW USED AS CARRIERS FOR SENSORS THAT MONITOR WORKING ENVIRONMENT PARAMETERS, WORKERS' HEALTH STATUS AND THEIR EXACT LOCATIONS ON THE JOB SITE.

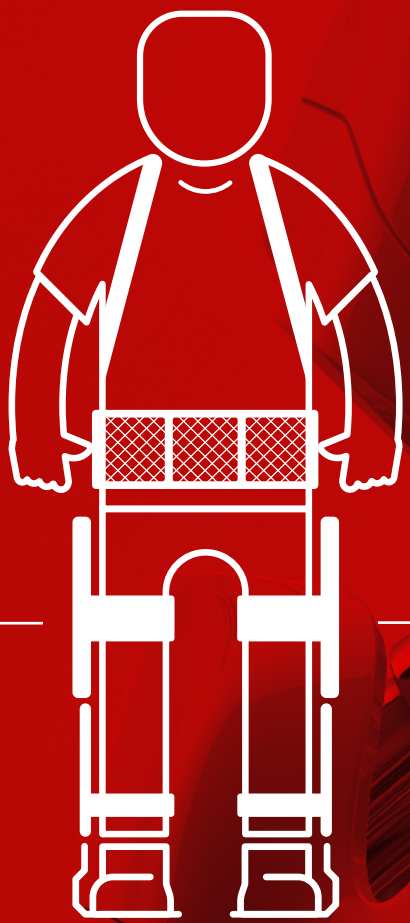


04 WEARABLES IN ROBOTICS

A wearable robot – also known as a bionic robot or exoskeleton – is a specific type of wearable device that is used to enhance a person's motion and/or physical capabilities. Some models of wearable robots can help individuals walk, which may be used for post-surgery or rehabilitation purposes. Others can help workers carry heavier loads or carry out their tasks more safely. They therefore have a wide range of uses in diverse sectors where workers have to carry loads or carry out strenuous or repetitive tasks: e.g. industrial, automotive, civil engineering, or defense.

The wearable robot interface has the specific characteristic that it can be programmed in a variety of ways. Sensors or devices can take in verbal, visual, behavioral or other input, in order to facilitate specific types of movement. These kinds of resources represent an exciting application of new technology to medical use. Paralyzed or disabled individuals may benefit greatly from these wearable robots, which combine sophisticated new hardware, big data and wireless technologies.

An important design constraint is that wearable robotics should fit the shape and function of the human body. The control unit consists of a suit worn by the operator. This suit, which may be as simple as a headset and gloves or as complex as a medieval suit of armor wired up with electronic devices, enables the wearer to put the robotic devices through human-like motions.



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1
A WEARABLE EXOSKELETON USED IN THE AUTOMOTIVE INDUSTRY REDUCING THE STRAIN ON A WORKER'S BODY AND THE LIKELIHOOD OF INJURY.

2
EXOSKELETON DESIGNED TO HELP CLEAN UP FUKUSHIMA POST MELTDOWN

3

THE COLEXO EXOSKELETON DESIGNED TO ASSIST WITH ROAD CONSTRUCTION

The road construction company Colas Suisse has developed a partial exoskeleton in partnership with the French company RB3D. Called *ColExo*, this wearable device was designed specially to assist with road construction. It is worn, for example, by workers manually installing bituminous pavements – an extremely repetitive, strenuous work. When they spread out asphalt on roads using a rake, operators adopt the same standing position for long periods of time, which is monotonous and very tiring. *ColExo*'s human-machine interface assists and guides the operator in real time, in order to obtain an optimal result. By multiplying the site worker's strength, the wearable reduces the risk of injury and increases productivity. It has many potential new applications to make work easier and more efficient.

TWIICE

As Dr. Mohamed Bouri, Group Leader, Rehabilitation and Assistive Robotics at the EPFL's Laboratoire de Systèmes Robotiques (LSRO) explains, *"Miniaturization and higher processing power in smaller devices are changing boundaries and pushing the limit of what is technically possible. The most exciting developments are the increasing bandwidth and speed of connectivity that is making more information available. This means that we can make more intelligent devices that react to the intent and behavior of the user, and connect the user more closely with his or her community. Since wearable robotics link the digital and physical worlds, we want to make them as intuitive as possible. We're always looking for ways of making information more useful, and increasing the density of power to make devices more autonomous and more reliable."*

© TWIICE

Tristan Vouga, also at EPFL's LSRO and Co-founder of the TWIICE exoskeleton, outlines his needs as a design engineer: *"Wearable robotics require the seamless integration of connectivity between a human body and devices, so factors like social acceptance, design and usability are important, in addition to reliable links. It's possible to do connectivity very badly, so that it's ugly, uncomfortable or breaks with heavy use. If it works perfectly nobody notices! That's why we design with the end in mind, keeping real-world constraints top of mind, and involving the users in the development process. With TWIICE, we set out to empower people to thrive in life and connect to their communities. Users are looking for more freedom, mobility and independence. What's unique about TWIICE is that it can adapt to different pathologies and morphologies to meet the unique needs of the individual, and fit their expectations and lifestyles, e.g. help people with paraplegia to stand and walk again, or amputees to run faster. The next step for TWIICE is to launch the first pilot project with target users in real life. Clinical contacts are interested because it's versatile, light and modular."*

© TWIICE

05 WEARABLES IN DEFENSE

Wearables are being used more and more in aerospace and defense, and this trend is likely to pick up momentum as the technology matures. Aerospace manufacturers and defense contractors are adopting an "all-digital mindset" and are eager to exploit the new opportunities offered by wearable devices and technologies to gain instant access to mission-critical information, increase collaboration, and improve the speed and quality of decision making. In some applications, wearables are also increasing workforce productivity, by reducing the risk of errors, or reducing or eliminating the need to travel.

On the battlefield, wearable devices and displays have a vital role to play. Since soldiers' performance is entirely dependent upon their physical condition, armed forces are using smart biosensors for monitoring and sensing soldiers' vital signs and injuries. Various types of sensor can be attached to their clothes to monitor breathing, heart rate and hydration, for example. Smart clothing's wireless communication capabilities enable soldiers' location, safety and potential hazards to be monitored with greater accuracy.

Interconnected and portable devices have until now mainly been used by soldiers on covert operations. However, there is a growing trend in wearable technologies for wider use in the defense market, with industry players partnering up for technology development; for instance, Apple, Boeing, and the U.S. Department of Defense are collaborating to develop wearable technology for defense purposes.

Typically, a soldier carries equipment weighing anywhere between 40 kg and 80 kg on deployment. Original equipment manufacturers (OEMs) are increasingly focusing on designing devices that are compact or can easily be integrated into a soldier's protective clothing. Customized wearables are also being designed to go unnoticed and blend in with soldiers' gear.

Another trend is for OEMs in the defense sector to replace radio handsets with more convenient hands-free communication devices. Augmented Reality (AR) is being integrated into visual systems to provide real-time information, and enhance decision making during immersive training or on deployment. An example is the ARA ARC4 system that overcomes the need for soldiers to look down at maps or smartphone devices to access key geo-spatial information. When their head is "down" and their attention is drawn away from what is happening directly in front of them, they are in greater danger. With their "heads up" and "eyes out" on the environment, users can remain alert, obtaining time-critical geo-spatial information with minimal effort.

A SOLDIER CARRIES EQUIPMENT WEIGHING ANYWHERE BETWEEN 40 KG AND 80 KG ON DEPLOYMENT.

HANDS-FREE WEARABLES INCREASE SOLDIERS' AUTONOMY.

© ARA

VISUAL DISPLAYS AND AUGMENTED REALITY ENHANCE DECISION MAKING.

KEY MARKET DRIVERS

Advances in materials and robotics are driving innovation in smart wearables for defense. Wearable e-textiles are a new field with opportunities to build innovative products that can revolutionize the way that soldiers interact with their garments. For example, carbon nanotubes can be used to make devices lighter and more flexible. They are used, among other things, to make flexible touchscreens that can be integrated seamlessly into clothing. More compact, lighter components that are nevertheless rugged and durable are also driving the manufacture of exoskeletons to minimize the risk of injury or fatigue.

A lack of reliable battery power and limited battery life have long been burdens for troops on the move and risk leaving troops in a compromising position in the field. This is because there is often a 72-hour deployment window, and batteries for these missions must be prepared and able to last extended periods of time without charging. Designers can, for example, use lithium thionyl chloride batteries that overcome power quality issues, including those caused by extreme climates. Unlike most batteries, which do not perform well in freezing conditions, these batteries can perform well in temperatures as low as -20 degrees Celsius (-4 degrees Fahrenheit).

The biggest driver for many battery manufacturers is to create a battery with extended runtime, to maximize the device's reliability.

OEMs must carefully consider the power source of their next interconnected device to ensure it is combat ready, especially as failing to deliver reliable equipment could risk a soldier's life. Thanks to wearable technologies, soldiers might be equipped with on-the-move, portable energy, thereby reducing the weight of gear they carry in the field. As an example, the *PowerWalk* knee braces harvest energy from the kinetic motion of human limbs during locomotion. This can generate an average of 12 Watts during regular walking.

Other alternative sources of energy are increasingly being harnessed for military wearables. For example, the *Lighting Pack* allows heavy loads on a wearer's back to move vertically, generating and storing electricity in re-chargeable batteries. With a load weighing 23 kg and walking at a military patrol pace, 20-35 Watts can be produced, greatly enhancing soldiers' autonomy.

Another example of how to increase efficiency and autonomy for dismounted soldiers is the integration of solar cells into backpacks and/or helmets to charge devices directly and store energy in rechargeable batteries.

The increased efficiency promised by IoT technologies, as well as the decreasing cost of suitable components, offer promising opportunities for next-generation military devices and applications like wearable technologies.

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1
INNOVATIVE POWER AND ENERGY SYSTEMS TO ENHANCE SOLDIERS' MISSIONS.

2, 3
WEARABLE SOLAR HARVESTING SOLUTIONS TO ENHANCE THE MANAGEMENT OF SOLDIERS.

06 WEARABLES IN SPORT

There is considerable buzz around connected wearables that are set to transform both amateur and professional sports. In addition to 'near-body' wearables like fitness watches, we are seeing 'on-body' smart clothing for sports, fitness and wellness – including t-shirts, caps, bras, trousers, socks and shoes. Wearable e-textile technologies with functionalities like heat regulation, luminescence, touch, and sensitivity are useful for several sports applications, as well as in other fields such as healthcare, space exploration, and gaming.

The main wearable e-textiles have embedded capacitive, resistive, and optical sensors allowing the textile to sense touch, strain, pressure, temperature, and humidity. The sensors are normally connected to control boards for processing information. Wi-Fi and Bluetooth are the most common communication methods for interactive textiles, with a hybrid approach to power. Battery requirements must be fulfilled either by detachable batteries or by thin, flat, and flexible batteries that are able to survive washing, drying, ironing, and dry cleaning.

The 2018 Winter Olympics in PyeongChang, Korea, where athletes braved sub-zero temperatures, showcased clothing with embedded heating technology. For the USA Olympic and Paralympic teams, Ralph Lauren designed water-repellent jackets equipped with a button on a slender battery pack that athletes could push easily, even wearing gloves, to get a jolt of warmth. They could also set their desired temperature level via their mobile phones.

Other examples include OM Signal's *PoloTech* connected t-shirt, designed by Ralph Lauren and woven with silver fibers, that integrates biosensensors to monitor temperature, stress levels, heart rates and breathing. Linked via Bluetooth to a mobile app, available on *iPhone*, *iPod* and *iWatch*, it also counts steps, and records the calories burned and activity intensity. OM Signal's *OMbra*, an intelligent bra made of a mix of polyester, elasthane and nylon for optimal stretch and using the same sensors as the t-shirt, links to the *OMRun* app or other health and sports apps. Both of these products are washable, with detachable sensors that can last for 10 sport sessions before needing to be recharged. In footwear, Digitsole *SmartShoes* can count steps, distances covered and calories burned, and integrate a foot-warming system and a torch.

OM SIGNAL'S POLOTECH CONNECTED T-SHIRT.

Solutions are being tested in professional sports that are currently too expensive for everyday consumer use. Until now, most attention has been paid to sports equipment and technology, as well as to the Internet of Things (IoT), to enhance sports performance. However, there is growing interest in real-time monitoring and biometric data capture to analyze human performance, e.g. breathing rate, heart rate, body temperature, hydration levels, and muscle tension.

In Formula 1 (F1) car racing, technical innovation has traditionally focused on the car, its components like tires, and supporting IT systems, with less attention being paid to the driver and supporting crew. The driver's performance is, nevertheless, key to winning any race. In a car cockpit, the driver's body is under great strain from cramped conditions, high temperatures, dehydration and G-force. Pit crews, engineers and other staff are also under considerable pressure from working in harsh environments, in different time zones and extreme climates. Drivers are increasingly wearing special suits wired to the car to monitor their states. Different types of smart wearable can provide a competitive advantage by enabling drivers and other team members to take a proactive stance towards their health and safety. Wearables that collect more data on how the body is behaving in real time can help improve individual decision making, reactions and recovery, and enable teams to take steps to optimize members' performance. Clothing that can adjust to the body, e.g. by regulating body temperature, could be particularly beneficial to users. Ultimately, it is their usefulness that will drive adoption of such wearables.

The IoT could also transform the audience experience by enhancing content and entertainment. Teams and fans can be linked thanks to smart wearables and smartphones. Via a mobile app connected to sensors on the racing track, sports field, or embedded in clothing, fans can follow their favorite driver, player or team through video feeds, take part in live polls, and share their experience on social media. In football/soccer and rugby, smart wearables enable efficient data tracking, including electrocardiogram (ECG) readings and 360° monitoring, which is useful for players and trainers. In some matches, fans can receive data on players' distances run or passes made on their screens. In Formula E (for electric cars), fans can vote to give drivers a power boost via the race's official app. There are plenty more exciting ideas in the pipeline to enrich the audience experience.

MARKET DRIVERS

Usability and comfort are crucial for both B2C and B2B sports applications. Bulky tactical jackets would disturb athletes or players and inhibit their movement, so less rugged, more flexible materials, including e-textiles, are being developed for sports applications. Nano fibers are being tested as a way of replacing inconvenient wires. As sensor technology gets thinner, lighter and more flexible, it will become more portable. However, it also needs to be stretchable, easy to integrate into clothing, and adjustable to individual bodies and their environmental conditions. Research is underway to improve washability, as well as to extend battery life and recyclability.

ELECTRICAL COMPONENTS

Wearable e-textiles would not be possible without electrical components, such as electrodes, connectors, and interconnectors. When wearable e-textiles are used to collect electrical biological signals, the electrodes provide a bridge between the body and the circuit. The energy needed to power e-textile circuits normally comes from lithium polymer batteries. Innovative power and energy systems are being developed and researched, to embed into sports garments and other types of clothing. The increasing miniaturization of electric circuits is also enabling the seamless incorporation of functionalities, which increases the market penetration of wearable e-textiles.

TEXTILE CIRCUITRY

Textile circuits are electrical circuits built on textile substrates, e.g. by incorporating embroidery-conductive thread into textile substrates. The conductive patterns can also be made using graphene-based inkjet-printed techniques. Another technique to build textile circuits is to iron a welded circuit onto the textile substrate. Once the circuit has been attached to the textile, it can be soldered like a traditional printed circuit board.

ADVANCED FUNCTIONAL FIBERS

Fiber technology offers another way of embedding functions in fabrics. Fibers can be integrated into textiles using conventional weaving methods. Advances in production methods, like the thermal drawing process, are opening up new opportunities. Multiple materials can now be assembled in complex geometries. Fibers that can sense, adapt and communicate can be made by modifying material properties. In the future, fabric that responds to stimuli by changing temperature, color or stiffness can be imagined.

FUTURE PERSPECTIVES

Progress in sports wearables will be determined by OEMs' ability to manufacture products with seamlessly embedded electronics to fulfill users' comfort and performance needs, as well as by the perceived usefulness of wearables to players, coaches, teams and/or fans. Huge growth opportunities are arising from combining cross-industry expertise – for example, circuitry design, textile innovation, system integration, and connectivity – to make smart, comfortable, high-performance sports wearables.

PEOPLE LOSE TRUST IN CONNECTED APPLICATIONS IF SECURITY IS BREACHED.

07 SECURITY AND DATA PRIVACY IN WEARABLES

As the greatest information technology revolution gets underway and we transition from a mainly paper-based world to a fully digital world, many people are enthusiastic about the increase in data and openness – and the related opportunities for learning and growth. However, security and privacy concerns are snowballing as the Internet of Things grows. Cybersecurity now needs to broaden its focus from traditional connected objects to all different kinds of wearables, some of which may even include in-body electronics – like Internet-connected pacemakers, and cochlear or microchip implants.

The burgeoning IoT and "Internet of Bodies" expose wearers to ever-changing risks from criminals or enemies who wish to harvest or manipulate data (e.g. through malware) for nefarious purposes. With data, there is always a two-way risk, and the level of risk exposure depends on the sensitivity of the data. Many hackers consider personal healthcare data to be as valuable as personal financial data, so wearables that track users' vital signs, health and fitness are particularly vulnerable to attack.

Risk is also related to how data is collected, stored and used. Researchers have developed attack scenarios involving wearables on three primary attack surfaces: the device, the application, and the cloud. Risk is highest on the level of the device, because it is in an uncontrolled environment and most exposed to attack. In IoT devices, one pragmatic solution is to fix problems only after they occur, but ideally devices should be designed from the outset with security in mind. For wearables, OEMs are advised to adopt a "Security by design" approach, embedding data integrity protocols into the device or on the edge. Data should be encrypted when it leaves the device and pass through a "secure tunnel" to a secure application server, thereby restricting access and protecting its confidentiality.

Security cameras and wearable video cameras in tactical vests, for example, need to be made secure in order to protect individual or public safety. There have been high-profile cases of such devices being hacked and videos being shown publicly. One solution is to encrypt data and implement fine-grained access control to restrict viewing to authorized persons. This would prevent hackers from harming law enforcement agents, or officers from acting illegally.

Since wearables can also be operated through smartphone apps, it is important to secure mobile apps and devices by, for example, updating the firmware to the latest version and refraining from using third-party apps. If Bluetooth is used for communication, there is the potential of information leakage or malware infection that aims at hijacking the Bluetooth feed from the wearables. This is a risk even when wearable developers have applied encryption and proper Bluetooth implementation. On the level of the cloud, where many wearables store data and perform analysis on user activity, there is the risk of exposing the data and enabling a wearable device to be identified and attacked.

PROTECTION STRATEGIES

It is the responsibility of wearables manufacturers to incorporate security into their products, starting with the design process. This process must provide a robust solution to the four major threats to IoT security: 1) securing the device, 2) securing the data, 3) managing access to the data and to the device, and 4) actively maintaining that security over time. The entire lifetime of the

product must be taken into account because a product that is secure at launch might not be secure for long if attackers develop new strategies that were not thought out during the design phase. This requires strong hardware security foundations in the device, a backend platform to manage those security features and enable secure communication of data, constant monitoring of the threat environment, and a swift and effective response to attacks.

SECURE FOUNDATIONS

Critical to the design of any device is an individualized "root of trust" – a secure, unique identifier stored on a device in a highly protected way, ensuring that the device can be uniquely identified, and forming the foundation for a large variety of other security functions as well. There is no "one-size-fits-all" security but "horses for courses" – depending on the overall architecture of the wearable. Decisions need to be made according to a decision hierarchy, taking first the cost of the technology and its operation, then the device capabilities, then the value of the data into account.

The choice of device protection levels has timing and cost implications. From the least onerous to most onerous, options include:

1. Advanced software protection techniques: obfuscation (scrambling code so it is difficult to understand); white-box cryptography (it allows cryptographic operations to be performed without revealing any portion of confidential information such as the cryptographic key). These can be further strengthened by running them within a secure OS or Trusted Execution Environment (TEE), i.e. a secure place on the chip to run software.

2. Hardware security: if an OEM is at the beginning of the design process with sufficient time to influence the device and chip design, it is best to integrate dedicated security functions in hardware. However, a longer integration period is usually required. There are several options:

   a. eSIM/iSIM for Cellular Devices: when connected to narrowband IoT networks that run on low power and transfer small amounts of data, security can be embedded on the eSIM/iSIM, a new standard that removes the need for a physical SIM card and SIM slot.

   b. Dedicated Secure Element: if an OEM is closer to product launch and has less time, a dedicated security chip can be integrated to achieve the necessary security levels.

   c. Integrated Secure Element: critical security functions are embedded into the device's primary chipset itself, integrating all security functions into the overall architecture of the device.

THE BROADER CONTEXT

The international dimension of cybersecurity adds an additional layer of complexity for OEMs and users to grapple with. Legislation and regulation for devices, and the level of security and data protection required, differ by market and sector, and often lag far behind more nimble hackers. For historical and cultural reasons, Europe is on the cutting edge of privacy concerns. The General Data Protection Regulation (GDPR) – effective as of May 2018 in the European Union (EU) – is widely seen as a positive step by consumers, since it gives them more control over their privacy. It will impact some wearables, since it covers the collection, storage and use of personal data and geo-location data (but not medical data or data in military applications). OEMs based outside the EU will be affected if their devices or services collect or process any data originating in the EU.

In addition to security and data privacy concerns relating to wearable devices, fundamental ethical questions are also being asked about what it means to be human in an age of technology-mediated bodies and artificial intelligence. However, those are beyond the scope of this paper.

THERE IS NO "ONE-SIZE-FITS-ALL" SECURITY BUT "HORSES FOR COURSES" – DEPENDING ON THE OVERALL ARCHITECTURE OF THE WEARABLE.

08 WHY CONNECTIVITY MATTERS

Connectors and cabling are small components of our everyday devices, but they are of critical importance to the functioning of these devices and to that of all the major equipment that makes the world function properly, reliably and safely. Should a single connector malfunction, the equipment and system break down – hence the importance of the reliable, rugged, high-performance connectivity solutions that companies like Fischer Connectors supply to design engineers and integrators. In networked wearables sharing a common power and data bus, connectivity can become a key innovation driver, helping to make devices smaller, lighter and smarter, while maintaining or enhancing their performance. For standalone wearables, which are mainly wireless, connectivity is needed primarily for charging (e.g. a Fitbit tracker). Nevertheless, innovation enables different wearable devices to be networked together (e.g. on a tactical vest) with a shared data and power hub.

In this paper, we have explored trends in wearables and given examples of applications in which there is a growing need for cutting-edge wearable connectivity suited to any context, environmental condition or mission. Common selection criteria for connectors across sectors are: lightweight, high density combining signal and power, compact for ease of movement, and easy to integrate into portable wearable solutions featuring sensors and data processing (e.g. IoT solutions).

With Fischer Connectors' new development approach, the Fischer Freedom™ Series opens up a new path for connectivity solutions. Its creation reflects the company's vision, which is to reimagine connectivity, helping turn ambitious ideas into solutions that shape the future. Developed from the outset in partnership with a customer, the new Series launched in June 2018 hits the nail on the head when it comes to fulfilling customers' specific requirements. It is fully aligned with Fischer Connectors' mission, which is to make its customers' lives easier through a collaborative approach, tailored connectivity solutions, and passionate employees who turn challenges into success.

INTRODUCING THE FISCHER FREEDOM™ SERIES

FISCHER FREEDOM™ OFFERS REAL BREAKTHROUGH TECHNOLOGY IN THE CONNECTIVITY MARKET BY:

Addressing urgent market needs, primarily in the defense & security industry

- It plays a major role in lifting one of the most basic roadblocks for "Dismounted Soldier Systems" and "Future Soldier" Programs: cable management – ensuring "no more twists and turns"

Driving innovation, addressing in an easy and effective way a major trend in connectivity design engineering – easy integration with portable and wearable devices

- It contributes to the development and integration of electronics into smart clothing (see "Easy integration" below)

Setting a new standard in usability

- Easy use
  (for end users), including:
  - Easy mating
  - Easy cleaning
  - Enhanced functionality, with 7 pins (power + signal with USB 2.0 and Ethernet)

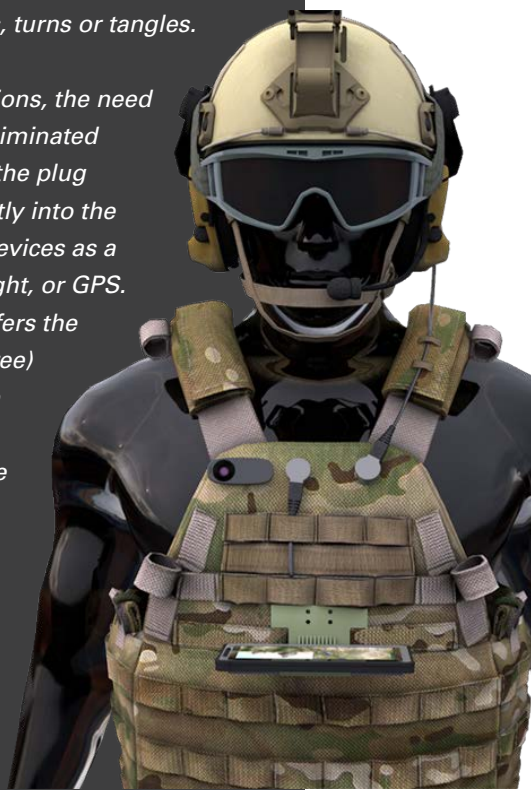
- Easy integration
  (for design engineers and integrators):
  - Integration into clothing such as actical and security vests, and Protective Personal Equipment (PPE) (right-angled, low profile)
  - Direct integration (vs. cabled version) – on a panel-mounted receptacle OR in a panel plug version directly integrated into the housing of an application

- Reliability – with IP68 sealing, robust design, lasting for up to 10,000 mating cycles, and withstanding harsh environments.

Wim Vanheertum, Product Management Director at Fischer Connectors, summarizes what makes the new Fischer Freedom™ Series special: "This product line offers a unique connectivity solution that has been entirely thought of and designed from the outset for the benefit of our customers. It fulfills, in a unique way, the need for usability and easy integration that our direct customers, the design engineers, constantly express – and also our customers' own customers: those who use the applications they've designed.

Our breakthrough lightweight, compact, extremely reliable and intuitive solution is easy to integrate into applications operating in diverse and challenging environments. This includes portable and wearable electronic ecosystems delivering power and data through an optimized plug-cable combination: the cable can always go in a straight line to the device, without any twists, turns or tangles.

In certain applications, the need for cable can be eliminated completely when the plug is integrated directly into the housing of such devices as a camera, sensor, light, or GPS. In that sense, it offers the "wireless (cable-free) without the hassle of the wireless", and thus paves the way for further expansion into breakthrough connectivity solutions for the Internet of Things (IoT)."



ABOUT FISCHER CONNECTORS

Fischer Connectors has been designing, manufacturing and distributing high-performance connectors and cable assembly solutions for more than 60 years. Known for their reliability, precision and resistance to demanding and harsh environments, Fischer Connectors' products are commonly used in fields requiring faultless quality, such as medical equipment, industrial instrumentation, measuring and testing devices, broadcast, telecommunication, and military forces worldwide.

Primary design and manufacturing facilities are located in Saint-Prex, Switzerland, with subsidiaries and distributors located worldwide.

Fischer® CONNECTORS

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