There is nothing simple about integrating electronics into textiles, and though projects abound from academia and start-ups to big corporations, many hurdles remain. The good news is that there now appears to be a market for smart garments and the trend seems to have turned many sports enthusiasts into data addicts.

Wearable tech textiles coming out of beta phase

The many pieces of the puzzle that are needed to put together a wearable smart biometric garment — the sensors, the textile electrodes and conductive yarns, the software and the algorithms — now exist or nearly all of them do. Bringing them together on a piece of clothing, setting up all the connections, making them work, resist washing and provide clear, useable data, is another matter.

Sports geeks looking for smart clothes that track their training sessions and biometric data do now have something of a choice of products. Launched in April, Heapsylon's Sensoria fitness bundle, consisting of two pairs of socks, an electronic anklet and a charger, is sold for $199 and shipped in four-to-six weeks. Available online in Europe since January, Carré Technologies' Hexoskin kit costs €449 and includes a compression top, a so-called 'gateway smart module' and a USB cable. OMSignal's Biometric smartwear top with its OM Box is sold for $249 (Canadian). As for earlier body-worn monitoring devices such as chest straps, Under Armour's 39 Module was sold out when checked online this May. Another first-generation product, the adidas Numetrex smart garment offers shirts and bras for $50 to $60, to which one must add a $19 transmitter and choose from one of three types of heart-rate monitors, sold at $60 to $70, to clip onto the shirt or bras.

Meanwhile, consumers equipped with fitness tracking devices and smart phones are already monitoring their workouts and biometric data everyday. As the hype builds up around these health and wellness accessories, market data similarly escalates. Market research companies are hot on the trend. Gartner projects wearable fitness devices will be a $5 billion market by 2016. Tractica estimates that smart clothing shipments will grow from 140,000 units in 2013 to 10.2 million by 2020. Smart straps must make up most of the 140,000 units sold in 2013, and the forecast may be a bit optimistic.

The Antelope suit will "activate 100% of your physical fitness potential" claims Wearable Life Science, founded in March 2014 and maker of the first wearable electro-stimulation system. The electronics are by Polar.

Dominik Pietsch

Smart suit 1.0

In reality, among the many smart garments in development, most are now in the beta phase of testing. The Antelope electric muscle stimulation suit made by Frankfurt-based Wearable Life Science may be available on a crowd-sourcing website this summer. The D-shirt (D as in digital) designed by Lyon-based Cityzen Sciences hasn't yet made it to market; its technology will in any case be licensed to other brands.

Hexoskin, developed by Montreal-based Carré Technologies, is one of the few products available in Europe. The company, founded in 2006, was commissioned by NASA and the Canadian Space Agency to develop an autonomous medical monitoring system for astronauts. This became the Astroskin, a shirt and a headband kit costing €6,000. Hexoskin is a derivative of that high-tech sensor-laden system. It is equipped with three ECG electrodes (one 256 Hz sensor to measure heart beat and two 128 Hz sensors to measure thoracic and abdominal breathing), a three-axis accelerometer (64 Hz) and a 40g device. The garments are made in a Revolutional fabric by

Italian knitter Carvico. For the ECG sensors to function correctly, the skin needs to be moist, either through sweating, via spray or simply by wetting the skin. "Breathing data is obtained via two respiration loops that pick up thoracic and abdominal movement to gauge the volume of air breathed," says Xavier Alexander, the European distributor for Hexoskin. The company does not include a GPS module, to avoid issues of tracking people, he says. The design of the shirt itself has been optimised over time and now includes a back strap to adjust the garment closer to the body. Another redesign is being considered as the current shirt is deemed too discreet. "People wearing smart watches can show off their technology," says Mr Alexander. "There's a certain amount of swag in this market that we didn't think to focus on when designing the first-generation garments."

The antelope motif knitted centre front on the smart suit developed by Wearable Life Science is one of the few graphic elements seen in early smart clothing. A double Ispo award winner in 2015, the suit doesn't (yet) track movement but

Sensoria's smart fitness socks are embedded with proprietary textile sensors and powered by a Bluetooth-enabled anklet. They give updates on distance, speed, number of steps and other information for walkers and runners.

Sensoria

is designed rather for electromuscle stimulation (EMS). The prototype compressive suit can accommodate 24 electrodes that activate 12 muscle groups, says Wearable Life Science co-founder and CEO Philipp Schwarz. Current EMS systems require multiple cables with the result that "people look like cyborgs" he says, making the Antelope suit "a big improvement on current EMS equipment." The technology department of Swiss embroidery specialist Forster Rohner developed the smart textile components. "The wiring will be invisible in the finalised product and future versions will include data tracking sensors," says Mr Schwarz. The estimated price for an Antelope suit will be €240, depending on how many muscles are to be activated. In addition to maximising workouts, the suit can also be used to correct posture the company stated.

OMSignal, a company founded by Stephane Marceau and Fred Chanay in 2011, began working on its own smart suit with Carré Technologies (the two are now in court). Its Biometric Smartwear is equipped with three ECG sensors, a breathing sensor, an accelerometer and a gyrsocope. These are connected via conductive silver yarns and powered by a box weighing 40g.

Calling on experts

As the components become more readily available, a new breed of company is emerging offering to develop tailored wearable tech solutions for brands. The staff at Cityzen Sciences includes engineers in electronics, software and textiles, "the varied expertise needed to develop smart clothing concepts," says company spokesperson Vincent Lambert. Cityzen Sciences heads a research consortium called Smart Sensing and raised €17.7 million for research and development, of which €7.2 was provided by the French administration. Awarded two prizes at the Consumer Electronics Show (CES) in Las Vegas in 2014 and 2015, the D-Shirt is fitted with ECG sensors, a GPS antenna, an accelerometer functioning as an inertial measurement unit that records velocity, orientation and gravitational forces, and a barometric altimeter. With the exception of the ECG sensors, these are all located in what the company calls a gateway. Placed in between the shoulder blades, this device also houses the battery and transmits data via Bluetooth in real time or after a sports session (if the user decides to leave the phone at home or in the locker room).

Cityzen Sciences is currently developing smart shorts for French cycling retailer CycleLab. These will have an additional sensor in the leg area to monitor movement and cadence. It could be ready for commercialisation by the end of 2015 and will be branded CNTD Pilot. A smart running shirt in development for Asics may not see the day until late 2016, says Mr Lambert. The Cityzen Sciences Facebook page also mentions a contract signed with Goldwin Japan for its Canterbury label. Like computers sold with 'Intel Inside', the smart components developed by Cityzen Sciences will be referenced as "by Smoozi".

In addition to lighting and heating elements, and a Sympatex membrane, the multifunctional jacket developed by Tection, a division of Sympatex and Ploucquet, is equipped with a high quality speaker system to listen to music.

Sympatex

In Germany, Sympatex and Ploucquet have created a new division called Tection that also plans to provide the technology needed for smart (waterproof and breathable) clothing. Presented at TechTextil in May, the smart jacket concept includes lighting, heating, speakers and communicating devices that connect to a smartphone. It is also washable. "The fact that we all now carry smartphones means consumers are more open to integrating similar technologies into their garments," says Patrice Morin, Tection business development director. Among the jacket's special features, he singles out the heating panel that shuts off automatically so as to avoid depleting the battery and the high-quality speakers.

In the highly fragmented marketplace that defines smart clothing developments today, the components, materials and supply chain are

slowly coming together, confirms Sabine Seymour, founder of the 'soft' wearable technology and e-textile company Moondial, a professor at Parsons Design School in New York and author of several books (including a new book on Computational Fashion to be released in 2016). She is now working on a new product to further build up the development process for brands and ultimately bring "smart garments to the mainstream, in sports, wellness and workwear". Textiles, electronics and software engineers along with garment experts make up the team. "My new heroes are pattern-makers. They are essential for design aesthetics and ergonomics, sensor placement and fit," she says.

Fashion embraces technology

Italian luxury brand Zegna develops a smart clothing concept every season, thus staying on top of the latest developments. The Fall-Winter 2015 Icon Warmer jacket features a wireless, induction-based charger, which when placed on a hanger will charge up the jacket's powerbank. Froster Röhner and InteractiveWear worked together on this project. While heating and lighting functions have become close to standard, InteractiveWear CEO, Andreas Röpert, sees motion-tracking as the next step for smart textiles, a development he believes is roughly five-10 years away. "We are building the infrastructure to make an embedded motion tracking system, incorporating 10-20 state-of-the-art sensors," he says.

Merging high technology with the fine art of embroidery, the Textile Innovations division of Swiss company Forster Rohner specialises in embroidered electronics, which are linked together with conductive yarns. The company provided the smart components for several light-emitting dresses, suits and accessories for the autumn-winter 2014 collection of Swiss fashion label House of Akris.

Connecting the pieces

AiQ, the smart component department of Taiwan-based Kings Metal Fiber, is working with Intel. Like other Silicon Valley companies, the chipmaker would like to see its technology enter the world of fashion. Here again, the textile manufacturer is still fine-tuning its smart elements and spent most of 2014 working on R&D to scale up production. One of its current projects, with a major brand, could be ready in 2015.

Circuitex is a new division set up by Noble Biomaterials, the maker of X-Static silver-coated yarns, to take advantage of the conductive properties of its silver-based products, which are available in the form of fibre, foam, inks for printing, aerosols and sewing threads. X-Static yarns are found in the smart clothing designed by Athos, Clothing+, adidas Numetrex and OM Signal (including the shirt it made for Ralph Lauren). "We have a long history of working with conductivity and have developed a toolkit for integrating biometric tracking elements in sportswear," says company CEO Jeff Keane, who believes wearable tech will soon be ubiquitous. Scrambled signals due to interference and noise remain a "unique challenge in textiles" he says. French e-textile designer Florence Bost points out that smart clothing poses a particular challenge in that the longer the conductive thread, the more energy is lost.

Cityzen Sciences uses stretch conductive yarns made by French spinner Payen. Swiss spinner Swicofil offers high-tenacity polyester yarns that can be plasma-coated with any metal (a process developed by EMPA), including gold to make high-quality conductive continuous filaments. As these can be quite expensive, some settle for the steel filaments made by Belgian company Beckaert, an option taken by Pauline van Dongen for her Solar Shirt, developed with the help of the Belgian microelectronics research centre Imec.

OMSignal embeds its biometrical devices around the torso, like a built-in chest strap, of a fitted seamless knit compression top made in polyester and elastane and treated with an antimicrobial silver-based solution.

OM Signal

Officially presented at the We Run Amsterdam 10k event organised by Nike on May 16, Pauline van Dongen's latest smart garment is laced with a LED ribbon. It follows up on the 2013 Mesopic Light Jacket developed in collaboration with Philips Research. The designer, a graduate of the ArtEZ, Academy of the Arts in Arnhem, the Netherlands, says she was frustrated when "running with illuminated armbands or seeing people wear flashy reflective vests."

Hammond Images

Powering the devices that collect and relay biometric data is another big challenge for all wearable technologies. There is much talk of reducing energy consumption by all possible means, including Bluetooth Low Energy, and a little talk of harvesting energy from the body to do away with the need for batteries, though some sort of hardware device to stock energy will probably always be necessary.

Heat and movement are the two main ways of harvesting energy produced by the human body. At rest, the human body is said to generate around 100 W of power in the form of human heat, but only 10% of this heat is believed to be harvestable. Walking is said to generate more or less 1 Hz of energy per step, enough to light up a diode on children's shoes.

PiezoTech, a division of French polymer producer Arkema, specialises in fluorinated electro-active polymers (EAP). These polymers convert mechanical or thermal energy into electrical energy. Arkema produces many fluorinated polymers such as PVDF (PolyVinylidene Fluoride) that is used in different textile and filament applications. PVDF is flexible and washable, which makes it "wearable", says Piezotech manager Fabrice Domingues Dos Santos. The companies are investigating the possibilities of printing these electro-active polymers or integrating them into a textile filament, and testing is being done at the French research institute CETI. "Since the piezo-electric function is activated by elongating PVDF, filament, applications are well suited to the polymer," says Mr Domingues Dos Santos. But that's only one step in making an energy-producing fibre. To generate electricity, two electrodes need to placed on either side of the polymer, and each one of these must be connected to another conductive material. Sceptical regarding the energy harvesting potential of PVDF and derivatives, Mr Domingues Dos Santos sees higher potential in using piezo-electric materials as sensors (for temperature or blood pressure).

Printed batteries are also being considered, though here again, they don't provide much energy. "Today's printed batteries generate 20 milliamps. You can't do much with that," says Florence Bost who recently co-authored a book on smart textiles ("Textiles innovants et matières actives", published by Eyrolles). What we're missing, she says, are smart trimmings such as a button that can be used as an on-off switch. Most of today's products use the textile only as a ground for electronic integration, and not as a smart material in itself, she continues, and adds: "There is a deep disconnect between the world of electronics and textiles: the textile industry's logic is to produce lengths and lengths of fibres, yarns or fabrics. In electronics, components are made piece by piece, and each chip is programmed for a specific function. It's as if each yarn were to have a different function requiring its own research and development process."

Commenting on the evolution of the industry, Jan Zimmermann at Forster Rohner has a similar point of view, saying: "What we've seen up till now is that it is easier to make hardware wearable, like Google Glass or the Apple watch, than to make textiles electronic." For Sabine Seymour, it's just a matter of time: "Soon enough, you won't buy a running shirt that doesn't have a heart-rate monitor. And all the major brands will have one on offer in their collections."

Designed by Carré Technologies, Hexoskin biometric clothing is used by astronauts working for the US, Canadian and French space agencies.

Hexoskin