
Smart Apparel, Smart Patches and the Related Constraints

1.1. Reminders and definitions

We have already detailed a large number of points relating to smart, communicating fibers, textiles, fabrics and apparel in an earlier work (Paret and Crégo 2018). However, for those who are new to the field, let us begin here with a brief description of the main families of textiles¹.

1.1.1. *Main families of textiles*

Generally speaking, the world of textiles can be subdivided into a variety of categories. Two very broad ones are “ordinary textiles” and “technical textiles” (TTs).

1.1.1.1. *Ordinary textiles and technical textiles (TTs)*

These two large families are generally defined as follows:

- normal textiles cover “clothing and homeware”;
- TTs are “textiles for technical and professional uses”.

The names reflect the purposes for which they were originally designed. The same is true of ordinary textiles. A more detailed view of what these categories contain is given in Figure 1.1.

¹ This first chapter has been written with the invaluable help of Florence Bost, and documents that she uses at conferences and training sessions organised by her company, *Sable Chaud* (Hot Sand).

		Applications											
Names													
Technical textiles (TIs)		Agrotech											
		Buildtech											
		Mobiltech											
		Geotech											
		Protech											
		Oekotech											
		Sporttech											
		Medtech											
Homitech													
Clothtech													
Packtech													
Indutech													
Ordinary textiles (clothing, household linen)		Outdoor activities and sports											
		Wellbeing											
		Decoration											
		Clothing											

Figure 1.1. Ordinary textiles and technical textiles. For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

Often, in the eyes of the general public, there is an overlap between some of these categories, because sometimes, the boundaries between them are rather fuzzy or flimsy, or poorly defined. In reality, despite the seemingly close fields of application, as shown in Figure 1.2, there are often separate worlds which must not be confused. Examples include:

- Medtech and wellbeing;
- Clothtech and clothing;
- Sporttech and outdoor sports;
- Hometech and decoration.

Technical textiles		Ordinary textiles (clothing, household linen)	
Agrotech	Sporttech	Outdoor activity and sport	–
Buildtech	Medtech	Wellbeing	–
Mobiltech	Hometech	Decoration	–
Geotech	Clothtech	Clothing	–
Protech	Packtech	–	–
Oekotech	Indutech	–	–

Figure 1.2. Areas of confusion between ordinary textiles and technical textiles. For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

Let us now briefly examine some textile systems.

1.1.1.2. Smart textile systems and types thereof

As ever, we shall begin with a few definitions.

1.1.1.2.1. Smart textile material

A “smart textile material” is a functional textile material (a technical textile) which actively interacts with its environment – i.e. which responds or adapts to changes occurring in its surroundings.

1.1.1.2.2. Textile system

A “textile system” is a set of components, both textile and non-textile in nature, integrated within a product which retains the properties of the textiles (for example, clothing, a carpet or a mattress).

1.1.1.2.3. Smart textile system

A “smart textile system” is a textile system displaying a pre-determined, exploitable response either to changes in its environment or to an external signal.

1.1.1.2.4. Types of textile systems

According to the European standardization body, CEN, smart textile materials and systems, which have the ability to interact with their environment, are characterized by two functions: firstly their energy function, and secondly that of external communication. This gives us the definition of four categories of terms, presented in the matrix in Figure 1.3.

		Energy function	
		Without	With
Communication function	Without	NoE-NoCom	E-NoCom
	With	NoE-Com	E-Com

Figure 1.3. Definition of “smart textile systems”
(source: CEN)

This figure clearly shows that there may be smart textile systems that do not have an energy function or communication ability, but are able to interact with their environment by means of two main functions:

- External communication by means of actuators, sensors and an information-management device. An example would be a garment made with shape-memory material.

- An energy function, using optical fibers, conductive wires, thermal heating, and fluorescent textiles, which make use of specific properties provided by the material, its composition, construction or finish.

Note that the majority of smart textile systems are able to fulfill at least one of these functions – for example, communication (respiration sensors) or energy (a backpack or pocket harvesting photovoltaic energy), or even both (a heat detector in a firefighter’s jacket which triggers a warning light).

1.1.1.3. Levels of integration of electronics into textiles

The normative work of CEN Working Group WG31 distinguishes between four levels of integration of electronic components, which add functions to textiles. Each level brings different constraints in terms of development and technological possibility. Different legislation also applies to each category. They have differing

effects on the human body (which must be taken into account when conducting risk assessments) and different implications for product safety.

Let us briefly examine each of these four levels of integration.

1.1.1.3.1. Level-1 integration

“The integrated electronic component can be removed without damaging the product.” The components can be treated as separate units, so there is no need for separate standards for products such as these.

EXAMPLE.– The textile and the electronics are side by side – The electronic component is attached to the textile by external pieces, and remains structurally sound in its own right. Examples include:

- a jacket with channels designed to contain headphone cables, for entertainment use;
- a jacket with a screen which can be removed, in order to clean, wash and iron the garment.

1.1.1.3.2. Level-2 integration

“The electronic component is attached to the textile in such a way that it is impossible to remove it without destroying the product.”

EXAMPLE.– This is a hybrid solution – The electronics are more closely coupled with the textile. In principle, they are made flexible and washable so that the garment can be cleaned. An example is a jacket with headphones built into the hood. In this case, the components can no longer be treated separately, and the system must be addressed as a whole.

1.1.1.3.3. Level-3 integration

“One or more components are textiles or have a textile-like finish. They are combined with electronic components which are connected, permanently or semi-permanently, to the textile matrix.”

EXAMPLE.– This is an integrated solution – The electronics are integrated into the textiles, and even woven into the threads. An example is a light-emitting diode (LED) connected to a woven conductive fabric. Depending on whether or not the components are removable, the consequences of levels 1 and/or 2 of integration need to be considered. The limitations of textile-based electronic components at level 3 must also be taken into account.

1.1.1.3.4. Level-4 integration

“All the components of the electronic device are textiles or have textile-like finishing (a fully textile solution).” The limitations inherent to textile-based electronic components need to be taken into account. In the majority of cases, it is necessary to develop dedicated standards for these types of systems or components.

EXAMPLE.– An intrinsic solution – The electronics are made of textiles.

1.1.1.3.5. In summary

Figure 1.4 summarizes the normative definitions of the four possible levels of integration of electronics in connected apparel.

CEN WG 31 nomenclature	Level-1 integration	Level-2 integration	Level-3 integration	Level-4 integration
Technology	Electronics connected to the fabric		Electronics woven into the fabric	
	Removable	Non-removable.	Integrated into the fabric.	Fabric/wire is integral.
	The electronic component can be removed from the smart textile without destroying the product.	The electronic component is attached to the textile, so it is impossible to remove it without destroying the product.	One or more components are textiles or have a textile-like finish. They are combined with electronic components which are connected, permanently or semi-permanently, to the textile matrix.	All components in the electronic devices are textiles or have a textile-like finish (a completely textile solution).
	The electronics are removable so that the components can be cleaned, washed and ironed.	The electronics are attached more closely to the textile and, in principle, are made flexible and washable like the textile itself.	The electronics are integrated into the textile and even into the threads.	The electronics are part of the construction of the textile itself.
	Parrot jacket: the screen is removable.	Google jacket: Bluetooth tag in the button.	–	–

Figure 1.4. Levels of integration of electronics in connected garments

1.1.1.4. *The three families of smart textiles*

Let us now look at so-called *smart textiles*. From a technological standpoint, this branch is divided into three categories:

- “active textiles”;
- “e-textiles”, which are a combination of textiles and electronics; this book discusses this family only, and e-clothing;
- “ecotechno-textiles”.

1.1.1.4.1. Active function textiles

In principle, we can define three categories of “active function textiles”:

– Active textiles: these fabrics have the peculiarity of emitting or diffusing molecules, light or heat, and have the ability to transition from one state to another. They have applications in the fields of cosmetics, paramedicine and safety. The technologies associated with active textiles include micro-encapsulation, luminescence, shape-memory polymers, thermochromism, etc.

– E-textiles: these fabrics need the passage of electrical currents in order to work. Usually, these currents serve to supply an electronic device, but may also serve directly to generate heat in the case of resistive wires.

– Ecotechno-textiles: this category covers all textiles whose creation, manufacture and application obeys a sustainable approach. The direct goal, however, is not usually one of eco-friendliness.

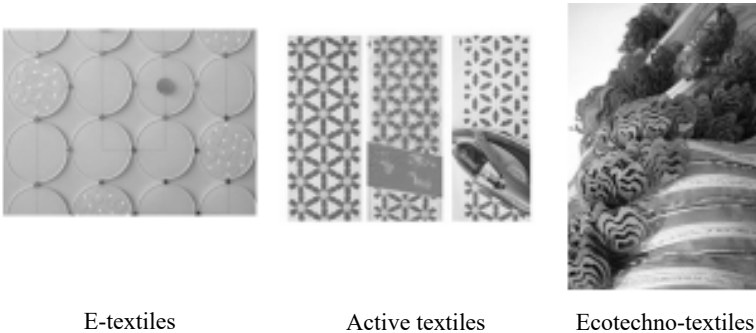


Figure 1.5. Examples of “active function textiles”. For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

Having set out this brief inventory, looked at some of the usual vocabulary and introduced our subject, touching on the near future, we shall now turn to the shape of this vast world, and the markets which it involves.

1.1.1.5. *Main areas of use of smart textiles*

The main fields of application for e-textiles (all types) are those which are highlighted in Figure 1.6.

Technical textiles		Ordinary textiles (clothing, household linen)	
Agrotech	Sporttech	Outdoor activity and sport	–
Buildtech	Medtech	Wellbeing	–
Mobiltech	Hometech	Decoration	–
Geotech	Clothtech	Clothing	–
Protech	Packtech	–	–
Oekotech	Indutech	–	–

Figure 1.6. *Predominant fields of use of e-textiles.*
For a color version of this figure, see
www.iste.co.uk/paret/smartpatches.zip

1.1.1.6. *Predominant fields of use of smart apparel*

Following this foray into e-textiles, we turn our attention to smart apparel, with onboard electronics, whose main applications are those which are highlighted in Figure 1.7.

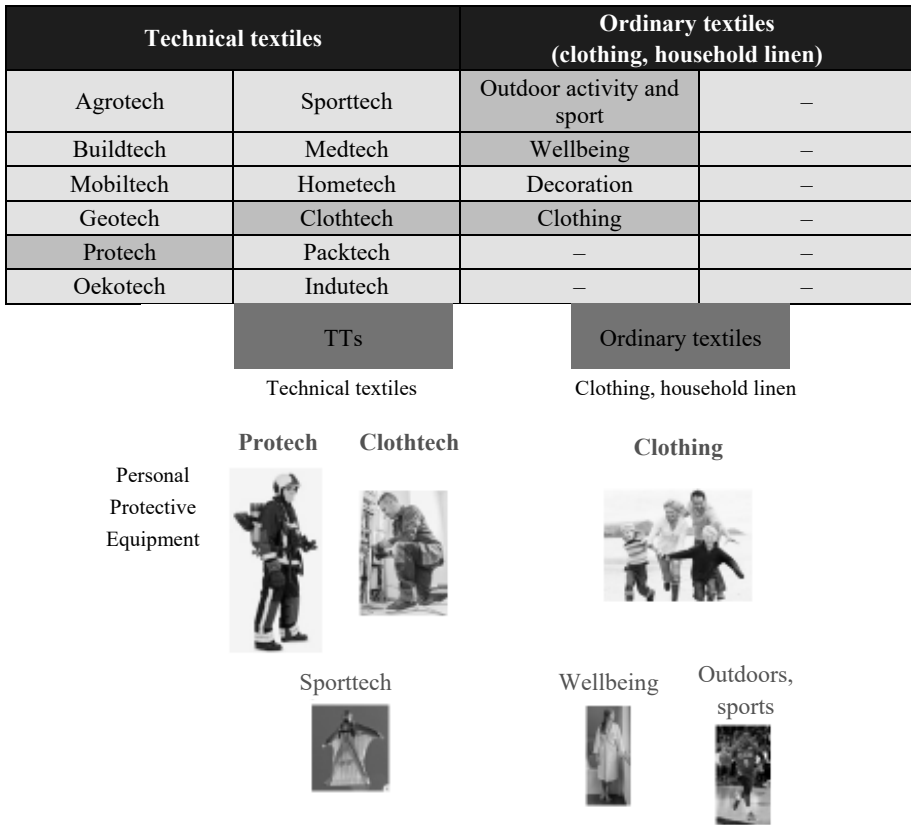


Figure 1.7. Fields of application of smart apparel. For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

1.1.2. Apparel

“Apparel” covers a range of areas. Let us focus on two particular points.

1.1.2.1. Conventional clothing

Whatever the electronic component that we add to a garment, it will follow the standard value chain for clothing, the architecture of which is represented in Figure 1.8. After the manufacture of the fabrics, the next step is “finishing”.

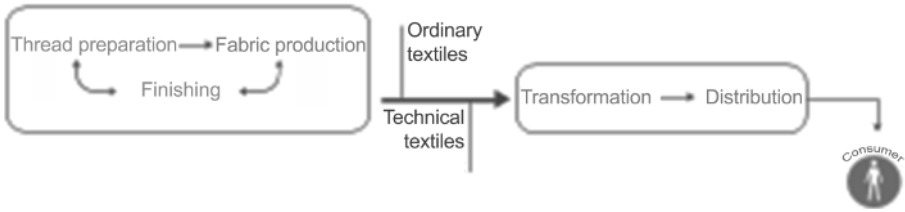


Figure 1.8. The standard chain of activity for clothing. For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

1.1.2.1.1. Finishing

“Finishing” is the generic name for the various stages of decorative final touches, and the techniques which, during and/or after its manufacture, lend added value to the fabric by altering the way it feels to the touch, its appearance or its properties. These operations are carried out no matter what the family of textiles (warp and weft, mesh, non-woven, etc.). There are three main areas within the finishing of materials and textiles, taking place:

- During *thread preparation* (reeling), over the course of all operations to transform textile materials into thread.

- During *coloring* (textile dyeing and printing). Dyeing is a process whereby a color is applied to a medium. The purpose of this operation is to permanently apply a colorant into the material being handled, by means of penetration, and so to color the whole fabric.

- During *finishing* (mechanical and chemical priming). Priming is the stage of finishing which is carried out on the so-called “loom-finished” fabric. Methods other than priming are also available to create specific types of fabrics. Priming refers to a series of operations that textiles undergo at the end of the manufacture process.

Hence, the patches must be able to stand up to the finishing processes wanted or needed for the applications of the textiles we wish to use.

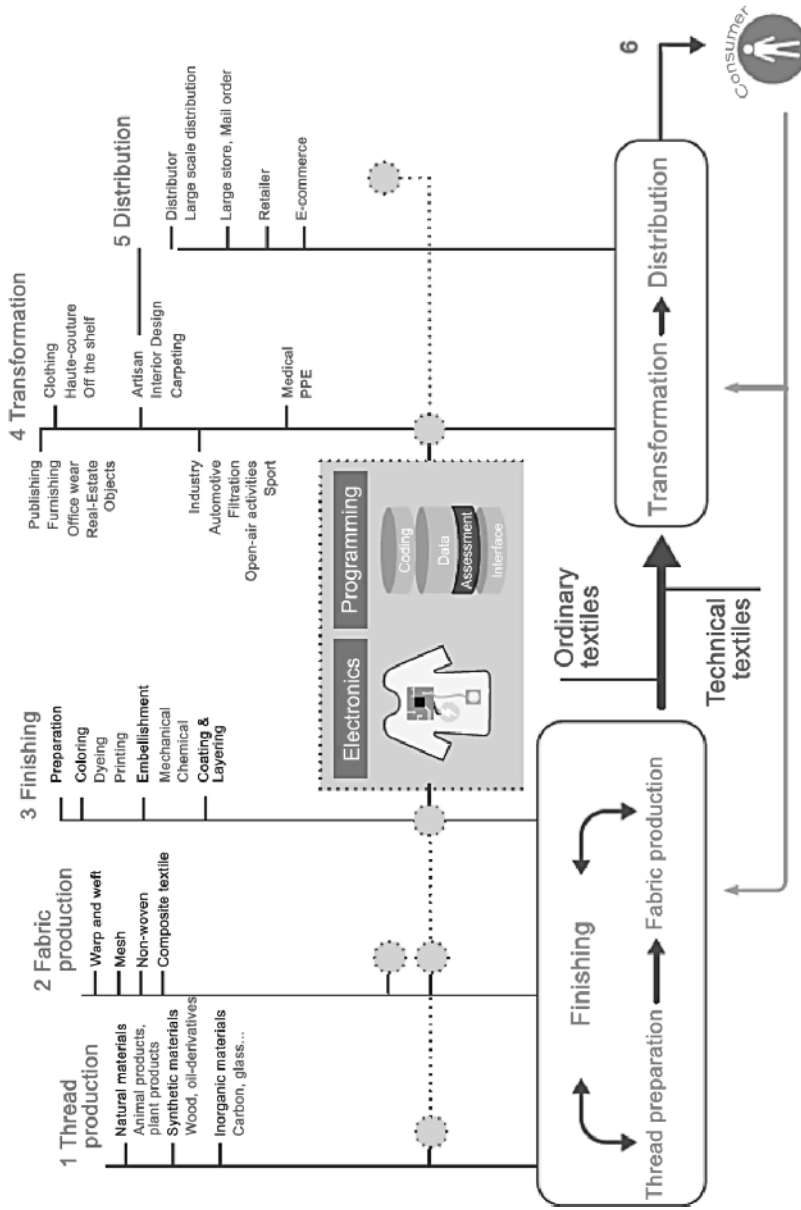


Figure 1.9. Complexification in the case of e-textiles: introduction of electronic components. For a color version of this figure, see www.iste.co.uk/paret/smarpatches.zip

1.1.2.2. *Smart apparel*

For the purposes of this book, we need to look a little more closely at the process of complexification shown in Figure 1.9, in the case of e-textiles into which electronic components are inserted. In this figure, we can see three possible levels of integration of the electronics into the garment:

- during the thread reeling;
- during the production of the material;
- during the finishing process.

1.2. The smart textile market from a consumer's point of view

There are four important aspects that shape the views expressed by end users – that is, ordinary people – in relation to the purchasing of smart apparel. Which levers can be used to persuade consumers to buy smart apparel? Which constituent elements most often present a barrier to the purchase of a smart garment? Which types of solutions can increase consumer confidence? Which are the most relevant devices which would facilitate the buying of a smart garment?

1.2.1. *Purchase levers*

The levers which can persuade consumers to buy, which smart apparel must have in order to be attractive, are their unique nature, the performances the product delivers, the innovative aspect of the product, and an attractive price point.

1.2.2. *Barriers to the purchase of smart apparel*

Below are the main barriers that exist and/or are perceived/cited by consumers and the general public when buying:

- price, lack of perceived utility, complexity in use, and lack of comfort in the solutions;
- data exchanges and data security;
- fear of breakdowns, and lack of after-sales services;
- general health risks, sensitivity to electromagnetic waves, and the effects of such waves on the brain or reproductive organs.

These are crucial points in relation to smart apparel, whether connected or otherwise, and a few remarks must be made about these points.

Lack of perceived utility, lack of comfort in the products, price, complexity in use, and the absence of after-sales services are problems that stem from a choice. They need to be addressed in the strategy employed by the company making the garments; in their design of a product line in relation to the market; their choice of marketing strategy; their choice of short-, medium- and long-term pricing policies; and the implementation of an after-sales service policy and strategy; etc.

1.2.2.1. *Personal data security*

Readers are invited to refer to the sections on the GDPR relating to social obligations for the protection of personal data and security. Succinctly put, it is easy to implement data security, and any good designer of SA should know what they need to do in this area. Therefore, it merely becomes a question of the company's sales direction and marketing strategy, which need to take data security into account. The obligation to comply with the GDPR is a reality, and it is not something which is particularly difficult to do.

1.2.2.2. *Concern about breakdowns*

As is the case in any system used by the general public (and/or a professional system, of course), there is a most extensive range of usage conditions which must be satisfied. Consequently, product design and development, which genuinely take account of the product's range of potential applications in the field, and well-written documentation that clearly and understandably sets out its concrete applications, will help to prevent a large proportion of concerns about breakdowns, which then become matters of misuse by the consumers, who have been properly informed before using the products.

1.2.2.3. *Health risks*

The health risks which are sometimes cited in this field often relate to electromagnetic sensitivity and the effects of electromagnetic waves on the brain or the reproductive organs. In this domain, the information carried by the general press ("I heard it through the grapevine") is often tendentious or improperly informed, throwing up certain barriers to the purchase of smart apparel and many other types of products. Badly needed responses to these concerns are included in the section on RF and health, which examines the regulations on RF pollution and health, and the effects of EM waves on the human body in the event of prolonged exposure to such radiation. That discussion will lay many readers' fears to rest. With that said, every professional in the world of smart apparel is supposed to be well informed about the law. In addition, they must comply with the technical regulations (issued by the ETSI, for example) and health regulations (issued by such bodies as the ANES, ICNIRP, the WHO, etc.) in place, and have measurements of the health effects taken by an independent authority in order to reassure consumers. Furthermore, the electrical and electronic components

must not be irritant, allergenic, or otherwise dangerous to the users (dangers may include the risk of cutting, burning, fire, electrocution or explosion).

1.2.3. Solutions to instill confidence

What are the solutions that can be implemented to instill confidence in consumers? Which mechanisms are most effective in persuading consumers to buy a connected textile? For information, according to a study carried out in early 2017 (already five years ago, at the time of writing), the following factors have an impact, in order of decreasing importance:

- a formal study on the impact on individuals’ health;
- a quality label borne by the product;
- direct feedback from other consumers;
- ease of use;
- positive reviews on the Internet;
- favorable reviews in the press;
- a good after-sales service.

1.2.4. The hype curve for innovations

Before embarking on a project to create smart apparel, we may legitimately ask whether the market for smart or connected apparel is sustainable. In order to answer this question, let us look at the “Hype cycle” published by the Gartner Group (Figures 1.10 and 1.11). This curve, whilst not always absolutely accurate, is usually not too far from the truth either. It offers a projected view of the development of emerging technologies. This hype cycle (or curve) comprises five key phases in terms of a technology’s visibility and maturity.

– *Phase 1: the Technology Trigger.* At the very outset of a new branch of activity, there are a great many innovative ideas circulating – some good, some less good, some idealistic but not particularly constructive, etc. This creates buzz and interest in the media. Some of the most enterprising will begin creating their future startups in their garages. At this stage, only mock-ups/prototypes (otherwise known as *Proof of Concept*, POC) are available, and the products’ commercial viability has not been proven.

– *Phase 2: the Peak of Inflated Expectations.* Publicity has led others to follow in the footsteps of the original innovators. There are a great many new players entering

the field, and numerous startups, micro-enterprises, SMEs and SMIs are being founded. At this point, we are beginning to hear *success stories* about businesses flourishing, but there is also some *bad buzz* from other quarters. This is the time to swing into production and make the product available, because the public harbor great expectations at this point.

– *Phase 3: the Trough of Disillusionment.* There is almost always a period of slowdown, linked to the fact that new products are not always available in time and do not completely live up to expectations, there are too many different products available, prices are still somewhat too high, there is a lack of standardization in the newly emerging market, there are too many proprietary protocols and standards, with little or no interoperability between the different systems, etc. In short, public interest dips, and companies need to decide whether they want/are able to invest to bring the product into line with what *early adopters* in the market really want. During this phase, a great many startups fail and fall by the wayside, due to lack of liquidity, funding, capital increases, assistance packages, and a solid financial footing. We therefore see many “crashes”, and the broken corpses of companies litter the field.

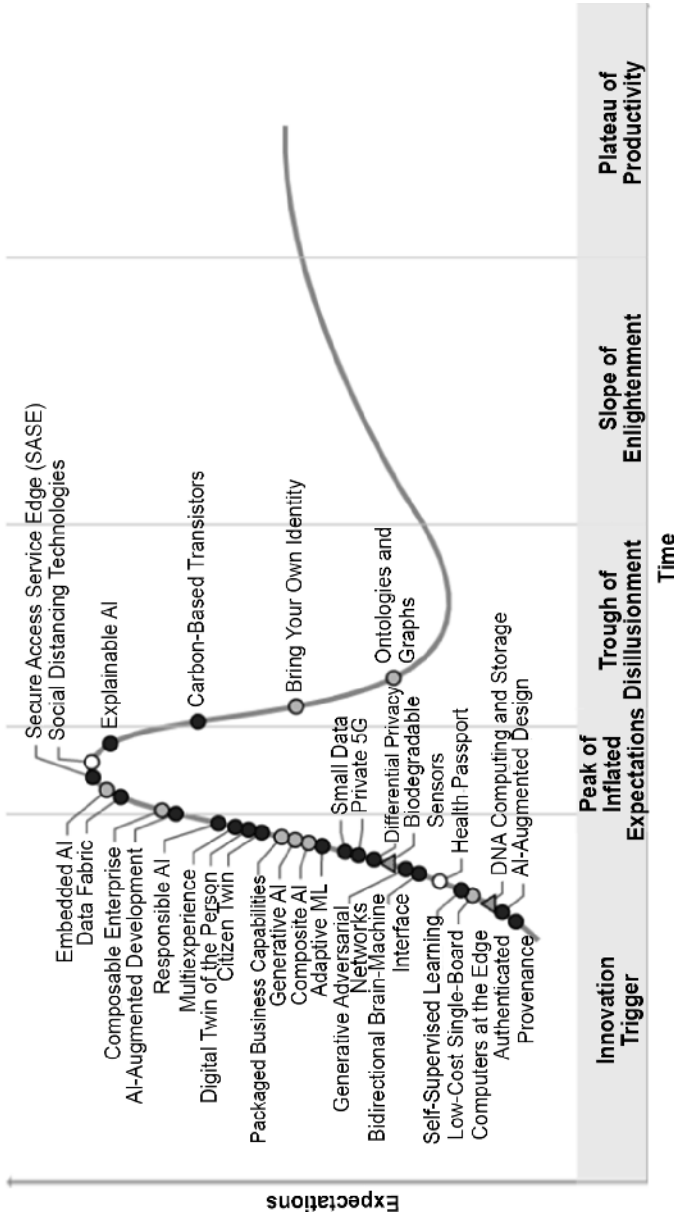
– *Phase 4: the Slope of Enlightenment.* Now, the project is reaching its final development phase. The surviving companies are gaining a greater understanding of the market which is actually available to them. During this phase, we see the formation of joint ventures, common interest groups, and buyouts of the best startups by larger companies or groups. This is the time when second or third generations of the product are issued.

– *Phase 5: the Plateau of Productivity.* Finally, the market as it truly is becomes clear; the use of the technology becomes more widespread, and it is finally adopted by an “early majority”. The viability criteria are more clearly defined, the relevance of the innovation is more convincingly proven, and finally, the companies begin making profit. And about time, too!

NOTE.— The durations and extents of these five phases vary depending on the technologies and the markets in which they emerge. Certain products may reach the plateau of productivity within two years; with others, it may take a decade; and others may find their technology obsolete before ever reaching that point.

Drawing upon real-world experience, Gartner succeeded in defining some 100 reference curves, spread across different technological sectors: e-commerce, telemedicine, transport, software, wearables, smart apparel, etc.

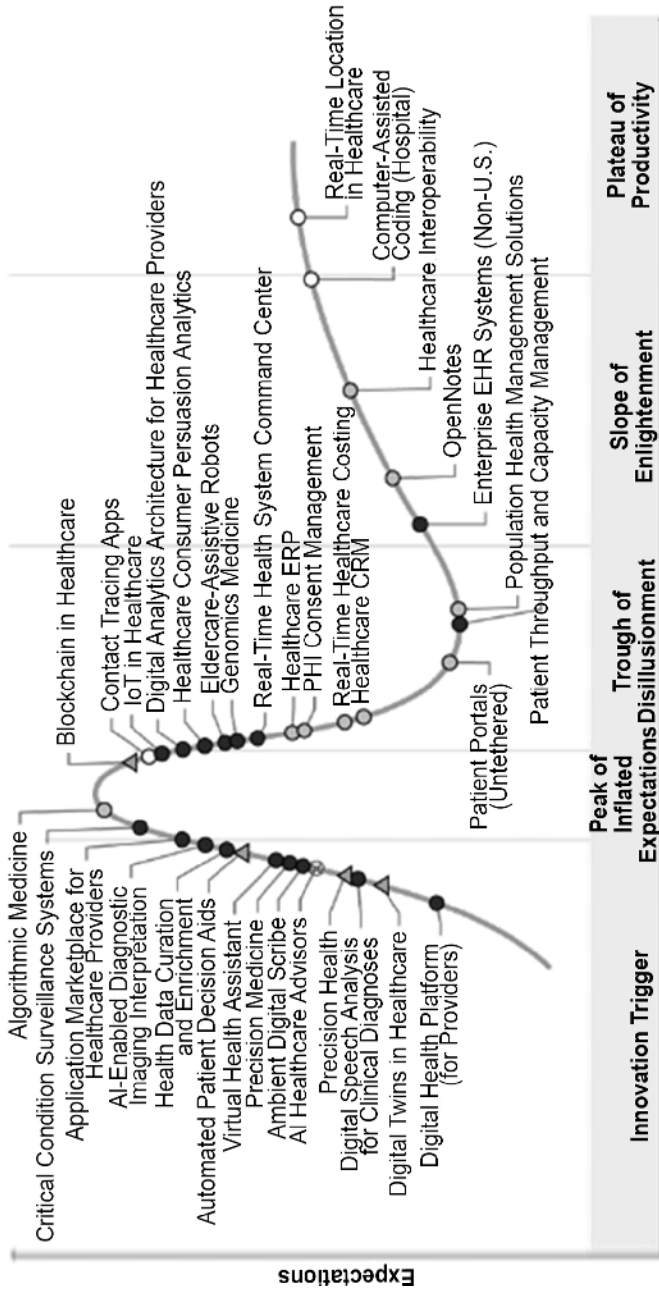
Interest in smart apparel for the general public should arise once the technology becomes truly mature – that is, in three to five years, so between 2024–2026. When it reaches the plateau of productivity, people’s interest will experience another upswing.



Plateau will be reached:

- less than 2 years
- 2 to 5 years
- 5 to 10 years
- ▲ more than 10 years
- ⊗ obsolete before plateau

Figure 1.10. Hype cycle for technologies (source: Gartner, August 2020). For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip



Plateau will be reached:

- less than 2 years
- 2 to 5 years
- 5 to 10 years
- ▲ more than 10 years
- ⊗ obsolete before plateau

Figure 1.11. Hype cycle for healthcare technologies (source: Gartner, August 2020). For a color version of this figure, see www.iste.co.uk/paret/smartpatches.zip

As indicated previously, this book will describe the basic steps that must be followed and observed for a project to avoid falling into the trough of disillusionment. These steps can also ensure that the project proceeds directly from the initial innovation to healthy production, or allow the project to escape from the immaterial, virtual world and become a real-world reality. With this goal in mind, the following sections guide readers through how to comply with the constraints of the regulations and norms – technical, financial, ergonomic, etc. The journey may seem a little long, and somewhat daunting, but it holds no surprises. You have been warned!

1.3. Constraints surrounding an SA project

Before embarking on a project, whatever it may be, it is always wise to know where to tread, otherwise we risk severe handicaps. The numerous sections which follow set out the majority of concerns and “questions that must be addressed before starting” with even the smallest piece of hardware or software in the field of smart apparel, and in particular, that of patches for applications in health, wellbeing and sport, designed for mass production.

Before designing or producing patches and smart and/or connected apparel (with or without Internet connection), the following aspects should be considered, which are relevant in one way or another to the concrete production of these technologies on an industrial scale. These are major waymarkers which are absolutely necessary whatever the project, and the multiple constraints which must be recognized, resolved or managed – financial, marketing, technical, industrial, regulatory and normative, pertaining to security or costs, etc. In addition, each of these aspects tends to be subdivided into a range of sub-aspects which are mandatory to address, with no other option available. Thus, close attention must be paid to whether a project is industrially viable. If any doubt remains in any of these areas before you embark on your project, you are not ready to start.

Now that we have defined the overarching context of this lengthy discussion, which is absolutely crucial to understand before proceeding further, we can now take a look at each aspect in a certain amount of depth.

1.3.1. *Financial and marketing aspects*

The financial and marketing category includes aspects relating to commercial strategy, cost, financial aspects, the financial resources at the users’ disposal, etc., marketing aspects, the quest to determine the true usefulness of the product, ergonomic aspects, definition of users’ needs and wants, and so forth.

These aspects, of course, are of prime importance, and must be studied in detail before investing any technical efforts in a project. After all, if we are developing a product, the goal is ultimately to make money. Indeed, it is all very well to make a product with a view to selling it, but then we need customers to buy it! This statement may seem so obvious as to be trivial, but unfortunately, many people forget about it. It is here that we begin to see the major difference between a “sellable” product and a “buyable” product. In this book, we will speak only of products which are designed to be buyable. What is it, though, that makes a product buyable? To find out, we need to precisely define the fields of application for the prospective product, and which potential markets we are developing it for (also see section I.6.1).

– If there is already a product on the market which serves the same application, we must think carefully about the so called “substitution value”, and how it will be weighted as we attempt to break into the market and thereby earn money. If the substitution value is insufficient, then frankly the project is not viable and we should not embark upon it.

– If the application is innovative and/or represents a technological breakthrough, then the key points to consider are: how much are people willing to spend in order to buy it? In parallel, we must consider whether the product represents a slice of the pie (market), or whether, in fact, it represents only a crumb of the mini-pie of sales?

1.3.1.1. *ROI (Return on Investment)*

Return on investment is usually a sticking point for smart apparel. How can we estimate the return on investment (ROI) for a project that achieves industrial rollout, and how long is that ROI going to take to materialize? What will the product’s estimated lifespan be in the existing market? Above all, it is a matter of balancing the “usage value”, which the users perceive with the proposed “production value”, which the industrial players attach to the product. In conclusion, it is worth remembering that in order for a solution to be attractive for everyone involved in the chain of its production, everyone needs to make some money out of it. Otherwise, the project will fall flat!

1.3.2. *Ergonomic aspects*

Ergonomics is another important point which must be given due consideration: “Poor ergonomics can see an otherwise excellent product dead and buried.” The shape, design, material, comfort, functional ergonomics², etc., of a garment must be

² Stemming from the Greek: *érgon* (work) and *νόμος/nómos* (law/study). Thus, ergonomics refers not to the design or visual attractiveness of a product, but the degree of comfort when working with it.

studied in minute detail. For example, we need to look at the choice of forms, esthetic attractiveness, cost, production time, etc. Beyond the design, the true ergonomics and flexibility of use must be given careful consideration, and of course, from the outset, we must take the needs of elderly, disabled or reduced-mobility users into account, so that they too can easily interact with the SA.

1.3.3. Technical aspects

From a purely technical standpoint (or, more accurately, an electronic standpoint), the following essential technical industrial aspects must be carefully considered when embarking on a project to create smart apparel for industrial purposes:

- technical aspects, technical specifications, etc.;
- energy-related aspects, such as power consumption, lifespan of power reserves, etc.;
- industrial aspects including prototypes, early-series models, full production, costs, etc.

This set of considerations marks a considerable difference from the POC (Proof of Concept) with which many people are familiar. Ultimately, the POC is only the first tiny step towards industrial production and rollout.

1.3.3.1. Life cycle of a new product

It is necessary to define a life cycle for a project, which includes the phases of innovation, definition of user requirements, and so forth.

1.3.3.2. Techno-economic assessment

During the techno-economic assessment (TEA) phase, we must look carefully at the technical and functional specifications for the proposed product. This may include a POC.

Similarly, we need to begin looking at the matters of sourcing, accreditation, choice of suppliers/partners, and also calculate budgets for R&D, industrialization, equipment, and cost price of the final product. Thus, the project can be given the green light, shelved (amber light) or abandoned (red light) – otherwise referred to as “GO or NO GO”.

1.3.3.3. *Design*

Next comes the active phase of hardware and software development, choices must be made, normative constraints must be observed, the design-to-cost (DTC) approach should be implemented, prototypes must be produced and assessed on technical criteria, and the necessary certifications must be sought.

1.3.3.4. *Industrialization, manufacturing process and quality*

This phase includes the validation of the design, the production of prototypes, processes to move the various subcomponents of the product to industrial readiness, the building and testing of systems, the accreditations/certifications, and finally the launch of industrial pre-series and full production of a series, all stages of accreditation of suppliers, prototypes, and the pre-series process.

1.3.4. **Energy-related aspects**

Among the crucial technical aspects of a smart (and connected) garment, we must remember how its intelligent electronic components will be supplied with energy, what its intrinsic power consumption will be, and all aspects relating to the battery life. This is often one of the fundamentally important points when considering smart apparel.

In this context, depending on the technical and technological design of the SA and the intended applications, the means of energy supply may need to be different. We will examine this matter from various angles in Chapter 4.

1.3.4.1. *Battery life and product lifespan*

When designing and selling smart apparel, the battery life and lifespan when performing the desired function must be part of the first discussions had with the representatives of the intended end user (buyers, retailers, etc.). It is essential to reach an agreement on these matters at the outset, or to inform the end user of the battery life and lifespan of the designed garment, and if possible, avoid making false promises for the sake of commercialization and marketing. These discussions may be lengthy, and failing to hold them may cost the company dearly in terms of corporate image.

1.3.5. **Industrial aspects**

As previously stated, the goal of this book is to lead to the concrete production of SA for commercial purposes. Thus, the stages of “tweaks”, “workarounds”, reference designs, Proofs of Concept, laboratory prototypes – made from small

commercial modules which all appear to work on the drawing board, but are still a long way from being industrial products – must be completed.

One of the first questions that we must ask ourselves is: “Do I have the technical and financial resources at my disposal to bring an industrial project to fruition on my own... or do I need a partner by my side, and if so, for which parts of the project?” The answers to these questions have an enormous impact in terms of time, workload, financial support and final viability of the project.

At the end of this book (see Conclusion), we present an example³ of a dashboard whose purpose is to successfully plan for each stage of a project.

1.3.6. Regulatory aspects and recommendations

In the specific context of smart apparel, the following sections detail the regulations (i.e. mandatory requirements), recommendations and norms (i.e. non-mandatory but highly recommended) that need to be respected, at the national, European and global levels.

Briefly put, a “regulation” consists of a series of official documents/rules issued by an organization attached to a “state” or a “community of states” (such as the EU), which must be complied with in light of prescriptions, rules and regulations, laws, decrees and/or other legal texts which govern a corporate activity. At present, the regulatory constraints applying to smart apparel and the associated worlds are generally applicable at five fundamental levels which we will now examine: levels of radiation and radiofrequency pollution; health risks from human exposure to non-ionizing electromagnetic fields; privacy; regulations on medical devices; the Public Health Code and Labor Code; and waste management. This is already a lot to deal with!

1.3.6.1. Radiofrequency regulations

The “smart” part of smart technology, with radiofrequency (RF) connectivity often raises a number of questions, on the part of the general public, consumer associations and other media; however, it is not terribly difficult to set these various concerns to rest. At a technical level, all we need to do is obtain the relevant documentation, primarily from:

³ The example of an industrial dashboard presented in the Conclusion takes quantities, stages of production, subcontracting of hardware and software, mechanical processes (molds, etc.), SE security, Cloud Computing, etc. into account.

- in France, the AnFr, ARCEP and ANSES, with its Santé-Travail (occupational health) subdivision;

- in Europe, for emissions, ERC 7003 documents issued by the European Radiocommunications Office (ERO), and for electromagnetic pollution levels, the ETSI;

- at the global level, as for human exposure to radiation, the ICNIRP (International Commission on Non-Ionizing Radiation Protection).

1.3.6.2. *Regulations pertaining to radiation and pollution*

All SA designed for the general public (jackets, sports gear, etc.) or for professional purposes (PPE, medical equipment, etc.) including RF connectivity will ultimately have antennas that emit RF waves. The regulations (enacted by the ERC, FCC, ETSI, etc.) give indications of permitted/authorized values of frequencies emitted, bandwidths, authorized radiated powers, specific patterns, occupation time, constraints and restrictions (radiation, pollution, susceptibility, etc.), governing equipment for contactless applications in the broadest sense (RFID, NFC, IoT, geolocation, etc.), and of course, connected smart apparel. One of the fundamental constraints, for obvious reasons, is that they must respect the levels of radiation and RF pollution set by national or international regulations, and indeed with global regulations on RF.

There are a number of organizations which govern and preside over the designing of parameters which directly impact communicating RF systems (including smart apparel), be they SRDs (Short-Range Devices) or LRDs (Long-Range Devices). These are recommendations which have then been passed into legally binding regulations:

- At global level, the ITU (International Telecommunications Union).

- In the United States, under the egis of the ANSI (American National Standards Institute), the FCC (Federal Communications Commission) issued the reference document “US Code of Federal Regulations (CFR) Title 47, Chapter I, Part 15. ‘Radio Frequency Devices.’”

- In Europe, the recommendation CEPT/ERC/REC 70-03 “Relating to the use of Short Range Devices (SRD)” published by the ERO (European Regulation Organization) is the binding standard. In addition, the measuring and testing methods of the ETSI, “Electromagnetic compatibility and Radio spectrum Matters (ERM); – EN 300 – xxx – frequencies from 9 kHz to x GHz”, conform to the recommendations of the ERO.

- In France, the ANFR (*Agence nationale des fréquences*) and the ARCEP (*Autorité de régulation des communications électroniques et des postes*) are in

charge of assigning and distributing frequencies that can be used for applications in the IoT, which includes smart apparel, and how they are used. These organizations refer to the European recommendations and produce documents serving as the basis for the development of France's own norms and regulations pertaining to *Non-Specific Short-Range Devices* (smart apparel applications fall within this category).

1.3.6.3. Health recommendations

Certain entities, associations, etc., do not have the legal standing to directly impose new regulations on states, but are so expert in their particular fields that they can recommend that states adopt certain values and criteria. After that point, the states themselves may accept, recommend, adopt, impose (etc.) such values by means of laws or decrees. The examples that follow will make this clearer.

1.3.6.3.1. Human exposure to electromagnetic fields

In the applications that we are dealing with here, sources of EM and RF fields represent sources of concern in terms of health impacts. These technologies, which are likely to increase the exposure of their users, and indeed of the general population, to EM fields give rise to new behaviors, and a great many questions (about the biological and clinical effects of such waves, epidemiology, regulation, use, metering, etc.) and concerns. Therefore, it is necessary to address the health consequences of human exposure to electromagnetic fields. The ICNIRP (International Commission on Non-Ionizing Radiation Protection), which is the global organization in charge of such matters, is represented in France by the ANES (*Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail*), and is regularly in attendance at the meetings of the World Health Organization (WHO).

1.3.6.3.2. ICNIRP and ANSES

The ICNIRP issues “recommendations” on values which should not be exceeded – in particular, for the Specific Absorption Rate (SAR)⁴.

The ANSES provides the French government, and the national and European bodies, with the information needed to make decisions on preventing risks to the general public or to professionals in occupational health, and back up the principles of public policy in the matter. The ANSES contributes to knowledge of emerging occupational hazards (relating to magnetic fields, electromagnetic waves, RF wireless communication technologies (Bluetooth, Wi-Fi, RFID, mobile telephony, etc.), electromagnetic hypersensitivity, etc.), and contributes to research and the imposition of reference values to protect workers and users.

⁴ SAR of 2 W/kg for 10 g of human tissue for signals of up to 300 GHz.

1.3.6.4. Health-related regulations

In marketing materials, a great many parameters and quality documents relating to smart apparel refer, not quite accurately, to “health”, often mixing up a device that is for athletic performance, comfort and/or wellbeing, etc., and one which is a true “medical device”.

To avoid certain application pitfalls, the following sections attempt to put certain misconceptions to rest, so as to start right, and eliminate some of the reigning confusion. In order to do this, let us come back to the sources.

1.3.6.4.1. Regulation on medical devices

In France, the *Code de la santé publique* (CSP – Public Health Code) fully includes the Medical Deontology Code, which healthcare professionals must abide by when administering healthcare. For example, there is a legal obligation to keep a formal medical record for every patient treated – this applies both to freelance doctors and to healthcare institutions⁵. These medical files represent a dataset which, often, in view of the volume involved, need to be processed automatically and stored by a specialist service-provider. The sensitive nature of these data, which pertain to patients’ private lives, means they need a higher level of protection, not only because of their intimate nature, but also because of the automated processing to which they are subjected⁶. In addition, the procedure for accreditation of personal health data hosters (informally known as the “Kouchner law”, after the Health Minister at the time in 2002) is intended to safeguard the security, confidentiality and availability of personal health data, when they are hosted externally by certified hosters.

APPLICATION TO SMART APPAREL.–

Smart apparel applications for “health” and/or “medical” purposes, which feed back information of this type to be centralized in some unknown location or cloud server, must comply with these regulations and constraints.

⁵ Indeed, all hospitals and similar institutions are required to maintain an up-to-date file. Article R 4127-45 requires self-employed doctors to keep a medical file for each of their patients.

⁶ Reminder: article 2 of France’s law on information technology and freedoms thus reads: “Processing of personal data is any operation or set of operations carried out on those data, irrespective of the process used – in particular, the collection, recording, organization, conservation, adaptation or modification, extraction, viewing, use, communication by transmission, dissemination or any other form of making the data available, compilation or interconnection, in addition to locking, erasure or destruction.”

Although the smart apparel for the general public to which this book refers does not fall into the category of medical devices, which is very tightly regulated (that is, true medical devices, not fitness aids), it should be noted that the EU MDR (Medical Device Regulation) came into force on 25 May 2020, and since that date, the pompous terminology can no longer be used for fitness clothes that measure EKGs, cardiac arrhythmia, etc. There is no longer any excuse: the use of certain commercial words and expressions surrounding the term “medical device” is punishable with heavy sanctions.

1.3.6.5. *Regulations on “individual and societal freedoms”⁷*

Smart apparel feeds out a huge amount of information/data specific to the wearer (biometric, behavioral data, etc.), and such “personal data” must be treated with all necessary care. Let us briefly examine the history of individual freedoms, computing and privacy.

1.3.6.5.1. France’s Loi informatique et libertés

In France, since 1978, article 1 of Law no. 78-17 (and its successive amendments) on information technology, files and freedoms states that: “Information technology must serve the needs of all citizens. It must be developed in a context of international cooperation. It must not infringe on human identity, human rights, privacy, or individual or public freedoms.” That is all that needs to be said in terms of the application!

In France, the *Commission nationale de l’informatique et des libertés* (CNIL – National Commission on Information Technologies and Freedoms) was set up with the aim of guiding professionals in complying with the law, and assisting private citizens to maintain control of their personal data and exercise their rights. The CNIL also analyzes the impact of technological innovations and emerging usages on privacy and freedoms, and works closely with its European and international counterparts to produce harmonized regulations. In 2008, the European Commission published “Mandate 436”, detailing all aspects of the problems raised by matters of privacy, individual freedoms and societal aspects of RFID, of which NFC, the IoT and SA are simply derivatives or specific branches.

1.3.6.6. *General Data Protection Regulation (GDPR)*

Since then, the European Union has conducted an in-depth examination of all types of data that may be affected, and in 2016, published the General Data Protection

⁷ For further information, please refer to Dominique Paret’s earlier works: Paret and Huon (2017); Paret and Crégo (2018).

Regulation⁸ (GDPR). This text, which came into force on 25 May 2018, is the authoritative frame of reference in personal data protection. It strengthens and unifies data protection for individuals across the European Union. The main purposes of the GDPR are to improve the protection for “data subjects” (people whose data are processed) and ensure those who do the processing act responsibly. In order to do so, it gives a broad definition of standard data and health data, and strengthens the obligation of transparency and informing the data subjects. Whenever personal data are collected, the medium being used (e.g. a form, a questionnaire, etc.) must include informational statements, specifying why the data are being collected, which authority will process the data, who has access to such data, how long the data will be kept for, how the data subjects can exercise their rights in this regard, and whether the data are to be transferred outside the EU. Data subjects have rights (the right of access, the right to rectify information held about them, the right to object to the processing of their data, the right to erasure, the right to data portability, and the right to limit their processing), which are shored up by the GDPR. The GDPR does not draw upon specific norms, because in itself, it defines the requirements that must be satisfied in order to process data properly, and also the rules that apply when the data are breached, including the applicable fines, at a very high level. Thus, the GDPR is applicable without the need for national legislation – it is a shared data-protection law to which all EU Member States have been subject since May 2018.

Before exploring the salient points of the GDPR, let us briefly examine the different types of data that may be processed, and which need protecting.

1.3.6.6.1. Personal data

Definition

“Any piece of information relating to a natural person, identified or who may be identified, directly or indirectly, by reference to an identification number or to one or more items specific to them”, such as their surname, first name, biological data, telephone number, social security number, postal address, etc. (article 2 of the French law on information technology and freedoms), constitutes personal data. In particular, this establishes the principle of the obligation to inform data subjects, and obtain their consent.

Which types of personal data are at issue?

The main types of sensitive, at-risk personal data that are already collected, or are intended to be collected, in projects relating to smart textiles and smart apparel, fall into the following categories.

⁸ The GDPR (around 150 pages) is free to access. We strongly recommend that readers download it from: <https://gdpr-info.eu/>.

Biometric personal data

Biometric data are those which pertain to the bio (i.e. living) human, and are metric in nature (that is, they are measurements). Examples include the contours or shape of the hand or fingers, fingerprints, vein patterns, temperature, face shape, iris patterns, heartbeats, etc.

APPLICATION TO SMART APPAREL.—

In applications relating to wellbeing, sport, fitness, PPE, health, etc., biometric data include “medical data collected or produced by professionals within the health system when providing healthcare to the person – i.e. during preventive health measures, diagnostics, care, or social and medico-social monitoring”, measured by means of blood tests, heart rate, blood pressure, transpiration, muscle contractions, brainwaves, etc.

Behavioral data

There are a great many different types of behavioral data.

APPLICATION TO SMART APPAREL.—

Lifestyle habits, walking or running pace, stride length, position and posture of a passenger in a car seat, etc.

Geolocation and mobility data

The same is true of personal data pertaining to geolocation and mobility.

APPLICATION TO SMART APPAREL.—

Route tracking, tracking a user’s movements over the course of various activities (a tracker built into a mobile application, etc.) or those of an employee for work (a PPE garment using GBP/GSM data).

Personal data collected in a business context

The problem is the same. We often need to deal with this type of scenario in examples of use of PPE in an industry.

APPLICATION TO SMART APPAREL.—

Employee absences, exposure to occupational hazards, detection of stress factors (PPE applications, etc.), journeys, etc.

1.3.6.6.2. Health-related personal data

To one degree or another, the smart apparel sector is closely connected to the monitoring of wellbeing and health, so deals with essentially personal “health” data. Health-related personal data are those data concerning the physical or mental health – be it past, present or future – of a natural person (including the provision of healthcare services), which reveal information about that person’s state of health. This concept covers not only all data collected and produced while the person is receiving healthcare, but also those which, in the hands of other actors (such as app developers) provide information about the person’s state of health. This definition includes information:

- *relating to a natural person* collected at the time of registering to receive healthcare services or in the provision of those services: a number, a symbol or a specific item attributed to a natural person, allowing them to be individually identified for healthcare purposes;

- *obtained by testing or examining a part of the body* or a bodily substance, including from genetic data and biological samples;

- *pertaining to a disease*, handicap, risk of disease, medical history, clinical treatment or the physiological or biomedical status of the person in question (regardless of the source of the information – for example, whether it comes from a doctor or other healthcare professional, a hospital, a medical device or an *in-vitro* diagnostic test).

This definition covers certain measured data on the basis of which it is possible to deduce some information about the person’s state of health.

What are the impacts?

The category of health data is a very broad one. It needs to be assessed, on a case-by-case basis, in light of the nature of the data collected. The concept covers three types of data:

- those which are inherently health-related: medical history, diseases, courses of healthcare received, test results, treatments, disabilities, etc.;

- those which, when used in conjunction with other data, become health data, in that they allow conclusions to be drawn about the person’s state of health or health risks: for example, cross-referencing a weight measurement with other readings (number of steps, calories consumed, etc.), or cross-referencing blood-pressure readings with effort measurements, etc.;

- those which become health data because of their destination – i.e. usage made of the data for medical purposes.

NOTE.–

– The law does not apply to the processing of health data for the person’s own exclusive use. For example, the law does not apply to health-related mobile apps whose functions include the collection, recording or compilation of data, provided that those operations take place locally, on a computer, a tablet, etc., without connection to the outside world, and for solely personal purposes.

– The concept of health data does not include data from which no meaningful conclusions can be drawn with regard to the person’s state of health (for example: an application that records the number of steps taken on a walk, without cross-referencing those readings with other data).

If a set of data is identified as health-related data, then a particular set of legal conditions applies⁹, in view of the sensitivity of the data.

– The information about a degree of disability is considered health data if the degree of disability reveals that the person is handicapped, as defined in article L. 114 of the French Family and Social Action Code.

– The information about care received at a healthcare institution, subject to data processing, is qualified as health data when it reveals information about the person’s state of health (e.g. admission to the specialized healthcare institution or hospital department).

– The CCAM code (this stands for *Classification commune des actes médicaux* – Shared Classification System for Medical Actions) is health data if the information stemming from that coding reveals information about the person’s state of health or receipt of care in relation with a particular condition.

– The registration number in the National Registry of Natural Persons (NIR) is not considered as health data, even when it is used as a national health identifier.

⁹ The list below gives an overview of the various pieces of a legislation which may apply (note that this is not an exhaustive list, so the situation needs to be assessed on a case-by-case basis): France’s Loi informatique et libertés (art. 8 and Chapter IX); secrecy regulations (art. L. 1110-4 of the French Code of Public Health – CSP); regulations on frameworks for security and interoperability of health data (art. L. 1110-4-1 of the CSP); regulations on the hosting of health data (art. L. 1111-8 and R. 1111-8-8 et seq. of the CSP); regulations on the disclosure of health data (art. L. 1460-1 et seq. of the CSP); prohibition from transferring or commercially exploiting health data (art. L. 1111-8 of the CSP; art. L. 4113-7 of the CSP) etc.; multiple disability or an invalidating health condition (art. L. 114 of the social action and families code).

– A certificate of fitness to practise a sport is not, in itself, health data. However, if combined and/or cross-referenced with other information such as the circumstances in which the certificate was issued, it is considered as health data. On the other hand, a certificate of *unfitness* to practise a sport is considered health data¹⁰.

Heath Data Hub

There are two new points which must be made on the subject of health data, the consideration of which will take us a long way in the design of patches, instituting “smartness” in apparel, and managing the devices.

France’s law of 24 July 2019 on the organization and transformation of the health system, informally known as “Ma santé 2022”, sets out the globalized data that can be accessed through the platform “Health Data Hub”. This law gives the Hub and the *Caisse nationale de l’assurance maladie* (Cnam – National Health Insurance Fund) the power to shape and operate the *Système national des données de santé* (SNDS – National Health Data System). That system is formed of two elements:

– the main database, covering the entire population, contains all data from the *Programme de médicalisation des systèmes d’information* (PMSI – Program to Medicalize Information Systems), the *Système national d’information interrégime de l’assurance maladie* (Sniiram – National Cross-Regime Health-Insurance Information System), the *Centre d’épidémiologie sur les causes médicales de décès* (CépiDC – Epidemiology Center Investigating Medical Causes Of Death) and the information system of the *Maisons départementales des personnes handicapées* (MDPH – Regional Associations for the Disabled);

– a non-exhaustive set of databases known as the “catalog”.

The Cnam is responsible for compiling these data, storing them and making the main database available. The main database is gradually supplemented by other data – pertaining to preventive healthcare, diagnostics, social and medico-social care or monitoring, data on loss of independence, data on healthcare at school or at work, data from mother-and-child protection services, and a representative sample of data on health insurance payouts made.

10 References: considering art. 35 and 4 of Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and free circulation of such data, replacing Directive 95/46/EC (General Data Protection Regulation: EUCJ, 6 November 2003, C-101/01; EC, 19 July 2010, n° 317182; EC, 19 July 2010, n° 334014; EC, 28 March 2014, n° 361042) (source: CNIL).

The Health Data Hub, for its part, is responsible for enriching the main database with these other data, matching the databases in the catalog with the main database, storing data, giving access to the data of the main database and all databases within the catalog.

The databases in the catalog contain data from the above-listed sources, and the sources of the main database.

The list of state institutions which have access to the uploaded data has been expanded. Finally, “the data provided by the SNDS are attached to each individual by means of a pseudonym” and “the health professional’s identification number can only be seen, if absolutely necessary, by compulsory health-insurance providers, personnel from the Department of Research, Studies, Assessment and Statistics, the Department of Social Security, the General Secretariat of Social Ministries and Regional Health Boards”. Other organizations that search the database will only see the subject’s pseudonym.

The text also sets out the obligations in terms of transparency, including the Hub’s publication of the list of projects and their characteristics, and the list of datasets and the characteristics of the samples available.

This section has been undeniably long, but this law has very significant applicational consequences for patches and the information received and transmitted.

Evolution of teleconsultations

The Cnam has published the trend in medical interventions paid for through insurance, week by week, from January to August 2020. From the time of the outbreak of the Covid-19 pandemic, the figures show an exponential increase in the use of teleconsultation (see Figure 1.12).

Today, over 50% of doctors use this solution to liaise with patients of all ages. At the end of 2020, it accounted for 3% of all consultations.

2020 (in France)	Teleconsultations paid for by the Cnam
9-15 March	15,837
16-22 March	93,403
23-29 March: first lockdown imposed	527,675

Figure 1.12. *Evolution of medical interventions reimbursed by the Cnam between January and August 2020 (source: Cnam)*

Two years after teleconsultations became part of the medical interventions covered by social security in France, *Health & Tech Intelligence* provided a dedicated indicator, giving a picture of the current state of the market for teleconsultation in France, so as to more clearly track the trend in use of the technology since lockdown was imposed, and thus help to anticipate opportunities which may be seized in this thriving sector:

- evolution of the number of teleconsultations reimbursed by health insurance since January 2020 (figures from the Cnam and key figures published by Doctolib);
- evolution of the regulatory framework since Covid-19 hit (exceptional measures put in place by the Government in the context of the health emergency);
- capital increases on the market since the end of February 2020: €53 million raised by French teleconsultation companies;
- main operations (aside from capital increases) on the market over the past year: six takeovers and one merger;
- main French teleconsultation companies.

In short, teleconsultation is advancing apace, and the use of the patches described in this book would greatly help progress in this direction.

1.3.6.6.3. PIA (Privacy Impact Assessment)

Finally, in new technologies such as smart apparel, prior to any processing likely to infringe the rights and freedoms of the data subjects, a Privacy Impact Assessment (PIA) must be carried out.

A PIA is a scenario that describes an event feared by the business or people processing the data, and is based on an approach for managing the risk of impact on privacy and data protection. It is designed in the context of privacy, to help detect risks associated with an application, assess the likelihood of those risks coming to pass, and document the measures that are being taken to address those risks. In addition, the concepts of data protection listed in the regulation indicate very clearly that *privacy by design* and *privacy by default* must be implemented – the companies must take appropriate technical measures and forms of organization appropriate to the issues at hand and the rights of the people concerned.

Such impacts (if any) may vary significantly depending on whether or not the application processes personal data. The PIA framework gives operators guidance as to risk-assessment methods; in particular, it suggests appropriate measures by which to effectively, concretely and proportionately deal with any likely impact on privacy or data protection. Depending on the sensitivity level of the data and the risk of

privacy impact as a result of their processing, the so-called data controller (DC – see below) must:

- carry out a full privacy impact assessment;
- produce a PIA report, setting out the life cycle of the data in relation to their nature and format, the purposes and the gains made as a result of data processing by the business of the person in question; and
- then rank these events in order of seriousness.

On the basis of the risks objectively identified, all threats likely to cause the event to come to pass must be anticipated by the data controller and the data protection officer (DPO – see below). Then, the privacy impact assessment conducted will identify whether the protective measures put in place by the company are sufficient in relation to the identified risks, and whether the remaining risks are acceptable. Then, the data controller will be able to approve or invalidate the PIA. Finally, the PIA report must be submitted to the overseeing authorities, it may even help build consumers' confidence if the company chooses to publish or otherwise disseminate it.

APPLICATION TO SMART APPAREL.–

Sooner or later, it is then necessary to carry out a detailed assessment of all risks linked to the privacy impact of smart apparel we produce, and it is mandatory to produce the PIA report – in accordance with the European norm CEN EN 16 571 (*Information technology – RFID privacy impact assessment process*) – which gives a detailed description of the procedure and methodology to comply with, and make sure to keep copies on hand so they can be presented in the event of questions.

NOTE.– The above paragraphs must not be taken lightly because, whether you are a creator, a designer, a start-up, an SME, etc., with shared DPOs, or huge companies with your own DPO and DC, you will inevitably have to submit to the GDPR: it is the law!

Privacy by design and privacy by default

As detailed above, the concepts of data protection are divided into two paradigms: privacy by design and privacy by default, requiring companies to take appropriate technical and organizational measures from the earliest stages of product development. The chain of security and privacy must then be examined, verified, verifiable and assured, from end to end. It is also plain to see how using the PIA process can gradually lead to improved privacy.

Example of privacy by design in smart apparel

Often, the design of a smart apparel solution (for professional PPE or for health applications among the general public) is based on a series of steps from the design stage onwards, with data being generated by the smart apparel, sent to the cloud and then, often, redistributed to various users. If security and end-to-end data protection are crucial criteria, the data will be encrypted locally in the smart apparel, before being fed back into the central system. This architecture represents the vast majority of cases in IoT solutions.

1.3.6.6.4. Personal data and smart apparel

Patches or smart apparel which, for whatever reason, are equipped with an identification system, capturing various types of data and processing that information, fall into the category of “connected things”. In addition, due to the fact that the patches and/or smart apparel are worn as close as possible to the body, like a “second skin”, closely in phase with the body and its biometric and behavioral properties, the data are often recorded, measured and exploited as “personal data”. Therefore, companies making patches and/or smart apparel accumulate a vast quantity of data (gigabits or even terabits of data) of this type, relating to the physical wearers of these types of objects. The crucial issue, then, is to ensure consumers have trust in the market of textiles, patches and smart apparel, which are sometimes viewed as spy gadgets, tracking the wearer’s movements, travel, keeping hold of their biometric data, behavioral data, private, health-related and other types of data – in short, their sensitive health or wellbeing data, and may transmit those data to practically anyone practically anywhere in the world. It is therefore important to anticipate and ensure that the smart apparel complies with the various pieces of legislation relating to personal data protection.

In addition, the majority of smart apparel is based primarily on principles of communication using RF (in HF or UHF), inspired more or less directly by technologies such as RFID, NFC, BTLE, Wi-Fi, LoRa, SigFox, IBC and others, which naturally fall within the remit of a PIA.

Industrial applications of the GDPR

The GDPR expressly mentions the right to have our data forgotten (art. 17) and the legislation (art. 33) specifies that personal data breaches must be notified to the CNIL and the data subjects. The text also sets the amount of the (enormous) financial sanctions which may be incurred in the event of failure to comply with the above regulations.

The above discussion may seem abstract and confusing, so let us now look at a concrete example of smart apparel.

EXAMPLE.— A company sells a garment, a smart jacket, which, in addition to a range of other things (such as offering comfort and wellbeing while practising sport) measures the wearer’s heart rate, recorded by means of an EKG – this is biometric and behavioral data, which is duly treated as personal data. The readings are sent by an application to the user’s mobile phone, which uses another application to send the data up to a cloud server (but which cloud?), located who knows where, which makes use of the data in an unknown way (for example, the data may be sold to an insurance company or, believe it or not, to a funeral provider – yes, that has happened in the past!). The records are then sent back to the user’s mobile phone by some unknown route. In short, there is quite a long chain of events that must be considered.

Establishing compliance with the GDPR in businesses

In the patches and/or smart apparel industry, as in many other areas, in order to properly implement the GDPR, we must comply with the regulation. That is, we must have a Data Protection Officer (DPO) who ensures that the organization is compliant with the regulation on personal data protection. We must appoint a Data Controller (DC) within the smart apparel company (designers, manufacturers, subcontractors, etc.), keeps up with data regulations and carries out privacy impact assessments, who is co-responsible for the people in charge of respecting the regulations on data protection.

When companies process data on a large scale (for example, in PPE, in the health and medical fields), regularly and systematically monitoring people, and processing sensitive data for their main activity, they are obliged to appoint a DPO, both for the data controller and their subcontractors. Thus, each data controller must establish/put in place documentation/an internal log of processing activities (which is typically a huge document) so that, if audited, they can prove to the authorities (a posteriori) that they are compliant with the regulation.

1.3.6.6.5. In conclusion

To conclude this section, the following paragraphs are addressed to companies, designers, manufacturers, etc., both present and future, of products for this new market, so they can easily reference the main points that need to be kept in mind.

Regulations on personal protective equipment

In this book on smart apparel and the patches used in its manufacture, we cannot possibly fail to mention the branch of smart apparel designed to serve as personal protective equipment (PPE), to protect an individual from a specific danger which they encounter in the course of their work; we must also discuss the regulations pertaining to PPE. Generally speaking, in the professional sphere, the whole body (head, hands, feet, etc.) can and should be protected. Generally, PPE comes in the form of professional gear such as workwear (jackets, parkas, trousers, etc.) or professional accessories (helmets, goggles, boots, gloves, etc.).

Before proceeding further, let us present a few definitions. In European Directive 89/686/EEC, “PPE means any device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards” at work, and any accessory or ancillary device for the same purpose. This definition includes all components of smart and/or connected apparel.

NOTE.— Beware: the phrase PPE is often misinterpreted to mean *personal equipment* for protection. However, the legal definition is perfectly clear: it is the *protection* which is personal, rather than the *equipment*. The concept of personal protective equipment stands in contrast to collective protective equipment (CPE). For example, it would be possible to make only one piece of PPE available – for instance, a single pair of safety goggles, to be shared by all users at a grinding station, rather than issuing all workers with their own pair of goggles.

The PPE category of smart apparel is often subject to specific constraints pertaining to certain risky professions such as civil protection, firefighting, electrical maintenance, etc. In addition, as they are designed to be highly resistant to all forms of attack, PPE garments are very problematic to recycle.

When, to a PPE garment, we add Internet connection (IoT) and a link to a database (Big Data) in the cloud for more profound analysis of the data captured, it can be used to provide new services such as geolocation, optimization of resources, assessment of strenuousness of the workload, alerts to potential risks, etc. However, this also means complying with very stringent regulations on data management, and with the GDPR.

1.3.6.6. Types of PPE

According to the French Labor Code, PPE can be classified into ten or so families, depending on the area of the body which it protects, so there are potentially entire families of garments. There is also PPE for sport and leisure, which is codified

in the Sport Code. To conclude the discussion on this topic, note that there are three categories of PPE, defined on the basis of the seriousness of the risks against which they protect. In addition, in order to be effective, PPE must be comfortable to wear, and not interfere with the task the user is performing (see the section on ergonomics, above).

Legally, for each type of activity, an employer is obliged to provide for the safety and protection of their employees. In France, the law requires employers to create and use a unique risk-assessment document (DUER), the purpose of which is to list all the risks inherent in each employee's activity. Once these risks are known, the employer is obliged to either eliminate them or mitigate them as far as possible. PPE is one way to achieve this. In addition, the Labor Code emphasizes that wherever possible, collective protective measures are preferable to personal protective measures, but also stresses that workers should not be unduly inconvenienced: they must only be required to wear PPE when it is absolutely necessary.

Nine general preventative principles have been established, which must be taken into account when designing smart apparel and electronic components for it: 1) preventing risks; 2) assessing the risks which cannot be prevented; 3) combatting the risks at their source; 4) adapting the work to the human operative doing it, rather than forcing the human to adapt to the work; 5) taking account of the degree of maturity and evolution of the technology; 6) replacing that which is dangerous with something that is less dangerous, or safe; 7) planning for prevention by considering, as a coherent whole, the technology, workflow organization, working conditions, social relations and influence of environmental factors – in particular, risks relating to psychological harassment; 8) taking collective protective measures and prioritizing those over personal protective measures; and 9) giving the workers the appropriate instruction.

1.3.6.6.7. Environmental and recycling regulations

When dealing with smart apparel, the questions of its environmental impact and the recycling of the “smart” parts (often electronic) at the end of their life cycle must inevitably be addressed. People often point to these issues as a barrier to the use of such technology, and it is necessary to examine this important and tricky issue, along with the regulations in force in relation to it. Here, then, are some musings to guide reflection.

Besides the fact that the presence of electronic components makes matters more complicated, in certain cases, it is possible to remove the purely electronic parts – in particular, batteries or power cells, sensors and the microprocessor to recover the

copper, the silicone from the integrated circuit board, the antennas and rare metals. Nevertheless, these problems are difficult to solve because garments using composite textiles contain a range of different fibers, be they natural or artificial. However, once a wire has been integrated into the thread of a garment, it is more difficult to recover, and no industrial players are willing to unpick a textile to recover only a small weight of conductive wire, which will have little value. In order to promote recycling, the best thing to do is to focus on eco-design, which, at the time of writing, is sadly underdeveloped in the companies currently marketing smart apparel. Future technologies are not necessarily likely to simplify the problem, because the materials used will be increasingly complex, when bio-sensors and the different components are directly printed onto the textiles or integrated into the fibers, and form an integral part of the textiles, as is the case with today's patch antennas. This will mean they are difficult or even impossible to separate, and therefore to recycle, and they will become a burgeoning source of waste.

Below, we discuss certain official texts which may help light the way.

1.3.6.6.8. Waste electrical and electronic equipment

Electrical and electronic equipment (EEE) often contains substances or components which are hazardous to the environment, and there is a high potential for recycling the materials from which it is made (ferrous and nonferrous metals, rare metals, plastics, etc.). In France, the Ministry of Ecology, Sustainable Development and Energy is in charge of regulating on waste electrical and electronic equipment (WEEE). In view of the environmental issues at stake, a specific logistical channel for the processing of WEEE (i.e. its collection and recycling) has been set up, based on the principle of extended responsibility of the producers of such equipment. The directives relating to WEEE and the dangerous substances contained in such devices define the conditions whereby EEE may be sold, and set out the regulatory framework for the management of WEEE. In addition, European Norm EN 50419 relates to the marking of electrical and electronic equipment, which applies (to smart apparel and/or patches as well), as long as the equipment in question is not part of a different type of equipment. It gives an indicative list of products in each of the categories, which serves to clearly identify the producer of the equipment.

Case of garments containing electronic components

The specific case of recycling and value creating from smart apparel is addressed through the annual contribution to ECO-TLC (*Éco-organisme du textile du linge et des chaussures* – Eco-Organization on Linen and Shoe Textiles), paid by companies who market clothing and household linen. There are solutions for appropriate recycling and value creation from the electronic components (batteries, sensors,

etc.), depending on whether or not they are removable, and the methods used when the components are integrated into the thread or the cloth. This issue of recycling complex products has already been identified in numerous channels, including that of medical devices containing electrical and electronic components and portable power cells. Those in charge of the relevant eco-organizations, such as the ECO-TLC, and of the various ecosystems, have produced a situation report. Even at this stage, there are two scenarios. In the first, the electrical and electronic components are integrated into the fabric, and are undetectable to the naked eye, in which case the usual procedures apply. In the second, the functional elements are removable (e.g. the casing, battery, etc.) or easily detachable, in which case, ECO-TLC sorters collect them separately and they are processed as small devices, by operators specializing in waste electrical and electronic equipment (ecosystems), or those specializing in the recycling of power cells or batteries.

EEE, as defined by the above-cited Directive 2012/19/EU, designed and installed to be integrated into a non-EEE article, is beyond the scope of ecosystems. However, the question of recycling of textiles is at the heart of the RETEX project, whose aim is to impose a global structure on the textile supply chain in the circular economy, taking action in three areas: the provision offered by economic actors in the textile sector, the management of textile products at end of life, and the demands of the market in terms of products containing recycled materials.

1.3.7. Normative aspects

The normative aspects are another point which must be considered. In facilitating the emergence of smart fabrics and apparel, there are two possible approaches to establishing norms – firstly, saying that innovation must be encouraged, leaving the field open for initiatives to thrive; or secondly, knowing that a lack of norms can lead to a fragmented, piecemeal ecosystem.

From the normative standpoint, this means either acting at an early stage, preemptively, so as to guide the market, or acting a posteriori, after the market is established, doing a little spring cleaning among the (over-numerous) proprietary systems which are present at that time. It should be noted that the market in smart apparel applications, as it stands today, is still on the borderline between these two approaches, because the true industrial market is still in the process of taking shape, so there is still time to structure the applications with compliance to certain norms.

Before delving into the subject in depth, let us briefly mention the normalization organizations which deal with textiles and smart textiles/apparel.

1.3.7.1. *The ISO, CEN and IEC, and CENELEC*

To better understand the discussion to come, know that:

– Firstly, the *Comité européen de normalisation* (CEN – European Normalization Committee) has signed agreements with the International Standardization Organization (ISO). Within the CEN, France is represented by its own normalization body AFNOR which, by delegation, is represented by the *Bureau de normalisation des industries du textile et de l'habillement* (BNITH).

– Secondly, the *Comité européen de normalisation en électronique et en électrotechnique* (CENELEC – European Committee for Electrical and Electrotechnical Normalization) has signed agreements with the International Electrotechnical Commission (IEC).

All four of these bodies work, through introducing international norms, to promote international standardization of the trade and markets. Let us briefly examine how the situation stands at the time of writing.

1.3.7.1.1. CEN (Comité européen de normalisation) and CENELEC

In the CEN, the working group WG31 *smart textiles*, within technical committee TC 248, “Textiles and textile products”, in October 2011, adopted and published a large and exhaustive technical report: CEN/TR 16298 – “Textiles and textile products - Smart textiles - Definitions, categorisation, applications and standardization needs” – setting out the main definitions and features concerning smart textiles. That norm describes the characteristics of these materials and smart textile systems.

Where the textile is a component in complex, multi-material systems, the BNITH has also established a report on the state of the efforts at normalization carried out in other technical committees of the CEN and normalization bodies such as the CENELEC and ETSI, the objective being to foster dialog on product norms and testing norms. In addition, at the request of the UIT (*Union des industries textiles* – Union of Textile Industries), the FIECC (*Fédération des industries électriques, électroniques et de communication* – Federation of Electrical, Electronic and Communications Industries) has produced an overview of these technologies, and listed the technical committees already in place at the IEC, which are likely to provide elements of normalization in the smart textiles and apparel sector. As we will see shortly, there are many.

1.3.7.1.2. IEC (International Electrotechnical Commission)

In late 2016, the Standardization Management Board at the IEC approved the formation of a specific technical committee (TC 124, Wearable Electronic Devices

and Technologies), assigning it the following scope: “Standardization in the field of wearable electronic devices and technologies which include patchable materials and devices, implantable materials and devices, ingestible materials and devices, and electronic textile materials and devices”.

Discussions on the subject of Wearable Smart Devices (WSDs) have taken place in the strategic group IEC SG10, with the following three objectives: to clarify terminology and achieve an agreed understanding of WSDs; to collect use cases for health, wellbeing and the automotive sector; to affirm the principle that all wearable electronic devices must contain procedures for identification, authentication and respect for privacy.

In France, a collaboration has been established between the BNITH and those responsible for normalization at the FIEC, to put forward one or more use cases for smart textiles to IEC TC 124. The French working group recommends using the definitions proposed in 2011 in technical report TR 16298 from the CEN, to describe these materials and smart textile systems. In addition, the UIT has granted the BNITH a mandate to represent the French textile industry on the relevant normalization committees at the CEN, ISO and IEC.

1.3.7.1.3. ISO/AFNOR

In addition to the mirror committee at AFNOR monitoring the works described above, at the ISO, in the Joint Technical Committee (JTC 1), the working group WG 10 is dedicated to the Internet of Things, very close to certain items of connected smart apparel (in the medical domain, and PPE, for example). To date, this working group’s main activities have focused on general matters of architecture and generic, theoretical and academic aspects of security and privacy, which are part of the fundamentals of the systems. The earliest documents published echo the ISO 30141 – *Internet of Things reference architecture*. With regard to the concrete reality of IoT applications, there is only one Technical Report available, on use cases.

1.3.7.1.4. IEEE

In relation to ISO WG 10, the working group IEEE P2413 has produced a norm, “Architectural Framework for the Internet of Things (IoT)”, including the descriptions of numerous domains within the IoT, the definitions of abstractions to the IoT domains, and identification of the common points between the different domains of IoT. The IEEE 802.15.4 and IEEE 802.15.6 standards are currently available.

1.3.7.1.5. ETSI

For its part, in 2012, the European Telecommunications Standards Institute (ETSI) decided to develop norms in the field of IoT connectivity, which can be used in wearables and textiles/smart apparel using Long Range (LR) LTNs

(Low-Throughput Networks), generalizing two principles that are used in narrow-band (NB) transmission solutions (on SIGFOX bases) and dynamic spectrum sharing (DSS) (on the bases of LoRA-Semtech) (see Chapter 5). This is the set of documents GS LTN xxx.

There are also other normative references that must be taken into account. One such reference is GB/T 15629.15-2010: “Information technology – Telecommunications and information exchange between systems local and metropolitan area networks – Specific requirements – Part 15.4: Wireless medium access control and physical layer (PHY) specification for low rate wireless personal area networks.”

1.3.7.2. *Overview of norm-setting actors*

Dating from late 2020, Figure 1.13 offers a complete overview of all normalization committees which concern, be it directly or remotely, smart apparel (the most significant are shown in blue).

1.3.8. **Applicative aspects**

In the professional world of smart apparel, applicative aspects are of prime importance, because numerous problems are linked to these aspects, stemming from difficulties with the applications and uses.

1.3.8.1. *Applicative constraints relating to “clothing”*

Let us point to the following aspects, because the fabric, the textile, and the smart garment as a whole must be esthetically pleasing, smooth, silky, lightweight, with a good drop, soft (must not chafe), strong, transparent, pliable, creasable, extendable, etc. (also see the list of finishing steps for details), and the textile/smart apparel combination must be functional, washable, pressable, reliable, of small dimensions and weight, antibacterial, hypoallergenic, etc.

To begin with, we shall give a brief and non-exhaustive list and description of other aspects and applicative constraints which must be satisfied by smart and connected apparel.

1.3.8.1.1. Prior to sale

It is crucial to undertake preventative measures with a view to explaining, training, educating, etc., future potential customers, so that only favorable sales levers apply.

Committee numbers	Committee names	Fields of activity
IEC		
SG 10	Wearable Smart Devices (since 2015)	Wearable Smart Devices, electronic textiles, near-body electronics, on-body electronics, in-body electronics.
TC 106		Methods to assess electrical, magnetic and electromagnetic fields in relation to human exposure.
TC 124	Wearable Electronic Devices and Technologies (since 2016)	Standards for electronic devices and technologies whose materials and devices are in the form of “patches”, implantables, edibles and textiles. “Links” with other technical committees (TC) at the IEC, the ISO, etc., working notably on flexibility and stretchability of the fibers and garments, and the safety of electrical and electronic devices in direct contact with the human body.
	WG1 (terminology)	Terminological definitions for wearable electronic devices and technologies.
	WG2 (e-textiles)	Measurement and evaluation methods for textile materials, devices and electrotechnical functional systems.
	WG3 (Mat)	Defining specific terms and determining the assessments, requirements and specifications for materials used in wearable electronic devices and packages, with the exception of electronic textiles. Analyzing the effectiveness of existing methods specific to the materials of wearable electronic devices and packages, with the exception of e-textiles. Developing methods for measuring and assessing materials for wearable electronic devices and packages, with the exception of e-textiles.

Committee numbers	Committee names	Fields of activity
ISO		
JTC 1/SC 41	Internet of Things and Related Technologies	
TC 38	Textile	
TC 94	Personal Safety	
TC 150	Implants for surgery	
CEN and CENELEC		
TC 162	WG 2 – PPE with electronics or ICT	M/553 Smart Textiles for protection against heat and flame
TC 206	Biological clinical evaluation of medical devices	
TC 248	Textiles and textile products Smart textiles	WG 31 – Smart textiles (2008) EN 16812 – Electrically conductive textiles – Determination of electrical resistance of conductive tracks (2016) EN 16806 – Textiles containing phase change materials (PCM) – Determination of the heat storage and release capacity (2016) EN 16806-2 – Textiles containing phase change materials (PCM) – Determination of the heat transfer using a dynamic method WG 25 – Cosmetotextiles WG 28 – Thermoregulation
SyC AAL		
	System Committee Active Assisted Living	Committee based on Active Assisted Living (related to the environment of the elderly), working on various points including the levels and accessibility of embedded systems and their means of communication.
CISPR		
	<i>Comité international spécial des perturbations radioélectriques</i> – Special International Committee on Radioelectric Pollution	

Committee numbers	Committee names	Fields of activity
ACSEC		
	Advisory Committee on Information security and data privacy	
IPC (recognized by the ANSI)		
IPC D-70 E	Textiles committee	
IPC-2292	Combination textiles and OE (organic electronics)	
IPC-WP-024	White paper on reliability and washability of smart textile structures	
IPC-WP-025	IPC white paper on a framework for engineering and the design of e-textiles	
IPC-8921	E-textile standard for warp/weft and mesh designs	
IPC-8941	Guideline on Connections for E-Textiles	
IPC-8952	Design Standard for Printed Electronics on Coated or Treated Textiles and E-Textiles	
IPC-8981	Quality and Reliability of E-Textiles Wearables	

Figure 1.13. Status of normalization committees dealing with smart apparel

1.3.8.1.2. Sale

In order to prove the possibility of purchase and sale, it is often important to show the future consumers of smart apparel that the products have a “new value dimension”, demonstrating that they are well founded on an applicative basis, and that the smart apparel in question is truly designed to serve a certain purpose, and is more than a mere gadget. Such would be the case, for example, with medicalized assistance. In the field, it is a matter of providing training to sales personnel and sales teams, so that rather than “selling a price” as they often do, they “sell a product, its usage, and its qualities”.

Maintenance and preventive maintenance solutions

Two questions soon arise when thinking about connected textiles and smart apparel. Given that such garments have electronics on board, how can we wash and recycle a connected textile? For this purpose, we need to specifically outline these

points in a set of usage instructions or a clear maintenance notice – something that is readable (rather than something in minute text) and understandable by mere mortals, without an advanced degree.

When the electronic components are directly integrated into the thread or the fabric, the question of maintenance (washing, pressing, drying) is essential, because it will have a particular impact on the item's life cycle (number of wash cycles – for example, warranty valid for 5, 20, 30 or 50 wash cycles), and consequently, on its usage, price, replacement value, etc. It must also fit in with existing practices, which are different in terms of the maintenance of clothing and household linen for private individuals (washing and pressing “at home”, folding, putting away, etc.) and for professionals (businesses, dry cleaners, hotels, restaurants, etc.). The garment manufacturer must provide clear information about guarantees, durability and properties of the smart materials or textile systems to their professional service providers and their customers. They must also inform them about how to operate and store the device (folded, unfolded, flat, on hangers, etc.), how to use it, the maximum number of cleaning cycles, the quality of the amalgamation of the materials and fibers, drying (means of drying, drying time, etc.), pressing or ironing (maximum temperatures, etc.), maintenance and disinfection. In short, there is a vast range of information which must be provided.

In the context of this book, the design of soft garments for the general public, with integrated biosensors and the unintrusive electronic components associated, is no easy task, because there are numerous quality and performance criteria which must be met, but which are mutually incompatible. Put simply, we need, as usual, to square the circle of technical, industrial, financial, etc. considerations. However, over the past 50 years, in a range of fields, that circle has indeed been squared more than once. Thus, it seems perfectly realistic to expect it could be again, within a timescale of, say, five years. The main problem is the willingness to take the bull by the horns and tackle the issues head on, in today's world.

1.3.8.1.3. After-sales

The subject of “after-sales management” of smart apparel is always a tricky one. In global terms, there are two generic scenarios:

- In the first, the product is expensive, and designed to last (as is the case with PPE, for example). In this case, the smart component will need periodic software updates (possibly carried out remotely) throughout the garment's life, or it will need normal functional maintenance.

- In the second, obviously, to make life easier, certain producers opt for cheaper products (which is a rare occurrence in this particular market) – single-use,

disposable items (e.g. a T-shirt for a competition), thereby avoiding the need for repair, replacement, networks of stores to offer support, etc.

Updates to software/apps

From the outset, the problem begins with how to effect software updates for smart apparel, who will perform these updates, etc., and also, how much they will cost. All solutions are, of course, feasible, depending on the underlying applications (expensive products with a short or medium life span, products with an extensive life span (PPE, military equipment, etc.)), which have varying levels of practicality, varying levels of cost, or which cannot be returned or exchanged.

Breakdown repair

Owing to the technologies employed (weaving of electrical wires directly into the material, non-removable integrated circuit boards, etc.), it is often difficult, or even impossible, to repair these products, and where it is possible, it can be highly costly, making this solution difficult and tricky to implement, both in technical and financial terms.

Replacement – service points

With after-sales service, the decision to simply replace a broken product must only be taken after lengthy static calculations for financial pre-costing and assessment of commercial risks. A different solution is to simply replace the product as a “goodwill gesture”. The problem is determining whether the replacement is made “within warranty” or “out of warranty”.

EXAMPLE.– You guarantee your product for 30 domestic wash cycles at 30°C. How can you know whether the product being returned to you has actually been washed 32 times, including once at 60°C. Should we question the customer’s word and good faith? It is a matter of “your word against theirs”, and from a commercial point of view, such a situation is not easily resolved.

1.3.8.2. Security aspects

To conclude this lengthy section, let us turn our attention to security aspects¹¹, which simply cannot be ignored, and must be dealt with when smart apparel is connected to other devices (in a BAN, for example – see Chapter 5) or to networks such as the Internet. Indeed, by the principle of applicational proximity, smart apparel (worn on the body) is very closely linked to issues of “personal data” belonging to the wearers – biometric, behavioral, geolocation data, etc., and

11 “Official” definition of security given by ETSI: “ability to prevent fraud as well as the protection of information availability, integrity and confidentiality.”

therefore sensitive data, which must be handled with care (see section 1.3.6.5), and with stringent “end-to-end” security in the application. Indeed, security is one of the most important issues to be addressed, closely followed by problems of interoperability. At present, these issues are difficult to solve, and new initiatives are needed from players in the industry.

1.3.8.2.1. Weak links

Often, security is not given due consideration. How are/will the smart apparel be rendered truly secure, to prevent, or at least limit, the new opportunities for hackers that it presents? Everywhere, this topic is high on the agenda, not because industrial actors are suddenly taking more notice of the threat, but mainly from fear of the negative media coverage they will suffer in the event of problems, and the fallout from that coverage in terms of image and cost. Consider an example scenario: a piece of PPE or sports equipment whose cardio readings are hacked and sent to the wearer’s insurer, and stress readings are sent to their employer (this is not a hypothetical: it has already happened in real life).

Let us briefly list some of the most usual weak links and “holes in the racket” of security, within the chain of connected smart apparel, which leave hackers a great deal of room to maneuver and carry out attacks (if it is helpful, think particularly of sports gear, PPE and medical devices).

To implement security (see Paret and Huon (2017)), it is necessary to know your enemy and define the security target. In order to do so, you must be aware of the requirements, assess the risks and consequences (for the designer and the user), know how to respond in the event of a problem, know how to and what to communicate to the customers/users, and determine the price to pay. All we need is a miracle! Thus, it is necessary to establish the desired “security target”, representing two major categories of parameters: the parameters for which we wish to establish security (the concentric segments of the target), and the levels of security we wish to attain for each of them. We then need to know whether and how these goals are achievable, and if so, at what cost. The following simple and pragmatic questions should be kept in mind constantly: are the benefits worth the costs? Does the chain as a whole deliver security from end to end? Is there still a weak link in the chain, and if so, where is it?

These considerations lead us to define the use of a truly *Secure Element* – a genuinely secure solution which can guarantee encryption security at the five conventional levels: identification, authentication, message integrity, privacy and nonrepudiation.

To our knowledge, usually for reasons of cost, few smart apparel solutions implement such a high level of security, which may become a necessity depending on the quality of the data being carried – increasingly sensitive, personal, biometric, behavioral, fragile and critical – and of course, this keeps costs as low as possible so that the product can be bought by the general public.

Vulnerabilities and attacks on smart apparel

To ensure the appropriate level of security for connected smart garments and their infrastructures (networks), it is necessary to carry out risk assessments, and implement adequate protective measures. Obviously, the levels of guarantees implemented must correspond to the acceptable risk level and the likelihood of those events actually occurring.

APPLICATION TO SMART APPAREL.—

In certain applications for connected smart apparel, the data handled are often very much “personal data”, in the regulatory sense of the term (biometric, heart rate, stress levels, location, etc.), relating exclusively to the individual in question. These applications include wellbeing (sleep regulation, etc.), sports (heart rate and variations, etc.), fitness (effort measurement, etc.), PPE (equipment for laborers, firefighters, military personnel, etc.), and the medical domain (detection of epilepsy, etc.). As such, the levels of security guaranteed are usually (or ought to be) defined in all software elements, all along the length of the chain, by design of the various electronic components, and the choice and applications of the integrated circuits. Finally, choices in this area will depend largely on the potential access routes available to a hacker to attack the various elements listed above.

This concludes the first chapter of this book, representing a very broad view of the extremely numerous aspects that need to be kept in mind and taken into account when making the move from a tenuous idea to a concrete reality in the form of a patch-based project. The long and winding road through the regulations, norms, applicative aspects, etc., has reached its end. This arduous journey was a necessary evil, for the reader’s own good.

In Chapter 2, we shall delve deep into the numerous applicative aspects of smart, connected apparel.