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Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations

D5.2 First responder prototype uniform design and first aid device for kids

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Executive Summary

Emergency first responders often encounter unpredictable and dangerous environments when responding to calls. Fire, blood, chemicals, and debris are just a few of the many types of hazards a firefighter or law enforcement officer might be exposed to when answering a call. For example, first responders may encounter broken glass at the scene of a car accident or risk exposure to chemicals upon venturing into an enclosed space that housed a meth lab.

The deliverables previously presented (D1.1 and D1.2), were intended to prepare the basis for the subject of this deliverable.

The goal of T5.2 is to design, develop and prototype an improved duty, comfortable and performing uniform designed to provide first responders with better protection from the many hazards they encounter in their daily duties also in extreme conditions. At the same time the uniform has to monitor first responders' health status and the environment conditions such as harmful gases, level of oxygen and temperature. The second objective of this task is to design and make a prototype of an innovative child rescue system. In most of the emergency cases, first responders usually need devices and kits for providing first aid support to injured people. In particular, it is important to provide them with a device like a paramedic tool for injured babies and kids able to carry and protect them, monitoring life functions before arriving at the emergency hospital. Similarly, a compact health condition monitoring device for adult victims will be developed that is easy and fast to place to the victims on the field and able to transmit their health condition to the Emergency Management System.

The D5.2 describes the design process for the prototyping of the first responders' suit, the first aid device for children and a health condition monitor for victims. The deliverable analyses also the requirements previously highlighted by the WP1, on which the project is based. Innovative materials and technologies used within the prototype, which have been developed with the help of the task partners, are also detailed.

List of the abbreviations

Abbreviation	Explanation
API	Application Programming Interface
ASTM	American Society for Testing and Material
BLE	Bluetooth Low Energy
BP	Blood Pressure
BT	Body Temperature
CE	Conformité Européenne
DC	Direct Current
DPI	Disponsable Protective Equipment
ECG	ElectroCardioGram
EMG	ElectroMyoGram
ERM	Emergency Response health condition Monitoring device
EU	European Union
FDA	Food and Drug Administration
FR	First Responder
GPRS	General Packet Radio Service
GPS	Global Positioning System
GUI	Graphic User Interface
HAZMAT	hazardous materials
HCD	Human Centred Design
I/O	Input/ Output
I2C	Inter-Integrated Circuit
IC	Integrated Circuit
ICT	Information Communication Technologies
IMU	Inertial Measurement Unit
IR LED	Infrared Light Emitting Diode
KPI	sKey Performance Indicators
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MIMS	Minimally Invasive Monitoring Sensor
MQTT	MQTT (not an abbreviation) is a lightweight, publish-subscribe network protocol
N/A	Not Applicable
N/C	Not Classifiable
NIBP	Non-Invasive Blood Pressure
NTC	Negative Temperature Coefficient
PAT	Pulse Arrival Time
PDA	Personal Digital Assistant
PP	Polypropylene
PPE	Personal Protective Equipment
PPG	PhotoPlethysmoGram
PTT	Pulse Transit Time
RFI	Radio Frequency Interference
ROM	Read Only Memory
RR	Respiration Rate
SAR, SnR	Search and Rescue
SPI	Serial Port Interface
SpO2	Peripheral Oxygen Saturation

SRAM	Static Random-Access Memory
UART	Universal Asynchronous Receiver/Transmitter
USAR	Urban Search and Rescue
UC	Use Cases
VIN	Input Voltage
VOC	Volatile Organic Compounds
WHO	World Health Organization
WIFI	Wireless Fidelity
WP	Work Package

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1 Introduction

The system is composed of the protective uniform for the First Responders with several embedded monitoring sensors connected to a dedicated smartphone, a first-aid device for kids to carry kids in safety away from the disaster scenario with sensors to monitor young victim health parameters and a health condition monitoring device for adult victims. All the sensors and the hand free monitoring devices communicate with a dedicated smartphone through Bluetooth while the smartphone communicates with the Web Server through 4G/5G and WIFI technologies if available.

1.1 First responder uniform.

The task aim is to design and develop an innovative performant uniform for first responders. The uniform purpose is to protect the FR from the many dangers they encounter in their daily activities even in extreme conditions. At the same time the uniform has to monitor the health status of first responders and environmental conditions of the scenario. The uniform needs to be as protective as comfortable, and it must be compatible and combinable with all the different DPI than the FR has to wear.

1.2 First aid device for kids.

The second aim of the task is to design and develop an innovative protective first aid device for kids. able to carry the young victim safely out of the disaster scenario and monitor his health parameters. The device has also to help first responders to easily provide first aid support to injured children. The device has to be compatible with all the different paramedical devices (such as stretchers and spinal board) to immobilize the young victim, if necessary, before arriving at the hospital.

1.3 Health condition monitor for victims.

The Emergency Response health condition Monitoring device or ERM is a compact patient monitor that can display and transmit the health condition and position of the person wearing it through a smartphone. The device will be easy to handle and fast to apply without many cables interfering with the wearer's motion with the purpose to be used on the field and track the condition of the victims.

2 Design Methodology

The research methodology referred to a multidisciplinary approach involving different actors and making various activities during the design process.
The design activities were related to the - UE/UI - User Experience, User Interface design and the Human Centered Design (HCD) approach, starting from the users' needs and behaviors both practical and emotional.
The Human Centered Design is a process defined in the ISO 13407 in 1999 and revised in 2010 with ISO 9241 - 210, representing a starting point of the design process. It refers to the specificity of the interactive system, even though it is a source to which the design can always refer when interactive system meant complexity of interactions determined by different entities. (Norman, D. A., Verganti, R., 2014)
The HCD, is related to getting information about the approach in question and to outlining useful design processes. In the Human Centered Design approach, the design, development, testing, and evaluation are the central activities of the field of human factors with the aim of designing products for human use.
The Human Centered Design processes for interactive systems, have to be considered as an approach to interactive system development that focuses specifically on making systems usable through multidisciplinary activities.
The standard specifies that it is necessary to develop four activities to follow during the design of interactive systems. These activities are the following:

1. to understand and specify the context of use.
2. to specify user requests.
3. to produce design solutions.
4. to evaluate the project.

In particular the standard ISO 9241:210/ 2010 paragraph 4.1 identifies six principles of the HCD as follows:

(i)the project is based on the explicit understanding of users, activities, and environments.
(ii) users are involved for all phases of design and development.
(iii) the project is guided and perfected by the User-Centered assessment.
(iv) the process is iterative.
(v) the project addresses the entire user experience.
(vi) the design team includes multidisciplinary skills and perspectives.

The designers could work according to their favorite procedures and the HCD approach could be applied using different procedures. These are really variations of the same general method, iteration of the four steps: observation, generation, creation of a prototype and verification. The HCD is like a design philosophy and not only a defined set of methods so the innovative line should start approaching users and observing their activities. (Norman 2014, pp. 222)

The human-centered design is one of the most effective method that designers have at their disposal to solve problems designing products and services. (Norman, Verganti, 2014)

The research used also a co-working approach that has been experimented as described below during the interviews and questionnaire activities with the end users involving them during the development of the present work. The research was structured in the following four steps:

1. **Research, analysis, and interviews**

During this step the research and the comparative analysis on the state of art on commercial/experimental products and materials were carried out. Moreover, a series of field research in local archives and interviews and questionnaire to the end users were performed.

2. Studies on referring literature

The second step of the work focuses on the analysis of user's needs, skills, and behavior according to different disaster scenarios.

3. Project ideas

During the third phase the research analyzed all the data and proposed the concept ideas on the protective and smart uniform and the first aid device for kids.

4. Ideas' evaluation

During this step the research team tries to test and to evaluate the project ideas during the co-working activities with the end users' partners.

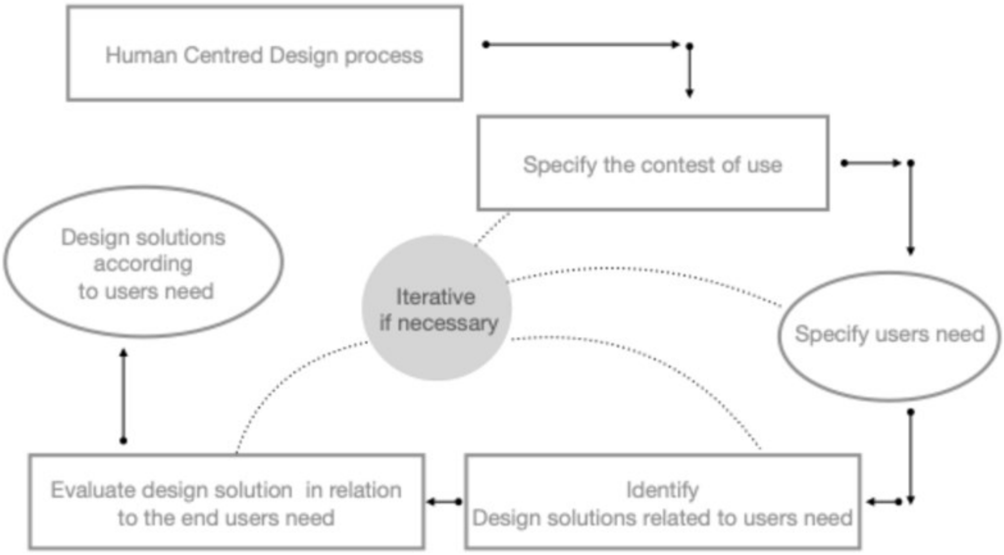


Figure 2-1: HCD activities interdependence. Source: ISO 9241-210:201

3 First responder uniform

A disaster scenario is a very complex, unpredictable, and extreme situation, which constantly puts at risk the safety of rescuers, both for the strong stress caused by the situation as for sudden worsening. For this reason, it is essential that the rescuer has adequate equipment that helps him to face various types of scenarios and that protects him as much as possible. An innovative performant equipment could improve the protection of the first responder, decreasing the vulnerability during the rescue phase.

The task aims to design and develop an innovative performant uniform for the first responders. The purpose of the garment is to protect the FR in hazardous situations and, at the same time, to monitor the FR’s health status and the environmental conditions of the scenario, using wearable biometrical and environmental sensors.

The uniform must be as comfortable as protective, compatible, and combinable with the other DPIs and devices that the FR has to wear and carry in the field scenario.
Moreover, it is designed according to the HCD approach, taking into account the users’ needs, behaviors and habits pointed out from coworking activities with them.

3.1 State of art

According to the purpose of the project, the designing process started from a thorough analysis of the state of art. The analysis was carried out using different approaches and tools. The following paragraphs present the methodologies and the most relevant outputs of the research on the state of art.

3.1.1 Summary of the state of art from D1.1

The analysis of the state of art in Deliverable 1.1 has the purpose to gather information on existing technologies used in SAR operations relevant to the location of entrapped victims, and the identification of limitations and gaps, as well as of future needs. The deliverable provided a well-structured analysis based on multiple research actions including a structured survey.[1]
Information was collected from 82 questionnaires completed by users (civil protection authorities) and project partners, including private companies and volunteer associations working in the field of R&D.

The following table summarizes the main results regarding the analysis of the state of art made in the D1.1.

[1] From SnR_D1.1 Report on user requirements, existing tools and infrastructure_v1.00.pdf

Type of existing SAR technology	Limitations	Gaps	Future needs
Protective uniform for First Responder	It provides only the physical and thermal protection of the First Responder.	Lack of: - Sensors to monitor the health of the first responder such as heart rate monitors, body temperature, accelerometers and other biometric sensors; - Radiation sensors; - GPS tracking; - Communication App for locating victims trapped under collapsed buildings; - No specific first aid for kid's devices.	Smartwatch with a dedicated emergency communication app that integrates through Bluetooth on the smartphone and provides messaging, ECG, EMG rate monitoring and alerting functions (fully embedded in the garment); Radiation sensors (mainly X rays) by means of fully plastic devices (wearable as they can be applied onto a textile substrate); GPS tracking will run even when there is loss of network connectivity; Smart-phone / Tough-phone for locating victims trapped under collapsed buildings; Emergency communication App for locating victims trapped under collapsed buildings.

Table 3-1: Results from D1.1

The questionnaires results provided by D1.1 highlighted that currently, the used uniforms provide only physical and thermal protection to the First Responders. As shown by the activity, currently, no one of the used uniforms provides the first responders' health parameters monitoring. The implementation of health biometric sensors, instead, could be a core tool able to strengthen the protection of the First responders during the rescue activities, improving on the other hand also the performance of the whole team. In fact, specific sensors could, as shown in the D1.1, monitor the stress status of the user (for example using cortisol-based sensors) or the ECG and EMG data and send alerts and notifications when reference values are altered, giving timely rescue to the first responders avoiding any complications.

Moreover, the embedding of environmental monitoring sensors in the uniform (such as radiation sensors) could facilitate the comfort and the work of the First Responder during the rescue activities. Furthermore, it could decrease the several analysis instrumentations that the FR has to carry by on the field, as well as the integration of GPS sensors that ensure continuous tracking even where there is a loss of network connectivity.
The use of wearable hands-free sensors could, in this way, greatly improve the comfort and the KPI of the First Responder during a rescue activity, improving the protection of the whole team

3.1.2 Reviews of uniforms/concepts for other extreme condition scenarios.

The analysis of the state of art of the most relevant uniforms, workwear and suits designed to be used in different extreme condition scenarios has the purpose to gather technical information on materials, fabrics, accessories, morphological and technical solutions used in order highlight their strengths identifying their innovation aspects related to the requirements needed by the end users operating in different scenarios. At the same time the benchmarking activity has the goal of underline the weaknesses of the evaluated products.
The carried-out analysis focused both on products already available on the market and concepts still to be validated.
Some of the analyzed uniforms were designed to be used in ordinary extreme condition scenarios, like professional sports competitions, military operations, and extreme workwear.
The others were designed to be used in extraordinary extreme conditions scenarios like in space.
Every uniform was analyzed and documented using a specific comparable table. The deliverable reports the most relevant evaluated uniforms.

Sonics Bioskin			
Company: Survitec group	**Designer:** N/A	**Company Country:** USA	Company website: https://survitecgroup.com/survitecproducts/15898/SONICSBio-Skin
Field of use: CBRN ENVIRONMENT		**Availability:** ☐ Concept to be validated ☐ Concept ready for distribution ■ Product available on the market	

Image/photo:

Product Description:
The SONICS Bio-Skin is a lightweight, discrete, and breathable stretch fabric that offers exceptional mobility, comfort and protection ina CBRN environment. Leveraging the very latest GORE® CHEMPAK® Selectively Permeable Membrane (SPM), the Bio-Skin's chemical and biological properties provide maximum protection while minimizing thermal burden. Its versatile design easily integrates with many types of outer garments for use in Air, Land and Sea environments. In addition, the GORE® CHEMPAK® Selectively Permeable Membrane used to construct the SONICS Bio- Skin is component certified to meet NFPA 1994, Class 3 current edition standards for 'warm zone' operations. Membrane can be exposed to water, sweat, sea water, petroleum, oils or lubricants without compromising protective properties. Unlike traditional carbon, the membrane can be easily decontaminated. Training suits can be reused multiple times. Constant wear protection up to 48 hours. Can be worn underneath virtually any outer garment making it multi-purpose. Minimal integration costs. Bio-Skin is worn next to skin, therefore there is no need to carry out costly platform or system integration. No need to replace the current PPE. The suit could be worn under every uniform.

Technical specifications: Weight: 270 g/m2 Dimensions: N/A Others: CBRN protection.	**Typology of the suit:** ☐ One piece ■ Two pieces

Innovation aspects: *(strengths from others similar product on market)*
It could be worn under every uniform, offering an additional protection to the uniform. In its brochure is compared to a classic protective suit, it is relevant to the protection factor against Ebola and HIV viruses.

Weaknesses: No attention is paid to the communicative aspects of the suit. There aren't sensors for the monitoring of the First Responders.

Sensor's description: No sensors are embedded in the uniform

Sources/Bibliography: https://survitecgroup.com/survitecproducts/15898/SONICSBio-Skin

Table 3-2: Sonics Bioskin

Sonics Bioshell			
Company: Survitec group	**Designer:** N/A	**Company Country:** USA	**Company website:** https://survitecgroup.com/survitecproducts/16266/SONICSBio-Shell
Field of use: CBRN ENVIRONMENT, Military field.		**Availability:** ☐ Concept to be validated ☐ Concept ready for distribution ■ Product available on the market	

Image/photo:

Product Description:
The SONICS Bio-Shell is a CBRN protective suit consisting of a unique slim, lightweight fabric that allows for significant weight/bulk reduction and enhanced CBRN protection. Leveraging GORE® CPCSU-2 Flex Fit technology, the Bio-Shell represents a step change in CBRN protection, with up to 50% reduction in weight compared to traditional carbon-based protective clothing. Its protective properties also combat a much broader threat, acting as a barrier against conventional chemical warfare agents in vapor form, toxic industrial chemicals, aerosolized particles, liquid under force (i.e., when kneeling or wearing combat equipment) and biological hazards such as blood-borne pathogens like Ebola and HIV. The Bio-Shell's core layer is constructed using the very latest GORE® CHEMPAK® Selectively Permeable Membrane (SPM). The protective SPM fabric is made from a lightweight, breathable film, which allows moisture vapor to escape, resulting in significant reduction in thermal burden and fatigue. The Bio-Shell also features several integrated stretch panels incorporated in key areas to facilitate improved mobility, ensuring its wearer can complete operational tasks such as evasion, combat manoeuvres, operating a vehicle or aircraft and first responder recovery duties. The Bio-Shell includes a separable outer garment that can be customized to any military or organization's pattern/colour preference. Integrated stretch panels in critical areas deliver improved mobility, reduced heat stress, and increased system level protection.

Technical specifications: Weight: 270 g/m2 Dimensions: N/A Others: CBRN protection.	**Typology of the suit:** ■ One piece ☐ Two pieces

Innovation aspects: *(strengths from others similar product on market)*
It is a combined uniform: "under suit" + uniform. It has very interesting technical aspects and in the table in the brochure is compared to a classic protective suit. The protection factor against Ebola and HIV virus is relevant. It is 50% lighter than the other suits on the market.

Weaknesses: No attention is paid to the communicative aspects of the suit. There aren't sensors for the monitoring of the First Responders.
Sensor's description: No sensors are embedded in the uniform
Sources/Bibliography: https://survitecgroup.com/survitecproducts/16266/SONICSBio-Shell

Table 3-3: Sonics Bioshell

Virgin Galactic Spacesuit			
Company: Virgin Galactic	**Designer:** Under Armour	**Company Country:** USA	**Company website:** https://www.virgingalactic.com/
Field of use: Space travel		**Availability:** ☐ Concept to be validated ■ Concept ready for distribution ☐ Product available on the market	
Image/photo: 			
Product Description: The uniforms feature a basic layer, a spacesuit, footwear, a training suit, and a limited-edition astronaut jacket. The suits, customized for each astronaut (the pockets dedicated to personal effects include a transparent internal section for photographs of their loved ones), were made with light fabrics, equipped with shock absorbers in the elbows, in the knees, and shoes to ensure safety in the absence of gravity. The materials have also been rigorously tested in laboratory conditions that adapt to the environment in all phases of flight. Temperature management is mapped to the body to provide perfect heat and humidity management while preventing overheating or cooling. *THE BASE LAYER*: The UA | VG Base Layer acts as a second skin to the body, retrofitting Under Armour's UA RUSH technology will enhance performance and blood flow during the high and zero G portions of flight. The entire base layer is built with UA's new Intelliknit fabric for total moisture and temperature management. From the hottest desert to the cold of space, UA Intelliknit provides temperature regulation and sweat management, making the impossible possible. The development process of UA Intelliknit is highly efficient and creates no material waste in the process - a testament to UA and Virgin Galactic's shared vision for a better, sustainable future. *THE SPACESUIT*: The UA | VG Spacesuit is a deep			

space blue, with atmospheric light blue elements and pops of gold throughout, inspired by an image of the sun in space, casting its rays on Earth. The Virgin Galactic flight DNA symbols are embedded along the spine, symbolizing the unity of the suit with the mission. UA Clone, a proprietary auxetic material that forms to the exact shape of the body for a precision fit and zero-distraction feel, is used in key parts of the UA | VG Spacesuit - namely the elbows and knees - for optimal mobility and comfort. UA's HOVR cushioning is also incorporated into the shoulder pads and neck area, which are high impact zones during the high G portions of flight. The liner of the spacesuit incorporates other new fabrics, like Tencel Luxe, SpinIt and Nomex, used for temperature control and moisture management, as Future Astronauts may experience a spectrum of temperatures throughout their journey. UA integrated all of the brand's performance fabrics – cooling, smooth, fast-drying, moisture-managing, comfortable and safe – to ensure the Future Astronaut has the most comfortable experience possible. An important part of the suit construction included functional features such as multiple pockets for necessary and personal items including an integrated solution for communications, with a push-to-talk button. Each spacesuit iteration underwent rigorous testing with key stakeholders in the VG team including pilots, spaceship engineers, medical officers, astronaut instructors and the customer experience team to ensure it would outperform in-flight expectations. The designers recognized what a transformative and hugely emotional impact the spacesuits will have on the astronaut experience. After spending time with Future Astronauts customers and the VG team, UA created a modern spacesuit that incorporates their feedback. UA added a clear pocket on the inside of the jacket above the heart for a photo of a loved one, and a patch unique to each mission that is removable from the suit to be attached to the Future Astronaut's flight jacket for everyday wear; a jacket which will be presented to astronauts after each mission. *THE FOOTWEAR*: UA reinvigorated the traditional space boot to create something that is highly functional, but also carries through the same style and design elements as the spacesuit. Taking additional inspiration from racecar drivers' footwear, coupled with UA's most cutting-edge footwear technologies, UA mimicked the lightweight feel for optimum mobility, moving away from what we'd all think of as the big, bulky boot astronauts have previously worn. UA Clone adaptive technology, also utilized in the spacesuit, forms to the exact shape of the foot for a precision fit and zero-distraction feel, while the UA HOVR cushioning, one of the softest foams available, provides support for a functional, comfortable, and flame-retardant piece of footwear. All distractions have been eliminated, resulting in a sleek, smooth, soft boot with nothing to snag on equipment or other Future Astronauts when floating in zero gravity. The aesthetic design elements complement the spacesuit, with the shades of blue and gold flashes coming together beautifully. The graphic on the sock liner reads, "We Stand on the Shoulders of Giants," inspired by a quote from Sir Isaac Newton that the Virgin Galactic program holds close. In addition, the Virgin Galactic flight DNA symbols and logo unify the full space kit.

Technical specifications:	**Typology of the suit:**
Weight: N/A Dimensions: N/A Others: Different models and sizes for women and man	■ One piece (the spacesuit) ■ Two pieces (the base layer)

Innovation aspects: *(strengths from others similar product on market)*
It is the first commercial space suit.
Lightweight and breathable, not bulky.

Weaknesses:
One piece suit.

Sensor's description:
The suit is embedded with Intracrew communication systems.

Sources/Bibliography:
https://forbes.it/2019/10/21/gli-astronauti-di-virgin-galactic-nello-spazio-con-tute-firmate-under-armour/
https://www.virgingalactic.com/articles/virgin-galactic-partners-with-under-armour-to-unveil-the-worlds-first-exclusive-spacewear-system-for-private-astronauts/. https://about.underarmour.com/news/2019/10/ua-reveals-technical-spacewear-for-virgin-galactic.

Table 3-4: Virgin Galactic Space Suit

<table>
<tr><th colspan="4">Biosuit</th></tr>
<tr><td>Company:
Dainese</td><td>Designer:
Trotti and Associates</td><td>Company Country:
Italy</td><td>Company website:
https://www.dainese.com/de/en/dainese/technology-innovation/space-suits.html#</td></tr>
<tr><td colspan="2">Field of use: Space travel.</td><td colspan="2">Availability:
■ Concept to be validated
☐ Concept ready for distribution
☐ Product available on the market</td></tr>
<tr><td colspan="4">Image/photo:
</td></tr>
<tr><td colspan="4">Product Description:
Starting from Arthur Iberall's studies in the Fourties, it has been discovered that there are certain points of the body that, despite movements, do not contract and do not stretch. By connecting these points through the so-called "lines of non-extention", pressure remains constant. BioSuit is designed to connect these points, being able to apply the necessary mechanic pressure to the body, although without compromising movement. The news is exactly the replacement of pneumatic pressurization with mechanical one. The inside of astronaut's suits, in fact, in order for humans to survive in the vacuum of space, need to provide pressure. The skintight suit allows for a degree of movement impossible in a gas-filled suit. BioSuit has not gone to space yet. BioSuit was born from one of NASA's needs who, for the first human journey to the Red Planet expected around 2030, has set up a project to design a new space suit, lighter and more practical. The lines of non-extension are represented by the red and black filaments that decorate the BioSuit prototype. The suit will be made of elastic material, but for all other features options remain open. For sure, BioSuit must guarantee to astronaut's oxygen inflow, protect them from effects of prolonged microgravity, solar radiation and impacts with micro-meteoroids, although offering greater flexibility and finding the perfect balance with ergonomics and comfort. Conceived by Dava Newman, MIT Professor and NASA'S Deputy Administrator, BioSuit has been designed by Trotti and Associates, owned by Argentinian space architect Guillermo Trotti, whereas the first prototypes are the outcome of the Dainese Science and Research Center's know-how. Newman's proposed BioSuit designs use elastic and polymers for stretch and nickel-titanium coils that pressurize the suit when heated. The big breakthrough, she explained at an event in Washington, D.C., is nucleated boron</td></tr>
</table>

minitubes spun into thread and sewn into these stretchy suits – effectively protecting the human body from space radiation.

Technical specifications:
Weight: N/A
Dimensions: N/A
Others: N/A

Typology of the suit:
■ One piece
□ Two pieces

Innovation aspects: *(strengths from others similar product on market)*
The designing process starts from the study of non-extension lines. It is not as bulky as the current space suits.

Weaknesses:
It has to be designed directly on the body of the specific person. Difficult to be worn.

Sensor's description:
No sensors are embedded in the uniform.

Sources/Bibliography:
https://www.dainese.com/de/en/dainese/technology-innovation/space-suits.html#

Table 3-5: Dainese Biosuit

<table>
<tr><th colspan="4">SPACEX Spacesuit</th></tr>
<tr><td>Company:
Space X</td><td>Designer:
N/A</td><td>Company Country:
USA</td><td>Company website:
https://www.spacex.com/</td></tr>
<tr><td colspan="2">Field of use: Commercial Space Travel</td><td colspan="2">Availability:
☐ Concept to be validated
☒ Concept ready for distribution
■ Product available on the market</td></tr>
<tr><td colspan="4">Image/photo:
</td></tr>
<tr><td colspan="4">Product Description:
Each custom-tailored suit meant to provide a pressurized environment for all crew members aboard Dragon in atypical situations such as cabin depressurization. The suit also routes communication and cooling systems to the astronauts aboard during regular flight. Additional features including the followings. The suit has a 3d printed helmet. The SpaceX spacesuits are not designed for spacewalks — just for backup during launches and landings. The SpaceX spacesuits were custom-made for the astronauts. The gloves were designed to work with the spacecraft touchscreens, and the spacesuits were made to plug into seat umbilicals carrying oxygen and cool air from the spacecraft. Moreover, it has a flame-resistant outer layer.</td></tr>
<tr><td colspan="3">Technical specifications:
Weight: N/A
Dimensions: N/A
Others: N/A</td><td>Typology of the suit:
☐ One piece
■ Two pieces</td></tr>
<tr><td colspan="4">Innovation aspects: (strengths from others similar product on market)
The suit completely innovates the morphological aspects of the spacesuit.</td></tr>
<tr><td colspan="4">Weaknesses:
The suit is not designed for spacewalks — just for backup during launches and landings.
The spacesuits were custom-made for every astronaut.</td></tr>
</table>

Sensor's description: N/A
Sources/Bibliography: https://www.youtube.com/watch?v=4LMwKwcMdIg https://www.spacex.com/

Table 3-6: SpaceX Spacesuit

The analysis showed the most relevant uniform and garments, both still concepts and products already available on the market, used in other extreme condition scenarios. In particular, the analysis aimed to study the most relevant technologies adopted and developed for the designing of an innovative smart uniform.
The mostly relevant garments analyzed came from the military and the space travel field. If, in the military field, the garments have several innovative aspects regarding the textile, the morphological aspects are still neglected.
In the space travel field, instead, the morphological aspects are highly improved. However, the most frequent weakness pointed out by the analysis is that often these uniforms are designed directly related to the body of a specific person. This method is not sustainable for a commercial product.

3.1.3 Reviews of smart and innovative materials for extreme condition scenarios

The selection of materials for the uniform project started with a preliminary desk analysis on technologies related to innovative and highly performing materials in the SAR and other extreme conditions scenarios (automotive, sport, defense and security, soft robotics, etc.) with a particular focus on wearable materials and solutions (wearable technologies). The first phase of the research embraced both innovative materials in the experimentation phase (Textile piezoelectric sensors, Climate active textile) and commercial materials that can be implemented immediately in the project (Bioceramic Resistex, Lenzing). Following the preliminary research phase, specific datasheets were prepared to classify the information on the materials identified in the desk analysis phase in a systematic way. Each material was filed, and the information was organized into qualitative ranks. This tool has been fundamental for ordering and comparing the various selected materials, guaranteeing a careful choice in terms of performance, ergonomics, and sustainability, both economic and environmental. The material sheets were divided into three groups respectively based on the set of materials useful for the design: - of the jacket, - of the dungarees, - of the underwear. The choice of material for the application on these three types of garments was conveyed upstream from the previously established selection criteria linked not only to the performance required in emergency contexts (impact resistance, water resistance) but also to the comfort and ergonomics of the FR (breathability, hypo allergenicity). For these applications, the comfort of the FR, the physical and chemical properties - therefore color, hygroscopy, melting temperature, density, corrosion resistance, thermal and electrical conductivity - and the general mechanical properties (compression resistance, shear, torsion, traction etc.). At the same time, the environmental properties of the life cycle (LCA) of the material were also evaluated, therefore recyclability, environmental impact in the assembly phase, energy consumption, emissions. Regarding the workability of the semi-finished product, and consequently the margin of use, the technological properties of the material were also evaluated, therefore malleability, ductility, fusibility, weldability, and hardenability. Catalog products of brands such as Dupont, Lenzing, Resistex, Noble Biomaterial, Ittai, Teijing, etc have been cataloged. After a careful evaluation of the materials performance and characteristics, according to the FRs' needs and the requirements of the Operative Scenario described respectively in the paragraphs 3.3 and 3.2, the

research team decided to use the JACKAL 8627 textile produced by Tech Santanderina company for the most part of the uniform prototype, given the excellent combination of technical performance and comfort for the FR. The fiber is composed of Meta-aramid 55% Lenzing TM FR 38% Para-Aramid 5% Anti-Static Fiber 2%. The technical chart of the textile is available in the Annex IV of the present document. The textile has been selected over others with similar mechanical characteristics for its additional excellent certified environmental sustainability. For increasing the mechanical properties and the level of protection of the uniform, according to the analysis, the research team decided to use the Kevlar yarn for all the seams of the garment. The detailed description of the chosen textiles and materials is provided in the paragraph 3.5.1 of this document.
The deliverable reports the data sheets of the most relevant evaluated materials in Annex III.

3.1.4 Reviews of technologies/sensors for wearables devices

Textile electrodes based on PEDOT: PSS for biopotential measurements

Wearable technologies for vital signs monitoring represent a driving force for the consumer market, by leveraging on the people's willingness to preserve a healthy condition with the progress of age, to improve/check wellbeing or to maximize workout effectiveness. In this context, electronic textiles represent a great opportunity to obtain unobtrusive sensing in conditions characterized by a difficult adoption of standalone wearable devices such as smartwatches, smart patches (for the electrocardiogram, ECG), etc. This is the case of first-responder's technologies, which need to be unobtrusive to allow free movement and operation. Among the different technologies, the most recent report on E-Textiles & Smart Clothing 2021-2031: Technologies, Markets and Players by IDTechEx (https://www.idtechex.com/en/research-report/e-textiles-and-smart-clothing-2021-2031-technologies-markets-and-players/828) reveals that the different players in the market use different technologies, mainly conductive yarns, inks and polymers (or combinations of them).

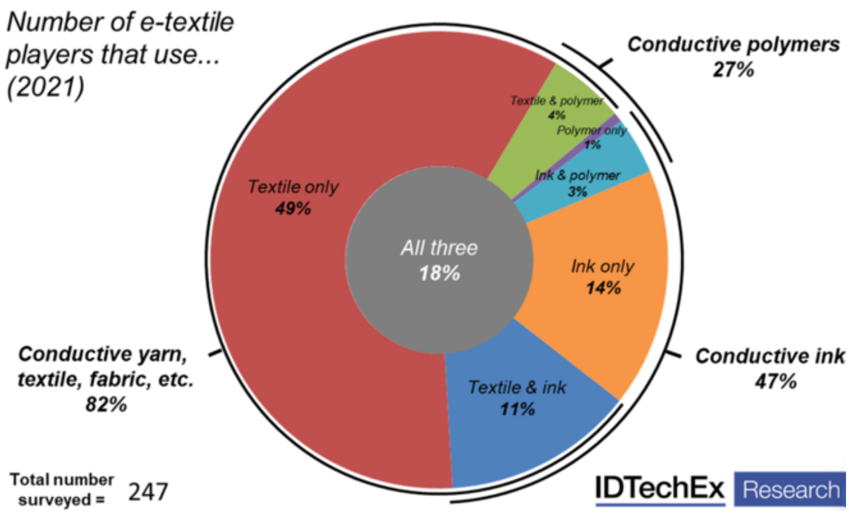


Figure 3-1: report on E-Textiles & Smart Clothing 2021-2031: Technologies, Markets and Players by IDTechEx

Such technologies can be conveniently exploited for sensing, actuating, wiring, etc.
The project studied and developed methods to integrate biopotential monitoring electrodes into stretchable fabrics, exploiting printed conductive polymers for sensing and conductive yarns for wiring. Integrating electrodes directly into fabrics collects a consistent portion of the effort profuse in the field of wearable electronics. In particular, textile electrodes are the basis for the development of wearable devices with applications in different fields, ranging from rehabilitation to prosthetics. In the largest part of cases, textile electrodes have been proposed for ECG detection (Pani et al., 2016), as

ECG is an important vital sign useful for diagnosis and monitoring. Textile electrodes for ECG detection are a long-standing research topic, with several studies on different materials that can be exploited to this aim [CITE]. More recently, surface electromyography (sEMG) (Guo et al., 2020) attracted the interest of the researchers but also new companies, for the possibility of exploiting this technology to monitor the workout or provide biofeedback. Several approaches to obtain high-performing and reliable textile electrodes have been studied so far, ranging from the employment of conductive yarns (Morozas et al., 2011, Weder et al., 2015, Shu et al., 2010) to the functionalization of natural fibers with conductive inks (Castrillòn et al., 2018). Amongst the different conductive inks that have been subjected to intense scrutiny, poly-3,4-ethylenedioxythiophene doped with poly (styrene sulfonate) (PEDOT: PSS) is undoubtedly one of the most significant. In fact, PEDOT: PSS is almost an ideal material for wearable biopotentials monitoring applications because of its relatively high conductivity (both ionic and electronic (Berggren et al., 2019)) and its use in textile-compliant fabrication processes such as ink-jet printing (Bihar et al., 2018), spray coating (Gong et al. 2018), electrospinning (Ding et al. 2017), dip coating (Ankhili et al., 2018), and screen printing (Guo et al., 2016), (Sinha et al., 2017).
Textile electrodes based on PEDOT: PSS have thus been extensively studied and employed particularly for sEMG (Pani et al., 2019) and ECG (Achilli et al, 2018) monitoring, thanks to the interesting properties and fabrication advantages, which make PEDOT: PSS-based textile electrodes more convenient than conventional gelled Ag/AgCl electrodes, especially in terms of comfort and unobtrusiveness, because they can be easily and seamlessly integrated into standard fabrics such as cotton and silk (Ankhili et al., 2018, Tseghai et al., 2020, Tsukada et al., 2012). Although to date we're not aware of the application of this kind of technology for first responders in search and rescue operations, their adoption for ECG and sEMG could allow to unobtrusively monitor the most important vital sign and a biopotential useful to detect fatigue in long-lasting rescue operations. As the performance of the electrodes depend on their coupling with the skin, which must be stable and characterized by low impedance, it is important the firmly attach the electrodes on the skin by using elastic bands or by exploiting stretchable garments that can guarantee a uniform and constant pressure over the skin. As such, the integration of these sensors in the uniform cannot be accomplished without the use of compressive underwear hosting these sensors.

Organic X-Rays detectors

To date, several commercial, portable X-Rays detectors were proposed on the market. Nonetheless, the integration of X-Rays detectors in garments is mostly unexplored. Behind this, the relatively high costs for area unit of typical X-Rays detecting materials can be cited. Moreover, as most of these materials are inorganic and crystalline, their stiffness does not allow a proper mechanical integration with fabrics.
The employment of flexible materials was investigated in the last few years. Among these, organic materials were particularly considered for their intrinsic flexibility, and for the possibility of depositing them on unconventional substrates by means of cost-effective techniques. Nonetheless, the low atomic number of organic materials is detrimental for X-Rays sensitivity: in most of proposed examples, organic devices are used as photodetector coupled with a scintillating material, i.e., a material capable to convert impinging radiation into photons (Agostinelli et al. 2008, Hull et al., 2009, Büchele wet al., 2015).
Direct conversion of X-Rays by means of organic materials were extensively explored in the last years (Intaniwet et al., 2011, Intaniwet et al. 2012, Fabroni et al., 2014, Fabroni et al., 2012, Basirico et al., 2015, Ciavatti et al. 2015). The University of Cagliari strongly contributed to this field, reporting about two and three terminal direct X-Rays detector fabricated on flexible substrates (Basiricò et al., 2016, Lai et al., 2017), with a sensitivity exceeding the one reported in literature for organic devices (Raval, et al. 2009, Raval et al., 2010) and approaching the values obtained by inorganic materials. Recently, their possible applications involving an intimate contact with the human body has been explored (Basiricò et al. 2020), thus paving the way to the development of a new class of direct X-Rays detectors mechanically suitable for the integration in wearable devices.

Portable monitors for multiple gas detection

During Search and Rescue operations, it is very likely that explosions or the release of toxic gases can occur following the collapse of structures or short circuits that can cause fires. In these critical contexts, it is primarily important to be able to detect the presence of gas on site and online, preferably at a safe distance from the source to protect first responders.
Furthermore, under the rubble of a collapsed structure, victims can be trapped, whose presence can be detected through the use of trained dogs, which can detect the smell of the human being, or thermal cameras that detect the body heat of the victims who are still alive. However, both these solutions have limitations: dogs get tired after intense research, they can get frustrated if they are not successful and the cost of training and maintenance is significant (Helton, 2009). Thermal sensors are useful for inspecting large areas even with limited visibility, but they tend to give false alarms when the temperature of the environment is similar to that of the human body, for example on very hot days.
For these reasons, the need has been raised for sensitive, economical, easy to use, safe and portable detectors, which can have a fast detection of a dangerous environment during SAR operations (Wong et al., 2004). These instruments can detect at the same time toxic and explosive gases (explosion-proof certification is required), asphyxiating and irritating volatile substances, the lack of oxygen and the presence of VOC (volatile organic compounds) (Mochalski et al., 2014, Giannoukos et al., 2016), and typically have man-down alarm function.
Many different types of gas sensors have been developed, such as optical sensors (Dong et al., 2017, Mäyrä et al., 2011), semiconducting metal oxide sensors (Staers et al., 2016,) and multi-walled carbon nanotubes (Ramalingame et al., 2016), all of which exhibiting good sensitivity and selectivity for single or grouped compounds. Regarding VOCs, various effective sensors are commercially available for detecting CO2, acetone, isoprene, and ammonia (Staers et al., 2016, Ramalingame et al., 2016, Güntner et al., 2018), and formaldehyde using biochemical gas sensors (Kudo et al., 2010) or applying fluorescent probes (Zhao et al., 2018). In the context of the European project ProeTEX which ended in 2010 (Curone et al., 2010, Bonfiglio et al., 2011) a prototype for the safety of firefighters was developed, including chemical sensors for CO and CO2.
Gas monitors can show real-time values in a multiple numerical display; they can be floor standing or portable units, and vary in ergonomics, power supply, size, weight, and cost. The most common limitations of commercial portable devices are that they typically have a maximum of four sensors and some sensor combinations are incompatible because they interfere with each other. Furthermore, their operational capacity can vary significantly in dynamic environmental conditions, for example due to the presence of concentration gradients in space and time, dust or high humidity, all factors that can distort the measurements (Giannoukos et al., 2016).
Due to the wireless nature of the main commercial solutions, real-time data transmission of instrument readings and alarms can be provided for increased safety and faster response times. These tools can send both data and alarms to both a smartphone or a remote PC; however, they mostly have a closed proprietary operating system, which is difficult to customize or capable of communicating with external applications (Korkalainen et al., 2012).

Flexible OTFT based strain sensors
A strain sensor is an electronic device capable of transducing a deformation, generally indicated as relative length variation, into an electrical signal, i.e., current or voltage variation. In recent years, a huge attention has been given to such kind of devices as they can be embedded into clothes (e.g., stockings, bandages, and gloves) allowing a constant monitoring and recording of human motion (e.g., breathing and speech) or also directly attached directly to the body (Yamada et al., 2011). With this aim, the employment of flexible electronics is of dramatic importance as being intrinsically flexible, such structures can be transferred into normal clothes without affecting their comfort.
The simplest way to obtain a strain sensor consists in the employment of a piezoresistive material deposited between two metal electrodes. In such a case, when a deformation is applied, a change in the conductivity of the material is obtained, giving rise to a measurable current/voltage variation. The gauge factor (GF) can be obtained from the slope of the relative change in resistance in function of the strain:

$$GF = \delta \frac{\Delta R}{R_0} \Big/ \delta \frac{\Delta L}{L_0}$$

where R is the gauge resistance, L is the length of the gauge along the direction of strain, and R0 and L0 are the values of gauge resistance and length without strain, respectively. Many semiconductors are characterized by relatively high strain factors (Barlian et al., 2009).
Several examples have been reported in the literature for achieving such functionalities, and the most of them consists in loading an insulating polymeric matrix with conducting filler.

For instance, Yamada et al. employed SWCNTs on PDMS to measure strains up to 280% (50 times more than conventional metal strain gauges). Also, graphene can be incorporated to a supramolecular polymer, polyborosiloxane (PBS), to fabricate self-healing composites that restore their properties after damage multiple times and without an external stimulus. DaElia et al. demonstrated electrical conductivities up to 90 S/m and sensitivity to pressure and flexion (D'Elia et al., 2015). Pani and PEDOT: PSS are other organic materials suitable to build strain sensors; however, their performance can be affected by local relative humidity (RH) and strain rate (Sezen-Edmonds et al., 2017, 2019). Moreover, Sezen-Edmonds et al. proved that a post deposition treatment of PEDOT: PSS with dichloroacetic acid removes excess PSS and, consequently, the performance instability while varying RH from 0% to 50% and strain rate from 0.34% to 1.12% strain min-1. Similar to graphene, PEDOT: PSS can be incorporated into other polymers to obtain tough and processable self-standing films. Taroni et al. achieved a remarkable strain-at-break of ≈700% for blends with 90 wt% of a commercial elastomeric polyurethane (Lycra), while maintaining high electrical conductivity (79 ± 5 S cm-1) (Taroni et al., 2018).
More recently L. Han et al. reported about a versatile nature skin-inspired composite film for the fabrication of flexible strain biosensors. Such devices have been developed on cellulose nanocrystals-polyaniline (CNC-PANI) composites by utilizing their percolated conductive network in polyvinyl alcohol (PVA) matrix. The fabricated sensors showed robust mechanical strength (50.62MPa) and high sensitivity (Gauge Factor=11.467) with easy water-induced self-healing abilities (Han, et al., 2021). Moreover, the authors have demonstrated that such devices can be efficiently employed for monitoring human mechanical parameters.

One more interesting example has been reported by R. Cheng et al. in their work the authors have fabricated a high performing multifunctional piezoresistive sensor based on AgNWs/ nano fibrillated cellulose aerogel (SNA). To achieve this, AgNWs and nano fibrillated cellulose were coassembled via the combination of unidirectional freeze-casting and thermal annealing technique.
Furthermore, the assembly of the film resulted in a 3D-interconnected AgNWs embedded in aerogels, allowing the authors to obtain a robust SNA with a very high electrical conductivity, that can act as multifunctional piezoresistive sensor with high sensitivity and stability (Cheng et al. 2021). More recently, H. Li et al have reported about the fabrication of highly stretchable piezoresistive sensors by embedding metal nanoparticles into an elastomeric matrix, managing to obtain a highly sensitive flexible sensor capable of detecting applied strain and contact force (Li et al., 2020). Such flexible films have been tested as strain sensors and eventually have been applied onto a rubber glove in order to measure human fingers joints movement ci s. A different approach for the fabrication of strain sensors consists in the employment of three terminal devices, namely thin-film transistors. In this case the main advantage of employing such structures is that the sensitivity can be tuned and amplified by means of the gate field. Moreover, when matrices or arrays of sensors are required, using a transistor as a sensing cell dramatically simplifies the addressing of each single element. Several reports have already demonstrated that organic semiconductors are characterized by a pronounced piezoresistive behavior due to their polycrystalline structure (Cosseddu et al., 2012, 2013).

Therefore, these devices can be efficiently employed for the fabrication of wearable strain sensors. However very few examples have been reported of their actual employment in a real wearable application. Recently, Lai et al. have demonstrated that a highly flexible and low voltage organic TFT can be embedded into a cotton glove and efficiently employed for measuring wrist movements (Lai et al. 2019), as shown in Figure 3-3 and Figure 3-4.

Figure 3-2: Pictures of the sensing glove: (a) the glove without sensors, where the position of the pocket is highlighted; (b) the Lycra® pouch where the OFET sensor is inserted; (c) glove provided with sensor (inserted in the pocket) and connector.

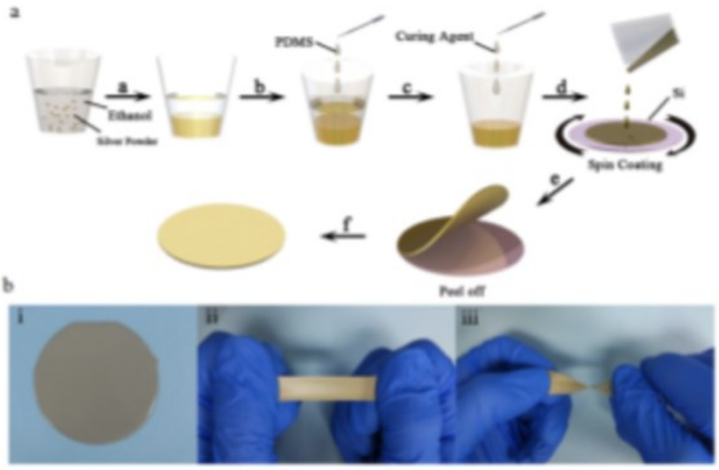


Figure 3-3: (a) Schematic of the Ag/PDMS based sensors fabrication procedure.

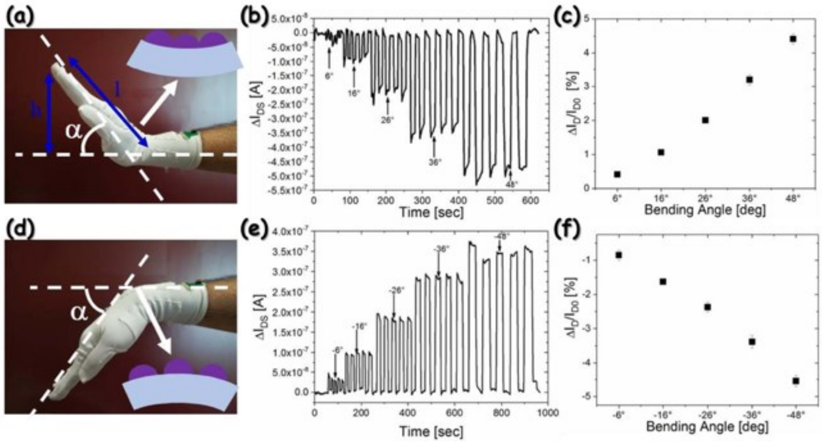


Figure 3-4: Photographs of the sensor showed excellent flexibility under stretching and twisting, respectively.

GNSS position detectors

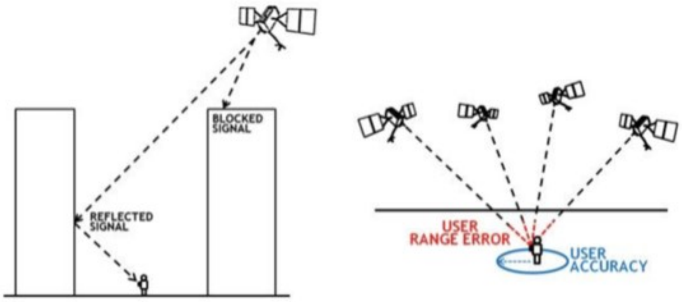


Figure 3-5: Right: blocking and reflection as possible interference in the GPS signal. Left: URE and User accuracy.

From the perspective of professional users, in the context of emergency situations, one might think that the coordinates provided by the global navigation satellite system (GNSS) have better accuracy if detected by professional military hardware. However, with the current technology on the market, this is not always the case. The level of accuracy depends on many factors, including user range error (URE), number of satellites connected, signal blockage (Figure 3-5), atmospheric conditions, characteristics, and quality of the receiver, etc. So, the receiver's quality is just one of the aspects that influences the accuracy of detection and is perhaps the only aspect on which action can be taken.

From US government sources, we can learn that commercial smartphones have an accuracy of around 4.9 meters, which can get worse near trees or buildings. This accuracy refers to devices that use only one frequency, whereas military receiving devices use a double frequency. This information, however, dates to 2015 research and today we know how sudden the evolution of a technology can be. Since then, with the release of new processors (such as Broadcom BCM47755), many smartphones use dual frequency receivers (L1 + L5), even if this information is never indicated by the manufacturers in the specifications. This has allowed a significant increase in accuracy in the detection of the position in the order of a few centimeters outdoors and in optimal weather conditions.

Another aspect to consider is the time required for the first localization (fixing), that is the time it takes for the device to provide the first coordinates with an acceptable accuracy. In this regard, fixing assistance systems (A-GPS) have been designed with the aim of reducing the signal acquisition time. These systems are based on the fixed position of the telephone cells (where it is assumed that the cell "sees" the same satellites that the telephone that is hooked on to it sees) or on the ephemeris of the GPS satellites.

With these premises we can say that the GPS receiver of a latest generation smartphone, in terms of accuracy and efficiency, can achieve good accuracy in the geolocalization in open air. The use of the smartphone's integrated receiver as a device for detecting the position is therefore an adequate choice also in the context of the Search & Rescue project, bringing advantages in terms of accessibility to an open system such as Android which allows for faster and flexible software development compared to devices with closed systems.

Previous project and commercial systems implement GPS/GNSS tracking of first responders, as this technology (either with standalone devices or integrated in other tools, as gas monitors, smartwatches, etc.) allows localizing the first responder over the operation area to support logistics and provide immediate interventions in case of risks.

3.2 Operative scenarios

According to the purposes of the project, a specific analysis of the operative scenarios was carried out by the end user partners, in order to identify the main requirements of the protective and performing uniform.

In the following comparative tables the core characteristics of the various USAR operative scenarios are described by different End Users organizations.

The analyzed scenarios refer both to the future projects' Use Cases pilots in which the uniform will be tested in the next year and to past real emergency scenarios in which the partners organizations had a relevant role during the rescue activity.
The analysis aimed to identify common scenarios characteristics and needs to be used for the identification of the uniform core requirements.

Each scenario is described using the following parameters:

- Scenario title (Place and period).
- Short description of the scenario characteristics and needs (conditions of the scenario: temperature, weather conditions, etc.).
- Mission type (e.g., earthquake, chemical disaster, etc.).
- Nature of the site (research under the rubbles, medical, rope rescue.).
- Mission objectives: first responders' specific actions done in the scenario (digging, speleological activities, etc.).
- Type of first responder organization involved in the rescue activity.
- Uniform requirements.

Scenario title *(Place and period)*	Use Case 5: Victims trapped under rubbles – June 2022

Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	Use Case 5 is the fifth pilot testing called «Victims trapped under rubbles» that will take place during SnR project, organized by the International Firefighters (Pompiers de l' Urgence Internationale - PUI France) with the technical support partners: KT, THALIT, ATOS & NTUA. UC5 will take place within June 2022 in a region called "La Souterraine, France" on a site of 3 ha/7.5 ac, which is the International Emergency Firefighters' training facility and has been approved by INSARAG in 2015. The UC meets the conditions of a real-life situation according to the United Nations INSARAG standards. The facility is well located between various European countries and can be easily accessed. The site can be easily accessed using various means of transportation: • by car: A20 motorway, exit 23. • by train: a station is 200 m (0.1 mi) away —Paris-Toulouse rail-line. • by airplane: the Limoges international airport is only 35 minutes away. The area is dedicated to training, maintaining, and increasing the specific skills of the first responders
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Disaster caused from an earthquake.
Nature of the site *(research under the rubbles, medical, rope rescue…).*	Research under the rubbles, rope rescue, medical assistance to the victims, management.
Mission objectives: first responders' specific actions done in the scenario *(digging, speleological activities, etc..)*	The components that will be tested are the MIMS and the drones. In the specific area, the first simulation/training activities will be carried out thanks to the first data acquired by the monitoring systems (vibrational - environmental - on images). A rubble area will be also created for the use of searching and locating devices, drone overflights and the medicalization of buried victims. Other layouts will enable USAR teams to work in real-life, operational USAR conditions with designated areas for a base of operations, a USAR coordination cell (UCC) and a medical center.
Type of first responder organization.	International Firefighters
Uniform requirements	Complete personal protective equipment (helmet, gloves, glasses …).

Table 3-7: Operative scenario contribution by PUI FRANCE

Scenario title *(Place and period)*	Place and period are not applicable because the scenario refers to a usual one of collapsed structure due to chemical origin explosion.
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	An explosion occurred in a phosphate factory, which, due to the shock wave, caused significant structural damage to surrounding buildings. Numerous victims were trapped under the structure.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Chemical disaster.
Nature of the site *(research under the rubbles, medical, rope rescue..).*	Research under the rubbles, rope rescue, medical assistance to the victims, management.

Mission objectives: first responders' specific actions done in the scenario *(digging, speleological activities, etc..)*	Rescue as many victims alive as possible.
Type of first responder organization.	Firefighters, medical staff, K9 teams and police.
Uniform requirements	After the firefighters determine the safe working areas, it is assumed that inside one of the buildings there are several trapped victims. That area can be considered a warm zone and medical staff (with uniforms + detectors) can access it. The chemical detectors embedded in the uniforms will be used to gather information that will allow us to know, in real time, if the area is safe to carry out our rescue work. It will also help us to determine, for one side, the hope of finding live victims (depending on the time of exposure, we can know the toxicity levels), and for another side, the safety levels so that the K9 teams can work in detecting them, and if the medical teams can work in a safety way. In addition, the biomedical sensors will be able to monitor the FR´s health data and know their physical conditions, as they are carrying out their search and rescue work.

Table 3-8: Operative scenario contribution by ESPD

Scenario title *(Place and period)*	UC7: Chemical substances spill, Madrid, Spain. October-November 2022.
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc...up to 1000 characters).*	CBRN incident with two separate scenarios. The pilot will be allocated to The National School of Civil Protection, Rivas Vaciamadrid, between October-November 2022. The main objective is to delimit the working zones according to the existing risks and toxicity levels, in order to guarantee the safety of the first responders and rescue dogs, and as well indirectly to the safety of the victims of the incident. The weather conditions expected at that time will be 65% humidity and cold temperatures (5ºC -Celsius degrees). The wind will be 6 m/s from the Southeast to North. The first scenario will contemplate a collapsed structure of a residential building due to an earthquake grade 5,5 on the Reiter scale. Later, the six-gas hazmat monitor will alert of the presence of flammable gas and consequently, the gas leak of scenario 1 after radiating at 50 m will produce a deflagration -second scenario-.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Natural disaster with two scenarios: the initial trigger will be an earthquake which will cause a collapsed structure of a residential building (first scenario). The flammable gas released in the collapsed structure (propane gas) will cause an explosion which will form a break in an upper part of the cistern that will produce a gaseous leak of the ammonia (second scenario).
Nature of the site *(research under the rubbles, medical, rope rescue...).*	• Research under rubbles with rescue dogs (K9 team): detect victims. • Firefighters' intervention (USAR –urban search and rescue- team). • Zoning of the incident assessing the risk zones and hazard materials/substances in the scenarios. • Medical intervention: SUMMA 112 emergency medical service. • Security forces and bodies, civil protections. • Emergency call center 112. Crisis management system device.
Mission objectives: first responders' specific actions done in the scenario	• K9 rescue dogs and dog handles will detect victims. • Search and rescue of victims. • Firefighters: Risk assessment. Zoning.

(digging, speleological activities, etc..)	• Commanders of all first responders: Forward command post. SUMMA 112 (EMS): Triage of victims. Priority of treatment and evacuation. Advanced and basic life support response. • Measurement of chemical substances released. Six gas hazmat monitors. • Donning and don off of PPE (personal protective equipment).
Type of first responder organization.	Emergency Medical Service (EMS), SUMMA 112.
Uniform requirements	• Comfortable, suitable, light, with reflective components, compatible pieces. • Appropriate for thermal stress. • Appropriate for chemical scenario (CAT III, type 3) • External pockets to carry communications (mobile, tetra) and medical phonendo.

Table 3-9: Operative scenario contribution by SUMMA112

Scenario title *(Place and period)*	Mozambique in March 2019
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	The mission lasted 4 weeks. Temperatures were on the day around 25°C and in the night around 15°C. Often there was rain. Not much wind.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Medical support
Nature of the site *(research under the rubbles, medical, rope rescue…).*	Medical
Mission objectives: first responders' specific actions done in the scenario *(digging, speleological activities, etc..)*	Giving medical support to hurt and ill people.
Type of first responder organization.	EMT 1
Uniform requirements	- Not too hot under the burning African sun - Protection against infectious diseases - Needs to be cleaned easily

Table 3-10: Operative scenario contribution by JUH

Scenario title *(Place and period)*	Use Case 2: Plane crash, mountain rescue, non-urban (Greece). Mount Chortiatis, October- November 2022
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	UC2 focuses on low and high impact off-site crashes. Low impact crashes, according to IFSTA, are ones that do not seriously damage or break up the fuselage and are anticipated to have a high percentage of survivors. There are two forms of low impact crashes: wheels up and belly landings, both of which can occur because of a hydraulic or electrical system failure. Fire is relatively unusual in these types of crashes, but the dangers are typically greater when the plane lands on airport runways rather than soft terrain. High-impact crashes cause extensive damage to the fuselage and have a significantly lower chance of passenger survival. Hillside collisions are examples of high impact crashes, which are typically caused by weather, pilot, or instrument failures. When the aircraft collides with the ground or trees, it frequently disintegrates. First responders should expect to see major structural components like the wings, tail, and undercarriage spread across a large area of approach and be prepared to evacuate the entire area. Under these circumstances, a rigorous and wide-ranging search for casualties should be conducted.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Plane crash, mountain rescue
Nature of the site *(research under the rubbles, medical, rope rescue...).*	Mountain (Non-Urban) field. Trapped passengers in the plane cabin. Prehospital Trauma Support Possible site difficulties: Heavy smoke and poor visibility, changing weather, numerous injured or disoriented passengers, and debris that may harm gear or obstruct the approach of any rescuer that first arrives at the scene.
Mission objectives: first responders' specific actions done in the scenario *(digging, speleological activities, etc..)*	Search and Rescue (SAR) activities, First Aid providing Possible risks include jagged metal, aircraft components, enormous amounts of fuel, poisonous hydraulic fluids, pressurized gas cylinders, explosive wheel assemblies, unstable fuselage portions, hazardous cargo, flammable metals, and composite aircraft construction material body parts and fluids.
Type of first responder organization.	Non-Profit, volunteer organization
Uniform requirements	Fire resistant and Incombustible, breathable, chemical resistant (eg. Brake fluid), water resistant, lightweight, comfortable with ease of movement, hypoallergenic, pilling resistance, tensile strength, tear strength, resistant to thermal convection, resistant to thermal radiation, antistatic.

Table 3-11: Operative scenario contribution by HRT

Results of the activity

The comparative tables described five different operative scenarios in which the first responders' organizations could be or was involved during the disaster rescue phase. The filed tables show the main characteristics of the sample scenario in which the uniform could be used.
The sample scenario refers to collapsed structure disasters in urban and non-urban areas due to a natural event (such as an earthquake) or to an explosion (caused for example by chemical agents). The main goals of the mission are the location, the rescue and the evacuation of the victims involved in the disaster. The main activities of the FR in the scenario are the research under the rubbles, the

rope rescue, the medical assistance to the victims, and the management of the disaster site. In the site are involved:

- Firefighters - USAR team.
- K9 Team.
- Emergency medical services.
- Security forces and bodies.
- Civil protection.
- Emergency call center.
- Volunteer organizations.

The weather could be both hot as well as cold, with a chance of rain, snow, and wind. The site can have a high temperature due to possible fires caused by explosions. The timing of the rescue action is undefined and unpredictable.

3.3 Users' requirements

The following research activities aimed to identify the core users' requirements to be used for the designing of the First Responder's uniform. The following paragraphs describe the requirements pointed out from the results of the D1.2, from the questionnaire activity and, finally, from the co-working activity with the end users' partners.

3.3.1 Inputs from other deliverables

Deliverables D1.2 and its subsequent update, D1.6 (submitted on M12) referred to the current state of the process of defining end-user requirements for chemical sensors (Six Gas HAZMAT monitor with VOC Detection and RESCUE MIMS (wear First Responders uniform, in hand, as backpack or on the platform of a RESCUE ROBOT) as foreseen by the S&R project in WP1 (First responders Requirements and Governance model) at T1.2 (End User Requirements for SAR equipment and tools), including the results obtained from a GAP analysis survey for building community resilience.
D1.2 emphasized on the minimum basic characteristics required by end-users for different components (e.g., RESCUE MIMS, RESCUE ROBOT and Six Gas HAZMAT monitor with VOCs) which included ergonomics, power supply, size, weight, and user interface characteristics. It is conceivable that these requirements are also applicable to the design of first responder uniforms, in particular with respect to the following:

- Saving lives and minimizing injuries to community members located in disaster areas.
- Improving First Responders occupational health and safety.
- Enhancing the overall operational efficiency of the First Responders service and the effectiveness of disaster prevention and protection.

In relation to the above, the end-user survey reported in D1.2 produced high-level qualitative requirement indicators/requirements as reported below (not prioritized):

- Improve the response time which is the most critical parameter for the timely recovery of victims. First responder safety and maneuverability are key factors in this respect.

- Produce lighter rescue tools and tools for detecting early toxic environments. This may also be applicable to wearables, especially in the presence of VOCs and where the use of hand-held devices may be obstructed by the field conditions.
    - Environmental assessment to ensure personal safety.
    - Facilitation of real-time decision making by incident commanders.
    - Increase of fundamental knowledge on risk factors and long-term exposure outcomes.
- Ability to accurately and non-invasively locate survivors following structural collapse – the ability to "see" through walls, smoke, debris, and obstacles. Interoperability and compatibility with relevant technologies need special consideration in this respect.
- Lighter, more efficient power sources and protective gear and equipment. Ergonomics is an important factor to consider.
- Improved monitoring systems (i.e., atmospheric, biomedical, personnel accountability, etc.) with real-time, portable, multi-function devices that expand on existing detection capabilities. In this respect the sensitivity to environmental conditions was a key aspect.
- Provide information about the type of emergency, time of deployment, status of hardware devices etc.

With regard to the use of the rescue MIMS the following features that may also be applicable to the design of uniforms were reported as important:

- Hearing aids.
- Thermal detection equipment.
- Fiber optic detection equipment.
- Scanning technique (radar).

In relation to the six Gas HAZMAT monitor with VOC detection embedded on wearable of First Responder can offer:

- Environmental assessment to ensure personal safety.
- Facilitation of real-time decision making by incident commanders.
- Increase of fundamental knowledge on risk factors and long-term exposure outcomes.

Efficiency and comfort in the field are also required to allow for faster and more accurate interventions, thus increasing the likelihood of a successful rescue of victims and of the responder's physical and mental endurance. Here as well, power supply, size, payload, user interface characteristics, durability and cost were the core characteristics required. The two major objectives were to ensure increased protection from toxic gases and from VOCs generated by industrially produced materials.
D1.6 confirmed the preliminary findings of D1.2 and stressed the importance for support systems, thus also applicable to the First Responder's uniform design, to focus on the following operative elements:

- Reliability in the field, meaning to work as it should and when it should.
- Usability in the field, (e.g., weight, bulkiness concerning the uniforms) with the need to be adjusted so that it is not an issue with the natural maneuverability of the operative staff.
- Durability in the field, meaning the ability to resist and withstand weather conditions (e.g., heat, rain), environmental and field impacts (e.g., dirt, falls and crashes), sudden changes in pressure or temperature, etc.

The above requirements should of course be adjusted to the scope of the specific Use Case where these will be tested and validated but are of generic importance as well. The literature search and

case study collection performed in D1.2 in relation to attributes needed for improving the 'community resilience' is also in line with the above and emphasized the promotion of communication, real-time information-sharing, improvement of cognitive capabilities and coordination and interoperability and compatibility of information communication technologies (ICTs) between different actors and technologies. Challenges in using/collecting data included the lack of access to communication networks to transfer data via WIFI, lack of reliable maps of the area, phone lines being saturated leaving only satellite phones as an option, the limited life of walkie-talkie and GPS batteries. Using different radio frequencies, as well as the time-consuming nature of writing down radio communicated messages were also reported. Legislation harmonization issues for the interoperability of the technologies/wearables was also mentioned.
In addition, the report D5.1 (submitted on M10) from T5.1 provided a summary of the KPIs of end-user's requirements for the RESCUE-MIMS as these were reported in D1.2, namely: portability, robustness, ruin penetration capability, ease of operation, user friendliness, and ease of deployment. The aforementioned may also indirectly partially relate to the first responder's uniform design. The gases to primarily take into consideration for the Use Cases to be performed in the project as reported by the SnR's partners (i.e., end-users) are provided in figure 3-6:

End-user	O2	CO	CO2	NH3	CH4 EXOX	Cl2	NO	H2S	C3H8	VOC
JOAFG JUH	X	X	X		X		X			
SUMMA ESDP SERMAS	X	X	X	X		X			X	
PUI	X	X		X	X	X		X		
PROECO	X	X	X		X			X		X

Figure 3-6: Most important gases to be considered for the UCs as reported by end-users.

The administered GAP survey (reported in D1.6) included 21 questions answered mainly by SnR Consortium partners, i.e., first, and early responders (e.g., fire and rescue brigade, civil protection individuals), technology developers and other partners (including Legal & Ethical Partner, Universities, Dissemination & Exploitation experts). Most of the questions focused on the community resilience and crisis management procedures implemented and needed within the organization of the responders. Additionally, the survey included some questions investigating the technical challenges faced during operations within the organizations of the responders and the importance of each feature and procedures. Also, the survey provided to the responders the ability to include additional options and suggestions for each feature/procedure.
Table 3-12 presents the list of the five most important features for each of the aforementioned three categories. Similarities and differences on the ranking of different categories of responders are thus revealed which allowed to focus on the shared important features and on the differences.

Order	1	2	3	4	5
First and early responder	Procedures for improving the physical health of first	Training	Procedures enabling cooperative risk	Level of interoperability between stakeholders to	Technical challenges faced in data collection for

	responders and victims.		assessment in crisis management.	improve crisis management operation.	situation awareness and risk assessment.
Technology developer	Training	Procedures to train, educate and up-skill civil society, organizations, and local communities about the rescue process.	Procedures enabling cooperative risk assessment in crisis management.	Procedures for improving the physical health of first responders and victims.	Procedures enabling shared knowledge between end-users and civil society, organizations, and local communities.
Others	Level of interoperability between stakeholders to improve crisis management operation.	Technical challenges of victim localization.	Procedures to train, educate and up-skill civil society, organizations, and local communities about the rescue process.	Procedures enabling shared knowledge between end-users and civil society, organizations, and local communities.	Procedures for improving the physical health of first responders and victims.

Table 3-12: Five most important features for the 3 categories of survey responders

As it may be observed, great importance is attributed to the procedures for improving the physical health of the first responders and victims, for enabling the cooperative risk assessment in crisis situations, the level of interoperability between the involved actors and to the technical challenges faced in data collection for situation awareness and risk assessment, in particular those faced by delay in receiving real-time, reliable, and accurate information. The last points were also stressed in the Focus Group discussion that preceded the GAP survey, in particular in relation to volunteers sometimes not being part of the information system and not having access to technologies despite being involved in rescue missions which is a gap. Challenges with interoperability (e.g., different communication systems used by the various actors involved; radio frequencies; GPS signaling) need to be addressed when sharing technologies. The aforementioned are also elements that should be taken into account when designing and integrating smart and innovative materials to the design of first responder's uniform. Trials of developed technology in various environmental conditions and the development of algorithms that can detect malfunctioning in data collection were mentioned as possible remedies. Moreover, feedback propounded the multi-operability of devices (same devices for several purposes). Use of the same communication codes was also proposed for bridging interoperability and compatibility gaps.
The detailed results and the analysis for the aforementioned are summarized in D1.2, D1.6 and D5.1 where the reader is encouraged to refer to for additional relevant details.

3.3.2 The Questionnaire to the End Users

According to the purpose of the project a questionnaire activity was carried out with the consortium end partners between February and March 2021. The questionnaire aimed to highlight preferences, behaviors, strengths, and weaknesses of the current state of the art of the uniform and other accessories they have at their disposal in USAR activities. Each question had a specific purpose in the design processes of the first responder's uniform. The activity was carried out anonymously using the Google form platform and the respective questionnaire form is attached in the present document in Annex II section.
The questionnaire was composed of two kinds of questions:

- Free questions - each participant could explain their point of view
- Multiple choice questions - each participant answered indicating a value from 1 (minimum) to 6 (maximum)

The questions concerned especially the level of comfort and protection of the uniform, the additional equipment that the FRs have to carry during USAR operations, and the integration of the biometric sensors to monitor the health status of the FRs during the rescue activities. The participants in the questionnaire activity belonged to the first responders' organizations explained in the chart below.

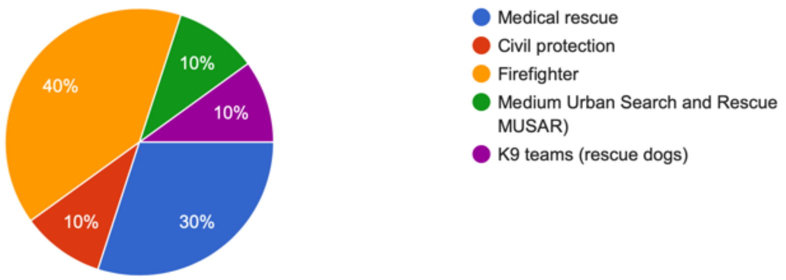


Figure 3-7: Organization's typology in the questionnaire activity

The results of the most significant questions are shown below.

Question (Q2): *Does the First Responders PPE provide adequate protection during the rescue phases?*

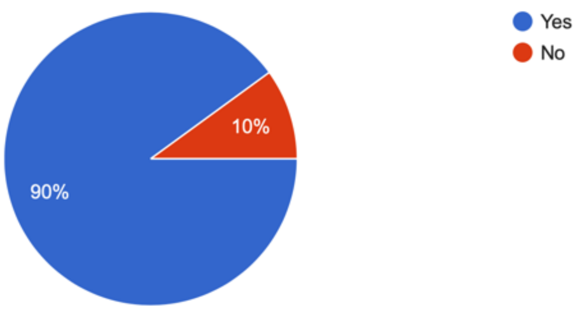


Figure 3-8: Results' chart of Q2

Question (Q2.2): *In your opinion, is the protection level right for the situation?* indicate a value from 1 (minimum) to 6 (maximum)

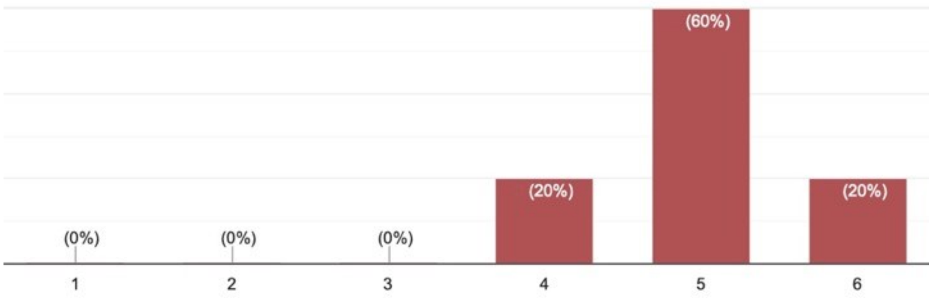


Figure 3-9: Results' chart of Q2.2

Moreover, the participants suggested:

- To use flexible and resistant materials.
- To design uniforms more suitable for a specific scenario.

Question (Q5): *How could you feel sharing your personal health data in real time to improve your safety?*

Most of the participants feel safe and agree to share their personal data, if the protection of personal data is ensured.

Question (Q7.1): *Which kind of alarm could be better for communicating to the First responder? Select one or more of the following options.*

Figure 3-10: Results' chart of Q7.1

Moreover, the participants suggested that the alarms should be:

- Multiple.

- Differentiated.
- Possibly, no sound alarms.
- Not be disturbing for the FR.
- Combination of more alarm typologies.

Question (Q8): *During rescue activities do you use a mobile phone (personal or standard equipment)? If yes, how do you wear it? Moreover, where would you like to wear it?*

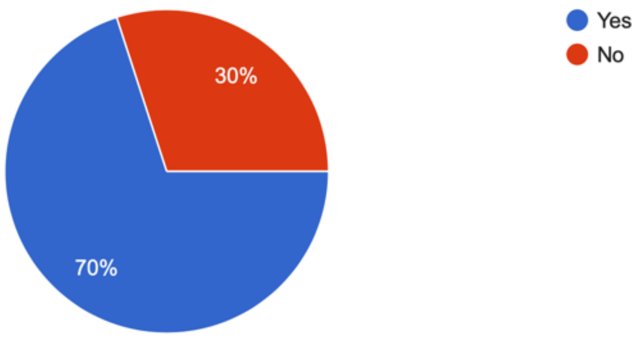


Figure 3-11: Results' chart of Q8

Moreover, the participants highlighted that the rescuers usually don't carry personal mobile phones inside the work areas, but they use a satellite one. They don't have a specific holder for the phone in the uniform. For this reason, they suggested to arrange a specific pocket, possibly with a zip closing, in the uniform trousers or an easy to wear portable cover.

Question (Q9): *What kind of uniform do you wear during your rescue activity? (For example: full uniform, two-piece uniform, disposable uniform, reusable uniform, other)*

62% of end users use a two-piece uniform
24% of end users use a full/one-piece uniform
21% of end users use different uniforms (depending on the scenario)

Lastly, the participants shared additional suggestions in the free advice section that could be summarized by the following list:

- For some participants, the uniforms are not suitable for all types of scenarios. The materials are fireproof, but some teams are not in direct contact with the fire during operations.
- The uniform should integrate communications in hands-free and sensors with visual alarms.
- The use of bright, light color materials for night and day visibility.

The questionnaire activity highlighted the following uniform's requirements. The uniform should be:

- Made of comfortable materials: flexible, resistance, suitable materials.

- Highly performing.
- Highly protective.
- Equipped with health sensors for monitoring the FR health parameters and the environment.
- Data sharing to reassure first responders.
- Equipped with visual alarms (not-invasive alarm).
- Equipped with pockets for accessories (mobile phone).
- Two-piece uniform.
- Designed using of bright colors.
- Suitable for specific scenarios.
- Easy to be decontaminated/cleaned.
- Combinable with other accessories according to different scenarios.

3.3.3 The co-working activities: one to one interview with end users

The interview activity aims to underline the strengths and weaknesses of the currently used uniforms. Seven different sessions were organized, and seven end User partners participated. During the interview, the questions were general ones to discuss USAR team uniform details. Each session lasted about 20 minutes. Before the interview, each organization shared some images of their current uniform using a Google Form. The interviews were taken using the Google Meet Platform. Only the interviews' audio was recorded, to ensure the anonymity of the participants involved. The official minutes of the activity were uploaded, according to the DPIA, on the Alfresco platform, and are available for the Consortium. The activity was taken between April 29th and May 6th, 2021. The table shows each session's details.

Session	When	Partner	People involved
1	29/04/2021 9:00 - 9:30 CET	ESDP	2
2	29/04/2021 9:30 - 10:00 CET	PROECO	2
3	29/04/2021 10:00 - 10:30 CET	SUMMA	3
4	30/04/2021 11:00 - 11:30 CET	CNR	4
5	30/04/2021 12:00 - 12:30 CET	HRT	1
6	05/05/2021 14:45 - 15:15 CET	JOAFG	3
7	06/05/2021 15:00 - 15:30 CET	PUI FRANCE	2

Table 3-13: Interviews activity details

The questions were about:

- The comfort of the uniform (materials and typology of the uniform).
- Communicative aspects related to the uniform (color, logos, etc.).
- Additional wearable equipment during the rescue activities.
- Pockets characteristics and related issues.
- Visibility and recognition of the uniform in darkness.
- Washing and decontamination issues.

- Additional removable protections.
- Security related issues.

The activity pointed out some relevant information useful for the design of the uniform. According to the end users' needs the uniform has to be designed taking into consideration the following aspects:

- Genderless Uniform
- Two pieces Uniform
- Personal Uniform
- Made by comfortable and breathable materials.
- Adjustable uniform according to the scenario needs.

The above points were pointed out by all the end-user partners involved in the interviews. In particular, many partners affirmed that the uniform is not often designed according to the specific scenario needs and to the specific First Responders' tasks. For this reason, the First responders often use an uncomfortable standard uniform not suitable for their task.

Moreover, the interviews highlighted important aspects regarding specific issues (such as materials, visibility, recognition…), explained in the following table.

Materials requirements	• Easily Washable and decontaminated using high temperature and chemical products. • Breathable fabric suitable for winter and summer weather. • Cut resistance. • Resistance to abrasion. • Mid Chemical resistance. • Heat resistance. • Water-repellent. • Slightly elasticated.
Visibility/Recognition General Requirements	• Insert main logo (chest). • High Visibility back lettering. • High Visibility elements. • Hidden elements for the recognition of the FR in case of health emergency. • The use of high visibility colors.
Specific requirements	• 4/6 Large Pockets (especially in the pants). • Pockets need the zipper closing. • Pocket for personal utilities. • Adjustable uniform according to the scenario needs. • Suitable uniform with other additional equipment. • Combinable with other DPIs. • Additional protection/paddings at critical points.

Table 3-14: Interviews activity results

Furthermore, the activity highlighted some critical points to take into consideration during the design process of the uniform, related to the comfort of the garment, to the protection provided by it and to movement related issues. The detailed points are shown in the infographic below.

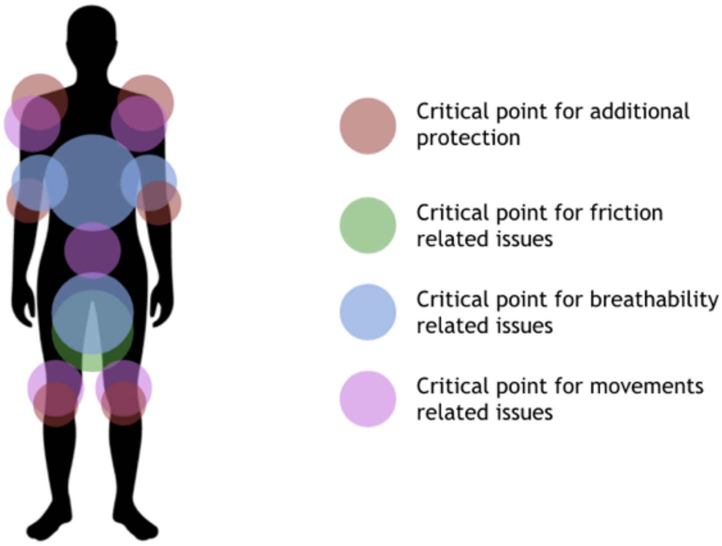


Figure 3-12: Critical points to consider during the designing process

Lastly, the above interviews showed that every end user organization uses different colors for the uniforms. This different chromatic characteristic does not help the first responders during rescue operations because it does not uniquely communicate the purpose of their presence or their skills. Another distinctive element that communicates their presence to the other stakeholders involved in the various SAR operations is their logo or the organization name applied visibly on the uniform, using high visibility textile.
These ones are not often sufficient for an immediate identification, especially from distance. The only elements of visibility currently present on all uniforms are those (finishes/inserts of fabric) made with high visibility materials (according to the regulation UNI EN ISO:20471:2017) but even they are not sufficient for an identification by skills.
It was therefore necessary to identify a specific color chart to easily identify the USAR team during a rescue activity.

3.4 System requirements

The system requirements have been identified after the research activities described in the previous paragraphs. Summarizing, the system is composed of a wearable monitoring device, the First Responder's protective uniform with the embedded sensors and the hand free devices for the monitoring of both the first responder's health parameters and the environment qualities. The sensors and the hand free devices communicate with the web server through an android app installed on the first responder's smartphone. The complete explanation of the software architecture is described in paragraph 3.5.2 of this document.

The uniform is designed according to the UNI EN ISO 13688 "Protective Clothing. General requirements" and the UNI EN 16689 "Protective clothing for firefighters".

Both the regulations give specific information about the protective clothing for first responders. In particular, the UNI EN 16689 explains in detail the general clothing design requirements. The regulation describes for example the closures requirements ("*closures shall be designed with a protective cover flap on the outside of the garments*"), the interface areas, the pockets ("*all the external pockets shall have a closure system that enables complete closure of the pocket*"), the paddings, the hardware, the collar, and the integrated personal protective equipment. Moreover, it analyzes the materials, the pre-treatment, and the cleaning. Finally, it is about the thermal and mechanical requirements, the visibility requirement (for which take into consideration the EN ISO 20471:2013 replaced by the EN ISO 20471:2017) and the marking requirements.
Additionally, UNI EN ISO 20471:2017 documents the requirements for high visibility clothing associated with a warning effect e.g., in traffic. Especially for EMS personnel, traffic is among the biggest dangers and therefore requires adequate protective clothing that is easy to spot. The regulation also foresees a restriction in materials to be used, focusing on washability among other things. The regulation categorizes requirements into 3 classifications based on traffic speed, with category 1 of up to 30km/h, category 2 up to 60 km/h and category 3 from speeds 60km/h and up which requires the highest proportion of fluorescent colors (fluorescent yellow, red, or orange). Basic requirement for category 3 is a coverage of $0.8m^2$ of fluorescent surface and a min. of $0.2m^2$ for reflective stripes. For jackets these have to also cover the back and shoulder area (Arbeitsschutz-Express, n.d.; SUTURA, n.d.).

The designed uniform is a protective clothing with a good resistance to heat and chemicals and bacterial agents. It is not a CBRN uniform or a walk-through fire uniform. The uniform is designed to be used in different operative USAR scenarios. In specific scenarios with different hazards, it is compatible with other more protective DPIs, such as the CBRN suit.

3.5 System architecture design

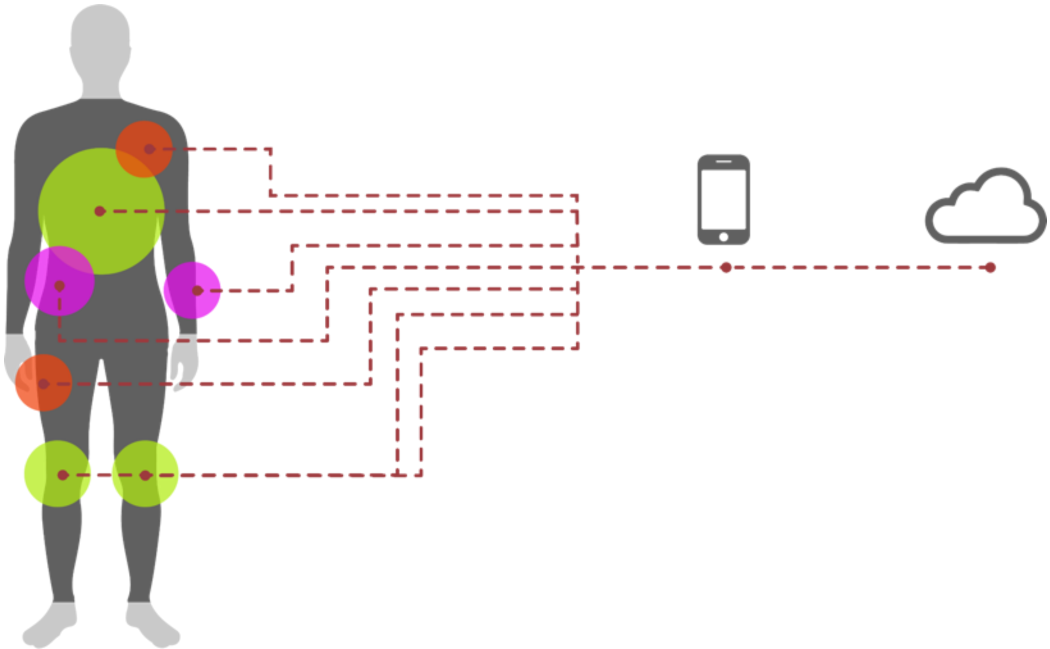


Figure 3-13: System architecture design infographic

The architecture of the system is composed of the two pieces uniform, the smart underwear T-shirt, the smart leggings, and the sensors both embedded in the T-shirt and in the trousers, under the knees (see Figure 3-14).
Referring to the sensors, their architecture is based on the use of a smartphone as a signals collector from many custom-designed and off-the-shelf sensor nodes forming a Bluetooth low energy (BLE) body area network on the first responder. Sensors integrated in the uniform and in the smart underwear allow monitoring the health status of the first responder and some environmental conditions such as the presence of gases. The smartphone, running a custom Android app, enriches the data with information and preliminary analyses too complex for the sensor node. Collected data are continuously streamed to the remote server at different sampling rates, allowing geo-localized remote monitoring of the first responder conditions and safety. Although several aspects will require refinements and are subject to changes and different choices in the timeframe of the project, the preliminary investigations are currently leading to the identification of the following hardware/software architecture.

3.5.1 System architecture components

The uniform is composed of four main parts:

- The jacket.
- The trousers with elastic bends.
- Smart underwear t-shirt.
- Smart underwear leggings.

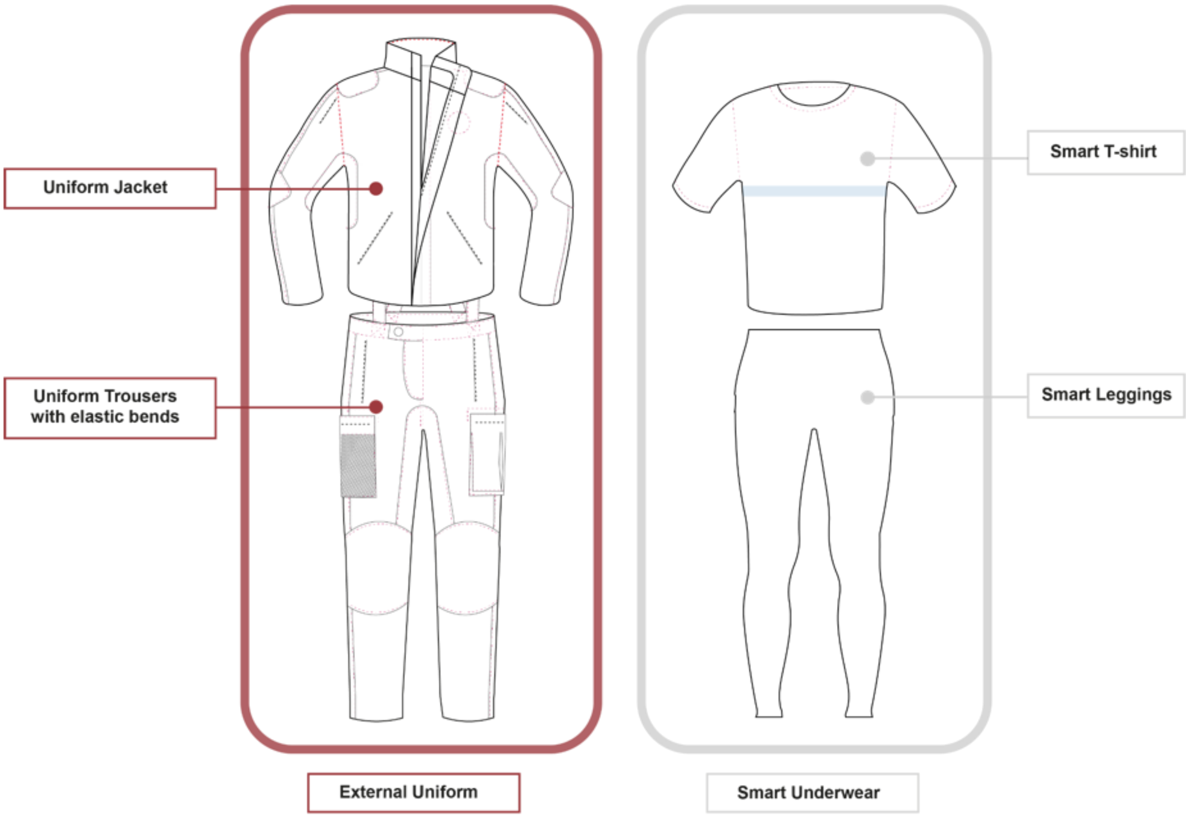


Figure 3-14: System architecture components' infographic

The main textile used in the uniform is the Santanderina Jackal 8627 produced by Textil Santanderina S.A. (Santanderina, Spain). The Jackal is a rip-stop textile with the following composition: 55% Meta-Aramid (CONEX) - 38% Lenzing Viscose FR/5% Para-Aramid (TWARON) / 2% antistatic fiber. The chosen textile is finished with a fluorcarbon coating that makes it waterproof and resistant to chemicals. The textile color is the Plain color 31454 Red. The technical and color chart of the textile is attached in the Annex IV of this document.

The textile has the following certification:

- UNE EN 11612 –A1-A2-B1-C1-F1 certified 100 washes ISO 15797
- UNE EN 116111 – Class 1 certified 100 washes ISO 15797
- UNE-EN 1149-5
- UNE-EN 13034 -6 with FC coating certified 5 washes ISO 15797
- UNE-EN 469 Outer shell certified 5 washes ISO 15797
- UNE-EN 16689 Rescue certified 50 washes ISO 15797
- ISO 15384 certified 50 washes ISO 15797
- AS/NZS 4824 (ISO 15384:2003, MOD). certified 50 washes ISO 6330
- UNE-EN 61482-1-1 ATPV = 10.9 cal/cm2 certified 5 washes ISO 15797
- UNE-EN 61482-1-2: APC = 1 / Class 1 (4 kA) certified 5 washes ISO 15797
- AS/NZS 4399:2017 Sun protective clothing - Evaluation and classification. 50+

- EN 61482-1-2 APC= 2 /class 2 (7 kA)
- EN 61482-1-2 APC= 2 / Class 2 (7 kA)

To ensure the waterproof and windproof properties of the uniform, all the internal seams are taped as shown in the image below.

Figure 3-15: Detail of the taped seams

All the zipper closing used in the uniform are YKK CNT10OR-56 DABLHD EF P16N N-ANTI P-TOP REVERSE. The tape of the zip is made of polyester fiber, coated with a polyurethane film. This typology of zippers ensures the waterproof properties of the jacket and guarantee the protection from the dust.

Figure 3-16: Detail of the YKK zip

For ensuring the integrity of the uniform, as requested by the UNI EN 166689:2017, for all seams the grey Kevlar fiber yarn was used.
All the uniform's parts are easy to wash and decontaminate.

The jacket of the uniform is a long-sleeved jacket as requested in the UNI EN 166689:2017, slim fitted with a double security closing, easy to open and close, to ensure a fast-undressing procedure, useful for security. The main textile used in the jacket is the plain red Santanderina Jackal 8627. The jacket closing system is composed of a YKK zipper and a protective cover flap closed with press studs as requested by the UNI EN 166689:2017
The end of the sleeve has a double final with a foldable fingerless glove in technical textile for an optimal thermal comfort of the FR. This foldable glove, which can be worn under the protective gloves, ensures and the total protection of the FR's arm (as requested by the UNI EN 166689:2017 and by UNI EN ISO 13688).

The jacket has a padded collar with a special zipper and a wind-proof and water-repellent extendable and formable hood. The jacket collar guarantees a total protection of the neck. The collar of the jacket remains in the vertical position when closed around the neck, but it is adjustable and it can be easily opened by the FR for better comfort.

Figure 3-17: Detail of the extendable and formable hood

The whole jacket is lined internally with the DRYRES V2 textile, a composite textile made of polyether sulfone and polyurethane leather. The technical chart of the textile is attached in the Annex V of this document. To ensure the waterproof and windproof properties of the jacket, all the internal seams are taped like already shown in the image above. The jacket has, in some critical points (especially in the area under the armpit and the waist), additional breathable stretchable inserts, to improve the comfort and the fitting of the uniform (see the scheme below). Additional protective inserts are implemented in the critical areas of shoulders and elbows. The inserts are made of GLASS-B 68x2 - DP 016, an innovative composite textile with fiberglass yarn. The textile ensures a higher level of abrasion and cut resistance. Moreover, in the aforementioned critical points, flexible removable soft protections are implemented, for an additional protection against sudden shocks and to improve the comfort of the FR during particular postural positions used in rescue activities.

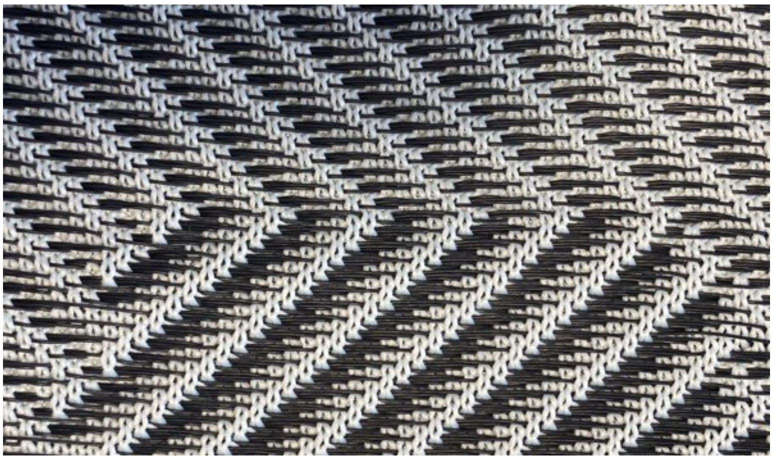
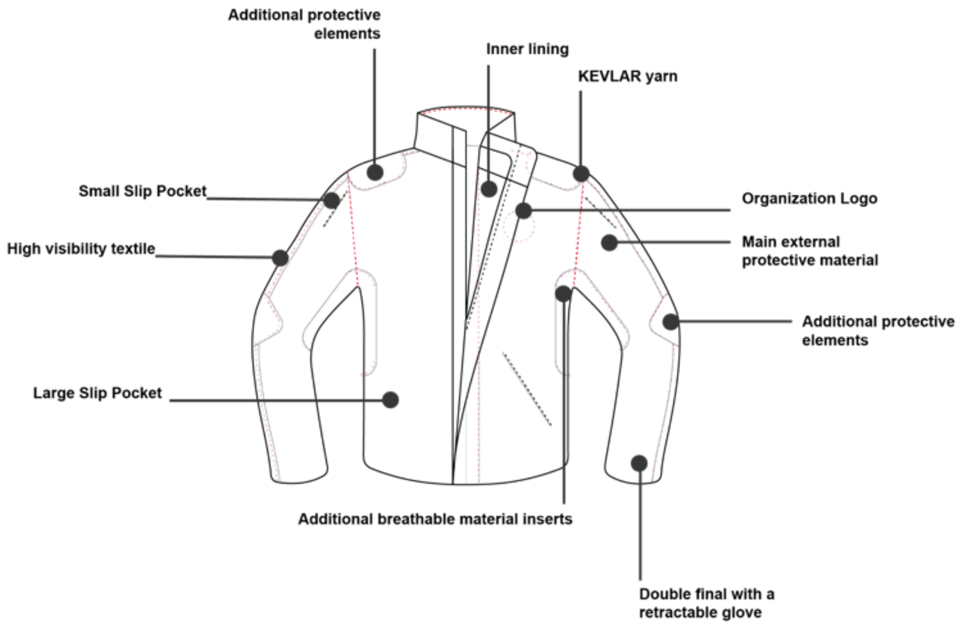


Figure 3-18: Detail of GLASS-B 68x2 – DP 016 inserts textile

Figure 3-19: Detail of the flexible soft removable protections

The jacket, as shown in the scheme below, has two main external large zipper slip pockets and two external small zipper slip pockets on each sleeve, for hiding personal identification documents. Moreover, it has two internal pockets, one on each side of the chest equally useful for right- and left-handed users.
As requested by the UNI EN 166689:2017 the jacket has high visibility elements both on the front and on the back, to easily see the FR also in darkness and in case of fog and smoke.
The logo and the name/acronym of the organization is placed in the chest area (the first one) and in the back area (the second one), using a high visibility textile.



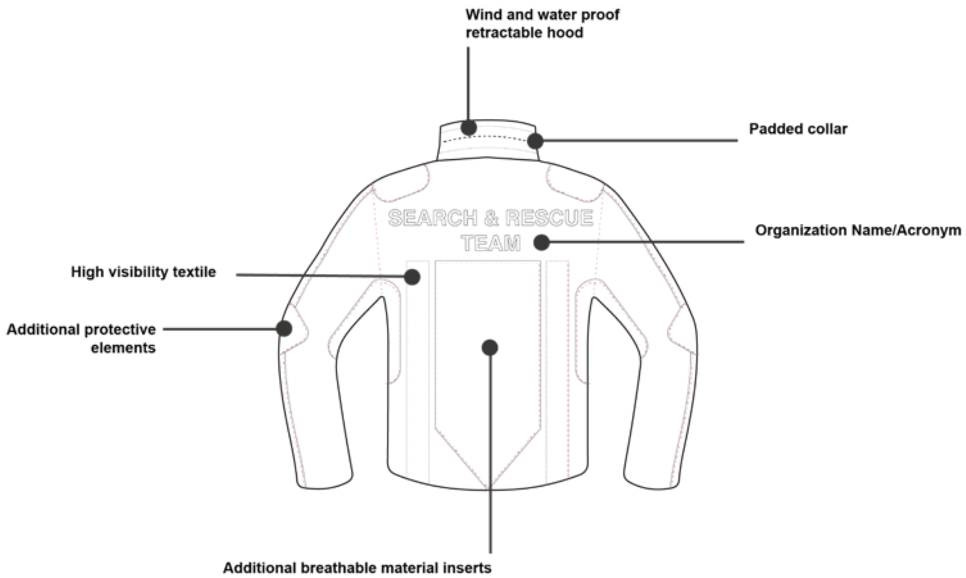


Figure 3-20 and Figure 3-21: Uniform Jacket architecture

The trousers of the uniform are long pants as requested in the UNI EN 166689:2017, high waisted and slim fitted with elastic adjustable bends and with a double security closing, easy to open and close, to ensure, for security reasons, a fast-undressing procedure. As well as the jacket, the trousers' closing system has a YKK zipper and a protective cover flap.
The main textile used in the jacket is the plain RED Santanderina Jackal 8627.

The end of the pant leg has a double final with a stirrup in technical textile for an optimal thermal comfort and protection of the FR by contaminants agents and dust. The stirrups are suitable with the existing protective technical shoes. The stirrup ensures the waterproof properties of the pants and the total protection of the FR's leg (as requested by the UNI EN ISO 13688). The trousers, as well as the jacket, are lined internally with the DRYRES V2 textile and all the internal seams are taped, ensuring the waterproof and windproof properties of the pants. The pants have in the inner thigh area additional breathable stretchable inserts, to improve the comfort and the fitting of the uniform (see the scheme below).

Additional protective inserts are implemented in the critical areas of the knees. The inserts are made of GLASS-B 68x2 - DP 016, an innovative composite textile with fiberglass yarn. The textile ensures a higher level of abrasion and cut resistance. Moreover, in the same areas, flexible removable soft protections are implemented, for an additional protection against sudden shocks and to improve the comfort of the FR during particular postural positions used in rescue activities. The technical chart of the removable protections is attached in the Annex VI of this document.

The trousers, as shown in the scheme in the next page, have four main external large zipper slip pockets (two in the front and two in the back) and two additional large pockets on each leg. The left one is a cargo pocket with a YKK zipper that enables the complete closure of the pocket to ensure the protection of the elements inside it. The right one, instead, is a zipper patch pocket with an additional PP polypropylene elastic mesh pocket sewn on it. The six-gas hazmat monitor is placed in the external mesh pocket.

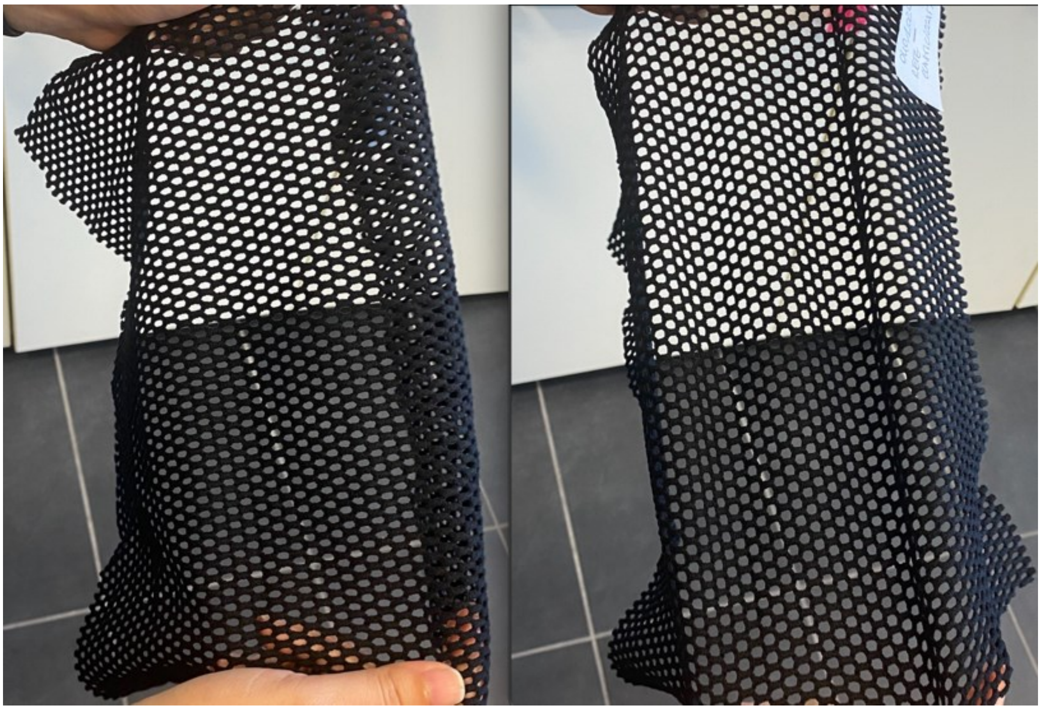


Figure 3-22: Flexibility test on the mesh pocket textile

As requested by the UNI EN 166689:2017 the trousers have high visibility elements both on the front and on the back, to increase the visibility of the FR in darkness and in case of fog and smoke.

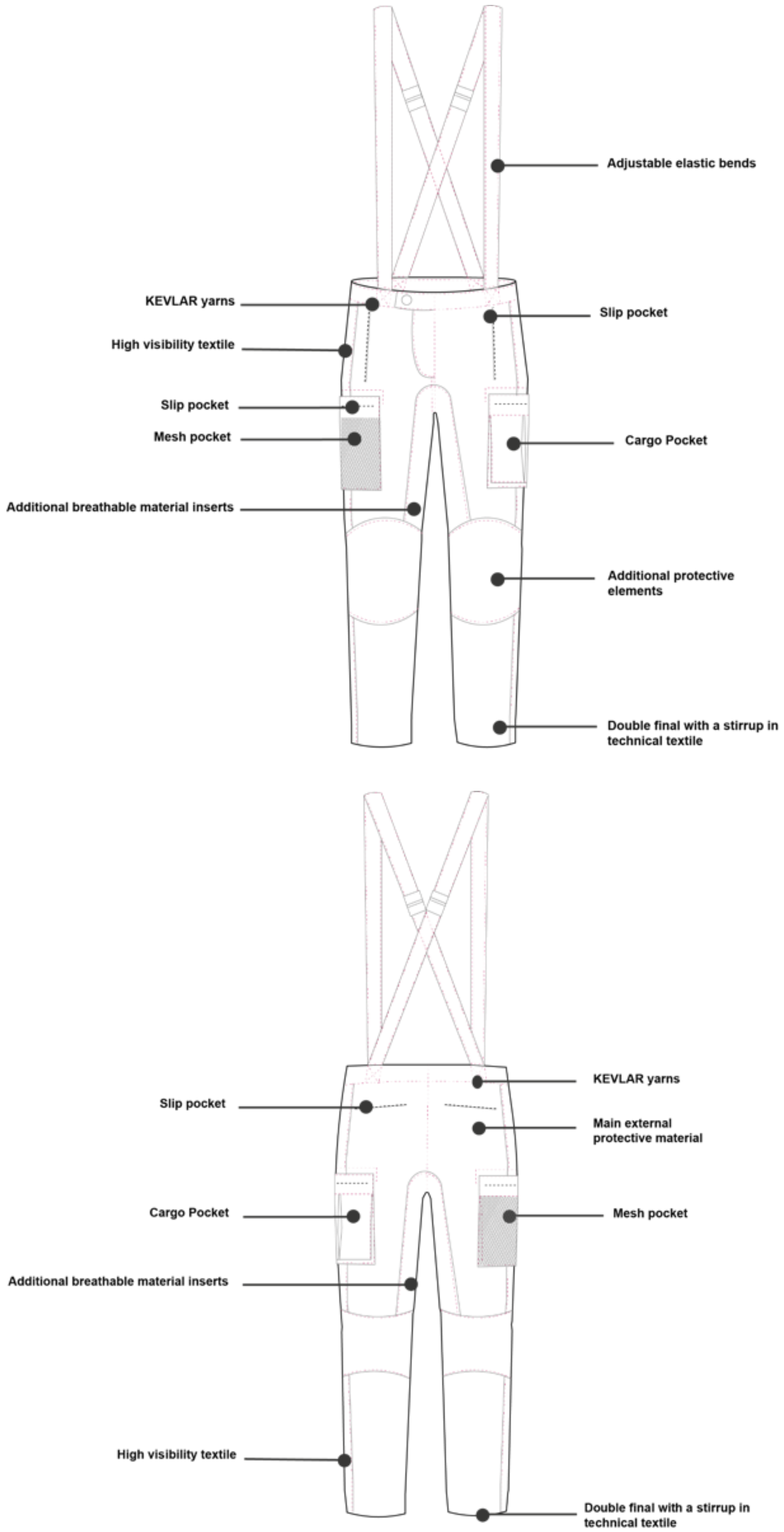


Figure 3-23 and Figure 3-24: Uniform trousers architecture

The Smart underwear is composed of a short-sleeved shirt and leggings made of a polyester stretchable textile. The underwear textile will be validated in the future version of this document.

The health and biometric sensors are embedded in the t-shirt and in the leggings as explained in the section 4.2 of this document and they are developed by the DIEE, Department of Electrical and Electronic Engineering of the University of Cagliari. The strain sensors with the Bluetooth sensor node are embedded in the knee's areas. The t-shirt and the leggings have a back slip pocket for the battery and card housing.

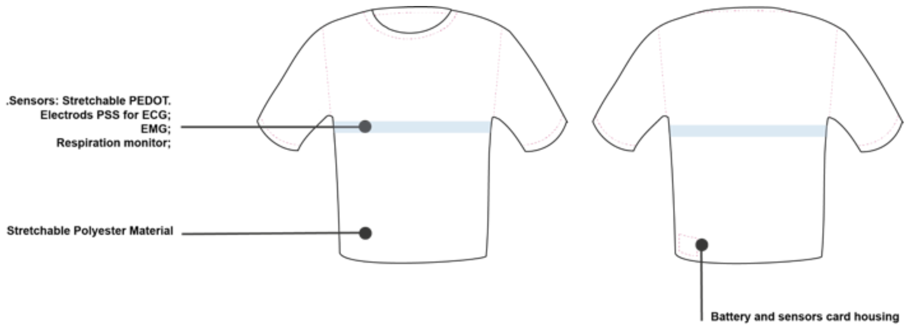


Figure 3-25: Smart Underwear t-shirt architecture

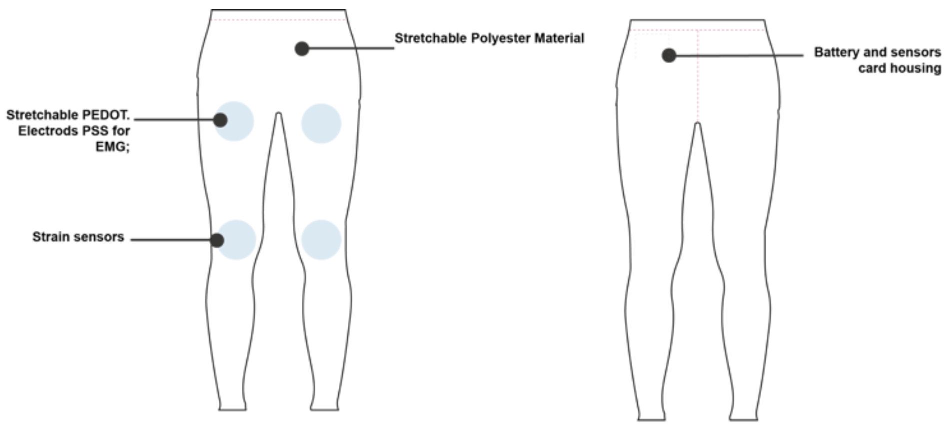


Figure 3-26: Smart Underwear leggings architecture

The uniform will host the multi-gas monitor, a flexible X-rays sensing tag, strain sensors on the knees (see paragraph 3.5) (these could be conveniently embedded in compressive garments in a knee-pocket on the uniform). In the smart underwear the electrophysiological signals will be collected, as they require tight contact of the sensors on the skin: ECG and EMG electrodes on chest and legs, respectively. Additionally, if possible, temperature sensors will be added to monitor the body temperature of the first responder.

Finally, the uniform will host the first responder's smartphone, featuring preprocessed (on-the-edge) data collection, geo-tagging by using the internal GPS-tracking sensor, visualization/alarm, transmission to the remote servers. The hardware architecture providing sensing capabilities to the uniform can be summarized in the following figure.

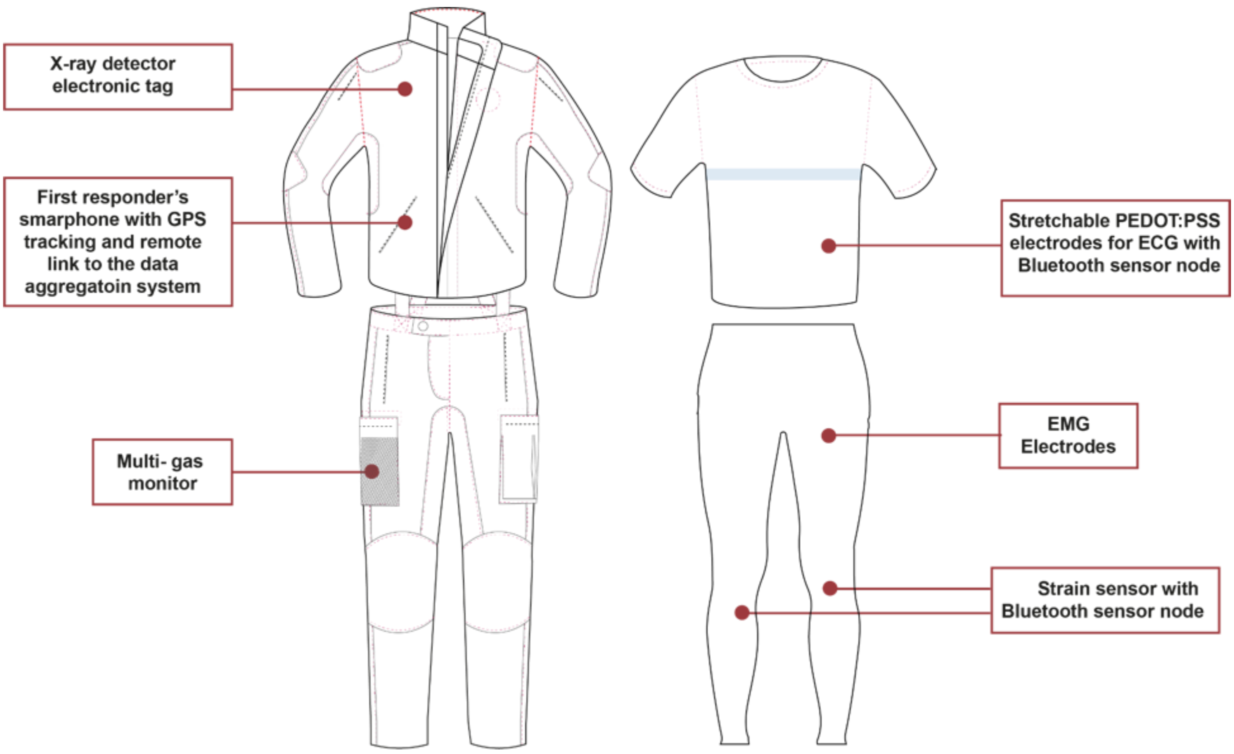


Figure 3-27: Integration of the sensors in the uniform architecture

The multi gas sensor monitor, as already explained in this paragraph, is placed inside the PP elastic mesh pocket (see scheme above). The multi gas sensor monitor is an off-the-shelf tool, whereas all the other sensors employed are being custom developed. Related to this case several choices were made in order to develop effective tools for real operations:

1. One sensor, one Bluetooth node. This is important to allow modularity and the possibility to equip the first responder only with the useful sensors for the given scenario. This allows avoiding over-connected and useless smart garments that could hamper the operation rather than helping the responder. Moreover, by using a Bluetooth node per each sensor, it is possible to completely avoid wiring, making the system more comfortable. However, this requires wearing multiple electronic nodes, requiring some further choices.
2. Small form factor. Based on the previous point, it is of paramount importance to develop small hardware nodes that can be conveniently placed close to the sensor. This removes the need for long wiring and improves robustness and resilience to external noises. Small form factor means that precise choices are required to reduce the hardware. As such, the battery size will be properly selected according to the duration of the typical intervention whereas battery charging could be implemented on the node or outside depending on the final size of the node. Moreover, hardware optimization requires the selection of area-saving solutions for the main components such as microcontroller and Bluetooth module.
3. Low power. Bluetooth classic is low power compared to other wireless protocols. However, its efficiency is reduced if compared to Bluetooth Low-Energy (BLE). Reduced energy requirements

allow preserving the battery which in turn means that the battery could be dimensioned in order to keep at the minimum its size.

4. Low cost. Multiple nodes require low costs in order to produce an effective solution. At the same time, it is important to select technologies that do not introduce further problems. For instance, RFID tags are surely extremely low-cost and powerless, but their use requires the adoption of an external reader providing power via radiofrequency link and data transfer. This solution adds complexity to the system and was excluded.

Based on the above considerations, some tests were carried out on commercial evaluation boards featuring BLE modules and low-power microcontrollers. The main idea is to have both the communication module and the microcontroller in the same chip, in order to reduce PCB size, power consumption and cost. Between the different options on the market, we successfully tested a few of them and finally selected the Texas Instruments LAUNCHXL-CC2640R2F evaluation board, developing an Android application prototype for data exchange, running on a Samsung A40 smartphone equipped with a BLE 5 receiver. The proposed board features the selected CC2640R2F microcontroller unit (MCU). This MCU presents several important features:

1. ARM Cortex-M3 processor (32 bit)
2. 48MHz clock speed
3. 275KB of non-volatile memory including 128KB of in-system Programmable Flash
4. Up to 28KB of system SRAM, of which 20KB is ultra-low leakage SRAM
5. 8KB of SRAM for cache or system RAM use
6. Ultra-low power sensor controller, which can run autonomous from the rest of the system
7. Peripherals:
    a. Four general-purpose timer modules (eight 16-bit or four 32-bit timers, PWM each)
    b. 12-bit ADC, 200-ksamples/s, 8-channel analog MUX
    c. UART, I2C, and I2S
    d. 2× SSI (SPI, MICROWIRE, TI)
    e. Real-Time Clock (RTC)
    f. AES-128 security module
    g. Integrated temperature sensor
8. Several operating modes (both active and low power)

In particular, the UltraLow-Power Sensor Controller can interface external sensors and to collect analog and digital data independently, while the rest of the system is in sleep mode.
The Radio Frequency module is equipped with a 2.4 GHz transceiver compatible with BLE 5.1 and earlier LE specifications. This module is characterized by excellent receiver sensitivity (–97 dBm forBLE), selectivity, and blocking performance, link budget of 102 dB for BLE, programmable output power up to +5 dBm, and single-ended or differential RF interface. This is also suitable for systems targeting compliance with worldwide radio frequency regulations:

- ETSI EN 300 328 (Europe)
- EN 300 440 Class 2 (Europe)
- FCC CFR47 Part 15 (US)
- ARIB STD-T66 (Japan)

Although custom PCBs can be developed for this purpose, several systems on modules providing the chip, some passive components, and the RF antenna, are available on the market at convenient prices lower than 8€.
According to the required accuracy levels for the different sensors, the internal AD converter could be conveniently used to save board area and reduce the form factor. However, some signals such as the

ECG can benefit from custom analog front-end (AFE) for improved quality. In this regard, based on previous experience on this, the powerful physiological AFE by Texas Instruments, such as the ADS129x family will be used to improve the quality of the recording. For the other sensors, custom circuitry will provide interfacing and conditioning before digitalization.
All the PCBs will be designed by UNICA and realized by third parties (service providers) according to the latest standards and safety regulations for the hazardous materials.

3.5.2 Software architecture

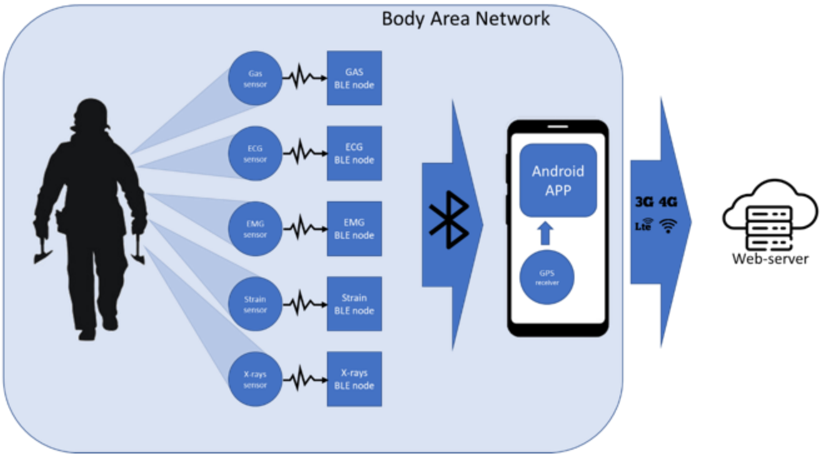
The software architecture is focused on the presence of a smartphone acting as a collector for the signals coming from the sensor nodes and the remote data lake. This means that the software architecture is divided in two parts and 5 layers:

1. Part one: firmware of the sensor nodes
2. Part two: Android app

At the same time, we have 4 layers, two per part:

1. Part one
    a. Signal acquisition and edge pre-processing
    b. BLE communication
2. Part two
    a. Data collection from sensor node and further processing (if needed), local storage
    b. User interface and alarms
    c. Internet access and data transmission

According to the BLE specifications, the smartphone can support simultaneous streaming from up to 7 BLE nodes. This aspect should be carefully considered when changing the default configuration developed for the project.



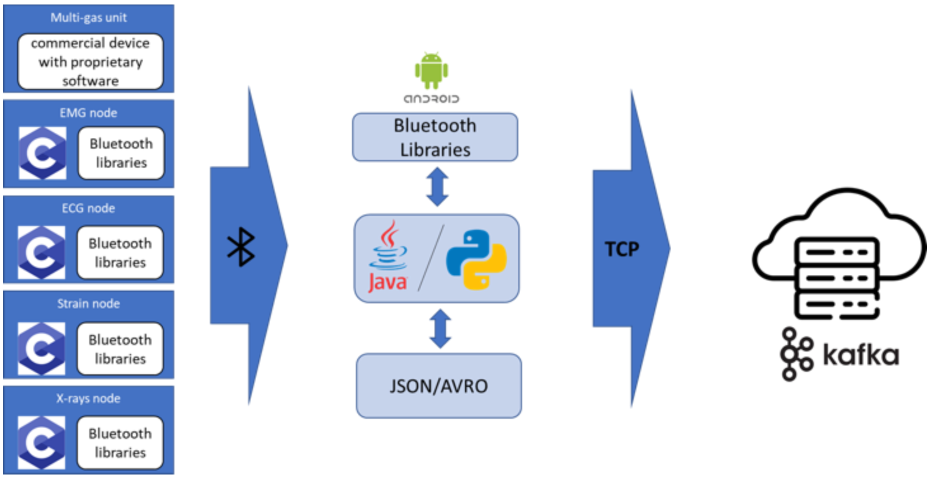


Figure 3-28: Software architecture

A general representation of the software architecture for collecting datasets from sensors can be seen in Figure 3-28.
The gas monitor is a commercial tool, so its software is proprietary and does not allow reprogramming. Based on the availability of APIs, the first responders' smartphone can collect the data sent by the device through the BLE link and then manage them similarly to the other (custom) sensor nodes.
Sensor nodes are based on a low-power microcontroller featuring data conversion (directly or by the adoption of monolithic AFEs) and BLE transmission. The microcontroller manages the signals acquisition, performs local pre-processing, builds data packets, and makes them available for the remote transmission through an Internet connection. The microcontrollers are programmed using C language; their firmware is divided into two modules: the Stack part with the BLE libraries and the Application part where signal acquisition, processing and data forwarding to the BLE stack is managed.
Through Android BLE libraries, the packets are received by the smartphone. The role of the Android application is to collect this data, carry out further processing on the signals that could be too complex for the sensing node, check for corrupted packets and prepare the data packets for their forwarding to the web server via the TCP protocol. Before data transmission, the application will read the data from the GPS receiver integrated into the smartphone and will add this data to the packet to be sent, thus allowing the geo-localization of the first responder. GPS position and all the data are stored in the internal memory if the Internet connection is unavailable and sent out at the first opportunity.
The development of the App for data handling and data forwarding will be done in Java language through Android Studio or in Python with Kivy framework, depending on the kind of processing to be performed on the data. The application will have the ability to insert and modify a Kafka endpoint on which to forward the datasets in JSON or AVRO format. To test the general framework, a test application was created in Python language with the help of the Kivy framework. This framework allows the development of the application in a higher-level language and through the Buildozer utility it is possible to perform a Python-Java cross-compilation. With the smartphone and the microcontroller placed at a distance of 1 m, the app was able to maintain a connection with the microcontroller and continuously receiveing some sample data packages. Tests have been made to send data at frequencies from 1Hz to 250Hz. Overall, the application was able to display the received data fluently and with a latency of some milliseconds.

4 First responders uniform Implementation

4.1 Uniform implementation

In this phase of the S&R project, the first concept of the uniform was designed according to the Human Centered Design approach, taking into consideration the end users' needs and behaviors. The morphologic aspects of the design of the uniform took inspiration from the anatomy of the human body, especially to the muscular-skeletal system. The design process analyzed and studied also the communicative values of signs and colors in the popular imagination regarding the "rescue" notion, in order to design an innovative uniform, able to immediately identify the first responders, to make them feel confident and powerful, but at the same time able to reassure the rescued victim involved in the disaster.
Regarding the communicative values, also an overview on the superhero figure, and his communication was carried out. The study analyzed the main characteristics of the most famous superheroes in both the cinematographic, comics and gaming universes[2].
Moreover, for the purpose of this work, a detailed analysis on the human anatomy was carried out, to identify the most critical points of the human body. The analysis pointed out the muscles and the movements mostly involved during the first responders' rescue activity, and all the weaknesses related to them. For this reason, the morphological aspect of the uniform emphasizes the main muscle groups, facilitating the most frequent movements (avoiding cuts and seams in critical points) by the creation of different areas according to the anatomic needs. This solution allows additional protection by strengthening only some areas (for example the shoulders, elbows, and front knees areas), without compromising the comfort and the freedom of movement of the FR.
Furthermore, by combining several types of materials with varying features and capabilities, according to the anatomy needs, this approach increases the fit and thermal comfort of the uniform (for example using a more breathable textile in the armpits areas and a more stretch textile in the hips area).
The document shows the preliminary technical drawings and 3D models of the uniform for the development of its first prototype.
The fit of the uniform will refer to the standard sizes used in the European Union. The first prototype is developed taking as reference a size L - 50 IT - 44 EU.

The final uniform prototype will be presented and described in the next version of this deliverable, after its validation during the UC pilots.

4.1.1 Technical drawings

The technical drawings (figures 4-1 and 4-2), show the front and back views of the uniform, describing the morphological aspect of the innovative uniform for FR, to be used in USAR operations.
The main colors chosen for the uniform are the plain red and the plain orange, in order to easily identify the rescuers in the disaster scenario.
The high visibility textile, both in the jacket and in the pants, emphasizes the muscle groups and identifies different areas according to the anatomy needs.
In the chest and in the back areas are placed the organization logo and acronym for easy identification of the rescuers.
Stretchable PEDOT electrodes PSS for ECG and EMG are printed both in the t-shirt and in the leggings. The detailed description of the sensors is available in the paragraph 4.2 of this document.

[2] Regarding the communicative values. the study refers to the Marvel cinematic and comics universe, in particular to the "Captain America" character in the films: "Captain America – The first avenger" (2011), "Captain America and the Winter Soldier" (2014), "Captain America – Civil War" (2016), "Avengers: Infinity War" (2018), "Avengers: Endgame" (2019).

Figure 4-1: Jacket front and back views with some detail's indications

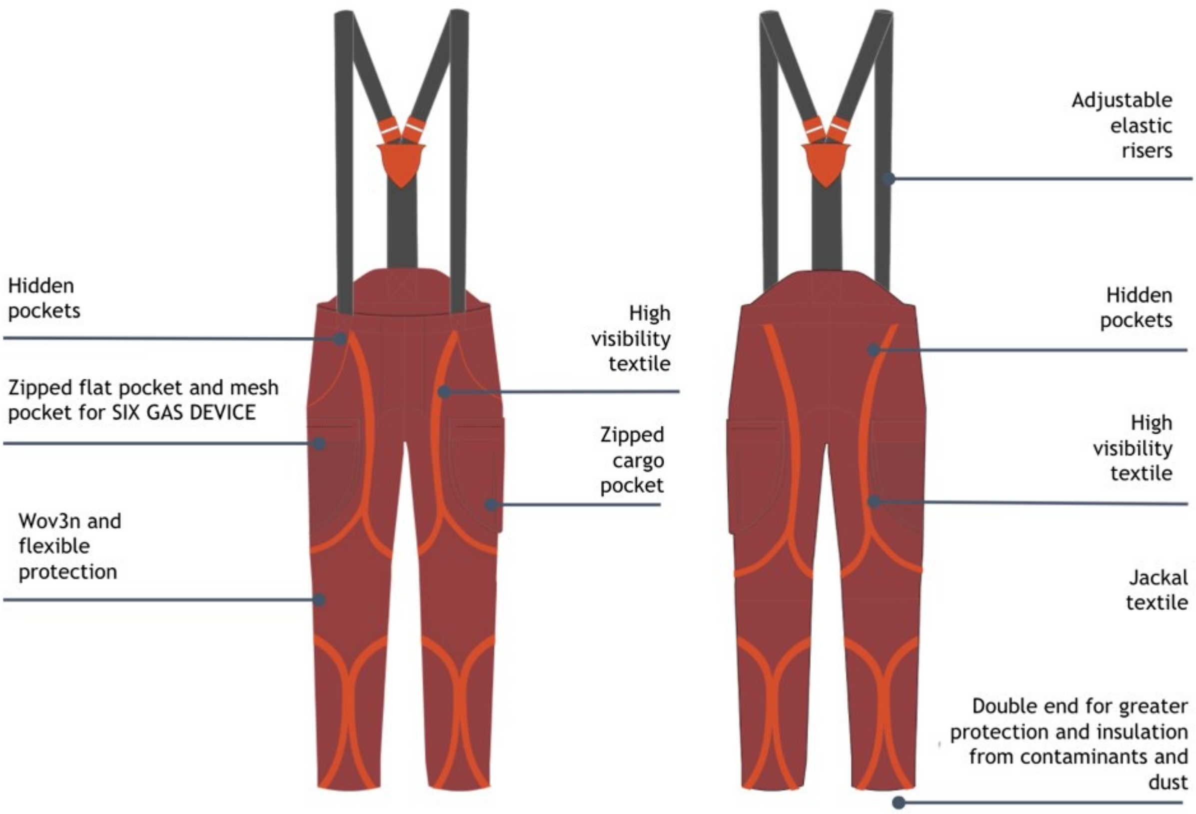


Figure 4-2: Pants front and back views with some detail's indications.

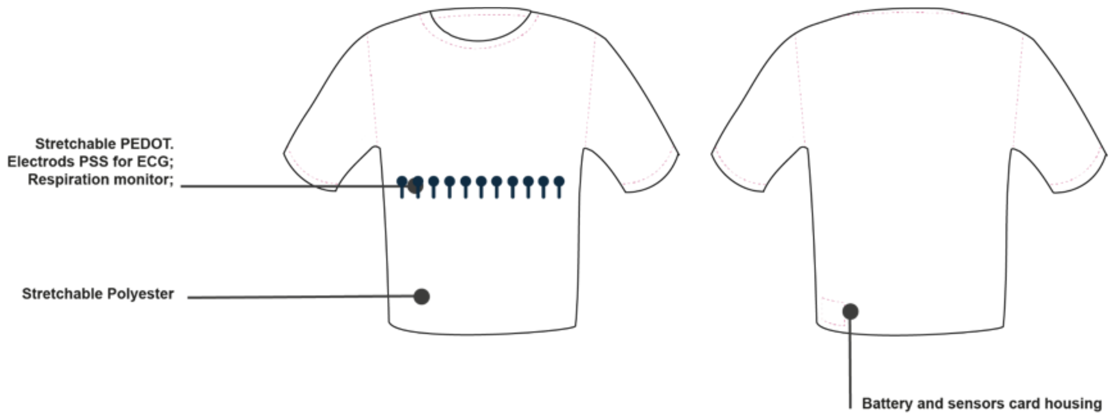


Figure 4-3: T-shirt front and back views with some detail's indications

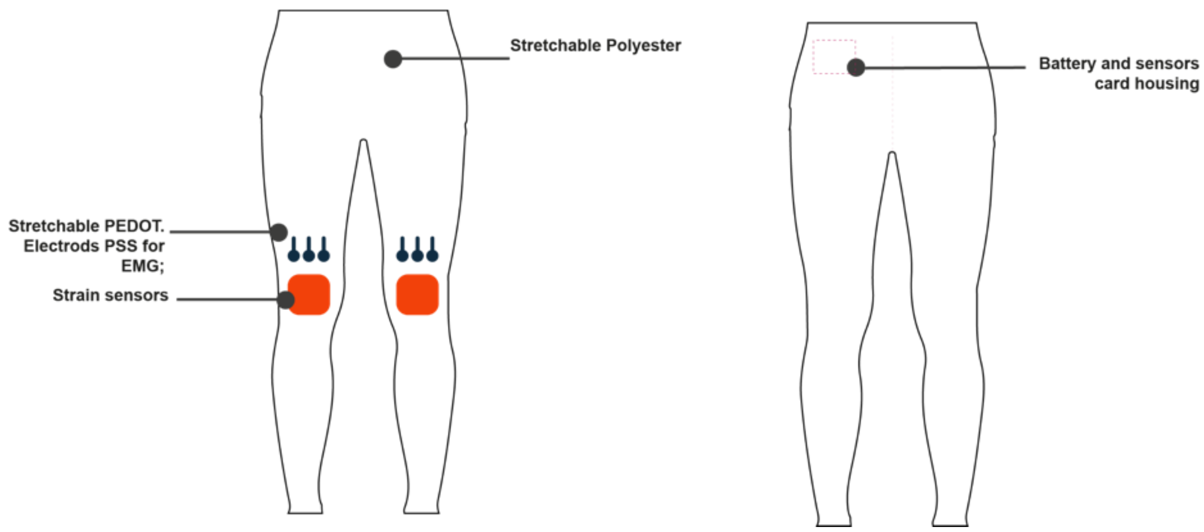


Figure 4-4: Legging's front and back views with some detail's indications

4.1.2 3D Models

The paragraph shows the first 3D models of the external part of the uniform.

A

B

Figure 4-5: 3D model front and back views of the jacket (A) and of the pants (B)

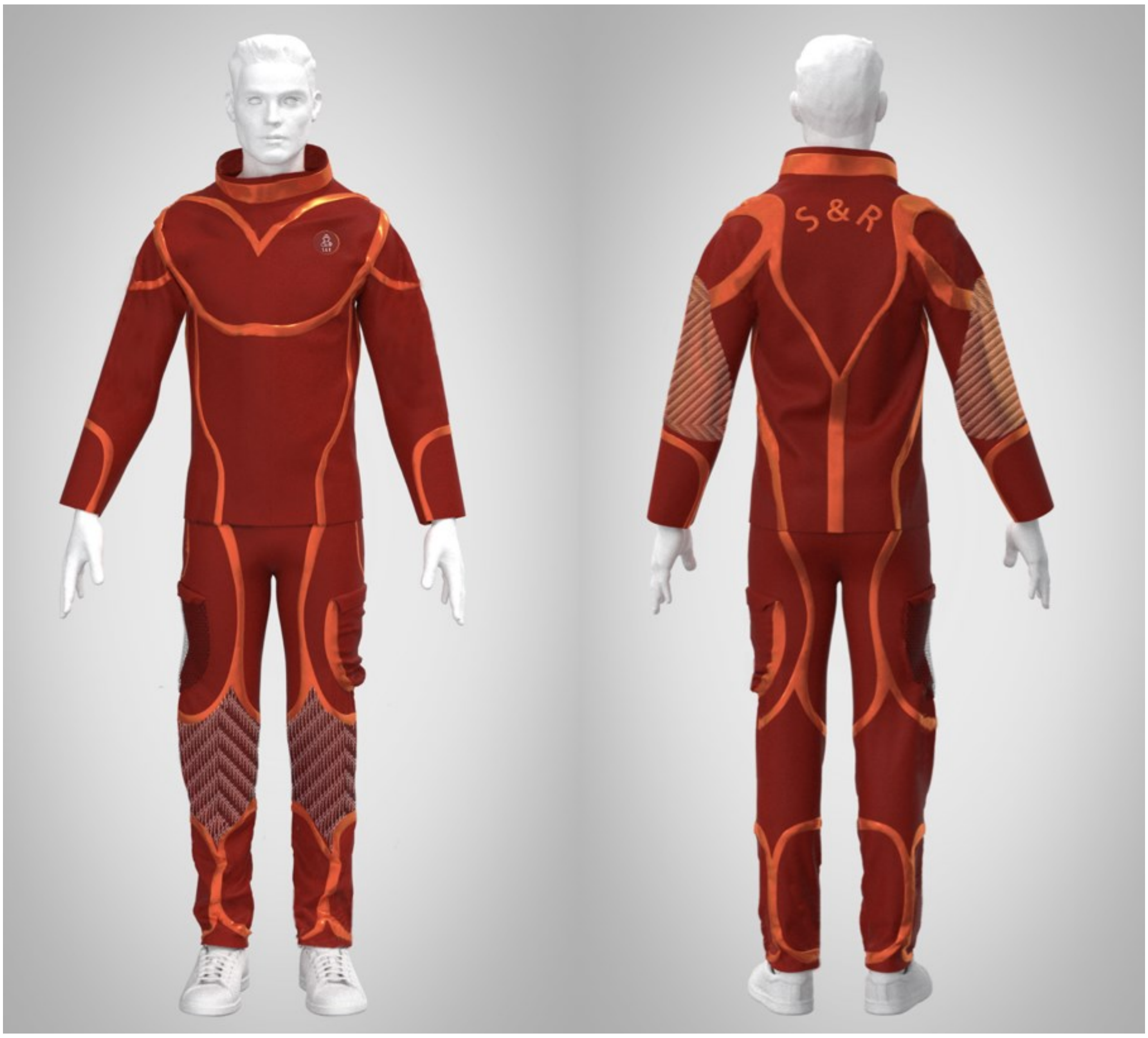


Figure 4-6: 3D model front and back views of the uniform

4.2 Smart materials and sensors

PEDOT: PSS screen-printed textile electrodes
During the first 12 months of activity, we developed a simple and convenient way to functionalize common textiles. In particular, we managed to embed PEDOT: PSS-based electrodes through screen-printing directly into commercial garments, both un-stretchable (cotton) and stretchable ones (polyester), to detect bio signals from the surface of the skin, such as ECG and sEMG signals. The choice of using PEDOT: PSS has been done due to the well-known characteristics of this conductive polymer. Some of them are the high ionic and electronic conductivity, the biocompatibility, and the fact that it can be used in high-throughput fabrication processes such as ink-jet printing, dip coating, and screen printing. The formulation of the PEDOT: PSS ink (Figure 4-8) for stretchable fabrics, which was improved compared to the previous studies on unstretchable fabrics, can be used also on non-stretchable materials. It consists of Ethylene Glycol (25% in vol), PEDOT: PSS PH 1000 (75% in vol), and 3-GlycidylOxyPropyltrimethoxySilane (1% weight). For the screen printing, a polyester screen with 43T mesh and a rubber squeegee has been used to transfer the desired electrode pattern on the

fabric (Figure 4-8B). An example of textile electrodes on cotton and on polyester is shown in Figure 4-8C and Figure 4-8D, respectively.

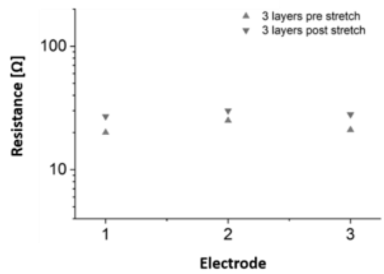


Figure 4-7: Conductivity of three textile electrodes with three layers of ink before and after the application of a repetitive stretch

To overcome the intrinsic mechanical fragility of PEDOT: PSS screen-printed textile electrodes and thus obtaining fully functional stretchable garments, the fabrication procedure has been modified. We transformed the procedure used for non-stretchable substrates in order to obtain an optimal ink penetration in the stretchable fabric, by applying a radial pre-stretch to the printing area. In Figure 4-8-D1 and Figure 4-8-D2 two polyester textile electrodes in the stretched and unstretched configuration are shown. This simple yet effective modification in fact mimics the operative conditions thus allowing a good resistance to stretch (figure 2). For the connections to the instrument, a stainless-steel yarn was sewn to the final part of the textile electrode (on one side) and to a medical-grade stainless steel snap button.

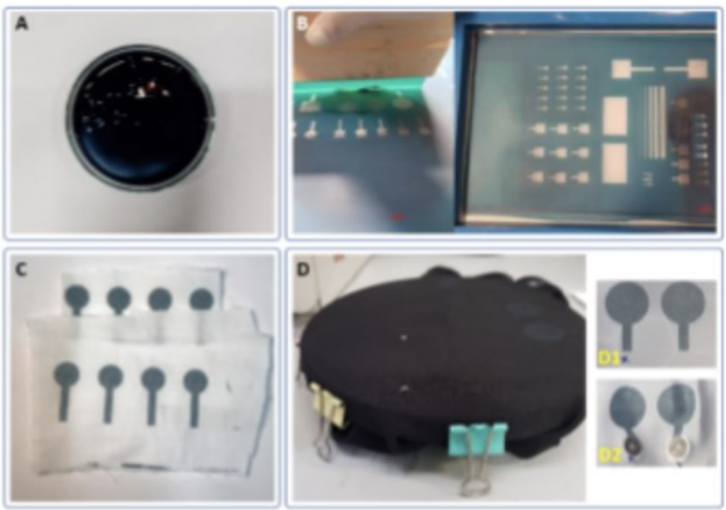


Figure 4-8: The PEDOT: PSS ink used for the fabrication of the textile electrodes. B) The frame used to transfer the electrodes pattern on the fabrics. C) PEDOT: PSS electrodes on cotton. D) PEDOT: PSS electrodes on stretchable polyester: D1) stretched and, D2) unstretched

Figure 4-9: The leg sleeve fabricated for the validation of the electrodes. Three couples of PEDOT:PSS electrodes have been placed on the Vastus Medialis (VM), the Vastus Lateralis (VL) , and the Rectus Femoralis (RF)

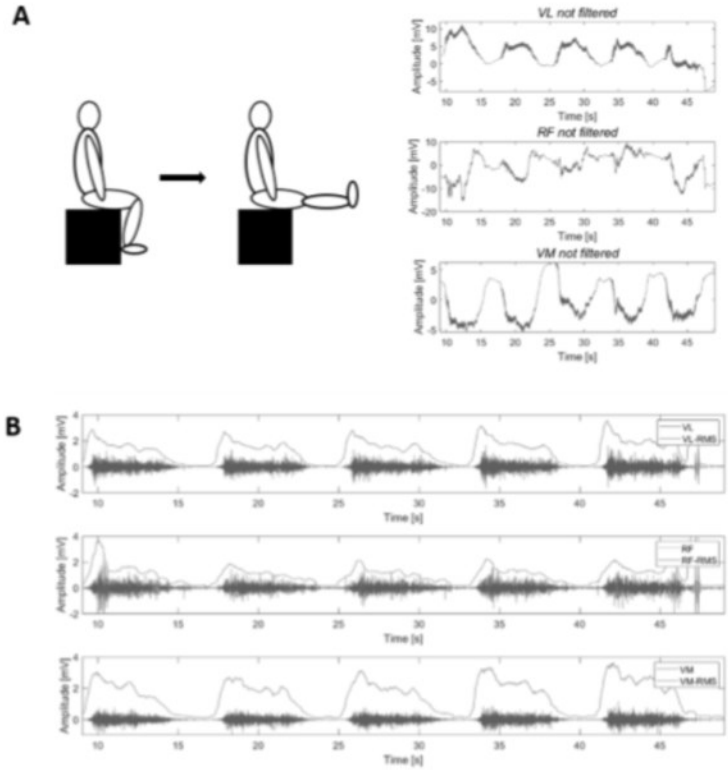


Figure 4-10: Experimental validation of the muscle activity using the PEDOT: PSS textile electrodes. A) Unfiltered signals during a simple leg extension movement. B) 10-400 Hz band-pass filtered signals and relative RMS envelopes

Using this simple technique, we were able to functionalize a 100% polyester commercial leg sleeve (as shown in Figure 4-9) thus obtaining a smart garment that was able to record the surface EMG (sEMG) in dynamic conditions. In particular, we targeted three muscles on the upper leg, namely the

Vastus Medialis (VM), the Vastus Lateralis (VL), and the Rectus Femoralis (RF), by printing three couples of electrodes that allowed us to obtain bipolar measurements (the commercial ground electrode was placed on the right hip). The recordings have been performed using a TMSI Porti 7 biopotential recording unit. These muscles are of great interest to assess fatigue during long rescue operations. A preliminary experimental validation performed on one subject, who was asked to perform five leg extension repetitions on a dedicated machine, highlighted a very good signal quality, as can be appreciated in Figure 12, where an example of the signals from the three muscles (and the relative RMS envelope) is shown, both before and after the application of a 10-400 Hz band-pass filter to remove the low frequency motion artifacts. Similarly, the same material can be effectively used to detect the ECG signal on the chest. According to our previous experience, even though the best positioning for the electrodes would be according to the bipolar lead I on the frontal plane, a bipolar lead placed on the chest parallel to lead I (i.e., horizontally) in the typical position used for the cardio chest belts ensures better stability of the recording during physical activity. A ground electrode placed on the thorax (right side, below the scapula) allows providing a common reference on the body for the AFE. Connections between the electrode and the electronics are ensured by stainless-steel yarns sewn on the compressive garments. For improved stability, the garment will be reinforced in the zone where electrodes and wiring are placed.
Electrodes have been bench assessed for surface conductivity. We performed a four-probe impedance measurement on the electrode not placed in contact with the skin by a high precision impedance meter (LCR Meter Agilent 4282A). However, surface conductivity is not the most important feature for smart textiles, as electrodes for biopotentials must facilitate the redox reactions at the interface between the skin and electrodes, rather than simply being good electric conductors. For this reason, the skin-electrode contact impedance was also assessed on different subjects in dry and wet conditions with the same device (from 20 to 250 Hz) and at 10 Hz using the FDA cleared Prep-Check impedance meter (General Devices). As the performance in dry conditions are influenced by the higher impedance leading to impedance unbalance and consequent amplification as a differential signal of the common noise, we're currently studying the possibility of using a new polymer formulation including ionic liquids to improve the detection of the signal in dry conditions. On the polymeric ink formulation, we deposited a patent before the project kick-off.
We performed functional tests at rest and during exercise with the current polymer formulation, comparing the performance with off-the shelf disposable Ag/AgCl gelled electrodes, representing the clinical choice for ECG monitoring.

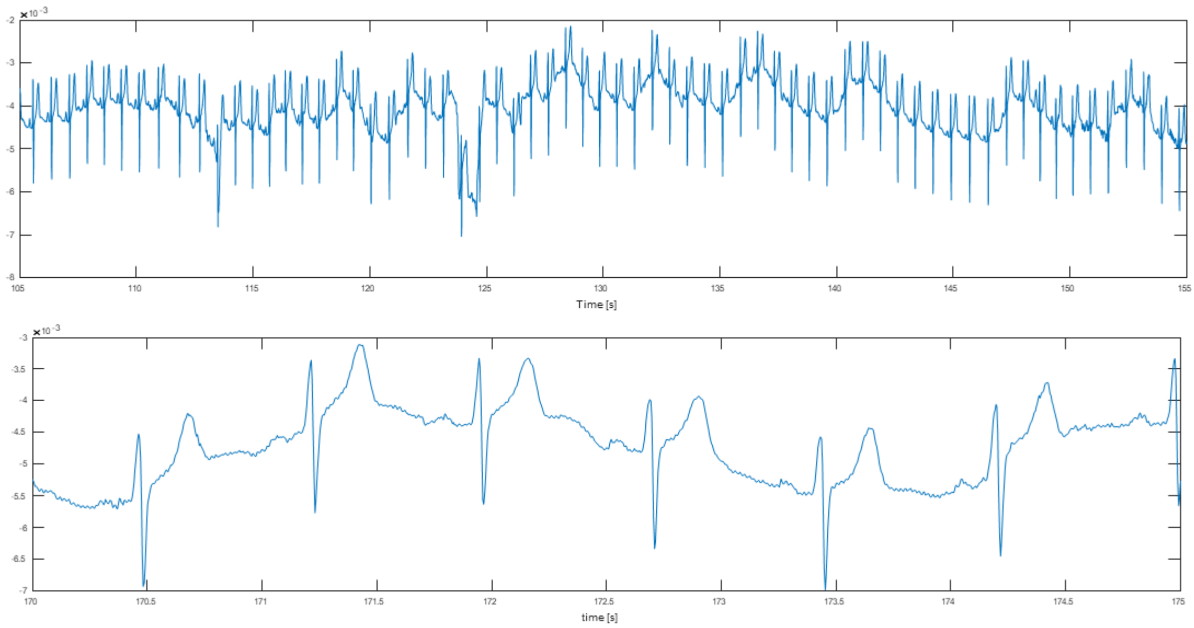


Figure 4-11: Test at rest of the proposed textile electrodes for ECG

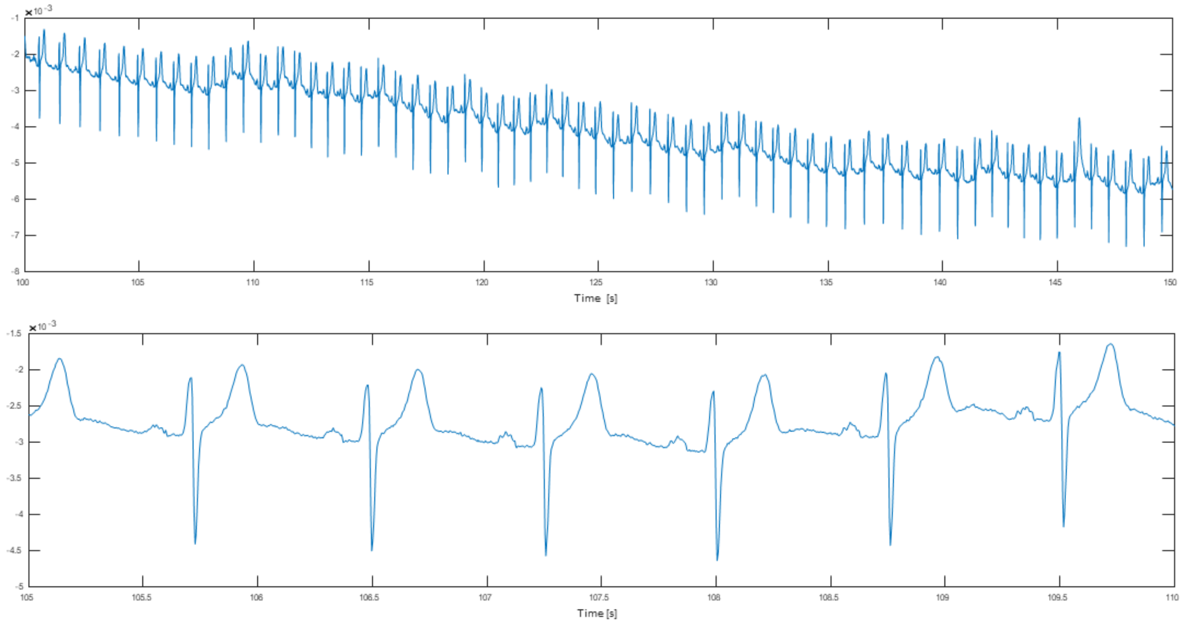


Figure 4-12: Test during walk of the proposed textile electrodes for ECG

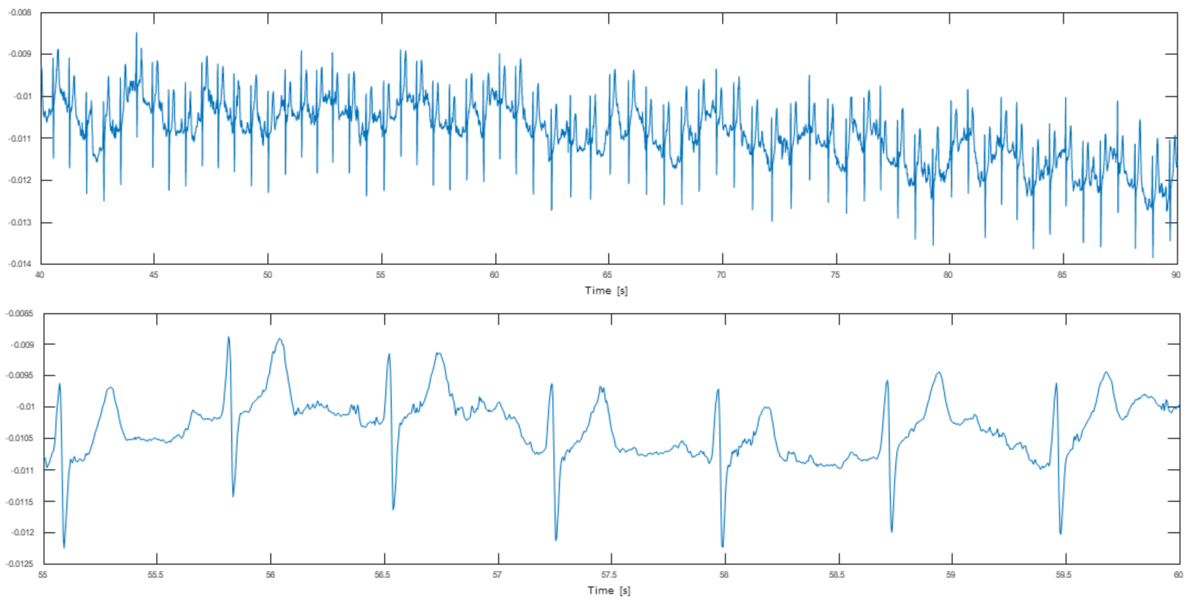


Figure 4-13: Test during run of the proposed textile electrodes for ECG

Overall, performance in controlled conditions is acceptable (also from a clinical perspective), considering that no processing was implemented on the signals acquired above, sampled at 250 Hz by means of an ADS1292R AFE, in a custom DAQ module featuring a Texas Instruments MSP430 microcontroller and an external Bluetooth classic module. Further tests with the new polymer formulation are currently ongoing.

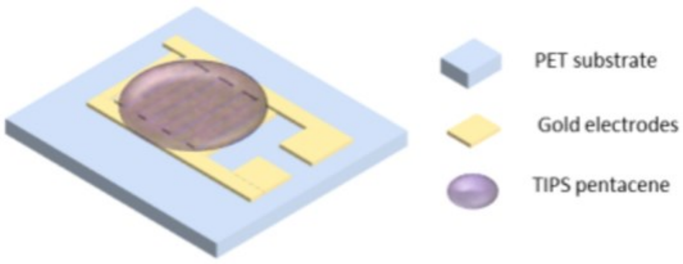


Figure 4-14: Device structure

Organic X-Rays detectors

Organic X-Rays detectors are two terminal devices fabricated on 175 μm-thick polyethylene terephthalate (PET) substrates by means of a photolithographic process of a thermally evaporated gold film (see Figure 4-14). Devices are patterned in an interdigitated shape, with a width of 5 mm and a distance among electrodes of 30 μm. The aspect ratio is about 1800. The active layer is 6,13-Bis (triisopropylsilyl ethynyl) pentacene (TIPS pentacene), a p-type organic semiconductor deposited by drop casting of a solution 1wt% in anisole and left drying at room temperature.
Eleven devices have been fabricated and characterized electrically. Their performances are reported in Figure 4-15. Resistance values are mainly distributed in the range 1±0.5 MΩ.

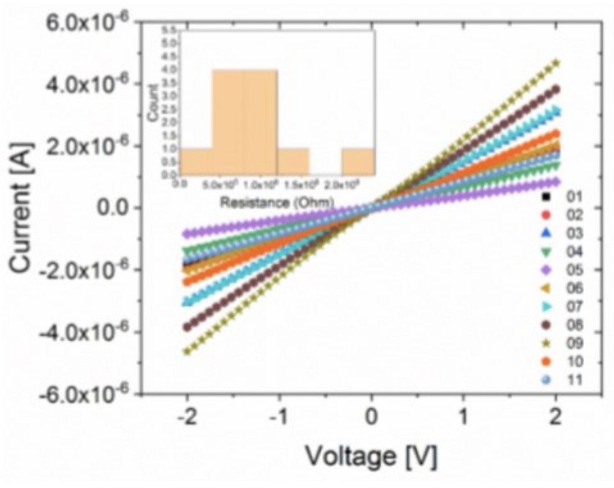


Figure 4-15: I-V characteristics of fabricated devices; in the inset, the resistance values are shown

The X-Rays sensitivity of devices is explained in terms of photoconductive gain (see Figure 4-16). The organic semiconductor is an intrinsic material, so most of the charge involved in the current flow is injected by the electrodes through an ohmic interface. The X-Rays can generate inside the semiconductor the separation of electron-hole pairs, but these two charge carriers undergo a different destiny: while holes take part in the current flow, electrons are trapped inside the semiconductor. To maintain the charge neutrality, these trapped electrons recall holes from the external circuit.

Therefore, for each electron generated by X-Rays inside the semiconductor, more than one hole is involved in the conduction: this is the concept of the photoconductive gain, which finally brings an increase of the current during the application of X-Rays.

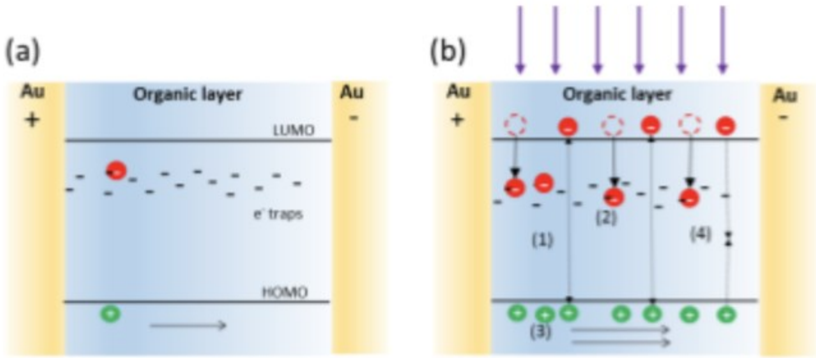


Figure 4-16: The concept of photoconductive gain: (1) without the application of X-Rays, each hole corresponds to a trapped electron; (b) during irradiation, the trapped electrons recall further holes to ensure charge neutrality.

An example of device characterization as an X-Rays detector is reported in Figure 4-17. The device was subjected to a DC polarization of 0.2 V and to different dose rates, generated by means of collimated molybdenum X-Rays tube. Each dose rate was applied three times for 60 seconds, followed by 90 seconds of recovery time. It is possible to observe that the device is able to distinguish between different dose rates, showing a sensitivity of about 55 nC/Gy.

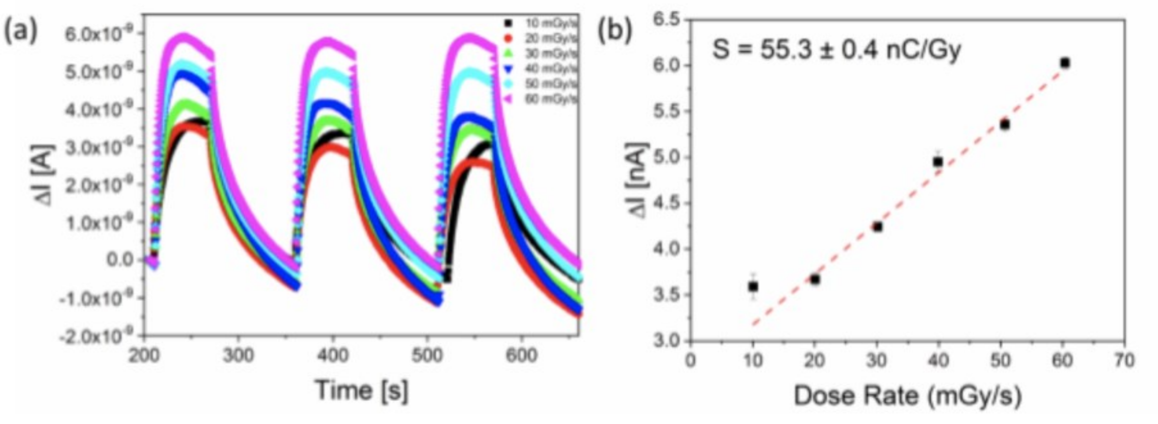
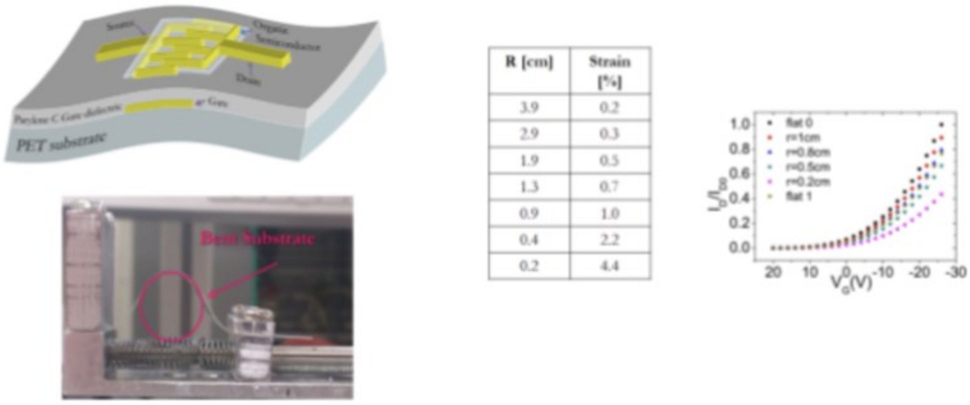


Figure 4-17: (a) real time response of an X-Rays detector as current variation, for different dose rates applied. (b) Current variation vs. dose rate, with linear fitting indicating the device sensitivity.

Flexible OTFT based strain sensor

In this activity we have developed a novel approach for the fabrication of wearable strain sensors that can be employed for monitoring the joints movements and quantitatively measuring their bending angles.

The approach is based on the employment of flexible organic field effect transistors, as it can be seen in Figure 4-18. Such devices have been fabricated using 175 um thick polyethylene phthalate foil. At first, an aluminum gate electrode is deposited by thermal evaporation and patterned by means of standard photo lithographic process.



R [cm]	Strain [%]
3.9	0.2
2.9	0.3
1.9	0.5
1.3	0.7
0.9	1.0
0.4	2.2
0.2	4.4

Figure 4-18: Schematic representation of a flexible OTFT, and of the experimental set up employed for the electromechanical characterizations (left); transfer curves variation induced by different bending radii and correspondence between bending radius and strain values (right).

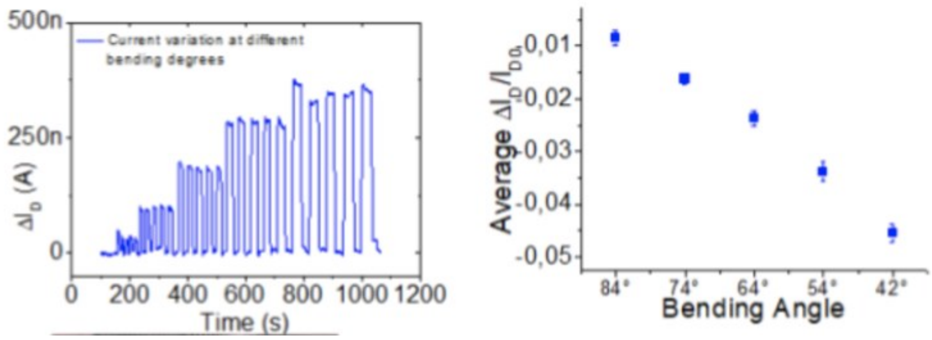


Figure 4-19: Current variations induced by different knee bending angles (left), relative current variations as a function of the knee bending angle (right).

After that, a 150 nm thin film of an insulating polymer, namely Parylene C, has been deposited all over the device area and acts as gate dielectric for the final device/sensor. At the top of this film, is deposited a metal gold film, that is patterned by means of photolithography in order to obtain an interdigitated source and drain electrodes couple. Finally, a thin film of a specific organic semiconductor is deposited in the device channel.

In this way the device can be bent at different bending radii and at the same time its electrical characteristics can be constantly recorded. Interestingly, the tensile strain induced on the active layer by bending leads to a reproducible and reversible change of the output current of the transistor. In fact, the active layer is a polycrystalline film that has a marked piezoresistive effect. Applying a tensile stress leads to the crystal domains to be separated, thus leading to a decrease of the carrier's mobility. When the flat condition is restored, the morphology of the active layer comes back to its intrinsic state, and the initial mobility is restored. Being such a phenomenon highly reproducible, at least when working below 2% of surface strain, these devices can be employed as strain sensors.

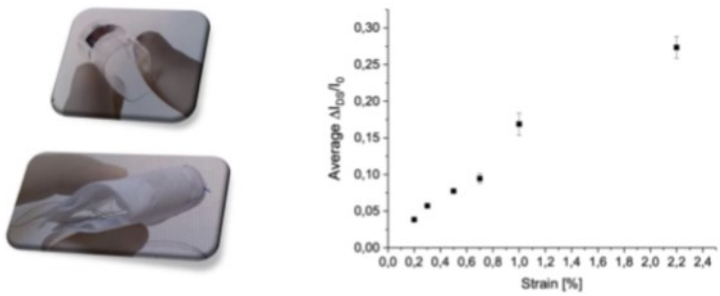


Figure 4-20: Example of a flexible OTFT based strain sensor and its integration into a fabric strip (left), relative output current variation as a function of the applied strain (right)

In order to do that, they have been encapsulated in a 2 um thick parylene C film and inserted into a fabric strip as shown in Figure 4-20. After this process the sensorised fabric strip has been sewn in an elastic bend that can be placed on a human knee or elbow and employed for monitoring the joints motion.

In the following we report some preliminary results obtained on the knee. In this case, the knee has been bent at 5 different bending angles (five times for each deformation), and the output current changes have been recorded. As it can be clearly observed from the graphs reported in Figure 4-19 and Figure 4-21, each deformation for a given bending radius gave rise to very similar results. Moreover, as it can be observed from the calibration curve, the average current changes varies linearly with the applied deformation, and it seems to be very stable over time even after continuous cycled deformation. Considering such results, we can state that this very simple approach can be efficiently employed for the fabrication of wearable, reliable, strain sensors, and that such devices can potentially be employed for monitoring many different joint motions.

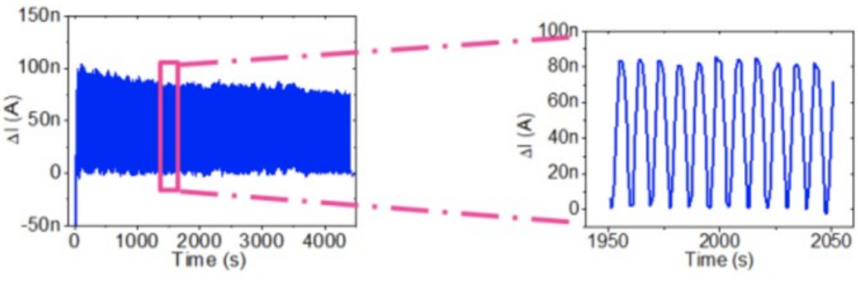


Figure 4-21: Cycling testing of the strain sensors (current variation for a given bending angle), showing the stability and reproducibility of the device.

Figure 4-22: Digitron's HLX3000 wireless portable monitor. The device has a compact ergonomic design, easy to carry.

Wireless portable hazmat monitor for multi-gas detection.
Digitron's HLX3000 wireless portable monitor has been selected among other commercial devices for gas detection during SAR operations (Figure 4-22). This high-performance instrument is part of the Digitron's Sky3000 series, it is able to detect multiple gases at the same time (toxic, explosive and VOC gases), through various configurations that can be customized according to the needs of the end user and has a compact ergonomic design that makes it easy to carry. The main features of the device are summarized in the following table 4-1.
The monitor is equipped with various functions, such as the man down alarm function and storage through password. Furthermore, it has obtained the main international anti-explosion certifications. In addition, it is equipped with a dual function of aspiration and diffusion: the device works mainly in aspiration mode, but if the air pump fails or emergency situations, it can automatically switch to the diffusion sampling method, thus improving the level of protection. The monitor is equipped with wireless communication, providing Bluetooth transmission function, with an open operating system capable of sending data and alarms in real time to both a PC and a smartphone, even with an external custom app.

Sampling method	pump suction & diffusion dual-use type
Gas type	Oxygen, Combustible gas, Carbon monoxide, Hydrogen sulfide
Principle	Catalytic combustion,Electrochemistry
Measure range	CO: 0-1000ppm, H2S: 0-100ppm, O2: 0-25%VOL, LEL: 0-100%LEL
Resolution	1ppm(CO), 0.1%VOL(O2), 0.1ppm(H2S), 1%LEL(LEL)
Response time	≤30 seconds
Precsiion	≤ ±2%F.S except for special gases
Language	Chinese/English (More language can be customized)
Automatically test and calibrate after power-on	Including reset, maximum value (MAX), minimum value (MIN), STEL, TWA value
Unit	PPM and mg/m3 can be switched and displayed by one key, and the concentration value is automatically converted by the system
Disaply	monochrome graphics (160 x96) ,screen can be automatically flipped
Backlight	The backlight time can be manually set, and will be turned on automatically when an alarm is issued
Data record	Can store 100,000 sets data, the storage interval is adjustable from 5 to 3600 seconds, data can be exported, with data cable
Alarm	95dB buzzer (@30cm), vibration alarm and flashing red LED and alarm status indication on the screen, alarm latched; diagnostic alarm and battery undervoltage alarm, pump block alarm; man down alarm, with early warning and optional real-time remote Bluetooth notification function
Battery	3.7V rechargeable lithium battery, battery capacity 2200mA
Working hours	More than 15 hours in continuous pumping mode
Charger	Travel charger with DC interface, charging time ≥ 4 hours
Explosion-proof grade	IECEx: Ex ia IIC T4 Ga ATEX: Ⓔx II 1G Ex ia IIC T4 Ga
Certification (EU regulations)	2004/34/UE (ATEX)
Protection grade	IP67
Working temperature	-20℃~+50℃
Humidity	0~90%RH (no condensation)
Environmental pressure	86~106Kpa
Size	157*84.5*59.5mm (including back clip/water trap filter) (length * width * height)
Weight	365g (including battery, belt clip and filter)

Table 4-1: Technical specifications of Digitron's monitor HLX3000.

The GPS sensors integrated into the smartphone

Access to the integrated GPS receiver on Android smartphones is widely documented in various programming languages (for example Java, Python, etc.); once the sensor reading permissions have been requested, it is possible to dispose of such data and process them, save them, or forward them with relative simplicity.

As an example, a Python application was created with the help of the Kivy framework (see Figure 4-23).

The most interesting data that can be taken from the GPS receiver are:

- Latitude
- Longitude
- Speed
- Altitude
- Bearing
- Accuracy

These values can be saved to a file (CSV, JSON, etc.) and be forwarded to a remote server via socket or http protocol.

Figure 4-23: Kivy GPS App GUI

5 First responders uniform Prototype

5.1 Integration of the components

The implementation of the sensors within the uniform will be described in the next version of this document.

5.2 Future Test plan

The validation tests of the uniform will be performed in 2022 and will be available in the second version of the deliverable. The validation tests will be performed both in laboratory and in a relevant field scenario according to the following regulations and during the following Use Cases project pilots:

- UC1 - Victims trapped under rubble (Italy)
- UC5 - Victims trapped under rubbles (France)
- UC6 - Resilience Support for Critical Infrastructures (Romania)

The uniform will be tested according to the UNI EN ISO 13688 and the UNI EN 16689.

5.2.1 End user testing

The regulation UNI EN ISO 16689 suggests usability tests to evaluate the value of the comfort and freedom of movement of the protective garment. However, it is necessary to test the uniform directly with the end users.
Depending on the type of first responder, the need for comfortability and freedom of movement is different. Firefighters have to be equipped with much more heavy and bulky devices, unlike, for example ambulance service operators. Also, the working environment is different. Ambulance service stays "in the green zone", whereas fire fighters are working in the "red zone" of disasters. These are determinant factors for the robustness of clothes, but it is also a limiting element.
The best judgement comes from experts from the field. Practitioners, who are confronted on a regular base with the limitations and challenges of their equipment can provide sound feedback.

5.2.2 PPE related project CAST[3]

Within several projects, personal protective equipment has been put into test. One of these projects for Search and Rescue and for counter terrorism was the FP7 Project CAST and the related deliverable D5.5a by A. Schwille and G. Aumayr. The deliverable gives the definition of "initial responders", defining that any first responder is active at sometime within the "warm zone". This means being active at the brink of the red zone to the yellow zone for a time span of about 5-10 minutes. According to this definition, the PPE has to therefore withstand 5-10 minutes of activities in a dangerous zone. This means all classifications need to be present to some extent. Special risks have been defined as mechanical risks, chemical and microorganisms, thermal risks, coldness and general medical usage and contamination protection.

5.2.3 Test Plan

The test plan consists of three phases. Phase 1 is independent of Phase 2 and 3. Phase 2 and 3 can be undertaken within the consortium and focused on the added value to the first responders.

[3] FP7, 2009-2011, Proj.ID:218070

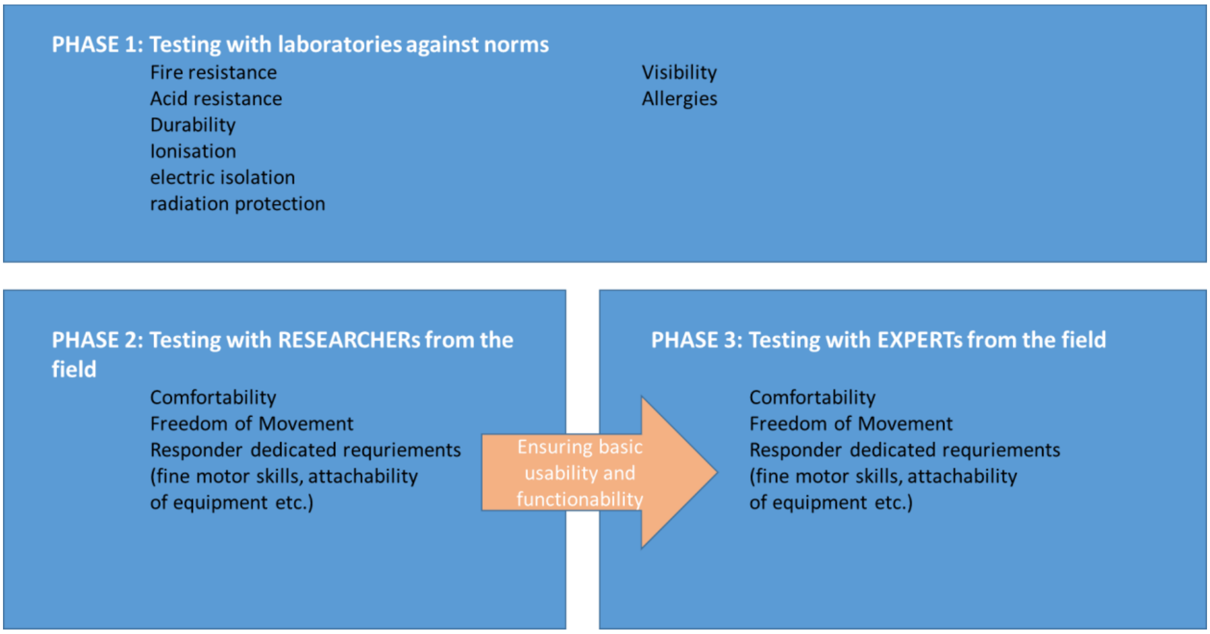


Figure 5-1: Testing phases

Phase 1 Testing against norms
This should be performed by a certified laboratory. It is carried out by several entities and external (to the project) organizations. For the Search and Rescue Project, it is not an aim.

Phase 2 Testing with researchers/developers with first responder background
The uniform will be tested by researchers with a background as either paramedics/EMTs and/or fire fighters and/or law enforcement to provide first feedback to the developers and designers. Especially the added devices in comparison to state-of-the-art uniforms, will provide a good foundation for the next development steps.

Phase 3 Testing with end users
Within a field trial during an exercise of demonstration, the uniform will be tested in a training environment under close to real conditions.
The assessment will be done based on the availability of prototypes of Search and Rescue and in accordance with the state-of-the-art uniforms. What is not available by developers of the Search and Rescue Project, will not be assessed.

6 First aid device for children

Injuries are the most frequent cause of death in children over one year of age. In addition, they are associated with significant morbidity and result in considerable sequelae and disabilities, which compromise the child's development and quality of life.
Pediatric trauma care includes multiple facets such as educational and preventive measures, but in major disasters, preventive measures are not always effective. The key factors are on-site assistance, transport to the reference center, specialized care in the acute phase and long-term support, rehabilitation, and social reintegration measures.
A very important role is played by the use of rescue devices to minimize the after-effects for children, where they can be rescued quickly and safely.
All First Responders and their actions are key to the vital prognosis and recovery of the victims' functions. Therefore, these professionals must know the theoretical and practical bases of the use of rescue devices, in this case those utilized specifically for children.
It is a reality that resources and their distribution are variable in each health system, as are the training of professionals and the possibilities of having to attend to and rescue traumatized children. It is therefore difficult to establish a common guideline for action, which in many cases would not be applicable, so it seems more advisable to unify knowledge, skills and rescue systems that allow them to be as effective as possible in the environment in which they carry out their work.
The creation of child rescue systems that are easy to transport and easy to use would improve the prognosis and subsequent sequelae of polytraumatized children in disasters or incidents involving multiple victims.

6.1 State of art

According to the purpose of the project, the designing process started from a thorough analysis of the state of art. The analysis was carried out using different approaches and tools. The following paragraphs present the methodologies and the most relevant outputs of the research on the state of art.

6.1.1 Summary of the state of art from D1.1

The analysis of the state of the art in Deliverable 1.1 had the purpose to gather information on existing technologies used in SAR operations relevant to the location of entrapped victims, and the identification of limitations and gaps, as well as of future needs. The deliverable provided an analysis based on multiple research actions including a structured survey.
The first analysis highlighted that a specific product for the first aid of kids, designed according to the children centered design approach, does not exist. In fact, the products analyzed refer to neonatal hospital transport or ambulance spinal stretchers, not focusing on devices used in the scenarios proposed by S&R.
The analysis results highlight that the products actually used in SAR scenarios are very often bulky and heavy and require the collaboration of multiple rescuers to be used. At the same time, the stretchers are the same used for adults, and for this reason appear unsuitable for carrying a child, not guaranteeing adequate comfort to the young victims.
Moreover, the analysis pointed out that the stretchers used in rescue activities are made of a single material. This choice makes the product essential and easy to clean, without padded, soft and welcoming elements, at the expense of comfort and of physical and emotional wellbeing of young victims.
In recent years, this type of products has had no formal evolutions, despite the discovery of new innovative materials that replace unsustainable ones. Therefore, this kind of devices in production and available on the market are not user-entered, because they are designed only according to the

main function. They avoid all the other requirements related to the rescuer's usability and the user experience of the victim, and not considering their emotional comfort, making the experience even more traumatic.
Another relevant data that emerged from the analysis highlighted that not all rescue devices are equipped with monitoring sensors. In fact, elements for communicating vital parameters, such as screens for ECG viewing and monitoring of the EMG rate for first responders do not exists.
The devices with monitoring systems on the market have a very low energy sufficiency, or require a direct connection to an energy source, making rescue very complicated.
These sensors do not take up much space and could fit into the baby first aid device, inside small side pockets, along with other accessories to protect the baby such as thermal blankets, windproof, waterproof, and fireproof.

In section 4 of Deliverable 1.1, the types of existing SAR technologies, limitations, gaps and future needs emerging from the survey of the first aid device are summarized in the following table.

Type of existing SAR technology	Limitations	Gaps	Future needs
First aid device for kids	A specific device for young victim protection during a disaster does not exist. The only examples of devices for children rescue refer to neonatal hospital transport or ambulance spinal stretchers. The devices on the market, found by benchmarking analysis provide only physical protection to the spine and they are bulky, difficult to be carry by a single people.	Devices on the market: are lack of: - sensors to monitor the health, body temperature and vital signs of the young victim; -Lightness to be easily carried by a single rescuer; -Children-centred design; - Protection from atmosphere condition; - GPS tracking; - Radiation sensor; - Ergonomics and comfort; - Communication devices.	- Sensors to monitor young victim health parameters with independent emergency alert able to communicate through Bluetooth with First Responder smartphone and to provide messaging, ECG, EMG rate monitoring and alerting functions (fully embedded in the device) and providing GPS tracking - Adjustable elements to protect young victim from fire and extreme atmosphere conditions; - Light, resistant and comfortable materials; -Radiation sensors, (mainly X rays) and additional protection system; - An appropriate energy self-sufficiency.

Table 6-1: D1.1 results regarding the First aid device for kids

6.1.2 Reviews of children's devices for other scenarios.

The analysis of the state of the art of the most relevant devices for the rescue of kids and other scenarios has the purpose to gather information on the existing baby carriers and car baby carriers, to identify their innovative aspects in terms of comfort, usability, and safety. Moreover, the analysis aim was to highlight the weaknesses about materials and fabrics properties, technical specification, and morphology of the products. At the same time, the analysis purpose was to identify communication aspects to be taken into consideration for the design of the first aid device for kids.
In the analysis, the most relevant baby devices were evaluated, using a specific comparative table as below. The document shows the most relevant evaluated device charts.

Baby Carrier MOVE			
Company: BabyBjörn	**Designer:** BabyBjörn	**Company Country:** Sweden	**Company website:** https://www.babybjorn.eu
Field of use: Baby carrier for everyday activities		**Availability:** ◻ Concept to be validated ◻ Concept ready for distribution ■ Product available on the market	
Image/photo: 			
Product Description: Move is an ergonomic and flexible baby carrier in soft 3D mesh. The carrier is simple to put on and easy to lift. The product is equipped with back support, waist belt, and padded shoulder straps. It allows you to have your hands free and allows the child the correct support for the back, legs, and hips. The seat width is adjustable to ensure that the child is always seated comfortably. It is simple to use and allows the child freedom of movement for the legs and arms and good support for the neck and head.			
Technical specifications: Weight: N/A Dimensions: N/A suitable for babies 0-15 months (min 3.2 kg - max 12 kg, from 53 cm)			**Typology of the carrier/device:** ■ One piece ◻Two pieces
Innovation aspects: *(strengths from others similar product on market)* The 3d mesh is a highly technological and breathable fabric, increasing the comfort of the parent wearing / carrying the child. The qualities of the 3D mesh ensure the baby carrier retains its shape after each wash. The fabrics meet the requirements of OEKO-TEX Standard 100, Class 1 for baby products.			
Weaknesses: Move baby carrier has no protective elements for the child able to protect him (such as a windproof hood).			
Sensor's description: There are no sensors for monitoring the baby			
Sources/Bibliography: https://www.babybjorn.eu			

Table 6-2: Baby carrier MOVE

Dualfix Ii-Size			
Company: Britax - Roemer	**Designer:** Britax - Roemer	**Company Country:** Germany/Britain	**Company website:** https://www.britax-roemer.com
Field of use: Car Baby seat		**Availability:** ☐ Concept to be validated ☐ Concept ready for distribution ■ Product available on the market	
Image/photo: 			
Product Description: DUALFIX i-SIZE is a car seat for children 0-4 years (105 cm). The 360-degree rotating seat offers maximum comfort for the child and can be used for both rear-facing and rear-facing. It offers constant comfort throughout the period from 0 to 4 years. It has 12 forward and backward facing reclining positions, including a lying position for the newborn. The seat cover can be easily removed without removing the harness, to be cleaned in the washing machine. (Age Birth - 48 months)			
Technical specifications: Weight: 15 kg Dimensions: 48H x 44W x 74D cm / for kids' kg: 0 - 18 kg /Stature: 40 - 105 cm		Typology of the carrier/device: ■ One piece ☐Two pieces	
Innovation aspects: *(strengths from others similar product on market)* DUALFIX i-SIZE has been equipped with many innovative safety features such as optimized side impact protection inside, implemented by a special steel element inside the seat (Patent Pivot Link ISOFIX). To ensure protection in any accident, the child is protected in whether front, side and rear.			
Weaknesses: The communicative and emotional aspects were not considered in the design process. Materials that ensure the baby's comfort have not been used. The product does not allow the total immobilization of the child. It can be used for children up to 4 years.			
Sensor's description: There are no sensors for monitoring the baby			
Sources/Bibliography: https://www.britax-roemer.com			

Table 6-3: DUALFIX i-Size

<table>
<tr><td colspan="4">First HempCotton</td></tr>
<tr><td>Company:
Manduca</td><td>Designer:
Manduca</td><td>Company Country:
Germany</td><td>Company website:
https://www.manduca.de</td></tr>
<tr><td colspan="2">Field of use: Baby carrier for everyday activities</td><td colspan="2">Availability:
□ Concept to be validated
□ Concept ready for distribution
■ Product available on the market</td></tr>
<tr><td colspan="4">Image/photo:
</td></tr>
<tr><td colspan="4">Product Description:
First Hemp Cotton is a baby carrier that can be worn on the front and back. There are straps and adjustable belts that fit the parent. It is dedicated to children with a weight between 3.5 and 20 Kg. (Complies with CEN / TR 16512: 2015).</td></tr>
<tr><td colspan="2">Technical specifications:
Weight: N/A
Dimensions: N/A</td><td colspan="2">Typology of the carrier/device:
■ One piece
□Two pieces</td></tr>
<tr><td colspan="4">Innovation aspects: (strengths from others similar product on market)
To ensure easier attachment of the baby carrier, First Hemp Cotton has fewer straps. There are some pockets for personal items.</td></tr>
<tr><td colspan="4">Weaknesses:
The communicative and emotional aspects were not considered in the design process. Materials that ensure the baby's comfort have not been used. The product does not allow the total immobilization of the child. It can be used for children up to 20 kg.</td></tr>
<tr><td colspan="4">Sensor's description:
There are no sensors for monitoring the baby</td></tr>
<tr><td colspan="4">Sources/Bibliography:
https://www.britax-roemer.com</td></tr>
</table>

Table 6-4: First HempCotton

Darwin Infant I-SIZE

Company:	Designer:	Company Country:	Company website:
Inglesina	Inglesina	Italy	https://www.inglesina.it/

Field of use: Car Baby Carrier

Availability:
- ☐ Concept to be validated
- ☐ Concept ready for distribution
- ■ Product available on the market

Image/photo:

Product Description:
According to the new ECE R129 i-size, Darwin Infant I-Size accompanies the baby from birth up to 75 cm in height. The correct posture is ensured by the angle of inclination which makes it extremely comfortable for the child. Polyurethane foam is inserted in the side Head protection system to ensure extra protection for the child. The product is lined with washable and removable breathable materials.

Technical specifications:
Weight: Not Available
Dimensions: Not Available

Typology of the carrier/device:
- ■ One piece
- ☐ Two pieces

Innovation aspects: *(strengths from others similar product on market)*
The polyurethane foam in the side head obtained an excellent score in the main European safety tests such as the prestigious ADAC, also being the best for ergonomics in its category.

Weaknesses:
The product does not allow the total immobilization of the child. It can be used for children up to 75 cm in height.

Sensor's description:
There are no sensors for monitoring the baby.

Sources/Bibliography:
https://www.inglesina.it/

Table 6-5: Darwin Infant I-Size

Aptica

Company: Inglesina	**Designer:** Inglesina	**Company Country:** Italy	**Company website:** https://www.inglesina.it/

Field of use: Baby Stoller	**Availability:** ☐ Concept to be validated ☐ Concept ready for distribution ■ Product available on the market

Image/photo:

Product Description:
To ensure mobility and rest of the child, Aptica could be transformed and adapted in a carrycot, a stroller, and a baby car device. In fact, the product is not bulky and heavy.
Aptica includes Carrycot, Welcome Pad and mattress, car seat, stand up support for carrycot, stroller seat, storage basket.

Technical specifications Weight: min 8,3 kg max 12,3 kg Dimensions: 90H x 84W cm	**Typology of the carrier/device:** ■ One piece ☐Two pieces

Innovation aspects: *(strengths from others similar product on market)*
The transformation of the product allows to have a single product for multiple uses. To ensure hygiene, a special closing system prevents the handle or the fabric from touching the ground. Mesh insert allows air to flow inside the product to keep the internal environment cool and ventilated. The product is equipped with a Welcome Pad, an innovative mattress that helps to keep the baby's airways aligned. It gives the child the environment and protection it needs, especially in the first 7-9 weeks of life.

Weaknesses:
Despite the portability of the product, the morphology of the device does not guarantee a correct posture in case of immobilization.

Sensor's description:
There are no sensors for monitoring the baby.

Sources/Bibliography:
https://www.inglesina.it/

Table 6-6: Aptica

The analysis showed that the products on the market are not adaptable for different ages. In fact, the height is limited in many devices. The materials used have an important role for the child's

comfort. The use of breathable, windproof, and waterproof materials allows to keep the child warm and safe. At the same time, materials must be easy to wash and decontaminate. To ensure the child feels safe, protective elements could contribute to the correct body position.
For this reason, the first aid device for kids' requirements are summarized as follows:

- Adjustable device.
- Use of breathable, comfortable, windproof, waterproof washable materials.
- Addition of protective elements.
- Reassuring elements.
- A rigid and flat board to be used like a spinal stretcher to immobilize the children if necessary.

6.1.3 Reviews of smart and innovative materials for the first aid device for kids

The selection of materials for the device for kids' project started with a preliminary desk analysis on technologies related to innovative and highly performing materials in the SAR sector and adjacent sectors (automotive, sport, defense and security, soft robotics, etc.) with a particular focus on shockproof, light, and resistant materials. The first phase of the research embraced both innovative materials in the testing phase (microlattex, aerogel) and commercial materials that can be implemented immediately in the project (Aluminum 7075, D30). Following the preliminary research phase, specific forms were prepared to classify the information on the materials identified in the desk analysis phase. Each material was filed, and the information was organized into qualitative ranks. This tool has proved to be fundamental for ordering and comparing the various selected materials, guaranteeing a careful choice in terms of performance, ergonomics, and sustainability, both economic and environmental.
The material data sheets have been divided respectively into three sets useful for the design of:

- the structure;
- the upholstery;
- the upholstery fabrics.

The choice of material for the application on these three types was conveyed upstream from the previously established selection criteria linked not only to performance in emergency contexts (resistance to shocks, lightness, water resistance) but also to the comfort and ergonomics of the victim (breathability, hypo allergenicity). As for the collection of materials useful for the device project, the research group explored materials from the world of automotive and "defense and security". Particular attention was paid to physical and chemical properties - therefore color, hygroscopy, melting temperature, density, corrosion resistance, thermal and electrical conductivity - and to mechanical performance (specific weight, impact resistance, tensile strength, compressive strength, etc.). At the same time, the environmental properties of the life cycle (LCA) of the material were also evaluated, therefore recyclability, environmental impact in the assembly phase, energy consumption, emissions. Regarding the workability of the semi-finished product, and consequently the margin of use, the technological properties of the material were also evaluated, therefore malleability, ductility, fusibility, weldability, and hardenability. High-performance products such as D30 and Ergal (alloy 7075) were listed, as well as experimental technologies such as expanded foams (Line-x) or composites in additive manufacturing) Markforged, Reboze.

After a careful evaluation of the documents, the research team decided to use a honeycomb polypropylene in the catalog of the Vetronova company in the supporting part of the device, given the excellent combination of technical performance, lightness, workability, and comfort.
At the same time, for the padded parts it is planned to use an Orsa Foam Water Lily foam covered in JACKAL 8627 in the catalog of the Santanderina company (material used for disaster scenarios). There will also be fabrics in bamboo fiber (Bamboo031 Maeko fabrics). A hypoallergenic material and therefore perfect for contact with the skin.

The deliverable reports the data sheets of the most relevant evaluated materials in Annex III.

6.1.4 Reviews of technologies/sensors to be used for children's monitoring.

There's no shared experience on specific tools for rescuing children during search and rescue operations. Overall, as in this case we are dealing with victims and not first responders, any wearable technology cannot be adopted. The wearing of tight suits is inappropriate, prone to harmful maneuvers and definitely non-practice as the size of the victim could be very different according to the age. The most important aspects to be considered in this case are the heart and respiration rates, and the body temperature. SpO2 could be also recorded if a suspect of asphyxia is present. Nevertheless, technologies for these sensors are the same used for adults, only with a different size of the electrodes (for neonatal use). If SpO2 is recorded, on neonates the probe is conveniently attached to the foot as the fingers and earlobes are too small: this cannot be done on adults. For body temperature, continuous monitoring can be effectively provided by medical-grade NTC thermistors for the detection of the temperature at the level of the skin. Rectal probes are usually preferred for neonates, but the transportation of the victim and the hygienic conditions suggest avoiding this approach. As said, in this case, only commercial sensors can be used, attached to custom sensing nodes if needed.

Figure 6-1: Commercial sensors for SpO2 and ECG for pediatric use

6.2 Guidelines of The European Resuscitation Council and Pediatric Trauma

The pre-hospital care of a trauma patient should be carried out sequentially and with the collaboration of available healthcare personnel, according to their roles and responsibilities[4]:

- Recognition of a potential trauma patient situation and effective allocation of available resources and rescue devices.
- First impression and assessment, with early recognition of severity.
- Identification of critical injuries and immediate treatment of life-threatening injuries.

[4] LIBRO ELECTRONICO SATRAPP SEPEAP (pediatriaintegral.es)

- Assessment of the useful center and anticipation of transport to it.
- Stabilization in situ (the child rescue devices come into play here) and transport to the useful center or definitive center, as the case may be.
- Coordination with the receiving center.
- Final re-evaluation of the action jointly, by all those involved.

The pathophysiological characteristics of children must be considered, especially by professionals who are familiar of treating adult patients. Due to their size, multi-organ injuries are frequent problems. The greater flexibility of the infant skeleton reduces its susceptibility to bone fractures, although their absence does not exclude visceral injuries in the thorax and abdomen. The existence of fractures, on the other hand, should enhance the possibility of high-energy trauma, the smaller the patient, the more so. The high body surface/weight ratio in children makes them more exposed to hypothermia. In children, blunt trauma is more frequent than penetrating trauma, so that hemorrhages (even major ones) may not be evident, which makes it necessary to have a high index of clinical suspicion. The anatomical characteristics of the head (relative macrocephaly, prominent occiput, and short neck, macroglossia, shape and location of the epiglottis) facilitate airway obstruction sense, knowing the mechanism of injury can be of great help in determining the risk of rapid deterioration of the child. The mechanisms of hemodynamic compensation in the child are characterized by increased heart rate and peripheral resistances, which cause them to maintain "normal" blood pressure figures in the initial phases of shock. In a child, the presence of hypotension is a clear sign of decompensated shock.
In terms of prognosis, although children are considered to tolerate multi-organ injuries better than adults, the sequelae can significantly compromise their physical and psychological development.
The prior phases to rescue a child during a disaster are the following:

1. Pre-alert.
2. Activation of resources.
3. Mobilization and approach.
4. Rescue and stabilization of the patient.

It is necessary to stabilize the injured children involved in the disaster, according to the upcoming steps:

1. Triage
2. Rescue and lifesaving measures if possible
3. ABCDE[5] Sequence:
   A: permeable airway
   B: oxygenation and ventilation
   C: Circulation and bleeding control
   D: neurological damage
   E: exposure and environmental control
4. Complete secondary screening

Spinal stabilization is frequently integrated into prehospital treatment for trauma victims, resulting in a uniform strategy to prevent additional spinal damage from deteriorating (Kornahll et al., 2021). These operations depend on the situation and on the age, the height, and the weight of the child. For instance, the rescuing and stabilization procedures of infants up to six months generally do not involve spinal immobilization.
According to the situation, for the stabilization of the spine, a combination of devices is utilized which includes rigid cervical collar, side head blocks, and straps to support the victim's body to a rigid stretcher. The Stabilization of the spine allows to: achieve the neutral alignment of the spine, reduce

[5] ABCDE stands for a check of Airway, Breathing, Circulation, Disability and Exploration

movement and secondary injuries in potentially unstable spinal column situations and optimize the safety of the victim during transport to the hospital. The application of cervical collar to the trauma victim is presented as a priority procedure in the American College of Surgeons (ACS) Advanced Trauma Life Support (ATLS) guidelines and in the Prehospital Trauma Life Support guidelines.
This priority for the protection of the spine is given by the application of cervical collar ABCDE principles (Breathing, Circulation, Neurological Dysfunction, Exposure) that aim to identify and treat life-threatening injuries to the trauma victim.
The European Resuscitation Guidelines describe the most recent evidence-based guidelines on resuscitation practice and the prevention and treatment of cardiac arrest and life-threatening emergencies across Europe with specific thematization of neonatal and pediatric life support. It is detailed how to recognize and manage a critically ill child, starting with an assessment using a 'quick-look' tool such as the Pediatric Assessment Triangle and follow the ABCDE approach which provides a step-by-step approach to assess the health of the child and take most immediate actions (Perkins et al., 2021).

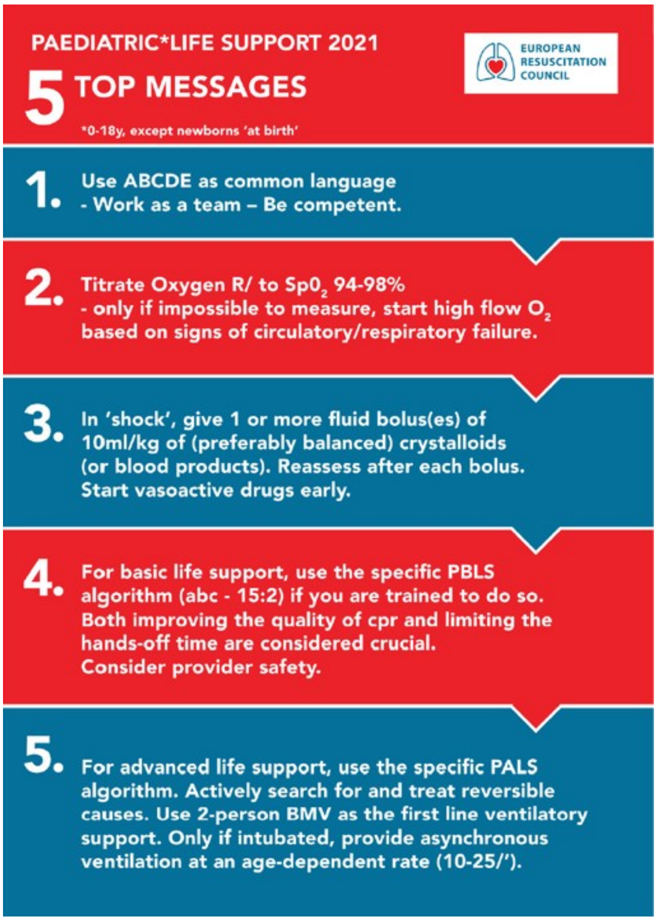


Figure 6-2: Paediatric Life Support (Perkins et al., 2021, p. 42)

Many medical emergencies of children involve a combination of problems that require a rather individualized approach. Treatment recommendations for children differ from adults, but also between children of different age and weight (Perkins et al., 2021). According to Johanniter International (2020), who established standardized first aid guidelines as recognized by the European Medical Association, categorization is made between infants (under 12 months) and a child, ranging from the age of 1 up to the age of 8. In order to estimate a child's weight first responder can either rely on information provided by parents or a caregiver. Alternatively, a length-based method can be applied using a tape measure, such as e.g., Pawper MAC. The measure tape is divided in different color-coded segments indicating e.g., which size of medical device to be used. These decision aids can provide dose/advice for emergency drugs and other materials (Perkins et al., 2021).

Equipment for emergency treatment of children is often organized in a modular set up, providing different sized materials and equipment that is age/size appropriate.
Following, an exemplary inventory list[6] for an EMS backpack specifically for the treatment of infants and young children is provided:

- ventilation mask (different sizes)
- children's ventilation bag
- single use ventilation bag
- laryngeal tube (different sizes) and fixing strap
- cuff syringe for laryngeal tube 60ml
- gastric tube
- suction catheters (2mm)
- PEHA-haft children's bandage (4x4)
- disposable clamp
- (elasto fabric) roll plaster
- clinical thermometer
- Stylet (2mm, 2.6mm, 3.3mm)
- cuff syringe (10ml)
- Spatulas (different sizes, straight and curved)
- Magill forceps for children
- rectal applicators
- syringes (1ml)
- corPatches for children (defibrillation electrodes)
- pack of electrodes for children
- SpO2 sensor for children (for peripheral capillary oxygen saturation)
- silver diaper with hood (to contain heat)
- blood pressure cuffs: child and toddler (incl. manometer)
- stethoscope (infants)
- set of child emergency tables (synoptic table)
- nebulizer mask child (for delivery of aerosolized/nebulizer medications)
- gauze bandage
- tube holder children
- Yankauer suction catheter (6mm)
- Color-coded bags according to height/age (ranges: -50cm, -76cm/infants up to 1 year, -92cm/1-3 years, -115cm/3-6 years, -135cm/6-10 years):
- Various types of tubes (with cuff, nasopharyngeal, oropharyngeal)
- Venflon/Neoflon (peripheral venous catheter)
- Oro-pharyngeal aspirator (-50cm)

[6] Based on standard equipment of Johanniter Austria

In addition, many ambulances are equipped with a children's restraint system for the transport of children. The 'Schmidt Kiddy restraint system' as an example, it should provide safety and sufficient comfort for children between the age of approx. 7 months up to 7 years (80-130cm). The system should provide protection against forward, backward, sideways, and upward forces during adjusted transport in the integrated vacuum mattress (Medical Trading, n.d.).

6.3 Users' requirements

The following research activities aimed to identify the core users' requirements for the designing of the First aid device for kids. The first aid device for kids is simultaneously used by two different types of users. Actually, it welcomes the injured child who becomes a passive user, while the FR actively uses the product during rescue operations. For this reason, the requirements refer to two different kinds of users: both to main and secondary ones. The following paragraphs describe the requirements pointed out from the questionnaire activity and from the co-working activity with the end users' partners.

6.3.1 PRIMARY END USER: the First Responder

Apart from the tailor-made materials and medical devices needed for the appropriate treatment of infants and children in emergencies, the following minimum requirements apply to a paramedical carrier device:

Number	Requirement	Category
PEU01	The carrier should provide a firm surface (to be able to perform chest compressions if necessary)	MUST
PEU02	The carries needs elements as belts to lock the child on the board to avoid any unnecessary and sudden movement	MUST
PEU03	The carrier needs a headrest to make it possible to fix the head position of the child	MUST
PEU04	The carrier needs to be washable/disinfected	MUST
PEU05	Sensors need to be easy fitting and adjustable to children of different size/age	MUST
PEU06	Sensors cannot obstruct actions to be performed by EMS personnel	MUST
PEU07	Health Monitor should be detachable from sensors (transmission via Bluetooth etc.) (lowering the risk of equipment falling etc.)	SHOULD
PEU08	The carrier is combined with emergency treatment equipment to have all necessary materials compiled	COULD
PEU09	The carrier should take minimal space in the ambulance car	SHOULD

Table 6-7: Primary user's requirements for first aid kit for children

6.3.2 SECONDARY USER: the child

For the design of a first-aid device for kids, it is relevant to understand, analyze and study skills, behaviors, psycho-physical and emotional needs of children at different age ranges and related to emergency scenarios. The collection of the requirements pointed out by the analysis of the children's needs and behaviors as second users cannot be done in the same way as the ones regarding the first user. Nevertheless, it is possible to develop a set of requirements using the Children Centered Design (CCD) approach and the involvement of professionals. The following user requirements from the children as secondary end user perspective were collected:

Number	Requirement	Category
SEU01	The carrier should allow the child to feel safe and comfortable	SHOULD
SEU02	The child must not be harmed during the operation	MUST
SEU03	The child should be able to communicate with the rescuer	SHOULD
SEU04	The carrier must ensure an optimal body temperature of the child	MUST
SEU05	The child must not get wet within the carrier	MUST
SEU06	Sensitive parts of the sensors within the carrier should not be in range of the child to avoid damage	MUST
SEU07	The materials of the carrier must be free of any pollutants	MUST
SEU08	The carrier must be ergonomically suitable for the child	MUST

Table 6-8: Secondary user's requirements for first aid kit for children

The World Health Organization - WHO - published the minimum technical standards and recommendations for reproductive, maternal, newborn and child health care. This book was made for emergency medical teams, but there are helpful suggestions for equipment that can also be used for first aid from first responders that are not specialized in childcare.

6.3.3 The Questionnaire to the End Users

According to the purpose of the project a questionnaire activity was carried out with the consortium end user partners between February and March 2021. The questionnaire aimed to highlight opinion, strengths, and weaknesses of the current state of art of the First aid device for kids used in USAR activities. Each question had a specific purpose in the design process of the first aid device for kids. The activity was carried out anonymously using the Google form platform and the respective questionnaire form is attached in the present document in Annex II section.
The questionnaire is composed of two kinds of questions:

- Free questions - each participant could explain their point of view.
- Multiple choice questions - each participant answers indicating a value from 1 (minimum) to 6 (maximum).

The questions concerned especially the heaviness, bulk, dimension (if the device is the same used for the adult), comfort and equipment.

Below, the document shows the results of the most relevant questions of the questionnaire.

Question (Q3): *Do you use specific equipment for rescuing children (3-15kg)?*

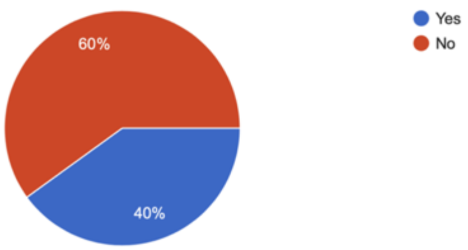


Figure 6-3: Results' chart of Q3

Question (Q3.1): *In relation to the previous question (Q3) If not, are this equipment the same as those used for adults?*

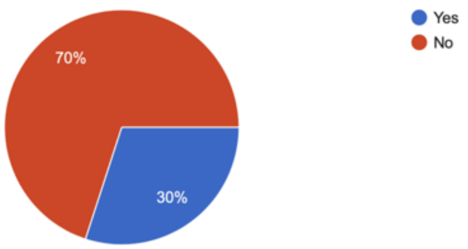


Figure 6-4: Results' chart of Q3.1

Question (Q4): *Is the carrier you use for children heavy? indicate a value from 1 (minimum) to 6 (maximum).*

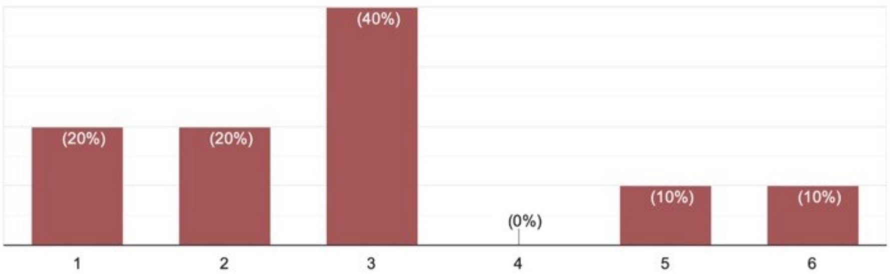


Figure 6-5: Results' chart of Q4

Question (Q4.1): *Is the carrier you use for children rescue bulky? indicate a value from 1 (minimum) to 6 (maximum).*

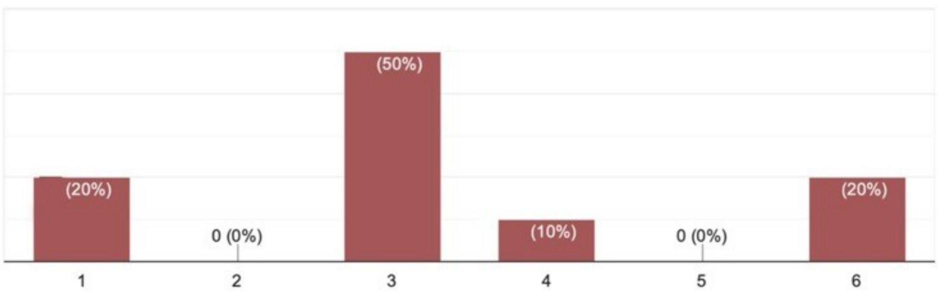


Figure 6-6: Results' chart of Q4.1

Question (Q4.2): *Is the carrier you use for children rescue equipped with a vital sensor?*

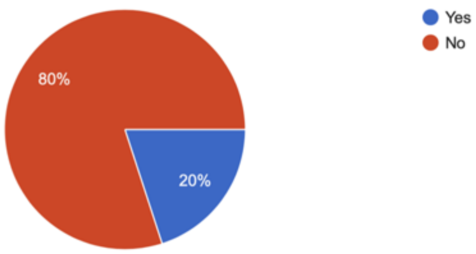


Figure 6-7: Results' chart of Q4.2

Moreover, the participants suggested to use mixed alarm (vibration, visual alarms, sound alarms) in order to improve the children rescue.

Question (Q5): *Do you think that the child carriers should have any alarm display or other sign alarm systems?*

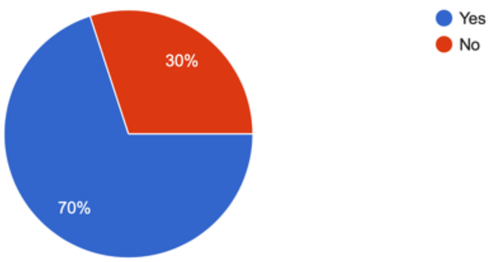


Figure 6-8: Results' chart Q5

Question (Q6): *Do you think the used baby carrier (if any) is comfortable?*

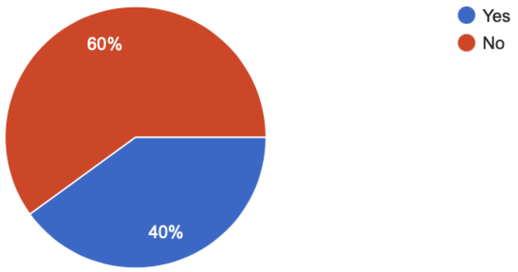


Figure 6-9: Results' chart of Q6

Question (Q8): *According to your experience, is the baby carrier properly equipped?*

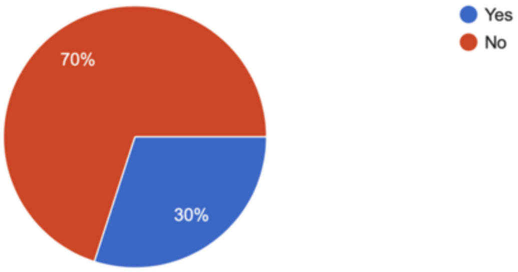


Figure 6-10: Results' chart Q8

Question (Q9): *Do you think could be useful to monitor the health parameters of the children (3-15kg) during the rescue activities?*

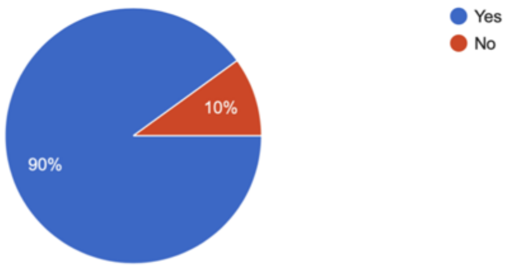


Figure 6-11: Results' chart of Q9

The analysis result of the above questionnaires shows that a specific first aid device designed for kids' rescue does not exist. In fact, the first responders usually have at their disposal the same devices and equipment used for the rescue of adult victims. According to the first responders experience, the devices used for the rescue of children are not properly equipped. The questionnaire results suggest to integrate the devices with vital sign monitorization (cardiac rate, pulse oximetry); thermoregulation control device/system; and headphones (music and white noises could help in reducing the stress of the child).

The first aid device for kids' requirements are summarized as follows:

- Adaptable according to the baby different percentiles
- Equipped with health sensors for monitoring baby vital sign
- Equipped with pockets for accessories (headphones, protective cover etc...)
- Highly protective
- Made of breathable and protective material (fireproof, waterproof, windproof)
- Lightweight and easy to carry.

6.3.4 The co-working activity: technical meeting with End Users partners

The interview activity aims to evaluate the strengths and weaknesses of the concept design of the first aid device for kids and, in particular, to verify some details of the device related to usability during the protocols rescue of young victims.
The activity was organized with medical and paramedical End Users partners to verify the design solutions in relation to the practical operations during USAR activity.

During the interview activity, the questions were focused to discuss immobilization practices.
The questions were about:

- Stretchers used for the transportation of the children
- Procedures used for the immobilization of children
- Additional equipment at disposal of First Responder during children rescue

The interview activity revealed that newborns (up to 6-month-old) cannot be immobilized, although neonatal ambulances utilize a special stretcher.
The child over six months old is immobilized with specific immobilizers on the critical points (the head and hips).

The interview was a very important co-working activity with professionals because highlighted the following aspects to be taken into consideration in the design process of the first aid device for kid:

- Protective elements (like cover, canopy…) that are able to protect the child from the atmospheric conditions (such as wind, rain, sun, hot, cold, ...), from the bad quality of air (dust, gas, ...)
- Comfortable elements that ensure the child's coziness and well-being (as foam and padding parts that fit for child)
- Reassuring elements, that permit the child to feel the child at ease during the rescue activities

The critical points are shown in the infographic below.

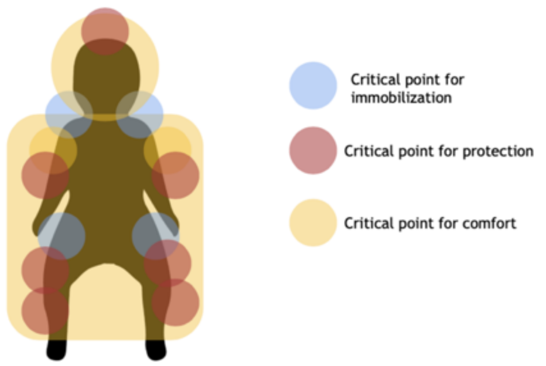


Figure 6-12: Child critical points infographic

6.4 Operative scenarios also from D1.1.

For the purposes of the project, in order to highlight the main requirements of the baby first aid device, a specific analysis of the operative scenarios was carried out by the end users partners.

Each scenario is described using the following parameters:

- Scenario title.
- Short description of the scenario characteristics and needs (status of scenario, temperature, weather condition, etc.).
- Mission type (e.g., earthquake, chemical disaster, etc.).
- Nature of the site (research under the rubbles, rope rescue, flooding etc.).
- Children's rescue protocol (if any).
- Identification and status of the victim (age, weight, height, etc.…) and physical examination.
- Medical devices used during the scenario (blood pressure gauge, oximeter, body temperature thermometer, electrocardiograph etc.).
- Type of first responder organization involved in the rescue activity.
- Device requirements.

In the following table are described the core characteristics of the USAR operative scenario, using a structured methodology.

Scenario title *(Place and period)*	Collapsed structure due to chemical origin explosion
Short description of the scenario characteristics and	Following with the previous case, we could add a kinder garden service on the first floor of the damaged building, where several kids were trapped at the time.

needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Location, rescue, and victim evacuation. Child rescue
Nature of the site *(research under the rubbles, medical, rope rescue...).*	Research under the rubbles, rope rescue, medical assistance to the victims, management.
Children's rescue protocol *(if any)*	Use of kids' device for safe extraction
Mission objectives	Kids extraction
Stakeholder *(e.g. type of first responder org.)*	Firefighters, medical staff, K9 teams
Challenges for first aid kids' device	To remove trauma patients, these devices are essential to ensure correct mobilization and to avoid causing further damage due to incorrect immobilization. In addition, it is important to control the aggravation of injuries and the general condition of the pediatric patient in this kind of situation.

Table 6-9: Operative scenario contribution by ESDP

Scenario title *(Place and period)*	UC7: Chemical substances spill, Madrid, Spain. October-November 2022.
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc... up to 1000 characters).*	CBRN incident with two separate scenarios. The pilot will be allocated to The National School of Civil Protection, Rivas Vaciamadrid, between October-November 2022. The main objective is to delimit the working zones according to the existing risks and toxicity levels, in order to guarantee the safety of the first responders and rescue dogs, and as well indirectly to the safety of the victims of the incident. The weather conditions expected at that time will be 65% humidity and cold temperatures (5ºC -Celsius degrees). The wind will be 6 m/s from the Southeast to North. The first scenario will contemplate a collapsed structure of a residential building due to an earthquake grade 5,5 on the Reiter scale. Later, the six-gas hazmat monitor will alert of the presence of flammable gas and consequently, the gas leak of scenario 1 after radiating at 50 m will produce a deflagration -second scenario-.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Natural disaster with two scenarios: the initial trigger will be an earthquake which will cause a collapsed structure of a residential building (first scenario). The flammable gas released in the collapsed structure (propane gas) will cause an explosion which will form a break in an upper part of the cistern that will produce a gaseous leak of the ammonia (second scenario).
Nature of the site *(research under the rubbles, medical, rope rescue...).*	• Research under rubbles with rescue dogs (K9 team): detect victims. • Firefighters' intervention (USAR –urban search and rescue- team). • Zoning of the incident assessing of the risk zones and hazard materials/substances in the scenarios. • Medical intervention: SUMMA 112 emergency medical service. • Security forces and bodies, civil protections. • Emergency call center 112. Crisis management system device.
Children's rescue protocol *(if any)*	1st: Pediatric Assessment triangle (breathing, circulation and general aspect): establishes a first impression of the child ´s severity.

2nd: Triage ☐ level of priority treatment/attedance) ☐ SUMMA 112 uses functional scales: JUMP START scale for kids under 8 years (it includes 5 insufflation if apnea and considers the respiratory rate of >45 rpm as an index of critical patient) . See SUMMA 112 triage card underneath. As you see in the card the triage includes saving gestures (guedel placement, blood control, 5 insufflations in the case of apnea, compassionate analgesia).
3rd: immobilization and mobilization techniques ☐ cervical collar, tetracameral immobilization, spinal board, scoop stretcher, vacuum mattress, immobilization splints, kidy safe (child restraint system for ambulances).

SUMMA 112 pediatric spinal board (in yellow). It is integrated with the adult version. This pediatric spinal board has 4 positions (up, down, front, and back) depending on the weight of the child (for the head position; as smaller the child is, the bigger size oh head).

SUMMA 112 kidy safe for ambulances.

4th: evacuation wheel to the advanced health post.
5th: advanced life support and evacuation triage (you can see it in SUMMA 112 triage card at the left side: black exitus; 0 priority in blue, I priority in red; II priority in yellow and III priority in green).

Front of the card:

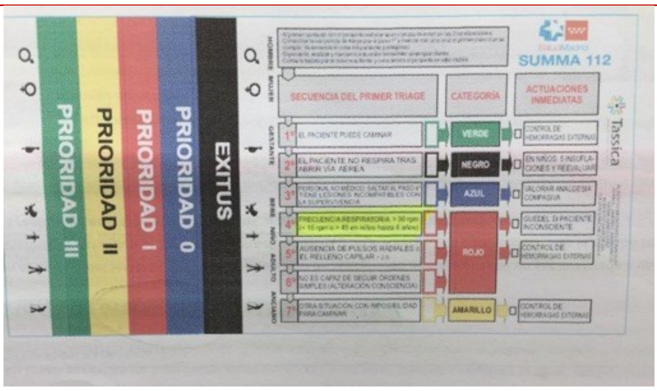
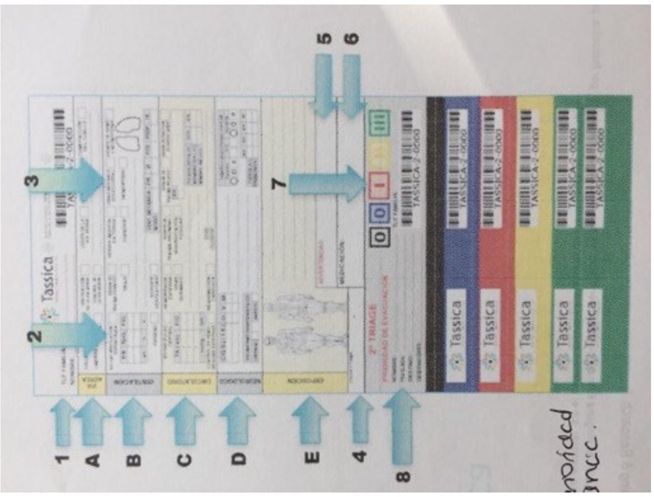
	 Back of the card:  6th: coordination for evacuation con trauma hospitals.
Condition - status of the victim *(age, weight, height, size etc…)*	UC7 finally won´t test the kids' device, so no kids will be participating in the UC.
Medical devices used during the scenario *(blood pressure, temperature, electrocardiogram etc.)*	• Cardiac monitoring: electrocardiogram, blood pressure, capnometry probe, pulse oximetry. • Glucometer. • Temperature. • Serum therapy infusion system. • Oxygenation systems and facemasks. • Respirator, secretion aspirator.
Type of first responder organization.	Emergency Medical Service (EMS)
Device requirements	• Bluetooth connections between defibrillator monitor and tablet. • Device system support for crisis management for call center 112. • Communications systems: mobile, TETRA. • Immobilization and mobilization devices. • Extrication devices.

Table 6-10: Operative scenario contribution by SUMMA112

Scenario title (*Place and period)*	Mozambique in March 2019
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc...up to 1000 characters).*	The mission lasted 4 weeks. Temperatures were on the day around 25°C and in the night around 15°C. Often there was rain. Not much wind.
Mission type *(e.g., earthquake, chemical disaster, etc.)*	Medical support
Nature of the site *(research under the rubbles, medical, rope rescue.).*	Medical
Children's rescue protocol *(if any)*	Not applicable
Condition - status of the victim *(age, weight, height, size etc…)*	Numerous children in all ages and sizes. Many of them were underweight.
Medical devices used during the scenario *(blood pressure, temperature, electrocardiogram etc)*	Stethoscope, pulse oximetry, pressure cuffs, thermometers, electrocardiogram
Type of first responder organization.	EMT
Device requirements	Having the right size, many things like the blood pressure cuffs or the pulse oximetry are too big, when they are in adult size.

Table 6-11: Operative scenario contribution by JUH

Scenario title *(Place and period)*	Use Case 2: Plane crash, mountain rescue, non-urban (Greece). Mount Chortiatis, October- November 2022
Short description of the scenario characteristics and needs *(conditions of the scenario: temperature, wind, cold, heat, etc...up to 1000 characters).*	UC2 focus on low and high impact off-site crashes. Low impact crashes, according to IFSTA, are ones that do not seriously damage or break up the fuselage and are anticipated to have a high percentage of survivors. There are two forms of low impact crashes: wheels up and belly landings, both of which can occur as a result of a hydraulic or electrical system failure. Fire is relatively unusual in these types of crashes, but the dangers are typically greater when the plane lands on airport runways rather than soft terrain. High-impact crashes cause extensive damage to the fuselage and have a significantly lower chance of passenger survival. Hillside collisions are examples of high impact crashes, which are typically caused by weather, pilot, or instrument failures. When the aircraft collides with the ground or trees, it frequently disintegrates. First responders should expect to see major structural components like the wings, tail, and undercarriage spread across a large area of approach and be prepared to evacuate the entire area. Under these

	circumstances, a rigorous and wide-ranging search for casualties should be conducted.
Mission type *(e.g. earthquake, chemical disaster, etc.)*	Plane crash, mountain rescue
Nature of the site *(research under the rubbles, medical, rope rescue..).*	Mountain (Non-Urban) field. Trapped passengers in the plane cabin. Prehospital medical Support
Children's rescue protocol *(if any)*	N/A
Condition - status of the victim *(age, weight, height, size etc…)*	Not applicable to UC 2
Medical devices used during the scenario *(blood pressure, temperature, electrocardiogram etc)*	Not applicable to UC 2
Type of first responder organization.	Non-Profit, volunteer organization
Device requirements	Any medical equipment designed for kids (e.g., child oxygen mask, child AED pads)

The comparative tables described four different operative scenarios in which the first responders' organizations could be or was involved during the disaster rescue phase. The filed tables show the main characteristics of the sample scenario in which the first aid device for kids could be use.
The sample scenario refers to natural disaster collapsed structure disasters in urban and non-urban areas due to a natural event (such as an earthquake) or to an explosion (caused for example by chemical agents) and plane crash.
The analysis of operative scenarios shows that there are specific protocols for child rescue, in fact it is not the same as the one used for the adult.

The main requirements that emerged from the analysis are summarized below:

- Connection and adaptability with other devices used for the rescue of children (Bluetooth connection, Communication system, etc.)
- Medical equipment designed for kids (tools used for adults are too large to be applied to the child)
- Immobilization, mobilization, and extrication device

- Easy and quick to use products (to ensure optimal rescue times)

6.5 System requirements

The research activity pointed out the system requirement for the first aid device for kids. The system, which includes a body temperature probe (NTC), ECG electrodes and optional PPG sensor, will allow pre-processed data collection to remote servers. The sensors are inserted in a pocket and used during the rescue activity.

6.6 System architecture design

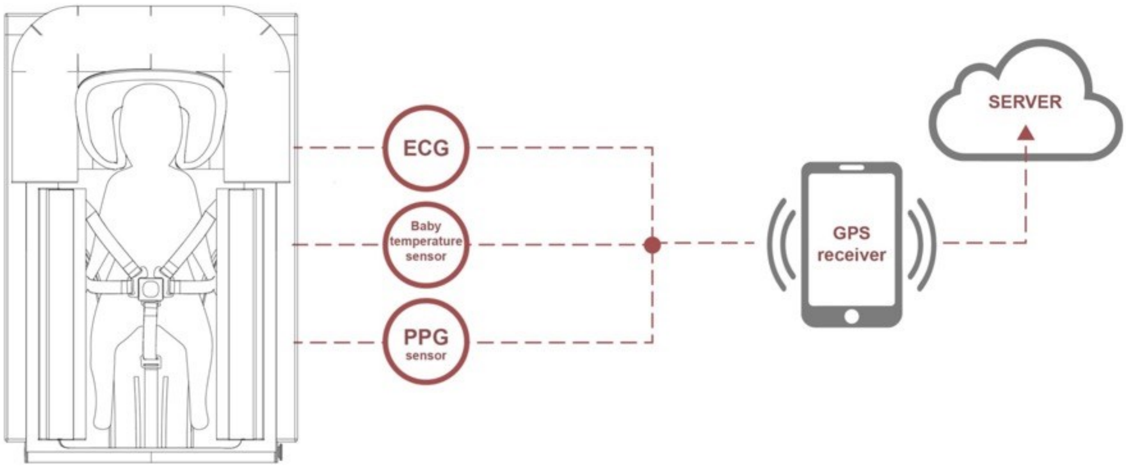


Figure 6-13: System requirements' infographic

The architecture of the system is composed of one adjustable device with embedded sensors to monitor child health parameters.
Referring to the sensors, the architecture shares the same approach used for the first responders. It is based on the use of a smartphone as a signals collector from many custom-designed and off-the-shelf sensor nodes forming a Bluetooth low energy (BLE), a small network around the baby (not on the baby). Sensors will not be integrated in any wearable, rather attached to the young victim, if necessary, with the electronics placed in a pocket inside the rescue device for kids. The smartphone, running a custom Android app, enriches the data with information and preliminary analyses that are too complex for the sensor node, optionally providing comfort and calming features for the baby like sound and lights in the device. Collected data are continuously streamed to the remote server at different sampling rates, allowing geo-localized remote monitoring of the victim's conditions. Although several aspects will require refinements because they are subject to changes in the timeframe of the project, the preliminary investigations are currently leading to the identification of the following hardware/software architecture.

6.6.1 System architecture components

The First aid device for kids is an innovative paramedical carrier composed of 9 parts described below.

1. **The stretcher.** It is a solid board in alveolar polypropylene consisting the base of the device where the child is laying down. It allows a correct posture of the child and the correct immobilization if necessary.
2. **The Head holder** (top side) is composed of an external padded structure and a memory foam pad for the immobilization of the child's head and neck. Each part is lined with hypoallergenic, antibacterial, and highly breathable fabrics.
3. **The Adjustable side holder elements.** The Side holders of the stretcher are lateral padding elements to ensure the immobilization of the child. According to the size of the child, elements can be adapted to the child's body. The Side holders allow the comfort and the correct posture of the child.
4. **The Mattress**. It has a thin thickness placed on the stretcher that allows the comfort of the baby. It is lined with hypoallergenic, antibacterial, and highly breathable fabrics, as the head and side holders.

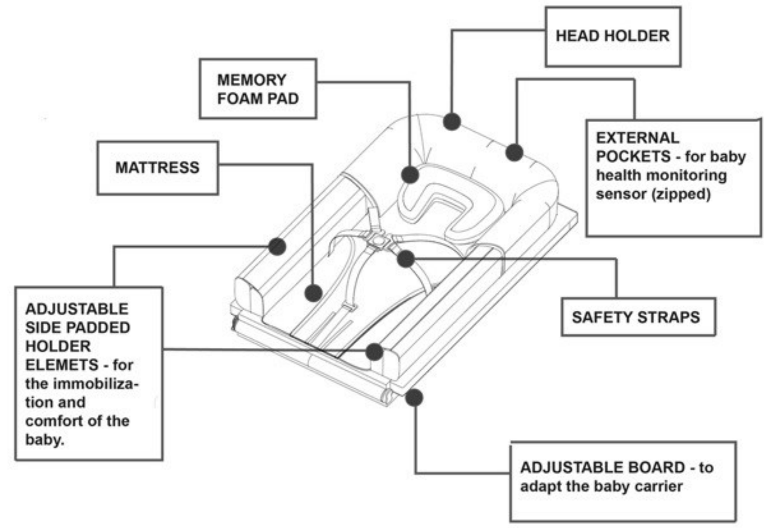


Figure 6-14: System architecture components' infographic

5. **Safety straps (5-point belt system)**
The 5-points belt system fastens the child on the stretcher. The belt has five points to hold the baby on the shoulders and hips, the most critical parts of the body. The system is adjustable for different child size range (from 3 kg to15 kg of weight).
Other safety straps are present in the lower part in order to fix the first aid device on ambulance stretchers. The lower safety belts are designed in compliance with UNI EN 1865 standards, which defines the minimum requirements for the design and performance of stretchers used in ambulances for handling and transporting patients.

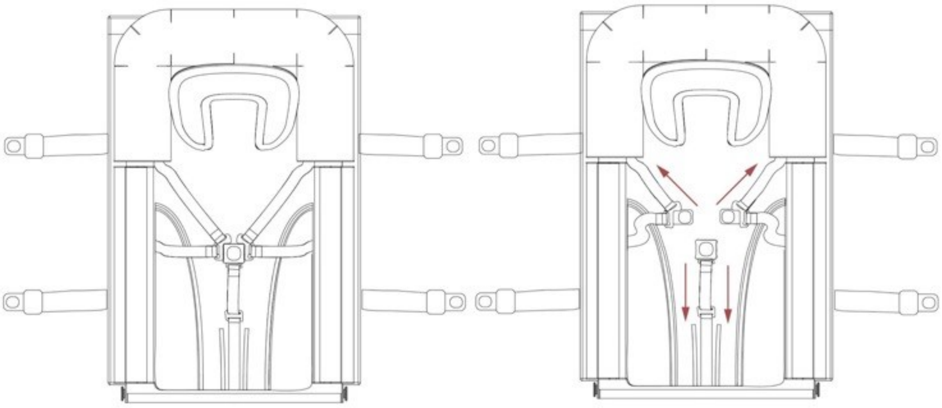


Figure 6-15: Safety system scheme

6. **Adjustable board**
Based on the age and size of the child, the first aid device can adapt through a spinal board extension (in the lower part). In fact, it is possible to overturn the extension board using a lateral knob. The board is covered with a layer of wadding to ensure the child's comfort and covered with Jackal textile.

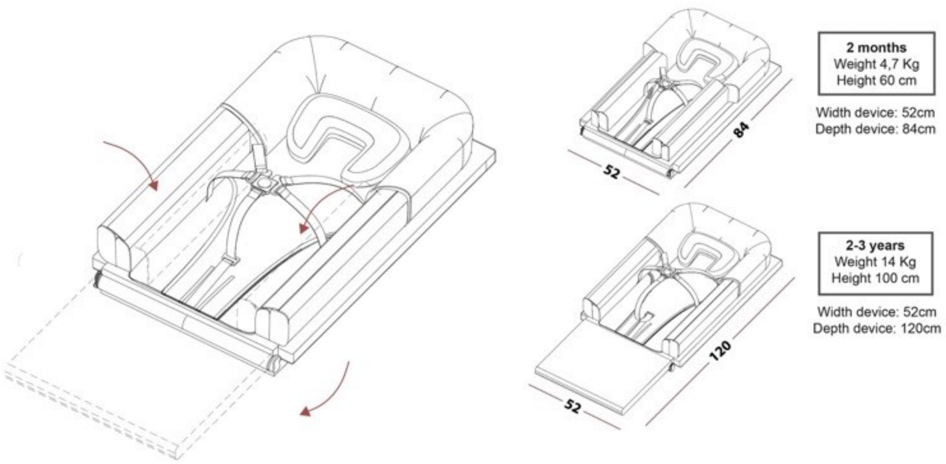


Figure 6-16: Adjustable board functioning scheme

7. **Health sensor**
The hardware architecture that provides sensing capabilities for the monitoring of the victim can be summarized in the following figure. It includes a body temperature probe, in the form of an NTC thermistor, ECG electrodes with the possibility of using the same electrodes to measure the respiration rate by impedance methods embedded in the AFE and some processing on the node, and optional PPG sensor for heart rate and SpO2 monitoring. Finally, the rescue kit will host its own smartphone in a pocket, featuring preprocessed (on-the-edge) data collection, geo-tagging by using the internal GPS-tracking sensor, visualization/alarm, transmission of data to the remote servers. Optionally, lights and sounds can be provided by the smartphone to calm the baby during transportation. The same choices discussed for the uniform were applied also to this case.

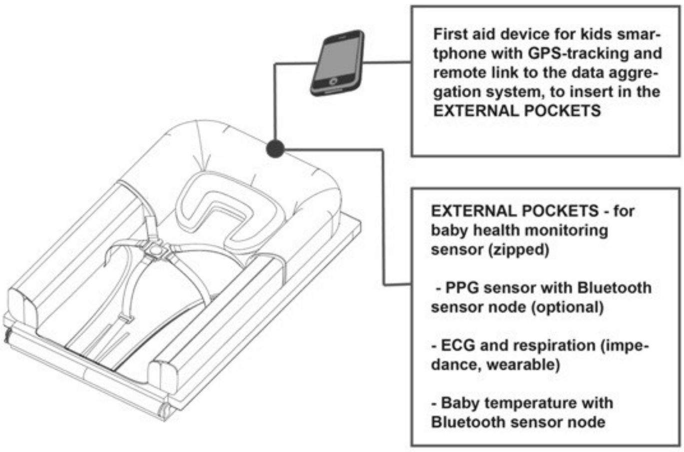


Figure 6-17: Sensors' scheme

8. **Protective cover for the baby**
On the internal side of the lateral holder there is a hidden zip pocket with a protective cover. The cover can protect and reassure the child during the rescue. For the child's comfort, the cover is made with breathable and thermal material.

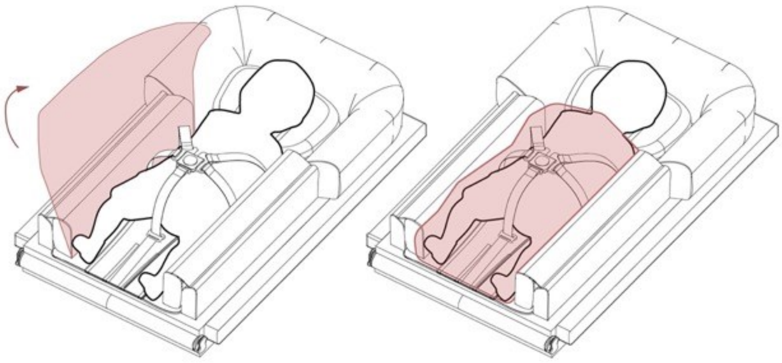


Figure 6-18: Protective cover for the baby - scheme

9.**The Device cover**
During the rescue activity, the first responders use a dedicated cover with shoulder straps, that can be worn like a backpack, to carry the first aid device for kids. This cover protects the device before arriving to the rescue scene. To avoid losing the cover, it is attached to the device.
The cover is made with Jackal Textile, the same fabric used for the uniform that makes it waterproof and resistant to chemicals. There are also present bright elements for high visibility.

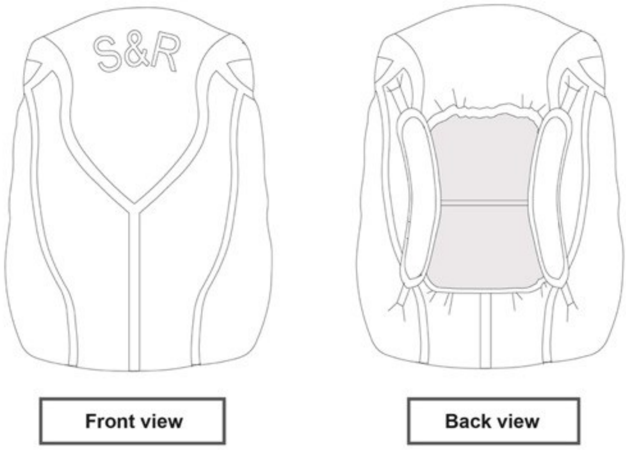


Figure 6-19: Device cover - scheme

To reassure the child, additional elements (such as Bluetooth speaker for music and sounds) are inserted in the external pocket. In this way, the child could be reassured during the rescue activities. Comfort sound and lights functions can be operated from the smartphone.

To ensure the comfort of the child, the mattress and the other holder elements in expanded padding are covered with
3D mesh and Jackal fabric. The 3D mesh allows air circulation, avoiding the humidity. The Jackal textile lining of adjustable board and holder elements allow good performance during USAR activity

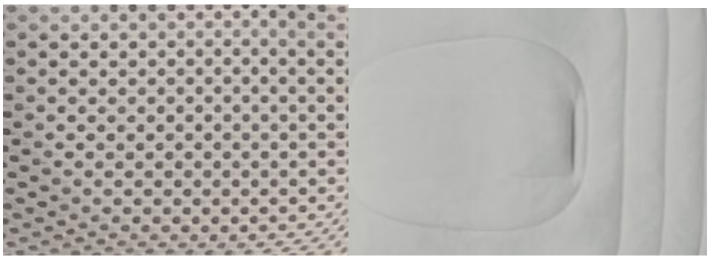


Figure 6-20: Details of textiles: 3D mesh textile, bamboo fiber textile

6.6.2 Software architecture

The software architecture of the first aid kit for children is the same adopted for the professional uniform, but with different sensors. It is focused on the presence of a smartphone acting as a collector for the signals coming from the sensor nodes and the remote data lake. This means that the software architecture is divided in two parts:

1. Part one: firmware of the sensor nodes
2. Part two: Android app

At the same time, we have five layers:

1. Part one
   a. Signal acquisition and edge pre-processing
   b. BLE communication

2. Part two
   a. Data collection from sensor node and further processing (if needed), local storage
   b. User interface and alarms
   c. Internet access and data transmission

According to the BLE specifications, the smartphone can support simultaneous streaming from up to 7 BLE nodes. This aspect should be carefully considered when changing the default configuration developed for the project.

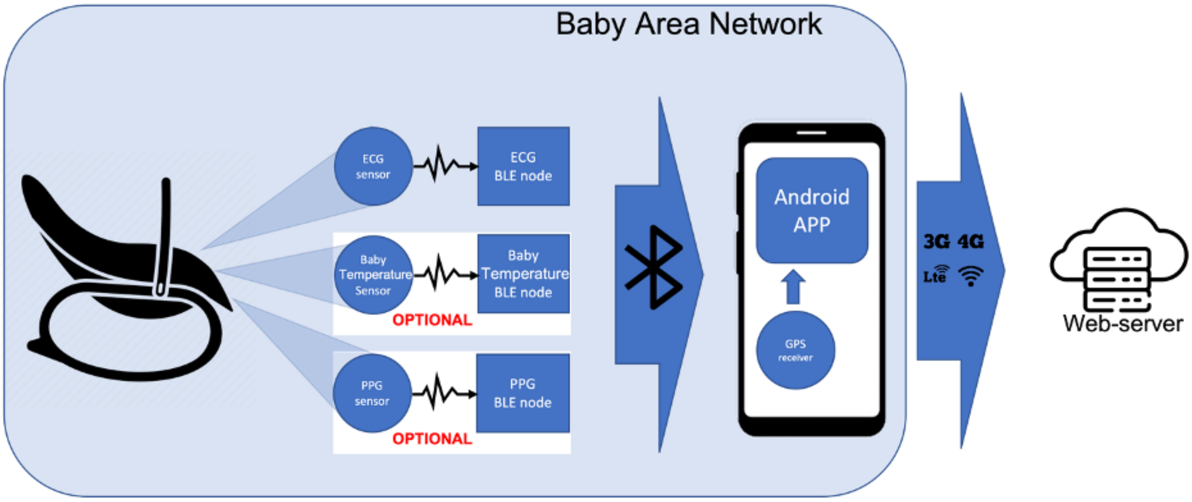


Figure 6-21: System overview - scheme

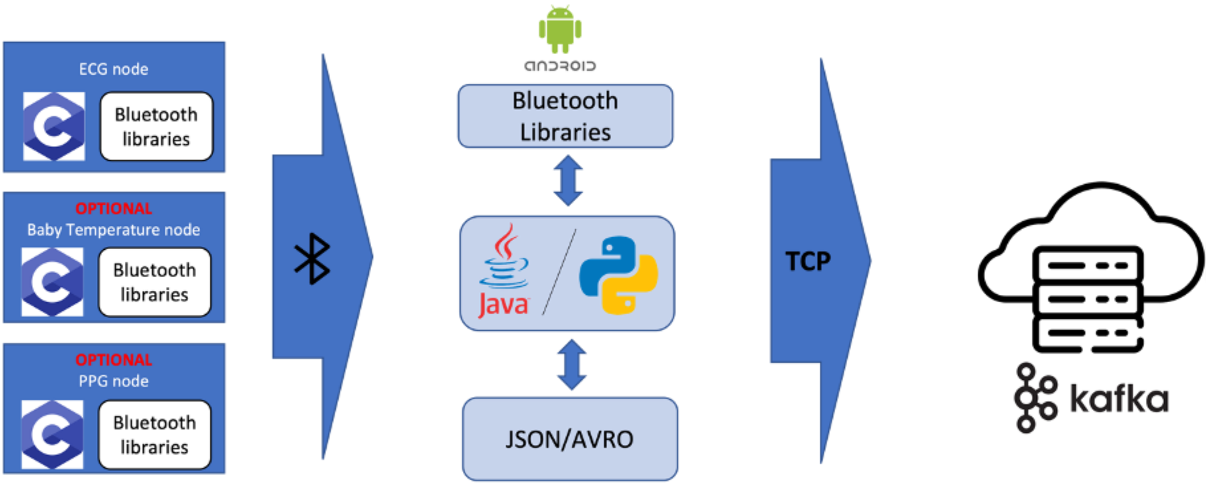


Figure 6-22: Software architecture

A general representation of the software architecture for collecting datasets from sensors can be seen in Figure 6-22. Sensor nodes are based on a low-power microcontroller featuring data conversion (directly or by the adoption of monolithic AFEs) and BLE transmission. The microcontroller manages the signals acquisition, performs local pre-processing, builds data packets, and makes them available for the remote transmission through an Internet connection. The microcontrollers are programmed using C language; their firmware is divided into two modules: the Stack part with the BLE libraries

and the Application part where signal acquisition, processing and data forwarding to the BLE stack is managed.
Through Android BLE libraries, the packets are received by the smartphone. The role of the Android application is to collect this data, carry out further processing on the signals that could be too complex for the sensing node, check for corrupted packets and prepare the data packets for their forwarding to the webserver via the TCP protocol. Before data transmission, the application will read the data from the GPS receiver integrated into the smartphone and will add this data to the packet to be sent, thus allowing the geolocalization of the first responder. GPS position and all the data are stored in the internal memory if the Internet connection is unavailable and sent out at the first opportunity when connection will be restored.
The development of the App for data handling and data forwarding will be done in Java language through Android Studio or in Python with Kivy framework, depending on the kind of processing to be performed on the data. The application will have the ability to insert and modify a Kafka endpoint on which to forward the datasets in JSON or AVRO format.
In order to test the general framework, a test application was created in Python language with the help of the Kivy framework. This framework allows the development of the application in a higher-level language and through the Buildozer utility it is possible to perform a Python-Java cross-compilation. With the smartphone and the microcontroller placed at a distance of 1 m, the app was able to maintain a connection with the microcontroller and continuously receive some sample data packages continuously. Tests have been made to send data at frequencies from 1Hz to 250Hz. The application was able to display the received data fluently and with a latency of some milliseconds.

7 First aid device for children Implementation

7.1 First aid device for children implementation.

In this phase of the S&R project, the first concept of the device was designed. According to the HCD - Human Centered Design approach, the device takes into consideration the child's need. For this reason, the design process performed an analysis and study of and the communicative values of colors and materials, in order to guarantee the comfort and reassurance of the child.

The document shows the preliminary technical drawing and 3D render of the first aid device for kids for the development of the first prototype.
The final device prototype will be presented and described in the next version of this deliverable, after the validation during the UC pilots.
The first aid device for kid implementation is described in the following sections.

7.1.1 Technical drawings

The adjustable board allows the use for children of different ages/sizes. In fact, there are two different configurations of the device as showed in the top view drawings. The first figure shows the device for children up to cm 60 of height, while the second one for children up to cm 100 of height

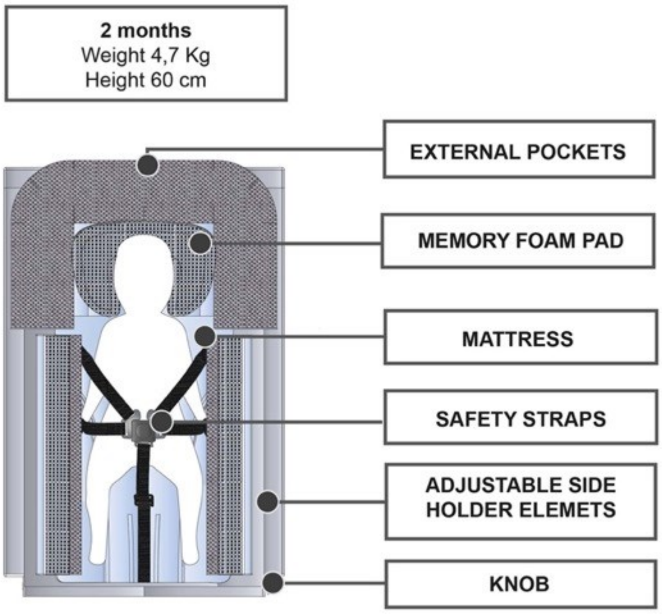


Figure 7-1: Top view of the first aid device for kids' configuration suitable up to 60 cm of height

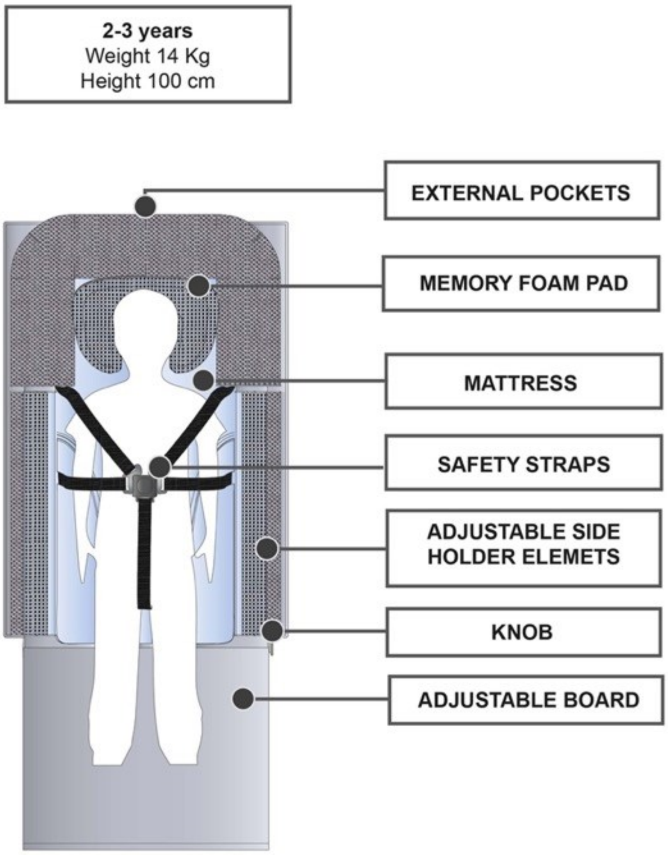


Figure 7-2: Top view of the configuration of the first aid device for kids suitable up to 100 cm of height

The first configuration was designed for children with a weight up to 4,7 Kg and height of 58 cm. The FR can use the side knob to rotate the adjustable board, in order to lengthen it by 38 cm. In this way the device can be used for children weighing up to 15 kg and height up to 100 cm.

7.1.2 3D Models

The first aid device for kids' 3D models are as follows.

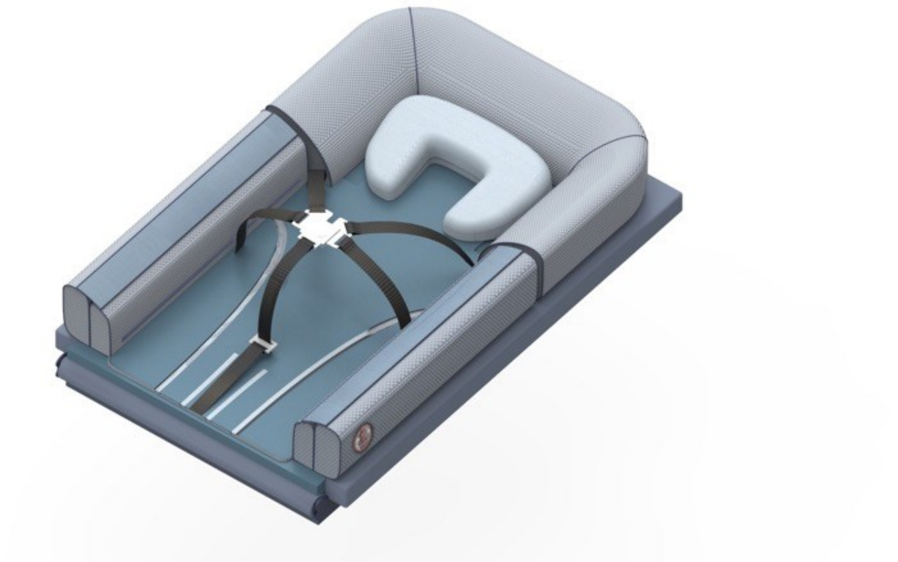


Figure 7-3: Perspective view of the first configuration of the rescue device for kids

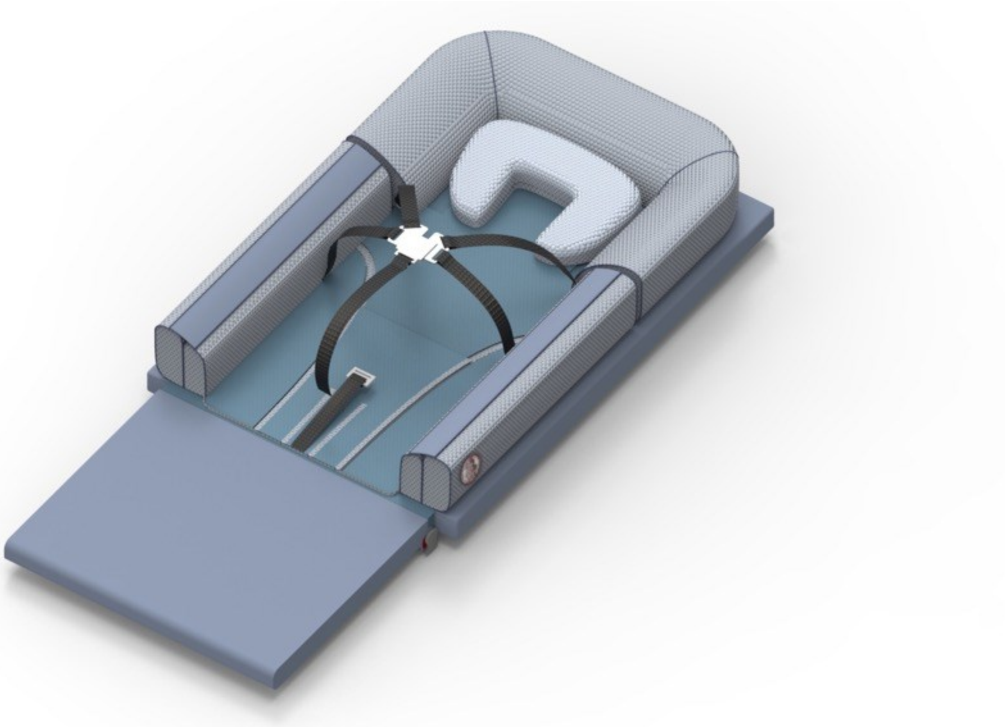


Figure 7-4: Perspective view of the second configuration of the rescue device for kids

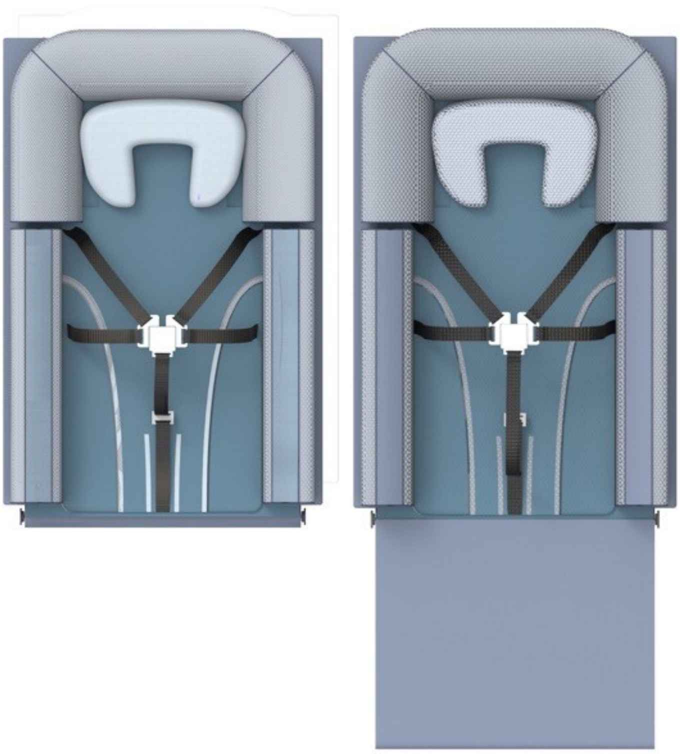


Figure 7-5: Top view of the first and second configuration of the rescue device for kids

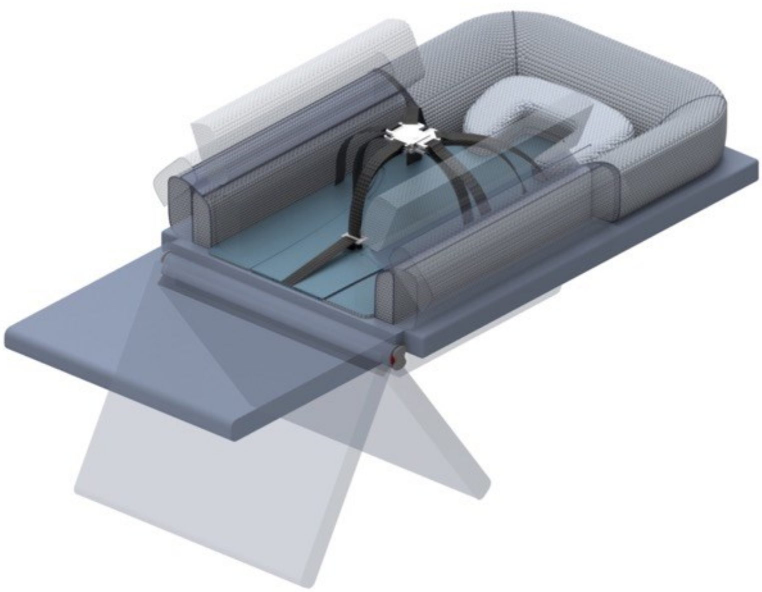


Figure 7-6: View of the first aid device for kids system

Figure 7-7: Side view of the first aid device for kids

Figure 7-8: Details of the head holders

7.1.3 Details and specifications

The First aid device for kids is designed to facilitate the operations of the First responders during the USAR activities. For this reason, the device is able to adapt to different situations and children of different ages.
The adjustable elements ensure to change the configuration of the device in a fast and practical way to adapt the dimensions of the stretcher to different body and size of children. The adjustable board can be rotated easily by the first responder using a knob as shown in fig. 7-9

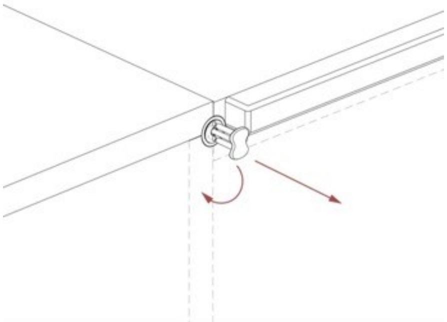


Figure 7-9: Knob function detail

To ensure First Responders grip, the knob is composed of an ergonomic handle coated with a grip texture and three metal pins. To allow the rotation of the board by 180 ° to extend the stretcher it is necessary to extract two of the three pins.
Moreover, the side holder elements of the stretcher (that are padded for the comfort of the baby) could be rotated to adjust to the body of the child holding it in safety using some Velcro straps. Furthermore, the rotation of the side padded elements could, if necessary, help the first responder to place the child in the stretcher without side obstacles.

Figure 7-10: Transportation scheme

All the materials used for the realization of the first aid device for kids take into consideration physical and emotional children’s needs. Fabrics with cold and soft colors and soft touch were used, in order to reassure the child during the USAR activity.
The main structure is made of alveolar polypropylene to ensure strength and lightness to the device. To ensure comfort and protection, an additional layer of Jackal has been used. Jackal is a rip-stop textile. The technical and color chart of the textile is attached in the Annex IV of the document. The child is covered with a removable blanket made of bamboo fiber, a hypoallergenic and breathable material able to keep him warm.

8 First aid device for children Prototype

8.1 Integration of the components

The implementation of the sensors within the First aid device for kids will be described in the next version of this document.

8.2 Future Test plan

The validation tests of the first aid device for children will be performed later and will be available in the second version of the deliverable. The validation tests will be performed during the Use Cases project pilots:

- UC1 - Victims trapped under rubble (Italy)
- UC6 - Resilience Support for Critical Infrastructures (Romania)

8.3 Future Test plan from system requirements

Similar to the test of the uniform in PHASE 2 and PHASE 3, the first aid device will be evaluated.

The categories for PPE will be adapted to the requirements of the first aid device for children. However, the mechanism will be the same in general.

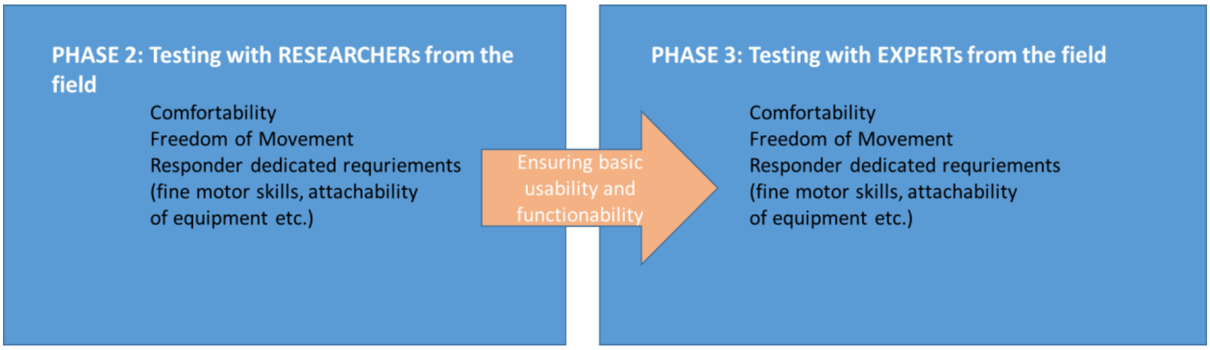


Figure 8-1: Test plan scheme

Categories needed for testing:

Certification	duration io of protection
Market price	Don/Doff
Entry location	Weight
Chemical Agents	training requirements
Biological Agents	package volume
Toxic industrial chems	field of view
Radiological/nuclear protection	shelf life
	sizes available

9 Health Condition Monitor Design

9.1 State of the art

9.1.1 Summary of the state of the art from D1.1.

The Emergency Response Health Condition Monitor (ERM) objective is to monitor the victim's health condition from the point they are discovered until they are transferred to an ambulance for treatment from medical professionals. The ERM is a compact patient monitor with internet connectivity that can be applied very fast in the field with minimal interference to the motion of the wearer.
Patient monitors' purpose is to monitor over time the health condition of patients at hospitals. This is performed by continuously measuring the vital signs of patients lying on beds presenting the values in the display and communicating them to a central unit. The main components of the patient monitor are the sensors, the transducer, the display, and the communication device. Mobile monitoring devices, which are typically used in combination with smartphones and wearables in Body Area Networks, are utilized for both medical and non-medical purposes to monitor the wearer's natural environment for extended periods of time. The purpose of the ERM is to develop a compact mobile monitor that incorporates all the functions of a patient monitor.
A review of mobile patient monitoring systems is available in (Pawar et al., 2009). The following systems are presented: Summary of the state of art from D1.1.(Suh et al., 2011)(Pawar et al., 2012)(Amin et al., 2018)(Kumar and Rajasekaran, 2016)(Varady et al., 2002)(Huang et al., 2013)(Galhotra et al., 2006)(Gao et al., n.d.)(Gao et al., n.d.)(Wac et al., 2009)(Logan et al., 2007)(Gómez et al., 2016)(Uddin et al., 2017)(Sebastian, 2012)(Pawar et al., 2009)(Tia Gao et al., 2005)(Deshmukh and Shilaskar, 2015)(Gao et al., 2008)(Singh et al., 2012) Yale- NASA mobile patient monitoring system, The Yale- NASA system was developed with application of monitoring the health of mountain climbers.

The sensor set used:

- Non-invasive sensors for measuring heart rate, 3-lead ECG, body surface temperature monitor, core body temperature pill
- Accelerometer (for gross body motion and activity)
- GPS system for position tracking
- Advanced Health and Disaster Aid Network mobile patient monitoring system
- Non-invasive sensors for measuring heart rate, 2-lead ECG, pulse rate, oxygen
- saturation, blood pressure
- LEDs signify triage class of the patient
- LCD displays oxygen saturation and heart rate
- Personal Health Monitor mobile patient monitoring system

The system was developed from the University of Technology in Sydney.

The sensor set used:

- Off-the-shelf non-invasive sensor systems
- 1 channel ECG monitor, pulse oximeter,
- blood pressure, weight scale, internal/ external GPS, accelerometer
- All external sensors with Bluetooth capabilities
- CMS mobile patient monitoring system

The system was developed from the Institute for Infocomm Research in Singapore for management of patients suffering from dementia.

The sensor set used:

- Commercially available wetness detection sensor with RF communication capabilities
- Actuators consists of LEDs and alarm for notification on detection of the wetness on the patient's underwear
- Actuators are integrated into so called relay nodes
- NTU mobile patient monitoring system

The system was developed from the National Taiwan University and is based on a wireless- PDA.

The sensor set used:

- Non-invasive sensors for measuring 3-lead
- ECG and pulse-oximeter
- MobiHealth mobile patient monitoring system

The patient monitoring system was developed with funding from the EC.

- The sensor set used:
- Any subset of 3, 4 and 9 channel ECG, surface EMG, pulse oximeter, respiration sensor, temperature sensor, activity sensors (step-counter, 3D accelerometer)
- Any wearable sensor with a suitable communication interface can be integrated
- GPS receiver

A summary of the review is presented in the table below.

Parameter	Yale-NASA	AID-N	PHM	CMS	NTU	MH
1. Supported number of sensors	5	3	>6	1	2	>10
2. Sensors to SFE communication	RF	Wired	Wired	RF	Wired	Wired
3. SFE to MBU communication	RF	Serial	BT	Wired	Serial	BT
4. Biosignals display on the MBU	No	Yes	Yes	No	Yes	Yes
5. Biosignals storage on the MBU	No	No	Yes	No	Yes	Yes
6. Intra-BAN comm. problems	No	No	No	No	No	No
7. Extra-BAN comm. problems	No	Yes	No	Yes	No	Yes
8. Extra-BAN communication technology	RF	Multi-hop ad-hoc	3G, GSM	Multi-hop ad-hoc	WLAN	WLAN, 3G, GPRS
9. Extra-BAN comm. protocol	SMAC	SMAC	TCP/IP	SMAC	TCP/IP	HTTP
10. BESys communication technology	TCP/IP	Web services	Web services	IP	HTTP	Jini
11. Intended geographic area for use	Outdoor	Indoor	Indoor/outdoor	Indoor	Indoor	Indoor/outdoor
12. End-to-End security	No	No	No	No	Yes	No
13. Reported trial problems	Yes	Yes	No	Yes	No	Yes

Table 9-1: mobile patient monitoring system (adapted from Pawar et al., 2009)

Additionally, in (Paliwal and Kiwelekar, 2013) another reviews of mobile patient monitoring systems the following systems with their specifications were analysed:

System	Body Area Network(BAN)	Mobile Base Unit(MBU)	Back-end Server(BESys)
IMHMS	Wearable Body Sensor Network (WBSN)	Patients Personal Home Server (PPHS)	Intelligent Medical Server (IMS)
MHCS	Body Sensors	Mobile Device	Data and Data Mining Server
MTDDS	Sensors	Multi-Touch Smartphone	Web server
WISS	Wireless BAN of Intelligent Sensors (personal server (PS) and multiple WISE clients)	primary MBU functions are provided by BAN	Central Workstation
MCWA	Wearable Sensor Suite Mobile	Smart Phone	Server
PHM	Body Area Network	Mobile Base Unit	Back-end System
MHS	Body Area Network (BAN)	Mobile Base Unit (MBU)	back-end system
THC	Wrist Pressure Sensor	PIC Micro-controller	GSM MODEM (Mobile)
UMHMSE	Wireless Wearable Body Area Network (WWBAN)	Intelligent Central Node (ICN)	Intelligent Central Server (ICS)
PBEHS	Sensor Nodes And Micro-Control Unit (MCU)	Bluetooth Module Centralized Controller	Back-end Server
CS	BodyNets	Smartphone Gateway Nodes	Remote Data Centers
AID-N	Embedded Medical Systems for Triage and Biomedical Sensors	BESys is available at the scene in place of MBU	Ad Hoc Mesh Network

Table 9-2: Overview of mobile patient monitoring systems (adapted from Paliwal and Kiwelekar, 2013)

The systems were compared with the Functional and Non-Functional requirements identified from the authors and adapted here in chapter 9.4. The comparison results is presented in the following table.

MPM System	FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	NFR1	NFR2	NFR3	NFR4	NFR5	NFR6	NFR7	NFR8	NFR9	NFR10	NFR11	NFR12	NFR13
IMHMS	√	X	√	√	√	√	√	X	√	√	√	√	X	√	X	√	√	√	X	X	X
MHCS	X	√	X	√	X	√	√	X	X	X	X	X	X	√	√	√	√	√	X	X	X
MTDDS	X	√	X	√	X	√	√	X	X	X	X	√	X	X	X	√	√	√	X	X	X
WISS	X	X	X	√	√	√	√	X	X	X	X	X	X	X	X	√	√	√	√	X	X
MCWA	√	√	X	√	√	√	√	X	X	X	X	X	X	√	X	√	√	√	X	X	X
PHM	√	√	√	√	√	√	√	X	X	X	X	X	X	√	X	√	√	√	√	X	X
MHS	X	√	X	√	X	√	√	X	√	X	X	X	X	X	X	√	√	√	X	X	X
THC	√	√	√	√	X	√	√	X	X	X	X	X	X	√	X	√	√	√	X	X	X
UMHMSE	√	√	√	√	X	√	√	X	X	X	X	X	X	√	X	√	√	√	X	X	X
PBEHS	X	√	X	√	X	√	√	X	X	X	X	X	X	√	X	√	√	√	X	X	X
CS	√	√	√	√	√	√	√	X	X	X	X	X	X	√	X	√	√	√	X	X	X
AID-N	√	√	√	√	X	√	√	X	X	X	√	X	X	√	X	√	√	√	X	X	X

Table 9-3: Functional and Non-Functional requirement satisfaction (adapted from Paliwal and Kiwelekar, 2013)

9.1.2 Reviews of vital signs/sensors for health condition monitoring

Vital signs traditionally consist of blood pressure, temperature, pulse rate, respiratory rate and pulse oximetry, and are an important component of monitoring the patient’s progress during hospitalization. The vital signs can be measured noninvasively in the hospital environment.

Heart activity can be monitored with Electrocardiogram (ECG) and Photoplethysmogram (PPG), outputs from this measurement are the heart rate, a more detailed study of the electrical conduction of the heart requires a thorough interpretation of the ECG. The ECG can have a different number of

electrodes, pairs of electrodes form a lead. In hospital environments the most detailed ECG is using 12 leads with 10 electrodes. The electrodes are placed both on the chest and on the limbs. The PPG can be placed in various locations as fingers, toes, earlobe, and forehead.
Blood pressure (BP) can be calculated with a Non-Invasive Blood Pressure (NIBP) measurement on the arm or estimated by using the Pulse Arrival Time (PAT) or Pulse Transit Time (PTT) by using the time delay between the peaks on the ECG and PPG in a regression formula.
The Body Temperature (BT) can be calculated with a Negative Temperature Coefficient (NTC) sensor in contact with the skin or an infrared temperature sensor with no contact. Both sensors do not measure the body core temperature but the temperature at the specific area of skin.
Blood oxygen saturation or Peripheral Oxygen Saturation (SpO_2) is measured with PPG.
Respiration Rate (RR) can be measured directly with capnography or a chest-strap with piezoelectric sensor or accelerometer or indirectly through the ECG or PPG.
All the above-mentioned vital signs will be measured with the ERM.

9.2 Users' requirements.

Based on (Gao et al., n.d.) the following user requirements were identified. The researchers identified by themselves the following requirements:

- ease of use
- portability
- wearability,
- ruggedness
- low power consumption
- capability of providing continuous vital sign data.

From questionnaires, focus groups and acceptance tests of prototype devices with end-users, they identified the following requirements:

- Pulse rate and oxygen saturation were rated to be the most important vital signs
- Customize detection algorithms to each patient
- Sort patients based upon priority levels and waiting times
- Enable the ability to turn off alerts for any patient
- Provide warnings to indicate alerts are turned off
- Set icons and text to universally accessible colors schemes and provide customization options
- Save text in files that can be easily modified or translated to specialized language in the future
- Align status codes with commonly accepted color codes (pink =stable, blue=critical)
- Provide warnings about changes in status codes instead of automatically triaging patients

9.3 Operative scenarios.

The use of ERM is for monitoring the health of victims and rescue units on the field with display of their condition locally (smartphone display) and remotely (Command Centre). The device is designed with purpose to be fitted easily and not interfere with the motions of the wearer. The use of the device from the Command Centre is the triage of the rescued victims and their health monitor until they receive proper medical help.

The ERM can be used in all kinds of disasters where there are many victims, and the available medical personnel and equipment is not able to support all of them simultaneously.
The ERM will be tested in the following two Use Cases during the SnR project.

- Use Case 2: Plane crash, mountain rescue, non-urban (Greece)
- Use Case 4: Forest fire expanded and threat to industrial zone (Attica Region, Greece)

9.4 System requirements.

9.4.1 Functional requirements.

The following functional requirements are based on (Huang et al., 2013) and are adapted for the ERM.(Huang et al., 2013)

- Biosignal Processing (FR1) The system should process biosignals and should be able to take decisions accordingly. Biosignals are initially collected by the ERM controller and processed on the smartphone.
- Biosignals Delivery (FR2) Biosignals acquired by the sensors should be delivered to the ERM controller and the smartphone in real time. The signals should then be delivered to the SnR datalake through wireless communications.
- Raise Emergency Alarm (FR3) The ERM system and the SnR platform should be able to generate an emergency alarm in critical conditions, since the biosignals are processed by both the components.
- Bio signals Interpretation (FR4) The ERM should be able to diagnose the critical condition signs from bio signal. Bio signals must be correctly interpreted by the smartphone.
- Bio signal Differentiation (FR5) The ERM should be able to differentiate motion artifacts on the signals.
- Data requisition (FR6) The ERM should be able to retrieve past critical data.
- Communication (FR7) The ERM should provide a communication interface between the patient and doctor. Graphical user interface provided on the ERM should facilitate the interactions.
- Medicine Infusion (FR8) Not applicable to the ERM.

9.4.2 Non-functional requirements (NFR).

Non-Functional Requirements adapted and based on (Huang et al., 2013).

- Genericity (NFR1) The System should be modified according to the patient monitoring needs.
- Security (NFR2) Connection between the ERM and the datalake should be secure and authenticated.
- Unique Patient Identification (NFR3) Patient should be provided with a patientID by which he/she can be globally uniquely identified.
- Interoperability (NFR4) The application should support various smartphones and sensor configurations.
- Privacy (NFR5) System should maintain the patient privacy by restricting the access to the patient records.

- Intelligence (NFR6) The ERM should be capable of taking decisions on the basis of past and current monitoring.
- Availability (NFR7) System Should be available 24 /7 for continuous monitoring.
- Response Time (NFR8) The ERM application should be fast enough so that on time emergency services can be provided to the patient.
- Easy Wearability (NFR9) The ERM should be small in size, easy to wear and convenient for the patient.
- Graphical interface (NFR10) 1. The system should provide a graphical interface to display bio signals on the ERM. It should provide a graphical interface where doctor and patient can interact with the system.
- Accuracy (NFR11) The data delivered to the datalake should be accurate.
- Data losses (NFR12) The ERM should be able to overcome data losses introduced due to various noise sources on the communication media.
- Standards (NFR13) The ERM should follow various Standards provided for data sharing to achieve interoperability between the systems.

9.5 System architecture design.

9.5.1 System architecture.

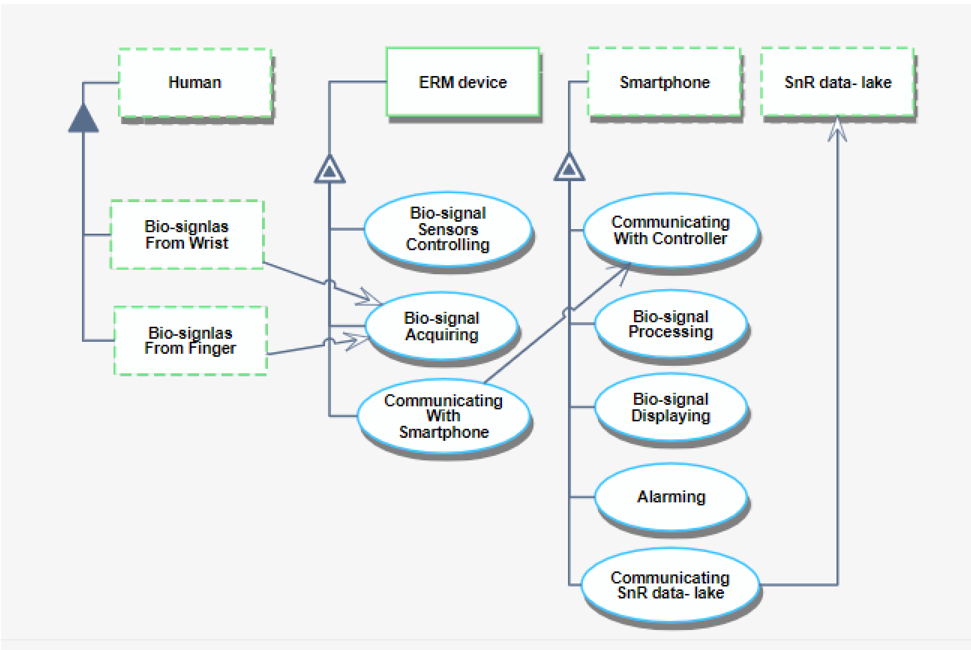


Figure 9-1: ERM System architecture

1. Human is environmental.
2. Bio-signals From Wrist is informatical and environmental.
3. Bio-signals From Finger is informatical and environmental.
4. Smartphone is environmental.

5. SnR data- lake is environmental.
6. Human consists of Bio-signals From Finger and Bio-signals From Wrist.
7. Smartphone exhibits Alarming, Bio-signal Displaying, Bio-signal Processing, Communicating SnR data- lake and Communicating with Controller.
8. Communicating with Smartphone relates to Communicating With Controller.
9. ERM device exhibits Bio-signal Acquiring, Bio-signal Sensors Controlling and Communicating With Smartphone.
10. Bio-signal Acquiring of ERM device consumes Bio-signals From Finger and Bio-signals From Wrist.
11. Communicating SnR data- lake of Smartphone yields SnR data- lake.

9.5.2 Software architecture.

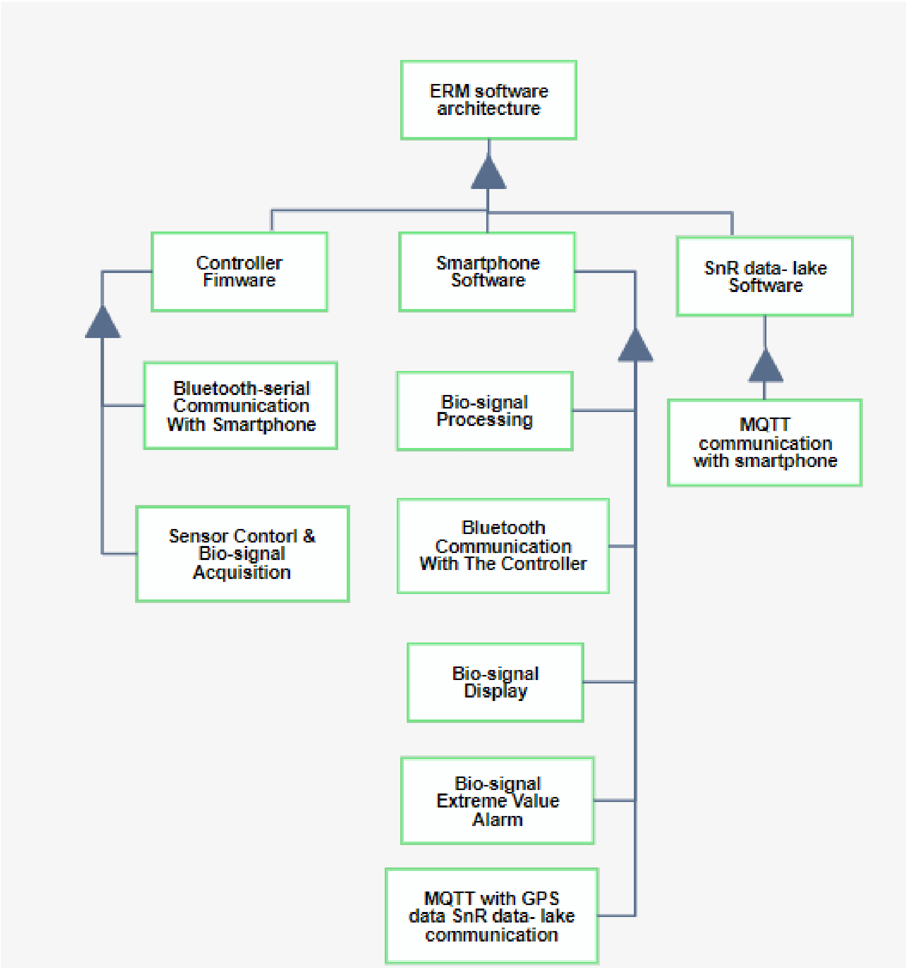


Figure 9-2: ERM software architecture

1. ERM software architecture is informatical.
2. Controller Firmware is informatical.
3. Smartphone Software is informatical.
4. SnR data- lake Software is informatical.
5. Bluetooth-serial Communication with Smartphone is informatical.

6. Sensor Control & Bio-signal Acquisition is informatical.
7. Bio-signal Processing is informatical.
8. Bluetooth Communication with The Controller is informatical.
9. Bio-signal Display is informatical.
10. Bio-signal Extreme Value Alarm is informatical.
11. MQTT with GPS data SnR data- lake communication is informatical.
12. MQTT communication with smartphone is informatical.
13. ERM software architecture consists of Controller Fimware, Smartphone Software and SnR data- lake Software.
14. Controller Fimware consists of Bluetooth-serial Communication with Smartphone and Sensor Contorl & Bio-signal Acquisition.
15. SnR data- lake Software consists of MQTT communication with smartphone.
16. Smartphone Software consists of Bio-signal Display, Bio-signal Extreme Value Alarm, Bio-signal Processing, Bluetooth Communication with The Controller and MQTT with GPS data SnR data- lake communication.

9.5.3 ERM System components.

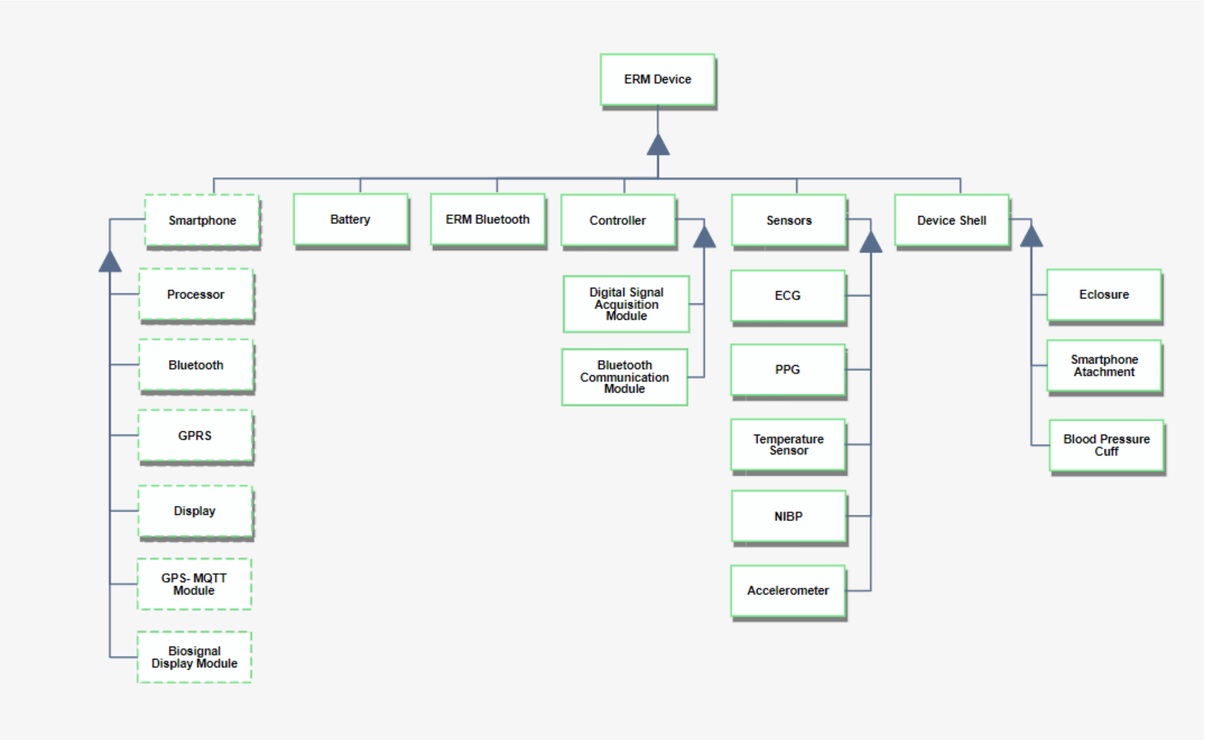


Figure 9-3: ERM System components

1. ERM Device consists of Battery, Controller, Device Shell, ERM Bluetooth, Sensors and Smartphone.
2. Device Shell consists of Blood Pressure Cuff, Enclosure and Smartphone Attachment.
3. Sensors consists of Accelerometer, ECG, NIBP, PPG and Temperature Sensor.
4. Controller consists of Bluetooth Communication Module and Digital Signal Acquisition Module

5. Biosignal Display Module is informatical and environmental.
6. Digital Signal Acquisition Module is informatical.
7. Bluetooth Communication Module is informatical.
8. Smartphone consists of Biosignal Display Module, Bluetooth, Display, GPRS, GPS- MQTT Module and Processor.
9. Smartphone is environmental.
10. Bluetooth is environmental.
11. GPRS is environmental.
12. Display is environmental.
13. Processor is environmental.
14. GPS- MQTT Module is informatical and environmental.

9.5.4 Components interfaces.

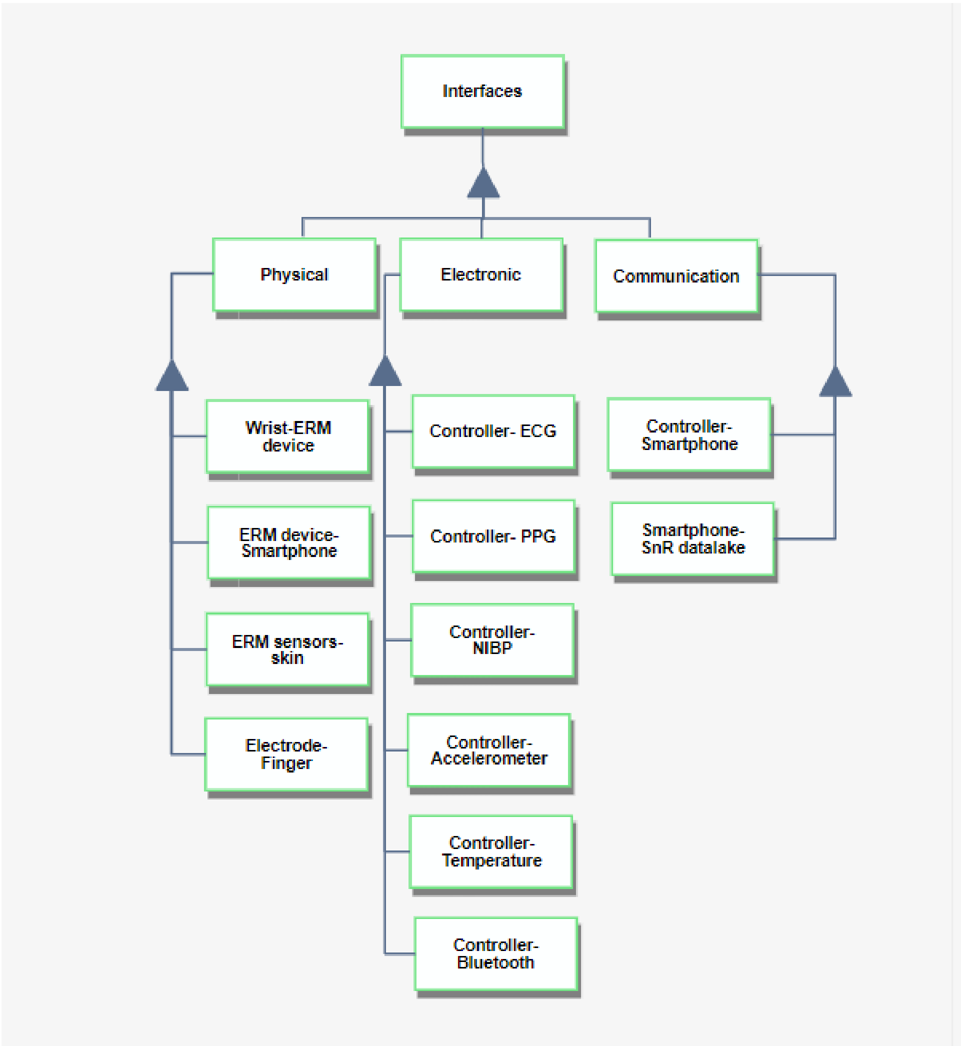


Figure 9-4: ERM Component interfaces

The ERM interfaces are both physical, electronic and communication.
The physical interfaces concern the mechanical interface between components of the device and the environment. The physical interfaces include the ERM device- Smartphone, ERM sensors- skin, Electrode- Finger and Wrist-ERM device.
Electronic interfaces concern the electronic connection and communication between the electronic components. The electronic interfaces include the Controller- Accelerometer, Controller- Bluetooth, Controller- ECG, Controller- NIBP, Controller- PPG and Controller- Temperature.
Communication interfaces concern the software only communication interface between different components with electronic interface. The communication interfaces include the Controller- Smartphone and Smartphone- SnR data- lake.

10 Health Condition Monitor Implementation

10.1 Kit implementation.

10.1.1 Drawing.

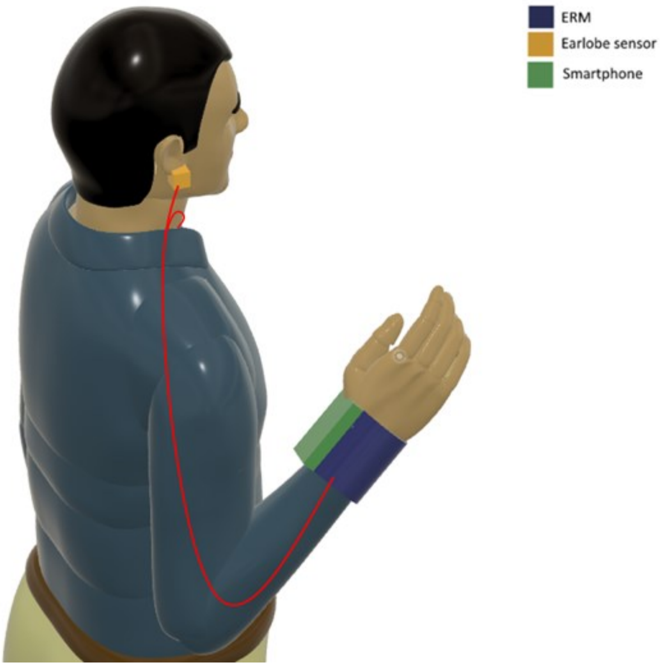


Figure 10-1: 3D Sketch of the ERM system on a patient

The ERM device is attached to the wrist. The smartphone is placed on the ERM device with a holder. An earlobe sensor is used for the single lead ECG and is connected with a cable to the ERM module. Attached with the same cable the temperature sensor is placed between the undershirt and the chest of the person.

10.1.2 3D Models.

The 3D designs of the ERM shell with all the components integrated will be available in the second version of the deliverable.

10.1.3 Details and specifications.

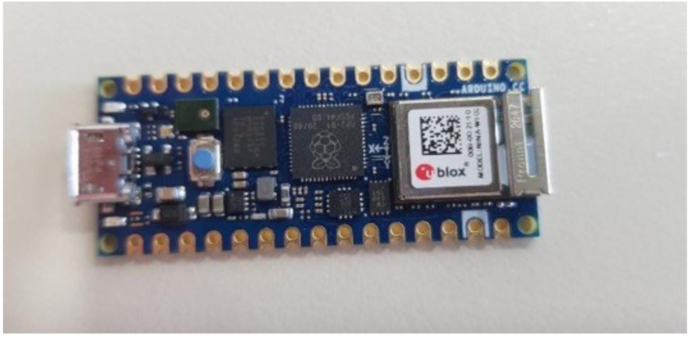


Figure 10-2: ERM controller

The controller of the device will be an Arduino rp2040 nano with the following specifications:

Board	Nano RP2040 Connect	
Microcontroller	Raspberry Pi RP2040	
USB connector	Micro USB	
Pins	Built-in LED pin	13
	Digital I/O Pins	20
	Analog Input Pins	8
	PWM pins	20
	External interrupts	20
Connectivity	Wi-Fi	Nina W102 uBlox module
	Bluetooth	Nina W102 uBlox module
	Secure element	ATECC608A-MAHDA-T Crypto IC
Sensors	IMU	LSM6DSOXTR (6-axis)
	Microphone	MP34DT05
Communication	UART	Yes
	I2C	Yes
	SPI	Yes
Power	Circuit operating voltage	3.3V
	Input Voltage (VIN)	5-21V
	DC Current per I/O pin	4 mA
Clock speed	Processor	133 MHz
Memory	AT25SF128A-MHB-T	16MB Flash IC
	Nina W102 uBlox module	448 KB ROM, 520KB SRAM, 16MB Flash
Dimensions	Weight	6 g
	Width	18 mm
	Length	45 mm

Table 10-1: ERM controller specifications

10.2 Sensors.

10.2.1 Blood pressure sensor

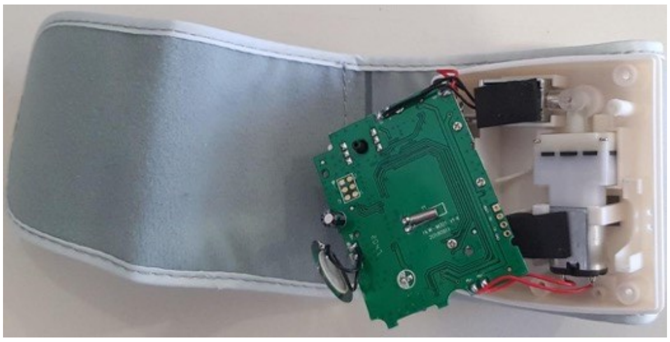


Figure 10-3: Blood pressure sensor

Measurement method	Pulse scanning
Range	20-280mmHg
Accuracy	± 3mmHg
Type	Wrist cuff
Cuff Circumference	135-195mm
Battery Type	2 AAA batteries
Functions	Systolic & diastolic blood pressure measurement
	Heart rate extraction
	Independent channels for blood pressure & heart rate
	Automatic pressurization, decompression & air discharge

Table 10-2: Blood pressure sensor specifications

10.2.2 ECG

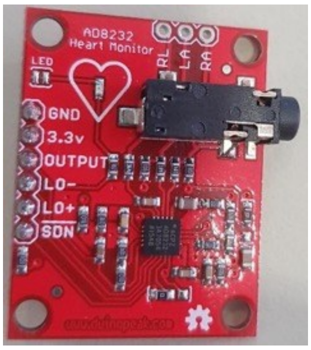


Figure 10-4: ECG sensor

Fully integrated single-lead ECG	
Range	20-280mmHg
Accuracy	± 3mmHg
Type	Wrist cuff

Cuff Circumference	135-195mm	
Power supply voltage	2.0 V to 3.5 V	
Functions	Fully integrated single-lead ECG	
	Two or three electrode configurations	
	Internal RFI filter	
Dimensions	Weight	4 g
	Width	28 mm
	Length	35 mm

Table 10-3: ECG sensor specifications

10.2.3 PPG sensors

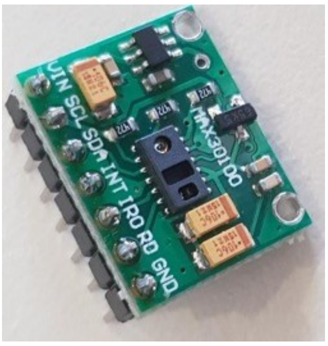


Figure 10-5: PPG sensor

Sensor	MAX30100	
Purpose	Pulse rate and oximeter	
Function	Sensor and signal processor	
LED	IR LED	880 nm
	Red LED	660 nm
Photodetector	Resolution	14 bit
Communication	I2C	
Power	Circuit operating voltage	1.8- 3.3V
Dimensions	Weight	4 g
	Width	14 mm
	Length	18 mm

Table 10-4: PPG sensor specifications

10.2.4 Temperature sensor

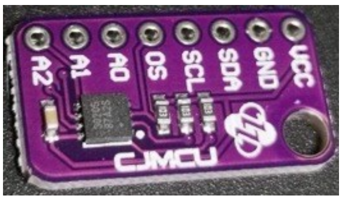


Figure 10-6: Body temperature sensor

Sensor	MAX30205	
Purpose	Body temperature sensor	
Function	Sensor and signal processor	
Resolution	16 bit	
Accuracy	0.1°C	
Communication	I2C	
Power	Circuit operating voltage	2.7- 3.3V
Certification	ASTM E1112	
Dimensions	Weight	4 g
	Width	14 mm
	Length	18 mm

Table 10-5: Body temperature sensors specifications

10.3 Communication tools and devices.

The smartphone will communicate with the controller through Bluetooth. While the smartphone will communicate with the SnR datalake through WIFI and 4G or 5G. This task will be completed in the second version of the deliverable.

10.4 Energy management system.

The ERM sensor module will be powered from two AAA batteries, and it will power the controller and the sensors. The smartphone will be powered from its own battery. This task will be completed in the second version of the deliverable.

11 Health Condition Monitor Prototype

11.1 Integration of the components.

The components will be integrated with a shell that can also hold the smartphone. This task will be performed later and will be available in the second version of the deliverable.

11.2 Test plan from system requirements.

The bio signals digitized from the ERM will be validated with a medical patient monitor. The patient monitor available at CERTH is the Contec CMS8000.

Figure 11-1: Contec CMS8000 Patient Monitor

The patient monitor has the following characteristics

- 7- lead ECG with arrhythmia analysis
- NIBP measurement
- SpO2 and Pulse Rate measurement
- Respiration measurement
- Dual-channel temperature monitoring.
- FDA certification and CE certification.

The patient monitor can be connected with a PC over ethernet, and all its signals are synchronized.

11.3 Test report.

The validation tests of the ERM will be performed later and will be available in the second version of the deliverable.

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Annex II: Questionnaire

Task 5.2 QUESTIONNAIRE

https://docs.google.com/forms/u/0/d/1vVmR2n-EQgH8j_CDX7dlLchMPebMERIWg3Qt7Xr4czg/printform

First responders' Uniform questionnaire

Introduction

The questionnaire aims to under-light opinions, behaviors, strengths and weaknesses of the state of the art. Each question has a specific purpose in the design processes of the first responder's uniform.

The results will be used by UNIFI team for the purpose of T5.2 of the S&R Project.

1) What kind of rescuers are you? Select one of the following options: *

- ❑ Medical rescue
- ❑ Civil protection
- ❑ Firefighter
- ❑ Others. (specify) ....

2) Does the First Responders PPE provide adequate protection during the rescue phases?*

- ❑ Yes
- ❑ No

- Which type of PPE do you use during rescue operations? Do you use always the same type of PPE or do you change it according to different scenario?

- In your opinion, is the protection level right for the situation?* (1 poor – 6 Excellent)

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Do you have any suggestions to improve the protection level?

3) Are the vital signs of the First responders monitored during the rescue phase?*

- ❑ Yes
- ❑ No

- Do you think there is adequate monitoring of vital signs of First Responders in the rescue phases? * (0 Not applicable – 6 Excellent)

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

Could a First Responder wearable monitoring vital parameters device be useful during the rescue phases? *

- ❑ Yes
- ❑ No

4) How could you feel sharing your personal health data in real time to improve your safety? *

5) Would you feel safer wearing a device able to monitor your health parameters and to send a real time feedback to the command post? *

6) In case of alarm, do you think that the device should also directly notify the rescuer wearing it?

- If yes, which kind of alarm could be better for communicating to the First responder? * Select one or more of the following options

- ☐ Multicolor light
- ☐ Sounds
- ☐ Vibration
- ☐ Others. (specify) ....

Add, if you need, a short comment about your choice:

7) During rescue activities do you use a mobile phone (personal or standard equipment)?*

- ☐ Yes
- ☐ No

- If yes, how do you wear it? Moreover, where would you like to wear it?

- If you use a special mobile phone, please, if possible, add an image here

+

8) What kind of uniform do you wear during your rescue activity? * (for example: full uniform, two-piece uniform, disposable uniform, reusable uniform, other)

- Please add an image of your uniform here. *

+

9) Is the uniform personal or it has to be shared with other rescuers? *

- ☐ Yes
- ☐ No

- If yes, are there any problem with sizes?

- Are the uniforms gender based? *

- ☐ Yes
- ☐ No

12) Do you think your uniform is comfortable? * (0 No– 6 Excellent)

- ☐ 1

- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Do you think your uniform is suitable for the purpose? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Do you think your uniform is compatible to PPE? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Please suggest how you would like to change it*

13) Is the uniform properly equipped?* (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4

- ❑ 5
- ❑ 6

- Do you think your uniform is suitable for the purpose? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Do you think your uniform is compatible to PPE? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Please suggest how you would like to change it*

14) Is the uniform properly equipped?* (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Could you give a brief explanation to your answer? What would you add on it?*

15) Is your uniform already equipped with health or other environmental sensors?*

- ❑ Yes
- ❑ No

- If yes, please describe them here. In addition, which sensors do you think are important improve the uniform?

- If not, could you explain your answer?

16) Does your uniform allow you to withstand extreme conditions? *

- ❑ Yes
- ❑ No

- Is the uniform able to protect you from these elements? * Select one or more options:

- ❑ Fire
- ❑ Chemicals
- ❑ Heat
- ❑ Cold
- ❑ Water
- ❑ Storm
- ❑ Wind
- ❑ Abrasions
- ❑ Shocks
- ❑ Other: ....

17) Could you suggest any aspect or questions that have not been considered in this questionnaire about the uniform? *

First aid kid device questionnaire

Introduction

The questionnaire aims to under-light opinions, behaviors, strengths and weaknesses of the state of the art. Each question has a speci7c purpose in the design processes of the 7rst aid device for kids (3-15 kg).

The results will be used by UNIFI team for the purpose of T5.2 of the S&R Project.

1) What are the first aid items you use during a rescue activity?*

2) Which kind of equipment do you use for child-care during rescue operation?*

3) Do you use specific equipment for rescuing children (3-15 kg)? *

- ☐ Yes
- ☐ No

- If not, are these equipment the same as those used for adults? *

- ☐ Yes
- ☐ No

- If yes, please add an image here.

+

4) Is the carrier you use for children rescue heavy? * (1 Not heavy – 6 Very heavy)

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐

- Is the carrier you use for children rescue bulky? * (1 Not bulky – 6 Very bulky)

  - ❑ 1
  - ❑ 2
  - ❑ 3
  - ❑ 4
  - ❑ 5
  - ❑ 6

- Is the carrier you use for children rescue equipped with vital sensors? *

  - ❑ Yes
  - ❑ No

5) Do you think that the child carriers should have any alarm display or other sign alarm systems? *

  - ❑ Yes
  - ❑ No

- If yes could you suggest any specification. If not, explain why.*

6) Do you think the used baby carrier (if any) is comfortable? *

  - ❑ Yes
  - ❑ No

7) Is the children (3-15 kg) always immobilized on the carrier during the rescue phase? *

8) According to your experience, is the baby carrier properly equipped?*

  - ❑ Yes
  - ❑ No

- If not, what would you like to add?*

9) Do you think could be useful to monitor health parameters of the children (3-15 kg) during the rescue activities? *

- Is the carrier you use for children rescue bulky? * (1 Not bulky – 6 Very bulky)

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

- Is the carrier you use for children rescue equipped with vital sensors? *

- ❑ Yes
- ❑ No

5) Do you think that the child carriers should have any alarm display or other sign alarm systems? *

- ❑ Yes
- ❑ No

- If yes could you suggest any specification. If not, explain why.*

6) Do you think the used baby carrier (if any) is comfortable? *

- ❑ Yes
- ❑ No

7) Is the children (3-15 kg) always immobilized on the carrier during the rescue phase? *

8) According to your experience, is the baby carrier properly equipped?*

- ❑ Yes
- ❑ No

- If not, what would you like to add?*

9) Do you think could be useful to monitor health parameters of the children (3-15 kg) during the rescue activities? *

- ❑ Yes
- ❑ No

10) Do you think could be useful to send real time children's health parameters to the triage center? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

11) Could you suggest any aspects or questions that have not been considered in this questionnaire about the device for kids?*

- ❑ Yes
- ❑ No

12) Do you think could be useful to send real time children's health parameters to the triage center? * (0 No– 6 Excellent)

- ❑ 0
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6

13) Could you suggest any aspects or questions that have not been considered in this questionnaire about the device for kids?

Annex III: Tables of smart and innovative materials

Bamboo 031		
Company: Maeko Tessuti	**Company Country:** Italy	**Company website:** https://www.maekotessuti.com/
Typology of material: (select one or more option and explain the choice) ☐ Fiber ………. ■ Textile ……. ☐ Gel ……... ☐ Foil ………. ☐ Other Polymer		
Description material composition: Fabric made from 100% bamboo. Used for the realization of garments with high softness required.	**Durability :** ☐ Disposable ☐ 0-1 years ■ 1-5 years ☐ 5-10 years ☐ over 10 years	
Ecological Quality: ■ Use of raw materials/ renewable materials ☐ Recycled materials ☐ Low energy consumption in production process ☐ Long life and low maintenance ☐ Harmless to the producer and the user ☐ LCA ☐ Other ……….	**Suitable for recycling:** ■ Use of single material ☐ Disassemblable material ☐ Suitable for combustion ☐ Landfill ☐ other …..	
Physical and Chemical Properties: Color: White, neutral Hygroscopy: N/A Melting temperature: N/A Density: 80g/m2 Thermal conductivity: N/A Electrical conductivity: N/A Corrosion resistance: N/A		
Mechanical Properties (Value from 1 - Low to 5 - High)**:** Mechanical resistance: • Cut resistance: ☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5 • Resistance to bending: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5 • Compressive strength: ☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5 • Torsional strength: ☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5 • Tensile strength:		

◻ 1 ◻ 2 ■ 3 ◻ 4 ◻ 5
Hardness:
■ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
Material toughness:
◻ 1 ■ 2 ◻ 3 ◻ 4 ◻ 5
Wear resistance:
◻ 1 ◻ 2 ■ 3 ◻ 4 ◻ 5

Technological properties of the material:
Malleability: N/A
◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
Ductility: N/A
◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
Fusibility: N/A
◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
Hardenability: N/A
◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
Weldability: N/A
◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5

Material processing technologies:
weaving, sewing

Strengths:
Sustainable label:

- FSC
- Oeko-tex®

Weaknesses:
Low durability

Field of use:
garments
coating
upholstered

Images:

Sources/Bibliography:
https://www.matrec.com/wp-content/uploads/2018/11/matrec_dt-03i.pdf
https://www.maekotessuti.com/fibre-bamboo/

Bioceramic

Company: Resistex	**Company Country:** Italy	**Company website:** https://resistex.com/

Typology of material: (select one or more option and explain the choice)

☐ Fiber.
■ Textile ....
☐ Gel ....
☐ Foil ....
☐ Other ....

Description material composition:
The Resistex® Bioceramic yarn is used for the production of fabrics that, thanks to the presence of the inorganic compounds contained within it, are able to absorb and reflect the heat of the human body, allowing an advanced form of photo-treatment as it does not require a source of active light, but uses the reflected light generated by the body heat. Once stimulated by heat, the compounds present in the yarn reflect high levels of light in the bio-infrared band (F.I.R) that penetrate the cutaneous and subcutaneous layers and interact with the water molecules and with the organic compounds present in the tissues.Bio-ceramic is therefore able to reflect FIR (far infrared rays), i.e. a type of electromagnetic waves of reduced length, belonging to the spectrum of sunlight and similar to its invisible radiations (gamma rays, X-rays and ultraviolet rays), as they are able to penetrate to a depth of 4/5 cm

Durability :
☐ Disposable
☐ 0-1 years
■ 1-5 years
☐ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable
■ N/A

Suitable for recycling:
☐ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
■ Landfill
☐ other .....

Physical and Chemical Properties:
Color: White, Black, Gray
Hygroscopy: High
Melting temperature: N/A
Density: low
Thermal conductivity:
Electrical conductivity:
Corrosion resistance: Medium
Other .....

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

□ 1 ■ 2 □ 3 □ 4 □ 5

- Resistance to bending:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Compressive strength:

□ 1 □ 2 □ 3 ■ 4 □ 5

- Torsional strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Tensile strength:

□ 1 □ 2 □ 3 ■ 4 □ 5

Hardness:
□ 1 ■ 2 □ 3 □ 4 □ 5
Material toughness:
□ 1 □ 2 □ 3 ■ 4 □ 5
Wear resistance:
□ 1 □ 2 □ 3 ■ 4 □ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 □ 2 □ 3 □ 4 ■ 5
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C

Material processing technologies:
weaving, sewing

Strenghts:

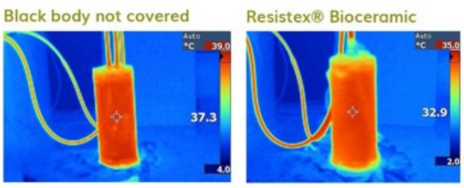
- last generation yarn made by polyester fibers and bioceramic materials resistent even after multiple washings.
- high level of flexibility in combination with natural fibers.
- total protection against UV-A and UV-B rays.
- active barrier against the sun: long lasting freshness for the body during sport activity or exposure to the sun.
- high level of thermal insulation due to bio-ceramic fibers that shields from cold.
- FIR emission to stimulate the body's microcirculatory system and the strengthening of the metabolism.

Weaknesses:
Low durability

Field of use:
The range of Resistex® Bioceramic yarns can be used in various sectors due to their extraordinary qualities. Resistex® Bioceramic, thanks to its characteristics of protection from UV-A rays (main cause of damage to fibrous tissues, drying and premature aging of the skin) and UV-B rays (absorbed by the skin and subjecting it to burns), and its extraordinary characteristic of reproducing FIR (far infrared rays), able to stimulate the microcirculatory system, finds multiple applications in:

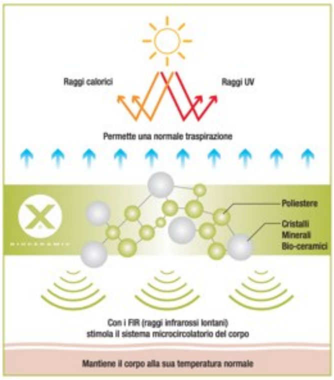
- Socks and sportswear;
- Underwear;
- Blankets;
- Mattresses;
- Casual clothing;
- Knitwear;
- Bed sheets.

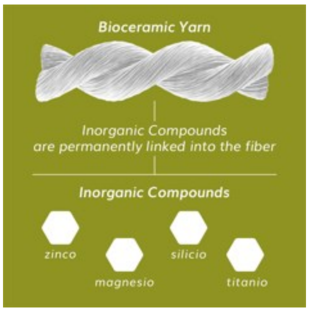
Images

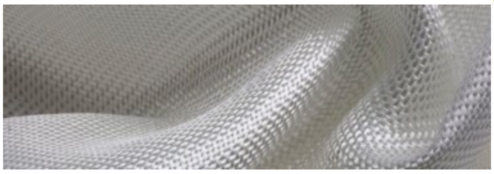


Sample	T°C	ΔT°C(1)	λmax μm(2)	Emissive power(3) (W•m⁻²)	Δemissive power(1),(3) (W•m⁻²)	Δemissive power(1),(3) (μW•cm⁻²)
Black body not covered	37,3		9,33	526,7	—	—
resistex BIOCERAMIC	32,9	4,4	9,47	497,5	29,2	2923

Notes:
(1) Difference between not cover black body temperature.
(2) Calculation according to Wien law.
(3) Calculation according to Stefan - Boltzmann law.







Sources/Bibliography:
https://resistex.com/wp-content/uploads/2019/10/Resistex-Bioceramic-2019-NEW.pdf

Carbon PA

Company: Reboze	**Company Country:** Europe (Italy) / US (Texas)	**Company website:** https://www.roboze.com/it/

Typology of material: (select one or more option and explain the choice)
☐ Fiber ……….
☐ Textile …….
☐ Gel ……...
☐ Foil ……….
■Other Polymer

<table>
<tr><td>Description material composition:
Innovative Polyamide reinforced with carbon fiber (20%), used to replace light metal alloys.</td><td>Durability: N/A
☐ Disposable
☐ 0-1 years
■ 1-5 years
☐ 5-10 years
☐ over 10 years</td></tr>
<tr><td>Ecological Quality: N/A
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Other ……….
■ N/C ……….</td><td>Suitable for recycling: N/A
☐ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
■ Landfill
☐ other …..</td></tr>
<tr><td colspan="2">Physical and Chemical Properties:
Color: N/A
Hygroscopy: Low
Melting temperature: 180 °C
Density: N/A
Thermal conductivity: N/A
Electrical conductivity: N/A
Corrosion resistance: High
Other Chemical resistance to hydrocarbons, oils and halogenated hydrocarbons</td></tr>
<tr><td colspan="2">Mechanical Properties (Value from 1 - Low to 5 - High):
Mechanical resistance:
• Cut resistance: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Resistance to bending: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Compressive strength: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Torsional strength: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Tensile strength: XY: 136 MPa and XZ: 138 MPa
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Hardness:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Material toughness: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Wear resistance: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Other …..</td></tr>
<tr><td colspan="2">Technological properties of the material:
Malleability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Ductility: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5</td></tr>
</table>

Fusibility: N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Hardenability: N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Weldability: N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Other:...
Material processing technologies: 3D printing process
Strengths: - Accuracy and repeatability of printing - Polymer with mechanical properties of metal alloys
Weaknesses: - Dimensional limit due to 3d printers
Field of use: - Used in the industrial sector for metal replacement applications and in the motorsport sector
Images: 
Sources/Bibliography: https://www.roboze.com/it/materiali-stampa-3d/carbon-pa.html

Carbon PEEK		
Company: Reboze	**Company Country:** EU (Italy) / US (Texas)	**Company website:** https://www.roboze.com/it/materiali-stampa-3d/carbon-peek.html
Typology of material: (select one or more option and explain the choice) ☐ Fiber .... ☐ Textile: ☐ Gel .... ☐ Foil .... ■ Other Polymer		

<table>
<tr><td>Description material composition:
Innovative composite with PEEK matrix</td><td>Durability : N/A
□ Disposable
□ 0-1 years
□ 1-5 years
□ 5-10 years
□ over 10 years</td></tr>
<tr><td>Ecological Quality : N/A
□ Use of raw materials/ renewable materials
□ Recycled materials
□ Low energy consumption in production process
□ Long life and low maintenance
□ Harmless to the producer and the user
□ LCA
□ Other ……….</td><td>Suitable for recycling: N/A
□ Use of single material
□ Disassemblable material
□ Suitable for combustion
□ Landfill
□ other …..</td></tr>
<tr><td colspan="2">Physical and Chemical Properties:
Color: N/A
Hygroscopy: No
Melting temperature: 280 °C
Density: N/A
Thermal conductivity: Medium
Electrical conductivity: N/A
Corrosion resistance: N/A
Other PEEK polymer matrix maks molded part chemically resistant to most organic solvents, acids and bases even at high temperatures</td></tr>
<tr><td colspan="2">Mechanical Properties (Value from 1 - Low to 5 - High):
Mechanical resistance:
• Cut resistance: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
• Resistance to bending: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
• Compressive strength: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
• Torsional strength: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
• Tensile strength: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Hardness:
□ 1 □ 2 □ 3 □ 4 □ 5
Material toughness: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Wear resistance: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Other …..</td></tr>
<tr><td colspan="2">Technological properties of the material:
Malleability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Ductility: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Fusibility: N/A</td></tr>
</table>

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Hardenability: N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Weldability: N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Material processing technologies: 3D printing process
Strengths: - Accuracy and repeatability of printing - High thermal resistance - High chemical resistance
Weaknesses: - Dimensional limit due to 3d printers (500mmx500mm)
Field of use: - Used in the industrial sector for metal replacement applications
Images: 
Sources/Bibliography: https://www.roboze.com/it/materiali-stampa-3d/carbon-peek.html

Carbon		
Company: Resistex	**Company Country:** Ita	**Company website:** https://resistex.com/
Typology of material: (select one or more option and explain the choice) ☐ Fiber. ■ Textile .... ☐ Gel .... ☐ Foil .... ☐ Other		

Description material composition:
Resistex® Carbon is a yarn with unique technical characteristics that act on human behavioral thermodynamics and is obtained from the union of textile fibers with a continuous filament of conductive material based on active carbon, created to improve the performance of every sportsman at every level, through the properties of the fibers that relieve fatigue and increase energy, thus denoting better results than those obtained by an athlete wearing normal polyester sportswear. Three tangible benefits: reduction of oxygen requirements, reduction of heartbeats and lactic acid.
Resistex® Carbon as protection from static electricity.

Durability :
☐ Disposable
☐ 0-1 years
■ 1-5 years
☐ 5-10 years
☐ over 10 years

Ecological Quality : N/A.
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable

Suitable for recycling:
☐ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
■ Landfill
☐ other .....

Physical and Chemical Properties:
Color: Onyx
Hygroscopy: High
Melting temperature: N/A
Density: N/A
Thermal conductivity: Low
Electrical conductivity: N/A
Corrosion resistance: Medium

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

Hardness:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Material toughness:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Wear resistance:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 □ 2 □ 3 □ 4 ■ 5
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Other:...

Material processing technologies:
weaving, sewing

Strengths:

- Resistex® Carbon is a continuous filament of conductive material based on active carbon and textile fibers. It prevents electrical charges from being discharged on the body, thus avoiding muscle contractions, cramps and fatigue.Carbon improves the electrical performance of the human body, the high conductivity of Resistex®Carbon improves the dispersion of moisture by promoting evaporation of sweat. Less moisture in contact with the skin, greater feeling of well-being.
- reduction of oxygen requirements, reduction of heart beats and lactic acid.

Weaknesses:
Low/medium durability

Field of use:
Sport, footwear, socks, t-shirt, upholstery, Underwear

Images


Sources/Bibliography:
https://resistex.com/wp-content/uploads/2019/11/Resistex-Carbon-NEW-2019.pdf

Circuitex®

Company: Noble Biomaterials	**Company Country:** USA	**Company website:** https://noblebiomaterials.com/

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
■ Textile …….
☐ Gel ……...
☐ Foil ……….
☐ Other ………

Description material composition:	**Durability :**
Circuitex yarns and fabrics are highly conductive and can detect and transmit human physiological data for medical and consumer applications. Circuitex technology can replace traditional electrodes and metal wires, making products more comfortable, flexible, and durable.	☐ Disposable ☐ 0-1 years ■ 1-5 years ☐ 5-10 years ☐ over 10 years
Ecological Quality : N/A ☐ Use of raw materials/ renewable materials ☐ Recycled materials ☐ Low energy consumption in production process ☐ Long life and low maintenance ☐ Harmless to the producer and the user ☐ LCA ☐ Recyclable	**Suitable for recycling:** ☐ Use of single material ☐ Disassemblable material ☐ Suitable for combustion ■ Landfill ☐ other …..

Physical and Chemical Properties:
Color: Dark gray
Hygroscopy: High
Melting temperature: depends from the yarn used
Density: N/C
Thermal conductivity: depends from the yarn used
Electrical conductivity: 62,1 10.E6 Siemens/m
Corrosion resistance: medium

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

Hardness:

□ 1 ■ 2 □ 3 □ 4 □ 5
Material toughness:
□ 1 □ 2 □ 3 ■ 4 □ 5
Wear resistance:
□ 1 □ 2 □ 3 ■ 4 □ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 □ 2 □ 3 □ 4 ■ 5
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C

Material processing technologies:
weaving, sewing

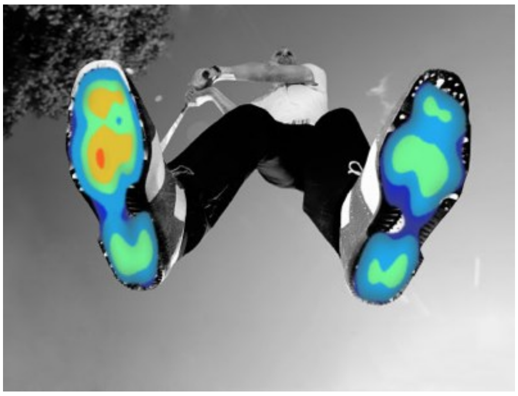
Strengths:

- Circuitex can be blended into fabrics at variable levels, it can offer the ultimate in conductive or dissipative design flexibility. This flexibility allows customers the pliability, tenacity, elongation and strength requirements needed to meet their design specifications.
- Circuitex materials are soft, lightweight, and flexible making it easy and comfortable to integrate detection, monitoring, and/or transmission of data into products, garments, and accessories. In medical applications,
- Circuitex yarns can be knit or woven into smart diagnostic garments and used to sense and transmit electrophysiological signals to a healthcare professional or data analysis app. In consumer apparel, Circuitex can be used for collecting data, delivering stimulus, storing energy, or controlling temperature, among other things. In biometric monitoring, Circuitex materials can detect and transmit information about sleeping patterns and weight distribution or can alert healthcare professionals about hot spots on patients who are confined to a bed or wheelchair. In electronic applications, soft, foldable Circuitex can replace metal wire to transmit data or conduct energy. The applications are endless.

Weaknesses:
presumed poor durability, few data available.

Field of use:
Remote Medical Monitoring Wearables, Consumer Wearable and Smart Garments, Fitness, Heated Fabrics, Personal electronics, Body Mapping and Pressure Sensing, Flexible circuitry, Antenna System

Images:....



Sources/Bibliography:
http://noblebiomaterials.com/circuitex/wp-content/uploads/sites/3/2016/05/circuitex_sell_sheet.pdf

Decell		
Company: D30	**Company Country:** UK	**Company website:** https://www.d3o.com/ https://www.d3o.com/partner-support/materials/ https://www.d3o.com/media/2165/d3o-decell-defence-tds.pdf

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
☐ Textile…….
■ Gel ……...
■ Foil ………. sheets
■ Other semi-finished products, foam ……...

Description material composition:	**Durability :**
D3O® Decell is a non-Newtonian material. It provides both long-term cushioning and shock attenuation.	☐ Disposable ☐ 0-1 years ☐ 1-5 years ■ 5-10 years ☐ over 10 years

Ecological Quality : N/A
□ Use of raw materials/ renewable materials
□ Recycled materials
□ Low energy consumption in production process
□ Long life and low maintenance
□ Harmless to the producer and the user
□ LCA
□ Recyclable

Suitable for recycling:
■ Use of single material
□ Disassemblable material
□ Suitable for combustion
□ Landfill
□ other …..

Physical and Chemical Properties:
Color: Orange
Hygroscopy: Method DTS028 - 52.0%
Melting temperature:
Density: 0.4 g/cm³
Thermal conductivity: N/C
Electrical conductivity: Low
Corrosion resistance: N/C
Other …..

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Resistance to bending:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Compressive strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Torsional strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Tensile strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

Hardness:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ variable
Material toughness:
□ 1 □ 2 □ 3 □ 4 ■ 5
Wear resistance:
□ 1 □ 2 □ 3 □ 4 ■ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/A
Ductility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/A
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/A
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/A
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/A

Material processing technologies:
foaming, padding, upholstery

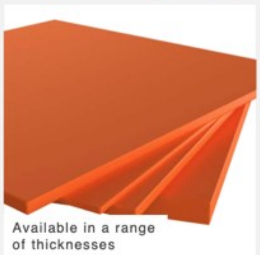
Strengths:

- D3O® Decell is available for simple integration of D3O® patented technology into product ranges.
- Optimised for moderate to high impact energies
- Soft, flexible and versatile material
- Designed for markets where high durability is key
- Frequently used for body protection, knee and elbow pads, gloves, footwear and chin guards
- Simple integration means the product development process can be greatly accelerated.

Weaknesses:
Flame

Field of use:
Defence, Foot and knee protection, electronics protections, Industrial protective clothing, DPI, sport

Images:



Sources/Bibliography:
D30 Decell data sheet:
https://www.d3o.com/media/2165/d3o-decell-defence-tds.pdf

D30 panoramic data sheet:
https://www.d3o.com/media/2260/d3o-sheet-data-material-matrix-2020.pdf

Ergall (alluminio 7075)

Company: CO.ME.FI. Metalli	**Company Country:** ITA	**Company website:** https://www.comefimetalli.it/lega7075.asp

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
☐ Textile…….
☐ Gel ……...
■ Foil ………. sheet
■ Other ……...semi-finished products, screws, parts, pipe, bars, rods, slab

Description material composition:
Ergall is an lluminum alloy in which the main alloying agent is zinc, an element that has the highest solubility in aluminum. Zinc increases the hardness, as well as favoring the self-tempering of the alloy.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
☐ 5-10 years
■ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
■ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

Physical and Chemical Properties:
Color: Metallic, tipically red
Hygroscopy: Low
Melting temperature: 475 - 635°C
Density: 2,81 g/cm^3
Thermal conductivity: 155 W/m °C
Electrical conductivity: (resistivity) 0.052 (Ω mm^2/m)
Corrosion resistance: Low

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Torsional strength:

☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Hardness:
☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5
Material toughness:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Wear resistance:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

Technological properties of the material:
Malleability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Ductility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Fusibility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Hardenability:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Weldability:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

Material processing technologies:
milling, cutting, turning

Strengths:

- The 7000 alloys, when heat treated, have the highest tensile strength of all aluminum alloys. In welded structures this alloy is technically competitive with some steels, with a lower volume density of about three times.

Weaknesses:
Low corrosion resistance due to the presence of Zinc, however, there are some variants such as the alloy known as "Titanal" with the addition of small doses of Zirconium or Chromium which makes it more resistant to corrosive agents.

Field of use:
Bolts and heavily stressed parts, automotive, sport, aerospace.

Images:

Sources/Bibliography:
https://www.comefimetalli.it/lega7075.asp
https://www.comefimetalli.it/img/leghe/L7075_ITA.pdf

eVent®		
Company: Iattai	**Company Country:** Italy	**Company website:** http://itttai.com

Typology of material: (select one or more option and explain the choice)
☐ Fiber ……….
■ Textile …….
☐ Gel ……...
☐ Foil ……….
☐Other Polymer

Description material composition: Innovative Fabrics composed of an ePTFE waterproof membrane.	**Durability :** N/A ☐ Disposable ☐ 0-1 years ☐ 1-5 years ☐ 5-10 years ☐ over 10 years
Ecological Quality : N/A ☐ Use of raw materials/ renewable materials ☐ Recycled materials ☐ Low energy consumption in production process ☐ Long life and low maintenance ☐ Harmless to the producer and the user ☐ LCA ☐ Other ……….	**Suitable for recycling:** N/A ☐ Use of single material ☐ Disassemblable material ☐ Suitable for combustion ☐ Landfill ☐ other …..

Physical and Chemical Properties:
Color: *N/A*
Hygroscopy: N/A
Melting temperature: N/A
Density: *N/A*
Thermal conductivity: N/A
Electrical conductivity: N/A
Corrosion resistance: N/A
Other …..

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance: N/A

□ 1 □ 2 □ 3 □ 4 □ 5

- Resistance to bending: N/A

□ 1 □ 2 □ 3 □ 4 □ 5

- Compressive strength: *N/A*

□ 1 □ 2 □ 3 □ 4 □ 5

- Torsional strength: N/A

□ 1 □ 2 □ 3 □ 4 □ 5

- Tensile strength: N/A

□ 1 □ 2 □ 3 □ 4 □ 5
Hardness: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Material toughness: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Wear resistance: N/A
□ 1 □ 2 □ 3 □ 4 □ 5

Technological properties of the material:
Malleability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Ductility: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Fusibility: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Hardenability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Weldability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5

Material processing technologies:
N/A

Strengths:

- Comfortable: fabric acts on the person’s body like a second skin.
- Instantly expels water vapor that is formed inside the fabric

Weaknesses:
There are not many information about the material

Field of use:

- Used in sports, medical, industries, Military, Police, Fire, and Workwear clothing

Images:

Sources/Bibliography:
http://itttai.com

Jackal

Company:	Company Country:	Company website:
TECH Textil Santanderina	Spain	https://www.techs.es/

Typology of material: (select one or more option and explain the choice)

☐ Fiber ……….
■ Textile …….
☐ Gel ………
☐ Foil ……….
☐ Other Polymer

Description material composition:
Composite textile for protective suit (protective jacket and trousers) according to EN ISO 13688.2013, EN 15614 2007 and EN 11612.2015. Meta-aramid 55% Lenzing TM FR 38% Para-Aramid 5% Antistatic Fiber 2%

Durability :

☐ Disposable
☐ 0-1 years
☐ 1-5 years
☐ 5-10 years
■ over 10 years

Ecological Quality :

☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
■ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA

Suitable for recycling: N/A

☐ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

☐ Other ……….	

Physical and Chemical Properties:
Color: Yellow, sand, Green, Orange, Blue, Black
Hygroscopy: N/C
Melting temperature: UNE-EN ISO 5077 5 x 75 ºC
Density: 220 g/m2
Thermal conductivity: Low
Electrical conductivity: Low
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending: N/A

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength: N/A

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- **Tensile strength:** UNE-EN ISO 13934-1 800 600 N

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Hardness:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Material toughness: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Wear resistance:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Technological properties of the material:
Malleability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Ductility: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Fusibility: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Hardenability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Weldability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Material processing technologies:
weaving, sewing, limited choice of colors

Strengths:

- comfort, aramidic, antistatic

Weaknesses:
Syntetic composite fiber

Field of use:

- Firefighters and wildland firefighters,
- Rescue and emergencies,
- petrochemical industry,
- military

Images:

Notes:
Certification:
UNE EN 11612 –A1-A2-B1-C1-F1
certificato a 100 lavaggi ISO 15797
UNE EN 116111 – Classe1
certificato a 100 lavaggi ISO 15797
UNE-EN 1149-5
UNE-EN 13034 -6 con finissaggio FC
certificato a 5 lavaggi ISO 15797
UNE-EN 469 Outershell
certificato a 5 lavaggi ISO 15797
UNE-EN 16689 Rescue
certificato a 50 lavaggi ISO 15797
ISO 15384
certificato a 50 lavaggi ISO 15797
AS/NZS 4824 (ISO 15384:2003, MOD).
certificato a 50 lavaggi ISO 6330
UNE-EN 61482-1-1 ATPV = 10.9 cal/cm2
certificato a 5 lavaggi ISO 15797
UNE-EN 61482-1-2: APC = 1 / Class 1 (4 kA)
certificato a 5 lavaggi ISO 15797
AS/NZS 4399:2017

Sources/Bibliography:
https://textilsantanderina.com/
https://www.techs.es/

Kevlar		
Company: Dupont	**Company Country:** USA	**Company website:** https://www.dupont.it/brands/kevlar.html

		https://www.dupont.com/content/dam/dupont/amer/us/en/safety/public/documents/en/Kevlar_Technical_Guide_0319.pdf

Typology of material: (select one or more option and explain the choice)
■ Fiber.
■ Textile ....
☐ Gel ....
■ Foil ....
☐ Other ....

Description material composition:	**Durability :**
Kevlar® is an organic fiber in the aromatic polyamide family. The unique properties and distinct chemical composition of wholly aromatic polyamides (aramids) distinguish them—and especially Kevlar®—from other commercial, man-made fibers	☐ Disposable ☐ 0-1 years ☐ 1-5 years ■ 5-10 years ☐ over 10 years

Ecological Quality : N/A	**Suitable for recycling:**
☐ Use of raw materials/ renewable materials ☐ Recycled materials ☐ Low energy consumption in production process ☐ Long life and low maintenance ☐ Harmless to the producer and the user ☐ LCA ☐ Recyclable	☐ Use of single material ☐ Disassemblable material ☐ Suitable for combustion ■ Landfill ☐ other .....

Physical and Chemical Properties:
Color: bright yellow
Hygroscopy: High
Melting temperature: Kevlar does not melt; it decomposes at relatively high temperatures (800°F to 900°F [427°C to 482°C]
Density: 1.44 g/cm³
Thermal conductivity: Low
Electrical conductivity:Low
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5 (3600 MPa)
Hardness:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Material toughness:

□ 1 □ 2 □ 3 □ 4 ■ 5
Wear resistance:
□ 1 □ 2 □ 3 ■ 4 □ 5

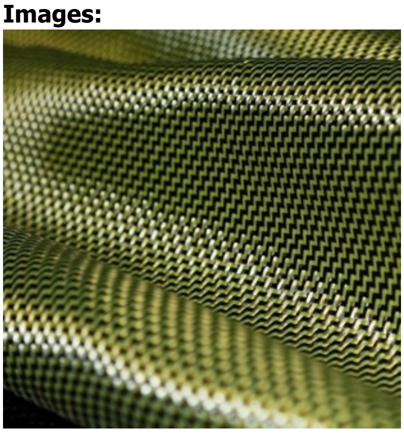
Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Fusibility:
■ 1 □ 2 □ 3 □ 4 □ 5
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C

Material processing technologies:
wrapping, vacuum printing, Sewing, weaving,

Strengths:
- Great mechanical resistance to traction, so much so that for the same mass it is 5 times more resistant than steel.
- Great resistance to heat and flame.
- Long plastic deformation range. When it gets damaged, it does so one strand at a time, so it will bend or give way instead of breaking. It has a much more predictable breaking process than other fibers such as carbon fiber.

Weaknesses:
- Quickly absorb moisture.
- Weak compressive force in the transverse direction.

Field of use:
Industrial protective clothing, militar uniform and tool, DPI, airplanes, boats and racing cars, aerospatial.

Images:



Sources/Bibliography:
https://www.dupont.com/content/dam/dupont/amer/us/en/safety/public/documents/en/Kevlar_Technical_Guide_0319.pdf

Lenzing

Company: Lenzing	**Company Country:** Austria	**Company website:** https://www.lenzingindustrial.com/Application/protective-wear

Typology of material: (select one or more option and explain the choice)
■ Fiber cellulosic.
☐ Textile …….
☐ Gel ……...
☐ Foil ……….
☐ Other ……...

Description material composition:
LENZING™ FR is a sustainably produced inherently flame-resistant cellulosic fiber based on Lenzing's renowned Modal fiber production process.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
■ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
■ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Other ……….

Suitable for recycling: N/C
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

Physical and Chemical Properties:
Color: N/A
Hygroscopy: N/A
Melting temperature: UNE-EN ISO 5077 5 x 75 ºC
Density: 220 g/m2
Thermal conductivity: low
Electrical conductivity: N/A
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Hardness:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

Material toughness: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Wear resistance: N/A
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

Technological properties of the material:

Malleability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Ductility: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Fusibility: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Hardenability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Weldability: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

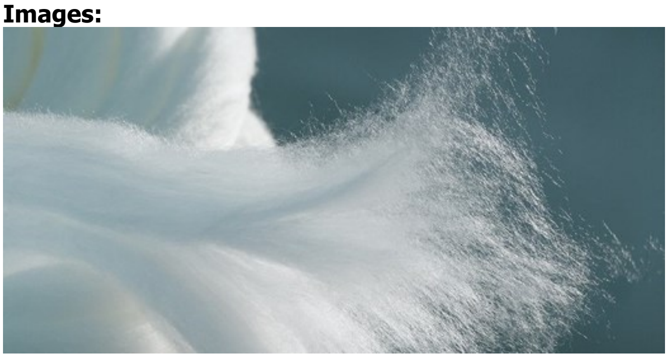
Material processing technologies:
sewing, weaving

Strengths:
comfort, aramidic, antistatic, excellent mechanical properties. It is made of recyclable fibers.

Weaknesses:
There is no 100% Lenzing textile available on the market.

Field of use:
Security, Firefighter, Rescue and emergencies, military, workwear

Images:



Sources/Bibliography:
https://www.lenzing.com/de/

Onyx FR

Company: Markforged	**Company Country:** USA	**Company website:** https://markforged.com/

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
☐ Textile …….
☐ Gel ……...
☐ Foil ……….
■ Other ……… 3D printing filament

Description material composition:
Onyx FR is a flame-resistant filament designed for use in applications where parts must be non-flammable. The material earned a UL Blue Card, and is considered V-0 (self extinguishing) at thicknesses greater than or equal to 3mm. It can be reinforced with any Continuous Fiber and is compatible with industrial composite 3D printers.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
■ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

Physical and Chemical Properties:
Color: Black/Gray Onyx
Hygroscopy: High
Melting temperature: UL 94 V-0 Blue Card certified.
Density: 1.2 g/cm³
Thermal conductivity: Heat Deflection Temp 145°c
Electrical conductivity: Low
Corrosion resistance: Medium

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Resistance to bending:

☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5

- Torsional strength:

■ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

- Tensile strength:

☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Hardness:

□ 1 □ 2 ■ 3 □ 4 □ 5
Material toughness:
□ 1 □ 2 □ 3 ■ 4 □ 5
Wear resistance:
□ 1 □ 2 ■ 3 □ 4 □ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 ■ 2 □ 3 □ 4 □ 5
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C

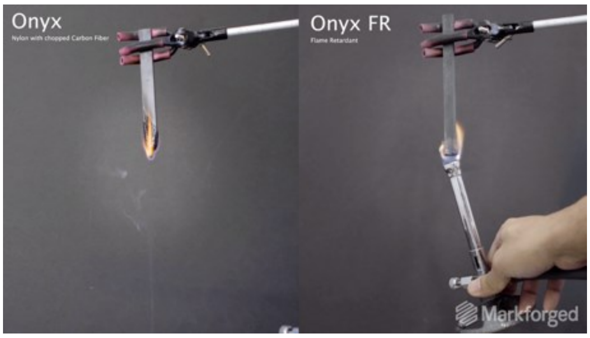
Material processing technologies:
extrusion, 3D printing

Strengths:
- Flame retardant
- High quality surface finish
- High strength and low weight, especially when reinforced
- Non marking
- Resistant to heat and chemicals
- Reinforced with continuous fiber

Weaknesses:
high costs, only 3D printers for production.

Field of use:
Weld Fixturing, Aerospace Clips & Brackets, Laser Marking Fixtures, Energy/Electrical Brackets & Fixtures

Images:



Sources/Bibliography:
https://markforged.com/
https://www.youtube.com/watch?v=jygbFH4gyAE

Paxcon®

Company: Line-X	**Company Country:** Italy	**Company website:** https://line-x.it/

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
☐ Textile …….
☐ Gel ……...
☐ Foil ……....
■ Other ……… Coating, spray

Description material composition:
PAXCON PX-3350 is a two component, 100% high performance aromatic polyurea spray elastomer systemzero VOC (Volatile Organic Compounds), 100% solid. It is a spray paint applicable to Dyneema®, armed vehicles, body armor and other military equipment. The PX-2100 was developed to absorb the impact of bullets, thus preventing both the bullet and the reinforced plate from disintegrating.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
☐ 5-10 years
■ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

Physical and Chemical Properties:
Color: Black/Gray
Hygroscopy: very low
Melting temperature: 140°c
Density: 9.5 lbs/gal
Thermal conductivity: N/C
Electrical conductivity: Dielectric Const. ASTM D150 3.6
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending:

☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Torsional strength:

☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5

- Tensile strength:

☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5

Hardness:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Material toughness:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Wear resistance:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Technological properties of the material:

Malleability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Ductility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Fusibility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C

Hardenability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C

Weldability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C

Material processing technologies:
polymerization, spraying

Strengths:

- It is the only polyurea approved under Reg 31
- Quick return to operation
- Abrasion resistant
- Resistant to chemicals
- Creates uniform water and airtight protection
- Remarkable elastic properties. It does not crack or deform
- Sprayable up to the desired thickness
- It adapts to the body of the product
- No maintenance required

Weaknesses:
It has to be combined with another support material. It is a coating.

Field of use:
pipe and pole coating, automobile/ van/pickup lining, loading bays, military defense, naval lining, industrial coating

Images

Sources/Bibliography:
https://line-x.it/
http://www.line-xferrara.com/
https://www.youtube.com/watch?v=Lfd7_p4SVBU
https://linex.com/security-and-defense

Twaron®

Company: Teijin	**Company Country:** JPN	**Company website:** https://www.teijin.com/

Typology of material: (select one or more option and explain the choice)
■ Fiber.
■ Textile …….
☐ Gel ………
☐ Foil ……….
■ Other Pulp, Filament yarn, staple fiber, Paper, Laminates, Powder ………

Description material composition:
Twaron® has become established as the preferred para-aramid product for manufacturers who want to deliver products that are stronger, lighter, and more resistant. Good combination of mechanical properties, chemical resistance, excellent durability and thermal stability.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
■ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..Recyclable

Physical and Chemical Properties:
Color: Variable (yellow, black)
Hygroscopy: Low
Melting temperature: decomposition at 500 ° C
Density: 1.44 - 1.45 g/cm3
Thermal conductivity: High
Electrical conductivity: Low (non-conductive)
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Hardness:
☐ 1 ☐ 2 ☐ 3 ■ 4 ☐ 5
Material toughness:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Wear resistance:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

Technological properties of the material:
Malleability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Ductility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Fusibility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Hardenability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Weldability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C

Material processing technologies:
Polymerization, Sewing, weaving, printing,

Strenghts:

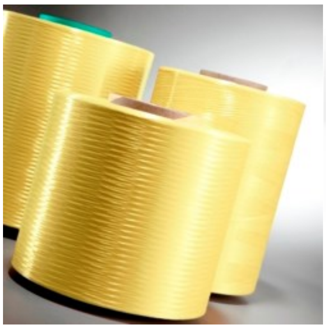
- Excellent strength-to-weight properties
- Resistant to heat, flames and chemicals
- High dimensional stability
- Adjustable to different applications
- Available in different colors
- Excellent cut resistance
- Superior strength-to-weight

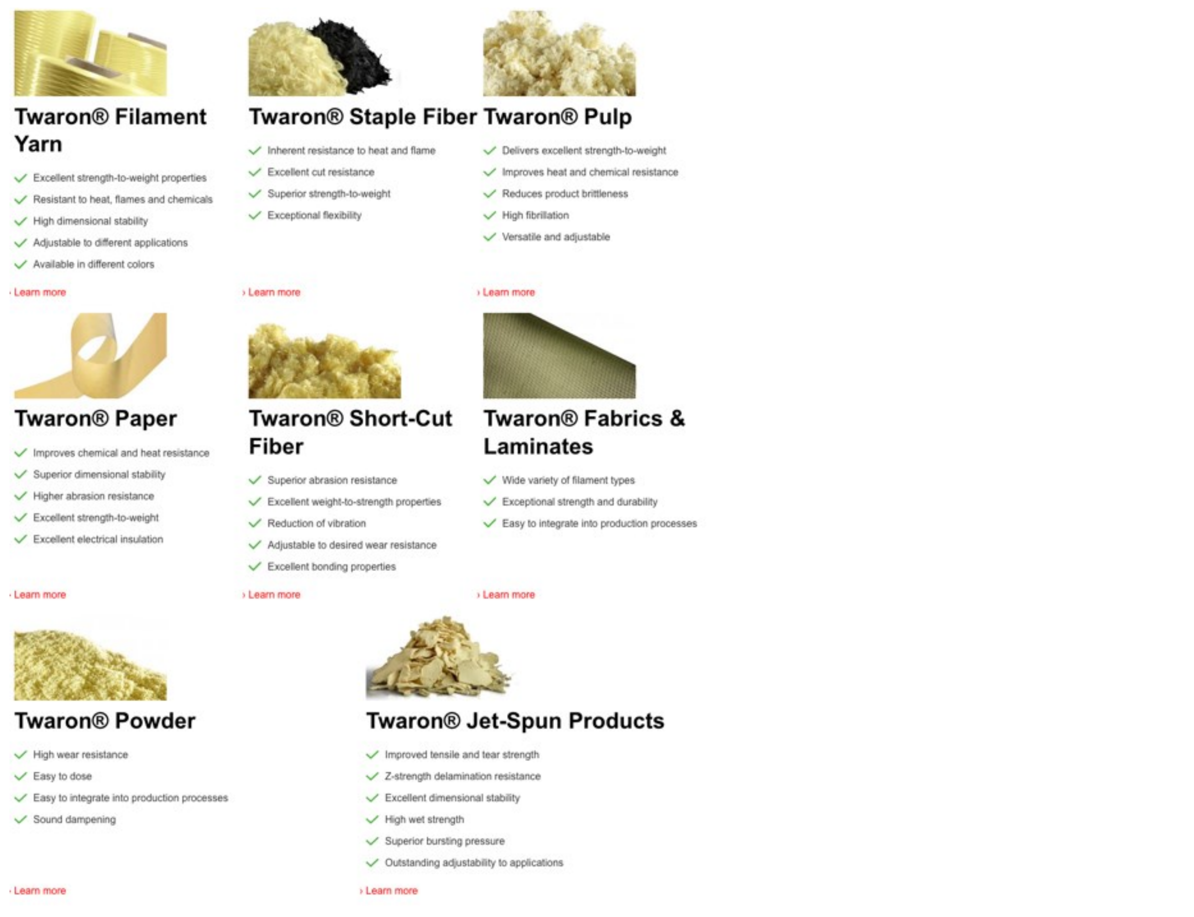
- Exceptional flexibility

Weaknesses:
It is made of synthetic material. No breathable material.

Field of use:
Industrial protective clothing, DPI, Air Cargo Containers, Aquaculture nets, Aramid honeycombs, Armored vehicles, Balistic protective vests, Brakes, Composites, Conveyor belts, Cut-protection products, engineering plastic, Heat- and flame-resistant garments, helmets, kiteboarding, parachute cords, ropes, etc..

Images:





Sources/Bibliography:
https://www.teijinaramid.com/wp-content/uploads/2021/02/Teijin_Aramid_Eco_datasheet_Twaron%C2%AE.pdf

https://www.teijinaramid.com/wp-content/uploads/2018/10/Product_brochure_Twaron.pdf

Tychem		
Company: Dupont	**Company Country:** USA	**Company website:** https://www.dupont.com/resource-center.html?BU=ppe https://www.dupont.it/products/tychem-2000-c-tccha5tyl00.html

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
■ Textile TNT …….
☐ Gel ………
■ Foil ……….
■ Other Coating ………

Description material composition:
These tough, high-performance coatings and film can be added to our protective fabric and help protect against exposure to 180 different chemicals. Tychem® fabric is designed for solid and durable protection even in difficult situations. Tychem® garments undergo rigorous independent testing before being approved for use. Additionally, Tychem® fabrics have been tested for permeation against numerous chemicals. As a result, they offer chemical protection from numerous toxic solids, liquids and vapors, from sarin gas to chlorine gas, as well as from biological threats.

Durability :
□ Disposable
□ 0-1 years
□ 1-5 years
■ 5-10 years
□ over 10 years

Ecological Quality :
□ Use of raw materials/ renewable materials
□ Recycled materials
□ Low energy consumption in production process
□ Long life and low maintenance
□ Harmless to the producer and the user
□ LCA
■ Recyclable

Suitable for recycling:
■ Use of single material
□ Disassemblable material
□ Suitable for combustion
□ Landfill
□ other .....

Physical and Chemical Properties:
Color: Variable (grey, yellow, orange, green)
Hygroscopy: Low
Melting temperature: Garment seams open at 98 ° C
Density: High
Thermal conductivity: Variable
Electrical conductivity: Low
Corrosion resistance: High

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

□ 1 ■ 2 □ 3 □ 4 □ 5

- Resistance to bending:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Compressive strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Torsional strength:

□ 1 □ 2 □ 3 □ 4 ■ 5

- Tensile strength:

□ 1 ■ 2 □ 3 □ 4 □ 5

Hardness:
■ 1 □ 2 □ 3 □ 4 □ 5
Material toughness:
□ 1 □ 2 □ 3 ■ 4 □ 5
Wear resistance:
□ 1 □ 2 ■ 3 □ 4 □ 5

Technological properties of the material:
Malleability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Ductility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Fusibility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Hardenability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Weldability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C

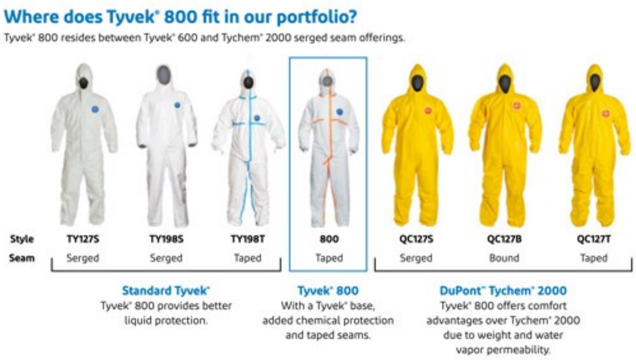
Material processing technologies:
Sewing, weaving, coating

Strengths:
- Certified according to Regulation (EU) 2016/425
- Chemical Protective Clothing, Category III, Type 3-B, 4-B, 5-B and 6-B
- EN 14126 (barrier against infectious agents), EN 1073-2 (protection against radioactive contamination)
- Antistatic treatment (EN 1149-5) - inside
- Seams reinforced and taped with a barrier adhesive for protection and strength

Weaknesses:
It is not flame resistant

Field of use:
Industrial protective clothing, DPI

Images:



Notes:
https://www.dupont.it/content/dam/dupont/amer/us/en/personal-protection/public/documents/en/EU_IFU_Tychem_2000C.pdf

Sources/Bibliography:
https://www.dupont.it/products/tychem-2000-c-tccha5tyl00.html

Tyvek

Company: Dupont	**Company Country:** USA	**Company website:** https://www.dupont.it/brands/tyvek.html https://www.dupont.com/tyvekdesign.html https://www.dupont.com/resource-center.html?BU=ppe

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
■ Textile TNT ....
☐ Gel ....
■ Foil ....
☐ Other ....

Description material composition:
DuPont™ Tyvek® provides a safe response to epidemics in a lot of applications, offers comfort and protection of human life. (HDPE)

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
■ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
■ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other .....

Physical and Chemical Properties:
Color: White
Hygroscopy: Medium/High
Melting temperature: 135 °C
Density: High
Thermal conductivity: $16.3*10^{-3}$ $m^2 \cdot K/W$
Electrical conductivity: Low
Corrosion resistance: Variable

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

- Cut resistance:

☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

- Resistance to bending:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Compressive strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Torsional strength:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5

- Tensile strength:

☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

Hardness:
■ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Material toughness:

□ 1 □ 2 □ 3 ■ 4 □ 5
Wear resistance:
□ 1 □ 2 ■ 3 □ 4 □ 5

Technological properties of the material:
Malleability:
□ 1 □ 2 □ 3 □ 4 ■ 5
Ductility:
□ 1 □ 2 □ 3 □ 4 ■ 5
Fusibility:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Hardenability:
□ 1 □ 2 □ 3 □ 4 □ 5 ■ N/C
Weldability:
■ 1 □ 2 □ 3 □ 4 □ 5

Material processing technologies:
Sewing, weaving

Strengths:

- Certified according to Regulation (EU) 2016/425
- Chemical protective clothing, Category III, Type 5-B and 6-BEN 14126 (barrier against infectious agents),
- EN 1073-2 (protection against radioactive contamination)
- Antistatic treatment (EN 1149-5) - on both sides
- Reinforced external seams
- Limited fluid loss from the inside thanks to an optimized design

Weaknesses:
For non-hazardous chemical*

Field of use:
Industrial protective clothing, DPI, Sterile Packaging, Design, Fashion, Art, Cladding

Images:

....


Sources/Bibliography:
https://www.dupont.com/tyvekdesign/design-with-tyvek/why-tyvek.html
https://www.dupont.it/brands/tyvek.html

Novalveolare		
Company: Vetronova	**Company Country:** Italy	**Company website:** https://www.vetronovasrl.com/ https://www.vetronovasrl.com/wp-content/uploads/2020/09/Novalveolare-SCHEDA-TECNICA.pdf

Typology of material: (select one or more option and explain the choice)
☐ Fiber.
☐ Textile …….
☐ Gel ……..
☐ Foil ……….
■ Other (panel)

Description material composition:
Polypropylene has excellent mechanical properties, resistance to impact and breaking at 23 ° C.

Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
■ 5-10 years
☐ over 10 years

Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
☐ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
■ Recyclable

Suitable for recycling:
■ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..

Physical and Chemical Properties:
Color: White
Hygroscopy: High
Melting temperature: 23°
Density: N/A
Thermal conductivity: N/A
Electrical conductivity: Low
Corrosion resistance: N/A
Other …..

Mechanical Properties (Value from 1 - Low to 5 - High)**:**
Mechanical resistance:

Cut resistance:
☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5
Resistance to bending:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Compressive strength:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Torsional strength:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Tensile strength:
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5
Hardness:
☐ 1 ☐ 2 ■ 3 ☐ 4 ☐ 5
Material toughness: N/A

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Wear resistance: N/A
☐ 1 ■ 2 ☐ 3 ☐ 4 ☐ 5

Technological properties of the material:
Malleability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Ductility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ■ 5
Fusibility:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Hardenability:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ■ N/C
Weldability:
■ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Material processing technologies:
Cut, Bending, Assembly

Strengths:

- lightness and ease of processing.
- Resistant to water, grease, alcohol and even certain solvents

Weaknesses:
These properties are severely compromised by low temperatures, particularly near or below 0 ° C.
Polypropylene is a polymer that swells when exposed to certain solvents.

Field of use:
Interior, product, furniture

Images:

Sources/Bibliography:
https://www.vetronovasrl.com/wp-content/uploads/2020/09/Novalveolare-SCHEDA-TECNICA.pdf
https://www.vetronovasrl.com/wp-content/uploads/2020/09/SCHEDA-PRODOTTO-NOVALVEOLARE.pdf

Waterlily

<table>
<tr><td>Company:
ORSA Foam</td><td>Company Country:
Italy</td><td>Company website:
http://www.orsafoam.it/</td></tr>
<tr><td colspan="3">Typology of material: (select one or more option and explain the choice)
☐ Fiber ……….
☐ Textile …….
☐ Gel ……...
☐ Foil ……….
■Other Polymer</td></tr>
<tr><td colspan="2">Description material composition:
Innovative polyurethane based on water and carbon dioxide.</td><td>Durability :
☐ Disposable
☐ 0-1 years
☐ 1-5 years
☐ 5-10 years
■ over 10 years</td></tr>
<tr><td colspan="2">Ecological Quality :
☐ Use of raw materials/ renewable materials
☐ Recycled materials
☐ Low energy consumption in production process
■ Long life and low maintenance
☐ Harmless to the producer and the user
☐ LCA
☐ Other ……….</td><td>Suitable for recycling:
☐ Use of single material
☐ Disassemblable material
☐ Suitable for combustion
☐ Landfill
☐ other …..</td></tr>
<tr><td colspan="3">Physical and Chemical Properties:
Color: White
Hygroscopy: No
Melting temperature: N/A
Density: 38.0 ±5%
Thermal conductivity: N/A
Electrical conductivity: N/A
Corrosion resistance: N/A</td></tr>
<tr><td colspan="3">Mechanical Properties (Value from 1 - Low to 5 - High):
Mechanical resistance:
• Cut resistance: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Resistance to bending: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Compressive strength: ±20%
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Torsional strength: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
• Tensile strength:
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Hardness: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Material toughness: N/A
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5</td></tr>
</table>

Wear resistance:
□ 1 □ 2 ■ 3 □ 4 □ 5

Technological properties of the material:
Malleability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Ductility: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Fusibility: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Hardenability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5
Weldability: N/A
□ 1 □ 2 □ 3 □ 4 □ 5

Material processing technologies:
N/A

Strengths:

- Absence of harmful substances
- High breathability: the open cellular structure guarantees the free passage of air and the rapid dispersion of heat and humidity
- Excellent elasticity that allows you to comfortably support and accommodate the different areas of the body, adapting perfectly to them
- Resistance to damp, ensuring the initial characteristics over time.

Weaknesses:
It is made of synthetic material

Field of use:

- Used in the furniture sector as padding, in particular for mattresses.

Sources/Bibliography:
http://www.orsafoam.it/

Annex IV: Jackal - Technical and colour Chart

11/03/2021

ΔTechs

Ref. 8627

JACKAL

ProtectiveWear

PARAMETER	METHOD	VALUE		UNITS	TOLERANCE
Weave	UNE 40.161	RipStop			
Composition	UNE-EN ISO 1833-1:20	Meta-aramid 55% Lenzing ™ FR 38% Para - Aramid 5% Antistatic Fiber 2%			+/- 3%
Weight	UNE 40.339	220		g/m²	+/- 5%
Total width	UNE-EN 1773	160		cm	+/- 1
Usable width	UNE-EN 1773	158		cm	+/- 1
		WARP	WEFT		
Tensile strength	UNE-EN ISO 13934-1	800	600	N	
Tear strength	UNE-EN ISO 13937-2	50	50	N	
Pilling	UNE-EN ISO 12945-2	4			
Abrasion	UNE-EN ISO 12947-2	50.000 @ 12 kPa		cycles	
Dimensional stability	UNE-EN ISO 5077 5 x 75 °C	-3		%	

AREAS

Police and Security Services

Electric power industry

Firefighters and Wildland firefighters

FINISHINGS

FC finish needed for EN 13034 garment certification. TECHSHIELD finish needed for EN 469 garment certification.

REMARKS

Available after 100 cycles of industrial wash (ISO 15797):
- ISO 11612
- ISO 11611

Available after 50 cycles of industrial wash (ISO 15797):
- ISO 15384

(*) Result obtained in combination with any of the following articles: TECHSALEXANDRA 150 (ref 8435) or TECHSALEXANDRA K200 (ref 28337)

STANDARDS	LEVEL
UNE-EN ISO 11612:2018	A1 A2 B1 C1 F1
UNE-EN ISO 11611:2018	Class 1
UNE-EN 1149-5:2018	PASS
UNE-EN 13034:2005+A1:2009	Type 6
UNE-EN 469:2006	Outershell
ISO 15384:2018	PASS
UNE-EN 16689:2017	PASS
UNE-EN 61482-1-1:2010	ATPV = 10,9 cal/cm²
IEC 61482-2:2018	APC = 1 APC = 2 (*)
AS/NZS 4399:2017	50+
AS/NZS 4824:2006	PASS

In case of industrial laundry, make sure to perform trials to addapt washing and drying conditions to each product.

SANTANDERINA GROUP

ΔTechs

TEXTIL SANTANDERINA, SA
Avenida Textil Santanderina S/N
39500 Cabezón de la Sal. SPAIN
marketing@techs.es

PRINTED: 11/03/2021


JACKAL
Techs
ADVANCED FABRICS BY SANTANDERINA
Innovative aramid blend solution for protectivewear
Solucion innovadora en aramida para tejidos de protección
Colour card Carta de color (Melange)
10045
Yellow
77114
Sand
63066
Green
Colour card Carta de color (Plain)
20307
Orange
31454
Red
43109
Navy blue
83762
Midnight
Main application areas Sectores
Firefighters and wildland firefighters
Rescue and emergencies
Petrochemical industry
Military
Certifications Certificaciones
ISO 11612
EN 469
EN 1149-5
IEC 61482-2
EN 13034
EN 15614
ISO 15384
Please check articles available
Por favor revise los artículos disponibles
There may be minor variations in shade in the other articles of the range due to different weights and compositions.
Special finishes: final colour may suffer slight deviations.
For more information on Techs' full range of fabrics, please check www.techs.es or contact your local representative.
Pueden producirse pequeñas variaciones de tono en otros artículos debido a los distintos pesos y composiciones.
Acabados especiales: los colores finales pueden tener ligeras desviaciones.
Para más información entra en www.techs.es o contacta con tu representante local.

Annex V: DRYRES V2 - Technical Chart

DAINESE	**TECHNICAL DATE SHEET (STD)**	**Cod. 0265000001**
	TESS. ART. 2316 X D-L.	Rev: 001
		Date: 06/02/2019

TECHNICAL FEATURES:

DESCRIPTION		UNIT	RESULT REQUIRED		STD NORM	DAINESE METHOD
F1149/15 DRYRES V2						
Composition			PU+PES			
Useful height roll (membrane side)		cm	≥143		UNI EN 1773 UNI EN ISO 2286-1	005
Weight		g/m²	120 ± 10%		UNI 5114 method 3 UNI EN ISO2286 2	004
N° of yarns for unit length		Yarns /cm	Warp(long.)	/	UNI EN 1049-2	010
			West (trasv.)	/		
Sensorial characteristics: Look			**accord. to sample**			
Hand			**accord. to sample**			001
Color tone			**accord. to sample**			002
Color fastness artificial light		European Blu Scale	≥ /		UNI EN ISO105 B02 method 3	020
Color fastness water (37 °C)		Grey Scale	≥ 4		UNI EN ISO 105-E01	021
Color fastness domestic and commer cial laundering (40 °C)		Grey Scale	≥ 4		UNI EN ISO 105-C06	022
Color fastness rubbing dry and wet		Grey Scale	≥ 4		UNI EN ISO 105-X12	029
Color fastness perspiration	• acid	Grey Scale	≥ 4		UNI EN ISO 105-E04	030
	• alkaline	Grey Scale	≥ 3/4			
Determination of dimensional change in domestic washing and drying Washing method: UNI EN ISO 6330 ANNEX B method 3N Drying method: UNI EN ISO 6330 procedure A – Line Dry		%	warp (long.) ±2%	weft (trasv.) ±2%	UNI EN ISO 3759 UNI EN 25077 UNI EN ISO 6330	011
Home washing behavior after n° 5 cycles at 40°C		/	No membrane detachment		UNI EN ISO 6330	011
Tensile strength (Strip method):	breaking load	N/5cm	warp ≥ /	weft ≥/	UNI EN ISO 1421 UNI EN ISO 13934-1 UNI EN ISO 2907 3/3[a]	012 014
	breaking elongation	%	warp ±/	weft ±/		
Tear strength		N/6cm	warp ≥ /	weft ≥/	UNI EN ISO 4674 method B	
Determination of the seam resistance with yarn: Cotton N° 50		N/5cm	warp ≥/	weft ≥/	UNI 4818/11 UNI EN ISO 13935-1	018
Abrasion resistance Martindale load: 9 kPa fabric side / abrasive surface * STD Wool Fabric (g/m^2 215 ± 10)		N° cycles	≥30.000		ISO 12947/2[a]	026
load: fabric side / abrasive surface * Velcro type HOOK without surface hair formation		N° cycles	≥100			
Resistance to surface wetting (spray test) Washing method: UNI EN ISO 6330 ANNEX B method 3N Drying method: UNI EN ISO 6330 procedure A – Line Dry			≥ ISO 4 (90)	after 5 washings ≥ ISO 3 (80)	UNI 4818/26[a]	003

Water penetration resistance	Mm H2O	new	after membrane side abrasion	UNI EN20811	023
		≥ 20000	/		
		with seal tape			
		liner stitching	cross stitching		
		≥/	≥/		
Water vapor transmission rate	g/m^2/24 h	≥700		UNI 4818/26[a]	024
Air permeability • At 200 Pa 825 mmH₂O) depression	l/min/20 cm^2	/	/	UNI EN ISO 9237	025

Seal tape whit cod. 0407210009	Temp. 380 °C Speed. 2-2,5 m/mins Phone pressure. 0,8 Roller pressure. 3

TOXIC -- HAZZARDOUS SUBSTANCES	SEE DOCUMENTS "TEXTILES AND ACCESSORIES -RESTRICTED SUBSTANCES LIST "RSL" -- CHEMICAL -- SAFETY REQUIREMENTS IN THE LAST REVIEW" IS REQUIRED CONFORMITY DECLARATION FOR EVERY DELIVERY.

Annex VI: Removable soft protections - Technical Chart

DAINESE / MAVET	SCHEDA TECNICA DI ACQUISTO	Cod. 0411010215
	ARTICOLO: PROTEZIONE PRO SHAPE 2.0	Rev: 03
		Data: 11/12/2019

MATERIALE/ MATERIAL	Materiale/Material	PP SLB 50V1
	Colore/Colour	Nero

CARATTERISTICHE TECNICHE:

CARATTERISTICHE TECNICHE PRODOTTO/ PRODUCT SATISFACTIONS	U.M.	VALORI NOMINALI RICHIESTI/ STANDARD REQUIRED	TOLLERANZA/ TOLLERANCE	NORMA STANDARD/ STANDARD RULE	METODO DAINESE/ DAINESE PROCESS
Aspetto/ Aestethics		Campione di riferimento/ Reference sample		UNI 9270	007
Dimensioni/Dimensions	mm	Disegno di rif./ See drawings	± 2 %	/	/
Peso/ Weight	gr	72	± 5%	UNI 5114 Metodo III	004
Densità / Density	gr/lt	1,23	± 5%	UNI EN ISO 2811-1	/
Odore /Smell	/	Non applicabile/ Not applicable	/	/	/
Solidità del colore alla luce artificiale	Scala dei blu europea	≥ 4	/	UNI EN ISO 105-B02 metodo 3	020
Solidità del colore all'acqua (37°C)	Scala dei blu europea	≥ 4	/	UNI EN ISO 105-E01	021
Resistenza Invecchiamento (cicli termici) -Range temperatura cicli: -15°c /+65°c -Range umidità relativa cicli: 40/90% -Tempo test 28h	Visivo	Nessuna alterazione	/	ISO 12097-2:1996 (E)	/
Resistenza all'impatto (Forza trasmessa con energia d'impatto di 50J) Temperatura ambiente (~ 23°C) media 3 impatti	kN	≤33	/	EN01621-1:2012	/
Resistenza a trazione (cucitura protezione con materiale di supporto) /Resistance to traction (sewing wit support material) (*)	N	Ambiente/Room environment; Trattamento idrolitico/ Hydrolytic treatment: ≥400	/	UNI EN ISO 13934-1	/
Sostanze tossico nocive Toxic Pollutants		VEDASI DOCUMENTO "PRODOTTI TESSILI E ACCESSORI – LISTA SOSTANZE PROIBITE (RLS) – REQUISITI DI QUALITA' ECOTOSSICOLOGICHI IN ULTIMA REVISIONE SI RICHIEDE DICHIARAZIONE DI CONFORMITA' PER OGNI CONSEGNA			

(*) Umido dopo invecchiamento idrolitico (72 ± 0,5) h in un a scatola chiusa sopra dell'acqua mantenuta a (+70 ± 2)°C
Moist after hydrolytic aging (72 ± 0,5) h in closed box above water maintained at (+70 ± 2) °C
+
(24 ± 0,5) h a (+23 ± 2) °C chiuso ermeticamente in un sacchetto a prova di vapore acqueo /
(24 ± 0,5) h a (+23 ± 2) °C hermetically sealed in a bag proof to water vapor test