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26 July 2025

H2020 – Secure societies - Protecting freedom and security of Europe and its citizens
SU-DRS02-2018-2019-2020– Technologies for first responders – Research and Innovation Action (RIA)

Search & Rescue

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

D1.1 Report on user requirements, existing tools and infrastructure

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Executive Summary

Due to climate change and the development of high-risk industrial technologies, European countries are facing a high magnitude and frequency of natural or industrial disasters. Therefore, challenges experienced by staff and state and private structures working in the field of R&D are constantly diversifying.

The main objective of this task is to gather information on existing technologies used in SAR operations relevant to the location of entrapped victims; the identification of limitations and gaps, as well as of future needs. Benchmarking of available commercial products will also be included.

The need for equipment to ensure the protection of First Responders against the possible effects of a disaster and the use of technologies that significantly increase the probability of survival of the victims in the search-rescue process have been addressed in chapter 3.

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. There have been a number of limitations and gaps in existing SAR technology on the market, including proposals to modernise it or design new technologies. In the same direction, the information obtained through questionnaires allowed, in chapter 4, the benchmarking of available commercial products. The conclusions underline the need for technological improvements in the field of R&D, as the best solution for an optimal cost-benefit ratio. New SAR technologies must add value to SAR actions, being able to address the requirements of users, for each type of technique, on the achievement of improvements in the following KPIs: ergonomic, power supply, size, weight, user interface characteristics, portability, sensitivity, low LODs, robustness and maintenance.

Based on this knowledge we discussed the most important technical features for the design of a general collective protective system. However, we must keep in mind that for different applications we can find numerous variations and that a process of design sophistication is needed if we want to address users needs in the best possible way. However, for the future we can expect progress in the following areas: Standardisation of equipment; Fielding of technology improvements.

Hence the conclusion is that it is indeed useful to conduct research in the directions brought forward by users of SAR technology.

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1 Introduction

1.1 Purpose and Scope

The main objective of this task T1.1, within the frame of which this document is issued, is to gather information on existing technologies used in SAR operations relevant to the location of entrapped victims; the identification of limitations and gaps, as well as of future needs. Benchmarking of available commercial products will also be included.

The main program objectives of the SAR are to:

- Minimise the duration of the search
- Limit the loss of life and property
- Minimise injury and damage to the environment

So the main objectives of this task are:

Obj.1 Gather information on existing technologies used in SAR operations relevant to location of entrapped victims;

- Full definition of set of functional and non-functional requirements of SnR;
- Finalised first version of the existing technologies;
- Full list of components for each procedure of SAR operations.

Obj2 Identification of limitations and gaps on existing technologies;

- Description of use-case and scenarios, providing a useful baseline and guidance;
- List of data sources to integrate limitations and gaps on existing technologies.

Obj.3 Future technology needs;

- A common vision of future technologies' models will be shared and validated.

Obj.4 Benchmarking of available commercial products.

- Identifying the best option;
- SWOT analysis of products.

1.2 State of the Art

State of the art is defined as the latest achievements in a field, here specifically the field of SAR. It is the definition of the highest level of achievements of general development in the field of equipment, technology or scientific development. The State of the art level refers to the most modern approaches, ideas and methodologies in the field of science, technology and informatics.

The SnR project aspires to build a State of the art framework that will integrate:

1. Advanced sensors, systems and procedures to obtain high level awareness capabilities;
2. Secured data collection and information flow between the different authorities and agencies which are involved in the crisis/abnormal events management;
3. Fusion of data from different sources and creation of a Common Situational Picture for supporting decisions of emergency and crisis management;
4. A multitier architecture of information processing, the result of which will be accessible in an easy way to be understood by all the actors involved.

1.3 Going beyond state-of-the-art

The crisis management business process involves multi-layered interaction between many actors, each having distinctive responsibilities and all operating within challenging circumstances and time frames. One consequence is that those exercising judgment and making decisions in this complex environment require a resilient agile framework that meet their multiple needs at many different emergency events. These events are sometimes not fully understood and predictable and can be changed from hours to years.

Because First responders act to save human lives from natural disasters or accidents, it is of great importance to define the characteristics and measurement of the variables of the environment, where the victims are found. These measurements are made with specialised sensors that will define the intervention methods and the subsequent decontamination of the protection equipment.

Information technology has transformed the way information is acquired and utilised, potentially adding tremendous value in the support of critical decision making. The current state of the art in information acquisition is provided to assess the ability of current building information modelling, devices, and people to support critical decision making in emergency events and to identify opportunities for advancement. This status is provided in terms of their application to essential functions, performance in basic metrics, and functionality in areas known to be important for true utility. These considerations will reflect the ability of current information acquisition technology to support current decision-making with regard to rescuing victims and, ultimately, for current and emerging technology to be widely adopted.

It must describe the newest technological achievement in a given field like SAR technology. Something that is state-of-the-art is modern and new.

Smart First Responder Framework

A Smart First Responder framework allows to:

- Collect and combine large quantities of information from a range of sources;
- Process, analyse, and predict usage of that information;
- Provide targeted decisions, based on those predictions, to communities, fire departments, Commander Rescue Center, as appropriate.

This framework will need to address many technical measurement and standard challenges, technical and implementation barriers, and environmental hazards on the disaster area.

The solutions will facilitate a paradigm shift from tradition-based First Responder protection to what is referred to here as 'smart First Responder'. That shift will involve many changes and will enable the shift of first response operations from the current state of information-limited decision making to a sensor-rich environment with present data collection, analysis, and communication, ultimately leading to data-driven and physics-based decision making (see Table 1-1).

Table 1-1 Change from the current state to the future state

Current State	Future State
Tradition-based tactics	Data-driven science-based tactics
Local information	Global information
Data-poor decision making	Information-rich decision making
Limited awareness	Situational awareness
Untapped or unavailable data	Comprehensive data collection, analysis, and communication
Isolated equipment and building elements	Interconnected equipment and building monitoring, data, and control
Human operations	Human controlled, collaborative, and automated operations with inanimate objects (buildings, machines, etc.)

Acquiring actionable information is critical for effective First Responder operations. The value of the information depends on its accuracy, completeness, and accessibility. While each information repository might have its own semantics, structure, and format, there need to be common protocols for information exchange if the data are to be shared and fully exploited.

1.4 Structure of the Document

The structure of this document is as follows:

- Section 2 describes in detail the methodology followed for carrying out task T1.1.
- Section 3 constitutes the core of the deliverable, presenting the technologies identified and analysed. Existing technologies presented, cover search and localisation techniques, release techniques, emergency response health condition monitoring devices, hazmat techniques,

rescue robots and autonomous vehicles, communication techniques, exhaust techniques, rescuers safety and water and food aspects, wearable monitoring systems, shelters, structures specialists equipment, wearable GPS trackers and COVID-19 aspects, and are analysed as per their strengths and weaknesses and strengths, whereas they are benchmarked against commercial products. Additional technologies identified and examined touch upon the use of CBRN sensors, respiratory protection, body protection, protective footwear, casualty protection, quality assurance, workplace safety, communication requirements, biological agents disinfection principles and practices, unmanned aerial vehicles and the use of biosensors for detecting acute stress of first responders.

- Section 4 then focuses on the identification of limitations and gaps in the current state of the art and determines future needs, while also benchmarking available commercial products and providing relevant suggestions.
- Section 5 summarises the conclusions drawn through the work carried out.
- Annex I cites the relevant bibliography and references.
- Annex II provides a record of the products examined and their evaluators, whereas
- Annexes IV to XII provide a more thorough description of the available tools and technologies and their benchmarking.

2 Methodological approach and SAR technologies

2.1 Methodology

The aim of this section is to outline and describe the methodological approach followed in SnR project for performing the State-of-the art review on existing SAR technologies for the location of entrapped victims and for meeting the objectives outlined in Section 1.3. In relation to these and according to the scoping activities one should keep in mind the following:

- SnR is an ambitious project. Although it is primarily focused in the SAR technologies proposed to be developed by the relevant partners and presented herein in Table 2-1, collection of information on other relevant SAR technologies will be performed when possible by various end-users.
- As mentioned in Section 1.3, SnR project's main objectives are the minimisation of the duration for SAR activities, the limitation of life and property loss, and the minimisation of injury and environmental damage. Within the context of identifying technologies for the quick location and rescue of entrapped victims and in view of meeting the general objectives, participating actors and end-users of these technologies have different needs according to their operational scope and thus experience different relevant gaps and limitations. The methodology needs to account for these different needs in order to ultimately propose and create a common and shared vision of future technology and innovation needs.
- An in-depth analysis is performed for the technologies to be developed within the SnR project, so as to benchmark these against relevant products already available in the market.

Table 2-1 SnR proposed technological equipment, TRL advancement and partner in charge

	Equipment	Present TRL	End TRL	Partners
1	Smart Glasses & AR Helmets	4	6	SIVECO
2	Emergency communication app	5	7	KT
3	Six Gas HAZMAT monitor	5	7	UniCa
4	Advanced Augmented Reality (AR) technologies	3	5	SIVECO
5	Wearable GPS Tracker	4	6	UniCa
6	Wearable ECG, EMG (wearable)	6	7	UniCa
7	Wearable Strain sensors (wearable)	5	7	UniCa
8	Emergency response health condition monitoring device	4	6	CERTH/HIT
9	Radiation sensors (wearable)	5	7	UniCa
10	Rescue drones	9	9	UHasselt

	Equipment	Present TRL	End TRL	Partners
11	AI services on top of rescue drones	6	7	AIDEAS
12	Rescue Robots & Autonomous vehicles	6	7	DFKI, THALIT
13	Chemical sensors	4	6	NTUA
14	CONCORDE EMS & Associated module / services	5	6	KT
15	Decision Support System (DSS)	4	6	KT, CNR, NTUA
16	Training through AR/VR	5	6	KT, SIVECO
17	Smart textile professional uniform	4	6	UNIFI
18	Rescue system for children	4	6	UNIFI
19	3D Mixed Reality Command Centre	3	6	CERTH/HIT

The Methodology (see Figure 2-1) includes five major (5) steps that are briefly outlined below:

1. Scoping of works.
2. Identification and clustering of end-users and key stakeholders.
3. Listing of existing SAR Technologies.
4. Identification of technological limitations, needs and gaps and SWOT analysis.
5. Creation of common vision for future technological needs.

The Methodology provides an approximate timeline for these steps in three (3) major phases:

- Phase A (M1-M4) runs until the submission of the current deliverable (D1.1) and includes steps 1-3 and part of step 4.
- Phase B (M5-M12) follows Phase A and runs from the submission of the current deliverable (D1.1) until the design and the preparation of the proposed Pilots and Use Cases (T8.1; D8.1 – D8.5 in M12).
- Phase C (M13-16) follows Phase B and runs until the submission of the second deliverable related to T1.1, namely D1.5 due by M16.

In the following sub-sections, each of these major steps are analysed in detail. It is to be noted that steps and sub-steps that are to be completed within the time fame of the current deliverable (D1.1) are analysed in more detail than those that are to be completed during the time frame following the submission of D1.1. The latter steps are conceptualised and described herein, however, additional details relevant to their application may be included in the second version of this deliverable (i.e. D1.5 due by M16).

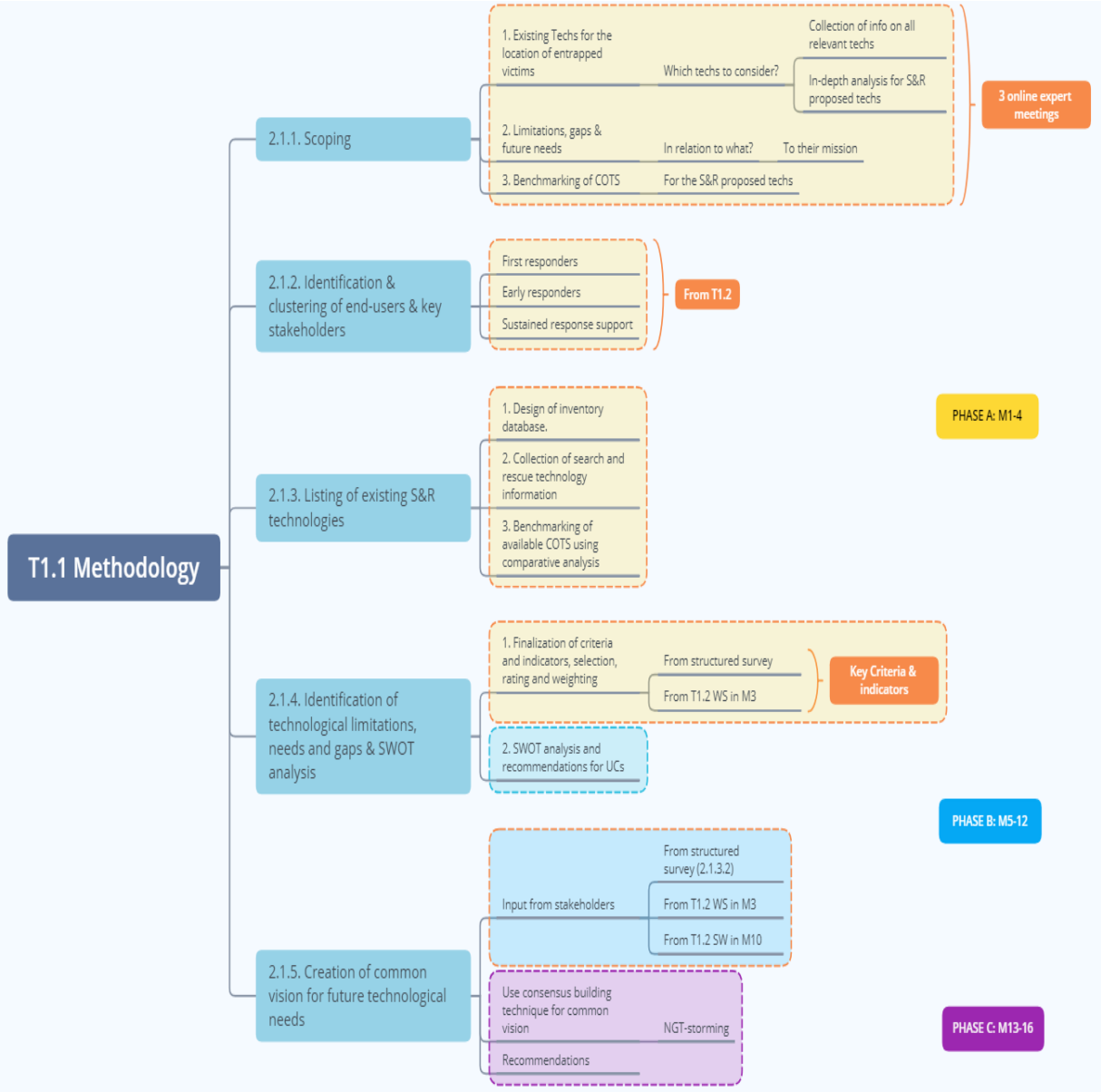

Figure 2-1 Methodology Outline

2.2 Scoping

Scoping is an important step of the methodological approach in order to set up the relevant context and obtain common understanding of the related activities from all T1.1 participating partners. Part of the scoping is to also establish and clarify the interrelations among Tasks that are running concurrently and which may provide relevant input to T1.1. The Description of Action (DoA) and the Grant Agreement (GA) were the two reference documents used for ensuring that scoping remains within the agreed contractual framework. Scoping activities were mainly based in three (3) expert group online meetings with the participation of T1.1 partners that contributed to the following refinements:

- The SnR project Kick-off meeting (KoM – July 21-22, 2020): during the KoM the vision for T1.1 was provided by the Task Leader (PROECO) and relevant attributes of the proposed methodology were presented. This was also done for all WP1 tasks and helped in identifying possible overlaps and issues that needed further clarification.
- T1.3 1st Online meeting (August 3, 2020): during this meeting, potential overlaps between T1.1, T1.2 and T1.3 were discussed along with preliminary draft Table of Contents (ToC) for the related deliverables. Following this meeting refined versions of D1.1 and D1.2 ToCs were sent to T1.3 partners along with assigned sections for each deliverable. A draft methodology outline was prepared and proposed to WP1 partners.
- T1.1 Online meeting (August 24, 2020): during this meeting, the proposed methodology was reviewed, refined and finalised based on additional clarifications provided by the Task and WP Leader (PROECO) and on reported work progress.

The aforementioned meetings are all documented by relevant Minutes that summarise the major points that were discussed and agreed. All participating partners reviewed these and their final version was uploaded in the Alfresco workspace. E-mail communication also supported minor refinements and clarifications. The major issues agreed and clarified during these meetings are reported at the beginning of Section 2.1 above.

2.3 Identification and clustering of end-users and key stakeholders

As this report concerns emerging technologies for the early location of entrapped victims under collapsed structures & advanced wearables for risk assessment and first responders safety in SAR operations, the relevant end-users and key stakeholders pertain to what has been characterised by (Rasanen et al., 2020[1]) as the "*Community of practice and interest*" which constitutes of networks of specialised and/or professional actors whose role is more prominent in the preparedness and response phases of Crisis Management.

These networks and actors may be further decomposed according to the timing of intervention of the different actors into two or three sub-categories. An example is presented below:

- First responders (e.g. Fire and rescue brigade, Emergency medical services, Civil protection, police-law enforcement personnel, by-stander individuals);
- Early responders (e.g. Emergency Coordination Centres, Infrastructure operators; hospitals, registered national voluntary organisations active in disaster & spontaneous volunteers); and
- Sustained response support (utility companies, primary care organisations, public authorities, UAV/robots/vehicle manufacturers, infrastructure manufacturers, support aid manufacturers).

[1] Räsänen A, Lein H, Bird D, Setten G. Conceptualizing community in disaster risk management. Int J Disaster Risk Reduct. 2020 May 1;45:101485

It is however not in the scope of works of T1.1 to specifically identify the various end-users as this will be done within T1.2. Instead, T1.1 will make use of the end-user clustering identified in T1.2 for the purposes of the analysis of the present deliverable D1.1. Therefore, Table 2-2 below presents the end-users and key stakeholders considered for D1.1. As it may be observed, end-users selected to survey were clustered in five major categories.

Table 2-2 End-users and key stakeholders identified for the SAR technology inquiry

Equipment / Module	Partner(s) providing technology and relevant references
Emergency response health condition monitoring device and information system	CERTH/HIT will develop (see T5.2 in WP5) an easy to place device equipped with sensors that can measure critical vital signs to be used both in first responders and victims. The device will be able to measure heart rate, respiration rate, blood oxygen levels, and body temperature and provide an approximate estimate of the blood pressure. The device will have communication capabilities. The rescuer will be able to read the victims condition on a smartphone or other communication device she/he is equipped with. The device will be based on previous research at CERTH/HIT (ADAS&ME project) and will be verified with medical grade equipment available at CERTH/HIT.
Six Gas HAZMAT monitor	UniCa designed a t-shirt for monitoring ECG and respiration with a small electronic module able to transmit sensor data to a smart phone application. UniCa developed sensors, designed the t-shirt, realised the electronic module and the smart phone application.
GPS Tracker	
ECG, EMG (wearable)	
Professional Uniforms	UNIFI will design and develop an innovative uniform for fire brigades' operators to protect critical parts of the body in case of fire rescue or first aid activities and at the same time monitoring the state of user's health. UNIFI will capitalise on this knowledge to start in the design of the first responder's uniform.
First aid device for kids	UNIFI will design an innovative first aid system for children to be used to carry babies during emergency situations. The rescue device has the characteristic to protect and reassure children involved giving a very first aid situation.

2.4 Listing of existing SAR Technologies

The primary aim of this step is to collect and list the major technologies that are utilised by end-users in SAR operations for the location of entrapped victims so as to create an inventory database of these. An in-depth analysis will follow the identification of these technologies which will focus on the specific technologies/equipment that will be developed within the SnR project as previously outlined in Table 2-1. This step consists of three (3) sub-steps which are detailed below:

1. Design of inventory database
2. Collection of SAR technology information
3. In-depth analysis of proposed SAR technologies

1. Design of inventory database

Although the importance of information gathering in emergency response is apparent, the task of compiling, processing, and integrating the information into actionable knowledge is challenging. Examples of such information include loss records, inspection records, fire-fighting resource information, building information modelling, and building supporting infrastructure. Much of such information is often stored in community resource databases and repositories.

Therefore, in order to facilitate the collection of this information from the relevant end-users, T1.1 partners devised a categorisation by considering the main operationalisation possibilities that the different technologies preliminarily identified through combination of expert input and desk-based search offer.

After the collection of SAR technologies, an analysis of each type of technique (search and localisation, release, hazmat, disinfection (SARS-CoV-2), rescue robots and autonomous vehicles, communication, exhaust and safety for rescuers) will be performed highlighting the strengths and weaknesses for each one.

2. Collection of SAR technology information

A structured survey was the method used to collect information from the end-users relevant to the SAR technologies. The survey aimed at obtaining feedback from organisations involved in first responder's operations and manufacturers who are relevant to the various technologies used in SAR operations for the location of entrapped victims.

The aspects addressed by the structured survey were agreed among T1.1 participating partners and related to the following information pertinent to:

- The type of technique used in SAR operations, the description of their current endowment, their strengths and weaknesses. End-users were allowed to complement the template

provided (i.e. Table 2-1) in case the respective technique was not included, thus offering the possibility to further enrich it.

- The limitations and gaps the end-users experience in relation to their intended mission in SAR operations.
- The end-users future needs in relation to their intended mission in terms of requirements for modern equipment and technologies that reduce the risk of injury or even death of first responders.

The survey was distributed by using both "push" (i.e. by directly sending to the broader network of consortium partners) and "pull" techniques (i.e. by inviting through SnR's project web page concerned end-users to download, fill up and send the completed survey template to the consortium). Various associations of end-users (e.g. volunteers, government entities, manufacturers) from the defined clusters were approached for obtaining relevant information.

In addition to the structured survey, a stakeholder Workshop concerning end-user requirements was organised at the end of M3 **(30 September, 2020)** by consortium partner KT which complemented the collection of relevant SAR technology information, limitation and future needs.

3. In-depth analysis of proposed SAR technologies

In order to facilitate the development and design of the SAR proposed technologies, an in-depth analysis of these was performed, following the preliminary collection of relevant SAR technology information, by benchmarking these against Commercial-off-the-shelf (COTS) available products.

A number of attributes that are relevant to their design and operationalisation will be examined in a comparative evaluation. In order to allow for a quantitative comparison of the different attributes, indicators will be developed (where relevant and if information is publicly available) that will allow to consider the following (indicative list): *Size and weight; Manoeuvrability; Interoperability; All hazards application; Ergonomics; Power supply; User interface; Price; Standard operating time; Size of the area of action; Sensitivity to environmental conditions; Mode of operation*.

2.5 Identification of technological limitations, needs, gaps and SWOT analysis

Processing of the feedback obtained from the survey aimed at the collection of SAR technology information, in conjunction with feedback obtained from the aforementioned stakeholder workshop in M3, compiled in a preliminary list of limitations, gaps and future technological needs.

Considering the heterogeneity and sometimes diverse purpose of the SnR proposed technologies, relevant criteria and indicators, against which the potential of the proposed SnR

technologies/wearables in meeting the user needs and reported limitations should be evaluated, had to be developed. For this, a focus group consisting of five internal consortium experts was formed.

This focus group compiled a list of criteria and indicators by considering desk-based search, expert input, KPIs from the proposed Use Cases and indicators selected for the in-depth analysis that the proposed SnR technologies should attempt to satisfy for meeting the user needs and overcoming the identified limitations.

Next, the process combined the rating and weighting steps of a Multi-Criteria Analysis (MCA[2]) and the Strength-Weakness-Opportunity-Threat (SWOT) analysis for the evaluation of the proposed SnR technologies.

2.6 Finalisation of criteria and indicator selection, rating and weighting

This sub-step was undertaken with the participation of one external expert, in addition to the five consortium experts, who attended the stakeholder workshop organised in M3. The steps followed are summarised below:

a. The identified user needs and limitations were presented during the M3 stakeholder workshop. User needs were assumed to be of equal importance. Additional stakeholder needs were considered based on the brainstorming session that followed.
b. The list of relevant criteria and indicators compiled by the 5-expert focus group was then presented, discussed and refined by workshop participants and external experts.
c. A similar process may be applied for the indicators that are relevant to each criterion in order to define the relative importance of each indicator to the respective criterion.

2.7 SWOT analysis and recommendations for Use Cases

Following the determination of the relative weighting and ranking of the selected criteria, a SWOT analysis will be undertaken for each of the SnR technology/wearable to be developed within the project.

The SWOT analysis will thus be able to consider both the relative importance and preference of the selected criteria and indicators that best address the users' needs in identifying strengths, weaknesses,

[2] Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex problems. In a situation where multiple criteria are involved, confusion can arise if a logical, well-structured decision-making process is not followed. Another difficulty in decision making is that reaching a general consensus in a multidisciplinary team can be very difficult to achieve. By using MCA the members do not have to agree on the relative importance of the criteria or the rankings of the alternatives. Each member enters his or her own judgements, and makes a distinct, identifiable contribution to a jointly reached conclusion. MCA allows including qualitative as well as quantitative criteria with their relative importance and consideration of different stakeholders in the decision process.

opportunities and threats that are relevant to the proposed Use Cases so as to guide their design and provide recommendations. The SWOT analysis will be completed following the submission of present deliverable D1.1 and its results and relevant recommendations will be documented and summarised in D1.5.

2.8 Creation of a common vision for future technological needs

The creation of a common vision for future technological needs mainly requires the following:

- Input from stakeholders in relation to the technological needs they envision as being of priority for supporting their mission. This will allow to preliminarily identify the attributes of the common vision.
- A participatory process leading to the creation and endorsement of a common view.

As far as stakeholder input is concerned, this will be obtained through the following processes:

a. Feedback collected from the structured survey described in Section 2.3. concerning the end-user's future needs.
b. Feedback collected from the aforementioned in Section 2.3. stakeholder workshop organised in M3.
c. Feedback collected from the stakeholder workshop titled "End-users requirement and beyond" to be organised in M10 in T1.2.

Following the collection of input from the stakeholders, an initial list compiling future technological needs will be created and reported in D1.5. For the creation and endorsement of a common vision, a modified version of the known process for group decision making, the Nominal Group Technique (NGT[3]), which also allows for brainstorming activity (i.e. NGT-storming), will be used. The major steps of the NGT-storming technique are briefly summarised below:

a. A focus group with different stakeholder representatives will be formed.
b. A list of future technological needs and relevant questions will be created by each participant either prior or during the participant's meeting. The initial compilation list of technological needs will also be considered during this step.
c. A group brainstorming session will initiate where people may contribute ideas and entries from their list.
d. At the end of the brainstorming session, people will be still able to supply ideas from their list that have not yet come up to the discussion.
e. A discussion of all listed ideas will follow.
f. Participants will be given some time to consider the different ideas.

[3]Delbecq A. L., VandeVen A. H., and Gustafson D. H., (1975). "Group techniques for program planning: a guide to nominal group and Delphi processes", Glenview, Illinois: Scott Foresman and Company.

g. Participants will individually rank their top ideas.

This process has the advantage to encourage participation, spontaneity and idea generation from all participants, even from those that are less vocal by limiting conflict and ensuring equal participation. However, although it certainly assists in forming a common vision through the voting process, it is not guaranteed that the process will necessarily converge. In case this happens, it will nevertheless allow for the possibility to provide the leading opinions while also indicating the major objections/doubts by respective stakeholders.

The resulting common vision with relevant recommendations will be documented and summarised in D1.5.

3 Existing SAR technology

This Section constitutes the core of the deliverable, presenting the technologies identified and analysed. Existing technologies presented, cover search and localisation techniques, release techniques, emergency response health condition monitoring devices, hazmat techniques, rescue robots and autonomous vehicles, communication techniques, exhaust techniques, rescuers safety and water and food aspects, wearable monitoring systems, shelters, structures specialists equipment, wearable GPS trackers and COVID-19 aspects, and are analysed as per their strengths and weaknesses and strengths, whereas they are benchmarked against commercial products. A more detailed analysis of the existing tools and technologies is included in Annexes III to XII. Additional technologies identified and examined touch upon the use of CBRN sensors, respiratory protection, body protection, protective footwear, casualty protection, quality assurance, workplace safety, communication requirements, biological agents disinfection principles and practices, unmanned aerial vehicles and the use of biosensors for detecting acute stress of first responders.

3.1 Inventory database

Equipment and consumables are routinely evaluated for inclusion or disposal in SAR equipment. Comparative evaluation of commercially available products has been conducted via a quantitative analysis by using indicators such as:

- Description of the technique from the current endowment
- Strengths of the technique
  - Size and Weight,
  - Manoeuvrability,
  - Interoperability,
  - All hazards application,
  - characteristics such as ergonomics, power supply, user interface, price, standard operating time, size of the area of action, sensitivity to environmental conditions, mode of operation, etc.
- Weaknesses of the technique
  - Size and Weight,
  - Manoeuvrability,
  - Interoperability,
  - All hazards application,
  - in terms of ergonomic, power supply, user interface characteristics, price, standard operating time, size of the area of action, sensitivity to environmental conditions, mode of operation, etc.
- Benchmarking of available commercial products

4. Search and localisation technique/tools

3.1.1.1 Acoustic Localisation Technique/Tools

Table 3-1 Acoustic Localisation Technique/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Device for detecting sounds emitted by a victim by means of 3 or 4 wireless sensors and placed on the ground, search by a triangulation method, reading the detection result on a tablet and in a headphone, right and left reading potentiometer with intensity adjustment, and use of 2 filters for parasitic noise.	• Wireless devices • Light • Weight • Identical reading tablet for several devices • Tool combined with a camera and sound sensors.	• Battery life • High battery • Consumption	Similar products exist but are wired and have no combined tools (camera / sensors).
B	Audio/sound device for the detection of humans through microphone and measuring technique with visual presentation of the results	• Easily available (standard equipment) • Localised detection possible • Continuous use possible	• Relatively slow technique • Weight load of FR on debris cone and potential victim • High risk for rescuers in areas at risk of collapse; noise-sensitive technique that requires relatively quiet surrounding.	Similar products exist but are wired and have no combined tools (camera / sensors).
C	The LEADER Scan sensors have Ultra-Wide Band (UWB) technology allowing the scanning of the rubble surface in order to search for movements of conscious or unconscious victims up to 30m in free field. LEADER Scan detects even the smallest movements (respiratory or gestural movements) and displays their frequency to deduce whether it is a human life or not. The Scan operates under the following two modes: AUTOMATIC search mode (automatically scans multiple areas to detect up to 7 living people); MANUAL search mode (selection of the search area manually and the minimum & maximum depth).	• Easy to use lightweight, • Carrying bag, • Screen visibility, • Wireless tablet reading • Control of the sensor from the box • Display of the movement detected at the depth detected • Real-time and Automatic modes • Selection of the depth • Strong or weak movement indicator • Oscillogram for the details of the movements	• Functioning of the WIFI signal, • Random results with false positives • Influence of movements of moving materials (i.e. wind) • Risk of detection of other stakeholders • WIFI signal quality.	-

		• Data recording • Record replay • Right and left hand mode • Brightness adjustment • Charge level.		
D	The AQUAPHON® system was developed for pipeline leakage search and supports and simplifies the detection process thanks to the outstanding quality of its microphone and measuring technology, intelligent analysis functions and the practical, visual representation of results on the display. This cutting-edge system offers comfortable, wireless handling, ease of use, versatility and a sturdy, ergonomic design. The AQUAPHON® system is ideal for both the pre-location and pinpointing of acoustic noise for confident excavation.	• High protection class (IP67) • Ear protection function • Filter optimisation • Carrying strap or belt clipping • Powerful rechargeable battery • Different microphones for paved and unpaved ground • Wireless headphones • Noise visualisation • Memory function	• not specifically developed for SAR operations, ear protection function settings required for optimal use, battery for microphone needed, 1m recommended measurement distance.	-

3.1.1.2 Optical Localisation Techniques/Tools

Table 3-2 Optical Localisation Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Search Cam: rotatable camera that can be entered into debris cones for a visual and audio connection.	• Easily available (standard equipment) • Fast set up • Localised detection possible • Continuous use possible	• Weight load of FR on debris cone and potential victim • High risk for rescuers in areas at risk of collapse • Not applicable in dusty/muddy environments.	-
B	Search camera on a telescopic pole, 360° camera rotation, reading tablet with colour screen, possibility of recording the image and interacting with the victim, LED lighting on the camera head, positioning system of the camera in space and direction of rotation of the camera	• Weight of the device • Reading tablet common to several devices	• Picture quality	Existence of infrared camera, thermal, which is placed on the telescopic pole.
C	The SearchCam® 3000 VLS is modular and can be configured to meet the needs of any	• Excellent video quality and clarity	• Heavy • Expensive	-

	rescue situation. The 240-degree articulating camera with built in audio provides rescuers with the enhanced ability to see and communicate with trapped victims. The Camera Head with the Environmental Sleeve installed, can be submersed in water up to 75 feet (23 meters) deep. It records videos and takes photos which are saved to an SDHC card (included). These files can be uploaded to a computer for playback, archive and search review purposes. If an attempt for taking video or picture is made when the memory card is not present or if the memory card is full, "No Memory Card" icon will appear in the centre of the screen. A microphone in the camera head allows a two-way communication with the entrapped victim.	• Versatile options: submersible, boom extension, rope drop head • Wide field of view • Piston grip provides convenient access to control buttons • Two-way communication • Quality headset • Carrying case: wheels, well-organised, • Location of battery indicator.	• Reboot required for whole system when articulating head would „freeze up" • Reboot required before use of audio system • Reboot required if contrast and brightness controls are engaged in the wrong sequence • Lengthy boot and shutdown time • Multiple power buttons • Inadequate spacing between controls and adjustment knob when using pistol grip with a gloved hand • Poorly designed monitor mount/display yoke • Obstruction of articulation button • Cables not long enough for the pole when extended • Carrying strap: not heavy-duty, not padded, too narrow, did not balance camera well, • Powered by lithium ion batteries only (no AC or DC power source capabilities).	

3.1.1.3 Thermal Localisation Technique/Tools

Table 3-3 Thermal Localisation Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Thermal camera - uses a process for making infrared radiation visible and thus living people	• Easy to use, can be used regardless of the lighting conditions or air quality (dust, smoke) • Shows body temperature • Measurement takes place without contact, even over a greater distance.	• Weight load of FR on debris cone and potential victim • Cannot be used to see through walls or debris (only measures surface temperature of objects) • Dependent on detection range • Expensive if good resolution	-
B	Hand-held thermal imager, generally used for finding hot spots in fires	• Lightness • Autonomy • Detection • Possibility to save images	• Contrast quality when used at high outside temperature	Many similar products, small or large, possibility to have a portative thermal camera
C	C) The BioRadar BR 402 is a high-tech equipment to detect and evaluate movements of creatures, in first order persons. The BioRadar can detect through all dielectrically materials, such as normal brick - or concrete construction, layers from sand debris, soil, snow up to a thickness of several meters. Parts of metal (steel in concrete) may cause a loss of sensitivity of the BioRadar. The equipment transmits radar waves, which are reflected by all things in front of it, received back and evaluated by the BioRadar. By this way all body moves, also breathing and heartbeat can be detected and evaluated. By help of analysis of the received signals it is possible to prove with high probability the presence of living people in front of antenna. Used by this equipment amount of radiation is fully harmless for all living	• Excellent video quality and clarity • Versatile options: submersible, boom extension, rope drop head • Wide field of view • Piston grip provides convenient access to control buttons • Two-way communication • Quality headset • Carrying case: wheels, well-organised, • Location of battery indicator.	• Heavy • Expensive • Reboot required for whole system when articulating head would „freeze up" • Reboot required before use of audio system • Reboot required if contrast and brightness controls are engaged in the wrong sequence • Lengthy boot and shutdown time • Multiple power buttons • Inadequate spacing	-

	creatures because of its low power. The only but necessary requirement for normal function of the system is good penetration performance for used radio waves through the material between antenna and person who is to be located.		between controls and adjustment knob when using pistol grip with a gloved hand • Poorly designed monitor mount/display yoke • Obstruction of articulation button • Cables not long enough for the pole when extended • Carrying strap: not heavy-duty, not padded, too narrow, did not balance camera well, • Powered by lithium ion batteries only (no AC or DC power source capabilities).	

3.1.1.4 Miscellaneous Localisation Techniques/Tools

Table 3-4 Miscellaneous Localisation Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	RES-Q-Cell mobile phone radio location – using signals from self-generated mobile network to activate and locate smartphones.	• High accuracy • Suitable for large-impact scenarios.	• Phones do not necessarily correspond to persons	-
B	Canine search equipment First aid case for dogs	-	-	Cameras installed on the dog exist on the market as well as GPS trackers to locate the dog, military special forces also use implants in the ears of dogs to guide their dog from a distance.

3.1.1.5 Drones (UAS)

Table 3-5 Drones (UAS)

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	DroneMatrix - Yacob, a (semi-)autonomous battery-powered drone that is launched from a docking station.	• Can be manoeuvred over a large area. • Automated functions.	• Susceptible to weather conditions, specifically heavy winds, rain, extreme temperature	There are many manufacturers. Local producer DroneMatrix offers professional-trade equipment at a lower cost than competitors. Various extra sensors in addition to traditional or IR cameras can be attached. The manufacturer is working on a laser that can be used to guide people at ground level from the drone.
B	DroneMatrix - Tythus, a tethered drone (a drone and docking station connected via a cable and pulley system, providing power and data-exchange).	• Nearly limitless flight time • Easy in operation	• Susceptible to weather conditions, specifically heavy winds, rain, extreme temperature • Limited in range due to the cable	There are many manufacturers. Local producer DroneMatrix offers professional-trade equipment at a lower cost than competitors. Various extra sensors in addition to traditional or IR cameras can be attached. The manufacturer is working on a laser that can be used to guide people at ground level from the drone.

5. People Release Technique/Tools

Table 3-6 Release Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Pneumatic powered tools: air lifting bags, different capacities, 24, 20 and 30 tons, powered by a portable compressor.	• Light cushions • Abrasion resistant • Different sizes, safety system to unplug a cushion	• Heavy weight • Risk of leakage	-
B	Hydraulic powered tools	• Efficiency	• Heavy weight • Risk of leakage • Requires a heat engine	-
C	Gasoline power tools	• Efficiency	• Emission of exhaust gases	-

			during operation • Risk of gas CO	
D	Electrical power tools: double disc concrete cutting tool, powered by 220 volts, screwdriver, saber saw, circular saw, core drill, electric concrete breaker, battery-powered perforator, electric fan.	• No gas emitted • Reinforced concrete cutting capacity up to 400mm	• Requires training and observance of safety measures • The drive must be cooled • Diamond discs have a high cost.	-

6. Emergency Response Health Condition Monitoring Devices

Table 3-7 Emergency Response Health Condition Monitoring Devices

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Drones MAVIC, and DJI ENTERPRISE	• Aerial view for safety and structural assessment	• Needs mapping software • Autonomy	-
B	Life Sense Radar/Rescue Radar/Ultra-wide band radar: flat, rectangular antenna and laptop applying radar technology measurement also used for the measurement of speed of vehicles; the radar can pick up on movements e.g. of the chest while breathing or the beating heart (reflected in the change of the frequency)	• Small mobile equipment which can be utilised quickly • Precision makes distinction e.g. between humans and animals possible • Can approximate the distance to survivor	• Limited range of 5-10m deep • Certain materials or surfaces hinder application completely (metal plates, closed water surfaces etc.) • Susceptible to noise interference from cell towers/radio communication systems	-
C	Defibrillation unit (e.g. LP 12)	• Health monitoring • Cardiac diagnosis	• Requires access to the patient (to connect device)	-
D	PIEPS System (for avalanche rescue)	• GPS tracking possible • Simple to use	• Can only report on victims that prepared for a potential incidence (carrying the device)	-

E	Active transmission equipment consisting of a transmitter, which is connected to a data processor which collects and handles data observed by sensors on the subject (e.g. WiCis Health I-Streme unit)	• Can transmit health, location and communication data over different satellite networks.	• Can only report on victims for whom an incident is impending (e.g. for mountaineers).	-

7. Hazmat Technique/Tools

Table 3-8 Hazmat Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Detection equipment Wireless, portable multi-threat monitor for radiation and chemical detection – multiRAE device monitors both chemical threats and gamma radiation. With the ability to wirelessly transmit threat and alarm data in real time to a central command station, the MultiRAE Pro offers improved visibility and awareness. It also gives the flexibility to swap out 25 different sensors for a range of threats, including VOCs, toxic gases, combustibles, oxygen levels, as well as gamma radiation detection. The MultiRAE Series of handheld gas detectors includes three models for detection of up to six threats simultaneously. One can choose from 25 toxic sensors, 3 PID sensors with a 9.8 eV lamp option, and even a gamma radiation sensor.	• Parts per billion VOC measurement • Industry-leading wireless multi-threat device • Simultaneous monitoring of chemical threats and gamma radiation • Real-time data access from central command • More than 25 different chemical sensors • Swappable sensors, man down alarm, • Simple maintenance with replaceable sensors • Pump, and battery • 5-way local and remote wireless alarm.	• The device cannot be used for CWA detection and identification • As the electrochemical sensors do not have the required sensitivity. • Use in environments with a lot of dust or high concentrations of toxic gases can lead to failure of the suction pump and poisoning of the sensors.	MultiRAE produced by RAE System (Honeywell) and similar systems from other manufacturers (Drager, Gastech, Crowcon, GfG, Scott / 3M, Viasensor).
B	Radiation equipment Dose rate Alpha and Beta, X-rays (RADEYE)	-	-	-
C	Miscellaneous - hazmat support Mass Spectrometry is an instrumental method for chemical analysis used for measuring masses of atoms and molecules in gaseous, liquid or solid state. Membrane Inlet Mass Spectrometry (MIMIS) works by creating ions from neutral	• High sensitivity (low ppt) • Fast and accurate analysis • Minimising the false alarms • No sample preparation requirements • Can be used for both simple and	• Using selective masses for monitoring permanent gases might not be distinctive for some of them, e.g. mass 28 can be attributed to	Electronic Noses (EN), Ion Mobility Spectrometry (IMS), Laser-based technologies, Gas Chromatography (GC), Spectroscopy techniques (IR, Raman, etc.), Gas, Chemical, Optical etc. Sensors, Cavity Ring-Down spectroscopy

	atoms and molecules and separating them according to their mass-to-charge ratios.	multicomponent mixtures simultaneously. • Comparatively lower size • Low weight • Low cost • Capable of air and aqueous analysis (detection and monitoring) of Volatile Organic Compounds (VOCs), SemiVolatile Organic Compounds (SVOCs) and a number of permanent gases, such as ammonia (NH3), H2S etc.	both CO and N2	(CRDS), Laser-induced breakdown spectroscopy (LIBS)
D	Chemical sensors ChemPro100i: The equipment allows the detection, classification and quantification of gaseous CWA and TIC in the atmosphere. With additional modules, it allows the measurement of doses and dose rates of X and gamma radiation, as well as biological contamination with BWA. Chemical detection is based on an orthogonal system of sensors composed of open IMS cell and electrochemical sensors.	• Low weight, short response time • Low detection limit for neurotoxic compounds • Easy to use, • The presence of electrochemical sensors for some TIC	• The device cannot identify CWA, it only performs classification and quantification. • The open IMS cell can give errors in case of high ambient humidity. • Use in dusty environments may damage the suction pump.	ChemPro100i produced by Environics and ChemRAE produced by RAE System. ChemRAE can integrate wirelessly through network systems provided by RAE. B) Portable explosimeter for CO and H2S, detection devices
E	Personal First Responders protective equipment Helmet, glasses, ear protection, gloves, rangers with reinforced hull, uniform for rescue operation, Chemical kit, Nitrile gloves, personal protection TYCHEM, PPE, masks with filters, protective goggles, FFP2 masks	-	-	
F	Decontamination technique COVID disinfection inflatable structure with fogger	-	-	

8. Rescue Robots & Autonomous Vehicles

Table 3-9 Rescue Robots & Autonomous Vehicles

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	A) DFKI – Coyote III: The DFKI intends to use Coyote III as robot platform carrier for the MIMS sensor. Coyote III is compact, lightweight, agile, and can hold the required payload for the developed mass spectrometer. It can climb stairs and rocks and pass difficult destroyed terrain, as its legged wheels have been designed for extra-terrestrial exploration missions. Also, it has already been used in similar SAR applications with a mounted gas sensor, hence it suits the use-case ideally. In contrast to competitor robot platforms, which use either regular wheels or tracks, it allows a stable and quick motion on all types of terrain without causing any unnecessary damage. The platform features various sensors for visual perception like a laser range finder and a high accuracy camera and inertial measurement unit.	• Robust • Lightweight frame • High mobility on difficult terrain • Can climb stairs and rocks • Modular mount for sensors and manipulator • May be remote controlled • Possible cooperation with other robots.	• Legged wheels may become fragile on high loads • Limited power capacity • No long-term operation.	-

9. Communications Technique/Tools

Table 3-10 Communication Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Portable – 1.5 miles: Motorola MTP3550 portable radio with colour display and full keypad delivers high performance and dependability required for enhanced workforce productivity and assured user safety. The MTP3550 delivers key features for public safety users including End-to-End Encryption, Man Down Sensor and Vibrate Alert. Embedded secure Bluetooth enables connectivity with accessories and collaborative devices. This TETRA radio is optimised for excellent audio performance	• Exceeds all 11 categories in the MIL-810 standard • Passed an Accelerated Life Test simulating over 5 years use • Connection to all first responder organisations in Austria, cellular phone style • Many accessories like remote speaker, IP65, IP66 und	• Selection of key necessary to speak • Difficult operation with gloves without remote speaker • Intercom (only one can speak while all can hear) • Limited indoor use • Isolation in direct mode.	-

	and durability for use in all types of noisy and demanding situations. Features a Class 3L power output option, which increases range and in-building performance. Coupled with high receive sensitivity, the MTP3550 has the capability for maintaining communications in the most demanding situations.	IP67, direct mode • Emergency key.		
B	Portable – 1.5 miles: Voice only, portable radio in UHF/VHF with holsters	• Waterproof IP stations • Small footprint • Light • Easy to use	• For digital radios, the signal can be on or off • Limited scope and obligation to have a relay to improve the scope	
C	Mobile – 3 miles Mobile in the command post in UHF/VHF	•	• For digital radios, the signal can be on or off • Limited scope and obligation to have a relay to improve the scope	
D	World-Wide (Satellite Phone) Explorer 700 satellite for voice and data for the command post, Wi-Fi, and Isat phone for the team on the ground	•	•	
E	Cellular Data Modem Wi-Fi router: mobile system which can convert 4G signal to Wi-Fi	• Mobile system which can convert 4G signal to Wi-Fi	• System that depends on the local 4G network which is sometimes destroyed and therefore unusable.	

10. Exhaust Technique/Tools

Table 3-11 Exhaust Techniques/Tools

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	The emergency rescue set consists of a carrying cloth, a rescue sheet with looped/preassembled tape sling and a carrying bag. (Material: PES, PA) These emergency rescue devices are set up very easily and therefore very quickly ready for use. They are designed for use in extreme situations,	• Light weight • Easy to use also in narrow places • 10 years' service life	• Roping only possible in sitting position • No stabilisation of the victim • User training required, if often used only 1 to 2	-

	when other rescue devices (rescue tubs) ambulance hammocks, rescue harnesses, rescue bags and similar cannot be used or are not available due to local conditions (in narrow shafts) or for reasons of time (acute emergency situation). The rescue sheet is suitable for the transport of sitting or lying people, but it must not be used for rappelling up or down. The rescue cloth is used to rope people up and down. It has the shape of a triangle and is made of a synthetic material. An extension strap sling is required to adapt it to the body size.		years' service life.	

11. Rescuer Safety Equipment

Table 3-12 Rescuer Safety Equipment

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Smart textile professional uniform Dräger: This suit is a combination of Nomex and Viscose. The Nomex thread of this special weave method with the 2,5% Kevlar makes the liner strong. The fire-retardant Viscose thread provides comfort and transports moisture to the outside of the liner. The multi-layer configuration ensures that each layer accomplishes its part of the job. The protective value of the "ESS® 5-layer system" in combination with the fabric composite is found in the air between the firefighter and the heat source. The used layer system creates a lightweight, durable and highly comfortable garment without compromises to the suit's protective features.	• Protection from fire and heat • Lightweight garment	• No attention is paid to the morphological aspect of the product • No technological elements were included in order to monitor the health of the first responder or increase the performance of the product	-
B	Portable CO2 Sensor	• Simple handling • Light-weight • No maintenance required	• Runtime limited to 2 years • Very sensitive to disinfectant	-

C	Personal Alert Safety System (PASS)- a motion sensor device carried by FR (fire fighter), sounding an alert to notify others about FR in distress	• Easy recognisable alarm to alert others for required support	• Late notification of a FR in distress (FR needs to be passed out/immobile for device to react)	-
D	Uniform (based on national guidelines e.g. ÖBFV KS-03 /07 RL and EN 469) consisting of long trousers and jacket optional: safety trousers, safety jacket	• Protection against dangers when used in public traffic areas • Protection against mechanical effects • Protection against climatic influences • Protection against infection • Visibility during operations, resistant	• Should only be washed in ambulance stations/ fire stations • Potential health problems due to high temperatures in summer • Expensive due to limited market	-
E	Helmet (based on EN 397 or EN 443)	• Optimal fit for all carrier profiles • Easy-care and wearer-friendly upholstery • Built-in lighting or lamp holder • Adjustable eye protection • Thermal and mechanical protection • Even in extreme heat • Optional: integrated headset	• Limited view • Expensive due to limited market	-
F	Protective gloves (based on EN 659) and/or Liquid-tight disposable gloves (based on EN 455)	• Protection against penetration • Heat and cold insulation • Breathable, waterproof • Protection against viruses, bacteria and body fluids, cut resistance • Abrasion and tear resistance • Finger joint and knuckle protection	• Poorer manual dexterity • Sweating during high temperatures • Expensive due to limited market	

		• Resistant to chemicals		
G	Combat boots (based on national guidelines e.g. ÖBFV ÖBFV KS-06 and EN 345 or EN 1789 or EN 15090)	• Protection against penetration and toe protection • Antistatic • Heat and cold insulation • Ankle protection • Slip resistance • Breathable • Waterproof • Protection against viruses bacteria and body fluids • Resistant to various chemicals	• Heavy • Less flexible • Expensive due to limited mar	

3.1.1.6 Smart Glasses & AR Helmets

Table 3-13 Smart Glasses & AR Helmets

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Smart glasses and AR helmets (HoloLens 2): Microsoft HoloLens 2 is a pair of mixed reality smart glasses developed and manufactured by Microsoft.	• Impressiveness • Ergonomics and business friendliness. • HoloLens 2 has a diagonal field of view of 52 degrees • Improving over the 34 degree field of view (FOV) of the first edition of HoloLens, while keeping a resolution of 47 pixels per degree • Holographic Processing Unit (HPU) 2.0 improvements compared to the HPU 1.0., 1.7x compute, 2x effective DRAM bandwidth • Improved hologram stability • New hardware accelerated	-	-

		workloads such as eye tracking, fully articulated hand tracking, semantic labelling, spatial audio and JBL filter		
B	Smart glasses and AR helmets (Oculus Quest)	• It can be used wirelessly as a standalone device with its own integrated hardware (based on the Qualcomm Snapdragon 835 system-on-chip, running games and software from the Oculus store using an Android-based operating system. It also utilises Oculus Touch controllers, which are tracked via an array of cameras embedded in the front of the headset. The cameras are also used as part of the safety feature "Passthrough", which shows a view from the cameras when the user exits their designated boundary area. A later software update added "Oculus Link", a feature that allows the Quest to be connected to a computer via USB,		-

12. Water and food

Table 3-14 Water and food

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Water purification system (portable, membrane filtration)	• Water purification process does not require chemicals or power • Quick deployment • Easy to use • Low resource requirements • Longevity (built to last 10+ years in operation)	• Requires some (but limited) knowledge for proper maintenance	-
B	Field kitchen	• Large capacities to feed team	• High logistical effort	-

13. Wearable monitoring systems

Table 3-15 Wearable Monitoring Systems

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Body/Health Monitor (smart wearables)– to measure vitals of FR (heart and respiration rate monitor via smartwatches, shorts, head mounts	• Effective in reducing on-duty fatalities (avoiding too high levels of stress and over-exertion) • Can support long-term health strategies for FR	• Inadequate measurements due to sensors not staying in place	-

14. Shelter

Table 3-16 Shelter

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	16m² inflatable tents and quick set up tent: logistics, command post, medical, food, shower, toilets, K9 and decontamination/Covid	• For inflatable structures • Rapid assembly • Low weight • Reduced volume of the dismantled tent for quick set up tents • Resistance of the tent to wind • Speed of installation	• For inflatable tents • Weakness in windy conditions • Fragility of the structure in the event of a breakthrough for fast-erecting tents, • Heavy weight • Risk of perforation of the structure	-

			with the frame and the feet of the structure	

15. Structures specialist equipment

Table 3-17 Structures specialist equipment

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	A) Tablet PC for structure assessment, laser telemeter with alarm	• Dematerialised document making it possible to assess the structure of a building and send it directly to the command post	-	-

16. Wearable GPS Tracker

Table 3-18 Wearable GPS Tracker

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	GPS tracker with direct contact with rescue team and recording of position and routes	• Possibility of directly alerting the emergency services in case of emergency, tracking of routes • Location on map connected to a smartphone	-	-

17. COVID-19 Prevention Techniques

Table 3-19 Covid-19 Prevention Techniques

	Description	Strengths	Weaknesses	Benchmarking of available commercial products
A	Personal First Responder protective equipment Standard equipment includes uniform, boots, optional helmet, disposable gloves, plus continuous wearing of face masks	• Already available and known use, face masks are cheap and easy to store or carry	• Breathing more difficult • Increase in sweating under the face mask • Direct protection only with FFP2 or FFP3 masks • Disposable material	-
B	Decontamination technique: Standard disinfection of equipment and hands	• Already available and known use	• Larger quantities necessary	

			• Sensitivity of equipment towards disinfectant	

3.2 CBRN Sensors – Key Technology for an Effective CBRN Countermeasure Strategy

The potential use of weapons of mass destruction (WMD), such as chemical, biological, radiological, and nuclear (CBRN) weapons and also anthropogenic accidents and natural hazards, is one of the most frightening present and future scenarios. Therefore, it is necessary to find an overall strategy for effective countermeasures.

Developments in recent decades have clearly shown that the immediate and reliable detection, identification, and monitoring of CBRN substances and its effects are increasingly a key technology in an international concept for CBRN risk management.

State of the art technology should provide a reliable detection and identification capability that covers a wide range of different CBRN targets in multiple environmental matrices by deploying a field compatible system. Therefore, one of the most significant challenges for the future is to get micro-based detection systems into service as well as to implement an international standard for quality risk CBRN management.

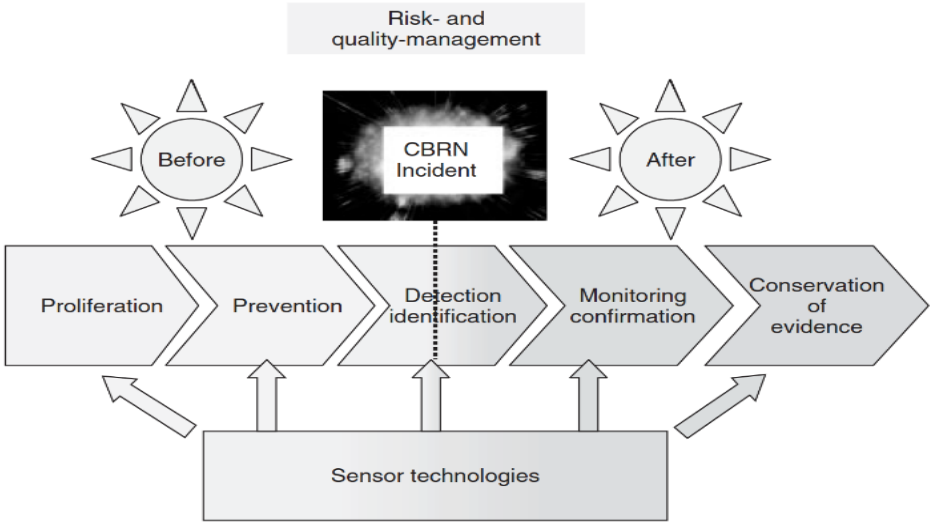

Figure 3-1 Sensor technologies as the key technology in the prevention, the case, and the aftermath of a CBRN incident

During a CBRN incident detectors are needed to identify the precise nature and extent of the CBRN agent. After, the CBRN incident detectors are essential for three main tasks:

1) To confirm the results of early identification,

2) To collect evidence for the use of international banned substances (forensic aspects),

3) To confirm that the area is safe for reoccupation after decontamination.

Based on this variety of requirements for detector technologies, we should have in mind that the perfect detector does not exist and no single detector technology possesses all the desirable features and functions. To make it even more complicated, decontamination procedures have to be adapted to the level of risk and the decontamination chemistry must not interfere with, for example, the protective layers in the IPE or with the detector equipment necessary for tracing the level of contamination.

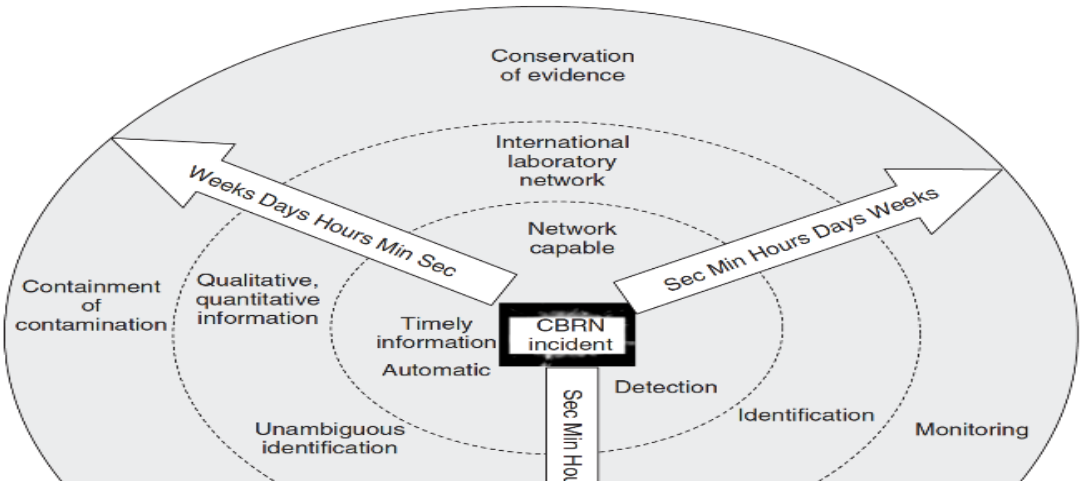

Figure 3-2 Time-dependent detection, identification, and monitoring of chemical, biological, radiological, and nuclear agents. Adapted from Reference

Levels of Identification of CBRN Substances:

1) **Provisional identification**: equipment required for provisional identification utilises one or more generally accepted analysis method(s) that can quickly provide (within seconds up to minutes) the additional information required to confirm warnings caused by positive detection.

2) **Confirmed identification** requires advanced analysis equipment and knowledge about the suspected hazard, and is performed by CBRN-specialists or medical experts with scientific training.

3) **Unambiguous identification** has to be performed by specialists in appropriate reference laboratories and may well take even more time than other identification levels (up to one or more days).

After identification of the hazard, continuous monitoring is necessary to determine if the hazard is still present.

In general, for proposed sensor systems for the detection, identification, and monitoring of CBRN incidents a set of competing requirements can be identified based on the operational parameters and can be represented by spider charts. The potential benefits of these spider charts are the possible

comparison between sensors and obtaining an idea of the overall usefulness of a tested sensor. Based on these general considerations we can characterise the detectors as follows:

- point detector;
- stand-off detector;
- remote detector.

A point detector reacts automatically to hazards at the location of the detector.

The requirements for point detectors are (i) to react quickly and (ii) to give a signal automatically in the presence of a CBRN hazard.

Furthermore, point detectors can be hand-held, portable, or fixed, and can vary from detection paper to advanced electronic equipment.

In contrast to detectors, identification equipment enables the characterisation and determination of the nature of a CBRN agent. Finally, there is one point we should not forget in the whole detection, identification, and monitoring process. Sampling equipment is necessary for the sampling of potential toxic materials in field or forensic analysis of a CBRN incident.

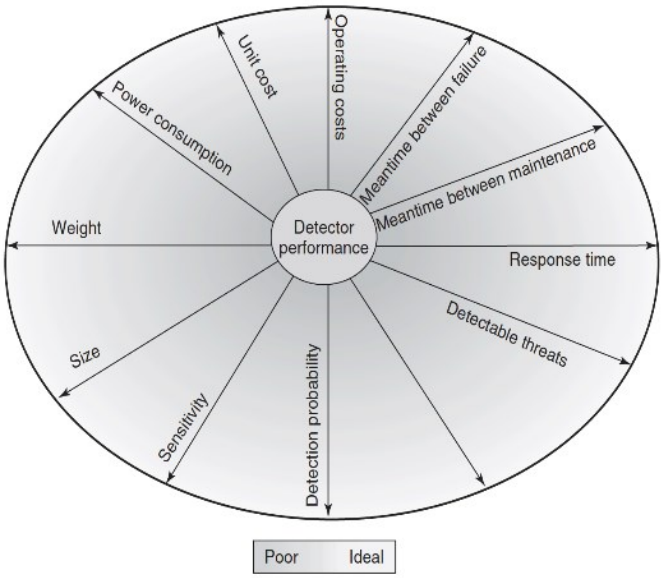

Figure 3-3 Spider chart as a useful tool for representing the most important parameters for sensor systems. For the different metrics the better performance is obtained on moving out from the center. Adapted from References

Sampling Identification Biological Chemical Radiological Agents (SIBCRA) International agreed and confirmed standards are required to provide documented evidence of the produced laboratories results. This means that the results from the laboratory must meet a prescribed standard, for example:

- Good laboratory practice (GLP);
- Quality assurance (QA);
- Quality control (QC);
- Standard operating procedures (SOPs).

Furthermore, it is necessary to demonstrate that the route from the raw data to the corresponding experimental results can be verified.

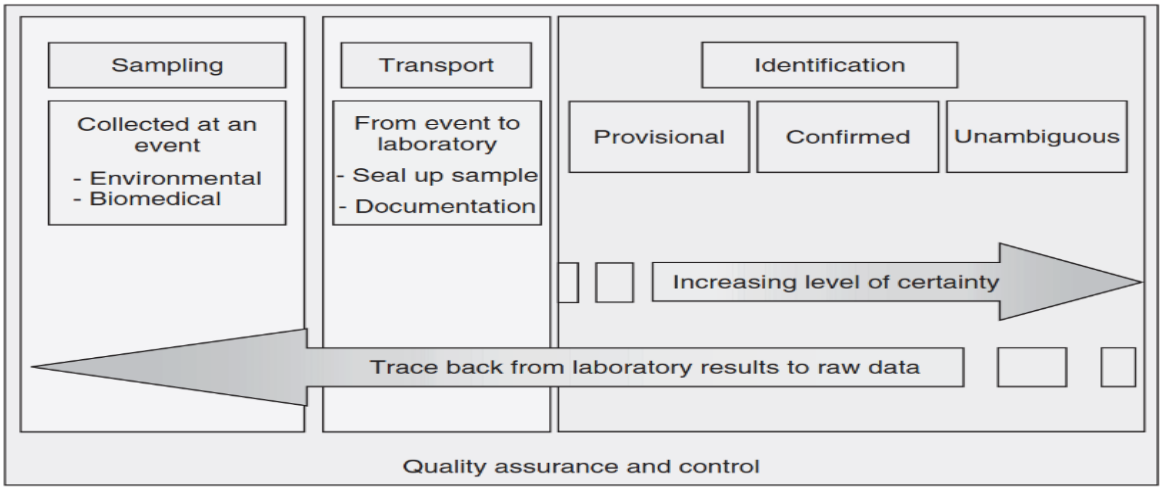

Figure 3-4 Generalised procedure for SIBCRA (Sampling identification biological chemical radiological agents) procedures as one possible step for a further forensic concept.

Low-Level Exposure and Operational Risk Management

To understand the difficulty of selecting the right detector strategy it is furthermore important to understand the complexity of a CBRN incident and thus some generalisations are needed. The severity of a health effect from CBRN agent exposure is the direct result of (i) the CBRN agent itself, (ii) its dose, (iii) the product of the CBRN agent concentration and duration of exposure, and (iv) the personal health situation of the affected individuals.

Owing to the diversity of environmental conditions and possible scenarios it is not possible to have for each possible CBRN incident an adequate policy. It is common practice to use generic scenarios for estimating the severity of effects.

These generic scenarios could be used as the basis for operational risk management (ORM) and furthermore to define low-level exposures and low-risk exposures and are therefore possible benchmarks for detectors. However, an international accepted standard does not exist and therefore further standardisation is needed.

Furthermore, we are not able to precisely estimate the time period that personnel can be exposed to CBRN agents. Therefore, only some generalised terms for duration of exposure are available. In particular, the consequences of the combination of exposure duration and low-level exposure concentrations are the primary focus of medical research at the moment. A low-level exposure is exposure to a CBRN at a concentration at which there is low risk to human health in the short term.

The most common terms for the range of low-level concentration and corresponding effects are the acute exposure guideline levels (AEGLs) for chemical substances.

AEGLs represent temporary threshold exposure limits (10 min to 8 h) for three levels of severity.

This concept is useful for chemical warfare agents and is generally not appropriate and not applicable for assessing ionising radiation and biological scenarios.

Instead of AEGLs, for ionising radiation scenarios a dosimetry concept has to be used that is based on the accumulated ionising radiation dose a person receives from external and internal contributions.

A more detailed description will be found in the appropriate chapters dealing with the radiological and nuclear aspects. For biological warfare agents a dosimetry concept is under discussion but not available yet.

The most important factors used to select the detector are shown in Table 3-20 Important factors for detector selection.

Table 3-20 Important factors for detector selection

No	Detection capability	Performance
1.	Selectivity Sensitivity Response time Limit of detection Response dynamic range False alarm rate	Set-up and warm-up time Calibration requirements Portability Power requirements Resistance to environmental conditions

Researchers, developers, and users have to adhere to different recommendation parameters for chemical warfare agent detectors capabilities, sensitivities, and response times for detector equipment. These parameters can be considered as guidelines and challenges for chemical warfare agent sensor systems.

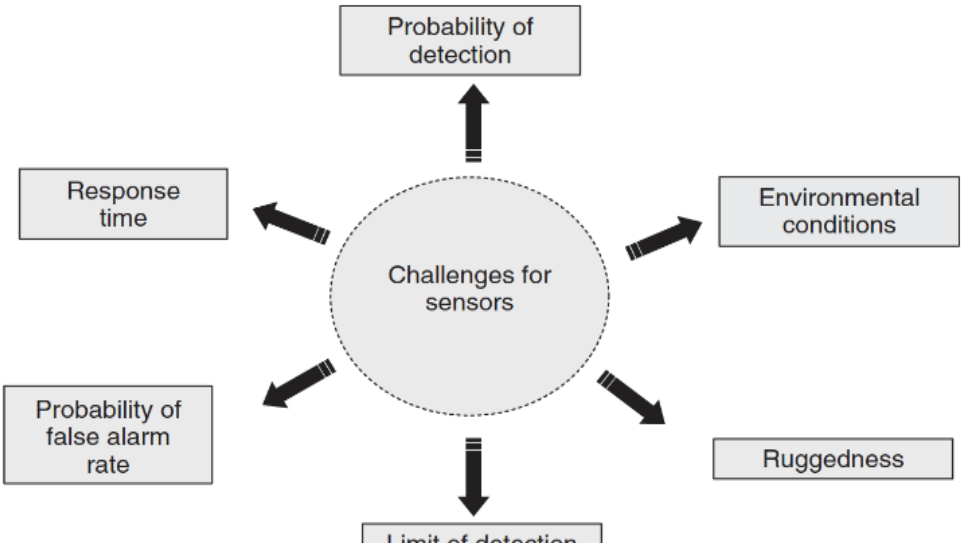

Figure 3-5 Filters – Needed Technology Equipment for Collective and Individual

We can accentuate that physical protection against a chemical, biological, radiological, and nuclear (CBRN) threat is nothing less than a part of employment protection and that filter technology is the key technology for effective individual and collective protection (COLPRO).
Therefore, we need to look at some aspects of air-filtration and air-cleaning systems before we discuss collective protection (COLPRO) and individual protection (IP) as parts of physical protection further.

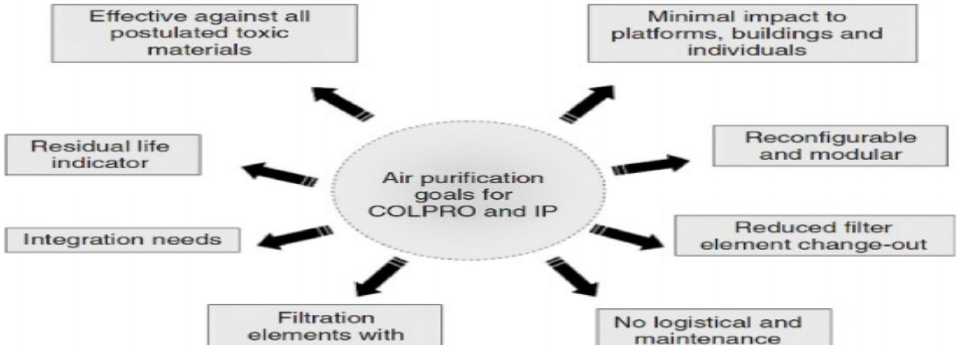

Figure 3-6 Air purification goals for collective protection (COLPRO) and individual protection (IP)

To choose the right filter technology for effective physical protection from chemical, biological, or radiological attacks, we have to answer the following questions:

- What are the principles of air purification and what types of air-filtration and air-cleaning systems are effective for various CBRN agents?
- Are we able to implement these systems in existing ventilation systems?
- Can we incorporate these systems into buildings, vehicles, and so on?
- Do we know how to properly maintain the air-filtration and air-cleaning systems installed in our systems?

For further details we refer to additional literature and standard text books. Based on this information, we will try to answer the question of how to select the right filter technology.

Selection Process for CBRN Filters

Based on knowledge of the filter principles and the results of the filter test methods we are able to think about which CBRN filter is the best one in a given scenario.
Importantly, before selecting a filtration and air-cleaning strategy that includes a potential upgrade in response to perceived types of threats, an understanding of our system to be protected and its CBRN system has to be developed. Initially, we have to answer several questions explicit in the Figure 3-7.

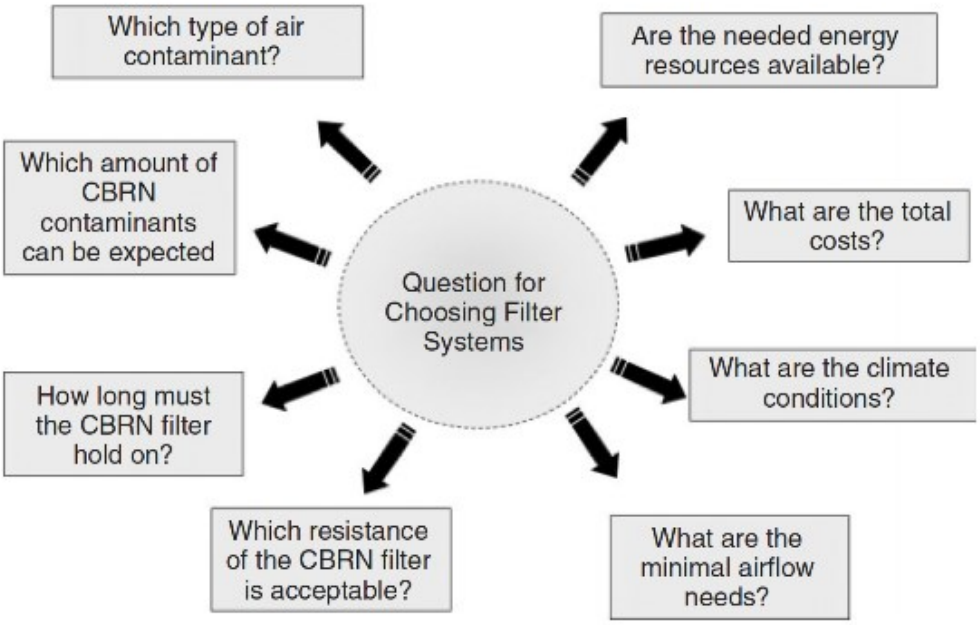

Figure 3-7 Important Questions for choosing the right filter system for collective protection (COLPRO) and for individual protection (IP)

The answers to these questions could be a guide in making appropriate decisions about what types of filters and/or adsorbents should be installed in the needed CBRN system, how efficient those filters and/or adsorbents must be, and what procedures we should develop to maintain the system.

It is important to recognise that improving physical protection is not an all or nothing question.

If we are able to answer these questions properly, we should be able to select the best filter for the given situation. We have to emphasise that CBRN filters are critical system components.

Filter trains often consist of two or more sets of filters; therefore, it is important to consider how the entire filtration system will perform and not just a single filter.

These may consist of single or multiple filters to remove sub-micrometre particles.

Different filters can be compared for collection efficiency and particle size.

3.3 Respiratory Protection

Though in a CBRN scenario full body protection is necessary, respiratory protection is the most important safety measurement as the inhalation tract is extremely vulnerable. This fact originates from the huge surface of the lung, which is "25–50 times larger than the entire surface of the skin," and the fact that the lung tissue is due to its composition more sensitive to agent exposure than the normal skin – agent permeation in lung tissue is much faster than through skin. Respiratory protection has to be chosen according to the hazard. Modern respirators use canisters with different layers of

impregnated activated carbon and particle filters to protect against a wide range of hazards. Respirators can only be used in atmospheres containing more than 17–19% of oxygen and if the dosage of the contaminant does not exceed the canister's capacity. Otherwise a Self-Contained Breathing Apparatus (SCBA) must be used. Respirators are manufactured in various styles. For CBRN use full-facepiece respirators, while for special tasks helmets are common.

• **Full-facepiece respirators** are adequate for general use as high protection factors (PFs) can be achieved. They offer a broad range of protection and can ideally be used with different canister types and a SCBA. They are easy to use and to maintain and do not require a special infrastructure.

• **CBRN helmets** are applied for special tasks only, such as jet pilots. Helmets are usually heavier, bulkier, and more complex than respirators, as very often electronic devices for communication and protection are integrated into it, which require an energy supply. The clean air for breathing is, for example, provided via an oxygen mask, while eye protection is achieved separately by ventilation. If the regular operation mode fails, additional protective measures come into place.
Helmets are highly specific and complex to employ.

• **Loose fitting face pieces or visors** need to be combined with a ventilation unit, otherwise the achieved protection factor (APF) is very low as the tightness of the system is not realised. Ventilation requires a blower unit with a reliable energy supply. The limited energy supply of batteries might lead to mission restrictions.

• **Half-face piece masks** are also not appropriate for missions under CBRN conditions as they leave parts of the face and the eyes unprotected. Simple hoods are also inappropriate as they are not adapted to their users faces but are designed to be "one-fits-all";' tightness can, for example, be achieved by a neck seal but they have limited operational capabilities.

Manufacturers of protective items usually provide datasheets with information on the retention capabilities. If protection against a special or uncommon substance is required, extra tests should be carried out for reliable mission predictions. Referring to respirator protection, the PF indicates the proper fit of the face seal as well as the tightness of all other elements such as exhalation valve and canister seal. A high PF can only be achieved if the person wearing the respirator has a smooth and even skin, facial hair in the area of the face seal leads to leakages.

3.4 Body Protection

The skin is the body's largest organ. Thus, an attack on it has to be effectively counter measured. The protective equipment therefore needs to be extended to cover the whole body, with special boots, gloves, coats, and suits that were first made of butyl rubber to achieve sufficient protection.

The closed "universe" prevents or slows down the penetration of toxic substances but leads to problems for the encapsulated individual because of the non-existent exchange with the environment: the missing

heat and humidity exchange lead to a severe physical burden. Different categories and types can be found to classify suits, for example, according to the EU directive 89/686/EEC.

Some general information on body protection must be considered before any mission can start, such as:

1) What kind of protection is appropriate for the hazard? *A threat analysis needs to be made*.

2) Depending on wear time restrictions and the number of users estimated: *How many suits, boots, gloves are needed?*

3) Is the protective equipment re-usable? *The time needed for the decontamination process must be considered in planning the number of equipment needed*.

4) Does the contaminated equipment need to be disposed of somewhere? *Methods for safe storage and disposal must be planned*.

3.5 Protective Footwear

Foot protection has to be adequate for the situation. For large amounts of splashing waters, decontaminants, and contaminants, rubber boots can be worn. Because of the bootleg, a tight connection to an impermeable protective suit is possible.

Protective footwear, especially rubber boots, should provide a proper fit and a good sizing to contribute to workplace safety. A bad fit might cause stumbling and leads to an unnecessary increase in the physical burden as the user experiences problems with traction.

For missions requiring the features of combat boots, especially when an extended wear time is expected, additional foot protection can be realised as protective over boots or protective socks (instead of regular ones). Protective socks need to be donned precautionary. Protective over boots are donned only if needed and should fit smoothly over the combat boot to prevent stumbling and to not hinder walking or driving a vehicle.

To facilitate logistics, some manufacturers offer ambidextrous over boots.

3.6 Casualty Protection

A CBRN emergency very likely includes the necessity to deal with casualty handling, either contaminated or not. In a contaminated environment, the CBRN protection and transportation of casualties might not be possible with an ambulance to the hospital for further medical treatment immediately. The ability of the casualty to breathe with a respirator might be impaired.

Very sophisticated versions allow basic medical treatment via integrated gloves and medical equipment. If transport is not required, casualty hoods might be sufficient. The risks and effects of lethal contamination must be taken into account to ensure safety for the survivors and the unconcerned population: special bags for contaminated bodies are available.

3.7 Quality Assurance

As the health and life of users rely on the flawless functionality of IPE, severe legal restraints exist for marketing IPE. In Europe, the EU directive 89/686/EEC includes the superior guideline for IPE – among other things it defines basic safety requirements.

The EU directive needs to be transposed into national law for each member state; national transpositions might differ. For employment protection reasons it is important that IPE without national quality certificates should never be used.

Information has to be supplied from the manufacturer for each IPE item such as detailed instructions for the handling, protective performance, limits of use, and more. Expressly not covered under this directive is IPE designed and manufactured specifically for use by the armed forces. The standards for civilian IPE as well as their test procedures might both not be sufficient in all cases for military IPE.

Manufacturers provide lists of substances their equipment protects against and information on which test was employed for the evaluation. If a threat analysis unveils missing information on hazardous substances, additional tests in accredited laboratories could close this gap. IPE should be tested to gain information on its performance when challenged with the expected level of contaminants and all other substances it could come in contact with such as decontaminants, disinfectants, and so on [e.g., petroleum, oil and lubricant (POL)].

During IPE procurement, a quality management has to be installed to ensure a constant quality for the whole tender; it might be necessary to carry out crucial performance tests along the production process. Methods to evaluate the protective features can, for example, be found in DIN EN ISO 6529 for the "determination of [the] resistance of protective clothing materials to permeation by liquids and gases" and in DIN EN ISO 6530 for the "Test method for resistance of materials to penetration by liquids."

3.8 Workplace Safety

Workplace safety is essential for the positive outcome of a mission; its basis is regular training and detailed knowledge of the protective equipment and of the requirements on how to act in a CBRN emergency. It includes knowledge of the protective level to be chosen for a hazard, training in the use of the protective equipment, knowledge of the limits of the equipment provided, and of the human physical properties and limitations.

National regulations are established for workplace safety concerning IPE but do not always apply for emergency situations. For missions in hot climate conditions, work-break regulations need to be established to ensure the health of the user wearing IPE that imposes thermal insulation and an additional work load. The fluid supply is extremely important.

International studies and practical experience show that psychosocial knowledge and action also support the operational performance and provide, hence, a contribution to workplace safety as stress

levels decrease and personnel feel more competent and secure. Training can prepare for ways the population might react in case of a CBRN emergency and how to deal with these additional effects. To handle these problems contributes to the coordination and safety of missions.

3.9 Input user requirements – SnR communication platform[4]

In order to adequately define user requirements for an information/communication platform some basic context for intended use is required. Taking Use Case 3: "Earthquake / heavy storms between Vienna Rail Station & Kufstein railway station heavy damages in the rail station (Cross-border pilot, Austria-Germany)" as a starting point, the following elements relating to communications should be considered:

(1) Communication breakdown (due to power cut);
(2) Patient routing system (incl. Triage structures);
(3) Data management of different medical first responder units;
(4) Interoperability between various command/communication structures of different FR organisations;
(5) SnR platform as additional information source for FR units.

(1) The scenario makes it necessary to consider a *communication system* that can be (re)established fast or may use alternative channels to be able to rely on basic communication between first responders and corresponding units. As part of this*, alternative energy sources* may have to be considered to ensure functionality*. Security* of such communication channels needs to be maintained.

(2) The JOHANNITER medical first responder unit, which will be in action during the field exercise of UC3 is in need of a well-functioning *patient routing system* in a mass casualty event, being able to document, track and share/receive information about patients during various steps of the response phase, from first contact with patients until hand-over at the hospital.

Different team members within one organisation (and across the overall response system) should have different functions and access rights to such platform.

Within our own medical first responder unit the following different role profiles would be necessary:

- Control Centre (mobile)
- Commander
- Chief inspection officer
- Head of treatment unit
- Treatment unit team member
- Control room

Important general features of the system:

[4] Johanniter Austria

- Time stamps for all information input and changes made (with log of authors)
- Potential access through phone app
- Patient documentation (personal data, diagnosis, location and destination for further treatment)

Features relevant for commander/command and control centre:

- Overview of all documented patients (in/out coming, in need of treatment etc.)
- Automatic analysis of all patients at an incident according to dynamically defined criteria
- Overview of available resources (ambulance cars, available FR etc.) and location (potential visualisation in map) → in order to (re)assign units to patients and activities
- Documentation should be made available in chronological order after the event, as part of the mission documentation/incident log

(3) Compatibility of different data management systems – finding best fit contextualised solutions for the use case. In the envisioned use case documentation relies on semi-digital handover of data (necessity to cope with disturbance of functionality of digital solutions)

(4) UC 3 is envisioned as cross-border case, which will make interoperability of documentation/information systems of e.g. medical first responder units from different organisations and/or countries necessary. Possibility to switch between different organisations and respective command centres to take over other fleets, run the logistics – in order to uphold the functionality of units despite disturbances, should be considered. For international missions it would be useful to have a function to switch between languages, for accessing the system and the information provided. Here it may also be considered to do a mapping of key terminology used by different types of responder organisations (military, civil, etc.)

(5) SnR platform could provide crucial information relevant for command and control and the operational picture – being able to combine and access information in one system and being able to display information through different layers giving the operator the possibility to filter information quickly and efficiently, depending on what is needed at a given time. Such system could be crucial for quick, informed decision making to be used by the mission commander.

3.10 Principles and Practice of Disinfection of Biological Agents including SARS-CoV-2

Key questions for decontamination and disinfection of biological agents are: "what is sufficient?" and "Is clean enough?" Is it possible to determine a necessary inactivation level that meets regulatory needs in the case of a biological incident or is an estimation of the reduction level sufficient?

Coronaviruses (COV) are a large family of viruses that cause illness ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS-COV) and Severe Acute

Respiratory Syndrome (SARS-COV). A novel coronavirus (nCOV) is a new strain that has not been previously identified in humans.

Coronaviruses are zoonotic, meaning they are transmitted between animals and people. Detailed investigations found that SARS-CoV was transmitted from civet cats to humans and MERS-COV from dromedary camels to humans. Several known coronaviruses are circulating in animals that have not yet infected humans.

Common signs of infection include respiratory symptoms, fever, cough, shortness of breath and breathing difficulties. In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure and even death.

Transmission[5]

In the case of COVID-19, as reported by the World Health Organisation (WHO) "Situation Report—12", the modality of transmission can be similar to the previous epidemics caused by other coronaviruses (MERS, Middle Eastern Respiratory Syndrome, and SARS, Acute Respiratory Syndrome), for which human-to-human transmission occurs through droplets, aerosols and direct contact.

In particular, the droplets, generated during speaking, coughing and sneezing by symptomatic patients, can spread up to 1–2 m; a recent study demonstrated that the infection can also occur from asymptomatic people and before the onset of symptoms.

Another mode of transmission is enabled by the inhalation of aerosols, which are microparticles with a diameter smaller than 5 _m, containing pathogens, which after having been released in the air, are transported by the flow of the air current, thus being able to cause diffusion even at a considerable distance (with reverse ratio due to their dilution). Currently, the literature cannot give information on the practicable concentration of SARS-CoV-2 to infect a human being; however, it has been quantified that SARS-CoV-2 remains practicable in aerosols after 3 h[6], with a reduction in the infectious titer from 103.5 to 102.7 TCID50 per litre of air. This reduction was similar to that observed with SARS-CoV-1, from 104.3 to 103.5 TCID50 per mL. The half-life of the viable virus was also estimated for aerosol based on estimated exponential decay rates of the virus titer in approximately 1 h.

[5] Huang, C.; Wang, Y.; Li, X.; Ren, L.; Zhao, J.; Hu, Y.; Zhang, L.; Fan, G.; Xu, J.; Gu, X.; et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020, 395, 497–506, doi:10.1016/S0140-6736(20)30183-5.

[6] Guo YR, Cao QD, Hong ZS, et al. The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak - an update on the status. Mil Med Res. 2020;7(1):11. Published 2020 Mar 13. doi:10.1186/s40779-020-00240-0

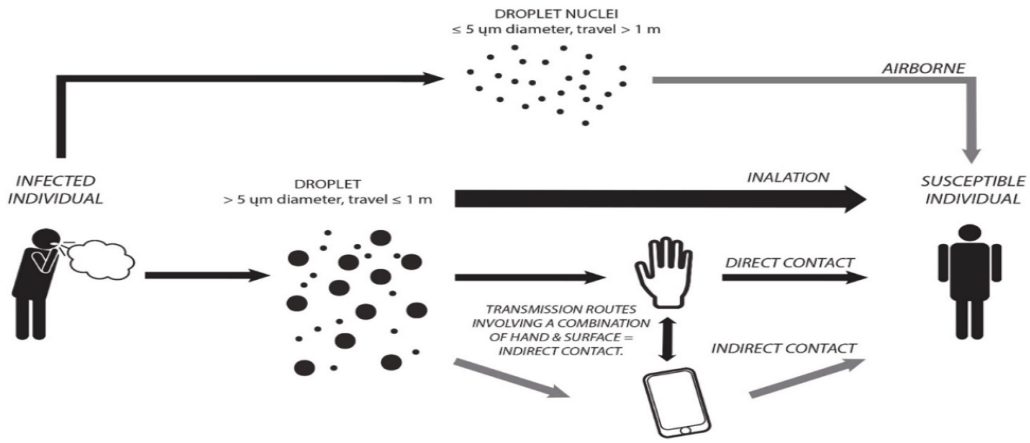

Figure 3-8 Transmission ways of COV-19

Finally, SARS-CoV-2 can also be transmitted through direct or indirect contact with infected people or by depositing droplets containing the virus on any person (handshake, greeting, hug) or inanimate surface; these droplets can contaminate the hands of other subjects by subsequently entering the body through access routes such as the oral cavity, the nasal cavity, the eyes and other mucous membranes. There are no studies in the literature that demonstrate in practice a vital concentration of SARS-CoV-2 necessary to infect a human being from inanimate surfaces. Instead, it has been shown how the half-life of SARS-CoV-2 varies on different surfaces such as plastic, stainless steel, copper and cardboard

Organisational Measures

General organisational measures regarding the containment and management of the epidemiological emergency of COVID-19 have been imposed by the competent authorities for an adequate and proportionate management of the evolution of the epidemiological situation.

The prevention and protection organisational measures therefore aim to minimise the probability of being exposed to SARS-CoV-2. For this purpose, measures must be taken to avoid new infections or even the spread of the virus where it has already been present.

The measures to be taken are:

- Blocking all trips to and from all areas defined as "red", in which cases of COVID-19 infections have already been ascertained.
- Possible 14-day home quarantine for those who live, work or return from these areas.
- Selective control and measurement of body temperature of all suppliers and external collaborators.
- Reduction of the number of operators within each confined environment.
- Prioritise, where possible, work from home (smart working).

- Composing, if possible, two or more closed and independent working groups, to be alternated every 14 days to work in the company or in smart working.
- Predisposition and maximum adherence to PPE dressing and undressing protocols.

Environmental Measures[7]

Environmental measures are aimed at reducing the risk of transmission of SARS-CoV-2 infection to individuals through contact with infected subjects, with objects, equipment, or contaminated environmental surfaces.

Even if there are no disinfectants registered specifically as active on SARS-CoV-2, viruses with similar biochemical and physical properties are inactivated with detergents and disinfectants commonly used in hospitals; this ensures a low or intermediate disinfection, following the manufacturer's instructions and the technical data sheet regarding dilution, contact time and handling.

In the literature, various evidence has shown how coronaviruses, including the viruses responsible for SARS and MERS, can persist, in optimal conditions of low humidity and low temperature, for up to 9 days on the inanimate surfaces of all shared rooms, especially bathrooms, changing rooms, canteens, rooms with distributors, smoking areas, and offices shared with several people. A role of contaminated surfaces in the transmission of SARS-CoV-2 infection is therefore to be considered as being possible, even if not yet demonstrated.

At the same time, available evidence has shown that the aforementioned viruses are effectively inactivated by adequate sanitisation procedures, which include the use of disinfectants based on sodium hypochlorite (0.1%–0.5%), ethanol (62%–71%) or hydrogen peroxide (0.5%), for an adequate contact time, providing adequate ventilation of closed rooms; or through the use of physical means such as ultraviolet irradiation (UV). Therefore, extraordinary cleaning and sanitisation procedures must be adopted using the appropriate disinfectants/disinfectants (Table 3-21 List of disinfectants active on viruses and their related areas of application) and remembering to pay the utmost attention to the removal of any organic residues, intensifying the frequency with which these activities are normally carried out.

Table 3-21 List of disinfectants active on viruses and their related areas of application

DISINFECTING SUBSTANCE	APPLICATION SCOPE
Alcohol	Cutaneous antisepsis, Disinfection of small surfaces
Chlorine compounds (chloramine, hypochlorite)	Cutaneous and wound antisepsis, Water treatment, Surface disinfection

[7] Van Doremalen, N.; Bushmaker, T.; Morris, D.H.; Holbrook, M.; Gamble, A.; Williamson, B.; Tamin, A.; Harcourt, J.L.; Thornburg, N.J.; Gerber, S.; et al. Aerosol and surface stability of HCoV-19 (SARS-CoV-2) compared to SARS-CoV-1. N. Eng. J. Med. 2020, doi:10.1101/2020.03.09.20033217.

Glutaraldehyde	Disinfection of inanimate objects
Hydrogen peroxide	Cutaneous antisepsis
Iodophors	Skin and wound antisepsis
Acetic acid	Disinfection of inanimate objects

Personal Protective Equipment (PPE)
Gloves

The general guideline is to use devices that comply with the requirements of the technical standard EN 374, classified as third category PPE for protection from microorganisms (a CE certification must have been issued by the notification body for the manufacturer certifying the CE marking as PPE).

The disposable protective nitrile gloves are made of a composition based on butadiene and acrylonitrile, which give it the characteristics of high comfort, ergonomics, elasticity and mechanical resistance, both to perforation and also if put in contact with some chemical substances. Finally, their hypoallergenic characteristic compared to latex gloves should not be underestimated.

Indications for the use of gloves:

- Must be clean gloves and they must cover the wrist well;
- Must be removed immediately after completing the procedures that they were used for; in particular, great care must be taken not to touch clean surfaces with contaminated gloves;
- Must be absolutely changed if dirty or not perfectly intact;
- Glove decontamination prior to glove removal with hypochlorite, after every contact with different inanimate surface, and during doffing procedures;
- Must not be reused or washed.

Disposable Masks/Respirators

Respiratory particles can be classified as droplets or aerosols based on the size of the particles and in particular in terms of their aerodynamic diameter.

Both types of particles, droplets and aerosols, are generated by coughing, sneezing, speaking or simply exhaling; while droplets settle quickly, small aerosols can remain suspended in the air and can be transported over long distances by the air flow.

Compared to droplets that cause infection at a distance of less than one meter, aerosols can cause contagion at greater distances, but with a ratio inversely proportional to the space covered and the dilution suffered.

Filter Masks

The principle on which these masks are based is to adhere to the face by creating a slightly negative pressure inside the mask and thus filtering the incoming air.

In order for these devices to actually protect those who use them, it is essential to plan and implement a training program related to the use of them.

The average filtering power offered by respirators with an N95 facial filter against particles in the range

of tested sizes is about 8-12 times greater than that provided by disposable surgical masks, whose filtering powers varied widely in the various studies, depending on the model and size of the aerosol particles (1.3 to 6.5 pm). This result is superimposable to that obtained by other studies, which claim that the protection provided by respirators with an N95 facial filter is approximately seven times greater than that of surgical masks.

The N95 respirators with an exhalation valve are designed to facilitate breathing. The results of the literature analysed by us have shown that the respirator with an N95 facial filter and exhalation valve does not lose its ability to protect the wearer from exposure to airborne particles in the range of bacterial and viral dimensions. The aerosol penetration through the exhalation valve was also studied for negative pressure respirators, reaching the conclusion that the penetration values were about 0.03%-0.04% with no valve fault.

Disposable Surgical Masks (Facemasks)

Facemasks (surgical masks), with disposable fabric or not, are formed by four layers (type II or IIR): external, which is filtering; central, which is impermeable to liquids but air permeable; the internal layer, which is in contact with the hypoallergenic skin, with upper deformable nose bar to conform perfectly the face mask and with fastening system formed of ties or elastic bands.

They protect the nose and mouth from contamination with particles with an average diameter of 4.5 pm. While originating from the need to protect the patient (surgical interventions, aseptic manoeuvres), they constitute an effective barrier system for potentially infected liquids even for those who use them.

The use of the surgical mask is recommended:

- For those who work in contact with subjects with suspected airborne disease (flu syndrome, chicken pox, measles);
- In activities for which there is the possibility of generating splatters or splashes of blood or other body fluids;
- In technical and administrative support activities;
- By doctors, nurses, biologists, midwives and all healthcare personnel;
- By the staff of contracting firms (e.g., cleaning);
- By public assistance staff.

Data indicate that a surgical mask reduces virus exposure 1.1 to 55 times (on average six times), depending on the mask design. They are currently indicated to be worn by the potentially infected subject.

Disposable surgical masks can confer a significant degree of protection, although less strong than FFP2 masks. However, surgical masks suffer less from limited supplies and do not need additional resources to supply on a large scale.

Indications on the use of the facemasks:

Of course, no mask, be it the tight-fitting NIOSH-approved N95 respirator mask or the loosely worn

surgical mask, provides perfect (100%) protection. But imperfect protection does not mean "completely useless".
In case of difficulty in finding the filter masks described above, surgical disposable masks can be used; even if with the limitations related to the imperfect adherence to the face, depending on the different design of the models on the market; these devices are to some extent protective, above all in preventing close contact with droplets, and even more effective if associated with other PPE (nitrile disposable gloves, protective glasses).

Safety Goggles and Splash Guard Visor - SARS-CoV-2

The conjunctiva is susceptible to the entry of microorganisms. For this reason, it is important to protect the eyes from exposure to SARS-CoV-2 when in close contact with an infected person.
These PPE must possess the certification issued by the notification body for the manufacturer as regards the CE marking as PPE for the "protection against splashing liquids" according to the requirements of the technical standard EN 166, elaborated for this purpose.
Devices for which the certifications of compliance with the aforementioned technical standard also certify the "protection from droplets" are preferred.
Visors are not able to be used if an FFP2 mask is worn. Therefore, in the procedures that involve splashes, goggles that guarantee protection from droplets must necessarily be provided.
All the PPE described above must be removed and disposed of by following the correct procedures by the wearer.

Isolation Gowns

Disposable (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films. They can be produced using a variety of nonwoven fibre-bonding technologies (thermal, chemical, or mechanical) to provide integrity and strength rather than the interlocking geometries associated with woven and knitted materials.

3.11 Unmanned Aerial Vehicles[8]

Deep learning has perfect capabilities for imitating representations from the complex data which gather in real environments and make it suitable for many kinds of autonomous robotic applications. Unmanned Aerial Vehicles (UAVs) are currently applied for several types of human tasks in applications going from security, surveillance, and disaster rescue to parcel delivery or warehouse management. In the case of natural disasters, they can scan the wide-area quickly and make the SAR faster to save

[8] AIDEAS OÜ

more human life. Below we will discuss some AI techniques which are used to detect objects like peoples, boats, vehicles, airplanes, etc, from video and images.

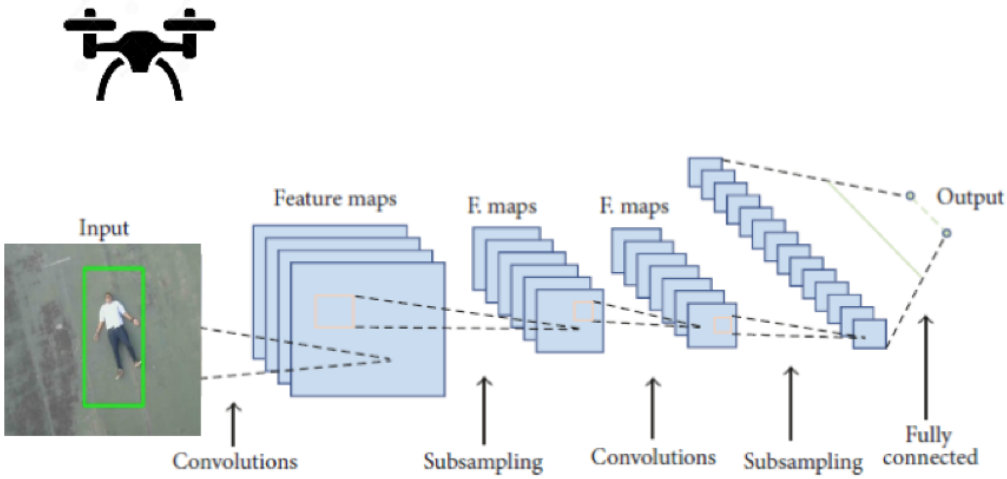

Figure 3-9 An example of architecture for Convolutional Neural Networks model layers

Deep learning for computer vision is usually associated with the learning of features using an architecture of connected layers and neural networks. They are commonly called Convolutional Neural Networks (CNNs). CNNs are a type of network created specifically for image and video processing. The relationship between CNNs and neural networks is quite simple because both have the same elements (neurons, weights, and biases).

The need for performing accurate and real-time human detection in aerial surveillance has sparked significant research in the past few years.

The following techniques cover the most relevant algorithms nowadays in supervised learning: Feedforward Neural Networks, a popular variation of these called Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and a variation of RNNs.

There are two categories for object detection are according to literature: Two-stage detection and one-step detection. The networks which are on the market for two-stage detection extract the features from the object proposals, and finally, a classifier determines if there is an object in the proposal or image patches. Region-based methods include Region-based Convolutional Neural Networks[9] (RCNN), Spatial

[9] M. Lodeiro-Santiago, P. Caballero-Gil, R. Aguasca-Colomo, and C. Caballero-Gil, "Secure UAV-based system to detect small boats using neural networks," *Complexity*, vol. 2019, 2019, doi: 10.1155/2019/7206096.

Pyramid Pooling[10] (SPP-Net), Support Vector Machine (SVM), Faster R-CNN, and Mask R-CNN[11], and Region-based Fully Convolutional Networks[12] (R-FCN).

The other category is the one-step approach, which is also called regression and classification-based object detection (OD), which mainly includes You Only Look Once (YOLO[13]) and Single Shot Detector[14] (SSD). Among the deep learning-based object detectors, SSD has outperformed, because it detects objects in a multi-scale framework.

A complete review of the recent literature on AI services for drones' vision can be found in "*A review of deep learning methods and applications for unmanned aerial vehicles*"[15].

So, in Table 3-22 Summary of networks that solve problem of object detectionTable 3-22Table 3-22 Summary of networks that solve problem of object detection we represented the summary of networks which solve the problem of various object detection.

Table 3-22 Summary of networks that solve problem of object detection

Object detection method in UAV images & video							
No	**Title**	**Year**	**Author**	**Objectives**	**Data**	**Description**	**Accuracy**
1	Secure UAV-Based System to Detect Small Boats Using Neural Networks[16]	2019	Lodeiro-Santiago et al	People and boats in sea	Image	In order to get the model used in this work performance improvements, modern object detector based on CNNs knowing as Faster R-CNN. This model depends in part on an external region used for selective search. The Faster R-CNN model has a design similar to that of Fast R-CNN , so that it jointly optimises	Correct classification of boats and pateras between 94 and 96% (although these ratios can vary from 92 to 99% depending on the frame)

[10] B. Mishra, D. Garg, P. Narang, and V. Mishra, "Drone-surveillance for search and rescue in natural disaster," *Comput. Commun.*, vol. 156, no. November 2019, pp. 1–10, 2020, doi: 10.1016/j.comcom.2020.03.012.
[11] B. Mishra, D. Garg, P. Narang, and V. Mishra, "Drone-surveillance for search and rescue in natural disaster," *Comput. Commun.*, vol. 156, no. November 2019, pp. 1–10, 2020, doi: 10.1016/j.comcom.2020.03.012.
[12] B. Mishra, D. Garg, P. Narang, and V. Mishra, "Drone-surveillance for search and rescue in natural disaster," *Comput. Commun.*, vol. 156, no. November 2019, pp. 1–10, 2020, doi: 10.1016/j.comcom.2020.03.012.
[13] M. Radovic, O. Adarkwa, and Q. Wang, "Object recognition in aerial images using convolutional neural networks," *J. Imaging*, vol. 3, no. 2, 2017, doi: 10.3390/jimaging3020021.
[14] M. Barekatain *et al.*, "Okutama-Action: An Aerial View Video Dataset for Concurrent Human Action Detection," *IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit. Work.*, vol. 2017-July, pp. 2153–2160, 2017, doi: 10.1109/CVPRW.2017.267
[15] A. Carrio, C. Sampedro, A. Rodriguez-Ramos, and P. Campoy, "A review of deep learning methods and applications for unmanned aerial vehicles," *J. Sensors*, vol. 2017, 2017, doi: 10.1155/2017/3296874
[16] M. Lodeiro-Santiago, P. Caballero-Gil, R. Aguasca-Colomo, and C. Caballero-Gil, "Secure UAV-based system to detect small boats using neural networks," *Complexity*, vol. 2019, 2019, doi: 10.1155/2019/7206096.

Object detection method in UAV images & video							
No	**Title**	**Year**	**Author**	**Objectives**	**Data**	**Description**	**Accuracy**
						classification and bounding box regression task.	
2	Small Target Detection for SAR Operations using Distributed Deep Learning and Synthetic Data Generation[17]	2019	Yun et al	Targets (e.g., person overboard)	Image	Combination of image segmentation, enhancement, and convolution neural networks to reduce detection time to detect small targets.	The average precision was 82.16% and the average recall was 76.83%.
3	Vehicle Detection Based on Drone Images with the Improved Faster R-CNN[18]	2019	Wang et al	Vehicle monitoring	Image	the Faster R-CNN is improved by using ResNet and constructing Feature Pyramid Networks (FPN) to extract the image features	96.83%
4	Human Crowd Detection for Drone Flight Safety Using Convolutional Neural Networks[19]	2017	Tzelepi and Tefas	Human crowd detection	Image	Adaptation of a pre-trained CNN, by totally discarding the fully-connected layers and attaching an additional convolutional one, transforming it to a fast fully-convolutional network that is able to produce crowd heat maps. Second, a two-loss-training model, which aims to enhance the separability of the crowd and non-crowd classes	95.32%
5	Drone-surveillance for SAR in natural disaster[20]	2020	Mishra et al	Human action detection for SAR	Image	Region-based methods include RCNN , SPP-Net , Fast R-CNN, Faster R-CNN, and Mask R-CNN, and RFCN. Another category is the one-step	98.00%

[17] K. Yun *et al.*, "Small Target Detection for Search and Rescue Operations using Distributed Deep Small Target Detection for Search and Rescue Operations using Distributed Deep Learning and Synthetic Data Generation," no. July, 2019.
[18] L. Wang, J. Liao, and C. Xu, "Vehicle detection based on drone images with the improved faster R-Cnn," *ACM Int. Conf. Proceeding Ser.*, vol. Part F148150, pp. 466–471, 2019, doi: 10.1145/3318299.3318383.
[19] M. Tzelepi and A. Tefas, "Human crowd detection for drone flight safety using convolutional neural networks," *25th Eur. Signal Process. Conf. EUSIPCO 2017*, vol. 2017-January, pp. 743–747, 2017, doi: 10.23919/EUSIPCO.2017.8081306.
[20] B. Mishra, D. Garg, P. Narang, and V. Mishra, "Drone-surveillance for search and rescue in natural disaster," *Comput. Commun.*, vol. 156, no. November 2019, pp. 1–10, 2020, doi: 10.1016/j.comcom.2020.03.012.

Object detection method in UAV images & video							
No	**Title**	**Year**	**Author**	**Objectives**	**Data**	**Description**	**Accuracy**
						approach, which is also called regression and classification-based OD, which mainly includes YOLO and SSD.	
6	Comprehensive analysis of deep learning based vehicle detection in aerial images[21]	2019	Sommer et al	vehicle detection	Image	SSD, Fast RCNN, and faster RCNN	88.70%
7	Using deep learning and low-cost RGB and thermal cameras to detect pedestrians in aerial images captured by multirotor UAV[22]	2018	Candido de Oliveira & Wehrmeister	Human detection	Image	Histogram of Oriented Gradients + Support Vector Machine, Convolutional Neural Networks	90.00%
8	Object recognition in aerial using convolution neural network[23]	2017	Radovic et al	Aeroplane detection	Image	Using a convolutional neural network implemented in the "YOLO" ("You Only Look Once") platform, objects can be tracked, detected ("seen"), and classified ("comprehended") from video feeds supplied by UAVs in real-time	84.00%
9	Okutama-Action: An aerial view video dataset for concurrent human action detection[24]	2017	Barekatain et al	Human detection	Images (from Video)	Single shot multibox detector	0.18 mAP at 0.50IOU

[21] L. Sommer, T. Schuchert, and J. Beyerer, "Comprehensive Analysis of Deep Learning-Based Vehicle Detection in Aerial Images," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 29, no. 9, pp. 2733–2747, 2019, doi: 10.1109/TCSVT.2018.2874396

[22] D. C. de Oliveira and M. A. Wehrmeister, "Using deep learning and low-cost rgb and thermal cameras to detect pedestrians in aerial images captured by multirotor uav," *Sensors (Switzerland)*, vol. 18, no. 7, 2018, doi: 10.3390/s18072244.

[23] M. Radovic, O. Adarkwa, and Q. Wang, "Object recognition in aerial images using convolutional neural networks," *J. Imaging*, vol. 3, no. 2, 2017, doi: 10.3390/jimaging3020021.

[24] M. Barekatain *et al.*, "Okutama-Action: An Aerial View Video Dataset for Concurrent Human Action Detection," *IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit. Work.*, vol. 2017-July, pp. 2153–2160, 2017, doi: 10.1109/CVPRW.2017.267.

Object detection method in UAV images & video							
No	**Title**	**Year**	**Author**	**Objectives**	**Data**	**Description**	**Accuracy**
10	Region proposal approach for human detection on aerial imagery[25]	2018	Marusic et al	Human detection	Aerial Image	Evaluated method based on Faster RCNN detection model showed promising preliminary results, as well as fast processing of high-resolution images.	Overall, detection model achieved 88.3% recall with precision of 67.3%
11	Real-Time, Cloud-based Object Detection for Unmanned Aerial Vehicles[26]	2017	Lee et al	Object detection	Images	Application of Faster Regions with CNNs (R-CNNs), a state-of-the-art algorithm, to detect not one or two but hundreds of object types in near real-time.	SSD300 for human 92,9 faster R-CNN 83,9 mAP overall for all objectives
12	A Deep Learning Model Based on Multi Objective Particle Swarm Optimisation for Scene Classification in Unmanned Aerial Vehicles[27]	2017	Rajagopal et al	Scene classification	Images	New multi objective optimisation model for evolving state-of-the-art deep CNNs for scene classification, which generates the non-dominant solutions in an automated way at the Pareto front.	97.88%

3.12 The use of wearable biosensors for detecting acute stress and enhance decision support in crisis responders[28]

18. Scope

Increasing research evidence shows that acute stress may have a negative impact on situation awareness and reduce efficiency of the decision-making process. Crisis responders have to deal with different forms of stress and other psychosocial strains and traumata. Therefore, the identification of psychological strategies and techniques focused on helping first responders in preventing, managing and dealing with the effects of acute stress is an important research challenge. Here, we focus on the possibility of introducing "smart solutions" for (i) the automatic detection of stress and (ii) training first

[25] Z. Marusic, D. Boxic-Stulic, S. Gotovac, and T. Marusic, "Region Proposal Approach for Human Detection on Aerial Imagery," *2018 3rd Int. Conf. Smart Sustain. Technol. Split. 2018*, no. March 2019, 2018.
[26] J. Lee, J. Wang, D. Crandall, S. Sabanovic, and G. Fox, "Real-time, cloud-based object detection for unmanned aerial vehicles," *Proc. - 2017 1st IEEE Int. Conf. Robot. Comput. IRC 2017*, pp. 36–43, 2017, doi: 10.1109/IRC.2017.77.
[27] A. Rajagopal *et al.*, "A Deep Learning Model Based on Multi-Objective Particle Swarm Optimization for Scene Classification in Unmanned Aerial Vehicles," *IEEE Access*, vol. 8, pp. 135383–135393, 2020, doi: 10.1109/ACCESS.2020.3011502.
[28] UCSC

responders dealing with the consequences of stress. In addition, our report aims at providing a benchmark analysis of technological solutions for monitoring stress, together with a SWOT analysis concerning the opportunities and limitations related to the use of these devices in operational contexts.

19. Psychological stress of direct exposure to extreme and traumatic stressors

The psychological effects of direct exposure to extreme and traumatic stressors such as natural disasters are well documented. Affected crisis responders have to deal with different forms of stress and other psychosocial strains and traumata. Stressful conditions can occur before, during and after a highly emotional event and, for this reason, psychosocial support is not only relevant during the crisis itself, but also afterwards during the recovery phase, sometimes even for the long-term, and may have to extend well beyond the persons directly impacted, such as first responders and the victims and public on the scene. Finally, psychosocial support is required to improve preparedness for crisis situations: training and intervention strategies are required to deal with stress during preparation, response and recovery phases.

Psychological stress occurs when an individual perceives that environmental demands tax or exceed his or her adaptive capacity[29]. This is mediated by (Figure 3-10):

1. The individual's appraisal of the stimulus: When faced with a stimulus, a person evaluates the potential threat (primary appraisal). *Primary appraisal* is a person's judgment about the significance of a stimulus as stressful, positive, controllable, challenging or irrelevant.
2. The personal, social and cultural resources available: Facing a significant stimulus, the second appraisal follows, which is an assessment of the individual's coping resources and options. *Secondary appraisals* address what one can do about the situation.

[29] Cohen, S., Janicki-Deverts, D., & Miller, G. E. (2007). Psychological stress and disease. Jama, 298(14), 1685-1687.

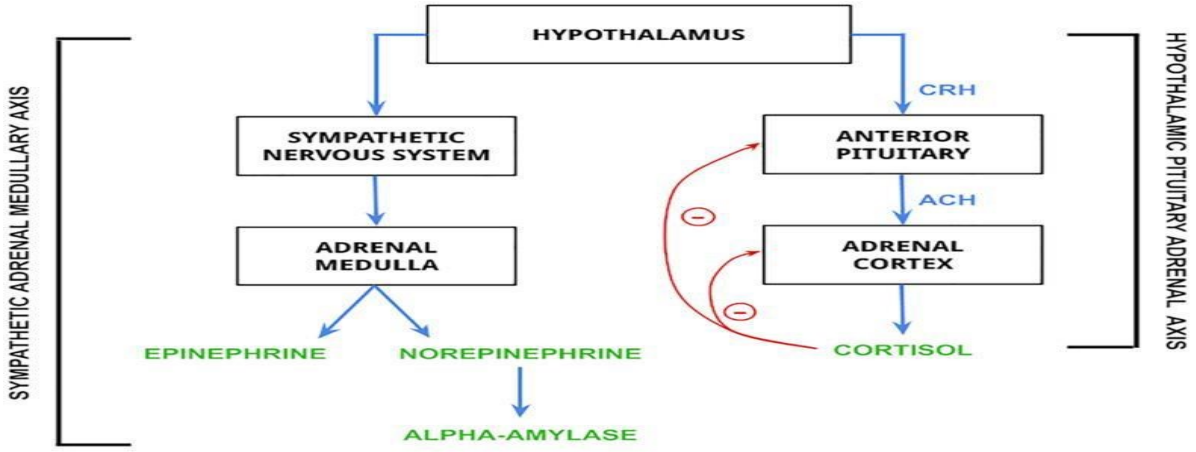

Figure 3-10 Stress results from the perception of an imbalance of environmental demands and adaptive capacities

3. The efficacy of the *coping efforts*: If required by the appraisal process the individual starts a problem management phase aimed at regulation of the external stimulus.

[30]

Accidents, natural disasters, and military combat are examples of situations that typically evoke high levels of stress and may result in emotions so intense that they interfere with normal functioning. Therefore, it is evident that first responders are frequently exposed to job-derived stressors of various types, hence the importance of effective and sustainable coping strategies. Extreme stressors set in motion a cycle of reactions aimed at restoring equilibrium between a person's self-concept and the new realities of his or her life. Pre-existing personality characteristics may interfere with an adaptive response after a disaster. People are likely to have long-lasting maladaptive reactions to traumatic situations if they see themselves as incompetent, if they tend to respond defensively to challenges (e.g., by using denial or projection), if they have conflicts involving themes similar to some aspect of the disaster, or if they believe that their past thoughts might somehow have influenced what happened. These prolonged reactions usually include feeling dazed and having intrusive thoughts and images about the traumatic event. Such thoughts and images may interfere with the ability to sleep. Further, a critical incident tends to produce strong emotional reactions in the individual, negatively interfering also with the use of their cognitive schemes and skills. In emergency workers, this condition can generate, over time, various effects, ranging from strong discomfort to a state of overt pathology.
More specifically, there are three conditions that, though different in their clinical presentations, are marked by crisis related stressors that serve as powerful triggers for behaviour that requires clinical

[30] Samson, C., & Koh, A. (2020). Stress Monitoring and Recent Advancements in Wearable Biosensors. Frontiers in Bioengineering and Biotechnology, 8, 1037.

attention. The triggers lead to strong emotional reactions— which may be denied— and clinical symptoms.

a) ***Post-traumatic Stress Disorder (PTSD)*** is the most common diagnostic category used to describe symptoms arising from emotionally traumatic experience(s). This disorder presumes that the person experienced a traumatic event involving actual or threatened death or injury to themselves or others -- and where they felt fear, helplessness or horror. Three additional symptom clusters, if they persist for more than a month after the traumatic event and cause clinically significant distress or impairment, make up the diagnostic criteria: Intrusions, such as flashbacks or nightmares, where the traumatic event is re-experienced; Avoidance, when the person tries to reduce exposure to people or things that might bring on their intrusive symptoms; Hyperarousal, meaning physiologic signs of increased arousal, such as hyper vigilance or increased startle response.
b) ***Acute Stress Disorder (ASD)*** is related to a recent traumatic event only. It involves symptoms similar to PTSD but without the one-month duration requirement: the disturbance lasts for a minimum of 2 days and a maximum of 4 weeks and occurs within 4 weeks of the traumatic event.
c) ***Secondary Traumatic Stress (STS)*** is any form of PTSD or ASD resulting from helping or wanting to help a traumatised or suffering person. Specifically, in STS the stress disorders symptoms are directly connected to the sufferer, the person in harm's way. STS is also called *Compassion Fatigue* because it is characterised by a state of tension and preoccupation with the traumatised patients by re-experiencing the traumatic events, avoidance/numbing of reminders, and persistent arousal (e.g., anxiety) associated with the patient. Sufferers can also exhibit several symptoms including hopelessness, a decrease in experiences of pleasure, constant stress and anxiety, and a pervasive negative attitude.

Chronic exposure to stressors in dangerous environments is considered by many investigators as an etiologic factor in the onset of symptoms associated with mental illnesses (i.e., anxiety, depression, post-traumatic stress disorder) and the development of dependence on drugs of abuse, which in turn exert direct effects on biological processes or behavioural patterns that influence disease risk. The attainment of positive adaptation within the context of significant adversity - often referred to as *resilience* – is therefore a crucial capacity to manage the negative effects on psychological and physical health[31].

20. Neuro-physiological pathways of the stress response

Psychological stressors are linked with the activation of two main neuro-physiological pathways, which are involved in the maintenance of homeostasis: the **hypothalamic-pituitary-adrenocortical**

[31] McEwen, B. S., Gray, J. D., & Nasca, C. (2015). Recognizing resilience: Learning from the effects of stress on the brain. Neurobiology of stress, 1, 1-11.

(HPA) axis and the **sympathetic-adrenal medullary system (SAM)**[32]. These same stress pathways in brain are now recognised as critical players in the onset and maintenance of mental disorders[33]. The concurrent activation of HPA and SAM results in a set of behavioural (i.e., increased excitement, vigilance, focus and general reactivity) as well as physiological adaptations (i.e., reallocation of energy to overcome real or anticipated stressors perceived during stress response) that enable the body to respond to the unpredictable aversive experiences:

- *Sympathetic-adrenal medullary system in a stress reaction*: The response to a short-term (acute) stressor is a reaction by the type of "fight or flight" and is based on the activation of the sympathetic branch of the autonomous nervous system, which then stimulate the release of norepinephrine from sympathetic nerve terminals and epinephrine from the adrenal medulla. Plasma levels of norepinephrine and epinephrine have been utilised as an index of SAM activity under basal conditions and following exposure to stress (McCarty, 2016). These catecholamines activate defence behaviour patterns, with increased aggressiveness, and have a stimulating effect on the cardiovascular and respiratory systems, with the inhibition of the gastrointestinal tract function, which allows for the re-distribution of blood from the gastrointestinal system to the muscular system and brain. The increased amount of catecholamine in stress situations stimulate lipolysis and glycogenolysis, thus increasing plasma concentrations of glucose and fat acids, basic fuels for the body. These types of reactions are significant for the purpose of survival and protection of the body from various physical factors that represent a risk for the body as a whole.
- *Hypothalamic-pituitary-adrenal axis in a stress reaction*: A somewhat slower, second response during a stress reaction is an increased activity of the so-called HPA (hypothalamic-pituitary-adrenal) axis. On the hypothalamic level, the stressors activate the secretion of the CRH and AVP as a synergist with the CRH. The CRH and AVP secretion to pituitary blood vessels brings about the release of ACTH from the pituitary gland frontal lobe into peripheral circulation. Through circulation, the ACTH travels to adrenal cells where it stimulates the synthesis and secretion of glucocorticoids. The ultimate effect of the HPA axis activation is the domination of catabolic processes in the body, in order to render available to the body enough energy substrates, with the aim of meeting the increased need of the body at a moment important for its survival. Actually, the high plasma concentration of cortisol stimulates gluconeogenesis in the liver and produces insulin resistance of peripheral tissues, while the increased secretion of adrenalin and noradrenalin stimulates glycogenolysis and lipolysis. Glucocorticoids play a rather important role in controlling the stress response duration, the negative feedback mechanism,

[32] Sawchenko, P. E., Li, H. Y., & Ericsson, A. (2000). Circuits and mechanisms governing hypothalamic responses to stress: a tale of two paradigms. Progress in brain research, 122, 61-80.
[33] McCarthy, C., Pradhan, N., Redpath, C., & Adler, A. (2016, May). Validation of the Empatica E4 wristband. In 2016 ieee embs international student conference (isc) (pp. 1-4). IEEE.

which aims to minimise catabolic, lipolytic, antireproductive and immunosuppressive effects of stress reactions.

21. Bio-physiological markers of the stress response

The HPA and SAM systems of stress results in several biochemical markers of stress, the prevalence of which, such as epinephrine and norepinephrine, are typically measured with blood assays; however, these can be problematic due to the invasive nature of sample collection and associated risks, along with poor compliance rates among subjects where blood collection is undesirable and difficult. Thus, in the following we will focus on key stress biomarkers that which can eventually be detected by means of wearable sensors.

3.12.1.1 Cortisol

Cortisol is currently considered the gold standard for evaluating the activity of the HPA axis[34] (Ali & Nater, 2020). Glucocorticoids are responsible for reallocation of energy to overcome real or anticipated stressors perceived during stress response. Cortisol synthesis and release are controlled by adrenocorticotropic hormone (ACTH), which is regulated by the levels of corticotropin-releasing hormone (CRH) by the hypothalamus. Cortisol fluctuates cyclically with the circadian rhythm, with concentrations peaking in the morning and decreasing throughout the 12-h day. Cortisol binds to intracellular receptors to reduce inflammation, maintain blood pressure, suppress the immune system, and manage stress. Cortisol is present in blood, saliva, sweat, urine, and cerebrospinal fluid. Especially, saliva and sweat are currently researched for stress devices because of their reliability and ease-of collection[35].

3.12.1.2 Heart rate variability

With respect to the SAM system, heart rate variability (HRV), defined as the variation over time of the period between consecutive heartbeats, is increasingly regarded as a potentially convenient and non-invasive marker of autonomic activation associated with psychological stressors in ambulatory settings[36]. The normal variability in heart rate (HR) is controlled by the balancing activation of the (acceleratory) sympathetic and of the (deceleratory) parasympathetic branches of the autonomic

[34] Ali, N., & Nater, U. M. (2020). Salivary alpha-amylase as a biomarker of stress in behavioral medicine. International Journal of Behavioral Medicine, 1-6.
[35] Choi, J., & Gutierrez-Osuna, R. (2009). Using heart rate monitors to detect mental stress. In 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks(pp. 219-223). IEEE.
[36] Kimhy, D., Delespaul, P., Ahn, H., Cai, S., Shikhman, M., Lieberman, J. A., ... & Sloan, R. P. (2010). Concurrent measurement of "real-world" stress and arousal in individuals with psychosis: assessing the feasibility and validity of a novel methodology. *Schizophrenia bulletin*, *36*(6), 1131-1139. Melillo, P., Bracale, M., & Pecchia, L. (2011). Nonlinear Heart Rate Variability features for real-life stress detection. Case study: students under stress due to university examination. Biomedical engineering online, 10(1), 96.

nervous system. However, under stressful events or contexts, there is a trend towards increased sympathetic control and reduced vagal tone, which is associated with decreased HRV[37]. On the other hand, higher HRV has been associated with the availability of context- and goal-based control of emotions[38]. Based on this preliminary evidence, several authors have been experimenting with wearable heart monitors for the identification of stress levels from HRV, in both healthy and clinical populations[39]. Kim and coll[40] used HRV patterns to discriminate between subjects reporting high and low levels of stress during the day, achieving an overall accuracy of 66.1%. In a similar study, Melillo et al.[41] compared within-subject variations of short-term HRV measures using short-term ECG recording in students undergoing university examination. By applying Linear Discriminant Analysis on nonlinear features of HRV for automatic stress detection, these authors were able to obtain a total classification accuracy of 90%. Kimhy et al.[42] investigated the relationship between stress and cardiac autonomic regulation in a sample of psychotic patients, using experience sampling in combination with cardiac monitoring. These authors found that momentary increases of stress were significantly associated with increase in sympathovagal balance and parasympathetic withdrawal. Cinaz et al.[43] proposed an adaptive system for stress recognition from physiological features based on subjective ratings of perceived mental workload. They measured participants' sympathetic and parasympathetic responses during three different levels of mental workload (low, medium, and high) in a controlled laboratory setting. Then, it was investigated whether the data collected in this calibration session were appropriate to discriminate corresponding workload levels occurred during office work. To this end, individual HRV responses of each workload level were used to train the models and test the trained models on the data collected while the subjects performed normal office-work, using a mobile ECG logger. A multiple regression analysis was applied to model the relationship between relevant HRV features and the

[37] Berntson, G. G., & Cacioppo, J. T. (2004). Heart rate variability: Stress and psychiatric conditions. *Dynamic electrocardiography*, 57-64

[38] Thayer, J. F., Åhs, F., Fredrikson, M., Sollers III, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*(2), 747-756

[39] Healey, J. A., & Picard, R. W. (2005). Detecting stress during real-world driving tasks using physiological sensors. IEEE Transactions on intelligent transportation systems, 6(2), 156-166. Kusserow, M., Amft, O., & Tröster, G. (2008, November). Analysis of heart stress response for a public talk assistant system. In European Conference on Ambient Intelligence (pp. 326-342). Springer, Berlin, Heidelberg.

[40] Kim, D., Seo, Y., Cho, J., & Cho, C. H. (2008, August). Detection of subjects with higher self-reporting stress scores using heart rate variability patterns during the day. In 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 682-685). IEEE.

[41] Melillo, P., Bracale, M., & Pecchia, L. (2011). Nonlinear Heart Rate Variability features for real-life stress detection. Case study: students under stress due to university examination. Biomedical engineering online, 10(1), 96.

[42] Kimhy, D., Delespaul, P., Ahn, H., Cai, S., Shikhman, M., Lieberman, J. A., ... & Sloan, R. P. (2010). Concurrent measurement of "real-world" stress and arousal in individuals with psychosis: assessing the feasibility and validity of a novel methodology. Schizophrenia bulletin, 36(6), 1131-1139

[43] Cinaz, B., Arnrich, B., La Marca, R., & Tröster, G. (2013). Monitoring of mental workload levels during an everyday life office-work scenario. Personal and ubiquitous computing, 17(2), 229-239.

subjective ratings of perceived workload. Resulting predictions were correct for six out of seven subjects (86%).

Despite these promising developments, continuous stress monitoring from HRV in everyday environments presents several challenges[44]. First, the system should be able to detect HRV changes using minimally-obtrusive ECG equipment, in order to reduce discomfort for the participant (which might constitute a source of stress in itself). Second, since physical activity influences HRV[45], it is necessary to discriminate effects of mental stress from those induced by physical movement.

22. The use of wearable biosensors for detecting stress

Biosensing systems consisting for the unobtrusive monitoring of physiological and behavioural signals of stress are continuously improving, also thanks to the increasing success of commercial "smart fitness" devices. These systems integrate sensors together with on-body signal conditioning and pre-elaboration, as well as the management of the energy consumption and wireless communication systems. Integrated wearable systems are able to transduce heart rate and electrocardiographic signals (ECG), surface electromyographic signals (sEMG), electrodermal response (EDR), respiratory values and arterial oxygen saturation, as well as gaze by means of hats embedded with cameras and processing devices. Moreover, modern tools like inertial platforms are inserted to infer human motion. Acquired information is correlated to obtain blood pressure, body temperature, hearth rate variability (HRV), CO2, thoracic impedance pneumographic values and activity plan. In the table below some of these commercial products are presented including the product name, description and key functional features. Devices like smart phones/watches are becoming increasingly common due to their applications in the sport/fitness and wellbeing domain. Contemporary wearables can be used to track steps and monitor other physical activities. Next, we provide a brief overview of research using commercial wearable devices that can be used to measure stress biomarkers, identify key characteristics, and outlines the challenges of using these tools in the emergency field.

23. Heart rate variability sensors for stress management

As mentioned above, wearable medical systems are an enabling technology for monitoring an individual's health condition on a continuous basis, giving relevant information back to the users and

[44] Choi, J., & Gutierrez-Osuna, R. (2009). Using heart rate monitors to detect mental stress. In 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks(pp. 219-223). IEEE.
[45] Bernardi, L., Valle, F., Coco, M., Calciati, A., & Sleight, P. (1996). Physical activity influences heart rate variability and very-low-frequency components in Holter electrocardiograms. Cardiovascular research, 32(2), 234-237.; Hautala, A. J., Karjalainen, J., Kiviniemi, A. M., Kinnunen, H., Makikallio, T. H., Huikuri, H. V., & Tulppo, M. P. (2010). Physical activity and heart rate variability measured simultaneously during waking hours. American Journal of Physiology-Heart and Circulatory Physiology, 298(3), H874-H880.

firing an alarm signal when an adverse condition occurs[46]. The commercial market of wearable technologies for physiological visualisation has more than anything else focused on sports performance and medical health monitoring, developing numerous products such as bracelets, personal watches, t-shirts, gloves, bands, mobile applications and tech devices for recording and performance feedback. These devices assess several parameters, including always heart rate variability ones. Their application can far exceed the conventional medical or sportive use due to their incomparability on clothing and accessories, allowing them to be operational and active without obstructing the rescuer's usual actions[47]. How can these technologies be a concrete supportive element for first responders? As already noted in the previous paragraphs, stressful situations can seriously compromise the detection of alarm signals during a crisis. Here follows a list of commercial wearable sensors measuring HRV and other parameters useful for stress management of first responders during crisis and emergency situations.

Table 3-23 Review of existing HRV-based stress detection devices

Device	Validated	Sensor type	Key functionalities	Cost
Vital Jacket **Cunha, Cunha, Pereira, Xavier, Ferreira & Meireles, 2010.**	**No**	**T-Shirt**	**Vital signs (ECG, temperature, respiration, movement/fall, posture, actigraphy, oxygen saturation, etc.)** **and psycho-social variables (panic button, medication delivery, activity habits, location). All vital variables are transmitted through wireless channels.**	**€399**

[46] Lymberis, A. (2003, September). Smart wearable systems for personalised health management: current R&D and future challenges. In *Proceedings of the 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (IEEE Cat. No. 03CH37439)* (Vol. 4, pp. 3716-3719). IEEE

[47] Lukowicz, P., Kirstein, T., & Tröster, G. (2004). Wearable systems for health care applications. Methods of information in medicine, 43(03), 232-238.

Device	Validated	Sensor type	Key functionalities	Cost
BioHarness™3.0	In progress Johnstone, Ford, Hughes, Watson & Garrett, 2012.	Three different application: on a module holder with standard ECG electrodes placed on the sternum, on a chest strap with module holder and on Zephyr's shirts.	Heart rate, breathing rate, Heart rate variability, posture, activity, peak acceleration, accelerometer, impact, explosiveness, peak force, body temperature, caloric burn, heart rate recovery, heart rate confidence, physiological load, physiological intensity, mechanical load, mechanical intensity, training load, training intensity, GPS speed, GPS distance, GPS elevation, SpO2. Measurements are sent to a mobile platform via Bluetooth	€170
Helo LX http://cert.ca/products/helo/	No	Smartwatch	Heart rate, blood pressure, body temperature, blood alcohol, blood sugar, breathing rate. It can be programmed to deliver an emergency message to others if the user is ill or injured.	€399
E4 Wristband McCarthy, Pradhan, Redpath & Adler, 2016.	No	Smartwatch	Blood pulse volume, HRV, 3-axis accelerometer for recording activity, electrodermal sensor to measure SNS's activity (related to stress, engagement and excitement), skin temperature. It can be connected to a mobile app and data stored in a cloud	€1440
Lief https://www.getlief.com/	No	Strap – Band	HRV and breath monitoring, Haptic engine, stress zones, lifestyle trends & personalised programs.	€255
Hexoskin https://www.hexoskin.com/	Yes Al Sayed, Vinches & Hallé, 2017.	T-Shirt	ECG and heartbeat, (HRV), stress monitoring, effort, load and fatigue assessments, heart rate recovery, breathing rate, minute ventilation, activity intensity, peak acceleration & key metrics deliverable. Connection with health platform Hexoskin SDK for Android/IOS and allows to download raw data.	€495 - €144
Spire's Health Tag https://www.spirehealth.com/	Yes https://www.accessdata.fda.gov/cdrh_docs/pdf19/K192952.pdf	Compact biosensor to attach on the existing clothing	Pulse rate (ECG), activity and step, respiratory effort (EtCO2). Increase well-being behaviour, de-crease stress and create a sleep routine.	€41

Device	Validated	Sensor type	Key functionalities	Cost
HeartMath emWave 2 https://store.heartmath.com/tech/?_ga=2.111273862.300114552.1601981807-1409777628.1601981807	No	Hand Held device	Heart rate variability, reduce stress, improve sleep, balance emotions, restore energy and increase focus.	€169
Apple Watch https://www.apple.com/healthcare/apple-watch/	Yes Hernando, Roca, Sancho, Alesanco & Bailón, 2018.	Smart watch	Heart rate variability, ECG app, health records, Fall detection also blood saturation	€338
StressEraser Pro http://www.stresseraserpro.com/how-does-stresseraser-pro-work	No	Compact biosensor to connect with Smartphone	Heart rate variability, stress level, emotional system, HRV biofeedback tool training.	€159
MindMedia NexUs 10 https://www.mindmedia.com/en/products/nexus-10-mkii/	Yes Askarian, Jung & Chong, 2019.	Hand Held Device	4 channel ECG or muscle tension (sMEG), 4 additional channels for peripheral signals like heart rate, relative blood flow, skin conductance, respiration, temperature, EEG, EMG, pulse, respiration, temperature, skin conductance, sPO2, accelerometer & force.	Only on request

24. Salivary sensors

Despite salivary detection methods not being suitable for wearable stress monitoring solutions, they may hold a potential when used in point-of-care applications. For example, Liu et al. have described a portable salivary cortisol detection to assess the stress level. The device features a portable differential pulse voltammetry (DVP) system functionalised via anti-cortisol antibodies being linked to a gold nanoparticle electrode surface. An individual with this system can initiate a cortisol reading through the application, which then communicates to the DVP system to start a scan, which in turn relays the cortisol concentration back to the application via Bluetooth. The miniaturised portable DPV system was tested for human salivary cortisol detection. A series current response of different cortisol concentrations decreased and exhibited a linear range of 0.5–200 nM, the detection limit of 0.11 nM, and high sensitivity of 30 μA M^{-1} (Liu et al., 2020). According to the authors, these findings suggest an appropriate performance of the smartphone-based immunosensor system and its potential application

for non-invasive human salivary cortisol detection at POC (Liu et al., 2020). However, it should be noted that although this type of system features a wireless connection to the smartphone and has the advantage of being portable, it does not allow for real-time analysis of stress. Research into salivary alpha-amylase for stress assessment is also being done and a prototype for handheld monitoring has been created. Given that salivary alpha amylase does not fluctuate with the circadian rhythm, as cortisol does, more emphasis on this area may be seen in the future.

25. Sweat sensors

Sweat can provide a number of physiological information, but so far its use has been limited due to technological limitations. However, in recent years significant progress has been made to overcome these limitations and wearable sweat sensors research and development has increased. The assay used to validate the devices for cortisol analysis is the enzyme-linked immunosorbent assay (ELISA), which is an immunological assay commonly used to measure antibodies, antigens, proteins and glycoproteins in biological samples. Electrochemical detection methods are used to transduce biological signals into electrical ones through functionalised electrodes[48]. Figure 3-11 shows the wearable device "CortiWatch" developed by Rice et al.[49] that uses alpha-cortisol antibody-antigen detection as the functional sensor of chronoamperometric cortisol sensing unit. The working electrode was fabricated by immobilising alpha cortisol antibodies onto a gold electrode surface, which was circuited to a potentiostatic robust circuit board to collect data[50]. While this device is wearable with all electronics housed in a 3D printed box, as shown in the figure, it does not conform perfectly to the skin surface, which can leave gaps in sample collection and analysis. Another flexible wrist-worn device has been developed by Kinnamon et al.[51] that overcomes this dilemma by integrating a flexible electrode system into their device. The electrode system contains molybdenum disulphide nanosheets functionalised with alpha-cortisol antibodies that allow for a dynamic sensing range of 1–500 ng/mL. This system also shows the ability to perform real-time analysis of cortisol, given that it takes only 3 min to perform a full frequency sweep for analysis.[52]

[48] Choi, J., & Gutierrez-Osuna, R. (2009). Using heart rate monitors to detect mental stress. In 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks(pp. 219-223). IEEE.
[49] Rice, P., Upasham, S., Jagannath, B., Manuel, R., Pali, M., & Prasad, S. (2019). CortiWatch: watch-based cortisol tracker. Future science OA, 5(9), FSO416.
[50] Rice, P., Upasham, S., Jagannath, B., Manuel, R., Pali, M., & Prasad, S. (2019). CortiWatch: watch-based cortisol tracker. Future science OA, 5(9), FSO416.
[51] Kinnamon, D., Ghanta, R., Lin, K. C., Muthukumar, S., & Prasad, S. (2017). Portable biosensor for monitoring cortisol in low-volume perspired human sweat. Scientific reports, 7(1), 1-13.
[52] Kinnamon, D., Ghanta, R., Lin, K. C., Muthukumar, S., & Prasad, S. (2017). Portable biosensor for monitoring cortisol in low-volume perspired human sweat. Scientific reports, 7(1), 1-13.

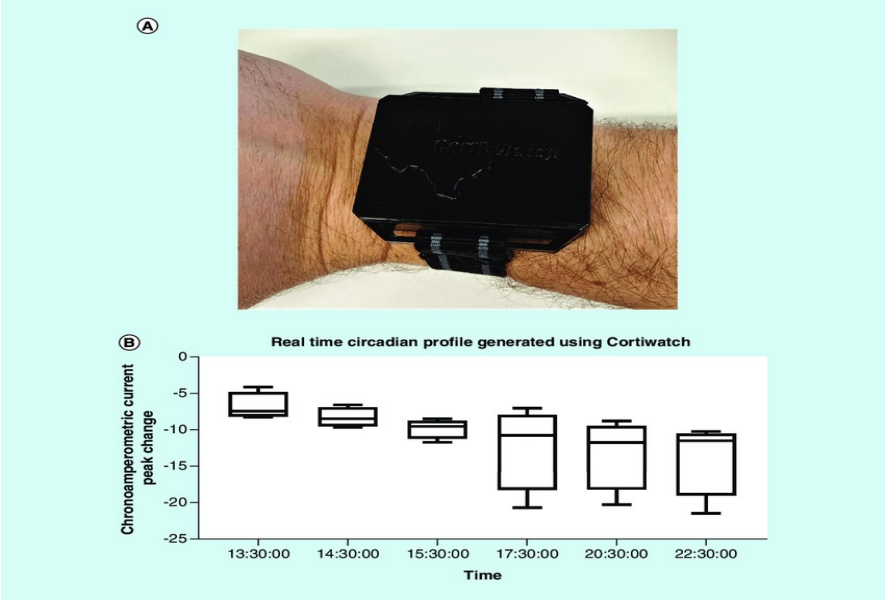

Figure 3-11 Example of wearable cortisol tracker: CortiWatch. The illustration also depicts real-time circadian profile for human participant generated using CortiWatch for a 9 h time period (Rice et al., 2019)

A recent review by Zamkah and coll. (2020)[53] has examined the current state of the art in the understanding of biomarkers present in sweat under stress events. Specifically, these authors present the most recent electrochemical sweat markers and skin VOC studies to hypothesise potential stress biomarkers for future affective technology sensors. The following table (Table 3-24) summarises and adapts the key indications resulting from this review.

Table 3-24 Summary of stress biomarkers from the sweat or skin, methods used to measure them, places flexibility, wearable device availability, and potential devices for future works [adapted from: Zamkah and coll. (2020)].

Biomarkers	Methods	Place	Wearable available	Potential device
Cortisol	Antibodies, aptamers, e-nose, and the molecularly selective organic electrochemical	Eccrine glands (antibodies, aptamers and MIPs) Apocrine (e-nose)	Wrist band + patch	E-nose + Flexible

[53] Zamkah, A., Hui, T., Andrews, S., Dey, N., Shi, F., & Sherratt, R. S. (2020). Identification of suitable biomarkers for stress and emotion detection for future personal affective wearable sensors. Biosensors, 10(4), 40.

Biomarkers	Methods	Place	Wearable available	Potential device
	transistor			
Cortisol metabolites	In labs only	Eccrine glands	No	Flexible
Stress antihormones	Zn+ ions	Eccrine glands	No	Flexible
VOCs i. benzoic acid, n-decanoic acid, a xylene isomer, and 3-carene ii. 1,2-Ethanediol Acetophenone Heptadecane Hexanedioic acid, dimethyl ester Benzyl alcohol Benzothiazole	Lab (GC/MS)	i. Eccrine glands (or skin) (forehead) ii. Underarms skin or apocrine glands	No	E-nose/gas array sensors

Legend: VOC's, volatile organic components; MIP, molecularly imprinted polymer; GC/MS, gas chromatography–mass spectrometry.

As noted by these authors, antistress hormones are present in human biofluids during stress but utilising them as stress biomarkers is significantly under-researched. For example, the antistress hormone oxytocin has several functions and indeed a biosensor has been developed to detect it, but not in stress detection events. That might suggest utilising oxytocin as a stress biomarker in future studies. Additionally, because its presence in biofluid has been already confirmed, confirming its presence in stressful situations could be further investigated.

26. Portable biofeedback system for stress management

Commercial biofeedback devices, providing direct evidence of individuals' psychophysiological activation, can be used as tools for training stress reduction and management skills[54]. These direct feedbacks given within specific tasks, such as relaxation training or simulated stressful experiences, can enable people to acquire and improve self-regulation skills. Therefore, by using these tools not only for monitoring purposes in conventional use domains (such as sportive and medical health), people can train and learn to regulate their reactions and their psychological states, in order to achieve more awareness, hence more control on their actions and responses in several situations.

To date, biofeedback techniques are used to improve individuals' resilience to acute stressful situations, as well as negative emotional and mental stimuli: these tools are generally employed throughout specific training sessions, during or immediately after the simulation of stressful experiences, such as

[54] Yu, B., Funk, M., Hu, J., Wang, Q., & Feijs, L. (2018). Biofeedback for everyday stress management: a systematic review. Frontiers in ICT, 5, 23.

stressful work tasks[55], mentally challenging tasks[56], or negative multimedia stimuli[57], with the aim to improve users' awareness of their stress and find a better approach to reducing or moderating stress responses. To this purpose, several studies used some of the commercial biofeedback devices listed in Table 3-23, already available on the market, for stress reduction and management. More specifically, *emWave* was used in Lemaire[58] et al. (2011) and in Ratanasiripong[59] et al. works (2015); *StressEraser* was used in Lee and Finkelstein's study (2015); *Apple Watch* was used in Drayer and colleagues' work (2019); *Empatica E3 sensor,* comparable to *Empatica E4 wristband*, was employed in Gaggioli[60] et al. study (2014). In particular, the new paradigm of Interreality described in Gaggioli[61] and colleagues' work (2014), which integrates the use of biofeedback sensors with Virtual Reality technologies, has been demonstrated to be effective in reducing stress and empowering individuals' coping skills. With this regard, this paradigm could be exportable and applicable also to first responders' population: being strongly subjected to situations of crisis and acute stress, first responders could benefit from specific stress management and reduction training, integrating VR simulations with biofeedback. This kind of training could improve first responders' awareness of their situational stress and to actively train and increase their coping strategies and stress management skills within realistic simulations, able to faithfully reproduce the real emergencies and crises that they are called to manage in their working reality.

It should be noted that all sensors listed could be potentially used for training stress reduction and management skills, but within tasks specifically designed with this objective.

27. SWOT analysis

Strength: First responders work in extreme situations which can have repercussions on psychophysical activity in relation to the following factors[62]: individual health condition, fitness level, drugs, hydration

[55] Yokoyama, K., Ushida, J. I., Sugiura, Y., Mizuno, M., Mizuno, Y., & Takata, K. (2002). Heart rate indication using musical data. IEEE Transactions on biomedical engineering, 49(7), 729-733.

[56] Prinsloo, G. E., Derman, W. E., Lambert, M. I., & Rauch, H. L. (2013). The effect of a single session of short duration biofeedback-induced deep breathing on measures of heart rate variability during laboratory-induced cognitive stress: A pilot study. Applied psychophysiology and biofeedback, 38(2), 81-90.

[57] Goodie, J. L., & Larkin, K. T. (2006). Transfer of heart rate feedback training to reduce heart rate response to laboratory tasks. Applied psychophysiology and biofeedback, 31(3), 227-242.

[58] Lemaire, J. B., Wallace, J. E., Lewin, A. M., de Grood, J., & Schaefer, J. P. (2011). The effect of a biofeedback-based stress management tool on physician stress: a randomized controlled clinical trial. Open Medicine, 5(4), e154.

[59] Ratanasiripong, P., Kaewboonchoo, O., Ratanasiripong, N., Hanklang, S., & Chumchai, P. (2015). Biofeedback intervention for stress, anxiety, and depression among graduate students in public health nursing. Nursing research and practice, 2015.

[60] Gaggioli, A., Pallavicini, F., Morganti, L., Serino, S., Scaratti, C., Briguglio, M., et al. (2014). Experiential virtual scenarios with real-time monitoring (interreality) for the management of psychological stress: a block randomized controlled trial. J. Med. Internet Res. 16:e167. doi: 10.2196/jmir.3235

[61] Gaggioli, A., Pallavicini, F., Morganti, L., Serino, S., Scaratti, C., Briguglio, M., et al. (2014). Experiential virtual scenarios with real-time monitoring (interreality) for the management of psychological stress: a block randomized controlled trial. J. Med. Internet Res. 16:e167. doi: 10.2196/jmir.3235

[62] Seoane, F., Mohino-Herranz, I., Ferreira, J., Alvarez, L., Buendia, R., Ayllón, D., ... & Gil-Pita, R. (2014). Wearable biomedical measurement systems for assessment of mental stress of combatants in real time. Sensors, 14(4), 7120-7141.

level, work performed, high thermal environments and exposure to extreme dangers during emergency responses. Wearable sensors that can be interpreted by physical parameters fundamental for the understanding of stressful states in first responders; the most important vital signs to continuously monitor are: HR, BR, SpO2 and BT[63]. Thanks to the sensors it is possible to obtain more information and more detailed, with consequently better results and performances during operations, exposing first responders to situations of controlled stress and promptly intervening if altered. The sensors are non-intrusive, can be applied to different surfaces (T-shirts, bands, watches, boots, bracelets, headbands, glasses, helmets ...) and do not limit the normal actions performed by first responders despite wearing highly insulating protective clothing. Further, many wearable devices are already available as affordable and commercial tools on the market, with fairly contained costs.

Weaknesses: Despite the use of wearable technologies evolving both in quality and quantity, the market has focused more on products relating to sports performance and general health self-monitoring. There are few scientifically validated products, but to date none is specifically designed and implemented thinking to the peculiar needs of first responders.

Further, usability is another aspect to be considered: usability of wearable devices is normally intuitive and fluent, but it requires a change and addition of equipment, training and understanding of feedback data.

Opportunities: Emerging technologies open perspectives for new possibilities, thus leading to the development of new monitoring approaches to assess a person's health condition, which could be more accurate and focused with respect to the use situations. For example, by monitoring the types of tasks each first responder is sent to, communication centres can prevent subsequent high-stress tasks to the same first responder, protecting not only his psychophysiological conditions but also his performance. The intent is to give the officer time to process and reduce stress levels rather than switching between tasks that exceed his actual possibilities and resources. First responders have little or no control over dangerous situations and the environments in which they find themselves: therefore, wearable technology can help them regain some of it when it comes to their health.

Threats: Some aspects of construction, design and processing of hardware and software will travel hand in hand with technological development, in particular the limits so far have been found in: body detection techniques, context awareness, ease of use, energy autonomy, intelligent data processing and the interaction of artificial intelligences with subjects. From the production point of view, it would seem necessary to further study the conductive material, maintainability and connectivity[64]. More

[63] Buller, M. J., Tharion, W. J., Cheuvront, S. N., Montain, S. J., Kenefick, R. W., Castellani, J., ... & Hoyt, R. W. (2013). Estimation of human core temperature from sequential heart rate observations. Physiological measurement, 34(7), 781.

[64] Lymberis, A., & Gatzoulis, L. (2006, August). Wearable health systems: from smart technologies to real applications. In 2006 International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 6789-6792). IEEE.

research is needed in the signal processing to ensure high signal quality during wearer's activity, and smarter algorithms are also needed to correlate and interpret data from multiple sensors.

4 Analysis of current SAR Equipment, limitations and potential improvements

4.1 Limitations, gaps and future needs on the SAR technologies for the early location of entrapped victims

SnR will work on defining a clear inventory of best practices, and existing equipment would help assessing the (fragmented) situation and facilitate the exchange of information between stakeholders. This will also be mapped to a semantic knowledge base that can support modelling and planning for scenarios under the SAR methodology.

One of the operational goals of this subchapter is to bridge the gap between the technologies that first responders have access to in the field now - and those that are already on the market or will be available in the near future.

The limitations and gaps of current technologies can be traced in the following tables. Similarly, the tables also contain technological solutions for the future needs of users to overcome current technical deficiencies.

Each table will be followed by a short comment that clearly outlines the technical boundaries of the proposed solutions.

Existing resource for SAR	Limitations	Gaps	Future needs
K-9 Unit (Dogs)	Limited number of K-9 units specifically trained for SAR compared to the operational needs of the multitude and complexity of the disaster typology; A limited capacity for resistance to fatigue and nervous tension, which leads to a reduction in the ability to sniff after more than an hour of searching; Variation in performance depending on the dog breed; Effects of "heavy" environmental conditions (humidity, dust, heat etc) on K-9 Units.	High vulnerability of K-9 dogs to unexpected toxic emissions; High vulnerability of K-9 dogs to the collapse of structural elements of buildings due to secondary shocks; Inadequate K-9 dogs protective equipment, which limits their physical abilities; Dogs K-9 is not expendable.	A portable Membrane Inlet Mass Spectrometer (MIMS) that can mimic K-9 dogs sniffing for the early location of entrapped people under the ruins ("chemical pattern of life") or people with disabilities that cannot communicate with the rescuer, such as people with speech, hearing or cognitive impairment.

Table 4-1 Summary of information for the module: K-9 Dogs

The portable SAR artificial sniffing tool will be developed, capable of measuring critical volatiles in the field, either for the early detection of toxic environments or for the localisation of entrapped victims. Variants on the use of RESCUE MIMS mounted on robots or UAVs will also be analysed.

Table 4-2 Summary of information for the module: Thermal Cameras

Type of existing SAR technology	Limitations	Gaps	Future needs

Thermal cameras	If other heat sources are present e.g. fire spot under ruins, it creates false-alarms; Temperature differences cannot be seen through obstructions.	These devices are not incorporated in the first responder's equipment, they must be handled manually, which makes it difficult for rescuers to work in difficult weather conditions or when the smoke generated by the disaster is very persistent in the intervention area.	Smoke-diver AR helmet: aiding fire-divers through their smoke diving SAR missions.

Table 4-3 Summary of information for the module: Acoustic technologies

Type of existing SAR technology	Limitations	Gaps	Future needs
Acoustic technologies	The presence of interfering signals which produce sound distortions; - Limited range of action; - Ineffectiveness in collapsed concrete and reinforced concrete structures.	Acoustic technologies are limited for location of people with disabilities, such as speech or hearing impairment and unable to detect unconscious victims.	A portable Membrane Inlet Mass Spectrometer (MIMS) that can mimic K-9 dogs sniffing for the early location of entrapped people under the ruins ("chemical pattern of life") or people with disabilities that cannot communicate with the rescuer, such as people with speech, hearing or cognitive impairment. The portable Membrane Inlet Mass Spectrometer (MIMS) can be mounted on a robot platform or UAV.

Table 4-4 Summary of information for the module: Protective uniform for First Responder

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.

This module suggests the need for new protective clothing and advanced wearables for all First responders against multiple hazards.
In this regard, advance wearables will be developed for the convenience and safety of the first responders. This next generation wearables will be completely textile, so that can be totally embedded in the uniform of the first responder and first aid for kids devices.
All new equipment will be hands-free, ergonomically optimised and can be integrated to the protective clothing.
This will give to First Responders the ability to detect, monitor, and analyse passive and active threats and hazards at incident scenes in real time.
As well, provide them with the ability to remotely scan an incident scene for signs of life and decomposition to identify and locate casualties and fatalities.
This will be achieved with the design and implementation of a state-of-the-art uniform for the "Smart First Responder" featuring the monitoring systems described in the column" Future needs".
Moreover, one should highlight the need to design and make a prototype of an innovative children rescue system. In particular, it is important to provide them a device like a "baby carrying" for injured babies and kids able to protect them, monitoring life functions and giving first aid before arriving to the emergency hospital.

Table 4-5 Summary of information for the module: First aid device for kid

Type of existing SAR technology	Limitations	Gaps	Future needs

First aid for kid's devices	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.

The research, as specified previously in the objectives of the SnR project, proposes the prototyping of a first aid device for kids. The questionnaires showed that there is no specific device on the market, designed according to children needs, to be used during a disaster to carry young victims. For this reason, the benchmarking research has not only focused on devices used in the scenarios proposed by SnR, but also on devices, with different purposes, having as main users the children. Table 4-6 summarises the characteristics and limitations of these products, shown up in the questionnaires, in relation to the SnR objectives.

Table 4-6 Summary of information for the module: Helmet and goggles

Type of existing SAR technology	Limitations	Gaps	Future needs
Helmet and goggles	Headphones and goggles provide only the physical protection of the First Responder, not having mounted, for example, a device, such as a thermal chamber, to help the correct visualisation of the intervention area.	The lack of the environmental data received by the optical thermal camera is sent to the computing device hand held by the team leader via Wireless Communication.	- Special Glasses and Helmets using Advanced Augmented Reality technologies with see-thru and hands-free abilities which does not restrict the personnel's body movements when performing a simulation or in a real-life scenario; - Smoke-diver AR helmet: aiding fire-divers through their smoke diving SAR missions.

Table 4-7 Summary of information for the module: Chemical sensors

Type of existing SAR technology	Limitations	Gaps	Future needs
Chemical sensors	Chemical sensors must be worn manually or on a device, making the first responder's reaction difficult as an unexpected and sudden emanation of a toxic substance, gas, etc.	Lack of portable monitoring chemical sensor with VOC detection attached to the First Responder uniform.	Six gaze Monitor with VOC Detection attached on the First Responder uniform to provide First Responder protection from several chemical sensors allowing for greater threat detection such as toxic gases, oxygen deficiency and carbon dioxide.

Table 4-8 Summary of information for the module: ICT (Information and Communications Technology)

Type of existing SAR technology	Limitations	Gaps	Future needs
ICT (Information and Communications Technology)	- The communication system between the First Responder, the coordination centres, robotics, UAV or the people of the community affected by the disaster, local authorities, etc. it is excessively multi-storeyed, there is no direct and fast communication link between them; - Often, parts of this system do not work either due to disaster effects (physical destruction of equipment, variations in the electromagnetic field generated by the earthquake, etc.) or exceeding the system's ability to process a large amount of calls or information.	- Lack of an application for locating the victim, indicating the route of evacuation of persons and communication between and with rescue services; - Lack of a Data Aggregation, Analysis and Decision Support to all decision levels; - Lack of a Communications Interoperability framework to all levels of operations, multiple technologies and administrative levels; - A Command Centre software for visualisation information's from disaster scene. - A notification, warning and information system.	- Smart-phone / Tough-phone including emergency notification service for alerting civilians to evacuate an area pointing them to an appropriate gathering and exit point; - 3 D Mixed Command Centre software for situation analysis and impact assessment; - A (Voice) Communications Interoperability framework including data exchange (video, text, image, location); - An SAR Decision Support System; - A Situational Awareness Systems (Sensors and platforms).

The key objective of SnR is to develop and promote the underlying framework (interoperability amongst systems and equipment, training and awareness) so that responders at all levels of command have access, familiarise and evaluate how to deploy innovative solutions.

The DSS, as a support information system to the decision-making activities, can be considered as the brain of the Emergency Management System.

Initially, existing databases that contain data related to the objectives of the SnR proposal will be identified, analysed and searched, in order to establish efficient and effective ways of obtaining their content.

The task prior to the development of the DSS components will be the design of the mechanism responsible for the aggregation of the data/information coming from sources.

The DSS modules will be designed to address the following three levels of decision making in crisis situations:

- Strategic level (allocation of resources from different regional establishments, interoperability with different countries)
- Operational level (communication among organisations, planning and data warehousing, logistic models)
- Tactical level pertaining to field deployment (ambulance, field teams, EU modules, triage, communication protocols, transmission of medical patient data)

This goal will be achieved through the to estimate the number of expected victims/patients and of ambulance units demanded, network models to capture the resource flow and mathematical programmers to optimise the allocation of the resources.

The provided services will cover the following objectives:

1. Recommended (optimal) allocation of available EMS units to incidents, depending on estimated needs;
2. Recommended (optimal) allocation of patients to transport vehicles and first receivers (hospitals), based on given order of evacuation and triage results for present injuries;
3. Recommended (optimal) allocation of tasks to available actors on the field, given demand pre-defined by the field commander;
4. Estimation of expected casualties and demanded resources (EMS units), given historical data on emergency incident recordings;

A 3D Mixed Reality Command Centre will be developed with the purpose of visualising all relevant situational information to the decision makers as well as the proposed actions from the DSS. The Command Centre will visualise in 3D the building or the area of the incident and the current situation adding relevant information in the appropriate 3D coordinates.

Sensor and media information as video and images from drones as well as the condition of rescue units and victims will be also registered to the appropriate coordinates of the 3D model.

The systems and services mentioned above are to be introduced to SnR platform:

- Communication Systems;
- Situational Awareness Systems (Sensors and platforms);
- Mobile SAR Systems;
- Integrated planning / Command and Control Systems / Data fusion and visualisation solutions;
- Logistics and resource planning systems;
- Disaster Medicine systems;

The system architecture is a modularised blueprint for the platform's construction, detailing how the software and hardware components involved will be put together and subsequently deployed. The principal aim of the architecture is to facilitate the initial design and development of the platform, by providing detailed enumeration, specification, and means of validation that each of the components built, meets the needs of the other components, or actors, using them.

Table 4-9 Summary of information for the module: UAV (drones) and Rescue Robotics

#	Type of existing SAR technology	Limitations	Gaps	Future needs
1.	**UAV (drones)**	Quality of sensory data; Energy limitations; Information sharing.	Lack of AI features based on deep learning detection algorithms for SAR operations; Lack of UAVs with downward-pointing cameras to detect victims on the ground.	The drones with AI features based on deep learning detection algorithms for SAR operations; Network connectivity between UAVs and between UAV-Ground Station. Alternating periods of flights and periods of rest, or sending only a subset of the UAVs to accomplish certain tasks whilst the rest remains idle (recharging batteries for instance).
2.	**Rescue Robotics**	Rescuers' distrust in the use of information provided by robots; Ineffective use of built-in radars (current robots do not detect people perfectly), Overlaps with the rescue activity of rescuers.	Lack of a Laser Imaging Detection and Ranging (LIDAR) to generate precise 3D images; Lack of chemical sensors.	A portable Membrane Inlet Mass Spectrometer (MIMS) that can mimic K-9 dogs sniffing for the early location of entrapped people under the ruins ("chemical pattern of life") or people with disabilities that cannot communicate with the rescuer, such as people with speech, hearing or cognitive impairment.

4.2 Benchmarking of available commercial products

On the market, for every type of technology, there are a multitude of offers.

Respecting the norms of business ethics and deontology, there is not enough information accessible on the manufacturer's website to make an adequate comparison to other products, especially regarding the production costs and the starting price in negotiating the sale of such a technique.

Out of the 24 questionnaires from users, partners of private companies or voluntary services, some summaries were made regarding the standards of current technology that can be used in the design of new technologies that correspond to future needs in the field of R&D (see Table 4-10, Table 4-11, Table 4-12).

Table 4-10 Benchmarking of existing state-of-the art technologies for detecting chemicals

Technique	Advantages	Limitations
EN (electronic noses)	1. Simplicity 2. Fast response times 3. Portability 4. Inexpensive	1. Unstable results 2. Specificity issues
MS (mass spectrometers)	1. High sensitivity (low LODs) 2. High specificity 3. High mass range 4. High resolution 5. Real time measurements 6. Measurements' stability 7. Accuracy 8. Portability 9. Fast analysis times (s) 10. Qualitative and quantitative analysis 11. No sample preparation 12. Ability for MS/MS or MS^n (extra confirmation steps and elimination of false alarms)	1. Relatively high costs (purchase and maintenance)
IMS (ion mobility spectrometry)	1. Instrumental simplicity 2. Small size 3. Light weight 4. Robustness 5. Low-power consumption 6. Fast response times 7. High sensitivity	1. False positive alarms 2. Potential compounds' adsorption onto the IMS surfaces 3. Limited selectivity 4. Lack of performance in highly contaminated environments 5. Humidity, temperature, and composition of the sample may affect detector's response 6. Bureaucracy due to the integrated radioactive sources
GC (gas chromatography)	1. Accuracy 2. Couples with other analytical techniques	1. Long analysis times
IR (infrared spectroscopy)	1. Reliable and repeatable results 2. Qualitative analysis 3. Quantitative analysis 4. Non-invasive technique	1. Lack of flexibility 2. Indoor use
CRDS (cavity ring-down spectroscopy)	1. Real-time measurements 2. High sensitivity	1. Lack of selectivity
LIBS (laser-induced breakdown spectroscopy)	1. Direct analysis 2. Sensitivity 3. Non-destructive real time analysis No sample preparation	1. False positive alarms 2. Plasma conditions vary with the environmental conditions
Raman (spectroscopy)	1. No sample preparation requirements 2. Sensitive to homo-nuclear molecular bonds 3. Fully integrated threat libraries 4. Portability	1. Cannot be used for metals or alloys 2. Fluorescence of the sample background may lead to false negative alarms

Technique	Advantages	Limitations
	5. Non-destructive 6. Fast response times 7. Analysis through glass and polymer packaging	
THz spectroscopy	1. Penetrates though materials 2. Non-destructive 3. Many non-metallic or non-polar materials are transparent to THz	1. Limited penetration in high-water content or metal objects 2. Distance limitations
Fluorescence	1. Excellent signal-to-noise ratio	1. Limit due to linear intensity
Instruments based on various sensors (e.g. chemical, electrochemical, immunochemical, colorimetric, etc.)	1. Portability 2. Sensitivity 3. Reliability 4. Easy operation 5. Low LODs 6. Fast response times	
Flame spectrophotometry	1. Sensitivity	1. Small number of excited atoms 2. Sample interferences 3. Reproducibility
Nanotechnology	1. Extreme sensitivity 2. Rapid analysis 3. Selectivity 4. Small size 5. Accuracy	
TLC (thin-layer chromatography)	1. Simplicity 2. Sensitivity (high) 3. Low cost 4. Fast separation	1. Humidity and temperature effects on the sample
Enzyme based sensors	1. Simplicity 2. Specificity 3. Sensitivity 4. Low false positive or negative alarms 5. Speed of analysis	1. Lack of stand-off detection

Supplier	Model	Mass analyser	Mass range (m/z)	Power (W)	Weight (kg)
INFICON	HAPSITE® ER Chemical Identification System	Quadrupole	41-300	N/A	34
FLIR Systems Inc.	Griffin™ 824	Cylindrical ion trap	N/A	N/A	22.7
FLIR Systems Inc.	Griffin™ 844	Cylindrical ion trap	N/A	110-240 VAC	20
Purdue University	Mini 12	Rectilinear ion trap	N/A-900	50	15
Torion Technologies (recently acquired by PerkinElmer)	TRIDION™-9 GC-MS	Toroidal ion trap	45-500	80	14.5
University of Liverpool	SNIFFLES pre-prototype	Non-scanning linear ion trap	50-500	34	14
Torion Technologies (recently acquired by PerkinElmer)	GUARDION™-7 GC-MS	Toroidal ion trap	50-500	75	13
Purdue University	Mini S	Rectilinear ion trap	N/A-925	65	12
Purdue University	Mini 10	Rectilinear ion trap	N/A-550	70	10
BaySpec Inc.	Portability™	Linear ion trap	40-650	65	9.9
1st Detect	MMS-100™	Cylindrical ion trap	15-625	N/A	8
Purdue University	Mini 11	Rectilinear ion trap	N/A-2000	30	5
908devices	M908 ™	Microscale ion traps	55-400	N/A	2
Samyang Chemical Corp	Palm portable (without pump)	Quadrupole ion trap	45-300	5	1.5

Table 4-11 Benchmarking of mass spectrometry based portable instruments

Table 4-12 Benchmarking of UAVs

UAV	Size	Weight	Sensitivity to environmental conditions	Operating time	Mode of operation	Reference
3DR Solo Quadcopter	46 cm, height 25 cm	1.5 kg	- Payload: 500g with gimbal, camera and other accessories. - Max wind: 40km/h - Operating temperature: 0° C - 45° C GoPro HERO3+ or HERO4 camera	- From 20 to 25 min - Max Speed: 55 mph / 88.5 km/h - Require Wi-Fi	APM flight control software	(Dawdi et al., 2020)
Aibot X6 hexacopter	Length/ Width/ Height 1.05 x 1.05 x 0.45 m	3.4 kg	- Payload: 2.0 kg - Max wind: 36km/h - Operating temperature: -20° C - 40° C No camera Ultra-sonic sensors may not work in a proper way under certain conditions like above water, snow, high grass or trees.	- Max 20 min - Max Speed: 40 km/h	Manual Mode or Assisted Mode	(INACHUS project)

UAV	Size	Weight	Sensitivity to environmental conditions	Operating time	Mode of operation	Reference
			If there are obstacles above the Aibot X6 V2 or when flying indoor, it is preferred to use Manual Mode.			
DJI M100 quadrotor **Price: around $3000**	Diagonal Wheelbase 65 cm	From 2.355kg to 2.431kg	- Payload: 1 kg - Max wind 36 km/h - Operating Temperature -10°C - 40°C - Obstacle avoidance: 0.2 m to 20 m - No camera	- From 13 to 40 min - Max Speed: 79.2 km/h (no payload, no wind)	Master-and-Slave control Long-range remote controller: 5Km	(Mittal et al., 2019) (built in obstacle avoidance) (Ruiz-Espitia et al., 2018)
DJI Matrice 210 **Price: 9250$**	Diagonal Wheelbase 65 cm 643 mm	4.8kg	- Payload 1.34 KG - Max Wind: 12 m/s - Operating Temperature: -20° - 50° C - Obstacle sensing range: 0.7-30 m	- From 24min to 34min - Max Speed: From 61 to 81 k/h	Dual Remote Controller Mode	(Forssén et al., 2020)
DJI Inspire 1 **Price: 3620$**	Length/ Width/ Height 43.7 x 30.2 x 45.3 cm	2.845 kg (without gimbal and camera)	- Payload: 600g with gimbal and camera. - Wind: 36 km/h - Operating Temperature: -10° - 40° C - Ultrasonic Sensor Operating Range: (5-500 cm) (Non-absorbing material) - Camera: Zenmuse X3 optical camera - Max Transmitting Distance: 5 km	- Approx.: 18 min - Max Speed: 79 k/h	- Dual remote Controller mode	(Middleton et al., 2018)
DJI Matrice 600 Pro UAV **$5,699**	Diagonal Wheelbase: 1133 mm	10 kg	- Payload: 5.5 kg - Max Wind: 28.8 km/h - Operating Temperature: -10° C to 40° C - Supported different DJI Gimbals	- From 16 to 32 min. - Max Speed: 65 kph (no wind)	- Dual remote Controller mode	(Albanese et al., 2020)

4.3 Proposals

New SAR technologies must add value to SAR actions, being able to accept the requirements of users, for each type of technique, on the realisation of the following KPIs: ergonomic, power supply, size, weight, user interface characteristics, portability, sensitivity, low LODs, robustness and maintenance.

We propose that all the technologies mentioned in the "future needs" column of the tables mentioned in subchapter 2.1 be studied, analysed and developed in order to bring them to the market of technologies specific to the R&D field.

Based on this knowledge we discussed the most important technical features for the design of a general collective protective system. However, we must keep in mind that for different applications we can find numerous variations and that a process of design sophistication is needed if we want to address the users need in the best possible way. However, for the future we can expect progress in the following areas:

1) Standardisation of equipment;

2) Fielding of technology improvements;

3) Full integration into standard shelter systems.

5 Conclusions

"The right tools for the job" will reduce the time needed to recover casualties from collapsed structures. There have been substantial enhancements in the tools and systems available for the recovery of people from wrecked cars, and the time for specialist rescue tools is long overdue. The current state-of-the-art relies too much on adapted construction of civil engineering equipment. Using such tools in a USAR setting, places extreme physical demands on the rescuer, who tires rapidly and so needs to be constantly substituted to prevent exhaustion. This situation delays rescue and reduces the chances of survival. The weight and designs of the current generation of tools is critically limiting. For example, the current maximum lengths of power hoses associated with pneumatic equipment are too short to enable such tools to be used deep inside collapsed structures, and also too short to ensure that fumes and exhausts from the generators do not disrupt the USAR operations inside the rubble. Innovation in battery-driven systems and designs to give lighter tools is also needed. Enhanced designs and materials for tools that move, cut, break- and chip-reinforced concrete, brick and cladding without putting survivors' safety at risk and exhausting the rescuer will also reduce rescue times. Such systems, ideally, will have flexible functionality to adapt to different materials and thicknesses, as well as, enable drilling in the direction that is considered optimum (which may often mean drilling into overhead structures).

This is a rescuer's charter of priorities for more efficient USAR operations:

- Correct decision-making at the beginning at political level (clear picture of what has happened, scale of disaster, available resources inside the country, need for requesting help)
- Early detection and location
- Safety of rescuers
- Better concrete cutting tools
- Better logistics (detailed description of the tools needed, especially at the point of arrival)
- Better information and planning
- Tools that can be easily deployed
- Satellite support
- Collaboration among international rescue teams
- Adaptability of tools to events
- Fast transportation of rescue teams to the scene of disaster Improving situation awareness
- Accurate knowledge of the disaster scale
- Better use of existing technologies and methods
- Better training
- Context information
- Obtaining information from the media

Innovations and enhancements needed to create a new generation of rescue, need to be led in partnership with the manufacturers of rescue equipment. Currently, the supply chain and market for extrication tools is fragmented and, as noted above, mostly focused on tools used in building construction. Few companies have the knowledge and insight required to guide their inherent expertise to develop tools for USAR operations, and they will need to pay attention to the priorities of rescuers.

Although a number of mature and emerging technologies for USAR exist and have been proven in a variety of scenarios, not necessarily involving collapsed buildings, most approaches and systems have not been properly tested, validated nor proven in applications regarding collapsed structures. Methods for enhancing USAR systems' efficacy and reliability may be seen to be based on effective integration of complementary technologies onto a single platform.

Such an approach has the following advantages: provision of a fast overview of the location of voids and, potentially, victims; improvements in the accuracy and sensitivity through orthogonal sensing approaches; reduction of false alarm incidence rates; provision of flexibility in deployment, with a single deployment for multiple SAR responses; enabling technology-based responses to be combined with community input; provision of new applications and markets for existing technologies.

This deliverable argues for the need to design, produce and operate new protective clothing and advanced wearables for all first responders that protects against multiple hazards.

All this equipment will be hands-free, ergonomically optimised and can be integrated to the protective clothing. This feature allows First Responder to detect, monitor, and analyse passive and active threats and hazards at incident scenes in real time. Moreover, it provides First Responder with the ability to remotely scan an incident scene for signs of life and decomposition to identify and locate casualties and fatalities. This will be achieved with the design and implementation of a state of the art uniform for the "first responder of the future" featuring the following monitoring systems: Smart glasses, AR Helmets, Six Gas HAZMAT monitor, GPS Tracker, Smartwatch, Smart-phone / Tough-phone, Wearable monitoring systems embedded in the uniform of the first responder and first aid for children devices.

The needs of users are also directed towards the use of hand-held Rescue MIMS, and MIMS mounted on robots or UAVs. Another need is the creation of an R&D platform that integrates the necessary services for R&D teams in the area affected by a disaster, among which we mention, at a minimum, the following modules: Situation Awareness, ICT (Information and Communications Technology), Decision Support System (DSS), 3D Mixed Reality Command Centre and a (Voice) Communications Interoperability.

One of the key objectives of SnR is to develop and promote the underlying framework (interoperability amongst systems and equipment, training and awareness) so that responders at all levels of command have access, familiarise and evaluate how to deploy innovative solutions.

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Annex II: Nominal summary of received answers

No	Company	Evaluator	Product name
1	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	Ioannis Symeonidis	3D Mixed Reality Command Center
2	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	Ioannis Symeonidis	Emergency response health condition monitoring device
3	German Research Centre for Artificial Intelligence	Nikolas Müller	Rescue Robots & Autonomous vehicles
4	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Sabrina Scheuer	Savox Searchcam 3000
5	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Sabrina Scheuer	Sewerin Aquaphon A100
6	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	Model 676 MedKids Baby Board
7	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	Model 677 MedKids Paediatric Sleeve
8	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	Neomate Paediatric Resistant System
9	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	INX Incubator Transporter
10	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	Survival Capule SC2001
11	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	INPRO – Infant Protector
12	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Debora Giorgi	Incubator Interface
13	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Sabrina Scheuer	Haberkron Emergency rescue set
14	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Sabrina Scheuer	Motorola MTP3550
15	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Pia Ferner	PAUL the 'WaterBackpack'
16	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Pia Ferner	Clip CO detector
17	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Pia Ferner	Motorola MTH800
18	Johanniter Österreich Ausbildung und Forschung gemeinnützige GmbH	Pia Ferner	Motorola 1400/1600

No	Company	Evaluator	Product name
19	**Microsoft**	**Andrei-Madalin OANCA**	**Smart glasses and AR helmets HoloLens 2**
20	**National Technical University of Athens**	**Sofia Karma, Nick Panagiotou, Stamatis Giannoukos**	**Chemical sensors**
21	**National Technical University of Athens**	**Sofia Karma, Nick Panagiotou, Stamatis Giannoukos**	**Mass Spectrometry**
22	**Oculus**	**Andrei-Madalin OANCA**	**Smart glasses and AR helmets Oculus Quest**
23	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**LEADER SCAN**
24	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Thermal technique**
25	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Acoustic technique**
26	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Optical technique**
27	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Pneumatic powered tools**
28	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Hydraulic powered tools**
29	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Gasoline power tools**
30	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Electrical power tools**
31	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Heavy Rigging**
32	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Technical rope**
33	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Hand tools**
34	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Canine search equipment**
35	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Drone (UAV)**
36	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Emergency response health condition monitoring device**
37	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Detection equipment**
38	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Radiation equipment**
39	**POMPIERS DE L'URGENCE INTERNATIONALE**	**Philippe BESSON**	**Personal First Responders protective equipment**

No	Company	Evaluator	Product name
40	POMPIERS DE L'URGENCE INTERNATIONALE	Philippe BESSON	Decontamination technique
41	POMPIERS DE L'URGENCE INTERNATIONALE	Philippe BESSON	Chemical sensors
42	POMPIERS DE L'URGENCE INTERNATIONALE	Philippe BESSON	Communications technique
43	JOHANNITER DEUTSCHLAND	Svenja Bertram	Half-shell helmet
44	Romanian Inspectorate for Emergency Situations	Cosma Robin	BioRadar BR 402
45	Romanian Inspectorate for Emergency Situations	Cristi Rotariu	FLIR Griffin GC/MS G510
46	Stimpex	Stimpex	Hazmat technique Detection equipment Wireless, portable multi-threat monitor for radiation and chemical detection
47	Stimpex	Stimpex	Hazmat technique Detection equipment ChemPro100i
48	Stimpex	Stimpex	RAE System
49	Uhasselt	IMOB / Uhasselt	Multipurpose UAVs (drones)
50	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	Fire crossing suit
51	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	GAS-TIGHT NBC WATERPROOF SUIT
52	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	LENZING FR SUIT
53	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	TEXPORT GARMENTS
54	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	LION PROTECTS
55	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	VALLFIREST
56	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	HYDROCOSTUME WRS Polar Zipered ATP CE
57	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	OUTSHELL FIRE SERVICE
58	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	FIRE MAX 3
59	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	FIREFIGHTER CLOTHING Drager
60	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	CPS 5800
61	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	CPS 7800
62	UNIVERSITA DEGLI STUDI DI FIRENZE	Laura Giraldi, Marta Maini	Smart textile professional uniform
63	University of Cagliari (Italy)	Piero Cosseddu	Wearable Strain sensors

No	Company	Evaluator	Product name
64	University of Cagliari (Italy)	Danilo Pani, Annalisa Bonfigli	Wearable device for ECG and respiration monitoring
65	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Acoustic technique
66	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Optical technique
67	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Thermal technique
68	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Pneumatic powered tools
69	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Hydraulic powered tools
70	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Gasoline power tools
71	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Electrical power tools
72	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Technical rope
73	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Hand tools
74	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Emergency response health condition monitoring device
75	ELLINIKI OMADA DIASOSIS SOMATEIO (HRT)	Iosif Vourvachis	Communications technique
76	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Acoustic technique
77	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Optical technique
78	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Thermal technique
79	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Pneumatic powered tools
80	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Hydraulic powered tools
81	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Gasoline power tools
82	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Electrical power tools
83	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Heavy Rigging
84	Direccio Generale de Protecion Civil de Catalunia	Rosa Mata Frances	Communications technique
85	SOFTWARE IMAGINATION & VISION S.R.L (SIMAVI)	Gabriela Panzariuc	Smart glasses and AR helmets (HoloLens 2)
86	SOFTWARE IMAGINATION & VISION S.R.L (SIMAVI)	Gabriela Panzariuc	Smart glasses and AR helmets (Oculus Quest)
87	AIDEAS OÜ (AIDEAS)	Patrick	Rescue drones

No	Company	Evaluator	Product name
88	**UCSC**	**Andrea Gaggioli** **Alice Chirico** **Elena Gianotti**	**Biosensor of stress detection**

Annex III: SAR equipment[65]

Company: LEADER Scan[66]

1.Description of the technique from the current endowment:

The Leader SCAN sensors have Ultra Wide Band (UWB) technology allowing the scanning of the rubble surface in order to search for movements of conscious or unconscious victims up to 30m in free field. Leader SCAN detects even the smallest movements (respiratory or gestural movements) and displays their frequency to deduce whether it is a human life or not. AUTOMATIC search mode: automatically scans multiple areas to detect up to 7 living people; MANUAL search mode: selection of the search area manually and the minimum & maximum depth.

2.Strengths of the technique:

Easy to use, lightweight, carrying bag, screen visibility, wireless tablet reading, Control of the sensor from the box, Display of the movement detected at the depth detected, Real-time and Automatic modes, Selection of the depth, Strong or weak movement indicator, Oscillogram for the details of the movements, Data recording, Record replay, Right-handed mode / left-handed, Brightness adjustment, Charge level.

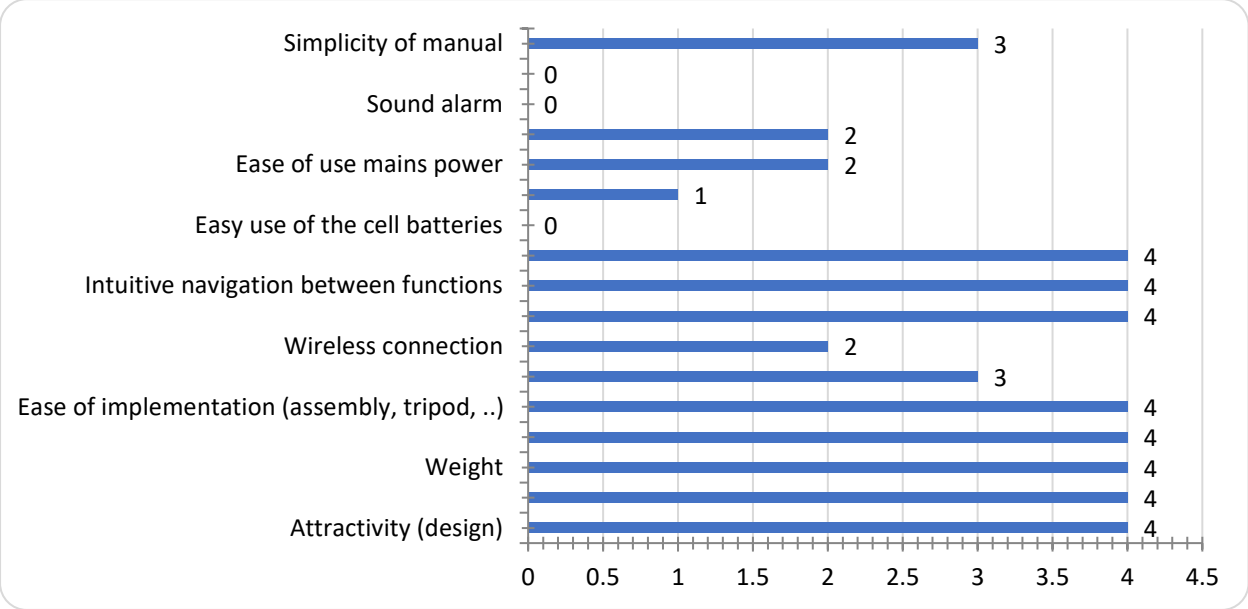
3.Weaknesses of the technique:

Functioning of the Wi-Fi signal, random results with false positives, influence of movements of moving materials (wind), risk of detection of other stakeholders, Wi-Fi signal quality.

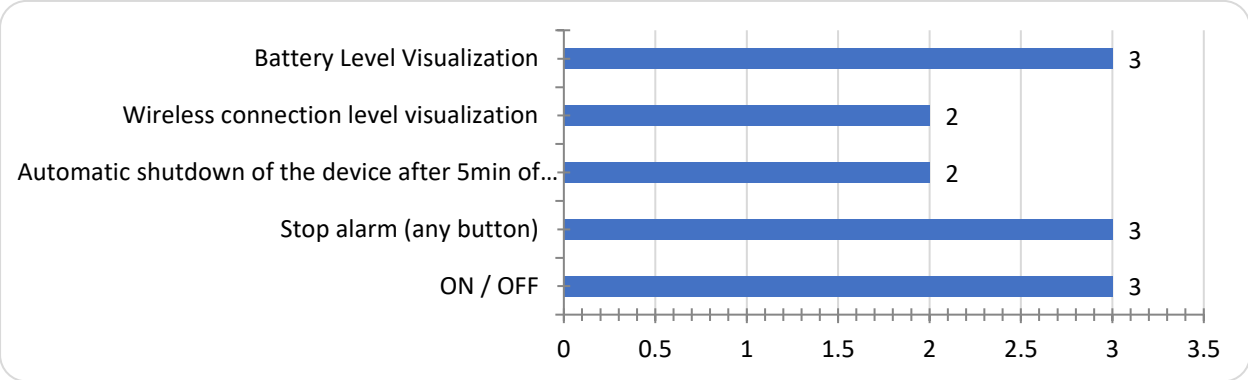
4.Benchmarking of available commercial products:

[65] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[66]Philippe BESSON

Ergonomics

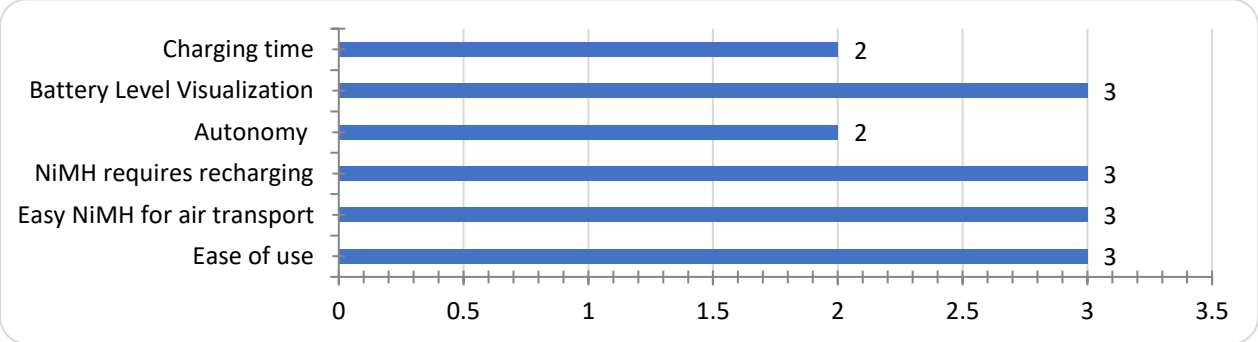


Functions



Wireless remote control: No wireless remote control

Rechargeable battery (external)



Company: BioRadar BR 402[67]

1.Description of the technique from the current endowment:

The BioRadar BR 402 is an high-tech equipment to detect and evaluate movements of creatures, in first order persons. The BioRadar can detect through all dielectrically materials, such as normal brick - or concrete construction, layers from sand debris, soil, snow up to a thickness of several meters.

Parts of metal (steel in concrete) may cause a loss of sensitivity of the BioRradar.

The equipment transmits radar waves, which are reflected by all things in front of it, received back and evaluated by the BioRadar. By this way all body moves, also breathing and heartbeat can be detected and evaluated.

By help of analysis of the received signals it is possible to prove with high probability the presence of living people in front of antenna.

Used by this equipment amount of radiation is fully harmless for all creatures because of its low power.

The only but necessary requirement for normal function of the system is good penetration performance for used radio waves through the material between antenna and person who is to be located.

2.Strengths of the technique:

Accordingly to described function following operation fields are possible:

- search for buried persons after disasters (rescue services)
- detection of hidden persons in cars and trucks (border control, transfer into and out of security areas)
- detection of movements in underground unmetallic channels and cavities
- detection of persons inside buildings from outside (building security)

3.Weaknesses of the technique:

Very weight: approx. 18 kg

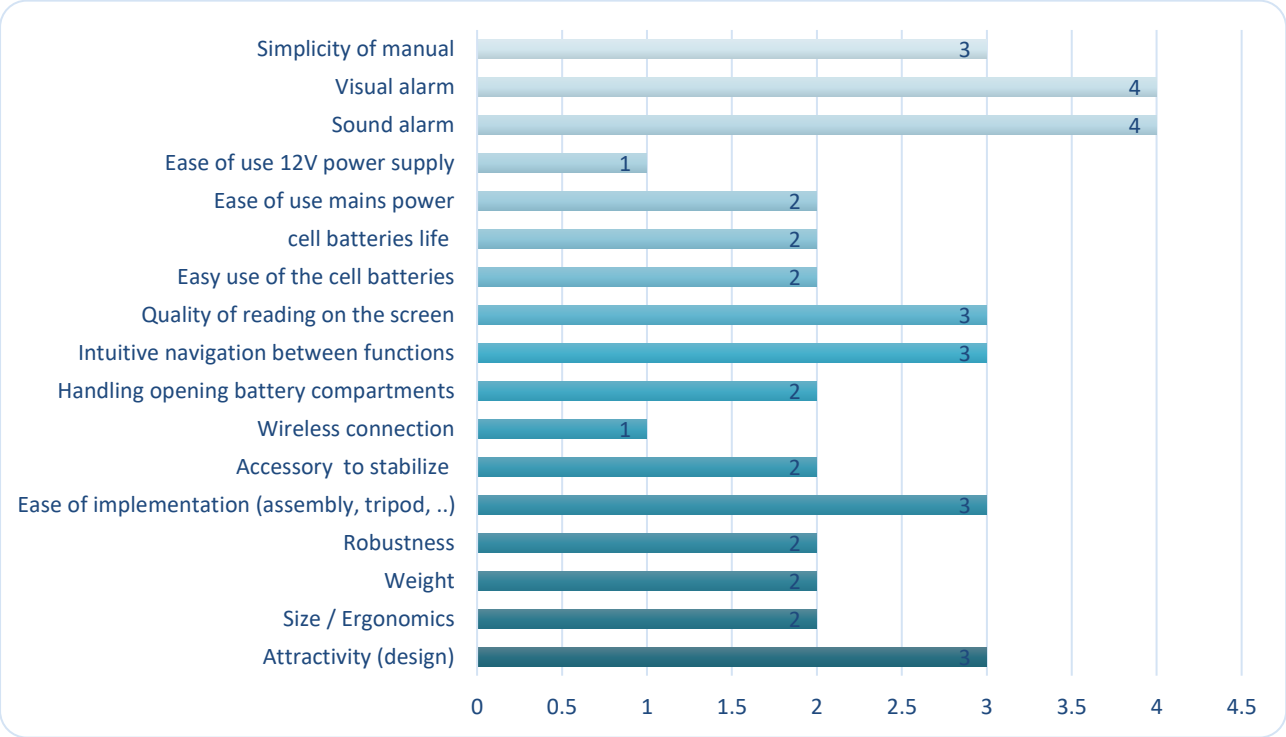
The equipment transmits radar waves, which are reflected by all things in front of it, received back and evaluated by the BioRadar, but does not know if it is a man under those rubble or a medium or large animal (a dog for example).

[67]Cosma Robin

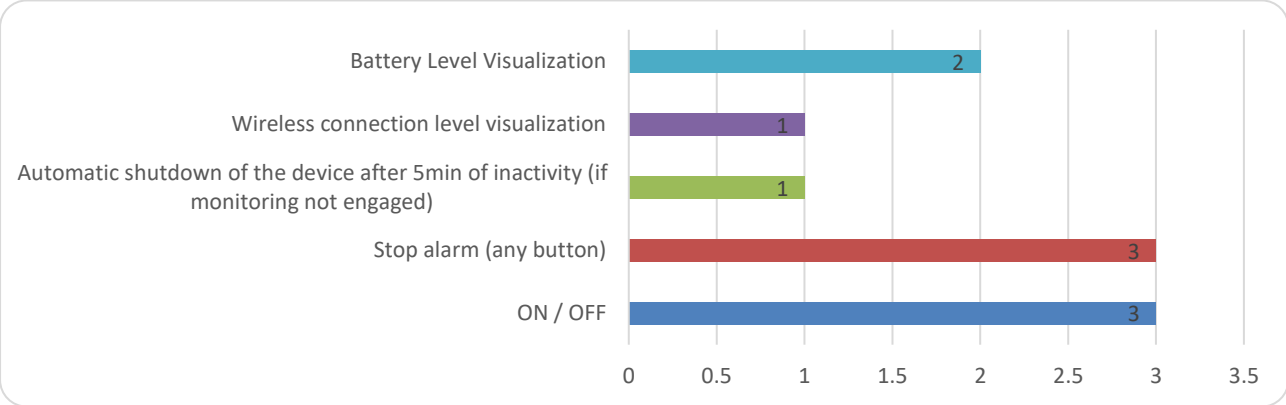
Battery capacity is not the best

4.Benchmarking of available commercial products:

Ergonomics

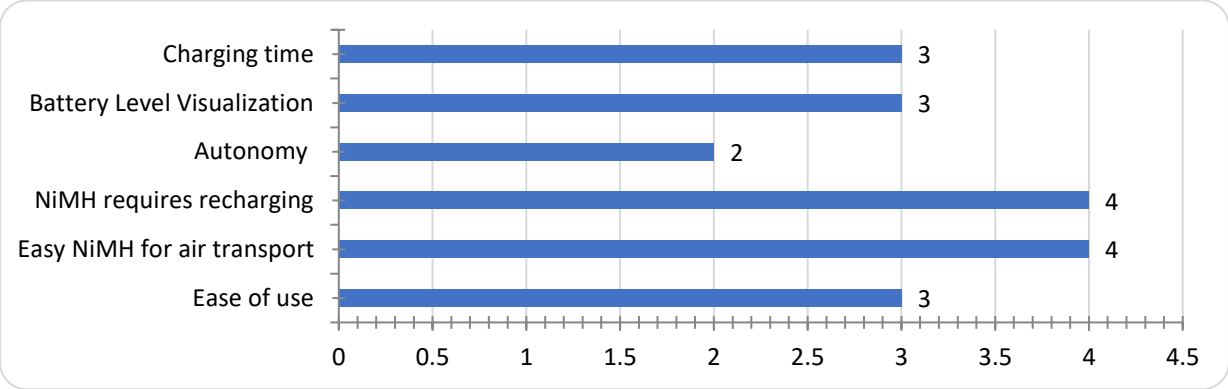


Functions



Wireless remote control: No wireless remote control

Rechargeable battery (external)



Company: Sewerin Aquaphon A100[68]

1.Description of the technique from the current endowment:

The AQUAPHON® system was developed for pipeline leakage search and supports and simplifies the detection process thanks to the outstanding quality of its microphone and measuring technology, intelligent analysis functions and the practical, visual representation of results on the display. This cutting-edge system offers comfortable, wireless handling, ease of use, versatility and a sturdy, ergonomic design. The AQUAPHON® system is ideal for both the pre-location and pinpointing of acoustic noise for confident excavation.

2.Strengths of the technique:

high protection class (IP67), Ear protection function, Filter optimisation, carrying strap or belt clipping, powerful rechargeable battery, different microphones for paved and unpaved ground, wireless headphones, noise visualisation, memory function,

3.Weaknesses of the technique:

not specifically developed for SAR operations, ear protection function settings required for optimal use, battery for microphone needed, 1m recommended measurement distance,

4.Benchmarking of available commercial products:

Ergonomics

Functions

Wireless remote control

Rechargeable battery (external)

[68]Sabrina Scheuer

Company: Savox Searchcam 3000[69]

1.Description of the technique from the current endowment

The SearchCam® 3000 VLS is modular and can be configured to meet the needs of any rescue situation. The 240 degree articulating camera with built in audio provides rescuers with the enhanced ability to see and communicate with trapped victims. The Camera Head with the Environmental Sleeve installed, can be submersed in water up to 75 feet (23 meters) deep. It records videos and takes photos which are saved to an SDHC card (included). These files can be uploaded to a computer for playback, archive and search review purposes. If an attempt for taking video or picture is made when the memory card is not present or if the memory card is full, "No Memory Card" icon will appear in the centre of the screen. A microphone in the camera head allows a two-way communication with the entrapped victim.

2.Strengths of the technique:

Excellent video quality and clarity, Versatile options: submersible, boom extension, rope drop head, Wide field of view, Piston grip provides convenient access to control buttons, Two-way communication, Quality headset, Carrying case: wheels, well-organised, Location of battery indicator

3.Weaknesses of the technique:

Heavy, Expensive, Reboot required for whole system when articulating head would "freeze up", Reboot required before use of audio system, Reboot required if contrast and brightness controls are engaged in the wrong sequence, Lengthy boot and shutdown time, Multiple power buttons, Inadequate spacing between controls and adjustment when using pistol grip with a gloved hand, Poorly designed monitor mount/display yoke, obstruction of articulation button, Cables not long enough for the pole when extended, Carrying strap: not heavy-duty, not padded, too narrow, did not balance camera well, Powered by lithium ion batteries only (no AC or DC power source capabilities).

4.Benchmarking of available commercial products:

Ergonomics

Functions

Wireless remote control

Rechargeable battery (external)

Company: FERNO[70]

[69]Sabrina Scheuer
[70]laura.giraldi@unifi.it,

1.Description of the technique from the current endowment:

Model 676 MedKids Baby Board[71]

Technical data sheet, picture of the product: The Medkids Baby Board makes neonatal and paediatric transportation safer. The Baby Board helps maintain cervical neutral alignment with the self-contained Pneumatic Positioning Device (PPD). Designed for pre-term neonates and larger infants ranging from 2 lb (1 kg) to 15 lb (7 kg).

2.Strengths of the technique:

Crescent-shaped head blocks secure cervical spines for too young children. The straps allow you to keep the baby safe.

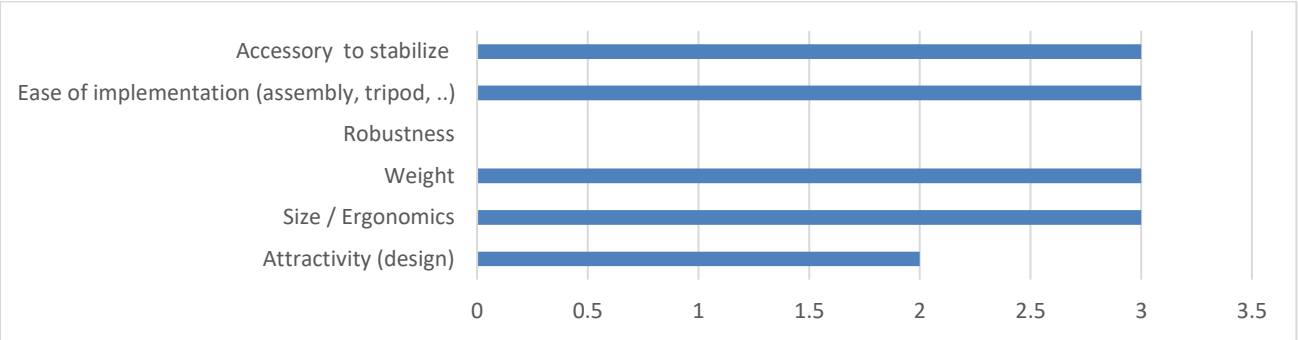
3.Weaknesses of the technique:

There are not elements for the communication of vital parameters.

At the moment the product is very bare and without adequate technology.

4.Benchmarking of available commercial products:

Ergonomics



Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABLE

Company: FERNO[72]

[71] https://fernoems.com/pediatric-immobilization/medkids-baby-board
[72] Laura.giraldi@unifi.it,

1.Description of the technique from the current endowment:

Model 677 MedKids Paediatric Sleeve[73]

Technical data sheet, picture of the product: The Medkids Pedi-Sleeve fits over standard adult backboards, adapting them for paediatric immobilisation for patients ranging from 12 lb to 60 lb. Repositionable, crescent-shaped compressible head blocks, restraint straps, and a self-contained Pneumatic Positioning Device (PPD) ensure patients are secure and fully immobilised.

2.Strengths of the technique:

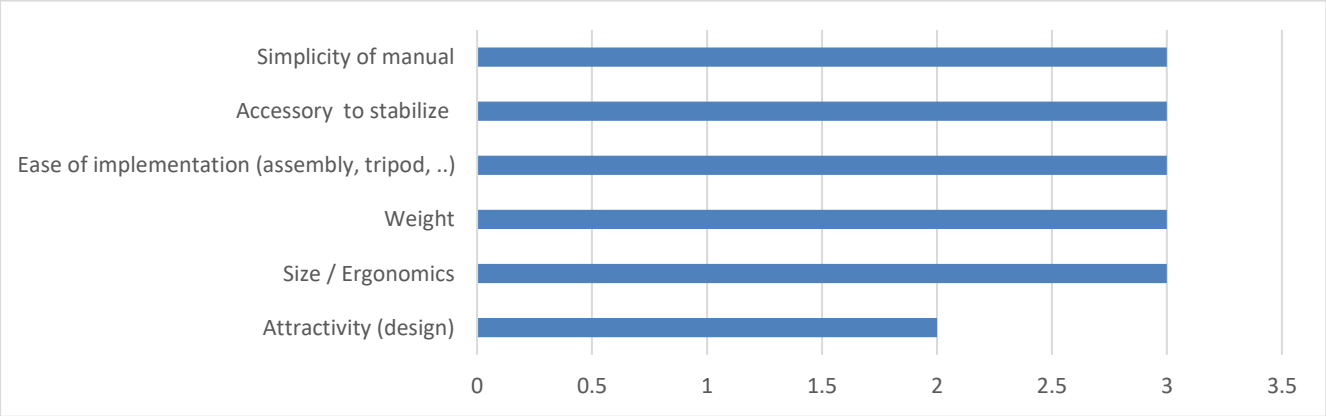
It wraps in a self-contained carrying case for storage in small compartments, drawers or under the seats. it is adaptable to traditional stretchers, allowing a fast rescue action

3.Weaknesses of the technique:

Disadvantages: there are not elements for the communication of vital parameters (as screen, LCD screen...). At the moment the product is very bare and without adequate technology.

4.Benchmarking of available commercial products:

Ergonomics



Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABL

Company: FERNO[74]

[73] https://fernoems.com/pediatric-immobilization/model-677-medkids-pedi-sleeve
[74]laura.giraldi@unifi.it,

1.Description of the technique from the current endowment:

NeoMate Paediatric Restraint System[75]

Technical data sheet, picture of the product: The NeoMate Paediatric Restraint System, designed for paediatric patients ranging in size from 5-14 lb (2.3-6 kg), provides a quick and efficient way to safely secure young patients to almost any cot without having to purchase additional equipment or specialised seats.

2.Strengths of the technique:

Vinyl construction is nontoxic and easy-to-clean.

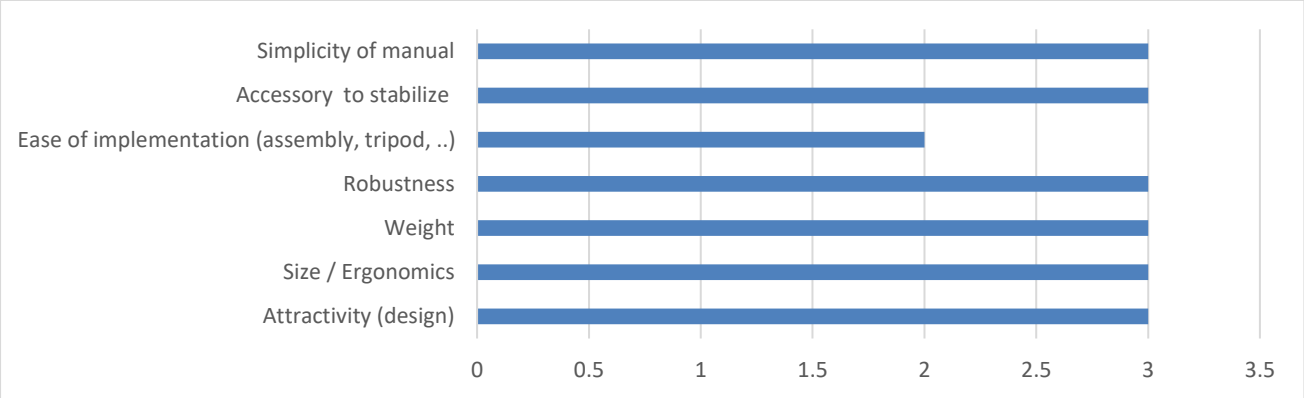
The padding of the product allows the comfort of the child.

3.Weaknesses of the technique:

There are not elements for the communication of vital parameters. Vinyl is an unsustainable material, despite its excellent properties.

4.Benchmarking of available commercial products:

Ergonomics



Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABLE

Company: FERNO[76]

1.Description of the technique from the current endowment:

[75] https://fernoems.com/pediatric-restraints/neomate-pediatric-restraint-system
[76]laura.giraldi@unifi.it, t

iNX Incubator Transporter[77]

Technical data sheet, picture of the product: iNX incubator transporter offers industry leading safety for both patient and operator during neonatal transport. With a flat surface at all heights and dual powered actuators that maximise stability, the iNX IT is up to the difficult task of transporting new-born patients as safely as possible

2.Strengths of the technique:

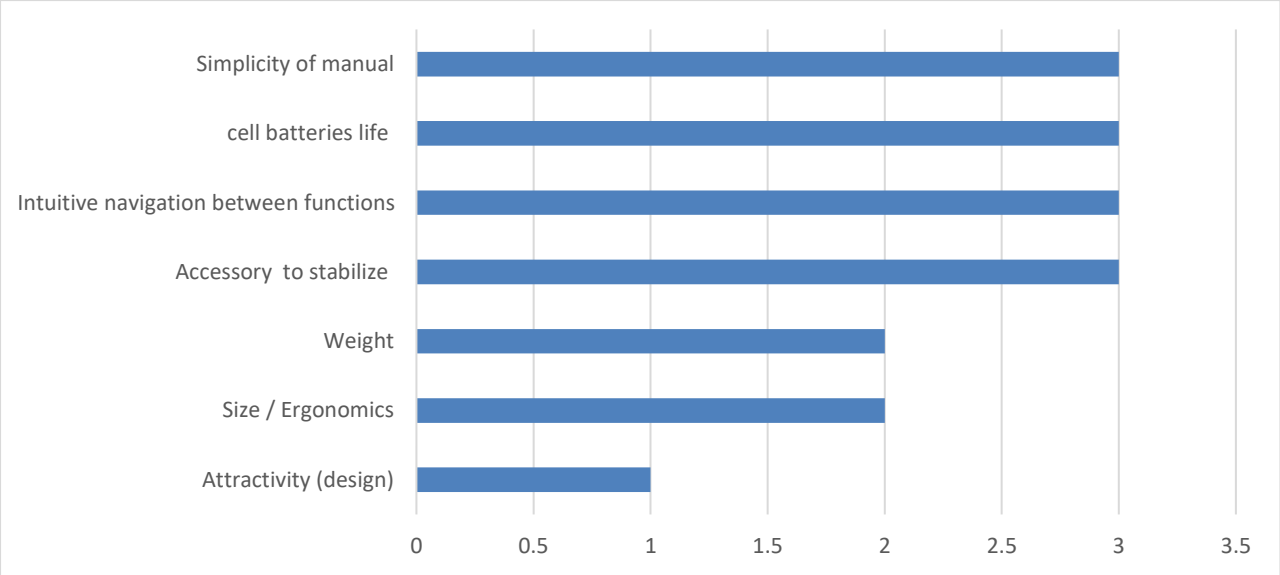
Automatic high-speed extend & retract reduces load and unload time. No-lift design protects operators' backs; lift, lower, load, and unload with the push of a button.

3.Weaknesses of the technique:

there are no elements for the communication of functions. It does not allow 360° rotation

4.Benchmarking of available commercial products:

Ergonomics



Company: Survival Capsule LLC[78]

[77] https://fernoems.com/incubator-transport/inx-incubator-transporter
[78]laura.giraldi@unifi.it,

1.Description of the technique from the current endowment:

Survival Capsule SC2001

Technical data sheet, picture of the product: The Survival Capsule is a patent-pending, personal safety system (PSS) designed as a spherical ball to protect against tsunami events, tornadoes, hurricanes, earthquakes, and storm surges (SC2001 --> Capacity – 2 Adults)

2.Strengths of the technique:

Presence of GPS device,

Air supply tanks and storage space (enough for five-day supply per person)

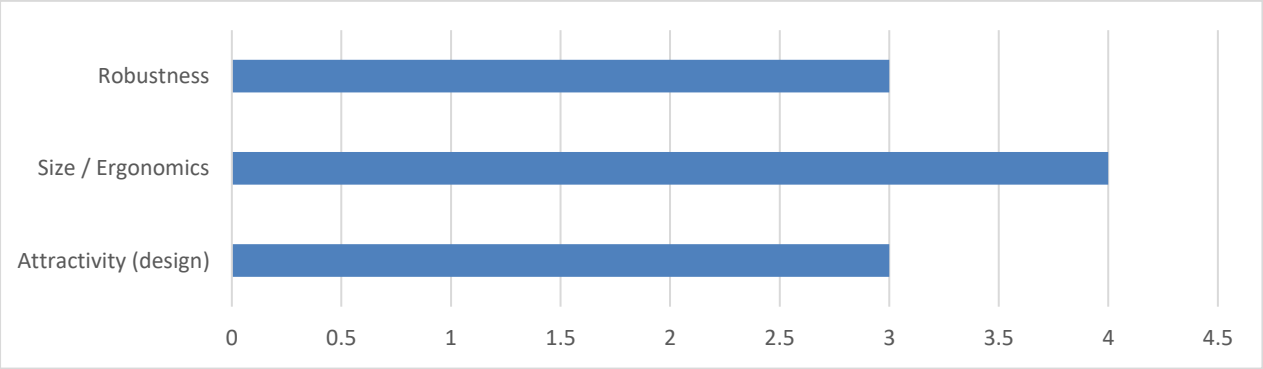
made from recycled materials, such as aluminium and plastic (light weight)

3.Weaknesses of the technique:

There are no devices or screens for communication with the outside

4.Benchmarking of available commercial products:

Ergonomics



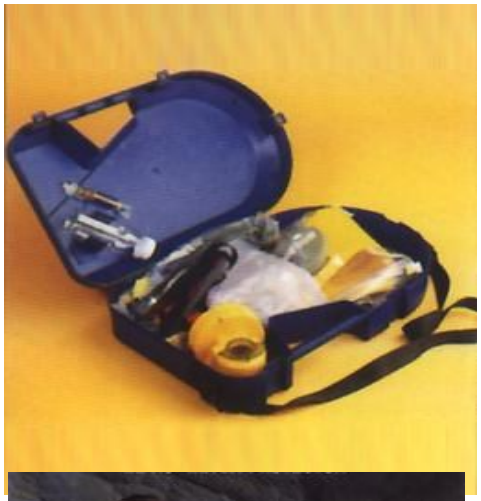
Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABLE

Company: Shalon Chemical Industries Ltd [79]

1.Description of the technique from the current endowment:



The Inpro Infant Protector is a positive-pressure system designed and developed by the Israel Defence Forces to protect new-born infants up to 3 years of age, from all known NBC agents.

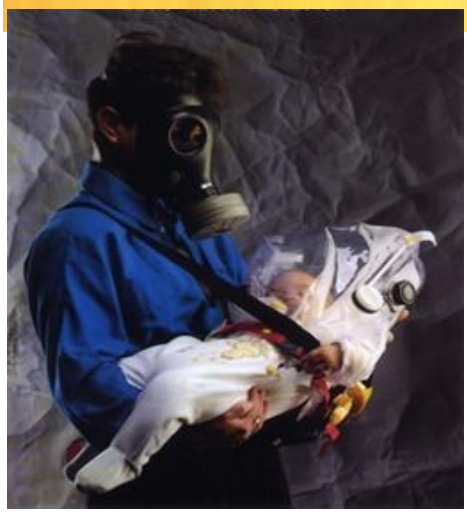
2.Strengths of the technique:

Positive pressure is maintained by a compact and reliable air supply unit, which draws in ambient air delivering it through the filter canister into the protector.

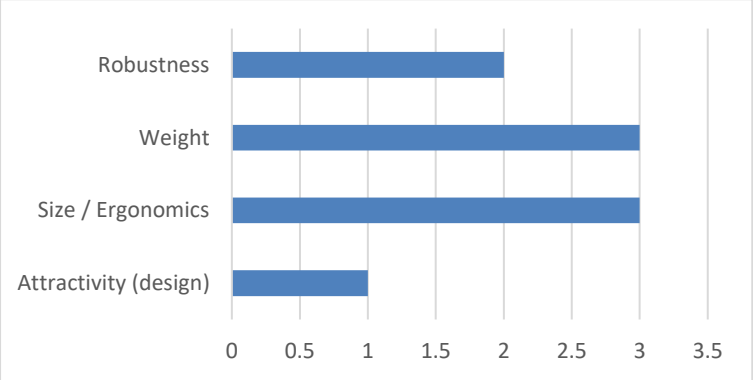
3.Weaknesses of the technique:

There are no devices or screens for communication with the outside. The charging method is dated.

4.Benchmarking of available commercial products:



Ergonomics



Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABLE

[79]laura.giraldi@unifi.it,

Company: E.M.S. Medical International S.r.l - STEM [80]

1.Description of the technique from the current endowment:

Revolutionary ambulance loading system, completely separated from the vehicle floor. Loading height from 0.7 to 1.60 m, with hydraulic and manual operation in case of emergency. The product is used for the transport of stretchers or incubators.

2.Strengths of the technique:

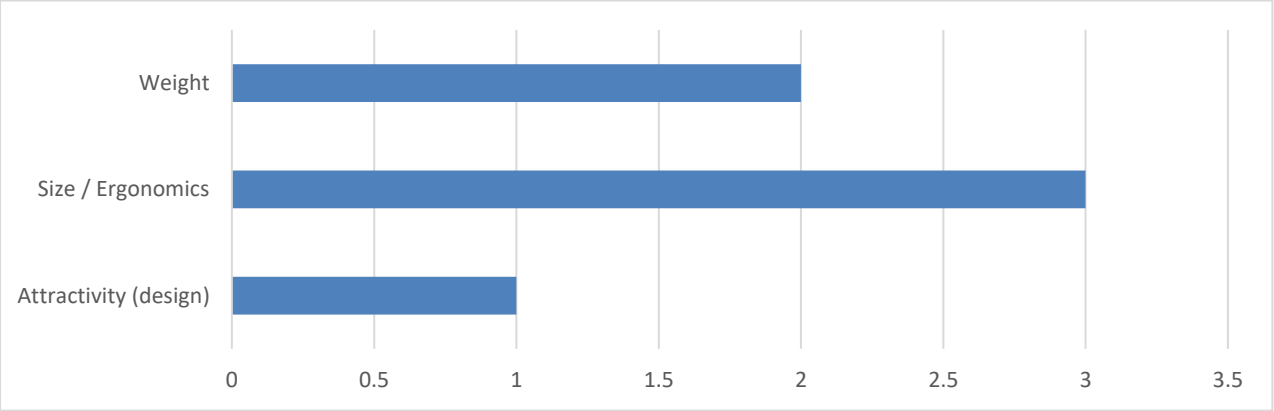
presence of shock absorbers for easy movement of the product, 360 ° movement. Adaptable to standard measures of stretchers and incubators.

3.Weaknesses of the technique:

The product is very bulky

4.Benchmarking of available commercial products:

Ergonomics



Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

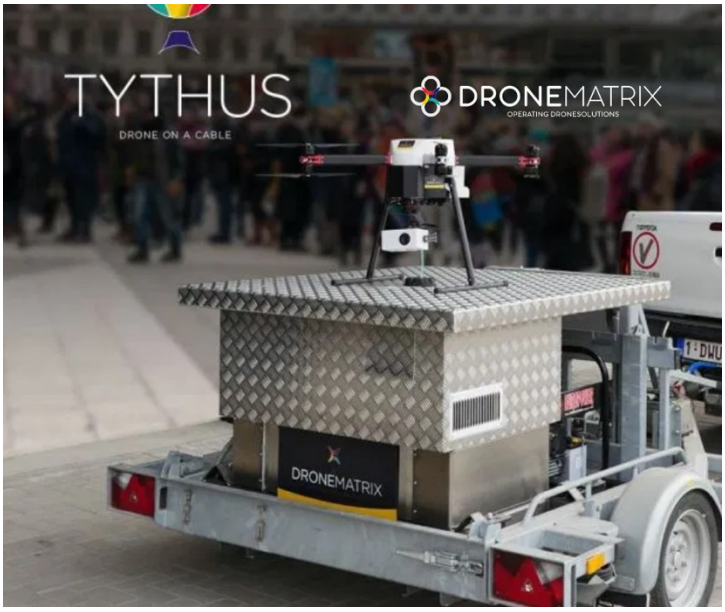
Rechargeable battery (external): NOT APPLICABLE

[80] laura.giraldi@unifi.it,

Annex IV: Multipurpose UAVs (drones)[81]

Company: Uhasselt[82]

1.Description of the technique from the current endowment:



Available to us are two types of drones from DroneMatrix. One is Yacob, a (semi-)autonomous battery-powered drone that is launched from a docking station. The second type is Tythus, a tethered drone (a drone and docking station connected via a cable and pulley system, providing power and data-exchange).

2.Strengths of the technique:

Yacob: can be manoeuvred over a large area. Automated functions

Tythus: nearly limitless flight time, yet limited in range due to the cable. Easy in operation.

3.Weaknesses of the technique:

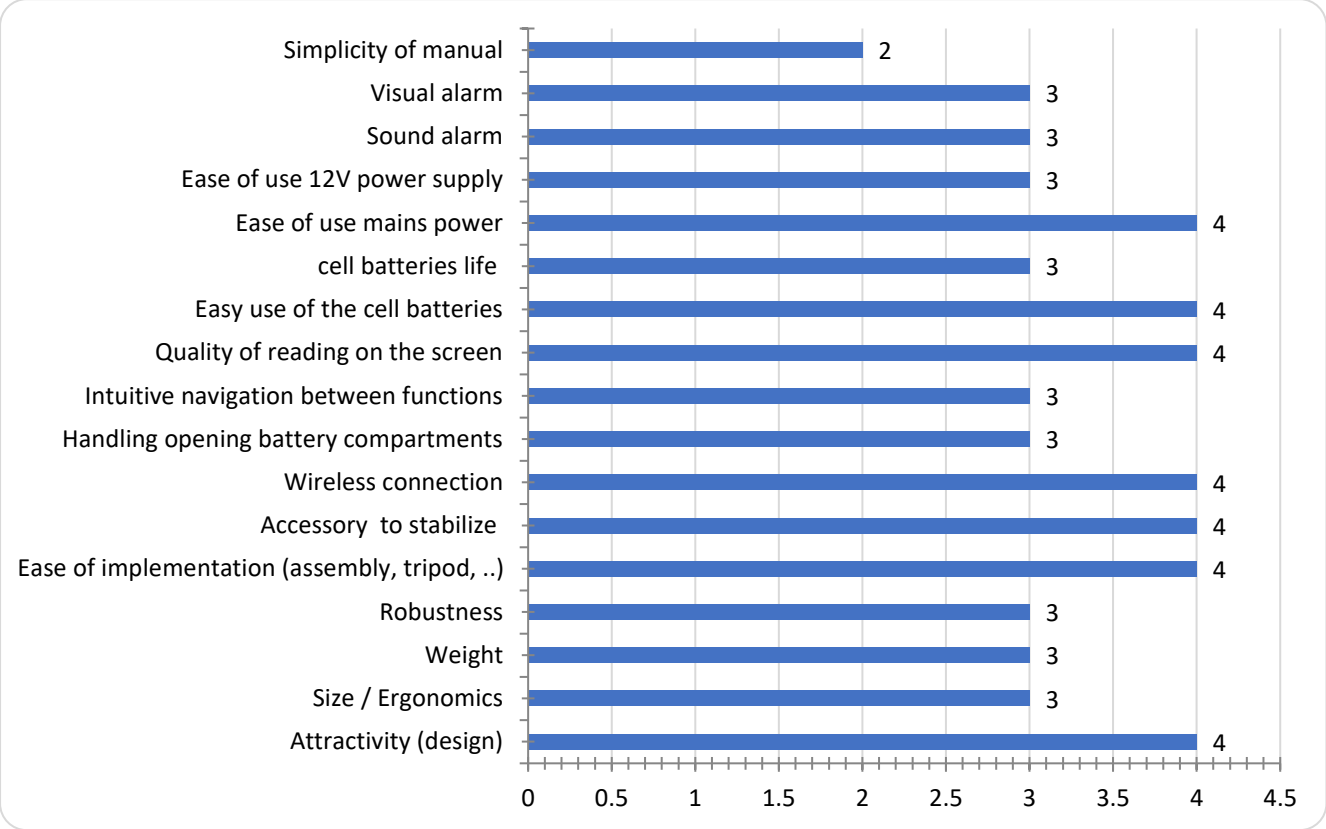
Both systems are susceptible to weather conditions. As a rule of thumb: if birds cannot fly (heavy winds, rain, extreme temperatures...), the drone cannot fly either.

4.Benchmarking of available commercial products:

There are many manufacturers. Local producer DroneMatrix offers professional-grade equipment at a lower cost than competitors.

[81] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[82] IMOB / UHasselt

Ergonomics



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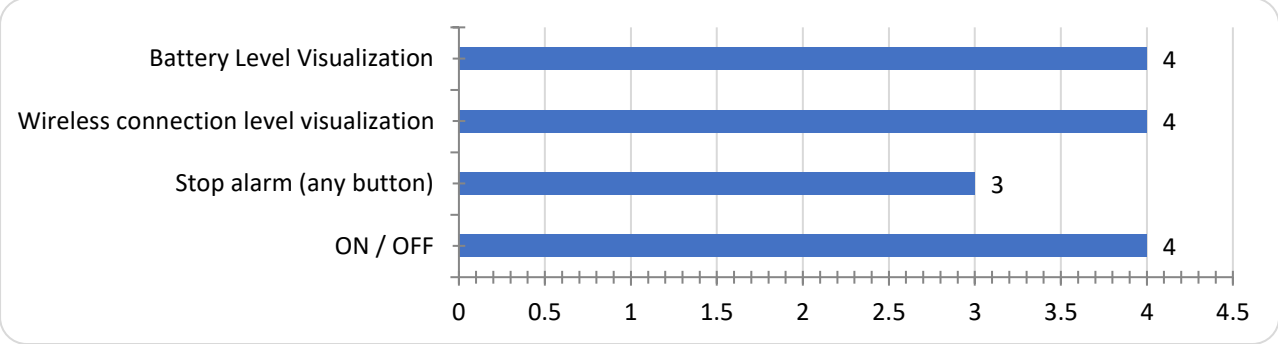
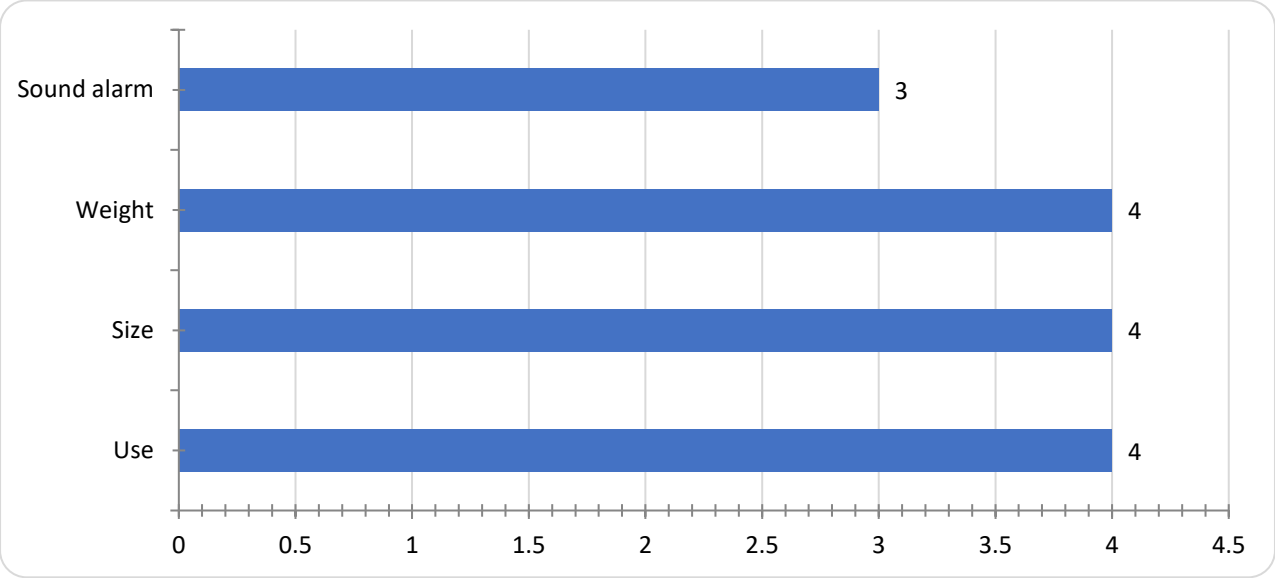
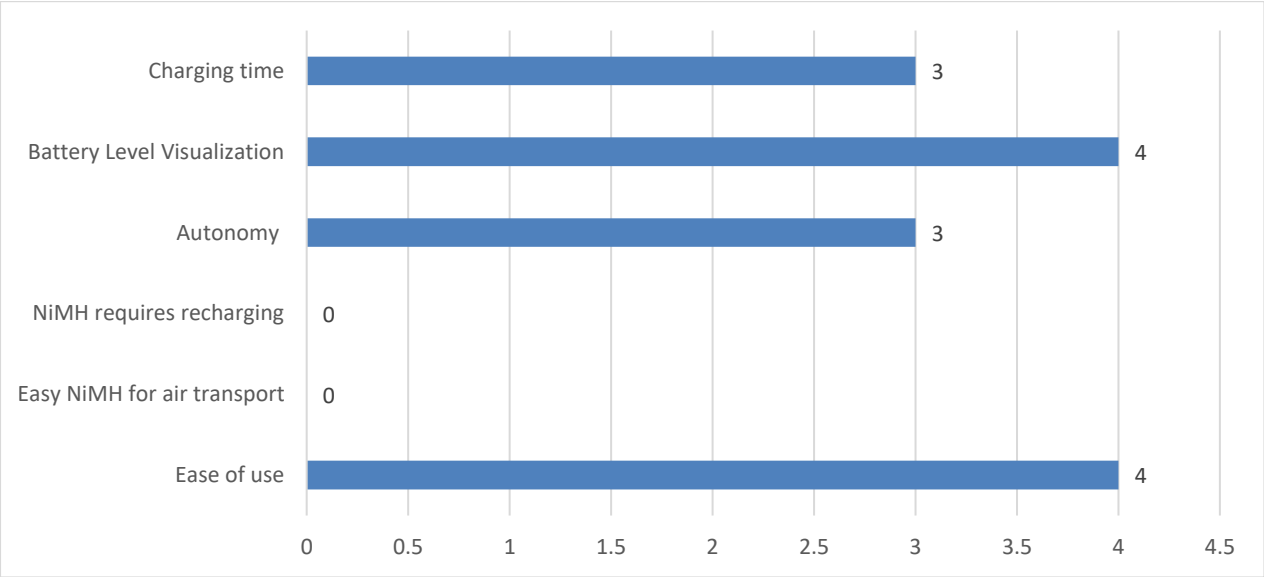


Wireless remote control



Rechargeable battery (external)



Annex V: Detection equipment Wireless, portable multi-threat monitor for radiation and chemical detection[83]

Company: RAE System[84]

1.Description of the technique from the current endowment:

multiRAE device monitors both chemical threats and gamma radiation. With the ability to wirelessly transmit threat and alarm data in real time to a central command station, the MultiRAE Pro offers improved visibility and awareness. It also gives you the flexibility to swap out 25 different sensors for a range of threats, including VOCs, toxic gases, combustibles, oxygen levels, as well as gamma radiation detection. The MultiRAE Series of handheld gas detectors includes three models for detection of up to six threats simultaneously. You can choose from 25 toxic sensors, 3 PID sensors with a 9.8 eV lamp option, and even a gamma radiation sensor.

2.Strengths of the technique:

- Parts per billion VOC measurement
- Industry-leading wireless multi-threat device
- Simultaneous monitoring of chemical threats and gamma radiation
- Real-time data access from central command
- More than 25 different chemical sensors
- Swappable sensors
- Man down alarm
- Simple maintenance with replaceable sensors, pump, and battery
- 5-way local and remote wireless alarm

Low weight, short response time, low detection limit for chemical compounds, easy to use, availability of a wide range of replaceable electrochemical sensors in use, PID and combustion sensors (LEL).

3.Weaknesses of the technique:

The device cannot be used for CWA detection and identification, as the electrochemical sensors do not have the required sensitivity. Use in environments with a lot of dust or high concentrations of toxic gases can lead to failure of the suction pump and poisoning of the sensors.

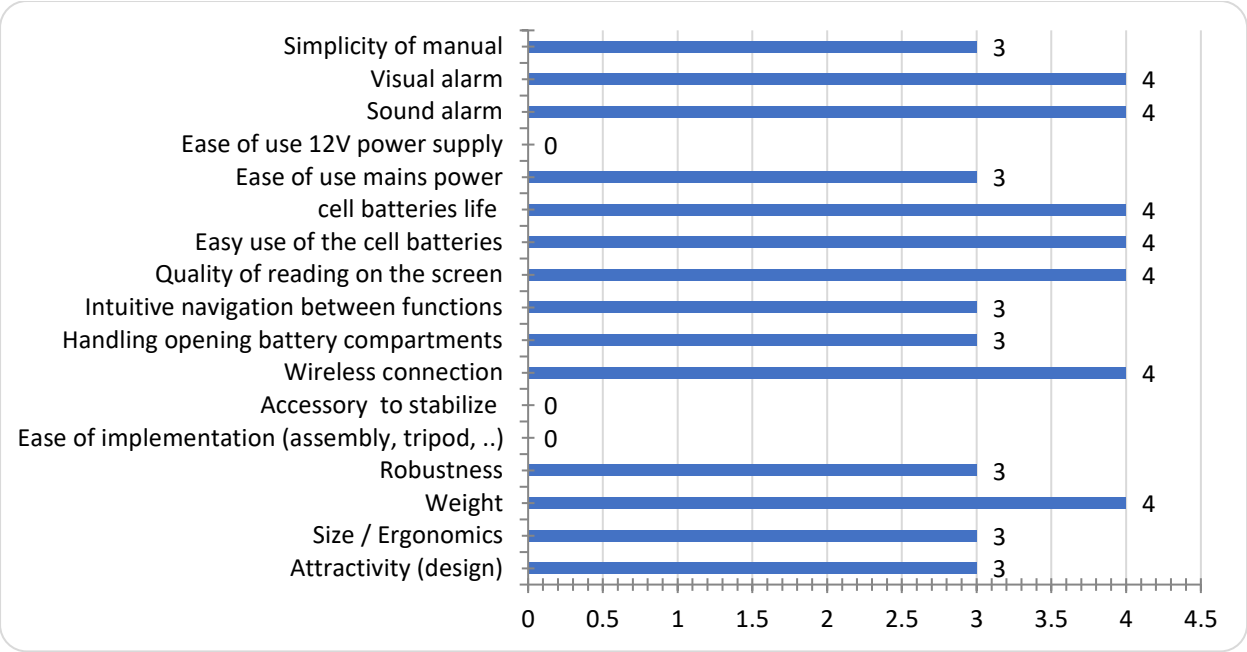
The device cannot detect and identify CWA. Use in dusty environments and high concentrations of toxic gases can lead to suction pump failure and sensor poisoning.

4.Benchmarking of available commercial products:

[83] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[84]Stimpex SA

MultiRAE produced by RAE System (Honeywell) and similar systems from other manufacturers (Drager, Gastech, Crowcon, GfG, Scott / 3M, Viasensor.

Ergonomics



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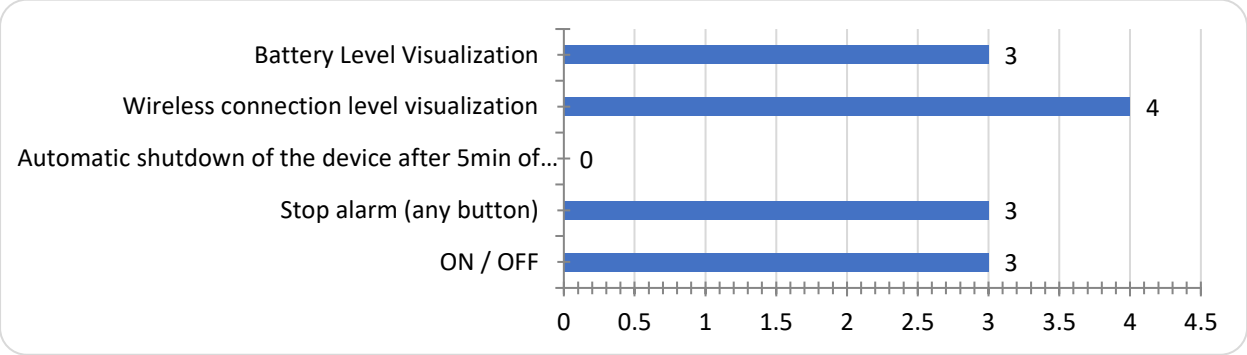
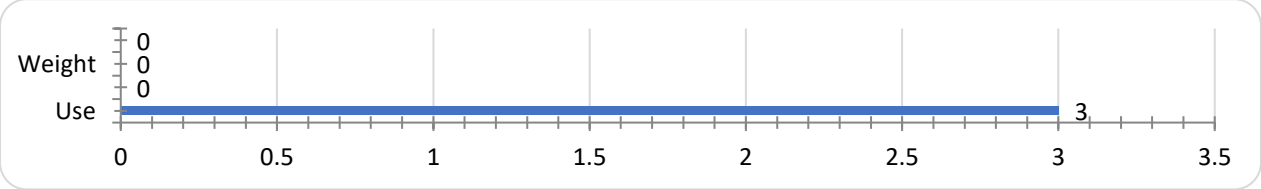
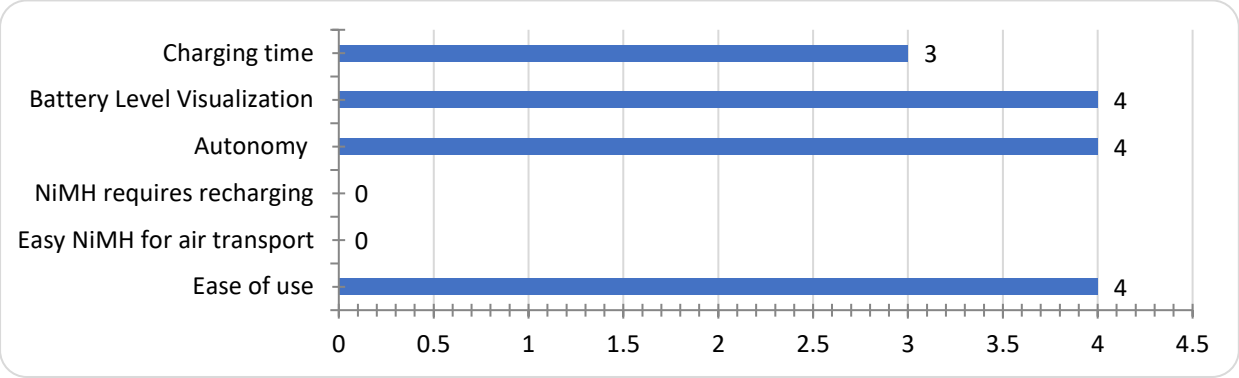


Wireless remote control



Rechargeable battery (external)



Company:ChemPro100i[85]

1.Description of the technique from the current endowment:

The equipment allows the detection, classification and quantification of gaseous CWA and TIC in the atmosphere. With additional modules, it allows the measurement of doses and dose rates of X and gamma radiation, as well as biological contamination with BWA. Chemical detection is based on an orthogonal system of sensors composed of open IMS cell and electrochemical sensors.

2.Strengths of the technique: Low weight, short response time, low detection limit for neurotoxic compounds, easy to use, the presence of electrochemical sensors for some TIC.

Low weight, short response time, low detection limit for neurotoxic compounds, easy to use, the presence of electrochemical sensors for some ICT.

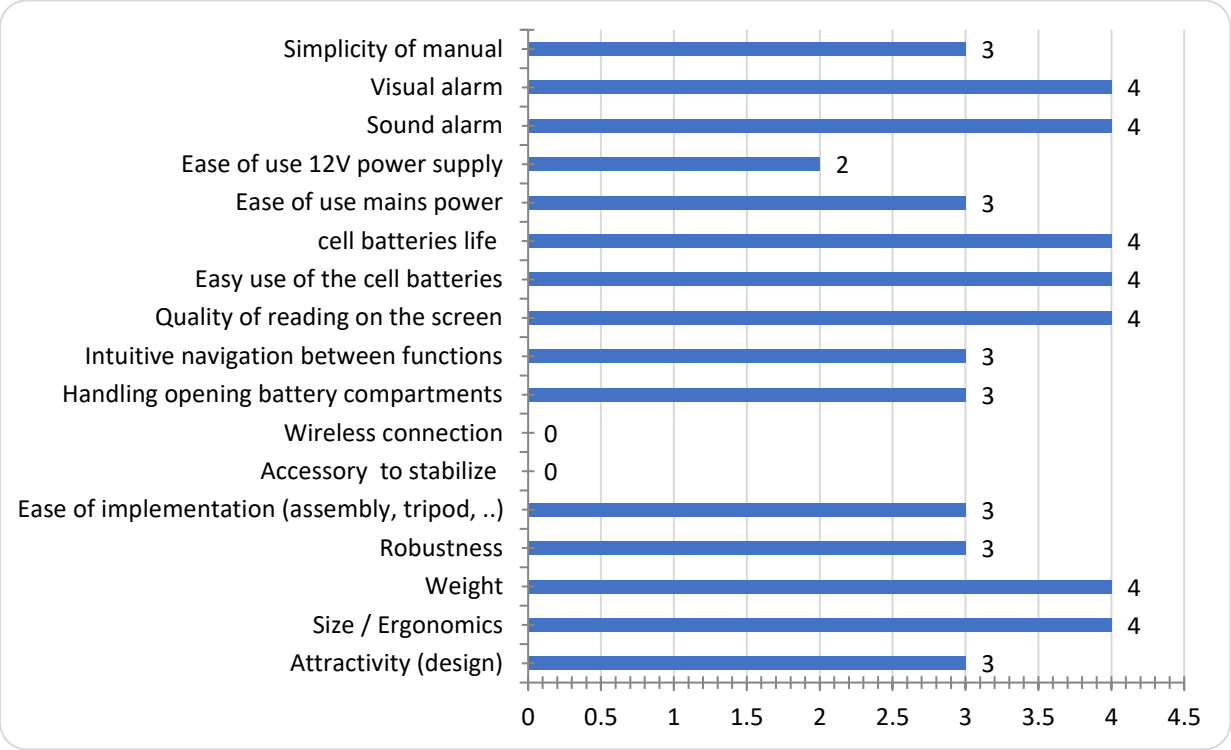
3.Weaknesses of the technique: The device cannot identify CWA, it only performs classification and quantification. The open IMS cell can give errors in case of high ambient humidity. Use in dusty environments may damage the suction pump.

The device cannot identify CWA, it only performs classification and quantification. The open IMS cell can give errors in case of high humidity. Use in dusty environments may damage the suction pump.

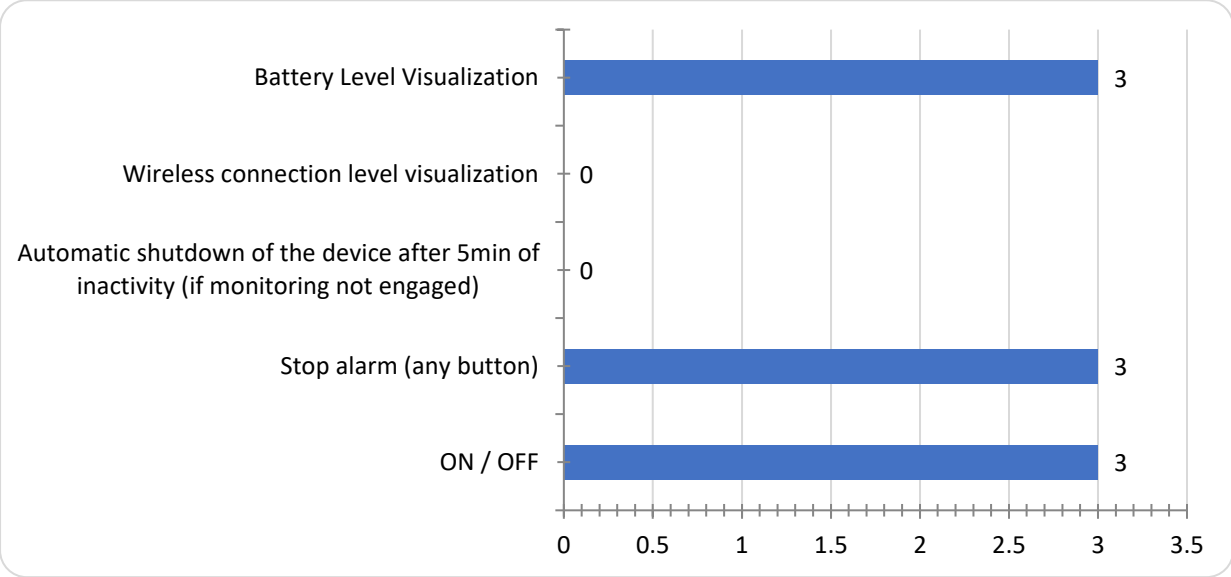
4.Benchmarking of available commercial products: ChemPro100i produced by Environics and ChemRAE produced by RAE System. ChemRAE can integrate wirelessly through network systems provided by RAE.

Ergonomics

[85]Stimpex SA

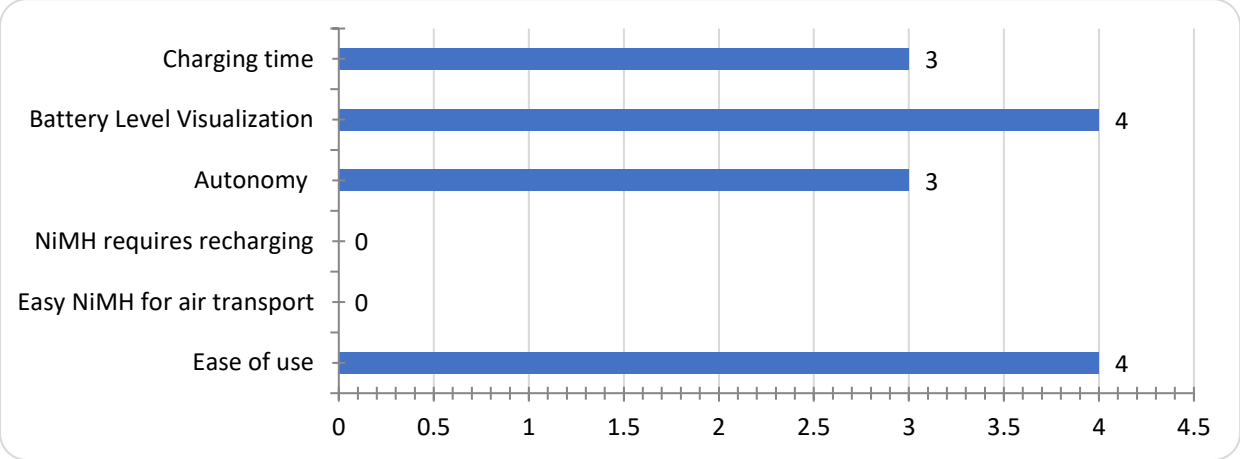


Functions



Wireless remote control: NOT APPLICABLE

Rechargeable battery (external)



Company: BW clip CO detector[86]

1.Description of the technique from the current endowment:

BW Clip is a portable, single-gas detector manufactured by BW Technologies by Honeywell (BW). BW Clip continuously measures the concentration of a specific gas in the ambient environment, and activates an alarm when concentrations exceed alarm setpoints. It is your responsibility to respond appropriately to the alarms.

2.Strengths of the technique:

Only usable for 2 years; reacts very sensitive to disinfectant

3.Weaknesses of the technique:

4.Benchmarking of available commercial products:

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

[86]Pia Ferner/ Schlöglhofer & Leimer (relief unit)

Annex VI: Chemical sensors[87]

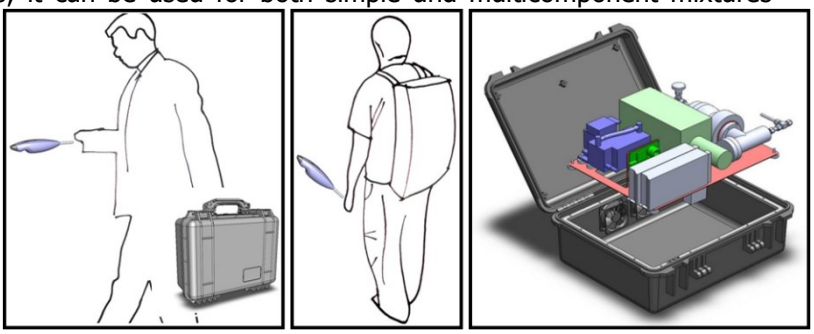
1. Company: Mass Spectrometry[88]

1.Description of the technique from the current endowment:

Mass Spectrometry is an instrumental method for chemical analysis used for measuring masses of atoms and molecules in gaseous, liquid or solid state. Membrane Inlet Mass Spectrometry (MIMIS) works by creating ions from neutral atoms and molecules and separating them according to their mass-to-charge ratios.

2.Strengths of the technique:

MIMS offers high sensitivity (low ppt), fast and accurate analysis, minimising the false alarms and with no sample preparation requirements; it can be used for both simple and multicomponent mixtures simultaneously. Also compared to other MS techniques (e.g. PTRMS and SIFT-MS), MIMS offers lower size, weight, and cost which make it ideal for the field. Moreover MIMS is capable of air and aqueous analysis (detection and monitoring) of Volatile Organic Compounds (VOCs), SemiVolatile Organic Compounds (SVOCs) and a number of permanent gases, such as ammonia (NH3), H2S etc.



- Real time or near real time chemical analysis
- Elimination of sample transportation/storage costs
- Reduction of sample contamination risks

3.Weaknesses of the technique:

Using selective masses for monitoring permanent gases might not be distinctive for some of them, e.g. mass 28 can be attributed to both CO and N2;

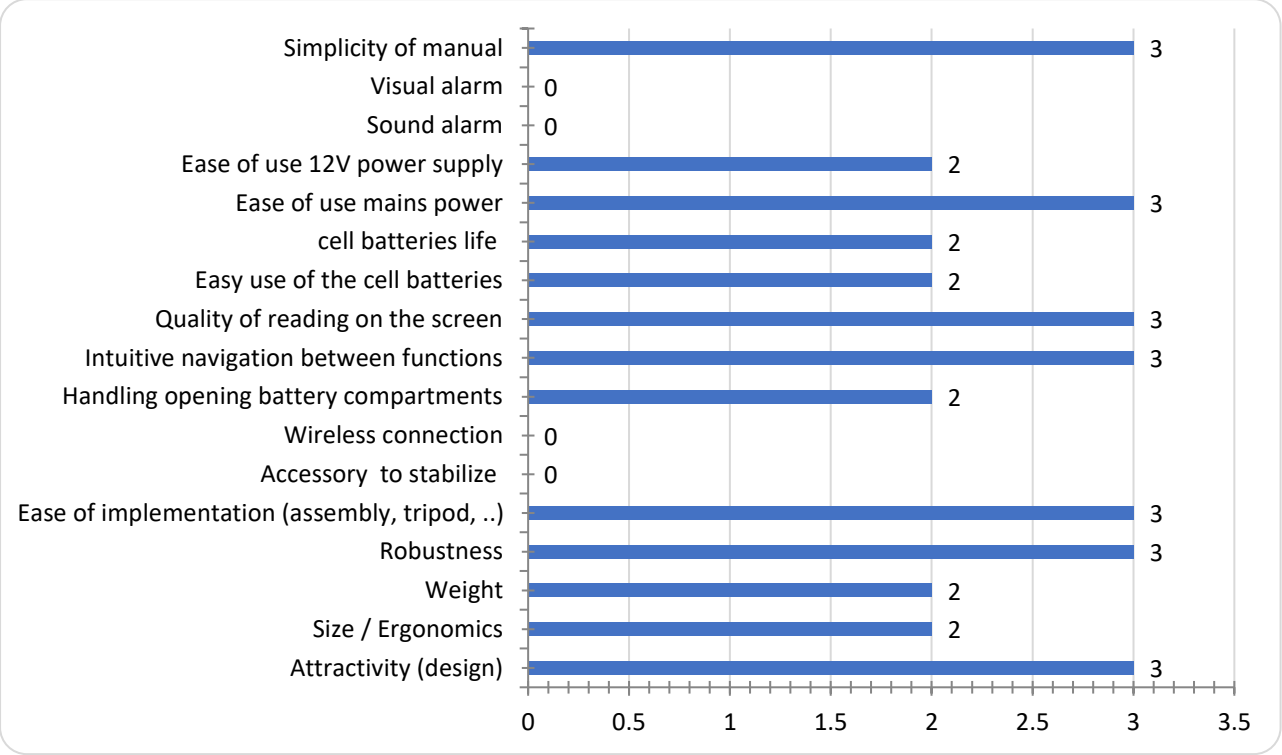
Selectivity issues for some permanent gases

4.Benchmarking of available commercial products:

Electronic Noses (EN), Ion Mobility Spectrometry (IMS), Laser-based technologies, Gas Chromatography (GC), Spectroscopy techniques (IR, Raman, etc.), Gas, Chemical, Optical etc. Sensors, Cavity Ring-Down spectroscopy (CRDS), Laser-induced breakdown spectroscopy (LIBS)

[87] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[88]Sofia Karma, Nick Panagiotou, Stamatis Giannoukos

Ergonomics



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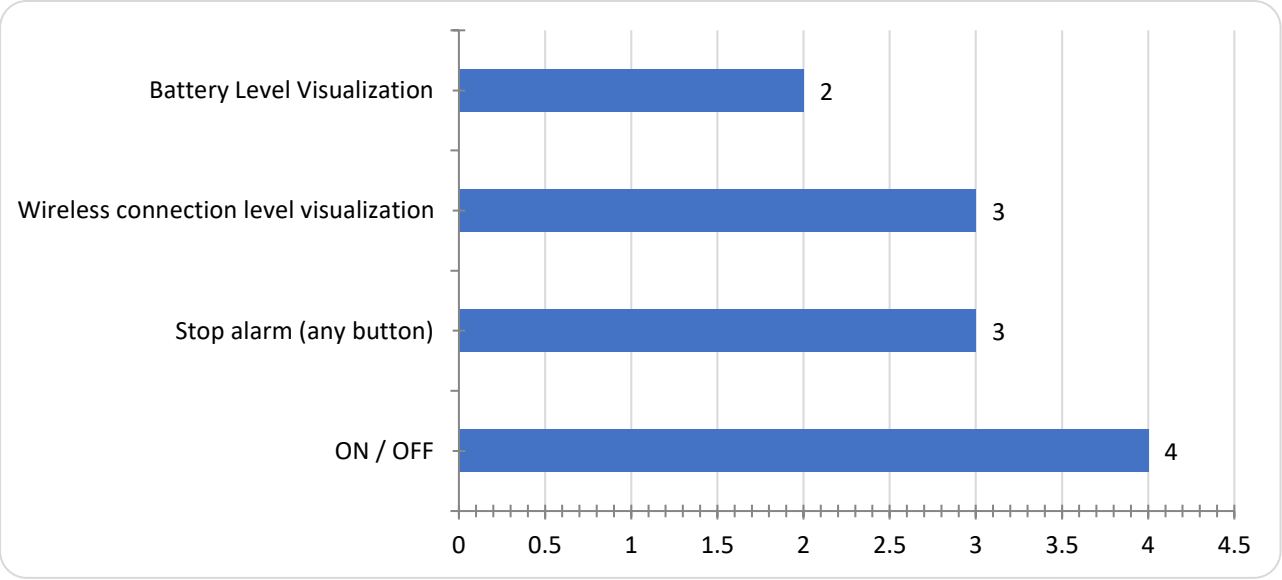


2. Wearable Strain sensors

Company: University of Cagliari (Italy)[89]

[89]piero.cosseddu@unica.it; annalisa.bonfiglio@unica.it (+39 3204373056 Piero Cosseddu)

1.Description of the technique from the current endowment

The system is still at a prototype level, consisting in a plastic strip embedded into a fabric band (we have tested different layouts and types of fabrics). It is able to detect deformations within the range from 0.2% to 2%, with a resolution of 0.2%. It has been tested as sensor for monitoring joints motion. Advantages: easy to fabricated and to be integrated into clothes: Disadvantages: still low reproducibility. A dedicated readout electronics has to be developed.

2.Strengths of the technique : NOT APPLICABLE

3.Weaknesses of the technique : NOT APPLICABLE

4.Benchmarking of available commercial products: NOT APPLICABLE

Ergonomics: NOT APPLICABLE

Functions: NOT APPLICABLE

Wireless remote control: NOT APPLICABLE

Rechargeable battery (external): NOT APPLICABLE

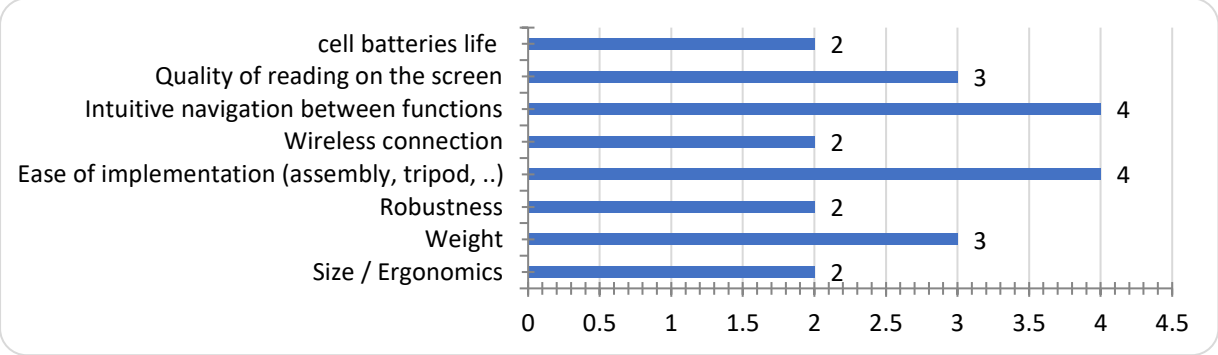
3. Wearable device for ECG and respiration monitoring

Company: University of Cagliari (Italy)[90]

1.Description of the technique from the current endowment:

This is a prototype. Sampling frequency up to 250Hz, resolution of 24 bits, 1 channel ECG and 1 channel respiration. Bluetooth classic module. Same architecture can be modified for more channels, higher sampling rate (for EMG) and other communication channels (BLE, Wi-Fi). There is a company that produces a version of the system developed by us, and we can get in touch with them if this is of interest to buy a final product. In the following, we refer to our experimental prototype and platform.

Ergonomics



[90]piero.cosseddu@unica.it; annalisa.bonfiglio@unica.it (+39 3204373056 Piero Cosseddu)

Annex VI: Rescue Robots & Autonomous vehicles[91]

Company: DFKI – Coyote III– German Research Centre for Artificial Intelligence[92]

1.Description of the technique from the current endowment:

The DFKI intends to use Coyote III as robot platform carrier for the MIMS sensor. Coyote III is compact, lightweight, agile, and can hold the required payload for the developed mass spectrometer. It can climb stairs and rocks and pass difficult destroyed terrain, as its legged wheels have been designed for extra-terrestrial exploration missions. Also, it already has been used in similar SAR applications with a mounted gas sensor, hence it suits the use-case ideally.

In contrast to competitor robot platforms, which use either regular wheels or tracks, it allows a stable and quick motion on all types of terrain without causing any unnecessary damage. The platform features various sensors for visual perception like a laser range finder and a high accuracy camera and inertial measurement unit.

2.Strengths of the technique:

- robust but lightweight frame
- high mobility on difficult terrain
- can climb stairs and rocks
- modular mount for sensors and manipulator
- may be remote controlled
- possible cooperation with other robots

3.Weaknesses of the technique:

- legged wheels may become fragile on high loads
- limited power capacity, no long-term operation

4.Benchmarking of available commercial products:

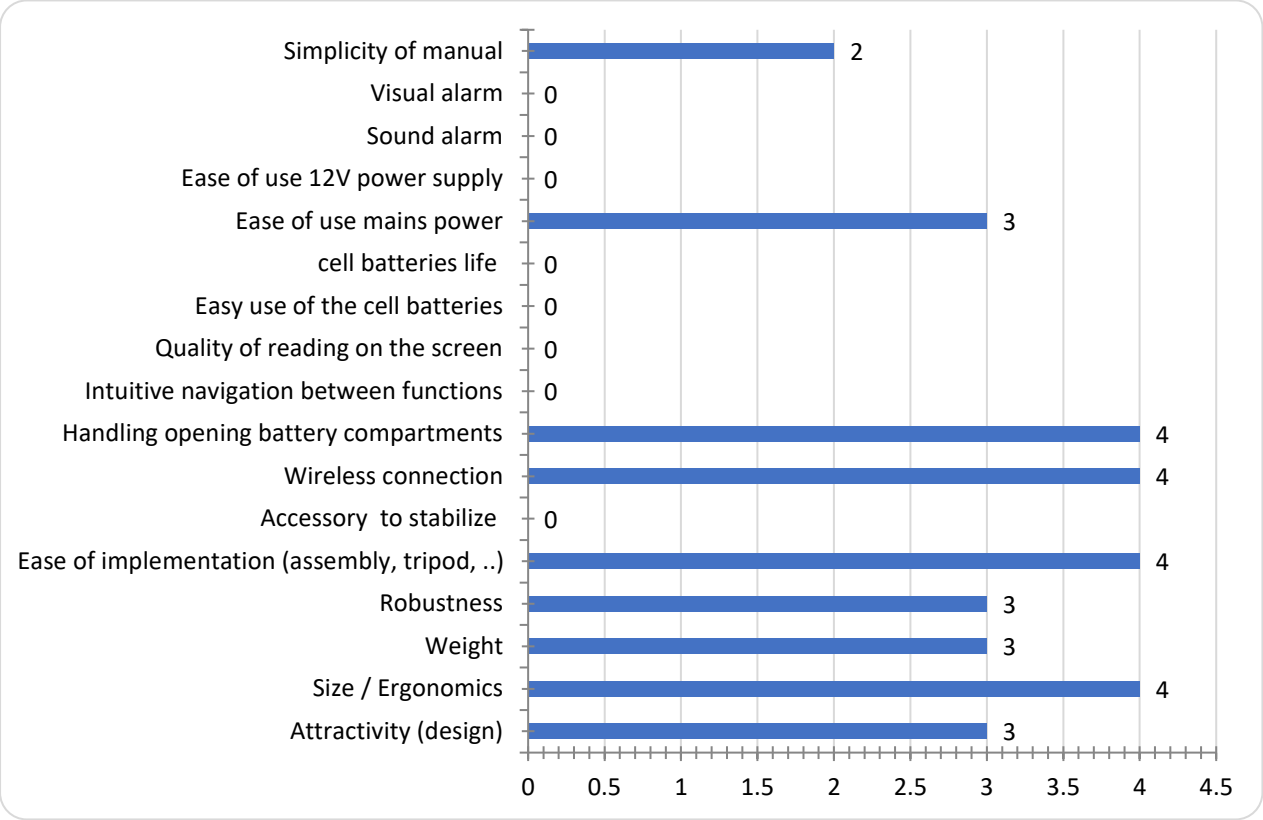
Ergonomics

Coyote III with fully integrated rover system-bus

Application: Space Robotics, Search and Rescue (SAR)

Projects:

[91] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[92]Nikolas Müller



Functions: NOT APPLICABLE

Wireless remote control: no information as of yet

Rechargeable battery (external): no external battery

Annex VIII: Smart glasses and AR helmets[93]

Company: HoloLens 2[94]

1.Description of the technique from the current endowment:

Microsoft highlighted three main improvements made to the device: impressiveness, ergonomics and business friendliness.
HoloLens 2 has a diagonal field of view of 52 degrees, improving over the 34 degree field of view (FOV) of the first edition of HoloLens, while keeping a resolution of 47 pixels per degree.
Holographic Processing Unit (HPU) 2.0 improvements compared to the HPU 1.0:
1.7x compute
2x effective DRAM bandwidth
Improved hologram stability
New hardware accelerated workloads such as eye tracking, fully articulated hand tracking, semantic labelling, spatial audio and JBL filter

2.Strengths of the technique:

Lightweight
Powerful hardware
Easy to use
Plethora of features
It's the market leader in the mixed reality marked.

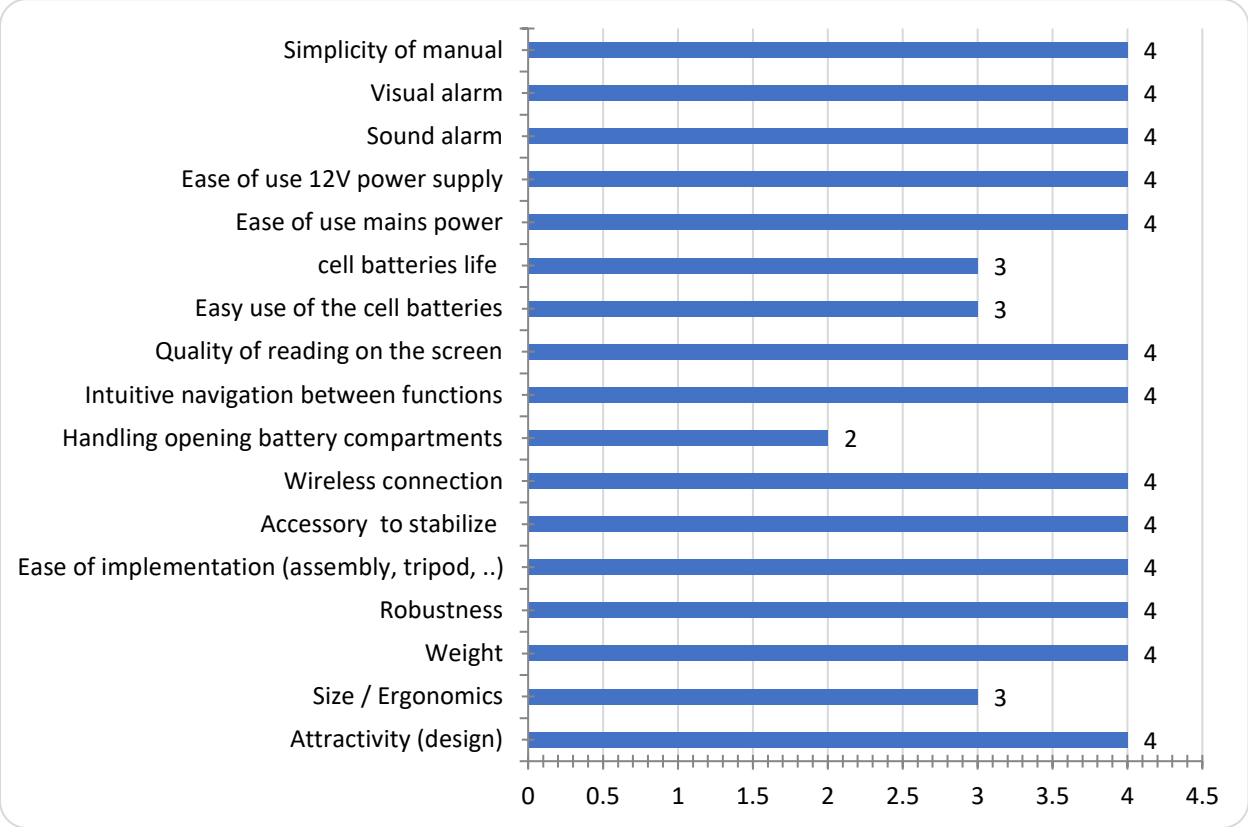
3.Weaknesses of the technique:

It can not be purchased at any store.

4.Benchmarking of available commercial products:

[93] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[94]bogdan.gornea@siveco.ro,gabriela.panzariuc@siveco.ro, razvan.gliga@siveco.ro, andrei.oanca@siveco.ro

Ergonomics



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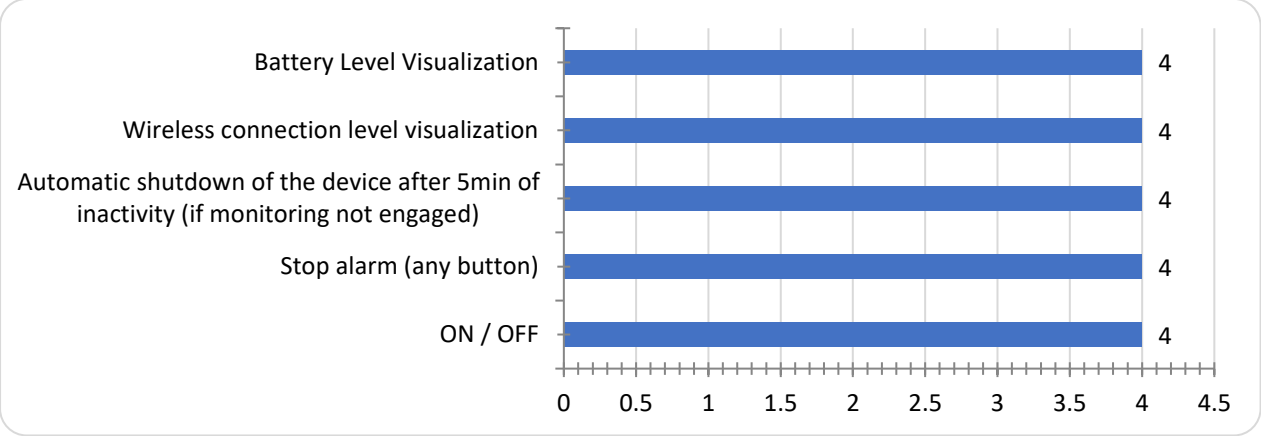
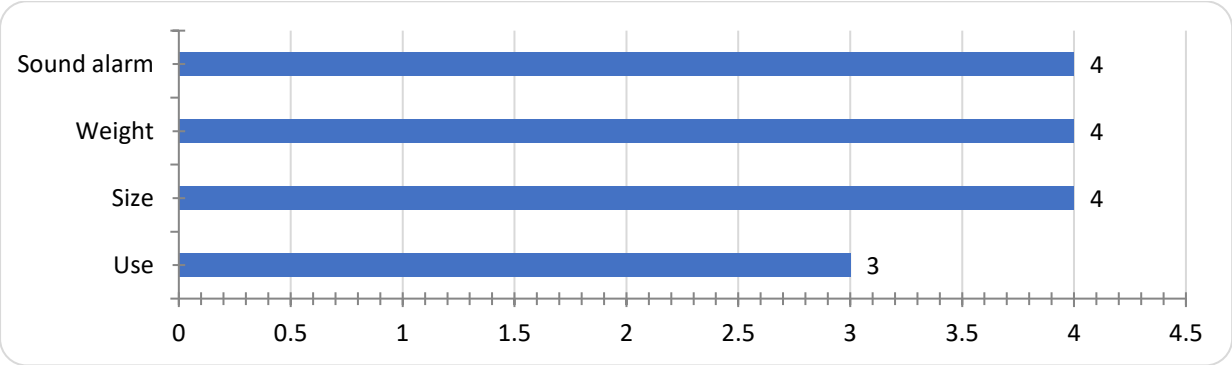
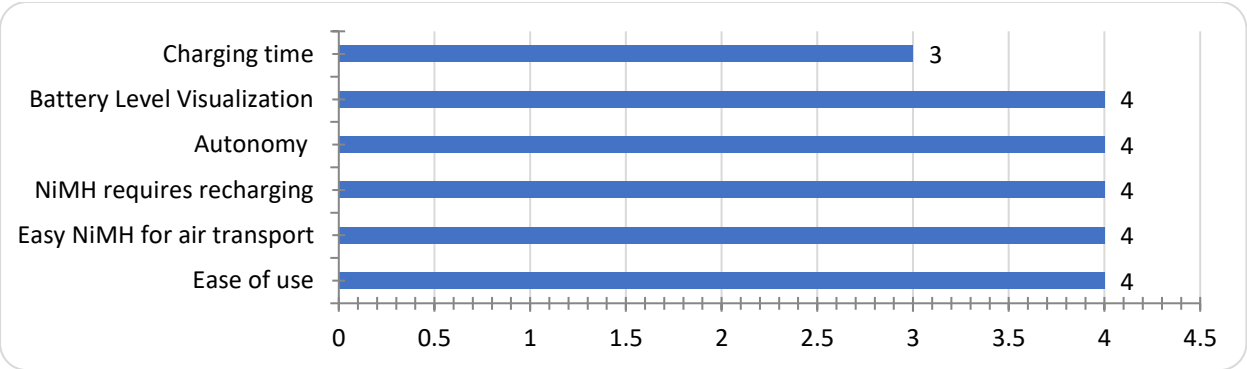


Wireless remote control



Rechargeable battery (external)



Company: Oculus Quest[95]

1.Description of the technique from the current endowment:

Similarly to its predecessor, the Oculus Go, it can be used wirelessly as a standalone device with its own integrated hardware (based on the Qualcomm Snapdragon 835 system-on-chip, running games and software from the Oculus store using an Android-based operating system. It also utilises Oculus Touch controllers, which are tracked via an array of cameras embedded in the front of the headset. The cameras are also used as part of the safety feature "Passthrough", which shows a view from the cameras when the user exits their designated boundary area. A later software update added "Oculus Link", a feature that allows the Quest to be connected to a computer via USB,

2.Strengths of the technique:

Lightweight

Powerful hardware

Easy to use

[95]bogdan.gornea@siveco.ro,gabriela.panzariuc@siveco.ro, razvan.gliga@siveco.ro, andrei.oanca@siveco.ro

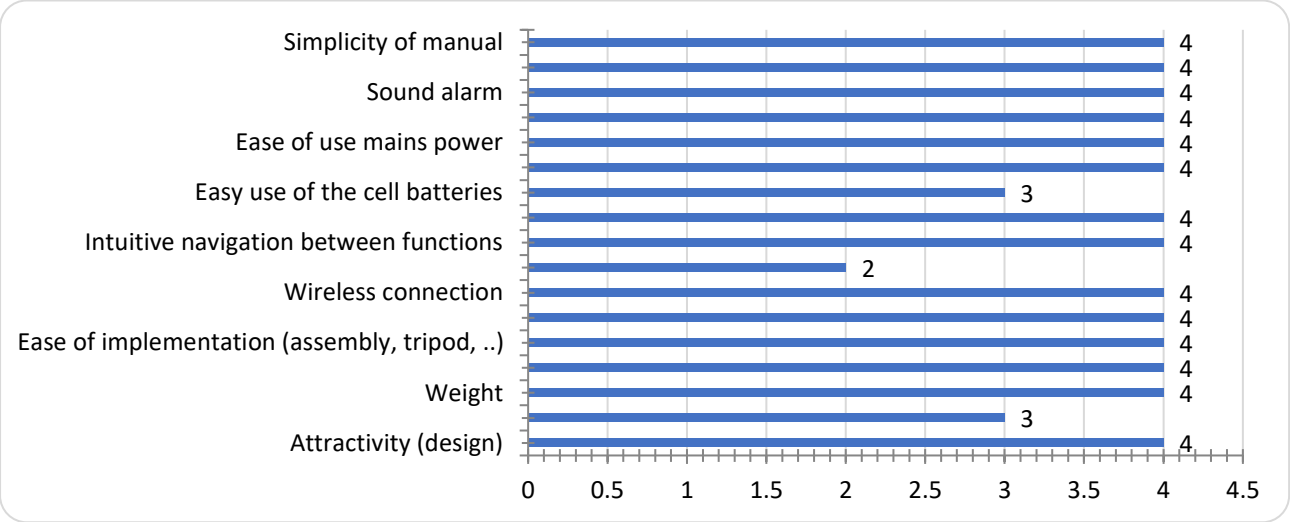
Plethora of features

It works independently or connected to a PC

3.Weaknesses of the technique:

4.Benchmarking of available commercial products:

Ergonomics



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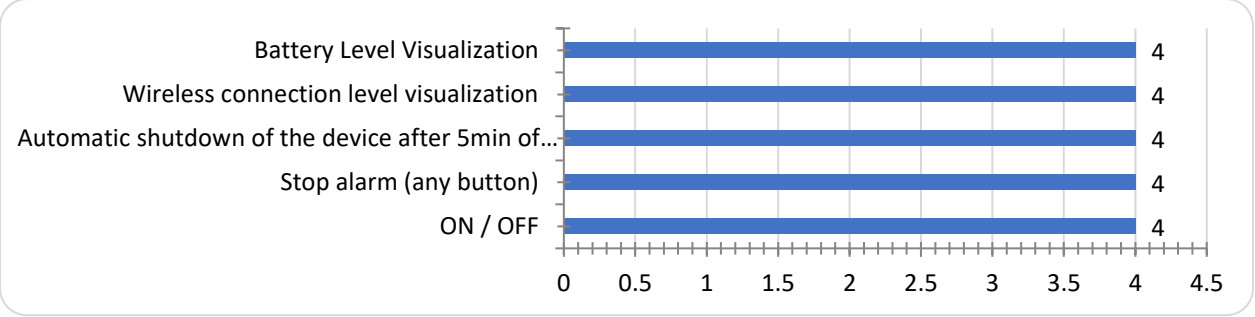
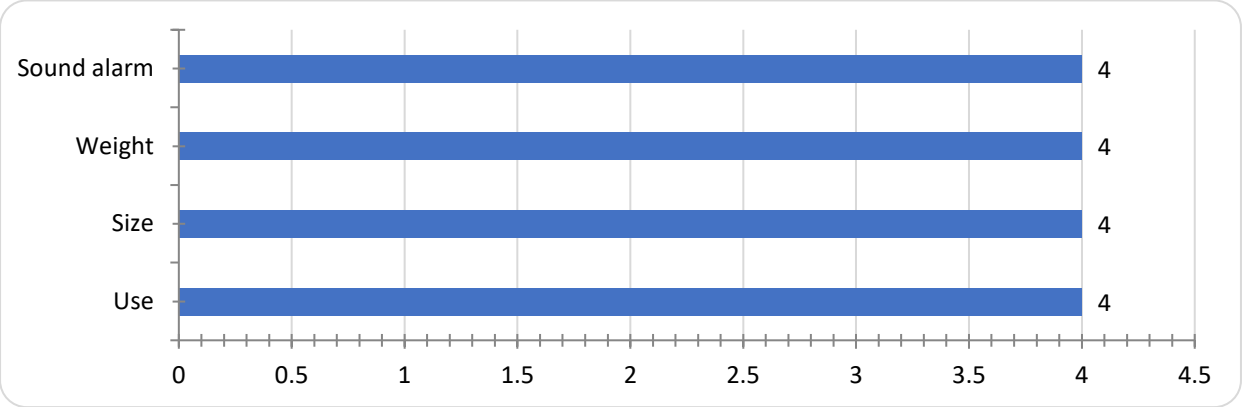
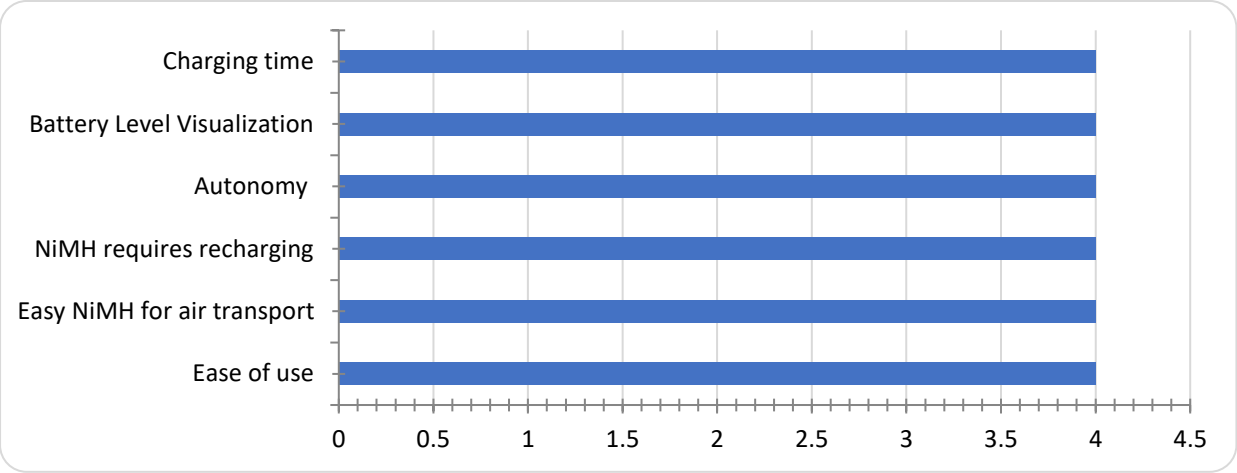


Wireless remote control



Rechargeable battery (external)



Annex IX: Communications technique[96]

Company: Motorola MTP3550[97]

1.Description of the technique from the current endowment:

The MTP3550 TETRA portable radio with colour display and full keypad delivers high performance and dependability required for enhanced workforce productivity and assured user safety. The MTP3550 delivers key features for public safety users including End-to-End Encryption, Man Down Sensor and Vibrate Alert. Embedded secure Bluetooth enables connectivity with accessories and collaborative devices. This TETRA radio is optimised for excellent audio performance and durability for use in all types of noisy and demanding situations. Features a Class 3L power output option, which increases range and in-building performance. Coupled with high receive sensitivity, the MTP3550 has the capability for maintaining communications in the most demanding situations.

2.Strengths of the technique:

Exceeds all 11 categories in the MIL-810 standard, passed an Accelerated Life Test simulating over 5 years use, connection to all first responder organisations in Austria, cellular phone style, many accessories like remote speaker, IP65, IP66 und IP67, direct mode, emergency key

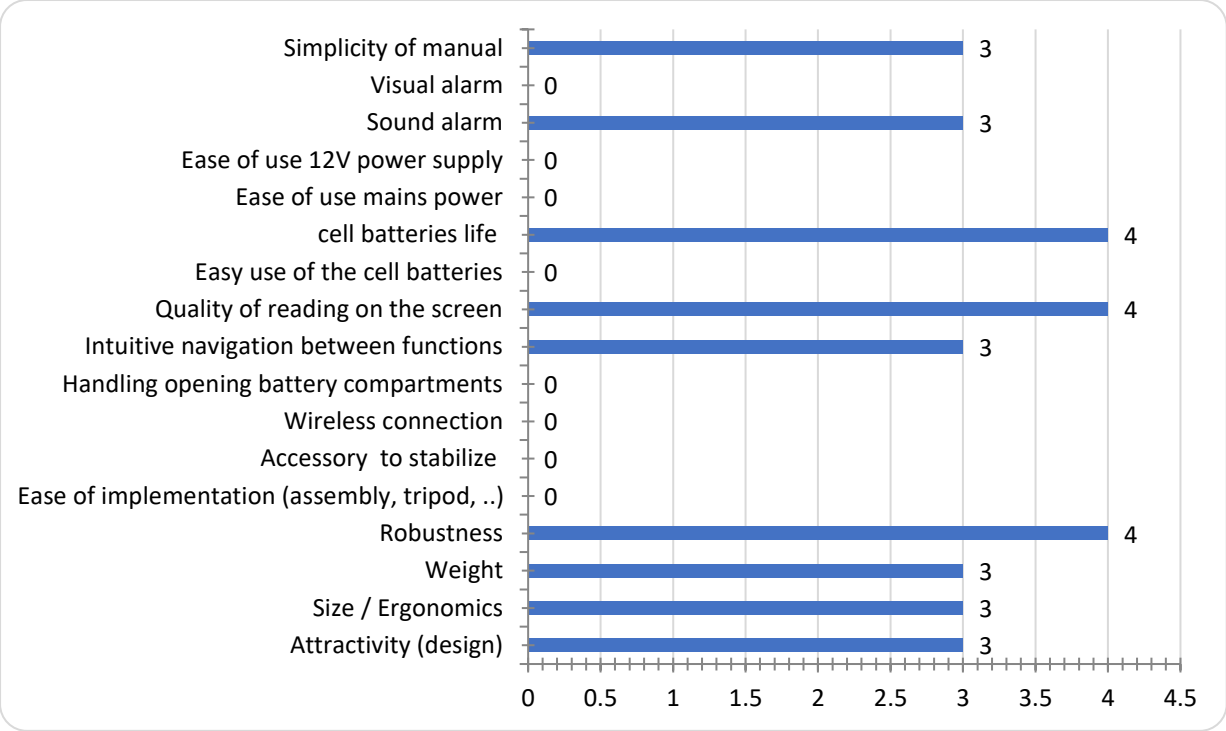
3.Weaknesses of the technique:

Selection of key necessary to speak, difficult operation with gloves without remote speaker, intercom (only one can speak while all can hear), limited indoor use, isolation in direct mode,

4.Benchmarking of available commercial products:

[96] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[97]Sabrina Scheuer

Ergonomics



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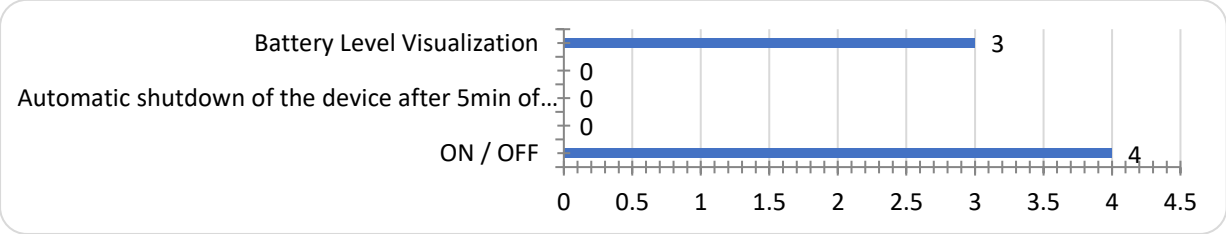


Wireless remote control: NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

Annex X: Exhaust technique[98]

Company: Emergency rescue set [99]

1.Description of the technique from the current endowment:

The emergency rescue set consists of a carrying cloth, a rescue sheet with looped/preassembled tape sling and a carrying bag.(Material: PES, PA) These emergency rescue devices are set up very easily and therefore very quickly ready for use. They are designed for use in extreme situations, when other rescue devices (rescue tubs) ambulance hammocks, rescue harnesses, rescue bags and similar can not be used or are not available due to local conditions (in narrow shafts) or for reasons of time (acute emergency situation).. The rescue sheet is suitable for the transport of sitting or lying people, but it must not be used for rappelling up or down. The rescue cloth is used to rope people up and down. It has the shape of a triangle and is made of a synthetic material. An extension strap sling is required to adapt it to the body size.

2.Strengths of the technique:

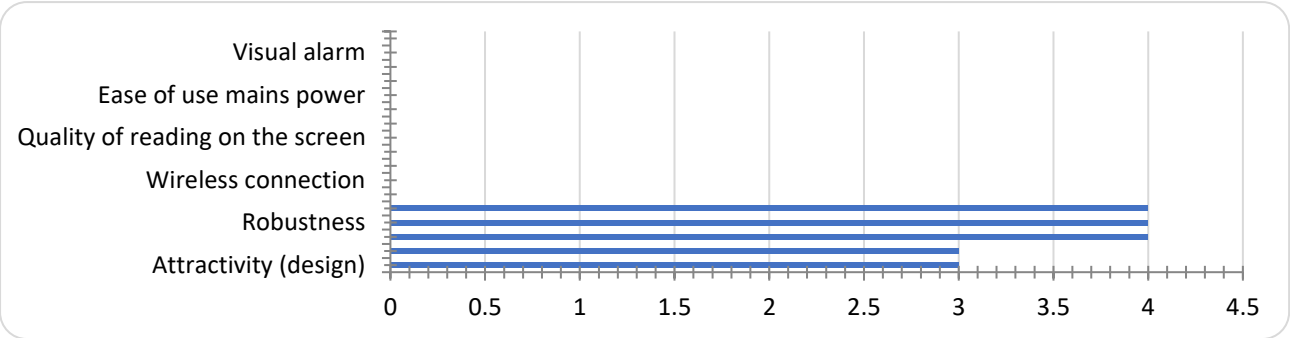
light weight, easy to use also in narrow places, 10 years service life.

3.Weaknesses of the technique:

Roping only possible in sitting position, no stabilisation of the victim, user training required, if often used only 1 to 2 years service life

4.Benchmarking of available commercial products:

Ergonomics



[98] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[99]Sabrina Scheuer

Annex XI: Smart textile professional uniform

Company: DIVITEC model: Fire crossing suit[100]

1.Description of the technique from the current endowment:

Suit designed to deal with emergency situations in the event of fire or special interventions in the presence of open flames and for all operations that involve approaching and crossing the fire. Heat reflective full suit / diving suit. Rear bag for housing any self-contained breathing apparatus with one or more cylinders; Wide front opening closed with zipper protected by two safety flaps fixed with snaps; Hood with integrated helmet equipped with fastening and spacer to facilitate the use of masks for self-contained breathing apparatus; Large golden screen; Three-finger gloves with musketeer cuff; Quick release rear boots and Kevlar-coated leather sole, anchored at the height of the instep with internal elastic system.

2.Strengths of the technique:

Protection from open flames and heat during operations that involve approaching and crossing the fire;

3.Weaknesses of the technique:

no attention is paid to the morphological aspect of the product; no technological elements were included in order to monitoring the health of the first responder or increasing the performance of the product ;

4.Benchmarking of available commercial products:

There is not enough information on the manufacturer's website to make an adequate comparison to other products.

Ergonomics

NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

[100]laura.giraldi@unifi.it, marta.maini@unifi.it

Company: DIVITEC model: GAS-TIGHT NBC WATERPROOF SUIT[101]

1.Description of the technique from the current endowment:

The suit meets the highest protection requirements against toxic and corrosive gases, liquid and solid chemicals. Made of multilayer fabric, the suit is completely encapsulated and covers the wearer as well as the self-contained breathing apparatus; The Ep platforms® raw material is composed of a series of high resistance polymers, including a 100% polyester filter; Packaged with joints covered inside and outside by a tape having the same chemical protection and mechanical resistance characteristics of the raw material; Internal pocket for housing the radio, welded to the garment, Can be combined with any model of self-contained breathing apparatus and helmet; Wide multi-layer trapezoidal visor (height 50 cm) which allows an excellent field of vision to the user, with high chemical resistance; Double pair of chemical and mechanical protective gloves tied to the garment with watertight ring attachments that allow easy replacement of the gloves; the outer glove is in butyl; the possibility of controlling the internal instrumentation supplied, deriving from the particular design of the "bat wing" sleeves that allows the operator to easily extract and reintroduce the hands from the gloves; Gas-tight zipper on the right side, 120 cm long and covered by a protective flap made of the same raw material as the garment; Internal sock for foot protection integrated with the garment and boot band; Internal red adjustable waist belt; Two overpressure valves.

2.Strengths of the technique:

Protection from the gas and chemicals; Reusable suit.

3.Weaknesses of the technique:

discomfort for the first responders, the suit is very bulky; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product.

4.Benchmarking of available commercial products:

There is not enough information on the manufacturer's website to make an adequate comparison to other products.

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Company: LENZING INDUSTRIAL model LENZING FR SUIT[102]

1.Description of the technique from the current endowment:

LENZING™ FR is a sustainably produced inherently flame-resistant cellulosic fibre based on Lenzing's renowned Modal fibre production process.

2.Strengths of the technique:

In structural fire fighting very low RET data of LENZING™ FR fibres, shows a big improvement in reducing fatigue and heat stress.

3.Weaknesses of the technique:

no attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product.

4.Benchmarking of available commercial products:

There is not enough information on the manufacturer's website to make an adequate comparison to other products.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

Company: TEXPORT GARMENTS [103]

1.Description of the technique from the current endowment:

TEXPORT® garments achieve high levels of comfort and breathability while at the same time maintaining high thermal protection for the wearers. TEXPORT® Air Blocker® creates a permanent air cushion in the insulation system around the shoulders that increases protection from compression injuries when wearing a respirator. The Ergopad® is a cushioned ergonomically prefabricated pad that fits around the knee in any position and prevents pressure burns.

2.Strengths of the technique:

Protection to heat, fire and hydro repellent. High comfort for the first responders.

3.Weaknesses of the technique:

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no attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product;

4.Benchmarking of available commercial products:

Unlike aramid nonwovens, it resists excessive water absorption.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

Company: LION PROTECTS[104] model: Redzone

1.Description of the technique from the current endowment:

Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, requirements for protection from liquid and particulate contaminants. RedZone is a particulate blocking firefighter turnout gear proven to have no ingress at the turnout coat, pant, glove, boot interfaces and closure points, giving firefighters another layer of protection against hazardous particulates contained in smoke and soot. RedZone performs consistently with existing turnout standards for heat stress management and mobility, requires no change in the donning/doffing process, and is compliant with NFPA 1971 (2018 ed.).

2.Strengths of the technique:

protection from liquid and particulate contaminants, protection from heat and fire.

3.Weaknesses of the technique:

no attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product.

4.Benchmarking of available commercial products:

particulate blocking firefighter turnout gear

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Company: VALLFIREST[105] model: SAFETY

1.Description of the technique from the current endowment:

Great anti-static resistance, protection against flames, tearing, traction and abrasion thanks to its NOMEX® seams. Adjustable wrists with fire-resistant Velcro®. Central safety quick open zipper and easy open system. Includes Velcro® for identification on the chest. Fabric based on NOMEX®, LENZING® F.R. and KEVLAR® fibres, 270 gr/cm3, for perfect thermal and radiation insulation. Raised neck for nape protection. **2.Strengths of the technique:**

comfortable and light garment with a high level of protection.

3.Weaknesses of the technique:

No attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product .

4.Benchmarking of available commercial products:

Different types of fabrics have been implemented in the product in order to improve technical performance.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

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Company: OZONE RESCUE[106] model Hydrocostume WRS Polar Zitered ATP CE

1.Description of the technique from the current endowment:

Hydrocostume designed for intervention in an aquatic environment, made of mixed fabrics and differentiated thicknesses to ensure maximum strength and comfort. The first hydro costume for surface use certified as Category III Personal Protective Equipment. The trousers are in sturdy tear-resistant fabric, reinforced in the points of greatest wear such as the lower back, knee, leg and ankle. The bust is instead made of breathable three-layer material, in a highly visible colour. Neck and cuffs are in soft 4 mm neoprene, while the feet are in trilaminate. All seams are taped and reinforced at each intersection.

USE: River, alluvial and research activities, ideal in the cold season and for use on boats in all weather conditions.

COLOR: Black-red with high visibility yellow bands

CERTIFICATIONS: Directive 89/686 / EEC, UNI EN 14605: 2009 - 14126: 2004 standards.

2.Strengths of the technique:

Protection in aquatic environment, made of mixed fabrics in order to improve the strength and the comfort of the first responder. Breathable materials.

3.Weaknesses of the technique:

no technological elements were included in order to monitor the health of the first responder or increase the performance of the product ;

4.Benchmarking of available commercial products:

First hydrocostume for surface use certified as Category III Personal Protective Equipment.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

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Company: TENCATE model: OUTSHELL FIRE SERVICE[107]

1.Description of the technique from the current endowment:

It is a outer-shell which provide a tough, durable and above all safe first line of defence against heat, flame and abrasion. The thermal-barrier with thermal-liner is a combination of both fabrics. The thermal liner insulates firefighters from the intense conducted, convected and radiant heat of structural fires. It reduces the heat stress experienced by firefighters. A thermal barrier typically consists of a thermal-liner quilted to one or more layers of non-woven. Thinners and lighter thermal barriers offer greater comfort characteristics, which can reduce the heat stress for firefighters.

This critical part of a firefighter's turnout gear provides a durable line of defence against water and hazardous liquids (such as chemicals and body fluids). The thermal-moisture barrier prevents moisture from passing through to the inside of the garment, but allows any perspiration to pass through. The thermal-moisture barrier helps to keep firefighters dry and protect them from hazardous liquids. At the same time it helps to reduce heat stress by facilitating the outflow of heat and vapour.

Reinforcement material has also been incorporated into the suit of a fire fighter. It is a high efficiency, durable protection fabric, which is designed specifically to reinforce areas of turnout gear receiving excessive wear, such as knees and elbows. The reinforcement materials of TenCate Protective Fabrics have a lightweight construction and exceptional thermal resistance. This makes it an excellent alternative to traditional reinforcement products.

2.Strengths of the technique:

Key considerations include inherent heat- and flame-resistance, tear resistance, abrasion resistance, thermal performance (during and after thermal exposure) and water repellence.

3.Weaknesses of the technique:

No attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product.

4.Benchmarking of available commercial products:

Protection against fire and heat and also water and hazardous liquids. Despite this, a good level of breathability is guaranteed.

Ergonomics NOT APPLICABLE
Functions NOT APPLICABLE

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Wireless remote control NOT APPLICABLE
Rechargeable battery (external) NOT APPLICABLE

Company: ROSENBAUER model FIRE MAX 3[108]

1.Description of the technique from the current endowment:

Certified as to EN 469:2005 + A1:2006 incl. Annex B and EN 1149-5:2008. The new FIRE MAX 3 protective suit was specially developed to offer firefighters the highest degree of protection while at the same time providing them with the best wear comfort. Certified as to EN 61482-1-2:2007-12, class 2 electric arc test. Moreover Rosenbauer fire protection clothing is tested according to EN ISO11612, protection against liquid iron splashes. The new FIRE MAX 3 impresses with a maximum degree of comfort, a sporty style and many practical details. The new FIRE MAX 3 is made of a completely new fabric. A high-quality PTFE membrane is used for the first time, which ensures a high degree of breathability while at the same time ensuring the best possible heat resistance. Thanks to the new composition, perspiration is transported away from the body to the exterior very quickly, which generally prevents heat accumulation. In a Ret Test (Resistance to Evaporating Heat Transfer) the new fabric achieved a low value of just 15 m2Pa/W. The lower the value, the better the breathability of the material. The required standard value is ≤ 30 m in the highest class2Pa/W. Despite the excellent breathability, a safety thermal lining is used in the FIRE MAX 3 to also provide a good protection in extreme situations. This version of the proven FIRE MAX 3 Jacket can be equipped with an integrated safety belt or rescue strap. The optional Rosenbauer IRS belt is installed (or retrofitted) into an internal tunnel in the jacket, giving the wearer the ability to secure victims or - in extreme cases - to facilitate his own rescue. The optional IRS belt is certified according to EN 1498 Class A and EN 358. It consists of an 85 mm wide aramid belt with a triple lock HMS aluminium carabiner according to EN 362. Extensive reflective striping is another highlight of the IRS jacket. With HuPF-like reflective striping, the jacket alone complies with Annex B of EN 469 (even the smallest size). As a result, it is unnecessary to wear a warning vest in some countries (warning vest exemption), as stipulated by statutory requirements. The IRS jacket is additionally equipped with a robust quick-release zipper. Two Velcro pieces on the back allow for a sign (38 x 8 cm) to be attached.

2.Strengths of the technique:

The product offers the highest degree of protection and the best wear comfort. Sporty style. protection against liquid iron splashes.

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3.Weaknesses of the technique:

No attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product;

4.Benchmarking of available commercial products:

The producer paid attention to the morphological aspect of the product, even if it could be improved. Unlike its competitors, the product allows the installation of useful accessories directly on the suit, improving the first responders comfort.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

Company: D**räger**[109] **model: FIREFIGHTER CLOTHING**

1.Description of the technique from the current endowment:

This suit is a combination of Nomex and Viscose. The Nomex thread of this special weave method with the 2,5% Kevlar makes the liner strong. The fire retardant Viscose thread provides comfort and transports moisture to the outside of the liner. The multi-layer configuration ensures that each layer accomplishes its part of the job. The protective value of the "ESS® 5 layer system" in combination with the fabric composite is found in the air between the firefighter and the heat source. The used layer system creates a lightweight, durable and highly comfortable garment without compromises to the suits protective features.

2.Strengths of the technique:

Protection from fire and heat. Lightweight garment.

3.Weaknesses of the technique:

No attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product;

4.Benchmarking of available commercial products:

There is not enough information on the manufacturer's website to make an adequate comparison to other products

Ergonomics NOT APPLICABLE

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Functions NOT APPLICABLE
Wireless remote control NOT APPLICABLE
Rechargeable battery (external) NOT APPLICABLE

Company: Dräger[110] model CPS 5800

1.Description of the technique from the current endowment:

The Dräger CPS 5800 is a limited-use chemical protective suit for industrial applications and operations on board that involve a gaseous, liquid or solid hazardous substance. With its external self-contained breathing apparatus the gas-tight Dräger CPS 5800 (type 1b) protects against a multitude of substances. The suit meets the highest international requirements of industry, fire departments and shipping. Therefore it fulfils EN 943-1+2:2002, and the SOLAS requirements, so that it is approved for the use on board ships. As a limited-use protective suit its resistance against mechanical influences and flames is not as high as the one from the reusable Dräger CPS 7800. With the proven Dräger design, this suit is very comfortable to wear and is equipped with the flexible Dräger face cuff. The suit is made of Zytron® 500, a very soft laminate material. All seams are welded in- and outside. This high quality material and the manufacturing techniques provide a long service life of up to ten years.

2.Strengths of the technique:

Protection against gaseous, liquid and solid hazardous substances. It is comfortable to wear and it is equipped with the face cuff.

3.Weaknesses of the technique:

Limited use protective suit. Not high protection against mechanical influences and flames. Use of not innovative smart materials in order to improve the product performance. no technological elements were included in order to monitor the health of the first responder or increase the performance of the product.

4.Benchmarking of available commercial products:

It could be used on board ships. Limited use protective suit.

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

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Company: Dräger[111] model: CPS 7800

1.Description of the technique from the current endowment:

The reusable gas-tight Dräger CPS 7800 provides excellent protection against gaseous, liquid, aerosol and solid hazardous substances even in explosive areas. Due to its innovative material and the new suit design it offers increased flexibility and comfort when entering confined spaces and working with cryogenic substances. The Dräger CPS 7800 increases the wearing comfort even during difficult work in hazardous areas. With its ergonomic cut and five sizes to choose from it offers the highest degree of flexibility for wearers ranging from 1.50 m to 2.05 m in height. In addition, the light and soft suit material adapts ideally for a full range of movement. Offered as an option, individually adjustable braces provide even greater wearing comfort to the user and an improved fit of the suit. A newly designed fit means you don the Dräger CPS 7800 with more ease, can put on and remove the suit by yourself, and shut the zip fasteners without assistance. The Dräger CPS 7800 (Typ 1b) protects against a multitude of possible dangers when dealing with hazardous substances. The novel antistatic material D-mex™ offers excellent chemical resistance and protection against mechanical influences. The Dräger CPS 7800 exceeds the requirements of international industry standards for reusable protective suits. Time and expense for regular testing could be reduced significantly through innovative materials and new service concepts. The suit can also be cleaned and disinfected automatically without complications. This reduces the effort required to keep the suit ready for use over its lifetime of up to 15 years. An unused suit with face cuff can even be stored for five years without servicing. If repair or maintenance is required, this can be performed by the service technician. Of course, DrägerService is equally happy to perform these tasks. D-mex™, the unique suit material, consists of five layers and its reliability has been proven during hazardous substance deployments by the fire service. Tear-proof textile forms the middle layer; on the inside and outside there is a particularly robust elastomer layer, as well as a chemically high-resistant barrier layer. With this design, the suit retains its full protection performance even if the outer material is damaged. With optional accessories, the Dräger CPS 7800 can be adapted to be even more individual to meet your specific requirements and in turn extend your deployment options further. The suit is available with an integrated Panorama Nova full face mask or face cuff. Stress reduction, especially during prolonged use, can be achieved by equipping the suit with ventilation systems. The Dräger CPS 7800 features an optional ventilation system with the integrated regulating valve PT 120 L that can be connected to different breathing air sources. The suit can also be printed with a customer-specific

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design, if desired. The Dräger CPS 7800 training suit permits you to perform exercises in realistic scenarios outside contaminated areas with the same equipment characteristics.

2.Strengths of the technique:

excellent protection against gaseous, liquid, aerosol and solid hazardous substances even in explosive areas. Due to its innovative material and the new suit design it offers increased flexibility and comfort when entering confined spaces and working with cryogenic substances. With its ergonomic cut and five sizes to choose from it offers the highest degree of flexibility for wearers ranging from 1.50 m to 2.05 m in height. Easy to put on and remove by yourself. Innovative material D-Mex. It could be used up to 15 years. It could be repaired. Possibility of customization.

3.Weaknesses of the technique:

No attention is paid to the morphological aspect of the product; no technological elements were included in order to monitor the health of the first responder or increase the performance of the product;

4.Benchmarking of available commercial products:

High protection. Easy wearability. Innovative material. possibility of customisation

Ergonomics NOT APPLICABLE

Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

Annex XII: Safety for rescuers[112]

Company: The WaterBackpack Company GmbH[113]

1.Description of the technique from the current endowment:

PAUL, the 'WaterBackpack', is a small and portable (20 kg) membrane filtration unit which removes bacteria, virus and other pathogens by 99.99% from contaminated water without chemicals or electric energy and can be operated even by illiterates in emergencies. He has a minimal capacity of 1200l/day. PAUL has a 10+ year lifetime. The PAUL standard unit can be used in emergencies and for simple permanent water supply.

2.Strengths of the technique:

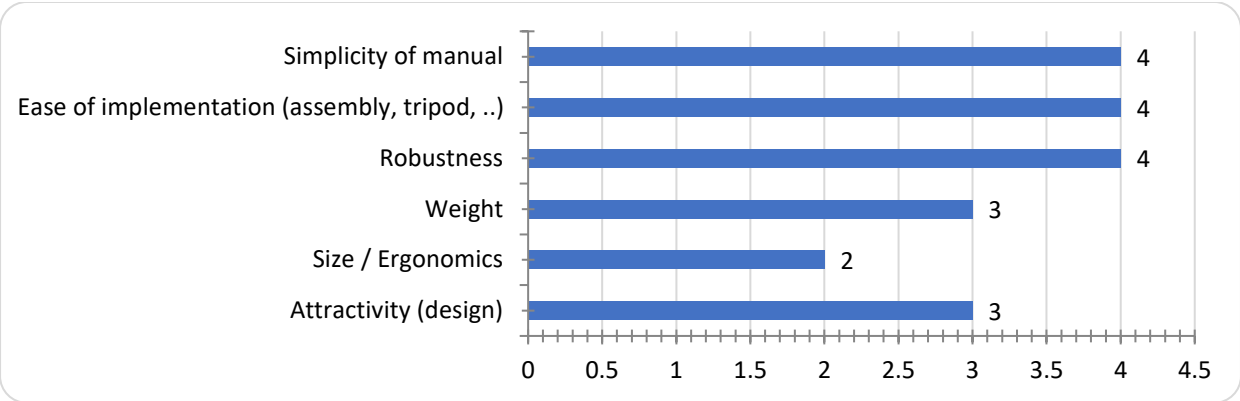
Water purification process does not require chemicals or power; quick deployment; easy to use; low resource requirements; longevity (built to last 10+ years in operation).

3.Weaknesses of the technique:

'bulky' backpack design (straps inappropriate for longer distances); requires some (but limited) knowledge for proper maintenance.

4.Benchmarking of available commercial products:

Ergonomics



Functions: NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external) NOT APPLICABLE

[112] **NOTE: 4=Very satisfaying; 3=Satisfaying; 2=Not so satisfaying; 1=Un satisfactory**
[113]Pia Ferner

Company:
SUNWATERLIFE [114]

1.Description of the technique from the current endowment:

The Sunwaterlife Aqualink system comes in the form of a suitcase. Weighing about twenty kilos, the transport of these and their deployment are facilitated. The power supply is provided by the 6 fold-out solar panels charging the battery, delivering the power necessary for its operation. Whatever the pumped water source, the water at the outlet is immediately drinkable. The output of the "trip version" case provides 800 litres of drinking water per day, the "UF version" 3000 litres per day. Five litres of drinking water per day per person is enough to cover basic needs, however the WHO says a minimum of 20 litres of clean water is required. A single suitcase can therefore meet the needs of at least 160 people. The filtration is ACF and NSF-ANSI certified with a filtration fineness of around 0.0001 micron by reverse osmosis and 0.01 micron for the UF version by ultrafiltration. The various germs, parasites and viruses responsible for diseases such as polio, cholera, hepatitis, gastroenteritis are eliminated.

2.Strengths of the technique:

It can respond to different scenarios such as major disasters, powering refugee camps, construction sites, hard-to-reach places where an electrical source is not available and many other scenarios. Its rapid deployment speed (5 minutes) its weight of 20 kilograms, the robustness of the NATO-classified Pelicase-type case provide mobility to adapt to each terrain configuration. The device is also very easy to understand, an eight-year-old child could use it. Its maintenance is also a positive point, membranes from space research can be used for up to 18 months, however, the filters need to be cleaned quite regularly. In addition, local partners provide a link between the facilities and Sunwaterlife.

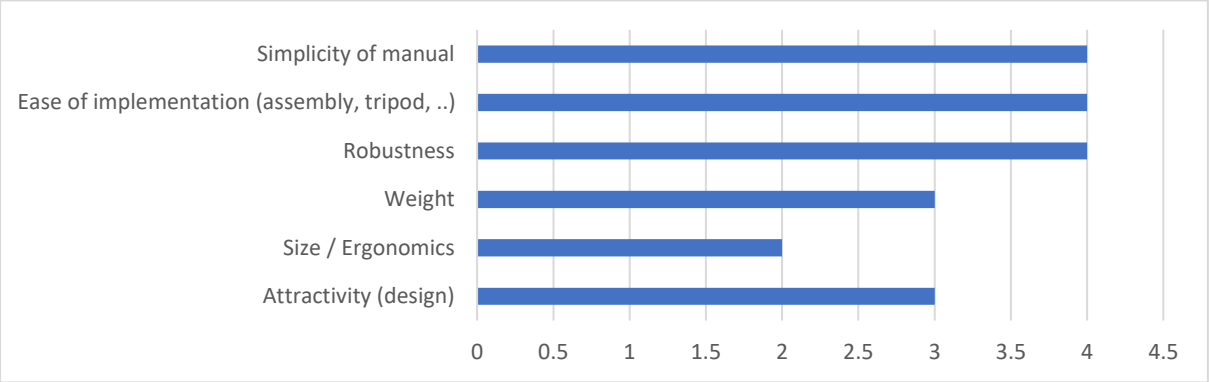
3.Weaknesses of the technique:

requires some minimum of knowledge for maintenance (filter to clean).

4.Benchmarking of available commercial products:

Ergonomics: very good, easy to transport, weight <23kg (transport by plane with luggage)

[114] Philippe BESSON-PUI FRANCE



Functions NOT APPLICABLE

Wireless remote control NOT APPLICABLE

Rechargeable battery (external): Yes