SPS internal use

Progress Report Received	SPS Reference:

Emerging Security Challenges Division

Science for Peace and Security Programme

Multi-Year Project Progress Report

insert project title

Smart Patch for Life Support Systems – SP4LIFE

submit completed report in **Microsoft Word format** to sps.admin@hq.nato.int

Kickoff Date	Project Duration	Date of this Report
10.03.2021	36 months	10.09.2021

Project Co-Directors

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Abstract & Current Status

provide an abstract of the project and its current status (no more than one-half page)

Abstract:

Wearable real-time systems collecting and smartly analysing information on respiration, heartbeat, SpO2, blood pressure and body temperature could help medical personnel adopting most suitable countermeasure in case of highly stressful situations in military and civil scenarios as a result of terrorist attacks, IEDs' or rescue operations. A system for remote real-time monitoring and analysis of emergency personnel and wounded victim's health status will be designed within the project. The system gives an alert if the health status of a person is changed to prevent overlook of critical health changes. A patch-like device prototypes and methodology enabling continuous evaluation of personnel or victims' vital parameters, using Artificial Intelligence to create software capable of real-time diagnostics and rapid countermeasures' selection will be developed.

Current status:

Scientific work is conducted according to the project schedule. The main limitation is the reduced possibility to organize face-to-face meetings and collaborative research in laboratories because of the COVID situation. We assessed the options for developing wearable graphene-based sensors and initiated development in two research directions. We reviewed the existing HW and SW modules for monitoring vital parameters and started development of applications for processing of selected physiological signal and vital parameters estimation. Databases with physiological signals were created to support development of algorithms using Machine learning. Existing triage

processes of wounded victims were assessed regarding possibilities of including innovative technologies into different stages of the triage.

Goals and Obstacles

summarize the major goals and objectives of the project; highlight any changes from the project plan or previous reports (this is unusual)

The project objectives are to:

- Develop wearable monitoring platforms with:

  a.) sensitive respiration, heartbeat and auditory sensors based on graphene (WP1 – lead member Marko Spasenovic),

  b.) ECG, SpO2, BP and body temperature sensor modules (WP2 - lead member Carlo Saverio Iorio, WP3 – lead member Milan Tysler),
- Create a biocompatible wearable body-sensing interface hosting electronics, alarm, low-power transmission for light-weight, portable applications (WP2 – lead member Carlo Saverio Iorio),
- Create a software that will generate alert in real time, at the moment of critical physiological parameter changes or changes of the triage medical status according to START algorithm (WP3 – lead member Milan Tysler),
- Use Artificial Intelligence to create unsupervised software capable of real-time diagnostics and rapid countermeasures' selection (WP4 – lead member Ana Madevska Bogdanova),
- Analyze existing (AS-IS) processes and consider their re-design (TO-BE processes) in organization of patient management on the site of accident with respect to wearable monitoring technology being developed (WP4 – lead members Ana Madevska Bogdanova + Oto Masar),
- Create a network of young scientists training in soft and hard skills in the wearable electronics for biomedical applications (WP5 – Milan Tysler).

The main obstacle during the first six months was the limited mobility caused by the COVID pandemics that influenced namely the networking of young scientists. All meetings of the partners and presentations on conferences were only on virtual platforms.

Summary of Accomplishments

summarize accomplishments under these goals to date, highlighting those that have taken place since the past report

Accomplishments related to the above objectives:

WP1 – Marko Spasenovic

- ICTM performed an assessment of existing commercial and research-grade solutions for wearable microphones that could be used for respiration, heartbeat, and auditory biological parameter detection.
- ICTM started to test graphene-based solutions for potential use in wearable sensing devices.

WP2 – Carlo Severio Iorio

- At ULB, a detailed literature review has been done on the suitable materials for hosting the sensing platform. Also, we have started to perform experiments on two materials – PDMS and PGDA – that fulfil different aspects of the platform as we would like to design it, namely conformable and antiallergenic. The preliminary testing concerned the measurement of tensile stress, young modulus, and maximum strength. Both base materials have also been doped with graphene to check for enhanced properties. Measurements are still on-going.
- In IMS existing sensors were reviewed and methodologies for measuring biological parameters such as ECG, EMG, Spirometric sensors, SpO2, blood pressure sensors etc., were evaluated.

WP3 – Milan Tysler

- IMS reviewed existing off- shelf OEM products and software solutions for assembling a smart patch for physiological data acquisition.
- IMS analyzed the requirements and implemented an Android prototype mobile application for ECG recording and visualization.

- FCSE reviewed methods for extracting HR, RR and Blood pressure from ECG and PPG signals with Python
- FCSE prepared Python scripts with packages and supporting functions and suitable comments needed to gather the data with high quality.
- FCSE continued the research of cuffless BP measurement using ECG, PPG and Machine learning.

WP4 – Ana Madevska Bogdanova

- FCSE started preparation of equipment, building own database and installation of required software;
- FCSE continued data collection from Zephyr (ECG, HR, RR);
- FCSE started processing of collected data:
  - Creatting database from Physionet data containing raw ECG, ABP, PPG signals as well as metadata including ID, ECG type, and frequency.
  - UCI Machine Learning Repository: Cuff-Less Blood Pressure Estimation Data Set;
- FM performed assessment of existing triage processes (e.g. START) regarding possibilities of including innovative technologies (e.g. telemedicine) into different stages of triage. Our clinical team discussed details of patient triage process with technological teams from IMS and FCSE. Focus was on selecting the proper places on human body to record physiological data (ECG, HR, RR, SpO2).

WP5 – Milan Tysler

- The Communication plan was developed and implemented. Network of all partners, including young scientists was established through online communication within each partner's institution and among project partners.
- Started dissemination of the research supported by the project and publication of its first results.

WP6 – Milan Tysler

- Financial and administrative management was established in all partner institutions.

Accomplishments

detail accomplishments and progress since the last report for each work package

WP1 – Marko Spasenovic

We assessed parameters that are relevant for wearable detection of audio signals, respiration, and heartbeat with a single device. In ICTM we are gauging our existing solution based on liquid-phase exfoliated graphene to other solutions based on electrochemically exfoliated graphene and laser-induced graphene. We produced several samples of graphene on flexible substrates that have the potential to be integrated into a wearable patch and are performing experiments on them to gauge their performance for monitoring physiological parameters. We initiated production of laser-induced graphene.

WP2 – Carlo Severio Iorio

The materials that we have tested at ULB performed quite well if compared with elasticity and conformability of skin. We have also created a preliminary design for the "patch" including the hosting of the sensing element. As a side accomplishment, we successfully tested a ZN-air battery concept that, in the future could be fully integrated in the bio-interface.

In IMS existing sensors were reviewed and methods for ECG, EMG, spirometric signals, SpO2 and blood pressure were evaluated. The advantages and disadvantages of different methods and corresponding sensors were assessed. The emerging possibilities of PPG sensors for monitoring of blood glucose and bilirubin levels were discussed.

WP3 – Milan Tysler

In IMS a state-of-the-art review of the methods for estimation of the heart rate (HR), respiratory rate (RR) and SpO2 was conducted. These parameters can be estimated from the recorded electrocardiographic (ECG) or

photoplethysmographic (PPG) signals. The algorithms must be suitable for real-time application and artifacts in these signals need to be eliminated. Therefore, the state-of-the-art review summarizes algorithms for real-time detection of selected vital parameters with a specific focus on noisy signals.

Requirements for a mobile application for ECG biosignal data acquisition were analyzed in IMS with partners from FM and first prototype of Android mobile application for ECg acquisition using Zephyr sensor was implemented. The sensor was chosen due to its sampling frequency of 1000 Hz and available development kit enabling direct communication with mobile phone through a Bluetooth interface.

In FCSE software modules for processing of ECG and PPG signals, for extracting HR, RR and BP were implemented in Python.

The software module, a Python script with packages for high quality ECG signals was developed and implemented the package neurokit to enable quality check of the ECG.

Another software module, a Python script for pre-processing of PPG signals can:
- detect flat lines in the signal, the threshold for downloading the signal based on flat lines is 5%,
- detect flat peaks in the signal, the threshold for downloading the signal based on flat lines is 5%,
- remove NaNs from the signals,
- remove steep steps at the beginning of the signal and spike at the end of the signal,
- apply the fourth-order Butterworth filter with specified cut-off frequencies.

WP4 – Ana MAdevska Bogdanova

In FCSE Several databases were created, using the developed SW modules (WP3):

Physionet (only data for patients for whom there is a PPG signal). The database contains records for the following signals/parameters: heart rate, respiratory rate, ECG, respiratory signal and oxygen saturation. Data are stored in two formats: .csv and pickle.

Physionet data containing raw ECG and ABP signals as well as metadata including ID, ECG type, and frequency. Data (7.5GB in total) are downloaded in 13 distinct chunks, each with variable size contains the following columns: ABP, ECG, ECG type, Hz, and ID.

UCI Machine Learning Repository contains data set for cuff-less blood pressure estimation.

Own FCSE database with data obtained from Zephyr biosensor. Every measurement was processed by taking 30s of the recording and is accompanied with measured SBP and DBP. Processed Zephyr files for ECG, HR, RR, Posture and PeakAcc are available.

At FM processes of existing triage approaches were analyzed with respect to possible incorporation of a wearable monitoring technology, with the focus on the organization of patient management on the site of the accident. Several issues were identified that need to be taken into consideration: proper warning of rescue teams in case of patient status deterioration, thresholds of physiological parameters that evoke changes in patient health status (green to yellow, yellow to red) and position of sensors for recording different physiological data to obtain the highest quality of PPG signals (chest, earlobe or finger-based recording).

WP5 – Milan Tysler

Within this WP the basic communication plan was established within the partners' institutions and among them:

- in IMS regular meetings and discussions with project members are organized on Tuesdays at 2 p.m. where the project progress is monitored and next steps are discussed. During the COVID lock-down the meetings are organized via Skype. Subgroup of researchers from IMS devoted to development of the mobile application prototype for biosignal acquisition and visualization organizes its meetings on Tuesdays at 4 p.m., during the COVID lock-down via Google Meet.
- ICTM organizes regular meetings in the lab to discuss progress and plan further steps.
- At ULB, we have organized monthly meeting about the activities' progress.
- Within the FCSE institution, regular meetings and discussions with project members to follow up progress and discuss next steps are organized in two weeks terms. Sometimes separate meetings are held with different working groups. Meetings are organized via internal Moodle plug-in BBB and Google Meet.

On the inter-institutional level the communication was very limited due to the COVID situation, mainly in three ways:

- collaboration between FCSE and IMS on Overleaf oriented to preparation of presentations and writing papers,
- audio-visual meetings of the project co-directors with possible participation of all project coworkers using the ZOOM link managed by IMS:
  https://zoom.us/j/98096100711?pwd=UStLV0tpbUJyaVVUK3FHb3Y5WXJoQT09

  Until now, 4 such meetings took place.
- regular communication and exchange of materials by emails.

During the first 6 months also the project web page was created at https://www.um.sav.sk/SP4LIFE , and several conference contributions were published as shown in the "Products & Dissemination" section.

WP6 – Milan Tysler

Financial and administrative management was established in partner institutions. Persons involved in project management were asked to get acquainted with the corresponding NATO regulations. If their activities were wider, they were rewarded according to man-hours worked from the funds in the "Other" category.

Obstacles

detail any obstacles, technical, administrative, or other encountered since the last report and how they were or are being dealt with; highlight ongoing issues

The main obstacle was the limited possibility to personal meetings and for several months also limited or prohibited access to laboratories. Many coworkers were on home-office or in quarantine and only electronic communication was possible.

Collaboration

detail the collaboration and consultation among co-directors and their groups since the last report

As mentioned in detail above within the WP5 acomplishments description, most consultations among co-directors were organized via emails. Due to the COVID situation during spring and summer it wasn't possible to organize face-to-face meetings among the groups. Audio-visual meetings of the project co-directors with possible participation of all project coworkers were organized using the ZOOM link:

https://zoom.us/j/98096100711?pwd=UStLV0tpbUJyaVVUK3FHb3Y5WXJoQT09.

Email communication and the online ZOOM meetings (on March 10, May 13, May 27 and September 7) were focused on project management issues, stipends payments and organising interactions between research groups from each partner.

Milestones & Deliverables

list milestones and deliverables due since the last report and their current status; if they are not complete, explain and detail plans and timelines for their completion

There were no deliverables planned for the initial 6-month period and Milestone 1. Below are shown the project tasks that were scheduled for the first 6 months and their preliminary results.

SP4LIFE	Year 1	Year 2	Year 3
WP1: Flexible Capacitive and Strain Sensors with Biocompatible, Wearable Interface			
T1.1 Design and Materials choice			
T1.2 Sensing element manufacturing, assembling and functional testing			
T1.3 Biocompatible materials choice			
T1.4 Mechanical properties assessment			

Deliverables

D1.1 (M18) Report on the development and testing of the sensing elements

D1.2 (M12) Report on the biocompatible interface protocol, including mechanical characterization

D1.3 (M18) White paper on biocompatible materials and their applications in the wearable electronics domain

Milestone

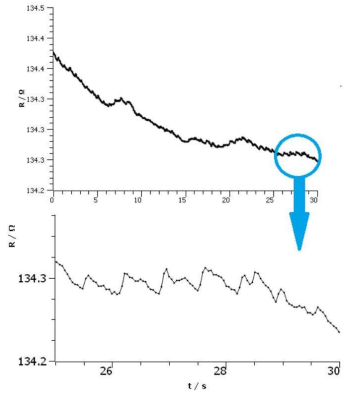
M1 creation of a working prototype of graphene-based sensors with biocompatible interface complying with the mechanical requirement of stretchability, light invasiveness and robustness.

We looked into commercially available and research-grade solutions for wearable biosensors made of thin-film materials on substrates that are potentially compatible with wearable electronics. A shortlist of potentially interesting solutions was created, with a summary of their advantages and disadvantages.

We assessed the design and material choice for our own sensing elements. Three different forms of graphene were considered: ultrasound exfoliated, electrochemically exfoliated, and laser-induced. Experiments are ongoing to test each of those three materials. The testing will proceed in three phases: testing for strain detection, testing as sound detector, and testing in-vivo for use as a detector of human voice, respiration, and heartbeat.

We purchased a laser for making laser-induced graphene and an electronic instrument for measuring the device response signal.

Laser induced graphene (LIG) on a flexible substrate.



Recording of a person's pulse with the same LIG.

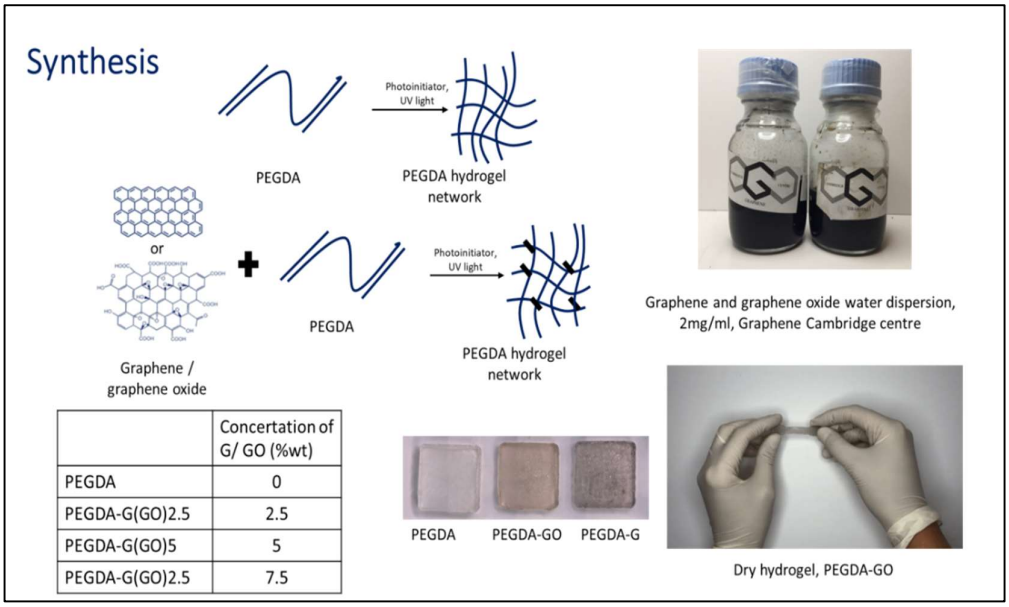
SP4LIFE	Year 1	Year 2	Year 3
WP2: Smart Patch HW Definition, Integration, Testing and Evaluation			
T2.1 Definition of the sensor modules for physiological data acquisition and analysis			
T2.2 Data processing, transmission protocols and network management			
T2.3 Assessment of power requirements for sensing, processing and transmission			
T2.4 Integrated platform assembly and testing			

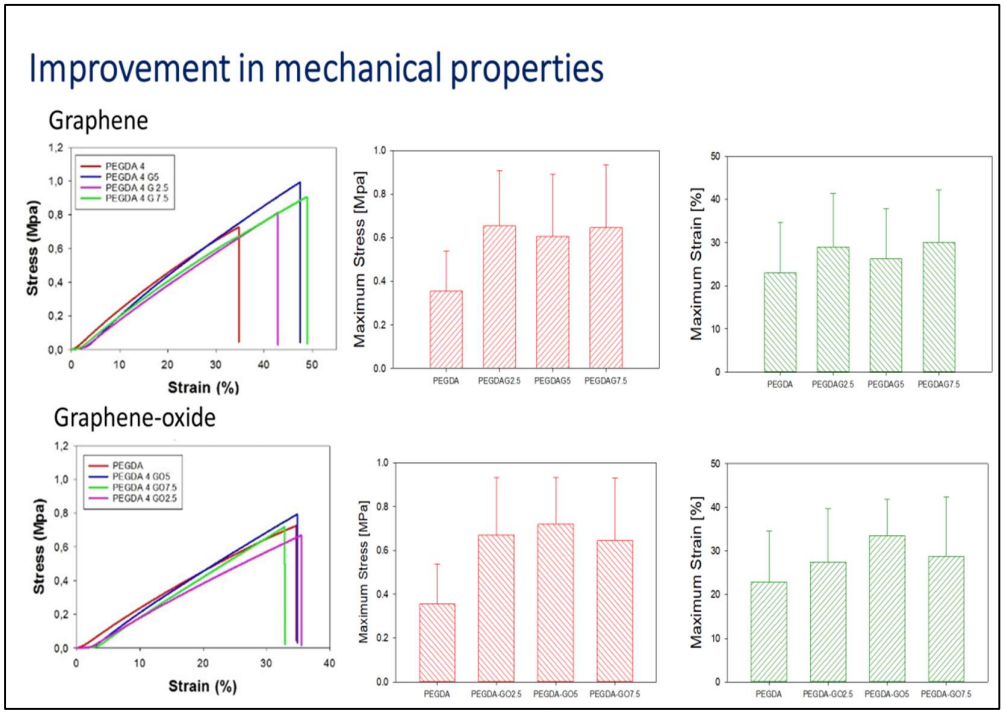
Deliverable

D2.1 (M12) Report on tested sensor modules and their performance.

Milestone

M2 Tested and operational wearable HW platform for physiological data acquisition and analysis





At ULB, we began to produce and test several materials that could be candidates for hosting sensing elements. We assessed those materials against biocompatibility, and begin to experiment their mechanical properties. We have also begun doping the materials to ensure better properties against aging, thermal and mechanical stability.

In IMS existing sensors were reviewed and methodologies for measuring biological parameters such as ECG, EMG, Spirometric sensors, SpO2, blood pressure sensors etc., were evaluated. The advantages and disadvantages of each methodology and corresponding sensors were assessed. Particularly, SpO2 sensors that allow sensing of heart rate and blood oxygenation were compared. The emerging possibilities for their further application for monitoring of blood glucose and bilirubin levels was discussed. On the other side, their disadvantages in the form of various factors such as patient movement, blood properties (anemia), skin properties (pigment, tattoos, skin diseases,

wounds, scar tissue), hypothermia, light interference and medications that affect the accurancy of the SpO2 measuring method were studied.

SP4LIFE	Year 1	Year 2	Year 3
WP3: Methods and Software for Acquisition, Processing and Evaluation of Physiological Signals			
T3.1 Specification, development and implementation of software modules for physiological data measurement, processing and analysis			
T3.2 Method, and software development and testing for cuffless blood pressure measurements			
T3.3 Methods and software for processing of acoustic signals			
T3.4 Fast and secured transfer of physiological data			

Deliverable

D3.1 (M18) Software modules for measurement and local processing of ECG, SpO2 and breathing signals.

Milestone

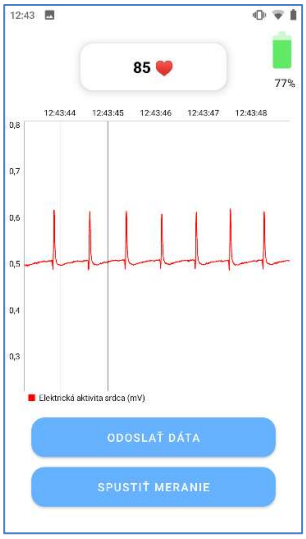
M3 Software modules for acquisition, local processing and possible transfer of physiological data.

In IMS a state-of-the-art review of the methodologies for the estimation of the heart rate (HR), respiratory rate (RR) and SpO2 was conducted. Those parameters can be estimated from the recorded electrocardiographic (ECG) or photoplethysmographic (PPG) signal. Because the ECG or PPG signals are often contaminated by noise caused for example by the patient's movement or powerline interference, these artifacts need to be eliminated in order to accurately estimate the selected vital parameter. Further, the algorithms for estimation of the selected parameter must be suitable for the real-time application. Therefore, the state-of-the-art review summarizes the algorithms for real-time detection of the selected vital parameters with a specific focus on detection from noisy signals.

Analyses of papers related to monitoring of SpO2 from different body parts that will enable the most unobtrusive data measurement from body. Papers were selected from online databases IEEE Xplore, Springer, Elsevier, PubMed, and grey literature (e.g. Google Scholar).

Mobile application module for Android OS for acquisition of ECG and breathing parameters was developed. Connection via wireless Bluetooth interface with Zephyr ECG sensor (https://www.zephyranywhere.com/) that enables also heart rate and breathing monitoring for victims and rescues crew member health status.

First prototype of a SW module for ECG and breathing signals (breathing rate) acquisition was developed.



Prototype of Android application for ECG signals acquisition

In FCSE analyses of papers related to processing the ECG and PPG for extracting HR, RR, SPO2 and BB were performed. Papers were selected from online databases IEEE Xplore, Elsevier, PubMed, and by key words from Google search, also by exploring github projects.

Several software modules were developed for T3.1. Python scripts were used for physiological data measurement, processing and analysis.

SP4LIFE	Year 1	Year 2	Year 3
WP4: Predictive Tools and Alerting System			
T4.1 Exploiting existing and building own databases of collected vital parameters			
T4.2 Big Data in support of the sensing platform			

T4.3	Training of the analysis software to understand correctly how to evaluate specific event
T4.4	Development of mathematical models for health status changes
T4.5	Analysis of AS-IS processes and definition of TO-BE processes of medical response to massive incidents

Deliverable

D4.1 (M18) Database of vital signs from ECG, SpO2, body temperature.

Milestones

M4 Software platform to analyse in real time physiological data including the cardiac and respiratory rhythm, and create mathematical models based on Big Data, AI and Deep Learning to connect them with known disorders, for assessment of person's health status change from YtoG and GtoY, and corresponding alarm generation.

Considering the T4.1, in FCSE existing databases were explored with the vital signals of interest, several Python scripts for data quality filtering were developed and downloaded in order to start the research for T4.2.

Currently, the following databases are available:

- Physionet databases Mimic2 and Mimic3 were checked for high quality ECG and ABP signal and those that satisfied the criteria were downloaded in 13 distinct chunks, 7.5GB total.
- Database with PPG with HR, ECG, RR and SPO2, databases are stored in two formats - .csv and pickle.
- BIDMS database - contains information about 53 patients and their ECG, ECG_AVG, RR, SpO2, HR, PPG, and other features
- Own Database using Zephyr, Data processing:
  - Every measurement was processed by taking 30s of the recording and accompany it with the SBP and DBP measured
  - Since Zephyr produces several different files for ECG, HR, RR, Posture and PeakAcc, all the files were processed and named accordingly.
- UCI Machine Learning Repository: Cuff-Less Blood Pressure Estimation Data Set

SP4LIFE	Year 1	Year 2	Year 3
WP5: Dissemination, Communication and Exploitation			
T5.1 Development of the Communication plan			
T5.2 Dissemination			
T5.3 Exploitation of the results			

Deliverables

D5.1 (M12, M24, M36) Annual report on Communication activities including Recruitment of young researchers

D5.2 (M12, M24, M36) Annual report on Dissemination and Communication activities

Milestone

M5 Organization of the events foreseen for the dissemination and communication campaigns in due time

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Within this WP the basic communication plan was established within the partners' institutions and among them as described in section "Accomplishments".

During this period, the project web page was created at https://www.um.sav.sk/SP4LIFE , and several contributions were or will be published as shown more in detail in the section "Products & Dissemination", on conferences listed in the section "Training & Professional Development".

SP4LIFE	Year 1	Year 2	Year 3
WP6: Management			
T6.1 Financial and administrative management			
T6.2 Technical Management of the whole project			
T6.3 Quality Management			

Deliverables

D6.1 (M12, M24, M36) Progress activity reports, including dissemination, communication and exploitation plans and timeline updates

D6.2 (M12, M24, M36) Annual progress reports incl. financial reports

Milestone

M6 Annual report in due time and correctly filled

Within this WP the current Progress report and Financial report were prepared.

Training & Professional Development

detail training and professional development activities since the last report

During the evaluated period the partners were involved in organization of several international conferences. Young students and scientists involved in the project prepared their presentations and publications on these conferences that are shown in section "Products & Dissemination".

- **MEASUREMENT 2021**, 13th International Conference on measurement, organized by IMS that was held virtually in Smolenice, Slovakia on May 17-19,2021: https://www.measurement.sk/M2021/

  Poster presentation by the young scientists Beata Ondrusova (IMS), Bojana Koteska, Magdalena Kostoska and Monika Simjanoska (FCSE) and published in the Proceedings registered in IEEE Xplore, WOS and SCOPUS: https://www.measurement.sk/M2021/efJedT43/doc/P4_7.pdf

- **PHOTONICA 2021**, VIII International School and Conference on Photonics, August 23 - August 27, 2021, Belgrade, Serbia:

  Poster presentation by young scientist Teodora Vićentić (ICTM): http://www.photonica.ac.rs/docs/posters/Teodora_kaskadna_ehg2.pdf

- **13th ICT Innovations Conference 2021** organized by FCSE that will be held online from September 27 to September 29, 2021: http://ictinnovations.org

  During the conference, the parallel international workshop on NATO SPS MYP project G5825 – "Smart Patch for Life Support Systems - SP4LIFE" will be held: http://ictinnovations.org/workshops

  Two papers will be presented by the young scientists involved in the project and published in the Web Proceedings.

- **CIIT 2021**, 18th International Conference on Informatics and Information Technologies, held online on May, 6-7 2021, North Macedonia: http://ciit.finki.ukim.mk

  Young scientists from FCSE attended the conference.

Impact

describe the impact of the project on the scientific community or the public since the last report; if nothing significant to report, write None

- Defended Diploma work at FCSE by the stipend from North Macedonia, Hristina Mitrova: "Models for Fraud detection in Health Domain", April 2021
- Diploma work in preparation at FCSE by the stipend from North Macedonia Ivan Kuzmanov : "Development and analytics models for non-invasive Blood pressure estimation with Deep Learning"

Looking forward

detail your plans for advancing project goals in the next reporting period including upcoming milestones and deliverables

SP4LIFE	Year 1	Year 2	Year 3
WP1: Flexible Capacitive and Strain Sensors with Biocompatible, Wearable Interface			
T1.1 Design and Materials choice			
T1.2 Sensing element manufacturing, assembling and functional testing			
T1.3 Biocompatible materials choice			
T1.4 Mechanical properties assessment			

Deliverables

D1.1 (M18) Report on the development and testing of the sensing elements

D1.2 (M12) Report on the biocompatible interface protocol, including mechanical characterization

D1.3 (M18) White paper on biocompatible materials and their applications in the wearable electronics domain

D1.4 (M20) Prototype of the sensing elements with body interface

Milestone

M1 creation of a working prototype of graphene-based sensors with biocompatible interface complying with the mechanical requirement of stretchability, light invasiveness and robustness.

Plan for the next 6 months:

- T1.2: We will continue through the first two phases of producing and testing our graphene-based bioparameter monitoring sensors. We will manufacture three types of graphene on two different flexible substrates, followed by testing their operation as strain and audio detectors.
- T1.3 and T1.4: We will test the two substrates for biocompatibility, including mechanical characterization, which will be crowned with a report in M12.

SP4LIFE	Year 1	Year 2	Year 3
WP2: Smart Patch HW Definition, Integration, Testing and Evaluation			
T2.1 Definition of the sensor modules for physiological data acquisition and analysis			
T2.2 Data processing, transmission protocols and network management			
T2.3 Assessment of power requirements for sensing, processing and transmission			
T2.4 Integrated platform assembly and testing			

Deliverables

D2.1 (M12) Report on tested sensor modules and their performance.

D2.2 (M24) Report on possible solutions for computational electronics, transmission protocols and power delivery.

Milestone

M2 Tested and operational wearable HW platform for physiological data acquisition and analysis

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Plan for the next 6 months:

In collaboration with the partners, we will select the most promising materials and elaborate a design capable of supporting the sensing element. Also, we will begin to test the actual sensing response once a sensing element integrated on the platform.

Based on the previous review, within T2.1 we will select and test several available sensors for physiological data acquisition. Optimal combination of sensors will be assessed and used in the patch prototype development.

SP4LIFE	Year 1	Year 2	Year 3
WP3: Methods and Software for Acquisition, Processing and Evaluation of Physiological Signals			
T3.1 Specification, development and implementation of software modules for physiological data measurement, processing and analysis			
T3.2 Method, and software development and testing for cuffless blood pressure measurements			
T3.3 Methods and software for processing of acoustic signals			
T3.4 Fast and secured transfer of physiological data			

Deliverables

D3.1 (M18) Software modules for measurement and local processing of ECG, SpO2 and breathing signals.

T3.2 (M24) Method, and software development and testing for cuffless blood pressure measurements: the new methodology developed by FCSE team for blood pressure estimation by using the ECG signal only will be introduced in the prototype patch sensor to enable measurement of the blood pressure without separate BP measuring device.

Milestone

M3 Software modules for acquisition, local processing and possible transfer of physiological data.

Plan for the next 6 months:

Within T3.1 software modules for measurement and local processing of ECG, SpO2 and breathing signals will be developed including:

- Analyses of methods for measurement of SpO2 from various body parts and its testing regarding reduction of delays of blood saturation
- Development of assessment methods of health status for victims and crew members using ECG, SpO2, breathing and temperature
- Software modules for extracting HR and RR from ECG or PPG signal

Within T3.2 software module for cuffless blood pressure measurement based on measured ECG/PPG signal will be developed. This includes:

- Analyses of existing methods and approaches for cuffless blood pressure estimation using above mentioned physiological signals
- Development of SW prototypes for cuffless blood pressure estimation based on analyses of existing methods including Deep Learning
  - The goal is to create an algorithm that can make estimations of the blood pressure categories
  - regression and classification algorithm will be considered
  - the SW will give the best results within the time and space constraints.

SP4LIFE	Year 1	Year 2	Year 3
WP4: Predictive Tools and Alerting System			
T4.1 Exploiting existing and building own databases of collected vital parameters			
T4.2 Big Data in support of the sensing platform			
T4.3 Training of the analysis software to understand correctly how to evaluate specific event			
T4.4 Development of mathematical models for health status changes			
T4.5 Analysis of AS-IS processes and definition of TO-BE processes of medical response to massive incidents			

Deliverables

D4.1 (M18) Database of vital signs from ECG, SpO2, body temperature.

D4.2 (M32) Transfer function for linking the status of the person and the parameters' space monitored based on unsupervised training and deep learning concepts.

Milestone

M4 Software platform to analyse in real time physiological data including the cardiac and respiratory rhythm, and create mathematical models based on Big Data, AI and Deep Learning to connect them with known disorders, for assessment of person's health status change from YtoG and GtoY, and corresponding alarm generation.

Plan for the next 6 months:

Within T4.1 we will focus on:

- extending the created Data bases from Zephyr sensor measurement with new subjects,
- updating the developed Python scripts for downloading qualitive filtered data from the public databases according the needs for SPO2 and BP estimation.
- download Big data from Physionet databases to try Deep Learning models for cuffless BP, SPO2 estimation.

Task T4.2 will be focused on Big data that are expected to be in size of Terabytes, in order to create, test and validate the proposed models for prediction of BP and SPO2 using Deep Learning. The data must be available to all included participants in the project and always available - the solution is to use a cloud storage for storage management according to the needs of project and its members. Since data is and will be further obtained in accordance to ethical committee, it is recommended to be private and only authorized access to be provided. The plan is to use ownCloud solution that will enable enough flexibility as well as control in above mentioned limitations and requirements.

SP4LIFE	Year 1	Year 2	Year 3
WP5: Dissemination, Communication and Exploitation			
T5.1 Development of the Communication plan			
T5.2 Dissemination			
T5.3 Exploitation of the results			

Deliverables

D5.1 (M12, M24, M36) Annual report on Communication activities including Recruitment of young researchers

D5.2 (M12, M24, M36) Annual report on Dissemination and Communication activities

Milestone

M5 Organization of the events foreseen for the dissemination and communication campaigns in due time

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Plan for the next 6 months:

- Organization of the SP4LIFE Workshop, within the 13th ICT Innovations Conference 2021, 27-29 September, 2021: http://ictinnovations.org/workshops

  Two papers will be presented by the young scientists and published in the Proceedings.

- Active participation in selected international conferences oriented to biomedical engineering, wearable technologies and artificial intelligence in biomedicine.

SP4LIFE	Year 1	Year 2	Year 3
WP6: Management			
T6.1 Financial and administrative management			
T6.2 Technical Management of the whole project			
T6.3 Quality Management			

Deliverables

D6.1 (M12, M24, M36) Progress activity reports, including dissemination, communication and exploitation plans and timeline updates

D6.2 (M12, M24, M36) Annual progress reports incl. Financial reports

Milestone

M6 Annual report in due time and correctly filled

Within this WP the first Annual report and corresponding Financial report will be prepared. There are 2 also deliverables expected in month 12:

- D1.2 Report on the biocompatible interface protocol, including mechanical characterization
- D2.1 Report on tested sensor modules and their performance

Project Participants and Roles

list the participants in the project and the rough fraction of their time spent on it since the last report; describe briefly how each person contributed to the project; add or subtract rows as needed

(Only persons that actively contributed to the project during the evaluated period are listed.)

Name	Affiliation	Position/Title	% Time	Role
Milan Tyšler	Institute of Measurement Science, Slovak Academy of Sciences (IMS)	Department Head	30%	WP2: Consultations to the sensor modules for physiological data acquisition and analysis with D.Gogola. WP3: Consultations with B. Ondrušová on specification and development of software modules for physiological data measurement WP5: Implementation of the Communication plan. Dissemination of knowledge. Exploitation of the results. WP6: Project management: meetings with co-directors.
Chyba! Nenašiel sa žiaden zdroj odkazov. Chyba! Nenašiel sa žiaden zdroj odkazov.	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	20%	Relevant parameter considerations for bioparameter monitoring sensors. Literature and product search for wearable microphone devices that can detect heart rhythm, breathing, and voice. Preparing a report on state of the art. Considerations of possible graphene-based alternatives. Research on technical requirements for laser to produce graphene, purchasing laser and measurement instrument.
Chyba! Nenašiel sa žiaden zdroj odkazov.	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	20%	WP1: Graphene-based sensing element manufacturing, assembling and functional testing WP2: Assessment of power requirements for sensing, processing and transmission. Integrated platform assembly and testing WP3: Methods and software for processing of acoustic signals to extract information on heart beating and breathing. WP5: Development of the Communication plan. Dissemination of knowledge. Exploitation of the results. WP6: Management.
Chyba! Nenašiel sa žiaden zdroj odkazov. Chyba! Nenašiel sa žiaden zdroj odkazov.	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	30%	WP3: Researching for models and software development and testing for cuffless blood pressure measurements. WP4: Coordinating the building of Python scripts for filtering the public data bases with physiological signals (very important because of the data quality), building own Zephyr database WP5: Development of the Communication plan. Dissemination of knowledge. Exploitation of the results, writing scientific papers. Coauthor of paper “Validation of Data correlation - Heart Rate and Respiratory Rate from ECG in Python” Coauthor of the Paper: Evaluation of Python HeartPy Tooklit for HeartRate extraction from PPG

				WP6: Meetings with the working group, coordination of the next steps, writing report, managing the documents for account opening
Chyba! Nenašiel sa žiaden zdroj odkazov. Chyba! Nenašiel sa žiaden zdroj odkazov.	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	**Chyba! Nenašiel sa žiaden zdroj odkazov.**	30%	WP3: Consultations on specification of software prototype functionality for physiological data measurement (ECG, HR, SpO2, blood pressure). This was used for the prototype design in IMS. The specification was created with respect to data acquisition in hospital setting and will be used for better understanding of the telemedicine by the clinical personnel. WP4: Analysis of AS-IS processes and definition of TO-BE processes of medical response to massive incidents with respect to the proposed technology innovation.
Fedor Lehocki	IMS	Senior Researcher	30%	WP3: Prototype design of mobile app. for physiological data acquisitions (ECG, SpO2 and blood pressure measurements). WP5: Dissemination of knowledge related to physiological data acquisition - preparation of poster and paper for Measurement 2021 conference (https://www.measurement.sk/M2021/efJedT43/posters.html)
Ján Zelinka	IMS	Senior Researcher	20%	WP3: Consultations on software modules for physiological data measurement, processing and analysis.
Daniel Gogola	IMS	PhD. Student (young scientist)	100 %	WP2: Review of sensor modules for smart patch HW, their comparison and evaluation WP5: Dissemination of knowledge.
Beáta Ondrušová	IMS	PhD. Student (young scientist)	100 %	WP3: Review of software modules for physiological data measurement, processing and analysis. WP5: Dissemination of knowledge: papers on Measurement 2021 and ICT Innovations Conference 2021.
Teodora Vićentić	ICTM	PhD. Student (young scientist)	*30%*	WP1: Flexible strain sensors: Design and material choice. Sensing element manufacturing from liquid phase exfoliated and laser induced graphene. Initial tests of graphene strain sensor performance for measuring audio. Dissemination of knowledge related to the manufacturing of sensors based on electrochemically exfoliated graphene - preparation of paper for Photonica 2021 conference (http://www.photonica.ac.rs/docs/posters/Teodora_kaskadna_ehg2.pdf)
Immacolata Grieco	ULB	PhD Student (young scientist)	60%	WP1: Biocompatible, Wearable Interface materials choice. Mechanical properties assessment.
Vanja Miskovic	ULB	PhD Student (young scientist)	15%	WP1: Biocompatible, Wearable Interface materials choice. Mechanical properties assessment.
Vladimir Trajkovik	FCSE	Senior Researc	10%	WP3: Research on patch-like devices

		her		WP5: Dissemination of knowledge, WS on ICT Innovations
Nevena Ackovska	FCSE	Senior Researcher	20%	WP4: Consultation about biosignal processing WP5: Coauthor of the Paper: Evaluation of Python HeartPy Tooklit for HeartRate extraction from PPG
Magdalena Kostoska Gjorcevska	FCSE	Postdoc (young scientist)	100 %	WP3: Research and exploration for BP from ECG+PPG, extraction on HR and RR from ECG signal using Python libraries WP4: Data processing: - Equpment preparation and installation with required software; - Every measurement was processed by taking 30s of the recording and accompany it with the SBP and DBP measured - Processing Zephyr's different files for ECG, HR, RR, Posture and PeakAcc. - preparation for Cloud platform for Big Data WP5: Coauthor of paper "Validation of Data correlation - Heart Rate andRespiratory Rate from ECG in Python"
Monika Simjanoska	FCSE	Postdoc (young scientist)	100 %	WP3: Python script with packages, supporting functions, main function, and suitable comments needed to enable the data download from Physionet database. To assure high quality ECG signals are downloaded, I implemented the package neurokit to enable the quality check on the ECG signals, and downloaded only those with quality of above 0.8 (maximum is 1). WP4 By using the script, all the patients from Physionet databases Mimic2 and Mimic3 were checked for high quality ECG and ABP signal and those that satisfied the criteria were downloaded in 13 distinct chunks, 7.5GB in total, WP5: Dissemination of knowledge
Bojana Koteska	FCSE	Postdoc (young scientist)	100 %	WP3: Developing software modules, Python scripts for downloading databases with PPG signals from Physionet (downloading only data for patients for whom there is a PPG signal). Databases contain records for the following signals/parameters: heart rate, respiratory rate, ECG, respiratory signal and oxygen saturation. Databases are stored in two formats - .csv and pickle. WP4: data from MIMIC III database; data from BIDMC database WP5: Coauthor of the Paper: Evaluation of Python HeartPy Tooklit for HeartRate extraction from PPG
Hristina Mitrova, from 10.06.2021	FCSE	BSc. (young scientist)	50%	WP3: optimization of the algorithm based on the fact that the lowest possible data frequency will be used and thus shorter evaluation time will be needed - additional preprocessing and editing of the database according to the optimized algorithm

				WP4: preprocessing the bidmc(https://physionet.org/content/bidmc/1.0.0/) database which contains information about 53 patients and their ECG, ECG_AVG, RR, SpO2, HR, PPG, and other features WP5: WP5: Coauthor of the Paper: Evaluation of Python HeartPy Tooklit for HeartRate extraction from PPG
Ivan Kuzmanov - from 10.06.2021	FCSE	BSc. (young scientist)	50%	WP3: researching for existing solutions by reading papers and exploring github projects for estimation of Blood pressure from ECG+PPG signal. Processing of ECG and PPG signal. Lightweight algorithm capable to function in real time is needed, produced SW modules in Python for optimization models. WP4: Storing and processing the UCI Machine Learning Repository database, producing he optimal segment length WP5: paper in progress

Criteria for Success

list the Criteria for Success established in the Project Plan and your estimate as to their current state of completion

Criterion	Relative Weight	Complete	Comments
Creation of a working prototype of graphene-based sensors with biocompatible interface complying with the mechanical requirement of stretchability, light invasiveness and robustness.	**20%**	**5%**	No obstacles, progress according to project plan (time table of WP). We have been active during these first months. We plan to move forward by strengthening the cooperation with the sensing elements developers.
Fully tested and operational HW platform for physiological data acquisition and analysis	**20%**	**2%**	No obstacles, progress according to project plan (time table of WP).
Software modules for acquisition, local processing and possible transfer of physiological data	**20%**	**2%**	No obstacles, progress according to project plan (time table of WP).
Software platform to analyse in real time physiological data including the cardiac and respiratory rhythm, and create mathematical models based on Big Data, AI and Deep Learning to connect them with known disorders, for assessment of person's health status change from YtoR and GtoY, and corresponding alarm generation	**30%**	**5%**	No obstacles, progress according to project plan (time table of WP).
Organization of the events foreseen for the dissemination and communication campaigns in due time	**10%**	5%	https://www.measurement.sk/M2021/ http://ictinnovations.org/workshops

Products & Dissemination

please list all products and outcomes of the project since the last report

Journal articles, conference papers, book chapters, and other publications (please do not attach copies)

F. Lehocki, A. M. Bogdanova, M. Tysler, B. Ondrusova, M. Simjanoska, B. Koteska, M. Kostoska, M. Majak, M. Macura, "SmartPatch for Victims Management in Emergency Telemedicine," 2021 13th International Conference on Measurement, 2021, pp. 146-149, doi: 10.23919/Measurement52780.2021.9446791.

T. Vićentić, S. Andrić, M. V. Bošković, J. Stevanović, I. Pašti, and M. Spasenović, "Optimization of Optoelectronic Properties of Electrochemically Exfoliated Graphene by Cascade Centrifugation", 2021 Photonica Conference, 2021, pp 184, ISBN 978-86-82441-53-3.

S. Jovanov, B. Ristovski, A. Madevska Bogdanova, M. Kostoska "Validation of Data correlation - ECG with Heart Rate and Respiratory Rate in Python", 13th ICT Innovations Conference 2021, 27-29 September 2021.

H. Mitrova, B. Koteska, A.Madevska Bodganova, F. Lehocki, B. Ondrusova, N.Ackovska, "Evaluation of Python HeartPy Tooklit for Heart Rate extraction from PPG", 13th ICT Innovations Conference 2021, 27-29 September 2021.

Conference presentations and public lectures

- Poster presentation at MEASUREMENt 2013 - the 13th International Conference on Measurement held from 17 to 19 May, 2021 in Smolenice, Slovakia:
  https://www.measurement.sk/M2021/efJedT43/doc/P4_7.pdf
  (all posters: https://www.measurement.sk/M2021/efJedT43/posters.html)
- Poster presentation at the 8th International School and Conference on Photonics, held August 23-27, 2021:
  http://www.photonica.ac.rs/docs/posters/Teodora_kaskadna_ehg2.pdf
- Poster or oral presentation for each WP leader and young scientists during the SP4LIFE Wokshop in the scope of the ICT Innovations Conference 2021, 27-29 September 2021. Presentation of the papers shown above in section "Journal articles, conference papers, book chapters, and other publications".
  http://ictinnovations.org/workshops

Inventions, Patents, & Licenses

None

Other products such as web sites, databases, etc. released to the scientific community or the public

The project web page is prepared at https://www.um.sav.sk/SP4LIFE.

Project publicity (please attach copies of articles or reports about the project)

Information on the project is available also on the web pages of partners Institutions:

IMS web page:
https://www.um.sav.sk/en/research/projects/?age=live&project_type=international&program_name=7cd8e4bf&solver=all

ICTM web page:
https://ihtm.bg.ac.rs/en/novosti-eng/2066-ictm-participates-in-project-sp4life-of-the-program-%E2%80%9Cnato-science-for-peace%E2%80%9D

FCSE web page:
https://www.finki.ukim.mk/mk/content/%D0%BF%D1%80%D0%BE%D0%B5%D0%BA%D1%82-nato-mutli-year-science-pease-project-nato-sps-project-g5825-%E2%80%93-%E2%80%9Csmart-patch-life

Schedule

provide a revised project schedule, including an updated Gantt or other suitable chart, indicating the current position and highlighting changes to the original schedule in the Project Plan

No changes are expected.

Budget

ensure that the budget table (Excel) is included and up to date

Please ensure that the MYP Detailed Budget for your project is up to date and attached to this report (in the same email). In particular, ensure that information in the following tabs is correct:

- **Financial Record**: should contain one entry for each payment from SPS funds spent both by the NPD and by other co-directors. A single line stating a bulk transfer to a co-director is not sufficient.
- **Milestone X**: contains the budget spent to date based on entries in the Financial Record. Please fill in budget predictions for subsequent milestones through the end of the project.
- **Property**: ensure that the property record is up to date with all durable equipment purchased for over €2,500.

During the first 6 months **34,206 € was spent from the total budget of 75,700 €.** The main reasons for this drawdown were the delayed delivery of one device at a price of about 30,000 € (for ULB) and restrictions due to COVID, which mainly affected the costs of Training (0 € from 1500 € was drawn at ULB and FCSE) and Travel (190 € from 1,300 € was draw at IMS and ULB) but also Consumables - limited access to laboratories (3,847 € from 7,000 € was drawn at IMS and ICTM). The stipends were not drawn in full (11,000 € from 13,200 € was drawn at IMS and FCSE) because their holders were approved only from April.

As we expect that the device for ULB will be delivered soon and the COVID situation will improve, **we would like to transfer the unused funds for IMS, ICTM, ULB and FCSE to Milestone 2 in the same category**. The literature and publications were covered from other sources **at FM, we would like to transfer the unused funds (400 €) to the Consumables category** to cover the material for emergency unit that will support preparation of telemedicine testing in the upcoming project phase.