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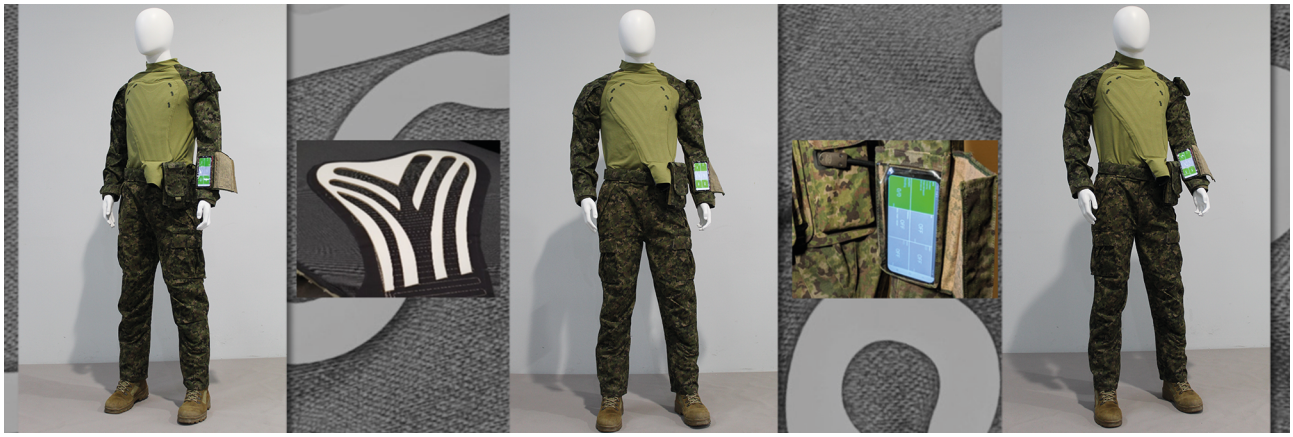

STILE: Smart TextILEs in defence

Looking at the soldiers of the future

Smart Textiles are a new generation of materials and systems with very interesting multifunctional properties (e.g. camouflage, moisture management, electronics integrated in textiles). These properties, together with the possibility of integrating the materials and systems in uniforms and platforms, have drawn the attention of the defence stakeholders. In this context, the European Defence Agency (EDA) has incorporated Smart Textiles into the Strategy Research Agenda (SRA) of the CapTech Materials & Structures and a Technology Building Block (TBB) is devoted to this area. Furthermore, other EDA CapTechs such as the CapTech CBRN and Human Factors and the CapTech Ground Systems, have performed initiatives related to "Smart Textiles".

EDA launched in 2018 the project STILE, assigned to a consortium led by the Spanish Textile Research Institute (AITEX), in collaboration with the Centro Tecnológico das Indústrias Têxtil e do Vestuário de Portugal (CITEVE) and Instituto de Ciência e Inovaçao em Engenharia Mecânica e Engenharia Industrial (INEGI).

The STILE project was designed with the aim of laying the foundation for a European Multifunctional Smart Textile industry focusing on defence and, specifically, tackling aspects of functionality, integration, comfort and lightweight.

FIRST PHASE

The first stage of the project was focused on two main objectives: firstly, the development of a credible roadmap, with the final goal of establishing how to pass from the current state of the art to a full system that integrates several functionalities in a textile substrate. Secondly, the fabrication of a proof of concept, integrating various functionalities in the same smart multifunctional textile combat system.

In particular, the STILE model integrates the following functionalities:

- **Signature management.** A textile with specific properties was developed by means of thermochromic formulations, studies of colour fastness to light, and measurements of colour coordinates in order to provide a multispectral camouflage with a special focus on visual, near infrared and thermal spectra, and aiming at decreasing the visibility of the soldier in combat zones, in both static and moving positions.

- **Monitoring of environmental parameters and CBR threats.** Several specific sensors were integrated in the combat uniform in order to detect the presence of hazardous agents in the environment surrounding the soldier.

- **Improved mobility.** STILE was designed and produced optimising parameters such as ergonomics, homogeneous distribution of weight, wearers' comfort, modularity, freedom of movement and functional properties based on a body mapping study aiming at defining specific functionalities for each body area (such as flexibility, compression and ventilation areas). Regarding the wearable electronic components, the most flexible, light and miniaturized elements were selected.

- **Flame retardancy, water and dirt repellence, and anti-mosquito solution.** Textile fibres and materials with flame retardant properties were selected, and the rest of the components were positioned in specific compartments, to avoid exposure to heat and flame. Other functionalities, such as water and dirt repellence and an anti- mosquito solution, were incorporated using the most innovative functional finishing technologies combined with thermochromic formulations and underwent through several colour fastness tests.

- **Physiological monitoring.** The monitoring of physiological parameters of the soldiers was carried out by means of heart rate sensors located in the inner layer of the smart multifunctional textile system, in contact with the body skin, and integrated in the textile substrate using conductive textiles and printed electronic techniques. The special stretching and flexible properties of the electrodes offered a comfortable solution without the need of hard and rigid elements.

- **Temperature auto-regulation.** A system capable of regulating the thermal comfort of the soldier, adapting it to the weather conditions while considering the physical activity carried out, was incorporated to the combat uniform. This solution included both heating and cooling effects through active and passive mechanisms.

- **Communication and wireless exchanging data.** Output of all sensors integrated in the smart multifunctional textile system can be sent via wireless networks. This enables the monitoring of different parameters related to the state of the soldier in the combat field. The various parameters can be adjusted, activated or deactivated from the control centre located in a smartphone. The information is shown by means of a mobile app that was ad hoc developed to show the valuable information in a user-friendly and intuitive way.

SIMULATION

Two simulation models were developed to evaluate the main concepts regarding the thermal protection capacity of the garment and the thermal signature under different ambient conditions.

A FEM (Finite Element Method) model was developed to study the thermal protection capacity of the clothing assembly. Three exposure scenarios were defined and simulated to evaluate the fire protection capacity by analysing the skin burning degree. In addition, three ambient exposure scenarios were defined and simulated in order to analyse the thermal signature of the garment under different body metabolic rates.
The added value is particularly evident when the textile material integrates very complex systems, which implies the need to arrive to the fabrication phase with a high level of confidence related to the expected results (e.g. thermal and signature management), in order to optimise the experimental cost associated to the design and fabrication processes.

SECOND PHASE

Aiming at making the most of the results achieved during the first phase of the project, the design of the proof of concept was improved throughout the second phase, considering aspects such as the encryption of data during signal transmissions. In addition, the integration of the electronic components and cabling in the textile system was reviewed in parallel to the increased modularity regarding the location option for the battery and control box pockets. The depth of the formerly developed simulation was refined. Moreover, the numerical results obtained were compared with the experimental results, taking the skin and different garment zones into account.
A full testing campaign of the proof of concept was carried out, considering different parameters in both controlled (laboratory conditions) and non-controlled (real conditions) environments.

The International Forum on Advanced and digitalised Smart Textiles (www.ifast-stile.eu) was organized online on 15-16 June 2021, with the aim to evaluate the development of advanced smart textiles in the European defence sector and to disseminate the results of the STILE project to a wider audience.
A book of abstracts was published with ISBN 9789295075580 (in pdf format).

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