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# EUROPEAN SENSOR SYSTEM FOR CBRN APPLICATIONS

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**ABSTRACT**
The paper presents the analysis of the EU-SENSE project as an example of European Union (EU) response to global threats in the field of chemical attacks. CBRN risks are noticed by EU which tries to handle them via many different actions, among others by encouraging small and medium enterprises, applied researches centers, industry and academic research to actively take part in establishing systems, both in detection and training modules. The EU-SENSE project meets all these requirements, hence it is a perfect example for the analysis of this type of projects, especially in relation to the methodology of collection of user requirements and development of the definition of key performance parameters.

Keywords: EU-SENSE project, chemical agents, user requirements, key performance parameters

## 1. INTRODUCTION

Significant progress has been made in recent years to protect European citizens from CBRN risks. However, recent developments in Syria, Malaysia, and the United Kingdom give good reasons to believe that the hazard posed by chemical agents remains high and is evolving. In the case of listed countries and, more generally, Western civilization, international community has to struggle with the Islamic State – the first non-state actor which is intensively developing chemical warfare agents and has reached the point, where agents were combined with a projectile delivery system. After the loss of Mosul in June 2017, chemical attacks stopped, mainly because 'caliphate' was not able to establish any alternative production facilities. Unfortunately, according to U.S. intelligence, cited by Columb Strack – analyst specializing in political and security risk forecasting for the Middle East, Islamic State has been set up a new chemical weapons cell in the Euphrates River Valley. This and other efforts in using and preparing chemical agents in combination with the specificity of modern fundamentalist terrorism give strong possibility that the group could export chemical terror to the West, among others by unmanned aerial vehicles (UAVs) and vehicle-borne improvised explosive devices (VBIEDs) (Strack, 2017). Furthermore, with reference to terrorists attacks in Europe, post-attack analysis pointed out that chemical substances were produced and bought in one country and sent to one of EU country where the attacks were executed. Moreover Interpol reported that numerous of CBRN materials were tried to gain or smuggle all over the world – the example of Litvinenko poisoning had shown that dangerous, radiological materials are still difficult to detect in EU (European Commission, 2014).

In addition to these extremely difficult challenges, there are still substantial shortcomings in, e.g., detection technologies in the different areas of public security. Fast and robust detection of an incident is paramount in order to safeguard the life and health of the population. The ability to rapidly detect CBRN incidents equates to faster response times, reduced hazard exposure, and more efficient use of limited resources. This kind of position is taken by EU and enriches it by adding more elements. For instance, according to reports under the EU CBRN Action Plan and the Action Plan on Enhancing the Security of Explosives in 2012, a new CBRN-E Agenda concentrates on improvement risk assessment, defines best practises in safety and security standards and spreads knowledge about it.

The Agenda highlights that effective mitigation strategy should contains:

- The effectiveness and performance of existing equipment and processes;
- New threat substances;
- New *modus operandi* for attacks;
- New concealment methods to attempt to by-pass security controls; and
- New attack targets, such as soft targets, critical infrastructures, public areas, non-aviation areas (European Commission, 2014).

EU focuses on improving detection of risk, usage results of research, testing and validation, supporting action to awareness raising and leading training sessions and exercises. Cooperation of all stakeholders, including academia, private sector or civil authorities is crucial to aim the goals.

Furthermore, improved detection was identified as a high-priority capability need in the Catalogue of

Technologies published by the ENCIRCLE project (http://encircle-cbrn.eu/) as part of the EU Horizon 2020 RIA call SEC-05-DRS-2016-2017: Chemical, biological, radiological and nuclear (CBRN) cluster part b). In the Catalogue there was pointed out that it is highly desirable to develop and implement fast and reliable detectors which could be applied in the prevention or preparedness phase.

## 1.1. THE PURPOSE OF THE PAPER

In the view of global challenges and EU initiatives which were presented above, it is scientifically interesting to look at one of the European project in order to examine how it tries to cope with chemical agents detection. For the purpose of analysing it, there is crucial to ask research questions. First of all, the careful look at architecture of the chosen EU project will led to pay attention to each elements are important for European Union, and in further perspective to answer the question which functions and modes should complement the main core of these kind of projects. Secondly, it is key to be informed which components could build systems of chemical detection and how they affect one on the other. EU projects, such a lot of other kinds of initiatives, are limited by the amount of financing, technological and organizational measures – what is essential in case of small and medium enterprises. And, last but not least question, what sorts of the expectations have end users of these types of systems? Are they only interested in getting information on detected chemicals, or systems should perform more functions.

The article is based on a case study methodology, which was considered as the satisfy method of organizing the content of the paper and coming to final conclusions. Case study methodology is used for both descriptive and explanatory purposes, but generally it is more suited to address the questions how and why, (than who, what and where), which are explanatory in nature. Because of the combination of the two characteristics indicated above, case study is especially essential for this paper. Moreover, the method supports studies which are still limited and do not need the generality of the situation or phenomenon – it is of secondary importance (Runeson, Höst, 2009). The case study methodology is not a one ordered collection of methods and forms of conducting research. It is an extensive set of approaches that allows people to explore the surrounding reality. In fact, the variety of ways to use this method in most areas of knowledge proves its great potential in explaining both simple and repetitive phenomena, as well as complicated and ambiguous ones. Applying any method to scientific work makes a set of constraints and opportunities happen. According to Geoff Easton – a professor at Lancaster University, the main constraint on the case study is the low statistical representativeness, while the key opportunity is the real possibility of understanding a phenomenon in depth and comprehensively (Easton, 2010). In the paper both opposite indicators appear. On the one hand, the analysis of a single EU project allows for a more precise look at its architecture and functions. On the other hand, it limits the possibility of drawing extended, general conclusions. Instead of this, it enables the researchers to prepare only a preliminary generalization which could be useful to identify wider needs declared by the European Union or to compare different European projects in further studies.

Key and organizational question in the paper is: why the EU-SENSE project was chosen as the example of the European project in the subject of combating threats of chemical attacks. First of all, it is connected with the great experience of the members of the EU-SENSE consortium. Wide representation of the various entities helps to develop project in the practical, technical and scientific context. All members have also experience in conducting research and works in the frame of EU requirements, or at least according to national guidelines. Secondly, authors of the article are the members of the project's research team what gives them the deep insight into the procedures, goals and activities which are taken during this kind of projects. It also allows to look carefully at the architecture of the system and its functions, and in the longer term to compare them with the basic assumptions of the EU Horizon 2020 RIA call SEC-05-DRS-2016-2017: Chemical, biological, radiological and nuclear (CBRN) cluster part b).

## 2. EU-SENSE PROJECT AS A RESPONSE TO CHALLENGES IN THE FIELD OF CHEMICAL ATTACKS

As it was mentioned above, chemical agents could be the source of dangers for European societies, especially in case of Islamic State's activity. EU, similarly like Interpol, predicts that it becomes more and more important to support initiatives taken, among others, by industry SMEs (Small and medium-sized enterprises) as well as by academic and applied researches to provide an innovative technical solution to deal with chemical detection. The answer for Work programme topic called SEC-05-DRS-2016-2017: Chemical, biological, radio-logical and nuclear (CBRN) cluster part b) gave a chance for involving the indicated entities to actively take part in preparing a novel network of sensors which will be using advanced machine-learning and modeling algorithms for improved performance in chemical detection. The success of the proposal of nine members forming EU-SENSE project's consortium has opened up the possibility of creating a step-change in chemical detection as well as implementing a dedicated mode covering CBRN practitioners training needs. The following sections will focus on specific aspects of the EU-SENSE project what will allow to explain the EU attitude toward the challenges connected with detecting and combating CBRN risks, especially referring to chemical agents.

## 2.1. EU-SENSE OBJECTIVES AND CONCEPT

The EU-SENSE project seeks to address the high-priority gaps and needs within chemical detection by developing a novel network of sensors for CBRN applications through exploitation of novel chemical detector technologies, advanced machine-learning and modeling algorithms. Specifically, the EU-SENSE project pursue three high-levels objectives. First objective aims to contribute to better situational awareness of the CBRN practitioners through the development of a novel network of chemical sensors, which will provide a technological solution to relevant gaps presented in the ENCIRCLE catalogue of technologies (high-level objective 1). Second goal was setting to improve the detection capabilities of the novel network of chemical sensors through the use of machine learning algorithms to reduce the impact of environmental noise and the application of contaminant dispersion models (high-level objective 2). In the context of the second high-level objective, environmental noise means any signal arising from pollutants in the environment that can cause either false positive (danger indicated with no danger present) or false negative (dangers not indicated when danger present) detection results. The third high-level objective proposes to showcase the usability of the EU-SENSE network to CBRN practitioners in order to validate the system and to maximize its exploitation potential (Proposal of European Sensor System for CBRN Applications).

Within the scope of conceptual design, EU-SENSE system is made up of the following three main components: chemical detection system, situational awareness tool and training and simulation module. The system with its main parts is illustrated in Figure 1. The chemical detection system will be comprised of a network of stationary and person-worn sensors supported with novel data fusion algorithms. Fused data from the network of sensors will feed into the situational awareness tool that will give end-users the ability to simulate the hazard dispersion over the area of interest. The hazard prediction will be comprised of inverse modeling for source estimation and ensemble forward modeling to calculate potential threatened area on the basis of uncertainties from the inverse modeling. Lastly, the EU-SENSE system will consist a training and simulation module that enables end-users to train on the use of the system and rehearse specific use cases.

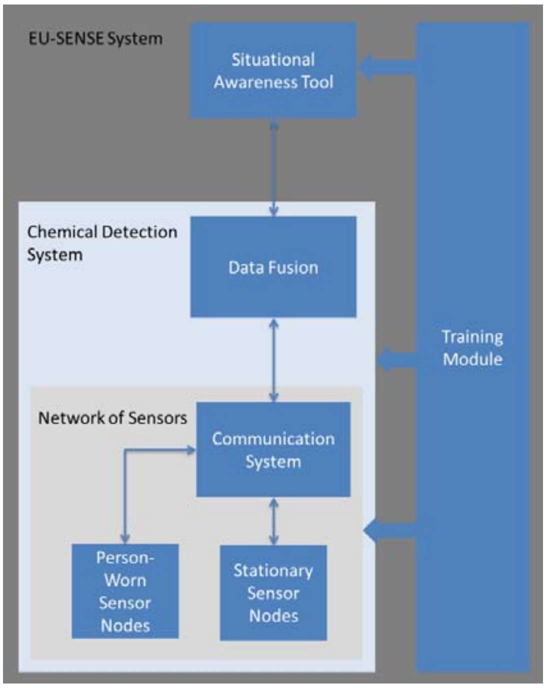


**Figure 1: The EU-SENSE system and its main components**

Developing the characteristics of the EU-SENSE system and its components, it is crucial to emphasize that the phase of chemical threat detection will provide novel data fusion algorithms which are going to accomplish the objective of fast and robust detection of a defined chemical agents' spectrum. Including heterogeneous sensor nodes in the network, it will give the opportunity to apply several types of sensors within a node. Furthermore, the development of the network, considering as adaptable and multi-purpose detection system, will also offer research on standardisation, which will contain definition of a unified data model prepared by the project partners. Together with network development and unified data model (especially in scope of incorporating different types of sensors with no interoperability problems), the members of the project will work on the reduction of false alarm rate. Chemical sensors are often affected by sensors reactions to environmental noise – EU-SENSE methodology aims for an automatic learning (including ability to separate between unusual, probably dangerous 'noisy' situations and normal, non-dangerous ones) and processing the environmental noise occurring in a given spatial environment, both rural and urban. Last but not least, there is the assumption that the project is dedicated to prepare sensors wear by people (end users) as well as those used in stationary way. According to this statement, it will be possible to adapt all three main components of the system to different conditions and various mission types, also to industrial incidents and mass events.

The second component – situational awareness tool – is aimed to increase situational awareness of the CBRN practitioners. Practitioners often rely on detection systems which do not guarantee an overall perspective in the area of interest. Such shortcomings cause delays in taking appropriate and timely remedies. Therefore, in response to these problems, the EU-SENSE system will include a situation recognition tool that integrates the results from the sensor network and data fusion results, and display them to CBRN practitioners on a dedicated user interface. As a result, the tool will efficiently support the decision-making process. Furthermore, EU-SENSE project will be working to develop a modelling tool that will enable end users to simulate the diffusion of threats in the area of interest.

Training and simulation module, the third part of EU-SENSE project, will provide modern and innovative tools for training crisis management units, both in the system developed under the EU-SENSE project and in general in crisis situations related to CBRN threats. The training module will contain functionalities of the operating system, with the exception of elements responsible for collecting data from actual data sources, for example sensor networks. The system will be delivered with artificial data previously prepared as training scenarios. At the same time, for the purpose of training, the functionality of preparing additional scenarios will be issued, as well as the impact of data from sensors. Such solution will allow the trainer to freely manage the training process and to train an unlimited number of scenarios with injections of various threats typical for a specific region of Europe or from specifications of end users.

## 2.2. REVIEW OF USER REQUIREMENTS

The EU-SENSE system is directed towards supporting users defined as end users or practitioners. Both terms relate essentially to the same extended group of people. On the one hand, they are persons directly involved in taking action at the scene of the real or potential chemical agents presence. For them, person-worn sensor nodes are dedicated. On the other hand, there are commanders (mainly from firefighters rescue teams) who are able to use stationary version of the system and supporting by it the process of making decisions, what it is extremely important in the face of any CBRN threat. Lastly, trainers could be interested in using EU-SENSE system (more precisely: training and simulation module) to train procedures for reacting, cooperating and coping with stress there it is need to deal with the chemical agents and where the EU-SENSE system is in operation. According to the scope of the interested entities, it was crucial to identified user requirements and then to check that them and scenario vignettes meet Key Performance Parameters.

### 2.2.1. METHODOLOGY OF COLLECTION OF USER REQUIREMENTS

A total of 42 user requirements for the EU-SENSE system were formulated as part of Task 2.1. All requirements were prioritized into “shall” and “should” requirements.

“Shall” requirements denote requirements that are mandatory whenever the criterion for conformance with the specification requires that there are no deviations. “Should” requirements denote guidelines or reco-mmendations whenever non-compliance with the specification is permissible.

In addition, all requirements were categorized as “functional” and “non-functional”.

A “functional” requirement denotes any requirement which specifies what the system should do, while a “non-functional” requirement denotes any requirement which specifies how the system performs a certain function.

The user requirements were presented for the system as a whole and for the following four sub-systems: (i) chemical detection system (stationary and person-worn sensor nodes); (ii) network of sensors; (iii) situational awareness tool; (iv) training module. The questionnaire was used here to collect the requirements from the participants of the EU-SENSE Stakeholder Workshop which took place at University of Warsaw, Poland, on 8-9 August 2018. Before the workshop, the author of the questionnaire – Stig Rune Sellevåg drafted and refined requirements on the basis of the Consortium Partners feedback. Then, he distributed the questionnaire to the end users and stakeholders at Day 1 of the Workshop and discussed in plenary on Day 2. After it, the collected user requirements were sent to the Stakeholder Group on 1 October 2018 for review with possibility to give additional comments. The questionnaire was comprised of 26 questions where 17 questions addressed the chemical sensor nodes, 3 questions – the network of sensors, another 3 questions – the situational awareness tool, 2 questions – the training mode, and the last question – subjects not covered by the previous questions.

Finally, for the purpose of the system, the two user requirements were formulated (according to the point which refers to the EU-SENSE system as a whole). First said that: “The EU-SENSE system shall demonstrate improved detection performance compared to the current state-of-the-art detection technologies that are incorporated into the system for the scenarios identified in the EU-SENSE project”. Second stated that: “The time needed for the EU-SENSE system to take a decision shall be equally good or improved while at the same time the false alarm rate is reduced, compared to the current state-of-the-art detection technologies that are incorporated into the system for the scenarios identified in the EU-SENSE project.”(D2.2 User Requirements, 2018).

## 2.3. SCENARIO VIGNETTES

As it was pointed above, identified user requirements and scenario vignettes should meet Key Performance Parameters. In case of the EU-SENSE project it is impossible to describe widely the suite of adapted scenarios, because of their status classified as Consortium Confidential information. Key Performance Parameters depend on scenarios so it is crucial to introduce scenario vignettes to the paper, even if it will contain only general information. In the EU-SENSE project's proposal there were described two scenarios concerning a mass event and an industrial accident. In perspective of these kind of situation it is possible to give here only basic input for designing functionality and actions connected with validation and demonstration. Despite restricting access to full information, it may help to understand the scope of the Key Performance Parameters.

Both scenario descriptions were composed of two integral elements. One of them gives detailed information about the event. And the second, closely connected with the first one, consists a set of vignettes focusing on the most important functionalities of the EU-SENSE system.

## 2.4. DEFINITION OF KEY PERFORMANCE PARAMETERS

According to Deliverable D2.3, prepared by Stig Rune Sellevåg, a key performance parameter (KPP), for the purpose of the work in the EU-SENSE project, is defined as: *a performance attribute of the system that is considered critical or essential to the development of an effective EU-SENSE system that meets the user requirements for the identified suite of scenarios. The KPPs must be specific and measurable in order to support an effective test and validation of the EU-SENSE system. The KPPs are expressed in terms of a unique identification number, specification of parameters that reflect measures of performance using a minimum threshold/target goal format, which scenario vignettes and user requirements that are covered, and any caveats and comments that are of consideration for the KPP* (Sellevåg, 2018)
In the context of such definition, it was also necessary to establish framework conditions for collection of the KPPs. Finally, there were designated the following conditions:

- Each KPP shall be specific and quantifiable;
- The total set of KPPs shall cover all main components of the EU-SENSE system;
- The total set of KPPs shall cover all scenario vignettes for the suite of scenarios;
- The total set of KPPs shall cover all quantifiable user requirements prioritized as "shall" requirements;
- The total set of KPPs shall cover as many quantifiable user requirements prioritized as "should" requirements as possible.

On the basis of these framework conditions, an initial set of KPPs was formulated by the consortium partners. The final set of KPPs was established on the basis of a sequence of refinements of the initial set against the suite of scenarios and the user requirements, using appropriate tools and engagement of the members of Stakeholder Group.
Summarizing. After the theoretical part and collecting general data, in accordance with the above-mentioned definition and characteristics of conditions for collection, the following key performance parameters (KPPs) have been identified:

1. End users are trained to use the EU-SENSE system.
2. Operating time for stationary sensor nodes without maintenance.
3. Operating time for person-worn sensors in the hot zone without maintenance.
4. Time needed for physical setup of the stationary sensor nodes after being deployed to the scene of interest.
5. Time needed for making person-worn sensors ready for use.
6. Time needed for machine learning for the chemical detection system when the EU-SENSE system is used in the preparedness phase.
7. No disruption of business continuity when the EU-SENSE system is applied in the prevention or preparedness phase.
8. Instant estimation of hazardous contamination level during incidents involving chemical warfare agents or toxic industrial chemicals.
9. Estimation of source location.
10. Hazard prediction.
11. Estimation of residual, post decon, contamination level after incidents involving chemical warfare agents or toxic industrial chemicals.

Together, the 11 formulated KPPs cover all scenario vignettes and 35 out of 42 collected user requirements. (D2.3 Key Performance Parameters)

## 2.5. THE CONSORTIUM MEMBERS, STAKEHOLDER GROUP AND THEIR IMPACT ON THE EU-SENSE SYSTEM

The project Consortium is build up by different types organisations – with various background and status. Among members are software developers and technical specialists as well as representatives from academia and end users community. Generally, the EU-SENSE project brings together nine partners from six European countries (Great Britain, Germany, The Netherlands, Norway, Poland, Sweden). One of the category of Consortium members includes ITTI – representative of small and medium enterprises and the leader of the Consortium. Another group refers to industry sector where actively works AIRSENSE ANALYTICS – manufacturer of hazardous substance detectors. The biggest member group is created by applied researches centers: Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), Totalförsvarets forskningsinstitut (FOI) and Forsvarets forskningsinstitutt (FFI). They are responsible for theoretical and practical expertise on dispersion modelling and situation awareness tool development. Research background has also two academic research partners: Szkola Glowna Sluzby Pozarniczej (SGSP) and University of Warsaw (UW). Both of them are public Polish universities. UW focuses on developing training system and materials, while SGSP concentrates on defining scenarios from end user perspective. Moreover, SGSP plays double role – it is the important part of academic research group as well as the end user category. In this category it is supported by Police Service of Northern Ireland (PSNI). Together they work on organizing demonstration events and validating the solution. Works of every Consortium members are divided into work packages which help to reach small goals and then milestones. A clear division of duties promotes substantive and technical work that uses the potential of all parties involved. Complicated project, which is the EU-SENSE system, requires properly planned work and skillful coordination that it is implemented from the very begging of the project.

Important role, especially in the case of identifying user requirements, plays the Stakeholder Group. As a result of engagement of the members of this Group, it was possible to designate conditions of Key Performance Parameters and then identified them. The Stakeholder Group as an advisory body outside the project management structure, consists of academia, experts, end users and industry partners who work and are interested in subjects closely related to the EU-SENSE project scope. The following members constitute the Stakeholder Group:

- Swedish Armed Forces, National CBRN Defence Centre (Sweden)
- VTT – Technical Research Centre of Finland (Finland)
- Norwegian National Unit for CBRNE Medicine (Norway)
- Imperial College London, Institute for Security Science & Technology (United Kingdom)
- CBRNE Ltd (United Kingdom)
- DJChem Chemical Poland S.A. (Poland)
- Hotzone Solutions BV (The Netherlands)
- Brandweer Zuid Limburg (The Netherlands)
- Research for Science, Art. And Technology (RFSAT) Ltd. (United Kingdom)
- Intrepid Minds Ltd (United Kingdom)
- Swedish Civil Contingencies Agency (Sweden)
- Municipal Headquarters of the State Fire Service in Siedlce (Poland)
- County Office Tarnowo Podgórne (Poland) (http://www.eu-sense.eu/stakeholder_group)

## 3. CONCLUSION

Chemical factors, as indicated in the first part of the paper, are now one of the elements of CBRN threats that require a lot of attention and commitment of appropriate forces and resources. The European Union, recognizing the threats and challenges in this area, supports industrial, scientific and applied researches centres so that they can work on systems supporting the efforts of practitioners. On the one hand efforts towards the issues of recognition and response in the face of chemical agents. On the other hand, towards those activities that support the training process, and that consequently allow for the substantive and practical preparation for the potential pose of a threat. Both directions are crucial from the goals point of view that the EU-SENSE project wants to achieve. The paper, briefly referring to the project, was aimed at specifying the project fully financed by the European Union. As a result of this approach, the paper presents the project which fully meets the expectations of the EU security policy. The emphasis placed on Key Performance Parameters and collection of User Requirements shows the importance that should be assigned to these elements in the process of preparing the system related to activities in the CBRN threats area. The methodology of collecting user requirements is a key process bringing members of the consortium closer to the goals, conducive to achieving further milestones and, consequently, providing a product that will meet the requirements of end users. Moreover, the Key Performance Parameters defined in the framework of the UE-SENSE project may also be used by other entities interested in determining parameters for the purposes of identifying, defining and implementing the expectations of end users in projects related to security, not only EU ones.

To conclude: it is essential to consider that the security EU projects coping with CBRN threats (on the example of the EU-SENSE project) see their goals in wider perspective than only technical and operational ones. Referring to the research questions presented in section 1.1 it should be emphasized that the main idea of developing any chemical (and other components combating CBRN threats) detection system must be supported by other, non-technical components. As a result, each implementation of, at least, a simple version of the training module is crucial here. Because of it, the EU-SENSE project aims not only to train end users how to use the system (what it is obvious), but also gives opportunity to open the system to the broader training of end users. In that perspective, end users can use the system and its training module in a tactical dimension as well as in a strategic one and wider – to help understand the methods of acting in the face of crisis threats, including those of a chemical nature.

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