RISCOS

territorium 32 (II), 2025, 129-143

journal homepage: https://territorium.riscos.pt/numeros-publicados/

DOI: https://doi.org/10.14195/1647-7723_32-2_9

Artigo científico / Scientific article

INTREPID PLATFORM: NEW TECHNOLOGIES AT THE SERVICE OF THE SAFETY OF THE FIRST RESPONDERS IN SEARCH AND RESCUE OPERATIONS*

PLATAFORMA INTREPID: NOVAS TECNOLOGIAS AO SERVIÇO DA SEGURANÇA DOS SOCORRISTAS EM OPERAÇÕES DE BUSCA E SALVAMENTO

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ABSTRACT

The scenarios that follow a natural or man-made disaster are always chaotic, changing, and, above all, dangerous for first responders, who must deal with complex and hostile areas while searching for and rescuing victims. Making urgent decisions on the ground, without having reliable information about the safety of the work area, makes it difficult to respond quickly and effectively. The INTREPID project is part of the HORIZON 2020 research and innovation programme funded by the European Union (EU). The main objective of INTREPID is to develop a single platform that integrates different modular solutions to facilitate the communication, exploration, and assessment of dangerous and potentially inhabited sites. For this, it uses technologies such as extended reality, positioning applications, network amplifications in hard-to-reach places, and intelligent cyber assistants among others. These realistic tools have been tested and improved throughout the project during controlled simulations in different scenarios such as a one-metre flood, an industrial chemical incident, and an explosion in a hospital. The data collected in these simulations has served to optimize this technology which is focused on meeting the specific needs of different groups of end users.

Keywords: Victim, rescue, first responders, technology, platform.

RESUMO

Os cenários que se seguem a uma catástrofe natural ou provocada pelo homem são sempre caóticos, mutáveis e, acima de tudo, perigosos para os socorristas, que têm de lidar com áreas complexas e hostis, enquanto localizam e resgatam vítimas. Tomar decisões urgentes no terreno, sem ter informações fiáveis sobre a segurança da área de trabalho, dificulta uma resposta rápida e eficaz. O projeto INTREPID faz parte do programa de investigação e inovação HORIZON 2020 financiado pela União Europeia (UE) e tem como principal objetivo do INTREPID desenvolver uma plataforma única que integre diferentes soluções modulares para facilitar a comunicação, exploração e avaliação de substâncias perigosas e locais potencialmente habitados, utilizando tecnologias como realidade estendida, aplicações de posicionamento, amplificações de rede em locais de difícil acesso e assistentes cibernéticos inteligentes, entre outras. Estas ferramentas realistas foram testadas e melhoradas ao longo do projeto durante simulações controladas em diferentes cenários, como uma inundação de um metro, um incidente químico industrial e uma explosão num hospital. Os dados recolhidos nestas simulações serviram para otimizar esta tecnologia focada em atender às necessidades específicas de diferentes grupos de usuários finais.

Palavras-chave: Vítima, resgate, socorristas, tecnologia, plataforma.

* *The text of this article corresponds to a paper presented at the VI International Congress on Risks, having been submitted on 16-10-2023, subjected to double blinded peer review on 17-11-2023 and accepted for publication on 25-03-2024. This article is an integral part of the* ***Territorium*** *Journal, N.º 32 (II), 2025, © Riscos, ISSN: 0872-8941.*

Introduction

In the 21st century, technological advances, present in many contexts, cannot be ignored, as well as in the improvement and resilience within the disaster risk management cycle.

The use of technology is an element of substantial improvement and resilience in the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030. Therefore, the increase in the use of new technologies has become evident in recent years, with special incidence in the management of both natural and man-made disasters.

The first responders usually have to deal with large, often complex, and hostile working areas while locating and rescuing victims. Decisions are to be made urgently on the ground, and the lack of reliable information on the safety of the working area hampers a rapid and effective response. This kind of emergency usually requires that different security and rescue teams work in unison. Each of the teams involved in these operations follow their own protocols and procedures, thus making it difficult for them to act as a coordinated group. Nevertheless, a single Coordinating Center would guarantee the optimal management of the incident, ensures the most effective response, and an efficient use of the resources available, adapted to the particular circumstances of the event. Therefore, it is essential to improve Information and Communication Technologies (ICT) communications between the different First Responder (FR) teams in the field with the Coordinating Center, to guarantee the detection and early warning of risks, resource management, with protection, alert behaviour, and rescue (PAR), as well as the triage of victims.

The main objective of INTREPID is to develop a single platform that integrates different modular solutions that, as a whole, are safe and scalable to facilitate the exploration and evaluation of dangerous and potentially inhabited sites. To meet this goal, technologies such as extended reality, innovative positioning applications, network amplifications in hard-to-reach places, and intelligent cyber assistants, among others are used. Likewise, the platform provides ICT to First Responders in Multiple Casualty Incidents (MCI) in order to improve communications. This will lead to a more effective response at the scene of the incident and minimize risks for both them and the victims. Additionally, it increases the possibility of saving more lives.

The INTREPID project is part of the HORIZON 2020 research and innovation program which, through the development of new technologies, offers a holistic approach to the role of the European Union in the effective response to emergency situations resulting from natural or man-made disasters. While projects within HORIZON 2020 such as FASTER (First responder Advanced technologies for Safe and efficienT Emergency Response [FASTER], 2019), INGENIOUS (The First Responder of the Future: a Next Generation Integrated Toolkit for Collaborative Response, increasing protection and augmenting operational capacity [INGENIOUS], 2019), CURSOR (Coordinated Use of miniaturized Robotic equipment and advanced Sensors for search and rescue OpeRations [CURSOR], 2019), and ASSISTANCE (Adapted situation awareness tools and tailored training scenarios for increasing capabilities and enhancing the protection of first responders [ASSISTANCE], 2019), among others, focus on providing support and protection to first responders, project INTREPID has a complementary approach that focuses on technologies, that facilitate both, communication and the rapid and safe exploration and assessment of incident areas, providing first responders with an effective and unified overview of the real-time changes occurring during their intervention.

Methodology

The INTREPID project (Intelligent Toolkit for Reconnaissance and assessmEnt in Perilous Incidents [INTREPID, 2020) consists of 17 partners from 8 European countries with the following profiles (Table I): four world-renowned technological research organizations (CERTH, FOI, TUM VUB), five leading European SMEs (CPLAN, ETELM, ROB, ALX, INC), and seven first responders from different emergencies fields (SUMMA112, DSU, BMPM, SSBF, ADMPOL, ESDP, HRTA), ranging from firefighting, search and rescue to medical and Chemical, Biological, Radiological and Nuclear (CBRN) teams, all coordinated by CS, a European industry leader in the security and defense sectors. The presence of first responders from different fields, both health and safety as well as prevention and treatment of specific risks with firefighters in chemical disasters can be valued because it allows the adaptation of tools to the needs of different emergency teams.

The Project started in October 2020 and has been developed for over 3 years. The development of INTREPID has been divided into 3 main phases (fig. 1): Phase I (Alpha release development) Phase II (Beta Release development), and Phase III (Final Release Development). We are currently in the final phase of the Project, having already completed phases I and II with their corresponding evaluation processes. As a result and which have given rise to the Alpha and Beta versions of the platform. After the final pilot, which will take place from September 18th to the 22nd in Madrid, the final version of the platform will be released with all the technological tools integrated into it.

Having in mind the objective of “transforming the needs of first responders into effective solutions”, a methodology has been developed. It involves final users

Table I - Members of the Consortium.

Tabela I - Membros do Consórcio.

ORGANISATIONS	MAIN ROLES	COUNTRY
	COORDINATOR	
CS GROUP (CS). Software engineering: leading company in the fields of security and defence. Expert in Virtual, Augmented, Mixed, and extended Reality products.	Coordinator of INTREPID. Develop both the INTREPID Mobile systems, including the eXtended Reality and Digital Mock-up modules.	**FRANCE**
	RESEARCH CENTRES	
Ethniko kentro erevnas kai technologikis anaptyxis (CERTH). Research organisation with world-class expertise in Artificial Intelligence and computer vision.	Develop the Intelligence Amplification and Symbiotic Control modules	**GREECE**
Totalförsvarets for Skningsinstitut (FOI) Research organisation with world-class expertise in 3D mapping and positioning.	Responsible for the development of a modular multisensor-based system for robust and accurate positioning in challenging environments.	**SWEDEN**
Technical University of Múnich (TUM). Europe's university with world-class expertise in the 3D mapping of the real world, BIM modelling, and path planning	Responsible for the development of the environment mapping and path planning modules	**GERMANY**
	ETHICAL MANAGER PARTNER	
Vrije Universiteit Brussel (VUB). European research institute in the area of technology regulation and Societal, Ethical, and Legal issues, especially in the frame of technological research and civil security domains.	Ensure that INTREPID respects international regulations and the rights of users.	**BELGIUM**
	SMEs	
Robotnik (ROB). Leading Designer and manufacturer of smart	Design and develop the INTREPID UGVs	**SPAIN**
Inconito (INC). Co-design, branding, communication, and marketing plans for innovative products.	Manage co-creation process, UX, and UI design.	**FRANCE**
CrisisPlan (Management) (CPLAN). leading SME consultancy providing vision, training, and education on crisis management.	Lead the definition of user requirements and pilot scenarios as well as training and pilot activities.	**NETHERLANDS**
ALX Systems (ALX). Leading designer and manufacturer of Smart UAVs and their AI-powered Operating System.	Design and develop the INTREPID UAVs.	**BELGIUM**
	END-USER REPRESENTATIVES	
Belgian Federal Pólice- Directorate of Especial Units (DSU). Police tactical unit of the Belgian Federal Police deployed in cases of terrorism, kidnappings, hostage-taking...	Provide expertise, define operational requirements and pilot scenarios; Organise micro-pilots and participate in the evaluation of project results.	**BELGIUM**
Ville de Marseille, Batallion de Marins-Pompiers de Marseille (BMPM). Fire brigade with several specialised units (NRBCe, K9, USAR…).	Provide expertise, define operational requirements and pilot scenarios; Organise middle-scale pilot, and participate in evaluating project results	**FRANCE**
Greater Stockholm Fire Brigade (SSBF). Rescue organization.	Provide expertise, define operational requirements and pilot scenarios; Organise small-scale pilot 1 and participate in evaluating project results.	**SWEDEN**
Servicio de Emergencias Médicas Prehospitalarias de Madrid Servicio Madrileño Salud (SUMMA 112). Madrid´s medical emergencies service.	Provide expertise, define operational requirements and pilot scenarios; Organise large-scale pilot 3 and develop the evaluation project results.	**SPAIN**
Madrid Police (ADMPOL). Madrid Municipal Police, General Coordination for Security and Emergencies.	Provide expertise, define operational requirements and pilot scenarios; Participate in large-scale pilot 3, and participate in the evaluation of project results.	**SPAIN**
Escuela Española de Salvamento y Detección de Perros (ESDP). Spanish School of Rescue and Detection with Dogs for Search and Rescue, Drug and Explosives Detection, Human Remains Detection, and Fire Investigation.	Provide expertise, define operational requirements and pilot scenarios; Participate in large-scale pilot 3, and participate in the evaluation of project results.	**SPAIN**
Hellenic Rescue Team Attica (HRTA). A non-profit organization that operates mostly for Search & Rescue.	Provide expertise, define operational requirements and pilot scenarios; participate in the evaluation of project results.	**GREECE**

in all phases of the project, allowing them to identify the required adjustments in the development of these technologies on the basis of the field experience of the intermediate pilots. In each phase, a complete cycle of requirements gathering, (re)design of the platform, development, and integration, and the evaluation of results have been carried out. These results have been considered for the development of the later version. In addition, legal, ethical, and social aspects have been taken into consideration in all phases.

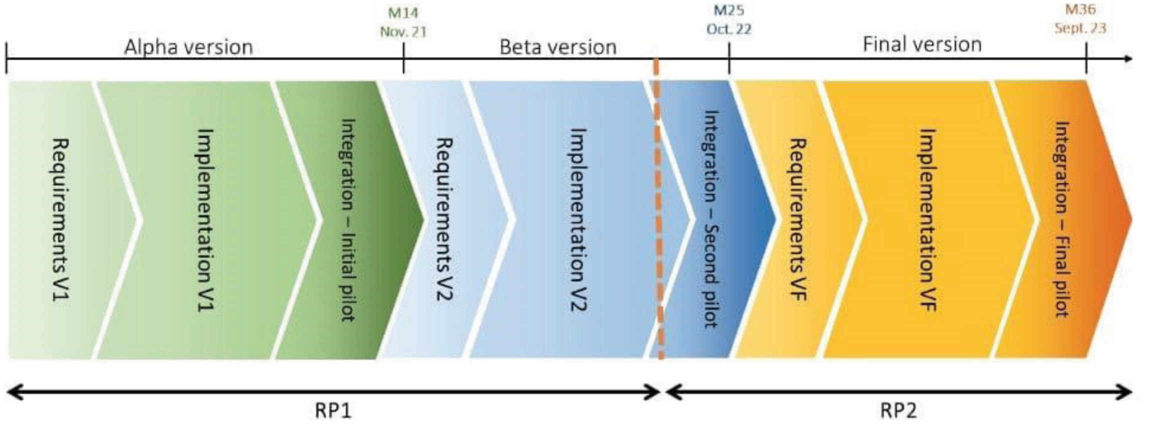

Fig. 1 - The interactive phases of INTREPID.

***Fig. 1** - As fases iterativas do INTREPID.*

Throughout the different phases of the project, pilots have been carried out in scenarios that represent different types of disasters in order to validate the tools and technologies that comprise the INTREPID platform in the field. The tools implemented are the following:

- *The INTREPID Mobile System is called INMOS (fig. 2) (INMOS allows a server, Message broker, and Authentication server)*: The INMOS system is the interface to the platform and runs on rugged laptops, tablets, or smartphones anywhere and connects to the INTREPID network. It receives and stores all the information collected by the sensors, the position of the units, as well as any support requests, reports, or commands intended for the user, providing an overview of the situation at any given moment. The Authentication server allows INMOS to limit access to its information to users with the appropriate access permission rights. Message Broker enables flexible communication between the different modules via messages that can be listened to by the recipients. The tools described above are integrated into the platform and the access of all first responders to the platform;
- *Digital Mock-up Module Digital (DMM)*: It is capable of storing all information about the environment and situation in a 3D Digital Twin model. It can store mapping data to build a 2D/3D overview of the area where the crisis is occurring and recreate a 3D presentation of the buildings involved. It also stores geolocated operational data (tactical data) and regularly updates, such as threats, casualties, routes, points of interest, agents, trajectories, images, etc., to complete the situational awareness at any given moment;
- *Extended Reality Module*: it consists in a technology that facilitates cross-device visualization and interaction with the digital model in 3D, virtual, augmented, mixed, and real reality, depending on the device available and most relevant to the task (command and control, scanning, training, debriefing...), using the touch screen of the INMOS device. New Mixed Reality devices (e.g. Hololens 2) offer an immediate understanding of the situation, even in very complex environments, thanks to the "Holographic" view of both the location and the situation;
- *Intelligence amplification module (IAM)*: this AI uses a series of learning algorithms together with data visualization techniques to gather information. All of this collected information is processed 'with a purpose', facilitating much more accurate and faster decision-making by first responders. This decision-making is based on a combination of a "doctrine" model (which will store knowledge, guidelines, and recommended actions specific to each first responder organization) and a Human-Machine interface that allows the FR to participate in the reasoning process;
- *Path Planning Module (PPM)*: It provides navigation assistance to responders and cyber-assistants (UGVs and UAVs) to reach or exit an area. It exploits the digital mock-up of the site, enriched with data captured in the field along with dynamic situational information such as the location of units, to generate optimal and safe trajectories suitable for the responder or the cyber assistant locomotion abilities. It also will enable first responders to control UxVs using high-level commands such as "go there", "exit now", or "scan this zone";
- *The Symbiotic Operation Control module*: It enables intelligent networking and collaboration between Cyber Assistants. In addition, it combines the results of trajectory planning which provides a faster and more accurate scanning of the area;
- *Intelligent unmanned ground vehicles (UGV)* (photo 1): Their main function is to explore and assess, with the help of embedded sensors, complex environments.

It is capable of opening doors, turning lights on and off, controlling elevators, and placing equipment on the ground. Equipped with four folding 5DoF robotic legs on wheels, it can roll, walk, crawl, and climb stairs and obstacles. It can also carry one or more INTREPID UAVs and provide them with a loading dock where they can land;

- *Smart Unmanned Aerial Vehicles (UAV)*: Their main function is to explore and assess, with the help of embedded sensors, complex environments. There are different types of UAVs, one for the rapid exploration of large unobstructed areas (outdoors) and another one for the exploration of cluttered multi-story indoor environments, including using lifts (detecting buttons, reading floor numbers, pressing buttons) or switching on lights, thanks to a specific actuator developed by INTREPID. Both can autonomously scan and generate 3D maps on the ground;
- *Environment Mapping Module*: It enables real-time automatic 3D mapping of interior and exterior spaces and together with existing reference geospatial data (such as BIM models or cadastral information) provides an accurate and up-to-date 3D map for decision-making. The Mapping module extracts the best results, through the viewing of the 3D map of the disaster area by the first responders with virtual reality glasses;
- *Environment Assessment Module*: It compiles all the information collected by the various sensors available in INTREPID (in UxVs and FRs) from the disaster site, in order to improve the detection of important sources of danger, people, obstacles, and other objects of interest, thus providing a better understanding of the environment in a crisis situation. It complements the Path Planning and Environment Mapping modules;
- *Real-Time Positioning Module (RTPM)*: It enables the positioning of first responders as well as cyber assistants. It is designed to be accurate, robust, and lightweight and allows positioning in changing lighting conditions, such as smoke, outdoors, and deep indoors. It is equipped with cameras, ultrasonic sensors, and inertial navigation units;
- *The Intrepid tactical communication System (TCS)*: provides the network over which all communications within the Intrepid platform are conducted. It integrates four main types of devices:
  - The tactical network device: small equipment, e.g. a rugged smartphone or network card that can be integrated into cyber assistants, using a SIM card specifically configured and secured to connect to an INTREPID network;
  - Tactical Centre Device: Compact network equipment that can be placed in a vehicle and creates extended secure private network coverage.

In addition to meetings of the technical partners and end-users throughout the design of the tools, questionnaires were designed to be filled in by the emergency professionals involved in the resolution of the disaster, in order to assess the appropriate development of the technologies.

Fig. 2 - INMOS interface (Source: intrepid-project.eu).

***Fig. 2 -** Interface INMOS (Fonte: intrepid-project.eu).*

Photo 1 - Intelligent unmanned ground vehicle (Source: intrepid-project.eu).

Fot. 1 - *Veículo terrestre não tripulado inteligente (Fonte: intrepid-project.eu).*

The applicability, effectiveness and usability of the tools developed in the INTREPID project were assessed. It has been done by means of anonymous questionnaires before and after the scenario. These questionnaires were developed furthermore to collect opinions and suggestions for improvement from the end users, together with questions to analyse each tool.

Results and discussion

Recent reviews have underscored the potential of novel technologies to enhance communication among first responders during mass casualty disasters, thereby improving patient care and optimizing resource utilization efficiency. Recent studies have explored the integration of new communication technology within emergency care settings (Zhang *et al.*, 2022) and how the type of disaster and the intended objectives infuence the selection of the most suitable technology for emergency response (Petlon, 2023). Furthermore, in critical and time-sensitive medical contexts like emergency care the information gathered in the field and while transporting patients to the hospital plays a crucial role in enabling emergency care providers to anticipate the severity of patient illnesses or injuries (Sarcevic *et al.*, 2012).

To optimize intervention in these very special disaster situations, the need arose to develop the concept of disaster eHealth (DEH), which was already proposed in 2015 (Norris *et al.*, 2015), in which it was proposed to integrate into the management equation of the crisis the two traditional elements of disaster management and disaster medicine with the new element of eHealth (which consists of the application of information and communication technologies to the field of medicine), (Madanian *et al.*, 2020).

DEH can be seen as a model that tells us what, when and how current eHealth technologies can be used in the disaster management cycle (DMC).

In addition, the relevance of including an innovative geolocation network to understand the cause of the incident, evaluate the area and search for threats has been demonstrated on the ground, achieving maximum safety for first responders and victims. In recent research, three-dimensional emergency medical management systems based on 5G are being built to be used in specific scenarios such as a natural disaster, thus increasing the radius and emergency response time (Lu *et al.*, 2023).

The INTREPID project has developed a unique platform to integrate different current technologies and improve the assessment of disaster-affected areas.To achieve this goal, it integrates the amplification of artificial intelligence and augmented reality through intelligent cybernetic assistants, including robots and drones. One of the objectives achieved was to integrate the mapping performed by the external drone, with the internal drone and the robot to obtain a 3D view of the structure and locate the victims with maximum precision, as well as to elaborate using artificial intelligence amplification. a safe route for First Responders on both the access and exit routes.

One of the improvements added to the standard use of the robot was the use of the articulated arm with which a conscious victim can be equipped with a smart watch that will monitor their vital signs; For this purpose, other more advanced means could be used in the future as they are developed. With the help of this improvement in the robot’s function, it is possible

These tools have been tested and improved during controlled simulations of subway flooding in Stockholm (2021), industrial chemical incident in Marseille (2022), and hospital explosion in Madrid (2023). The last pilot will take place in September in Madrid with all the technology integrated.

Spanish end-users’ feedback has been collected to evaluate the usefulness of the tools developed in the INTREPID project. This was done through by paper filling questionnaires before and after each pilot. Before completing the questionnaires, all the end-users were informed that the questionnaires were anonymous, and that no personal data would be collected. By answering the questionnaires, participants consent to INTREPID partners to process the answers. All the data will be stored for five years, thereafter it will be archived according to current legislation.

Innovation with Information Technology (ICT), developing sensors into autonomous vehicles, mixed reality for value the disaster area and ongoing common communication platform between all stakeholders, increases the efficiency in the attention to major catastrophes.

Effective inter-group communication, obtaining information in real time and coordination through technology adapted to our needs, helps to reduce the initial chaos of the catastrophe, improve our assistance to patients and increase our safety in the intervention, while increasing the quality of the performance of the emergency services involved in the scene.

Evaluation of results

When a man-made disaster happens, it is very important to have all the possible information about the disaster in order to save as many lives as possible.

First responders need to decide quickly for the right course of action even though information is scare, unconfirmed and difficult to obtain.

For this reason, first responders need to understand the terrain and the nature of the incident, enter the zone and safely reach the right places, and localize and identify threats, obstacles and victims.

One of the main objectives of the Intrepid project is to ensure that the technology developed is useful and effective in order to be able to act in the most appropriate way in disaster situations.

During the Intrepid project the final users have had the opportunity to test the developed technology, the different drones and robots. Different scenarios (Intrepid pilots) have been created based on disasters as realistic as possible, to be able to evaluate and validate the technology in the most effective way.

Critical factors to enable validation is to test the technology in a realistic setting, which is the aim for the Intrepid pilots.

All these tools are specifically designed to assist first responders in the exploration of their environment as well as making informed decisions in time-critical phases of a disaster. Ensuring that these tools fit the needs of first responders is of great importance for the viability of the project.

INTREPID relies on end-users to guide the development of the tools, sharing their experience and current practices, and giving feedback about the functionalities of the tools, the design of the user interface, and how they can best add value to their work. End-users are involved at every step of the development process.

The Field Validation Methodology focuses on assessing the operational benefits of the tools.

Validation is to answer the question of “does this system solve the relevant problems?”. For the INTREPID field validation methodology that means answering questions of how tools and systems support first responders and end users in the field handling the complex situations corresponding to emergency response in dynamically evolving crisis environments.

The purpose of these questionnaires is to test the Field Validation Tools.

The questionnaires

The way in which the feedback from the users is collected to check if the technology is useful is through questionnaires. In these questionnaires, End-users can express their opinion and make suggestions for changes or improvements in order to develop the technology that best suits their needs.

Before to complete the questionnaires all the end users are informed that the questionnaires are anonymous and no personal data will be collected.

In order to ensure that this process is correctly performed, end users start the questionnaire with choosing an Alias. This Alias needs to be easy to remember, so we recommend to all the participants use the same alias for all surveys. This is important for linking questionnaires to parts of the pilots.

By answering the questionnaires, participants consent to Intrepid partners to process the answers. All the data will be stored for as long it is needed, thereafter it will be erased or archived according to current legislation.

We now analyze the answers and the results obtained in these questionnaires.

In the questionnaire conducted after the pilot, questions were elaborated to analyze in detail each of the tools used. In general, the answers provided by the responders affirm that the tools are very valuable for the performance of their profession, in the different scenarios that may occur, especially in those involving extra risk, such as a chemical, biological or radiological catastrophe.

The tools improve the safety and response times of first responders, as well as the intercoordination of first responders and cyber assistants, by having the real information, about risks, possible hazards, access to the scene, teams working in the area and the overall view of the incident.

Let's take a look at each of the responses given by the different members of the team, with their details:

A. INTREPID Mobile System, INMOS:

   a. "It is of great help in incidents with multiple victims and risky environments. Normally, when there is an incident with multiple victims, communications are made only by radio voice, those of us who are on the ground do not have access to risk information until the security forces and firefighters communicate it to their superiors and it is shared by remote coordination center, or it is done in person if we are close to the area; but communication is very difficult when there are many victims, and large spaces so it is very useful and greatly increases the effectiveness of first responders that there is a communication platform like this, both in terms of coordination and operational task and security"
   b. "It is a very useful tool to know the real-time position of the victims and rescuers"
   c. "It is a great help as it increases the safety and efficiency of the operations"
   d. "As possible modifications to be included in the tool, the following were mentioned: Greater use for all emergency services"

B. Path-planning Module, PPM, in the question: In your opinion, what is the expected value of this tool for your profession?

   a. "Scene scanning saves time and increases job safety. Time is valuable in order to help the victims in need as soon as possible".
   b. "Finding first responders and being able to access victims by safe routes".
   c. "Risk assessment, getting safe ways to access victims, thanks to the digital scene assessment that this tool facilitates".
   d. "It is very good for assisting in communications".
   e. "it would be useful to improve accuracy and agility in working with victims, thus saving time".

C. Real-time Positioning Module, RTPM: in the question: In your opinion, what is the expected value of this tool for your profession?

   a. "All participants agree that the expected value of this tool for their profession is absolutely essential and very useful, as it allows knowledge of the geolocation of professionals and victims".
   b. "It increases safety, in all situations where it is used".
   c. "Its use should be systematic".
   d. As modifications, they bring the following: "improve connectivity and quick access to data, improve the accuracy of the location of participants and victims".

D. Symbiotic Operation Control Module, SOCM:

   a. Participants believe that this tool is also very important, as it provides safety and speed in the evacuation of victims.
   b. By working together with drones and robots and sharing information with INMOS, great value is added to everyday interventions, gaining in safety and facilitating rapid evacuations, when the scenario involves dangers and risks for the interveners.
   c. The information and tasks developed jointly by drones and robots and shared by INMOS are of great value to our professions when we are working in a mass casualty with hazards in the environment and also with possible threats of human origin.
   d. Most of the participants agree that the time saved, although it is difficult to specify how much, would be very valuable, reducing the time spent at the scene of the incident. These events are different from each other, and their characteristics vary from one to another, but it would certainly facilitate the work, reducing time, by working together with UAVs and UGVs, and integrating the information from both
   e. More information is provided on how the tools share the results with INMOS.

E. Smart UAV:

   a. Participants believe that it increases the level of safety and saves time by scanning the area digitally and avoiding walking through risky places, minimizing problems for first responders.
   b. It adds speed in detecting possible spills of toxic substances, as well as facilitating the location of victims and their possible access route.
   c. In general, everyone believes that it would be highly recommendable to count on their collaboration in incidents that involve complexity, either due to the number of victims or the geography of the areas, as well as in every catastrophe, whatever type it may be.
   d. Improving agility and the ability to enter contaminated areas without suffering damage, improving communication skills.

F. Smart UGV:

   a. "Intelligent UGVs are of great value to our professions, as multiple casualty incidents are increasingly encountered in chemical, biological or man-made threat environments".
   b. "It increases safety for responders and the scene".
   c. "I used it, doing a START triage with the robot, inside the chemical environment interviewing the victim and passing a monitoring sensor".

d. "I would use the Smart UGV in all scenarios similar to this one".

e. As modifications to improve the experience, more training was suggested in scenarios with stairs and debris.

G. Environment Mapping Module, EMM

a. It provides safety for the responder by mapping the intervention area and also facilitates the evacuation of victims.

b. It helps to map the intervention zone when there are collapsed structures or to find accessible routes that are not provided by the maps or those that exist are damaged.

H. Environment Assessment Module, EAM

a. "This tool provides information on the risks and status of the work area".

b. "It increases safety in general and in particular in areas at risk of fire or other dangerous situations".

c. As modifications, they suggest improving environmental nuclear sensors.

I. Intelligence Amplification Module, IAM

a. "Contributes to the analysis and assessment of the scene, providing a more accessible overview".

b. "It ensures greater safety for those involved".

J. Doctrine Authoring Tool, DAT

a. "It makes it easier to have a guide and for everyone to know what to do in different situations".

b. "This tool gives support in the tasks of coordination between teams and execution of the established plan".

c. "Provides security and assessment of the scene".

K. Digital Mock-up Module, DMM

a. "It shares the results digitally with all teams and tools involved".

b. "It provides security for those involved and facilitates the evaluation of the field".

L. Augmented Reality Common Operational Picture, AR COP:

a. "It provides safety for first responders".

b. "The quality of these graphics is valued, as they are very similar to reality, thus helping to pinpoint the location of the incident".

c. No modifications are made, it is only emphasised that more training on the tool would be necessary.

M. Tactical Communication System, TCS

a. "It apports speed in communication, which is essential in this type of incident".

b. Speed in assisting victims.

c. Improved executive tasks for emergency professionals.

End-user background

Fourteen end-users answered the questionnaires before and after the scenario. In general, all participants responded to most of the estimation questions, but only a few free-text responses were given. Eight of the end-users worked in the police field and six in the medical or healthcare field. As a group, they had an average of 22.5 years of experience working as first responders, ranging from 17-34 years. They rated their own experience and ability on some factors related to working in large-scale operations, collaboration with other organisations, use of computerized command and control systems, and use of UxVs (Table II). As a group, they were not used to either using or operating UxVs in emergency response operations (mean 1.92-3.43), but some individuals had extensive experience at it (ratings of 5 or higher). End-users, as a group, had rather little experience using computerised command and control systems (mean 3.64), but their answers ranged from 1 to 7, meaning that some of them had limited experience, and some had very extensive experience.

Table II - Rating of personal experience and ability on a scale of 1 (very limited) to 7 (very extensive).

Tabela II - Classificação da experiência e capacidade pessoal numa escala de 1 (muito limitada) a 7 (muito extensa).

	Mean	Median	Answer range
Working in large-scale emergency response operations?	5.64	6	3-7
Collaborate with other organisations in emergency response operations?	5.86	6	4-7
Commanding large-scale emergency response operations?	3.50	3	1-7
Using computerised command and control systems?	3.64	4	1-7
Execute command and control without computerised systems?	3.86	4	1-7
Execute command and control with computerised systems?	3.50	4	1-7
Using UAVs in emergency response operations?	3.43	2	1-7
Operating UAVs in emergency response operations?	3.29	2	1-7
Using UGVs in emergency response operations?	2.14	1.5	1-6
Operating UGVs in emergency response operations?	1.92	1	1-5

The INTREPID tools:

After the scenario, end-users (13 responded) were asked about the value that each INTREPID tool would have in an emergency response operation; they rated their answers on a scale of one (no value) to seven (extensive value). Results for all tools showed a mean score above 4.83, indicating that most end-users considered all tools to have good or extensive value (see Table III.)

Table III - End users' assessment of the value they believe the tools have after the scenario.

Tabela III - Avaliação dos usuários finais sobre o valor que acreditam das ferramentas após o cenário.

	Mean	Median	Answer range
Intrepid Mobile System	5,77	6	4-7
Path-Planning Module	5,15	6	3-7
Real-Time Positioning Module	5,23	5	3-7
Symbiotic Operation Control Module	5,50	6	3-7
Environment Mapping Module	5,17	5	3-7
Environment Assessment Module	5,42	5,5	3-7
Intelligence Amplification Module	5,25	6	2-7
Doctrine Authoring Tool	4,92	5	2-7
Digital Mock-Up Module	4,83	5	2-7
Augmented Reality Common Operational Picture	5,18	5	3-7
Smart UAV	5,17	5	2-7
Smart UGV	5.25	5,5	3-7
Tactical Communication System	5	5	2-7

Opinions on the scenario and organization

When asked about the scenario, the end-users (only 10) rated high on all questions (Table IV). They believed the scenario was realistic and something they were likely to encounter. At the same time, it was sufficiently complex, and it could be used to demonstrate the INTREPID tools. When asked if there was something they missed in the scenario, two things were pointed: better network coverage and the possibility to see how decisions were made in the command center.

Specific evaluation:

SUMMA 112 participants (pilot hosts). The end-users from SUMMA112 did an in-depth evaluation of pilot 2.5. Five SUMMA 112 participants answered the questionnaires. The following paragraphs show the responses to the questionnaires both before and after the pilot.

Part 1 – BEFORE Pilot 2.5 tests

Own Experience

1. How do you rate your personal experience or ability concerning the tasks below? Mark your rating on each row in the scale, 1=very limited – 7=very extensive

   Based on the answers provided in the questionnaires, the following conclusions can be drawn:

   Most of the participants who responded to the questionnaire had worked and collaborated in large-scale emergency response operations. However, the experience in running such operations was held by fewer participants.

   Most had experience in executing command and control both without computerized systems and with computerized systems.

   Only 20 % of the participants had had previous experience of driving or using UAVs and UGVs in emergency situations, 60 % none and 20 % a little.

2. Your view on computerised support tools

   Where do you believe that the INTREPID tools will contribute the most regarding the following categories? Mark your rating on each row in the scale, 1=no use at all – 7=very extensive use.

   All participants rated the **usefulness** of **intrepid tools** highly in commanding a global operation, in coordinating between different organizations, and in commanding separate tasks of a global operation

   All participants rated the usefulness of INTREPID tools highly in the following functions: supporting the initial survey of the operational area, supporting continuous surveillance of the operational area, supporting

Table IV - End users' assessment as to how the scenario was perceived, from one (not representative/unrealistic) to seven (representative/realistic).

Tabela IV - Avaliações dos usuários finais sobre como o cenário foi percebido, de um (não representativo/irrealista) a sete (representativo/realista).

	Mean	Median	Answer range
The scenario is something we could be set to handle	6,11	6	4-7
The scenario was useful for demonstrating the INTREPID tools	5,90	6	1-7
The scenario was realistic	6,10	7	1-7
The scenario was complex enough	5,80	6,5	2-7
The scenario held to much details	6,22	7	3-7

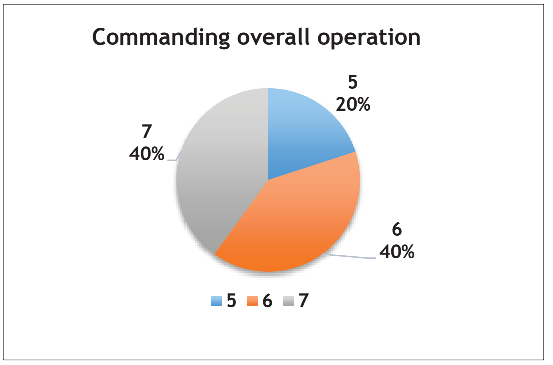

Fig. 3 - INTREPID tools contribution (Source: intrepid-project.eu).

Fig. 3 - *Contribuição de ferramentas (Fonte: intrepid-project.eu).*

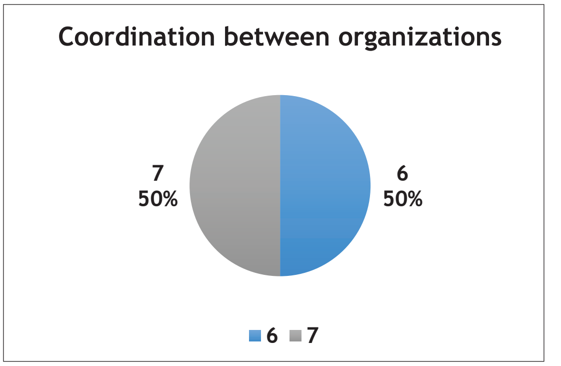

Fig. 4 - INTREPID tools contribution (Source: intrepid-project.eu).

Fig. 4 - *Contribuição de ferramentas* (Fonte: intrepid-project.eu).

dynamic communication in the operational area, supporting commanders in situational awareness, supporting task leaders in situational awareness, supporting team leaders' situational awareness, and supporting task navigation equipment in the area of operations.

Other comments on use and operational value:

- These tools are very relevant for advancing in the coordination into disasters, avoiding also hazards of the environment;
- Support commanders situational awareness support task leaders awareness and support team navigation in area of operation had the same score.

3. How big a change do you believe such support tools would encompass for your organization regarding methods, command and control, communications and behavior?

The responses of the participants were that the use of these tools would mean an important change,

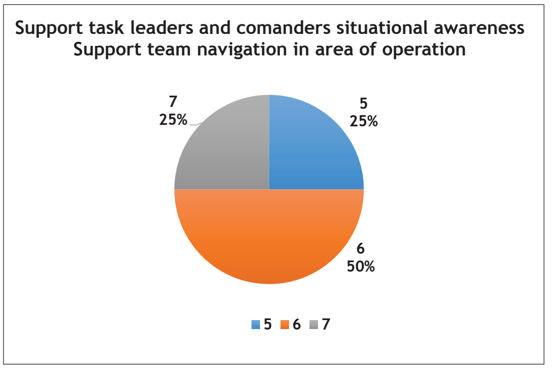

Fig. 5 - INTREPID tools contribution (Source: intrepid-project.eu).

Fig. 5 - *Contribuição de ferramentas* (Fonte: intrepid-project.eu).

since currently the coordination of communication when an incident with mass casualties occurs is one of the greatest difficulties and it also makes it possible to avoid risks such as human threats and CBRN environments.

4. What problems/risks would a system like this possibly mean for your organization, regarding categories below? Mark your rating 1-7 on each row of the scale.

The survey results of this question:

66 % of the participants considered the security for external people accessing the site to be low and 67 % considered also low score the time required for handing material, charging batteries etc.;

The participants agreed that it was necessary to improve cyber security, the time needed to handle the material, and charge the batteries;

They considered that there were no problems due to the delay in data communication;

They did not see compatibility problems with other equipment and systems. Other comments were that when working with other emergency teams, interoperability and data protection to avoid cyber risks would be the most important keys, as well as geolocation of professionals to correctly access the victim.

5. What is your *believed* value of the tool? Mark your rating on each row in the scale. (1=no value at all - 7=very extensive value)

The INTREPID tools: Smart UAV, Smart UGV, Symbiotic Operation Control Module (SOCM), Environment Mapping Module (EMM) and Environment Assessment Module (EAM), were rated highly by all participants (100 % score > 6).

The rest of the tools scored above 5: Real Time Positioning Module (RTPM), INTREPID mobile system

(INMOS), Tactical Communication System (TCS), Intelligence Amplification Module (IAM), Doctrine creation tool, Route Planning Module (PPM), Digital Model Module (DMM), Augmented Reality Common Operational Picture (AR COP), (figs 24 and 25).

Part 2 – AFTER Pilot 2.5 tests:

1. What is your *believed* value of the tool after the scenario? Mark your rating on each row in the scale. (1=no value at all – 7=very extensive value)

   The majority of the valuations (media and median) were around the maximun graduation;

   The evaluation of the following INTREPID tools after the pilot was very high, higher than 6 for 100 % of the participants: Smart UAV, Smart UGV, Symbiotic Operation Control Module (SOCM), Environment Mapping Module (EMM), Environment Assessment Module (EAM), INTREPID Mobile System (INMOS), Tactical Communication System (TCS), Intelligence Amplification Module (IAM) Doctrine Authoring Tool (DAT), Path-planning Module (PPM), Digital Mock-up Module (DMM), Augmented Reality Common Operational Picture (AR COP).

2. **Comments on INTREPID Tools:**

   2.1 Is there anything you are missing among the INTREPID tools?

   - *One person answered that the different regulations of the countries where first responders operate should be taken into account.*

The 80 % of the participants rated the scenario as useful, realistic, sufficiently complex and with sufficient detail to demonstrate the INTREPID tools.

Conclusion

The INTREPID project has been a unique experience of coordination of efforts between different countries. Its purpose is to develop a unique platform to improve the assessment of disaster areas and scenarios that are either difficult to access or potentially dangerous for both the victims and the first responders. To achieve this major goal, artificial intelligence and robotics have been set at the service of victim location and rescue.

Over the course of 3 years, several teams, from different European countries, have developed different technologies focused on the various aspects involved in the search and evaluation of scenarios and victims. With innovative networking and indoor positioning it will help the FR to evaluate the cause of the incident and to plan the operation minimizing the risks for FR and victims.

In order to test these devices, three experiments were carried out with three possible scenarios. These simulations not only served as a technology testing ground, but also allowed the different teams involved in victim location and rescue to share experiences and adapt their strategies to the new technologies. The use of all these tools makes it possible to find quick and safe evacuation routes for disaster victims, as well as plan the actions of the different FR teams in a coordinated manner, improving communication and minimizing risks. This has enriched all the partners, as it has provided a new perspective focused on collaboration, communication and safety of those FR teams involved.

On the one hand, some devices and technologies, proved to be strong and reliable from the very beginning of the project, and are already being used:

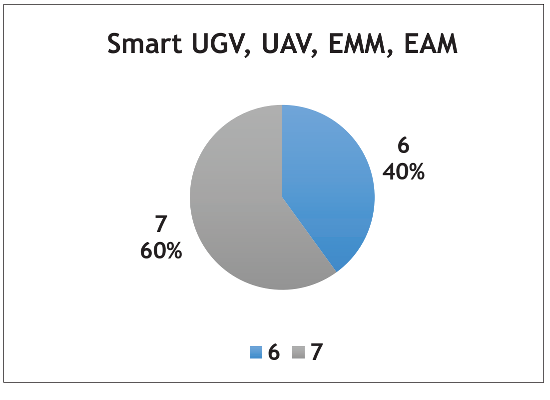

Fig. 6 - Believed value of tool (Source: intrepid-project.eu).
***Fig. 6 -** Valor acreditado (da ferramenta* (Fonte: intrepid-project.eu).

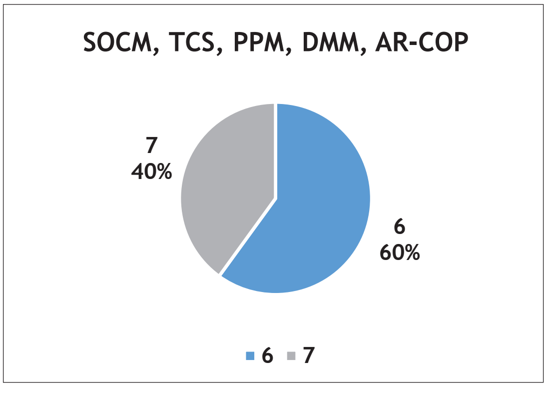

Fig. 7 - Believed value of tool (Source: intrepid-project.eu).
Fig. 7 - *Valor acreditado da ferramenta (Fonte: intrepid-project.eu).*

- The INTREPID platform stands out for being a scalable, user-centered, affordable, resilient and easy-to-implement project. The communication and network components allow the secure exchange of data between the FR and the rest of the users;
- The tactical central device is portable and can be placed on any vehicle and allows a quickly deployed on the ground. Tactical manpack technology creates a secure private network that allows the FR to go deeper into the disaster zone, explore areas where the INTREPID tactical center network is not available. In addition, the Tactical Range Extender, being portable, allows the range of the INTREPID network to be extended in environments where the network signal is limited;
- Smart unmanned ground vehicles (UGVs) have a robust and low-consumption structure and use commands that work symbiotically and synergistically with the UAVs providing mission status updates;
- The real-time positioning module (RTPM) uses sensors placed in cameras and ultrasound thar, merged with the mapping, allow knowing the location of the FR in real time;
- Extended reality module collects all the information created, imported and acquired during the incident and stored by the digital model module. Includes support for on-screen display, virtual reality, augmented reality, or mixed reality modes. It, also, offers various levels of immersion when inspecting the terrain, whether indoors or outdoors, holographic representations included.

Furthermore, the efforts of the operators have focused on learning about the management of these devices and technologies to avoid any interference with other systems, the planning of the routes that the Intelligence unmanned ground vehicles (UGV) must follow to avoid collisions in spaces with poor visibility, and the satisfactory performance of all devices, such as the Real-time positioning module (RTPM), inside previously unknown environments that may be full of smoke, collapsed or in adverse weather conditions.

On the other hand, field simulations carried out throughout the project demonstrated that it was necessary to take into consideration a series of improvements in other to guarantee the correct usage of these technologies and devices:

- First of all, in order to guarantee the correct operation of all devices, it is necessary to guarantee the bandwidth and quality of services necessary for the simultaneous connection of all applications;
- Another problem that was detected was the cognitive overload of the INTREPID platform, which received an excess of all kinds of information. Therefore, the platform has been reconfigured to provide only relevant information and thus avoid information overload;
- Finally, to prevent access to sensitive information by unauthorized users, detailed user rights have been stipulated to ensure the security of the platform.

Hopefully, after the final pilot, which took place from September 18 to 22 in Madrid, the final version of the platform was launched with all the technological tools integrated into it and in perfect working order.

Since the scenarios address different environments, the findings of progress in resolving the multi-victim incidents in which they have been tested confirm the usability of the INTREPID tools in different hostile environments. It is a resilience of the system, with the point of improvement in the creation of aquatic robots for immersive environments.

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