Faculdade de Engenharia da Universidade do Porto

Applying Real-Time Strategy Game Principles to Emergency Management

Hugo Miguel Gonçalves Crespo Machado da Silva

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Orientador: Prof. António Fernando Vasconcelos Cunha Castro Coelho

Co-orientador: Prof. Rui Pedro Amaral Rodrigues

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To the members of my family that have always been my friends.

To the members of my friends that have always been my family.

To all those that continually risk their lives so we can keep the company of friends and family.

To all those that contributed to this work with their time and effort, to all those who spend their life training, learning and acting to contribute to everybody's life, a most sincere THANK YOU!

Abstract

Emergency response is a key component in today's society. In many cases, funds are insufficient and methodologies are not as adequate as they could be. Regardless of technological advances, Portugal still uses paper maps to locate fires, as well as boards with hand-written information to manage occurrences in many situations.

RTS (Real-Time Strategy) games have been providing ludic tools for managing virtual teams and resources, and they have achieved very high standards, although in more specific contexts and without requiring large amounts of responsibility. Many RTS games focus on Disaster Management and provide adequate tools to achieve the tasks. While some of these tools work for a recreational activity only, without the unpredictability of real world scenarios, many of the mechanics used in this type of game can be applied to Disaster Management.

Unlike Civil Protection, which very often relies on limited funding, the game industry is a multi-million-dollar field in which money invested usually results in more money earned. It is therefore not surprising that the AAA game business, and lately the field of casual gaming, advance faster than other less profitable areas.

This dissertation analyses the current state of Civil Protection and Disaster Management in Portugal, and uses the findings to propose an interaction framework that utilizes relevant RTS game mechanics, hoping to achieve better results in the real world with the help of teachings gathered from computer games.

The result of this study should provide planning, training, mission analysis, mission command and automatic report generation using a collaborative metaphor applied to what may be understood as a serious game, based on the aforementioned mechanics with non-ludic objectives.

Keywords: Serious Games, Real-Time Strategy, Emergency Management, Training

Resumo

A resposta a emergências é uma componente chave na sociedade actual. Em muitos casos, as verbas são insuficientes e as metodologias não são tão adequadas quanto poderiam ser. Independentemente dos avanços tecnológicos, Portugal ainda usa mapas em papel para localizar incêndios, bem como placas com informações manuscritas para gerir ocorrências em muitas situações.

Os jogos RTS (estratégia em tempo real) têm vindo a fornecer ferramentas lúdicas para gerir equipas e recursos, e alcançaram padrões muito elevados, embora em contextos mais específicos e sem exigir grandes responsabilidades. Muitos jogos RTS focam o tópico de gestão de ocorrências e fornecem ferramentas adequadas para completar estas tarefas. Embora algumas dessas ferramentas funcionem apenas como actividade recreativa, sem a imprevisibilidade dos cenários do mundo real, muitas das mecânicas utilizadas neste tipo de jogo podem ser aplicadas à gestão de ocorrências.

Ao contrário da Proteção Civil, que muitas vezes depende de financiamento limitado, a indústria dos jogos é um campo de vários milhões de dólares em que o dinheiro investido geralmente resulta em mais dinheiro ganho. Portanto, não é surpreendente que o negócio dos jogos AAA e, ultimamente, o campo de jogos casuais, avance mais rapidamente do que outras áreas menos lucrativas.

Esta dissertação analisa o estado atual da Protecção Civil e Gestão de ocorrências de desastre em Portugal e usa as descobertas para propor uma estrutura de interacção que utiliza mecânicas de jogos RTS relevantes para alcançar melhores resultados no mundo real, com a ajuda de ensinamentos recolhidos dos jogos de computador.

O resultado deste estudo deverá fornecer planeamento, treino, análise de missóes, comando de missões e geração automática de relatórios, usando uma metáfora colaborativa aplicada ao que pode ser entendido como um jogo sério, com base na mecânica supra-mencionada e com objetivos não lúdicos.

Palavras-chave: Jogos Serios, Estratégia em Tempo-Real, Gestão de Emergências, Treino

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List of Acronyms

ABC – Air, Breathing and Circulation

ABCDE – Air, Breathing, Circulation, Disability and Exposure

AIS – Automated Information System

ANPC – Autoridade Nacional de Protecção Civil – National Authority for Civil Protection

API – Application Programming Interface

AR – Augmented Reality

BIM - Building Information Modelling

C4i - Command, Control, Communications, Computers, and Intelligence

CB – Corpo de Bombeiros - Firefighters

CBNR – Chemical, Biological, Nuclear and Radiological

CDOS – Centro Distrital de Operações de Socorro - District Center for Rescue Operations

CMOEPC – Centro Municipal de Operações de Emergência da Protecção Civil - Civil Protection's Municipal Center for Emergency Operations

CNOS – Centro Nacional de Operações de Socorro - National Center for Rescue Operations

CODU – Centro de Orientação de Doentes Urgentes - Guidance Center for Emergency Patients

COM – Comandante Operacional Municipal - Municipal Operational Commander

COMBINED – Chaotic Open world Multi-agent Based Intelligently Networked Decision-support systems

CONAC – Comandante Operacional Nacional - National Operational Commander

COS – Comandante de Operações de Socorro - Rescue Operations Commander

COP – Common Operational Picture

CSV – Comma-Separated Values

CVP – Cruz Vermelha Portuguesa - Portuguese Red Cross

DCIF – Dispositivo de Combate a Incêndios Florestais - Forest Fire Fighting Device

DERMIS – Dynamic Emergency Response Management Information System

DGAM – Direcção Geral de Autoridade Marítima - Directorate-General of Maritime Authority

DoF – Degrees of Freedom

DoP – Dilution of Precision

EPFL – École Polytechnique Fédérale de Lausanne

ERAS – Equipa de Reconhecimento e Avaliação da Situação - Recognition and Situation Assessment Team

FA – Forças Armadas – Armed Forces

FEUP – Faculdade de Engenharia da Universidade do Porto - Faculty of Engineering of the University of Porto

FoV – Field of View

FoW – Fog of War

GIPS – Grupo de Intervenção, Protecção e Socorro - Intervention, Protection and Rescue Group

GLOR – Grupo Logístico de Reforço - Logistics Reinforcement Group

GNR – Guarda Nacional Republicana - Republican National Guard

GPS – Global Positioning System

GREL – Grupo de Reforço Ligeiro - Light Reinforcement Group

GRIF – Grupo de Reforço para Incêndios Florestais - Forest Fires Reinforcement Group

GRUATA – Grupo de Reforço para ataque Ampliado - Amplified Attack Reinforcement Group

GTF – Grupo Técnico Florestal - Technical Florestal Office

HDoP – Horizontal Dilution of Precision

HMD – Head-Mounted Display

HTML – Hyper Text Markup Language

ICNF – Instituto de Conservação da Natureza e Florestas - Institute for Conservation of Nature and Forests.

IMACSIM – Interactive Multi Agent Crisis simulator Interpreter and Monitor

IMU – Inertial Measurement Unit

INAC –Instituto Nacional de Aviação Civil - National Institute for Civil Aviation

INEM – Instituto Nacional de Emergência Médica - National Institute of Medical Emergency

INOP - Inoperable

ISCRAM – Information System for Crisis Response and Management

JSON – JavaScript Object Notation

LIDAR – Light Detection And Ranging

OSM – Object Street Map

PASR – Preparatory action for Security Research

PDA – Pocket Digital Assistant

PHP – [PHP] Hypertext Preprocessor (recursive acronym)

POSIT – Ponto de situação - Situation Status

PR –Public Relations

PSP – Polícia de Segurança Pública - Public Security Police

RTS – Real Time Strategy

RTW – Real World Terrain

SALOP – Sala de Operações - Operations Room

SEPNA – Serviço de Protecção da Natureza e do Ambiente - Nature and Environment Protection Service

SfM – Structure-from-Motion

SGO – Sistema de Gestão de Operações - Operations Management System

SICCE – Sistema de Informação de Controle e Comando do Exército - Army's Command and Control Information System

SIM (card) – Subscriber Identity Module

SIOPS – Sistema Integrado de Operações de Protecção e Socorro - Integrated System for Protection and Rescue Operations

SIRESP – Sistema Integrado de Redes de Emergência e Segurança de Portugal - Integrated System of Emergency and Security Networks of Portugal

SITAC – Situação Táctica - Tactical Situation

SMS – Short Message Service

SQL – Structured Query Language

SRTM – Shuttle Radar Topography Mission

TIFF – Tagged Image File Format

TO – Theatre of Operations

UAV – Unmanned Air Vehicle

UEQ – User Experience Questionnaire

URL – Uniform Resource Locator

UTM – Universal Transverse Mercator

UX – User eXperience

VASCO – Virtual Studio for Security Concepts and Operation

VCOC – Veículo de Comando e Comunicações - Command and Communications Vehicle

VCOT – Veículo de Comando Táctico - Tactical Command Vehicle

VPCC – Veículo de Planeamento, Comando e Comunicações - Planning, Command and Communications Vehicle

VMER – Viatura Médica de Reanimação - Medical Resuscitation Vehicle

VR – Virtual Reality

VUCI – Veículo Urbano de Combate a Incêndios - Urban Fire Fighting Vehicle

WAAS - Wide-Area Augmentation System

XML – Extensible Markup Language

1 Introduction

RTS (Real-Time Strategy) games have been around for a long time. Utopia [1] was released in 1982 for the Intellivision and Mattel Aquarius consoles and is cited as one of the first God-Games in history. Fifteen years later, 1997 saw the release of the first 3D RTS Game, Total Annihilation [2]. The third dimension added improved visuals, better immersion and new mechanics. Since then, RTS games have improved and matured, and nowadays a citywide game area is nothing out of the ordinary. Games allow players to create and destroy buildings and vehicles, and even change the terrain. They also turned into online multiplayer experiences in which different players can fight or collaborate from different parts of the planet, in real time.

Battlefield 4 [3] is a recent game dating from 2013 in which a player can take the role of commander, in which case they assume an RTS position in an otherwise action game. The commander acts as an aid to the other players, being able to visualize them, as well as obstacles and assets, and contributing to the mission with a more organizational job. In this case, the game is comprised of operatives of different specialities, as well as the commander who oversees the mission and does not usually get directly involved in battle.

If games focusing on defence, protection and crisis management have evolved a lot in the last three decades, the panorama of real crisis management and disaster management still lags behind in many cases. Being such a relevant area for the well-being of every citizen of our planet, this is a field which can benefit from any advances. In the research for this document, cases have been witnessed in which fire watch towers communicate an azimuth for a sighted fire to the national command, which in turn places a pin on a paper map and tie a string to that pin, stretching it in the direction that has been communicated. Doing this with two towers reveals the approximate location of the incident, at the cost of time, personnel and accuracy.

Many advances have been achieved in civil protection as presented in the State of the Art. However, they are usually expensive and many times lack the maturity achieved by the game industry. Furthermore, many fire brigades are comprised of voluntaries and have a very small budget for research. Being part of a billion-dollar business, games constantly push the boundaries of what is possible, as every second and penny spent can represent a huge difference in income. And many games are nothing if not simulations of real cases, albeit with a ludic objective. Going back to the example of Battlefield 4's commander position and his team, it is possible to see the parallel in the *modus operandi* of armies or crisis management forces.

The interest on Serious Games has also increased in recent times. As described in the State of the Art, crisis management is one of the areas that can benefit a lot from Serious Games. A Serious Game directed to crisis management based on RTS Game principles would apply the maturity that game design has achieved and could bring not only better interaction techniques, but also open ground for more advanced solutions.

1.1 Motivation

First responders and related institutions are usually extremely under rated. These selfless people dedicate their lives, and unfortunately often times lose them, to save the lives and possessions of others. However, they are mentioned in the news from time to time, and many times when something went wrong. They are unknown heroes who, at least in Portugal, dedicate part of their time to collect money on the streets to help the cause. And most people close the car window when they see them coming. Funding is almost always insufficient and they are forced to make do with little or no assets. In a world where soccer players or TV presenters are idolatrized and get paid huge amounts of money, anything that can be done to help those who help us might be considered a moral obligation. Working on this area is motivation by itself, as it is the belief of the author of this dissertation that benefiting these professionals helps the entire world population.

Having dedicated most of a lifetime to study, research and work in the field of casual and serious games, as well as mixed realities – which include Virtual Reality and Augmented Reality, the experience acquired while working in these areas seems to fit a solution to improve the workflow of Crisis Management.

As described in the State of the Art, there have been experiences with AR and VR for Crisis Management. The initial proposal for this work was based on connecting operatives using AR to the command center, which in turn might use VR. Iterating on the idea to focus the study and maximize the contribution, it became clear that VR and AR were not the target, but tools to achieve interaction. Having said this, the underlying concepts of Mixed Reality can still be used with the proposal, by just adding an HMD (Head-Mounted Display) to the commander and AR hardware like Google Glass to operatives. This document tries to remain hardware agnostic, but applying these concepts to mixed realities should be straightforward.

Strategy games, on the other hand seem to fit the concept perfectly. The passion for games developed more from creating them than playing them. However, this type of game has always resulted a sense of flow that made hours pass without realizing, and it can be safely said that the author spent more time playing RTSs than all the other types of game together. The mechanics involved in RTS games usually provide situation and team awareness, by panning and zooming the game world, unit selection – single or multiple, orders and feedback, as well as control of static and moving structures, including building, setup, repair, upgrade, among others. This is not far from the job of a commander. As future chapters will show, situation and team awareness represent one of the most valued assets in crisis management. Interaction with units is also mandatory. First responders do not build barracks or living quarters, but weather stations or other types of equipment have been used. These have to be placed and setup before they can provide relevant information. For higher levels of the national protection plan, different cell like logistics or traffic must be created on the field.

The main motivation for this work comes from using the acquired knowledge of the subjects cited above for simplifying and improving security in the jobs of the men and women that look after all of us.

1.2 Problem statement

Currently, paper maps are widely used by the Portuguese National Protection, both in command centers and Theater of Operations (TO). These maps represent the surface of the terrain in 2D and are many times complemented with dimension lines, from which it is possible to infer the terrain height at set points. This approach, while it has been working for decades, is far from perfect. Reading the terrain height at one point from these maps is not as direct as seeing and manipulating a 3D map. An analogy might be established between these two methods of collecting height information to seeing sales figures in a spreadsheet or in a graph. While the first shows exact values for specific points, it is hard to get a general idea of a situation. A graph gives a general panorama from which it is easier to evaluate growth or decline over the whole picture.

In a situation where a fire in a canyon can quickly become extremely dangerous, or the water pressure may not be enough to elevate water to a certain level, a quick analysis of terrain relief can drastically increase response time and improve attack methods. Furthermore, in urban environments, it makes a big difference if a victim is trapped on the first floor or on the twentieth.

Flat paper maps present some benefits if we consider current fire attack methods. As already mentioned, pivots are pinned on paper maps from which a string is stretched. Having said this, it is extremely simple, as well as accurate if good sensors are used, to replace these techniques with computer aided methods.

3D maps are available for a lot of the earth's surface, but if an urban area is needed, with buildings and constructions, they are usually closed and can be used only within proprietary products like Apple Maps or Google Earth.

Communication between operatives and team leaders or central command is achieved by radio transmitters. Although recent models allow for data transmission, the main medium for exchanging information is still voice over radio. This brings several problems. Radio communications are usually one-to-one, which means it is hard to send information to a set of people, filter incoming information or prioritize communications.

When command changes hands in the TO, the previous commander needs to transfer the current state of the TO to his replacement. As described in chapter 3, this is achieved by the POSIT – a set of information and schematics in paper or boards. This means that time is spent on this task every time command changes. Time that is, more often than not, needed for action. It would be much faster and efficient if the new commander could look at a real-time representation of the TO and instantly become aware of the whereabouts of teams, devices, cells, as well as terrain geometry and proximity to water or dangerous substances.

During a prolonged attack, every man must be replaced after not more than twelve hours. It is therefore important to keep track of the time that each man has already spent in the TO. Other relevant information that should be known at all times regards to water, pressure and fuel tank capacity for vehicles, wind speeds, temperature and many more. Normally this is achieved by reading gauges and displays and communicating the relevant data over radio when requested. There is no direct access to relevant data.

At the end of each mission, independently from its dimension or duration, reports must be filled and kept. These reports can represent a problem on their own, since it can be hard to remember details, especially from stressful situations. Although hopefully not usually relevant, there is usually no way of confirming if a report is accurate, neither by accident nor on purpose. The value of these reports is directly proportional to the amount and accuracy of information they contain.

Summarizing these problems, interaction, communication and access to information can be improved. The aim of this dissertation is to present an alternative to current methods to respond efficiently to these difficulties by complementing the current workflow, rather than replace it.

1.3 Research questions

The problems described above will be addressed by a proposal for a Serious Game based on RTS game mechanics to target Crisis Management. This proposal tries to find solutions to the following questions:

- What are the best map types and 3D feature sources for representing the TO?
- What RTS mechanics should be implemented to respond to a crisis?
- What other functionalities become available by using RTS design principles to crisis management?

1.4 Contributions

Computer games can be a very lucrative business, contrasting with emergency management, which does not return profits. Emergency response can, however, avoid losses that may surpass the profits of the video game industry. But the goal of receiving usually speaks louder than the possibility of loss. The amount of money and hours placed into video game research is therefore larger than the effort placed into emergency response. This fact dictates that the video game industry is very advanced, while the more modest results in emergency response struggle to be implemented and gain traction.

This study aims to contribute to emergency management with some of the advances from the video game world. Video games, with strong emphasis on Real-time strategy due to its relationship with the topic, usually result in simulation with a ludic objective. One of the contributions of this document is the application of the mature mechanics from RTS games to emergency management. Some challenges include the command and visualization of real thinking operatives and both autonomous and controlled units instead of objects that can adapt to the orders, terrains and obstacles where the computer has full control of both units and the game world.

The second contribution concerns the reproduction of real-world terrain and features as opposed to computer generated ones. While there are several techniques to bring real world information into a virtual environment, they differ in difficulty, quality, speed, among other factors. An analysis, proposal and evaluation of some techniques should direct future research in the right direction.

With the information from the terrain and features, actions and movements from units in the terrain and georeferenced services, many interesting results can be achieved that were not possible when using traditional tools, like radios and paper maps. A third contribution of this study is the way in which the available information gathered from a mission using the proposed system can be used to generate value.

1.5 Methodology

Coming from a background completely unrelated to crisis management, it is of the most importance to familiarize oneself with the methodology used by professionals of this area. As such, the study of the state of the art was complemented with open and semi-guided talks and interviews.

With the knowledge acquired from the interviews, a survey has been elaborated to help select the most and least relevant topics, need-to-haves and nice-to-haves. This survey, after gathering information from members of the Portuguese Civil Protection, served as a basis to design the solution.

In possession of this knowledge, the proposal was elaborated considering applications for field units and command, a database, server scripts and communication methods. RTS game principles were used to interact with the TO and mechanics will were mapped to relevant situations.

To test the hypothesis, a working prototype was developed and tested. Having one or more teams of civil protection members testing the prototypes turned out to be close to impossible. The chosen alternative was a ludic activity that consisted of independent voluntaries who collaborated in two local missions at the FEUP campus using the elaborated prototype. Quantitative and qualitative results were gathered from this experience, and the whole missions was be recorded by the application. Missions were later played back to a group of firefighters who are familiar with crisis management. These firefighters also had the opportunity to navigate and inspect the recorded missions, as well as act as commanders for simulated missions.

After the firefighters were familiar with the platform, its characteristics and its usability, they were asked to fill a survey that analysed several subjects relevant to the study. Firefighters with command experience participated in a semi-guided interview which gathered qualitative information regarding different parts of the proposal.

The results collected from the fictional missions and firefighter's opinions were analyzed to validate the solution. Besides from validation, this section served to find strengths and weaknesses, as well as important points that might have been missed. The information that resulted from this data can be a valuable source of information to support further work in the area.

Finally, conclusions were gathered and the work was be discussed. From the experience gained, the feedback received, eventual problems found and possible proposals, a guide for future work in the topic will be suggested.

1.6 Thesis Outline

This dissertation is composed of seven chapters. The present chapter – Introduction – briefly introduces the theme and explains what led to this work. It then presents the problem to be studied and states the research questions that will be answered before the end of the thesis. The contributions to science that can be gathered from the study are also exposed, and the methodology followed is described. Finally, this outline clarifies the structure of the document, and the related publications list the scientific papers and posters that originated from or were created in tandem with the dissertation.

Chapter two analyses the State of the Art and related work. The study it describes represents what has been or is currently being done in three areas relevant to the dissertation. The first two sub-chapters, Serious Games and Emergency Response, relate to the subjects that serve as foundation for the study, making sure that it does not focus on problems that have already been solved and also provides the learnings necessary to advance. The third sub-chapter, Map Sources, can be viewed as related work, since it touches a subject that, although not directly connected to the final contributions, is closely related to the proposed framework.

The third chapter focuses on the preliminary research conducted to get familiarized with Emergency Response and Disaster Management and evaluate how the framework – if applied to a complete solution – would be received by the professionals of the area. This chapter also assesses the requirements for the framework, in what concerns to both necessity and usefulness. The analysis present in chapter three is based in both surveys and interviews.

Chapter four addresses the framework proposal. Based on the learnings from the previous chapters, the involved actors and roles are considered, and relevant tasks for both commander and operative are listed. Finally, a parallel is traced between interaction on RTS games and the proposed solution.

Implementation of the prototypes is described in chapter five, where the database is designed and services and applications are documented. From a subset of the rules hereby described, a prototype will be developed, which will be used to test the hypotheses and collect results to validate the framework. The development of this prototype is also described in this chapter.

Chapter six covers the tests the proposed solution and validates the research questions enumerated in chapter 1.3. The tests are divided in two parts – real-time simulated missions with the collaboration of heterogeneous voluntaries, and playback of these missions combined with hands-on experience with the prototype from trained professionals. Data will be collected in the form of surveys and interviews, to be converted into information by analyzing results. Qualitative analysis will be used to provide a clear idea of what works and what does not, as well as collect information that can be used in future work.

Finally, chapter seven presents the conclusions gathered from the study and discusses these conclusions, contextualizing the proposal for future work that can result from this document.

1.7 Related Publications

Although this work does not focus on location technologies, indoor location still faces a big problem and the suggested platform would benefit from better indoor location technologies. Another concern addressed in the game-oriented paper is latency for location-aware games.

During the study of present technologies for fire-fighting, the sighting of fires from watch towers and their consequent localization gave rise to a suggestion of an automatic method for crowdsourced localization of fires.

The following papers were published in tandem with the development of the current dissertation:

2C - Mobile Collaborative Fire Hazard Detection System – Extending fire detection and reporting to civilians [4]

After the first visits to Civil Protection and the firefighters' headquarters, the methods used to infer the position of a fire reported by the towers were adapted to the currently available mobile communication technologies. Based on the same principles, 2C – Mobile Collaborative Fire Hazard Detection System proposes a method for crowdsourcing fire detection by using a standard smartphone. The smartphone's position is collected by the GPS system, while the IMU returns the azimuth. By combining two or more reports from different users, this publication proposes a method to communicate the location of the fire to the Civil Protection, as well as methods to minimize errors. 2C also suggests how these methods could be made available country-wide by means of the applications and infrastructures provided by the service provider.

A Ubiquitous Solution for Location-Aware Games – Indoor Location Technology Under Unprepared Environments and Real-time Communications for Games [5]

While the focus of this dissertation is on the collaborative metaphor, the proposed methods benefit from high-accuracy location. The GPS system has improved accuracy over the last few years due to better and faster hardware, deactivation of Selective Availability, WAAS (Wide-Area Augmentation System) and complements from the European Galileo, Russian GLONASS and Chinese BeiDou. However, indoor location still faces a lot of difficulties. Most systems require preparation of the environment, which could be added to places that require an emergency plane, but is usually not available for most buildings. A Ubiquitous Solution for Location-Aware Games proposes a relatively reliable method for adding indoor location to the proposed solution. The publication also targets communication methods that aim for low-latency.

Although not directly related to the work presented in this document, three other scientific papers were published:

Towards Location-Based Augmented Reality Games [6]

Modelo de Descrição de Experiências Multissensoriais Multiutilizador [7]

User Redirection and Direct Haptics in Virtual Environments [8]

2 State of the Art

The study of the State of the Art focuses on three different subjects: Serious Games, Emergency Response tools and 3D map sources. While the first two points may be self-explanatory, since the proposal aims to dictate rules for an Emergency Response directed Serious Game, the last one does not represent a requirement for the development of the solution. However, information gathered during the study was unanimous in that 3D maps present far too great advantages to be left out. These maps have just been widely made available to the general public not too long ago, and even then as part of closed platforms. It is generally very hard to collect 3D map information to the general public, which means that map sources deserve a place in this chapter.

2.1 Serious Games

Serious games research is advancing quickly, but depending on the definition, the topic is relatively new. Although it can be argued that Serious Games have existed for centuries, the subject gained traction after the publication of the paper entitled “Serious Games: Improving Public Policy Through Game-based Learning and Simulation” [9]. Also in 2002, the game America’s Army – considered by many as a key point in the history of serious games - was released by the US Department of Defense [10]. Ben Sawyer himself referred to America’s Army as “*the first successful and well-executed serious game that gained total public awareness*” [11]. Similar in many ways to other war-related shooters, America’s Army is a relatively violent game based on real army situations and tactics. The game has been freely available on the internet since its launch and can presently be found for free on Steam. It does not hide the fact that, more than a game, it constitutes a recruitment tool, and the game’s web site [12] displays links to subjects like “Life in the Army”, “Army Career Navigator” or “Officer Specialties”. Also on the same year, Ben Sawyer co-founded the Serious Games Initiative.

The definition of Serious Game has undergone some changes, and Sawyer refined it to “*Any meaningful use of a computerized game/game industry resources whose chief mission is not entertainment*” [13]. However, if the word “*computerized*” was to be removed from this definition, serious games could be traced to a long time before the digital revolution. In fact, Chen & Michael define serious games in their 2005 book as “*Games that do not have entertainment, enjoyment or fun as their primary purpose.*” [14]. “Origins of Serious Games” [11] mentions the book “Serious Games” by Clark Abt dating from 1970, where the author’s goal is to use games for training and education.

Serious Games currently target a variety of fields, including but not limited to education, healthcare, military and government. Classifications have been proposed based on primary market [14][15][16], or purpose [17][18][19]. Sawyer and Smith's "Serious Games Taxonomy" [20] is shown in table 1.

	Games for Health	**Advergames**	**Games for Training**	**Games for Education**	**Games for Science and Research**	**Production**	**Game as Work**
Government & NGO	Public Health Education & Mass Casualty Response	Political Games	Employee Training	Inform Public	Data collection / Planning	Strategic & Policy Planning	Public Diplomacy Opinion Research
Defense	Rehabilitation & Wellness	Recruitment & Propaganda	Soldier/Support Training	School/House Education	Wargames / Planning	War planning & weapons research	Command and Control
Healthcare	Cybertherapy / Exergaming	Public Health Policy & Social Awareness Campaigns	Training Games for Health Professionals	Games for Patient Education and Disease Management	Visualization & Epidemiology	Biotech manufacturin g / design	Public Health Response Planning & Logistics
Marketing & Communication	Advertising Treatment	Advertising marketing with games, product placement	Product Use	Product Information	Opinion Research	Machinima	Opinion Research
Education	Inform about diseases/risks	Social Issue Games	Train teachers / Train workforce skills	Learning	Computer Science & Recruitment	P2P Learning Constructivis m Documentary ?	Teaching Distance Learning
Corporate	Employee Health Information & Wellness	Customer Education & Awareness	Employee Training	Continuing Education & Certification	Advertising / Visualization	Strategic Planning	Command / Control
Industry	Occupational Safety	Sales / Recruitment	Employee Training	Workforce Education	Process Optimization Simulation	Nano / Biotech Design	Command / Control

Table 1 - Serious Games Taxonomy [20]

Other classifications have been proposed, applied to specific areas like rehabilitation [21], or the G / P / S model [22]. This latter classification considers (G)ameplay, or the "Game" part of "Serious Game", the rules, input methods, Space-related setup, Time-related setup Drama-related setup. (P)urpose contemplates the "Serious" part of "Serious Game", or the objectives and used tools to achieve the factors other than entertainment, similarly to the already mentioned classifications based on purpose. Finally, (S)cope corresponds to the target market, audience, etc. In the G / P / S model, *State & Government*, *Military & Defense*, *Healthcare*, *Education*, *Corporate*, *Religious*, *Culture & Art*, *Ecology*, *Politics*, *Humanitarian*, *Advertising*, *Scientific Research* are considered, covering a wider base than Sawyer & Smith's taxonomy.

2.2 Emergency Response

Following Sawyer & Smith's classification table, Emergency Response and Crisis Management can be covered by the scopes of at least "defense", "corporate" and "industry". Purpose may be any of the column titles. Serious games perfectly wed crisis management, and they have been strongly researched in the latest years. ISCRAM (Information Systems for Crisis Response and Management) [23] is a reference in the area, with a wide range of free learning material. The ISCRAM Summer School is also a great source of learning material. Furthermore, the annual ISCRAM conference has been held since 2004, joining researchers in the area and publicly releasing proceedings free of charge every year. Among many other tools, frameworks, taxonomies and studies, serious games have been a constant present in the ISCRAM conferences for the last few years.

911 – First Responders [24] and *Emergency 4: Global Fighters for Life* [25] are two relatively successful games that touch the border of serious game for emergency response. They fail to fit the definition in the fact that their main objective is indeed fun and entertainment. However, they contain many valuable rules and mechanics and are based in real emergency response. *HazMat Hotzone* [26] however is an example of a serious game that targets first responder training, focusing on hazardous materials. The game was developed at Carnegie Mellon University in collaboration with the Fire Department of New York, with the aim of being freely distributed to fire departments across the United States. *Incident Commander* [27] teaches and trains first responders in incident management for multiple scenarios like terrorist attacks or natural disasters. *Tactical Incident Commander* [28] is constituted of three modules: The scenario player, the scenario creator and the log analysis tool. Using the scenario creator, it is possible to generate multiple scenarios that will be used by the scenario player to train incident commanders. The log analysis tool provides further analysis of the trainees' performance, letting them learn from their mistakes, or even keep well executed missions to play back as examples.

Simulations are mandatory to analyze, train and prepare. They are, however, expensive, time-consuming and usually require a large quantity of men to be "unavailable" for anything else while the simulation is running. Computer simulations minimize these problems, and data can be collected automatically for further analysis. They can also include some assets that would not be possible in real-world simulation, like agents or the possibility of controlling weather variables or terrain topology.

For a real crisis scenario, different forces often collaborate in the attack. This represents an organizational difficulty for field simulations. With the aim of minimizing these problems, training and simulation tools have been developed, integrating several technologies that augment the normal training scenarios. "*Situated learning with cooperative agent simulations in team training"* [29] contemplates a collaborative environment in Virtual Reality and integrates intelligent agents that complement partly constituted teams.

IMACSIM (*Interactive Multi Agent Crisis Simulator Interpreter and Monitor*) [30] is another example of a simulation platform involving agents, with three main goals: create a crisis environment that allows for the simulation of different occurrences, create a communication layer to handle agent messages and create intelligent agents whose actions can change events in the simulated world. IMACSIM fits in the framework of *COMBINED* (*Chaotic Open world Multi-agent Based Intelligently NEtworked Decision-support systems*) [31], a project aiming to combine human actors and artificial agents, funded by the Dutch government. The project was developed in the DECIS laboratory in the Netherlands, constituted by four major partners: Delft University of Technology, Thales Research and Technology Netherlands, University of Amsterdam and the Netherlands Organization for Applied Scientific Research [32].

The INDIGO project [33] represents an innovative decision support system for crisis management and training, supporting five critical crisis management tasks: Sense Making, Coordination, Decision Making, Meaning Making and Debriefing [34]. It is based on the first eight premises developed in DERMIS (the design of a Dynamic Emergency Response Management Information System) [35], listed here – as described in the INDIGO project's words - due to their relevancy in the work at hand:

1. Premise 1: The system is a decision support tool. By "plugin" an optional trainer, it is enhanced by a trainer's directives. Only one tool is designed for the trainer, and has a connection to all others;

2. Premise 2, 3, 5, 7, 8: Information is created, shared, and visualized in real time. COP information is organized by type and can be filtered, e.g. localization information is visualized on maps;

3. Premise 4, 5, 7: Even though one must be able to see any information shared, the way to visualize the information differs. For example, in a crisis center many people are gathered around a table. Thus, a specific digital white board was designed for this use. A mobile tool that can be carried easily and able and still be connected was designed for operational commanders on the field.

4. Premise 3, 6: Crisis managers in crisis centers are often away from the crisis location and do not see images of the disaster. Having a clear picture of the problem is part of the decision support. A novel technology has been developed for creating and exploring 3D environments thanks to real-time photos streamed. Moreover, the

INDIGO symbology takes information validity into account by displaying planned and unsure information with different line styles in the frame shape and colors.

On the 23rd of June 2004, the first call for PASR (Preparatory Action for Security Research) proposals received 173 applications from all the 25 member states of the European Unity (at the time), from which 12 were selected. The second call received 156 proposals on the 3rd of May 2005 with 13 accepted, and the final call, which ended on the 10th of May 2006 received 165 new proposals, from which 15 received funding [36]. Table 2 lists 11 projects funded on phase 1 [36][37].

Name	Method of Preventing Terrorism	Implications for Security Integration
ASTRO	Develop Europe space industry	High
CRIMSON	3D virtual reality crisis-simulation technology	Potentially High
ESSTRT	Study to analyze threats and recommend new cooperative measures	High
GEOCREW	Study of early detection of man-made crises	Potentially High
IMPACT	Foundations for integrated CBRN counter-terrorism plan	High
ISCAPS	Integrated surveillance of crowded areas	Potentially High
SeNTRE	Consult a network of technology experts for integrated security	High
SUPHICE	Create a common EU crypto not owned by any member-state	High
TERASEC	Develop terahertz radiation and laser for remote & near-by detection of CBR and explosive weapons on people or in the mail	High
TIARA	Constitute an EU network for treatment after radiological accidents	High
VITA	Assess threat to highly transnational, networks of infrastructure	Potentially High

Table 2 - Preparatory Actions on Security Research 2004 [36], [37]

The rightmost column on table 2 concerns Security Integration for European states. As can be seen by the header of column 2, these projects were aimed at terrorism prevention, but all fields of crisis management can benefit from security integration. One very relevant aspect with these PASR proposals is the fact that they helped to lay down a set of rules and foundations. In 2004, the idea of crisis management using a 3D map to visualize the TO was revolutionary. The CRIMSON project "effectively spread norms about crisis response in Europe through the development of a 3D virtual-reality simulation CBNR (Chemical, Biological, Nuclear and Radiological) attack on the EU" [36].

The aforementioned project INDIGO followed CRIMSON and widened its horizons with the inclusion of inter-organizational preparation and response in any threat environment. INDIGO represents information on top of a 3D map and it can replay events after the crisis for analysis and allow first responders and field units to be involved in simulated exercises. VASCO (Virtual Studio for Security Concepts and Operations) [38] continued the work of CRIMSON and INDIGO and it introduced methods to quickly build a 3D picture of a building and its environment, providing an interactive visualization and manipulation of information that can be used for all phases of security management [39]. Figure 1 - INDIGO. Interactive visualization and annotation of the geographic environment shows the user interface for the INDIGO project.

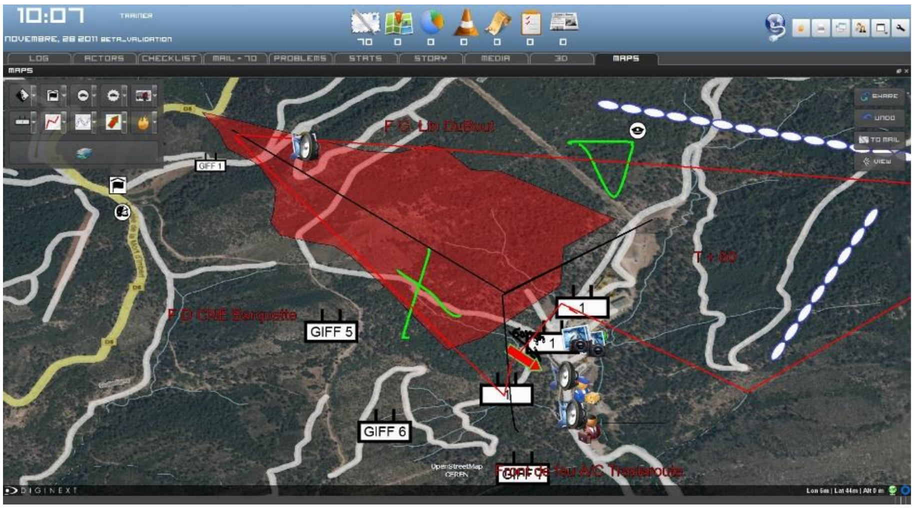

Figure 1 - INDIGO. Interactive visualization and annotation of the geographic environment

2.3 Map Sources

The CRIMSON, INDIGO and VASCO had large challenges to overcome. CRIMSON was developed in 2004, when Far Cry by Crytek [40] was one of the most visually impressive 3D games. As impressive as it was, available graphics hardware at the time meant it fell short from being able to display a convincing picture. Even Crysis [41], released in 2007, although acclaimed worldwide for its impressive visual quality, was very far from convincingly depict the idea of realism. It also required top of the range computers to run without significant delays. This is a compelling argument to call CRIMSON, INDIGO and VASCO three very ambitious projects. Having said this, it was expected that technology would keep improving –

as it did – and the lack of visual fidelity at the time would later be overcome. Data collection and subsequent transformation into information was the a much bigger contribution rather than its visualization. VASCO especially, aimed at researching and developing several techniques to collect usable information from real world data.

In 2014 and 2015, Diginext published six scientific papers that integrate with the VASCO project. The contributions of these publications target reconstruction, Structure-from-Motion (SfM), panoramic views of 3D environments, indoor mapping, omnidirectional image capture and automatic floor plan generation.

Similarly to Photosynth [42][43] or PhotoCloud [44] which allow the user to navigate between photographs in a nearly seamless way based on supporting point clouds, "Stereo-browsing from Calibrated Cameras" [45] proposes a system to visualize an environment by means of photographs and the corresponding point cloud. The *StereoSpace* domain, as the authors describe it, provide a continuous navigation based on a discrete domain of stereo views.

ExploreMaps [46] takes a renderable model and automatically calculates probes that render depth cube maps and generates smooth paths between those probe points. The end result is a visualization of high quality sequences of images which resemble a continuous video following the pre-calculated paths according to user directions. Unlike the model that originates the complementary information, the end result is a very high-quality render even on devices with modest specifications, like mobile phones or tablets.

Another VASCO publication [47] addresses easy, fast and accurate generation of floor plans and building interiors by any person who carries a modern smartphone. By combining data from both the phone's IMU (Inertial Measurement Unit) and camera as the user walks inside the building, the process first builds a coarse representation of each room and calculates statistics regarding potential errors. The coarse representation is shown to the user, and problematic data is highlighted to instruct the user to provide more refined measures for that spot. This technique can be used by first responders and can be transmitted to the command center, where the representation of the interiors can be viewed.

With the same objective – automatic generation of floor plans – a second method is proposed in a VASCO publication [48]. Instead of relying on the IMU and optical flow, the authors developed a method based on panoramic photos of each room. By detecting floor and ceiling edge points on a panoramic photo, and after filtering false positives, it becomes possible to calculate the room height, and after edge segmentation it becomes possible to infer room corners. An analysis of the compass direction between rooms results in the localization of doors, which can be used to connect rooms and infer the approximate geometry for a full story. With panoramic cameras continuously getting their price and size lowered, this approach presents itself as an instantaneous way to generate building interior approximations.

One third approach to fast indoor mapping was presented as part of VASCO. With this proposed methodology [49], there is no need for *Manhattan World Assumption* [50], which means that irregular shapes with corners of any angle, instead of a necessary right angle. This method acquires wall directions as well as corner positions creating a full room which can be composed with others to automatically generate multi-room models. The process involves capturing a 360-degree video from the approximate center of each room, tapping the smartphone's screen for every corner and door. After this capture step, the reconstruction application generates single straight lines for each wall by calculating the line that best defines the analyzed samples. When walls and corners are calculated, a statistical method makes use of the implied strong redundancy to obtain walls directions and positions in metric coordinates.

Several publications outside the VASCO project address the problem of automatic indoor plan generation using similar methods. Even Android and iOS applications are available (e.g.: MagicPlan, STANLEY Floor Plan) for free, with paid plans usually available. Like for indoor spaces, the outside of buildings can be generated with different techniques. For manual modeling, several applications have been available for decades and professional modelers are usually comfortable with them to digitally recreate buildings based on floorplans. The quality of the results is usually directly proportional to the amount of time invested and, more often than not, the required period is more than the available time to complete the work. While interior modeling mostly requires a fast data acquisition, since first responders many times have to access private property for which information is not yet available, buildings and terrain elevation are publicly visible and a lot of data exists for most of the world. With this in mind, procedural modeling and 3D reconstruction may aid in the relatively quick recreation of the outside features. Procedural modeling is able to generate information in real-time, usually with lower quality and recognizable elements, 3D reconstruction can be applied in advance to any part of the world.

Terrain elevation data collected with LiDAR (Light Detection And Ranging) is available for most of the world. The SRTM (Shuttle Radar Topography Mission) [51] recently released topographic data for outside the United States with a resolution of 1 arc-second, which results in new samples every 30 meters. This is a big improvement when compared to the resolution of 3 arc-seconds, or 90 meters per sample, previously available for coverage outside the United States. Data can be downloaded freely, and terrain geometry can be quickly generated from the resulting files. For an even quicker and more automatic application, several Unity add-ons were developed. An example of such add-ons is RWT (Real World Terrain) [52] which, for $90, generates Unity terrains based on SRTM v4.1 (3 arc-second resolution) and complements elevation with texture data from Google Maps, ArcGIS, MapQuest, Nokia Maps, Bing Maps or Open Street Maps. The GeoStream framework [53][54] is another example of a Unity plugin that generates terrains at design time or runtime by connecting to Open Street Maps, Google Geolocation API, Google Altitude API and other data providers. With the data gathered from these different sources, GeoStream procedurally generates Human structures like buildings, roads, bridges, traffic lights, terrain geometry and textures, Points of Interest and even weather information.

GeoStream goes one step further than RWT by procedurally generating roads, buildings and bridges, among other features. To achieve this, collected data includes – for the example of buildings – a base polygon and building heights. Geostream generates a 3D solid to approximate the look of the building. This approximate look can be improved by assuming Manhattan-World buildings. Based on one or more calibrated input images, “Building Reconstruction using Manhattan-World Grammars” [55] achieves a much more realistic look by generating different volumes that constitute the building, as well as building textures that originate from the inverse distortion of parts of the input images.

Other approaches to procedural modeling result in complete streets or even cities based on available data. CityEngine [56] is a relatively well know application that can generate full cities based on real data, or pseudo-random generators that result in a city that does not exist, but looks like it might. Sceelix, whose first iterations were called Construct, resulted in several publications [57][58](Pedro Brandão Silva, Coelho, & Rossetti, 2012) before it went on sale [60]. Sceelix handles not only buildings, streets or bridges, but it can also procedurally generate terrains, vegetation, building interiors, lights, physics, among many other features. It also integrates seamlessly with Unity, but other game engines are in the pipeline.

Other approaches to the semi-automatic generation of buildings include 3D reconstruction techniques. By capturing a video or several photos of a building or feature, and after a calibration step, these techniques rely on the finding of feature points in one image and the correspondent features on other photos, the camera location when each photo was taken is calculated. The process usually starts by generating a sparse point cloud which can be cleaned before generating a dense point cloud. The resulting points correspond to some of the points of the building surface. A mesh can now be generated, usually by following the steps of subsampling, normal reconstruction, surface reconstruction and cleanup. Vertex colors and textures can also be generated from the original photos, and a complete texture with all the features can be generated, as well as UV maps [61].

Google Earth, Here Maps / Bing Maps and Apple Maps are examples of services that have been using 3D maps, including all buildings and landmarks for certain cities since 2012 [62]. Apple has a history of keeping their property inside closed doors and, although Google usually shares most of their content with the world, 3D maps are the exception. Here Maps navigation is currently free, but 3D maps are not available for most of the world, as with Bing Maps. However, the fact that three giants embraced the technology this quickly proves that it presents large benefits.

Despite the long research, no sources were found that allowed public downloads, except for some small areas in specific places. Having said this, there is now a relatively large offer in software for 3D reconstruction. Hardware-wise, recent developments in drone technology brought aerial photography to the masses. SenseFly is a French company that specializes in development of UAVs (Unmanned Air Vehicle) targeting 3D data collection. Parrot, a French market leader in civilian drones, invested 5 million Swiss Francs in 2012, when it acquired the majority of SenseFly's shares. At the same time, Parrot invested another 2.4 million Swiss Francs in Pix4D, a software company that specializes in 3D reconstruction [63]. Both SenseFly and Pix4D are startup companies with already proven technologies, and both originated from EPFL - École Polytechnique Fédérale de Lausanne.

2.4 Conclusion

This chapter analyzed the state of the art regarding serious games, emergency response and map sources. The sub-section referring to the state of the art presented a general taxonomy of serious games in the present world while focusing on the relevant areas of emergency response and military.

The main theme researched was emergency response, since this is the area for which the solution is presented. It became obvious that a lot of effort is being made in this field, although it has not advanced as much as games, especially AAA. It also became evident that specific details are hard to find, and some of the developments are not as open as one might desire to accelerate progress.

Finally, map sources were studied. While not directly relevant to the proposal, 3D maps of the terrain and buildings are extremely important for the proposal to succeed, since it relied on these features for team and situational awareness, as well as some useful proposed features.

3 Preliminary research – Interviews with defense and protection forces

The framework presented in this study developed from the idea of turning flat 2D maps into virtual worlds that correspond to the real structures as a way of interacting with real people on the real world. While this approach could be beneficial to several different areas of work, it soon became obvious that defense and protection forces represent areas for which the solution might bring great benefits. As such, with the objective of collecting as much information as possible in order to develop guidelines, interviews were performed with representatives from the Military Academy, the GIPS, the voluntary fire brigade and the ANPC.

3.1 Military Academy

The Military Academy is a higher education establishment devoted to teaching, researching and supporting the community aiming to develop professionals for the National Army and the National Guard. Semi-structured interviews were performed with communications and medical professionals, with the aim of understanding the needs and available technology.

3.1.1 The information system and organization of units

Military forces rely on strict authority by designated entities over resources for achieving the designated goal. This is accomplished by C2, Command and Control, which refers to the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. C4i is one of several expanded versions of C2, and it signifies "Command, Control, Communication, Computers and Intelligence", an AIS (Automated Information System) [64]. Decision support databases are at the center of C4i, and these databases are common to the different defense and protection forces in Portugal.

On top of C4i databases, each institution may use different software platforms. In the case of the Portuguese National Army, SICCE (*Sistema de Informação de Controle e Comando do Exército*) - the Army's Command and Control Information System permits the combination of different types of information which may be disperse [65]. Different charts are available for the same region. It is possible to visualize 3D representations of the terrain with illumination based on altimetry data and with colors ranging between red, yellow, green and blue the user can deduce terrain inclination. When a path is drawn on the map, a height profile is traced, but if this information is not enough, terrain may be represented in 3D and its height can be exaggerated in order to better visualize slopes. Any object in the database can be geographically referenced. An object can be anything, from human resources to vehicles or equipment.

The command post has access to the information, from the highest to the lowest rank. For human resources, as long as such information is available, several different types of data are available, including blood type, division, specialty, types of weapons available, physical or psychological condition;

The commander has the options to issue an order for one element or a group of operatives to move to a certain position. This information is received on a laptop or a PDA (Pocket Digital Assistant), if available. However, equipment is kept to a minimum, with objects like weapon or binoculars taking precedence over digital devices. The operative may report events as long as he/she is online, and a symbol representing those events will be available in real-time.

Situational awareness is contemplated, representing friendly units in blue and enemies in red. A unit may be selected on a map, and in this case a unit usually represents a group of individuals, although anything may be a unit. Units are categorized as equipment and people, where dogs, for example, are part of equipment. Several types of vehicle are available, including classes like transportation helicopters, ambulances, fire attack, fuel supply, water supply or moving offices. Units are organized in a hierarchical scheme, where a fire hose can be part of a fire truck, which in turn can be part of a group. These vehicles may belong to different types of unit, including types like navigation, security, air transport, medical transport among others. Equipment can be transferred between units, and a vehicle which is part of unit A may be temporarily “borrowed” by unit B, maintaining the information that it organically belongs to unit A.

Presently only the quadrant where a unit is placed is known, but it was specified by the Military Academy that ideally the precise location of the unit would be known. Technical limitations are responsible for not reporting the exact place of each unit, and an approximate location is enough for achieving results. The last known location is used if a unit is lost; a search is initiated based on the latest confirmed location. Other models are used to predict the placement of the unit, like tides and winds. Sector of fire, which consists of a defined area which is required to be covered by the fire of individual or crew served weapons or the weapons of a unit, is also considered. Usually only one GPS receiver is available per unit. When enquired, the spokesman from the Military Academy stated that the use of a smartphone for location and coordination would not be out of the question, although that might raise security due to counterintelligence, in case a friendly smartphone was captured, and it might also increase chances of false information.

Information available at the command center is provided by operatives, since they are the ones who select what information is useful for decisions. The propagation of this information depends on the profile; it can go to the command center immediately above who decides if the information moves on to the next step in the hierarchy. If a unit's profile states that the information may enter the database directly and becomes automatically available to whoever has the need and access credentials.

The smallest human unit – the pair - is constituted by two men represented by two objects in the database. Under no circumstances does one man leave by himself to any objective. On a military level, equipment carried by each man depends on the mission. For missions that last between one and two hours, this may be as little as a water flask, whereas twenty-four-hour missions may require a backpack with a sleeping bag, 1.5 liters of water, food, etc.

In what concerns to communications, bandwidth is reduced except in times of war, which in practices forbids real-time communication. Mobile phones and SMS (Short Message Service) are used as well, with one message every minute allowing the database to be updated with the location of a unit based on the identification of the mobile phone which sent the message. This approach also decreases costs when using a message package.

Network security is not as relevant as it might be thought, and many times there is no encryption at all. Especially in times of peace, but also in times of war, even in the case the enemy could intercept a message they would not be able to react in time. Signal power can be varied to increase security. If the communication source is 100m away from the receiver, power may be decreased because the enemy may be 10Km away. The most important condition is that the signal can be received clearly and quickly.

Although possible, the position of operatives is usually not tracked, and an estimate of their location can be inferred based on origin, elapsed time and target location. The situation is reported when the unit reached its destination. If there is no report after the estimated time, the possibility that something unexpected happened is considered. It was noted by the representatives of the Military Academy that, if resources allowed for it, the permanent knowledge of each unit's location would be extremely useful.

When data is available, location is visualized in the application but orientation is not. The unit's orientation is not relevant, unlike location and displacement path. History is maintained regarding the positions of each unit. Only the most relevant information is kept in the database with the objective of keeping databases within reasonable limits. The information relating displacement or orders usually takes between five and seven Kilobytes. In what concerns to vehicles, if the unit's GPS position is not known, information such as type of vehicle, terrain and speed is considered. Its representation is visualized as a green circle in the style of a pie chart which decreases with time according to the estimate. When the estimated time for reaching the target is completed, the vehicle is drawn at its destination. Only time is estimated, the position is not, and only a label is shown describing the vehicle's status as "Moving".

Under urban areas the situation changes, since building plans are necessary instead of terrain charts, and displacement is not possible in every direction, contrary to other situation. It is possible that a narrow street makes it impossible for a certain type of vehicle to cross it. In natural environments it is usual to send a unit to its destination over an alternative path when the slope is too big, for example. The same happens in urban areas, and since it is impossible to know which doors are open or closed, only streets and public areas are considered as available for troop movement. The knowledge of alternative paths is extremely relevant and the decider may ask the police to block traffic. It is of extreme importance that the decider possesses enough information to choose where he wants units to be located. The information of which way traffic is processed in each street is extremely important. Vehicles are usually prepared for off-road driving, but some obstacles may appear that are not present in charts, like fences or collapsed structures. Therefore, the driver responsible for the vehicle has the power to decide and take an alternative route, since the command center may not be aware of these obstacles. Alternatively, the command center can enforce that the route will be completely based on known streets.

Vehicles mostly move as a group and remain relatively close to each other in order to optimize refueling times and other tasks. Under some situations, however, one vehicle may take an alternative path, without ever getting to far from the group, in which case a meeting point is pre-arranged. This action is not reported to command, since it does not represent relevant information. It becomes relevant information if, for example, the vehicle needs to be toed. In these circumstances an incident is created based on the vehicle's position. Any sub-unit may be marked as INOP (Inoperable) and ceases to be part of the mother unit in the hierarchy.

3.1.2 Emergencies

Aside from the representative of the military Communications and Information Systems, information was also collected regarding medical procedures on a non-guided interview with medical personnel at the Military Academy. Although the interview was shorter, relevant information was gathered focusing on the workflow of medical emergencies in military forces.

CODU stands for *Centro de Orientação de Doentes Urgentes*, or Guidance Center for Emergency Patients. INEM is the *Instituto Nacional de Emergência Médica*, which translates to National Institute of Medical Emergency. In Portugal, INEM has four CODUs in the biggest cities, namely Lisbon, Oporto, Coimbra and Faro, roughly equidistant from each other covering the Portuguese territory. Calls received at the European emergency number (112) in Portugal that regard emergencies are directed to a CODU. It is the CODU's competence to answer and evaluate in the shortest possible time interval every request with the objective of determining the necessary and adequate resources for each case. Its functioning is assured 24 hours per day by teams of qualified professionals, medical and technical, with specific instruction to provide treatment, triage, counseling, selection and dispatch of support media. For the effect, the CODU possesses a set of equipment related to telecommunications and information systems which allow for the coordination and management of human media and technical resources.

The CODU manages a set of help resources which includes motorcycles, ambulances, medical vehicles and helicopters. Resources are criteriously selected according to victim clinical status, proximity to the occurrence and accessibility to the occurrence. Their service ensures the accompaniment of help teams on the terrain through received clinical information. It is also possible for the CODU to select and prepare hospital reception for the patients based on clinical and geographical criteria and resources on the health facilities [66].

Triage is usually performed by INEM, even if the fire department can also intervene in less serious situations, with medical vehicles and the communication equipment they are prepared with. These units carry laptops with victim related information provided during the report call.

The VMER (*Viatura Médica de Reanimação*) is a Medical Resuscitation Vehicle armed with equipment for the task. This equipment includes radio communications equipment fixed to the vehicle as well as a portable radio, both operating in a closed network with the CODU central, mobile phone, fixed phone and pager at the base. Medical equipment is present in the form of a medical case with medicine and administration tools, defibrillator, vital signs monitor, reanimation bag, ventilator and several other pieces of equipment. Non-medical material is also provided in the form of a fire extinguisher, protection helmets with a light source, other light sources, etc.

When a call is received at the European Emergency Number, if the reported condition is not a medical situation, the police is responsible for triage and redirects the occurrence to the nearest police station or vehicle. If a medical professional is necessary, he contacts the CODU for providing / requesting information. Depending on the type of occurrence, the fire department or the GIPS may be called to intervene.

All support units are prepared for triage and have some level of training in what concerns to first response. In the eventuality of an element that is not capable of helping victims, the CODU is prepared to provide information over the phone and help the responder determine the gravity and the type of response needed. Teams are multidisciplinary with different specialties. An ambulance may contain a professional rescuer, a driver, a doctor and nurses. In this case, the doctor works as the team leader.

Combat triage usually varies between ABC (Air, Breathing, Circulation) and ABCDE, which adds Disability and Exposure). Colors are used to indicate victim state, where black is on one side of the scale and signifies “Does not move” (dead). Red, orange, yellow and green describe different degrees of severity. Conventional triage is also used, like Manchester Triage.

3.2 GIPS – Grupo de Intervenção, Protecção e Socorro (Intervention, Protection and Rescue Group)

The GIPS is a Military force which is part of GNR (*Guarda Nacional Republicana*), the Republican National Guard. They are one of the Civil Protection Agents, as well as the Professional and Voluntary Fire Brigades, the GNR, INEM, the Army, the Red Cross and the PSP (*Polícia de Segurança Pública* – Public Security Police), but as a Military Force they have military training. That signifies that unlike firemen, they are used to topographic charts, dimension lines, military communications, wind charts, among others.

The GIPS intervenes in collapsed structures, earthquakes, dangerous substances, fire – even if something has to be collected from inside a burning building, forest fires or underwater operations to name a few. They focus on the first contact. Fires should be controlled within the first ninety minutes or they usually last for several days. The GIPS and firemen are called to the occurrence during those first ninety minutes, and only after that other entities are called. The elements of the GIPS are placed as close as possible to the fire where they remain. If after ninety minutes the situation is not resolved, the GIPS does not persist unless people are at risk. At that point, the number of fire fighter increases from between twenty and thirty to one or two hundred. There is a lot of dispersion and difficulties of coordination.

Each entity operates within its own guidelines, but their work is facilitated by SIRESP – *Sistema Integrado de Redes e Emergência de Segurança de Portugal* (Integrated System of Emergency and Security Networks of Portugal), a communication infrastructure dedicated to emergency situations. The management system can be seen in Figure 2 - SIRESP - Sistema Integrado de Redes e Emergência de Segurança de Portugal.

Figure 2 - SIRESP - Sistema Integrado de Redes e Emergência de Segurança de Portugal

The ANPC (*Autoridade Nacional de Protecção Civil)* is the Portuguese National Authority for Civil Protection. As a coordinating entity, they do not have forces on the terrain but rather direct firemen, the GNR, INEM or armed forces. They have command vehicles, computers and other equipment, but not men. The ANPC manages the CNOS (*Centro Nacional de Operações de Socorro*) – National Center for Rescue Operations which in turn coordinates several CDOS (*Centro Distrital de Operações de Socorro*), or District Center for Rescue Operations, of which there are 18 in total. The CDOS is the first to intervene when there is an occurrence within its district, and it organizes its media in order to respond.

The main type of catastrophe in Portugal is related to fires, and every structure is organized to respond to fires. DCIF stands for *Dispositivo de Combate a Incendios Florestais*, or Forest Fire Fighting Device. Helicopters, for example, are dispersed all over the country, managed by the CNOS but distributed to each CDOS. The CDOS coordinates local situations, whereas the CNOS manages circumstances that involve several districts or national media. There is a common language to every CDOS, but the ways of operating may vary. As an example, the city of Bragança located in the interior of the country provides special attention to forest fires, whereas the city of Oporto which is located by the sea focuses on dams.

Associated to the Center of Social Studies, OSIRIS Risk Observatory handles the specific approach to risk situations that may cause damage and unintended situations that arise from interaction between the environment and human activities [67]. The Nature and Environment Protection Service SEPNA (*Serviço de*

Protecção da Natureza e do Ambiente) aims to uphold forest law, organize prevention activities, surveillance and forest fire detection and generally maintain the order in what concerns to the environment [68].

Watch towers are distributed along the Portuguese territory with the objective of detecting forest fires as soon as possible. On these towers, a watch guard traces an azimuth from his position towards a fire he may spot. This information is communicated to the CDOS, which triangulates data from ate least two towers in order to locate the fire. An alert is launched to a helicopter that investigates further. The GIPS intercedes, equips the helicopter and performs the first approach to the situation. Making use of SIRESP, the GIPS synchronizes the radio with the watch posts. Unfortunately, some difficulties exist, as there is a lag between the fire detection and the launch of the helicopter, which ideally would be immediate. The GIPS forces get into the helicopter and are ready to leave in thirty seconds. The helicopter has a range of 40 km, but usual displacements are between 10 and 20 km, and the speed of the helicopter varies with different factors, like cargo and atmospheric conditions, as in higher temperatures the helicopter moves slower. The information regarding the place of fire is received in the form of a direction and a distance, as opposed exact coordinates. At a distance of 40 km, an error of one degree in the direction translates into a significant error.

Fires are categorized according to three characteristics, namely the type of fire – involving trees, flammable substances, etc., vertical location – over or under ground, and intensity – weak, average or high. All the GIPS agents attend an intensive course with practical and theoretical components with tests in real situations, with real scenarios and real fires. It was mentioned that there is a need for simulation and prediction software. There are 580 GIPS agents distributed as 60 for each district. There is a specific group for search and rescue in collapsed structures and within that group there are recon teams.

Planning and report are two of the phases of firefighting. The reports consist of an A4 size sheet of paper with a summary description of the occurrence. During firefighting, the helicopter provides support and drops water over the fire according to the GIPS' indications. In situations of fires and floods the GIPS adapts to circumstances, but when dealing with chemical incidents, for example, prior knowledge would be extremely beneficial, for one minute of lack of intervention can turn into the loss of many lives.

The ANPC maintains a time strip with operation history and report. There would be advantages in automating the record of information and not allowing information to be altered. Different situations result in different reports since decompression time, for example, is necessary and available in underwater operations but not in other circumstances. The command receives in its report information like equipment damage. A copy is delivered to logistics and operations and other divisions if maintenance is necessary.

Different forces are independent from each other and usually there is no necessity for one force to know information regarding another. The situation changes, however, if a larger emergency happens. Frontiers are dropt and all information is useful.

The idea of Theater of Operations is shared with the military, and in this case it refers to the physical area in which military forces concentrate. The GIPS agents carry a survival kit prepared to endure at least one day. Although it was never problematic, previous complications were reported which would have been easier to resolve if each unit was geographically referenced, in which case the supporting helicopter would have quickly rescued the operative. The GIPS use military hand signals and are prepared to signal the helicopter, although that becomes complicated in specific situations like areas of low trees. Every half an hour the situation is analysed. If after a certain time there is no communication, the last known position is used to approach the incident. Some radios have an alert button, but they do not transmit location data, only the fact that something is wrong.

3.3 Fire Brigade

The voluntary fire brigade is a group of people unselfishly devoted to helping fellow citizens but working voluntarily does not mean that they do not take the job seriously. Fire men and everybody through the chain of command go through theoretical and physical training and they have a busy schedule – they do not show up at the headquarter only when required, they work there and sleep there following a rigid timetable. The universe of the Volunteer Firemen is very heterogeneous in terms of literacy. In the professional fire brigade, it is mandatory that men have completed the 12th year of the Portuguese education system, whereas the voluntary firemen range between the 4th year and university graduates. The Firemen school, however, is common to both and it includes six months of theoretical subjects plus another six months of field work where they are integrated into an already existing team. For many of them, technology is a complicated subject and when introduced to the initial idea behind the present work, it was stressed that any simplification possible would be welcome. The framework was described as a welcome effort especially in what concerns to multi-force catastrophes and calamities. For day-to-day operations, the workflow that is presently used should suffice and the platform would not bring major advantages.

The firemen operate in teams, and within each team there is Search and Rescue group. Like other protection forces, the minimum unit is a pair of men and never is a man asked to perform a mission by himself. Each team is led by a team leader who receives orders and information that he then transmits to team elements. Fire brigades are constituted by multiple teams and other collectives exist like brigades and groups. In forest fires it is possible that a man is lost between smoke and trees, but the same does not happen in urban areas, where fires usually happen within buildings.

The highest rank officer in the Theater of Operations is the COS – *Comandante de Operações de Socorro*, or Rescue Operations Commander. The COS contacts the group leader who in turn leads several teams. At the command post, the CODIS – *Comandante Operacional Distrital* is the Operational District Commander, aided by the second CODIS. One CODIS is in charge of each CDOS. The CNOS is managed by the CONAC – *Comandante Operacional Nacional*, or National Operational Commander.

Each municipality has a Municipal Emergency Plan which is activated in case of emergency, and it involves only resources from that municipality. In situations like forest fires, an inter-municipal plan may be activated. Calamities must be enacted by the state. For each municipality a COM – *Comandante Operacional Municipal*, or Municipal Operational Commander exists. The COM is contacted when a Civil Protection Agent requires equipment like a backhoe or power supply.

The CDOS may issue special alerts that indicate that an emergency situation exists or is likely to come to exist. There are four states of alert: Blue regards to a normal situation which does not present special risk factors. Yellow indicates that a risk situation has some probability of being affected by natural or technological factors. Orange represents a pre-emergency which presents a serious risk of occurrence of a severe accident. Red activates the CMOEPC – *Centro Municipal de Operações de Emergência da Protecção Civil*, or Civil Protection's Municipal Center for Emergency Operations and is triggered when the risk situation is affected by a catastrophic occurrence [69]. Blue alert requires routine monitoring, while the next three mobilize 25%, 50% and 100% respectively of the municipal civil protection resources.

Simulations are performed, usually coinciding with the Civil Protection's day. Municipal Emergency plans are used, the event is monitored and parameters like response time. A briefing takes place and evaluation charts are filled.

Water vehicles have a pump which forces water through hoses. Each hose is twenty meters long and multiple segmented may be connected in order to achieve longer lengths. In some situations, like chemicals and dangerous substances, the vehicle remains at a considerable distance from the fire, while in urban situations it is kept close to the fire. The driver operates the pump and also retreats if the flame develops too much. One kilogram of force is necessary to elevate the water 10 meters, which makes a pressure of three kilograms necessary for the water to reach a fifth floor. As such, there is no need to place the vehicle in a higher ground. Fire hydrants can power the hose but usually fill the water tank instead and the vehicle remains responsible for pumping the water. In forest fires, water tank vehicles are used to refill the main vehicle. The Portuguese law required that when a building is built, hydrants are present within acceptable range considering the building's height and volume. Water hydrants are geographically referenced and their positions are known.

Orders given to a fireman are mostly of two types: attack and retreat. Their main function is to attack the fire, but sometimes the fireman has no perception of the whole context and an outside element can better understand the severity of the situation. Furthermore, winds can change and firemen have died between fire and counter-fire. In forest fires, the command post monitors the meteorological conditions, wind direction, temperature and humidity, among other factors. This information may be transmitted to the group or team leader. The command post also monitors several teams and may instruct one of them to attack another fire front when their previous objective is complete.

Field operatives return the POSIT (*Ponto de Situação* – Situation Status) to the command post with information regarding what is happening around them, reporting information like victims or dangerous substances. One usual type of report obeys to the lines of "I am", "I see", "I do".

The ANPC's organizational model recently evolved grouping districts in clusters, adapting the new model of operational organization of SIOPS (*Sistema Integrado de Operações de Protecção e Socorro*) – Integrated System for Protection and Rescue Operations [70]. SIOPS is the set of structures, norms and procedures that ensure that all civil protection agents act, under the operational plan, under one sole command, without detriment of their respective hierarchical and functional dependency [71]. More strength has been given to the CNOS and district clusters of rescue operations aim to provide synergies in the capacity of coordination and control.

3.4 ANPC

The ANPC is not directly involved in emergencies in the TO, but it manages all the personnel and logistics behind operations. The SGO (*Sistema de Gestão de Operações)* - Operations Management System is divided in evolutionary phases depending on the number of means and capacity of control in the Theater of Operations.

On the first phase the COS, responsible for the strategic plan of action, coordinates up to six teams, as shown in Figure 3 - Phase I of the SGO, where one team is a set of men attributed to a vehicle. All management is developed in the TO. The command of rescue operations aggregates all three cells: Planning, Combat and Logistics. There are not many means so it is possible for the COS to manage everything. Phase two takes place when more than six teams are necessary.

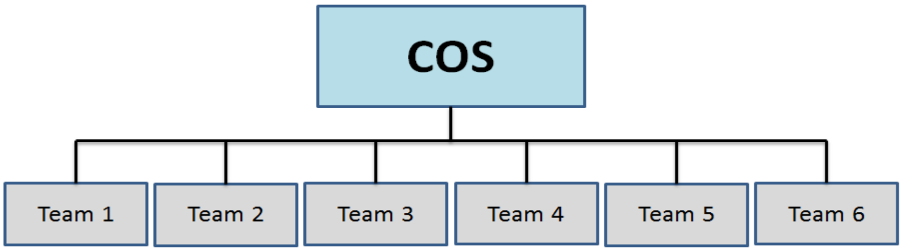

Figure 3 - Phase I of the SGO

On phase two, the command is necessarily attributed to at least a fireman official. He is responsible for all management of the occurrence. The command post is created in any space, not necessarily a pre-configured vehicle, and imposes the creation of the first cell, the combat / operations cell. The term "combat" is used when the situation involves a fire, where in other types of situations "operations" is the term used. This cell has an operations official, responsible for the cell, who works at a tactical level implementing actions in order to execute the strategic objective.

A point of traffic is mandatory on phase two. The point of traffic is a place where everything – vehicles or means – must stop before going into the Theater of Operations in order to enter in an organized fashion. They may arrive from different directions and through different paths, but they all must pass the point of traffic where they are directed to the sector where they are destined.

The Theater of Operations can spread over a very large area; therefore the number of sectors is not limited. Each sector has a set of means and one sector commander who coordinates up to six teams, answering directly to the commander of operations, who in turn answers to the COS. When more than 18 teams are present in a sector, phase three takes place. A diagram of phase II can be seen in Figure 4 - Phase II of the SGO.

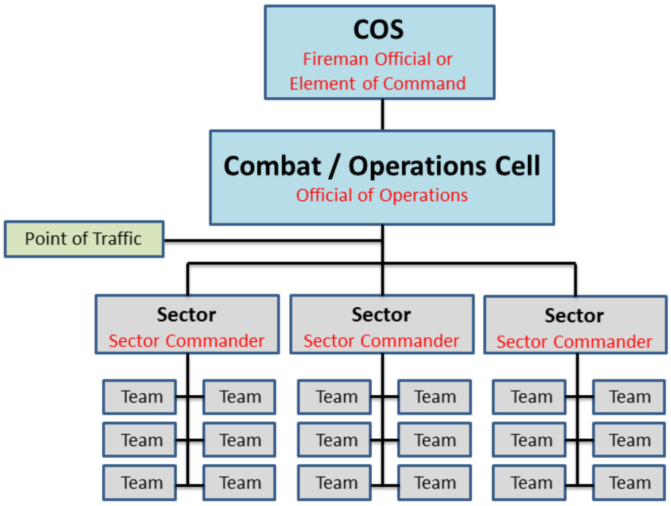

Figure 4 - Phase II of the SGO

Phase three demands tactical reinforcement spaces and at least one ERAS (*Equipa de Reconhecimento e Avaliação da Situação*) – Recognition and Situation Assessment Team. Up to eighteen intervention groups are created with up to six teams each, as well as the sector commander like in phase two. In this case, however, the COS must be the commander of the fire department, ideally the local fire department.

At least two deputies from a maximum of three are nominated. Deputies answer directly to the COS. The function of the Connections Deputy is to manage the bridge with all the elements in the cell's operational command, which in turn communicate with the joint operational command post. The latter integrates members that do not belong to the structure, like the ICNF (*Instituto de Conservação da Natureza e Florestas*) – Institute for Conservation of Nature and Forests or the GTFs (*Gabinete Técnico Florestal*) – Technical Florestal Office of the city hall. The Safety Deputy is the "eyes" of the COS and is not involved in combat but operates outside the maneuver in order to have a general view.

The three cells are mandatory. A logistics officer is nominated by the COS, and may be represented by a man or a group of men depending on the dimensions of the Theater of Operations. A means and resources core is necessary, as well as a communications and security core.

The ERASs are created and move in front of the combat teams in order to monitor the situation and confirm if the implemented strategy is effective. ERASs are not involved in combat. Many vehicles are armed with equipment that uses an internet connection to communicate the state of play to the CNOS or the CDOS in real-time. It is through the ERAS that the CNOS and CDOS maintain control over the situation.

Inside the logistics cell a concentration and reserve zone exists, which includes the points of traffic, reserve areas and refueling zones, usually outside the TO. The operations cell coordinates all the above in a more amplified way. Everything follows a pyramidal scheme. Each cell has up to six sectors, each sector has up to three groups. One group can have up to six teams with one leader for each team. Each group also has a leader who reports to the sector commander, who in turn reports to the COS. The operations management system relies on three principles: There is only one person in command at each moment, all the elements in the TO must have defined functions and the principle of control unity – each man can only command up to six units.

After a few hours, a maximum of twelve, teams must be replaced because they lose productivity and their capability of decision is affected. When information is passed on some details are usually lost. Figure 5 - Phase III of the SGO shows a schematic of phase III.

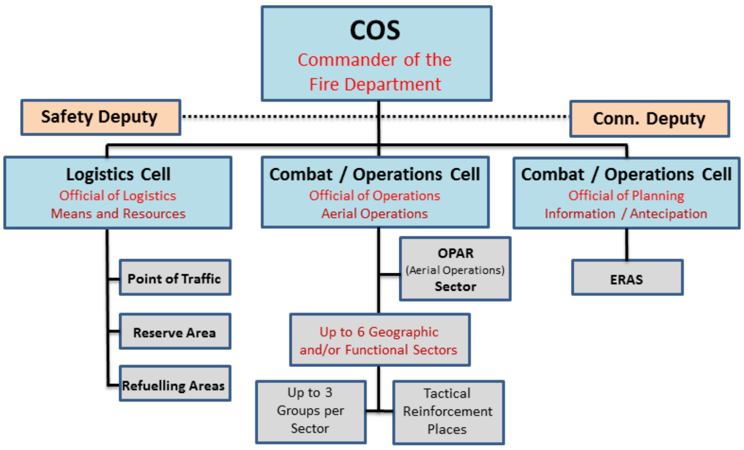

Figure 5 - Phase III of the SGO

Phase IV is the last phase and demands a lot of people involved in the operation. The organization of phase IV can be seen in Figure 6 - Phase IV of the SGOIt is extremely hard to manage and more than one command post may be created. The COS is now replaced by the ANPC's Command Structure. A new deputy is nominated, in charge of Public Relations. The PR Deputy prepares briefings in conjunction with the media. The Logistics cell now comprises not one but several people responsible for each topic, including supplies of fuel, water and equipment. Food, rest, maintenance and hygiene support the other services. Reserve areas are created according to what is planned by the planning cell. In fact, the planning cell proposes, the logistics cell prepares and the combat / operations cell executes. The combat cell faces an especially difficult job. Aerial operations depend on the combat commander. Psycho-social teams may be requested for this type of occurrence. Each sector has one person in charge, in order for the person responsible for each area to talk to one person only. The planning cell is able to request specialists. For example, if a fire is moving towards a factory with certain chemicals inside, an expert in that area may join the planning cell.

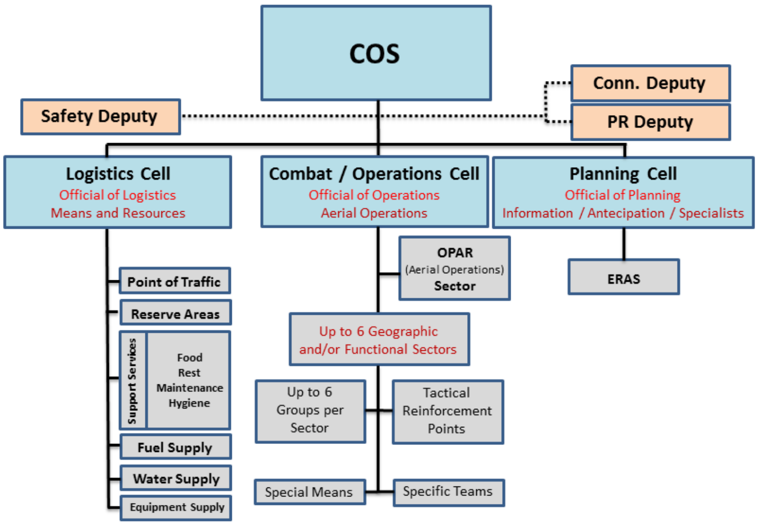

Figure 6 - Phase IV of the SGO

In Porto, the general staff is composed of command elements that are perfectly trained and integrated with ANPC. Teams may be called to the command post and projected onto the TO when necessary, they are reinforcement teams. Other reinforcement groups include the GRIF (*Grupo de Reforço para Incêncios Florestais*) – Forest Fires Reinforcement Group, GRUATA (*Grupo de Reforço para Ataque Ampliado*) – Amplified Attack Reinforcement Group, GLOR (*Grupo Logístico de Reforço*) – Logistics Reinforcement Group, GREL (*Grupo de Reforço Ligeiro*) – Light Reinforcement Group, among others [72];

The four phases of the SGO vary with the situation and necessity. For phases two to four, different vehicles are used for support of the SGO. The VCOT (*Veículo de*

Comando Táctico) – Tactical Command Vehicle, an all-terrain vehicle with the purpose of reconnaissance and tactical command is used on phase 2. Phase 3 relies on the VCOC (*Veículo de Comando e Comunicações*) - Command and Communications Vehicle, conceived for the creation of Operational Command Posts with perfectly delimited communication and command areas. The VPCC (*Veículo de Planeamento, Comando e Comunicações*) – Planning, Command and Communications Vehicle. Table 3 shows the most important metrics that define an SGO phase.

SGO Phases	Command (COS)	Mandatory PCO Cells	Maximum number of Teams	Sectorization	SGO Support Tool
Phase I	Most graduated in the TO	None	6 Teams	Not mandatory	Command and Control Guide
Phase II	Fireman Official	Operations	18 Teams	Up to 3 Sectors	VCOT
Phase III	Commander of the Fire Department	Operations Logistics Planning	54 Teams	Up to 6 Sectors	VCOC
Phase IV	ANPC Command Structure	Operations Logistics Planning	216 Teams	Up to 6 Sectors	VPCC

Table 3 - Phases of the SGO

The ANPC's way of action for operation management is mostly based on traditional means. Pre-formatted boards are used and placed on vehicles, which allows anybody to fill in relevant information with felt pens. The SITAC (*Situação Tática*) – Tactical Situation for example is drawn over an A3 sized acetate which is placed over a cartographic map on a scale of 1:25000 representing the affected area. On this acetate, information like fire placement and direction, position of means and other information is drawn. This approach is quick and information is easily transferred to the COS that takes place when people are substituted.

The SIRESP is regulated by the ANPC, and the latter is responsible for configuring and providing the radios for the firemen. When coordinates are needed, they are requested through the radio. This information and other is transmitted to the SALOP (*Sala de Operações*) – Operations Room, where they are received by employees from the TO. This information is registered and necessary means are deployed. Connection officers from GNR monitor the occurrences. The SALOP is also equipped with surveillance cameras that permit the visualization of most of the areas of higher risk.

The ANPC does not have dedicated support software; they use only a operational decision support system that serves only as a tool for support and logging. The SIRESP is not more than a communication infrastructure, and it was reported that a software tool would be very useful if it could join all these steps and information create the SITAC on a PDA with different layers of information, but it should be agile and quick. It would not replace the COS but it could help with alerts and predictions.

3.5 Survey with members of the ANPC

The previous interviews provided general information regarding the *modus operandi* of the different forces involved in crisis management. In order to better develop a valuable solution further information was gathered in the form of a survey. This survey was designed to evaluate the necessities of information that could be used by operatives and the Command Center with the objective of compiling necessary and helpful information, separating the need-to-have from the nice-to-have.

Eighteen members of the ANPC were invited to give relevancy rates to different types of information, as well as complementing with any data that they considered important. All the members were informed of the voluntary character of the survey and filled an Informed Consent Form. The Survey was divided in three sections: Information relative to the Command Center, information relative to the Operative and other possible uses that might emerge from the platform.

The survey presented here was developed from the beginning to be informal, since it did not aim to validate a hypothesis but rather to collect ideas that would complement the prototype. Validation, as will be seen in chapter 5, was performed with a new group so that results would not be influenced by previous knowledge of the solution. The tests performed for validation of the hypothesis were also based on UEQ, a pre-validated UX (User Experience) questionnaire as opposed to the informal approach used at this point.

3.5.1 Information relative to the Command Center

This section of the survey intended to gather data regarding what information is useful for or should be issued by the Command Center. The objective was to provide team awareness and situation awareness to and from whomever might be directing the operations, either in the TO or in a remote command post. Some types of information were derived from the previous study and presented in order to receive an index of relevance, while a field was provided for open suggestions of other data that might not have been considered. In the following figures, the last bar is always empty or full, being that a full bar indicates that suggestions were provided, where empty represents no suggestions. All other bars present a quantitative value based on the relevance of each feature.

Starting with team awareness the first question analyzed what should be visualized concerning each unit. All the proposed information was considered relevant. On a scale from one to ten, the collected responses pointed to an eight regarding the position of a unit in the map, the orientation of the unit, the 3D image of one each unit can see in the TO, a photograph of what the unit can see and variable information regarding each operative, like time since he/she started the mission, biometric data, levels of water, etc. Constant information for each unit, like rank, age or total capacity of water was considered slightly less relevant, although only by a small margin, receiving an average of seven. An open field was also present for suggestions, but none of the collaborators filled it. The results for this first questions are shown in Figure 7 – Relevancy of information – Team Awareness.

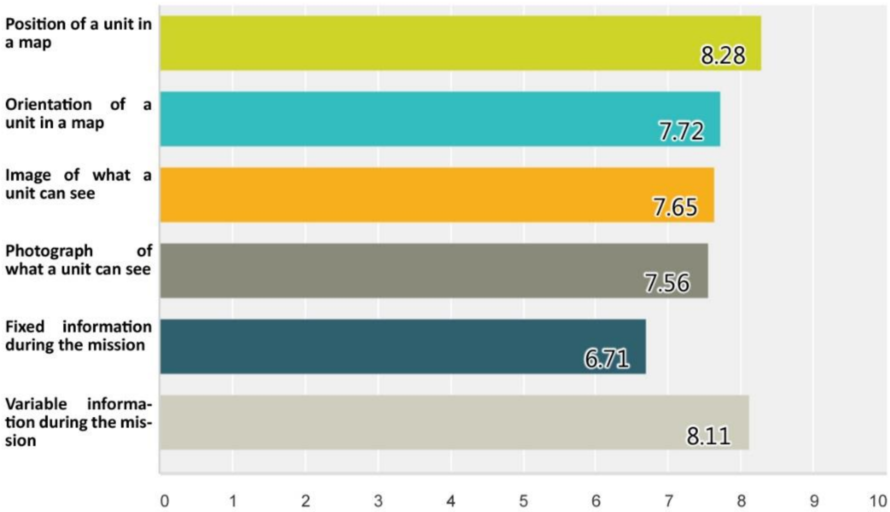

Figure 7 – Relevancy of information – Team Awareness

The second question focused on situational awareness. The suggested information was the position of events (fires, victims, etc.) on the map, the elevation of that same event (how high or how deep underground, or on which floor of a building) and a description of that same event. Again, each of the suggested topics received an average of eight for their importance. An open field was left blank by all the interviewees. Seventeen answers have been collected as one person left this section blank, and the results can be seen in Figure 8 - Relevancy of information – Situational awareness.

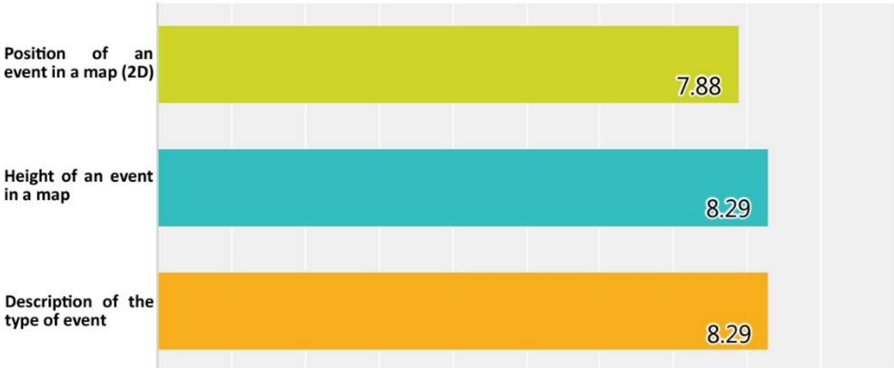

Figure 8 - Relevancy of information – Situational awareness

The next question was similar to the first, but regarding a voluntary action by the operative to send the information, instead of data gathered automatically. The questions focused on generic and specific data respectively. Generic refers to information that might be picked from a preset list (like "Victim here" of "Fire controlled"), while specific represents information dictated on the spot by the operative. Generic information was considered extremely important collecting an average result of nine, while specific information was considered slightly less important with an average of eight. No further suggestions were presented. Seventeen members filled the data for this question, returning the results illustrated in Figure 9 - Relevancy of information – Voluntary trigger by operative.

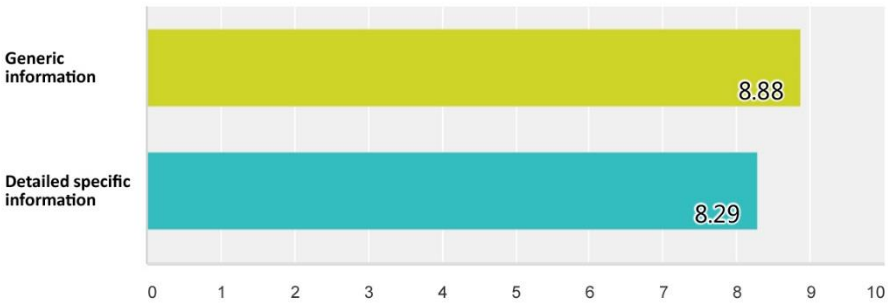

Figure 9 - Relevancy of information – Voluntary trigger by operative

Question four turned attention to information that the Command Center may send to operatives as opposed to information received from them. The presented options were the position of the target, the type of objective (fire, victim, collapsed structure, etc.) and variable detailed information. Although it had been confirmed by several sources that each person in the TO has a fixed objective and is aware of his/her mission, the type of objective received the highest importance with an average result of nine. Both the position of the objective and variable information collected an average of eight for relevancy, as can be seen in Figure 10 - Relevancy of information – Information sent by the Command Center. Once more there were no further suggestions from each of the seventeen collaborators that filled an answer to this question.

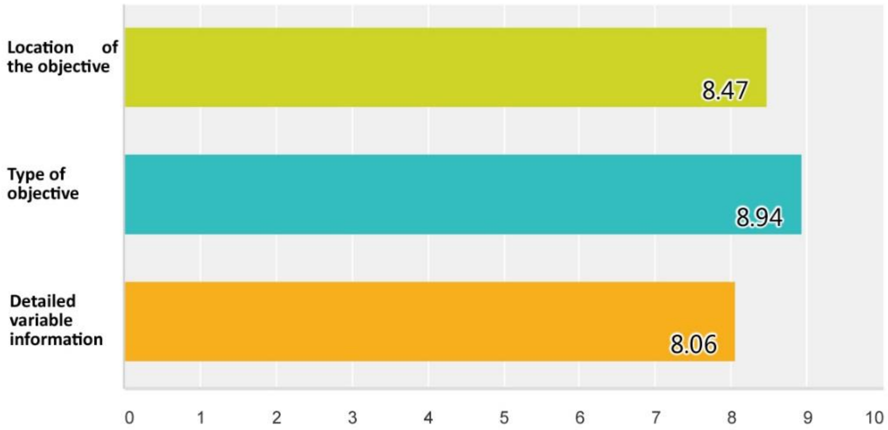

Figure 10 - Relevancy of information – Information sent by the Command Center

3.5.2 Information relative to the Operative

The second section of the survey was directed to information relative to Operatives. When an operative receives an order, he already knows what he must do (although, as confirmed in the previous section, it is relevant to know what he is facing). Therefore, orders focus on moving to an objective and doing what must be done once this objective is reached. The first question in this section evaluates what benefits the Operative in order to reach his/her goal. The position of the objective including navigation data (direction and distance to the objective) received an average of nine, being considered the most important information. Both the type of objective and variable detailed information averaged at eight out of ten. Seventeen of the inquired replied to this question and there were no further suggestions. Figure 11 - Relevancy of information - Received order summarizes the results for this question.

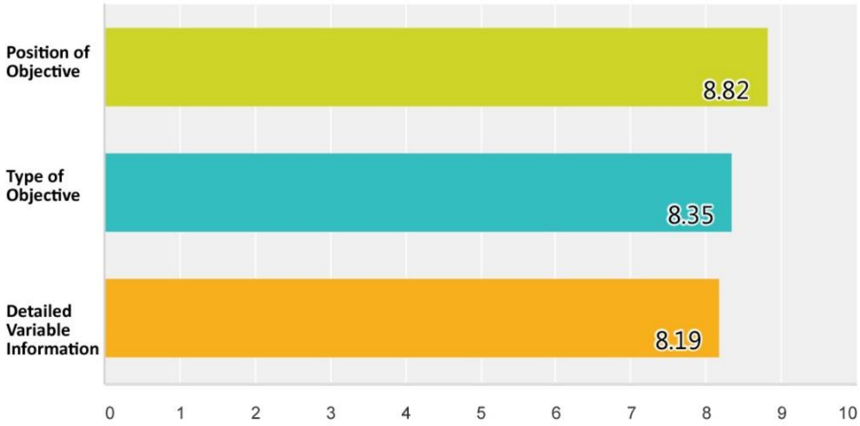

Figure 11 - Relevancy of information - Received order

While navigating to an objective, the direction of the objective relative to the Operative was considered the most important piece of information with an importance of nine. Distance to the objective received an average of eight, as did direction of the geographic north. Once again, there were no further suggestions from any of the seventeen people who replied to this question. A graph representing the results can be seen in Figure 12 - Relevancy of information – Directions to objective.

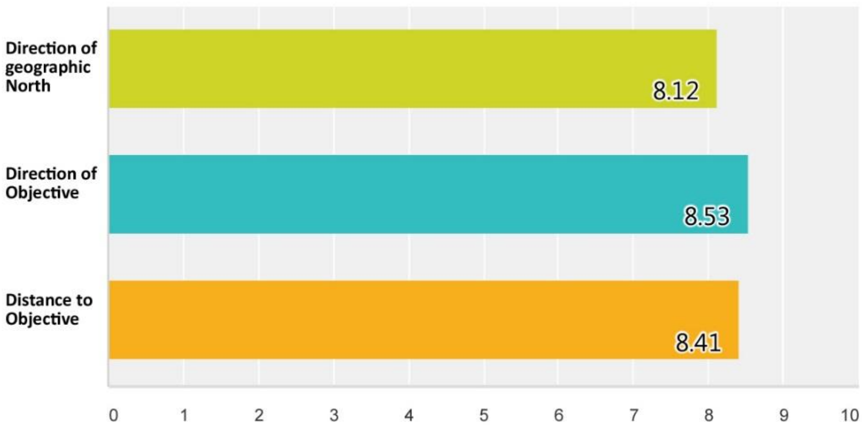

Figure 12 - Relevancy of information – Directions to objective

For team awareness the most important factor was predictably the position of the other element of the pair followed by the position and distance to every member of the team, both averaging at nine out of ten. Position and distance to the closest team members followed with an average of eight, while the position and distance to the furthest team members and to the highest ranked member (the chief of the team) received an average of seven out of ten. Figure 13 - Relevancy of information – Team Awareness summarizes the seventeen responses collected.

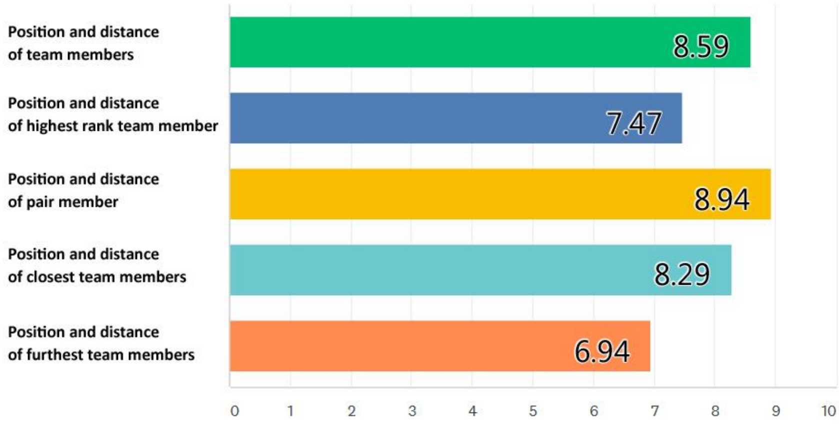

Figure 13 - Relevancy of information – Team Awareness

Regarding information relative to events on the TO, members of the ANPC were questioned about two distinct situations: information relative to events happening where an operative is located, and information relative to an event within the field of view of the operative but distant from him/her. The first received an average of eight points, while the latter followed with a close seven. Again, one of the enquired chose not to answer this question, lowering the sample to seventeen responses, as shown in Figure 14 - Relevancy of information – Events on the TO.

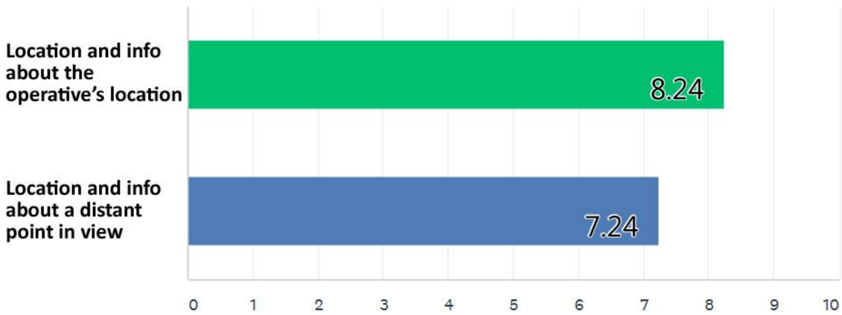

Figure 14 - Relevancy of information – Events on the TO

Finally, Figure 15 - Relevancy of information – Other services represents the survey that attempted to collect information regarding other services that the platform might provide. This time eighteen opinions were collected. The suggested services included real-time command of the operation while being aware of the visual state of the TO from any angle, which received an average of nine points. The other three suggestions were the post analysis of the mission with control of playback time and time speed, a similar situation for training missions and the automatic generation of reports regarding a mission. These three suggestions scored eight points.

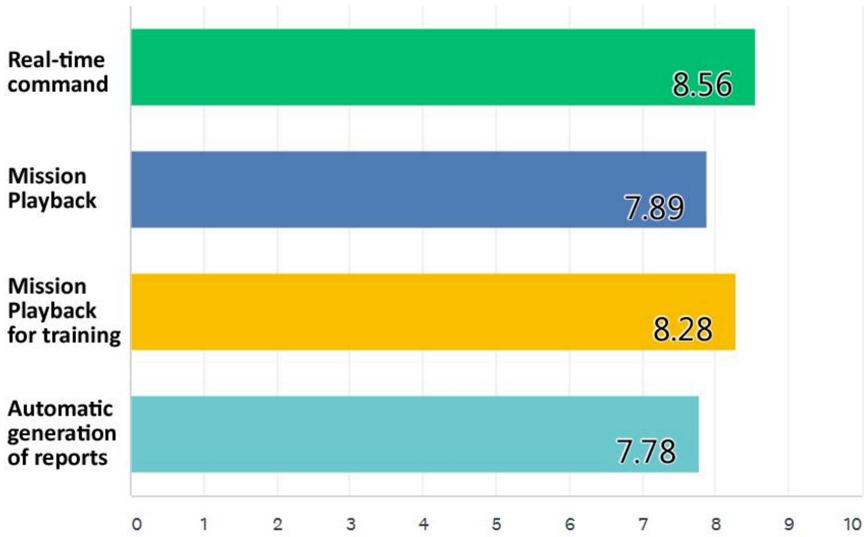

Figure 15 - Relevancy of information – Other services

3.6 Conclusion

This chapter led to a better knowledge of the work methods of different forces and of the technology behind it. Data gathered from a representative of the Communication and Information specialist at the Military Academy provided relevant information regarding bandwidth, security, databases and useable material. From Medical representatives, a better understanding of emergency workflow was achieved, as well as work methodology and organization.

The GIPS and the Fire Brigade provided information regarding their methods and organization as well, and while both share many objectives, several differences in training and procedures were identified. The differences between military and civilian training were identified, as well as differences in equipment and methodology. The strength and determination to achieve their objective was however present in all of them in the same degree. The received evidence provided guidelines on what and how to progress, but it also showed that it would be extremely beneficial to produce a platform with which all could interact without worrying about differences in training and education.

The visit and talk with the ANPC provided more detailed knowledge regarding the organization and workflow in what concerns to rescue operations. The understanding of the different phases was especially beneficial and the knowledge of how information is retrieved, transferred, recorded and analyzed was useful for understanding what is being done, as well as complement hypotheses with information that may lead to better solutions.

With the information collected from the different institutions, a survey was created with the purpose of separating the need-to-have from the nice-to-have and to discover details that may justify extending the solution to provide more relevant services. With scores between seven and nine for every proposal, it became clear that in a crisis scenario every bit of information counts.

The data collected resulted in a series of guidelines for integrating the most relevant features of existing solutions as well as proposing and testing new techniques that may be helpful in multi-force disaster management solutions.

4 Proposed Framework – Disaster Response and Management

Disaster management is a complicated subject in many ways. It is a topic of extreme urgency and importance as it represents the difference between saving or losing many lives, it involves many people and resources, work must be done under pressure and usually in a very short amount of time. When a small fire takes place, a group of individuals – usually firemen – used to the type of situation and who know each other and their ways of operation are called. On the other hand, as shown in the previous chapter, a larger occurrence may implicate different forces with different ways of operating, specialists in specific areas and a hierarchical chain of command.

The number of involved actors varies greatly, as does the role that each actor takes. A fireman may be fighting a fire in a smaller scale situation but may be assigned as a sector commander if the situation requires it [72][71]. The large amount of different actors and this variation in roles demands that a solution is focused on these roles and not on the actors themselves.

4.1 Involved Actors

Speaking generally, involved actors in a catastrophe would be part of one of two types: The ANPC and the protection agents. According to the DON #2 [72], there are nine protection agents, namely the CB (*Corpo de Bombeiros* - Firefighters), GNR (*Guarda Nacional Republicana* - National Guard), PSP (*Polícia de Segurança Pública* - Public Security Police), FA (*Forças Armadas* - Armed Forces), DGAM (*Direcção Geral de Autoridade Marítima* - Directorate-General of Maritime Authority), INEM (*Instituto Nacional de Emergênca Médica* - National Institute for Medical Emergencies), CVP (*Cruz Vermelha* Portuguesa - Portuguese Red Cross), INAC (*Instituto Nacional de Aviação* Civíl - National Institute for Civil Aviation) and ICNF (*Instituto da Conservação da Natureza e das* Florestas - Institute for Nature and Forestry Conservation). These agents vary widely in their type, training, main task and even the way of doing things. Not only that, but they may involve different forces – the GNR for example is mainly known for its police force, but the GIPS are also one of their groups.

Although the agents involved may be extremely heterogeneous, they all share the same objective when a catastrophe occurs. It also became known from the interviews performed that regardless of the force they belong to, all units on the TO have a pre-defined function and they all know how to proceed. With this in mind, roles become much more important than actors.

Besides from human actors, objects and vehicles exist. In a C4i database every object may be geographically referenced, and that also applies to vehicles and dogs, which are considered as an object. These non-human actors exist in a hierarchical system – a tank being part of a vehicle is an example. Some may be totally dependent on their parent, while others can detach voluntarily or involuntarily. For example, a dog has a man or a team responsible for it, but it might happen that the dog could get frightened and run away, get trapped under a collapsed structure of fall down a cliff.

With so many people, vehicles, objects and animals involved, it became relevant that different types of actors should be considered with each unit being part of one of the types represented in table 1.

Type	Description	Sends	Receives
Inanimate object	Does not move or moves with parent.	Status information like position or amount of water left.	Nothing. Operator may receive dynamic information.
Moving object / Vehicle	May move when controlled by a human.	Status information like position or amount of water left.	Target location and dynamic information.
Human	Has free will and may move freely.	Bio information, pre-formatted or dynamic information.	Target location and dynamic information.

Table 4 - Types of Actor

The following figures show examples of each of the considered types of actors:

Figure 16 – Inanimate Object – Tactical Meteorological Observation System

Figure 17 - Vehicle - VUCI

Figure 18 - Human – Fireman

The above types apply to units in the TO that can receive orders or send information. This information is sent to the command who in turn issues new orders. The command is another type of actor who may or may not be in the TO but has a different function, the organization of the above actors.

4.2 Roles

The commander of a fire department can be found fighting a fire with the rest of his teams, but he can also be named as COS if the situation calls for it. Although he is always an actor of the type human, his role can change between fighting a fire and commanding a force. With this fact in mind, a role must be attributed to every human actor.

The role of operative applies to any unit that is attending an occurrence focusing on a specific task. An operative has a clear mission and a specific view of his objective; he follows orders and sends information to the command. His tasks may include putting out a fire, retrieving a victim or closing a road. The operative is not responsible for any other task that another member may be involved in and he has a specific view in order to focus as much as possible on his mission. A fire fighter or a member of the ERAS while in a reconnaissance mission are operatives.

The role of commander is attributed to any unit who coordinates the response to the occurrence. Anybody at the SALOP would be considered a commander, as they have a view of the general situation but cannot focus only on a specific case. On the TO, any member who is managing the occurrence is considered a commander. A commander has a general view of the TO concentrating on situation awareness, receiving all the information relevant and issuing orders to operatives.

Some individuals like people at the SALOP or members of the general staff always assume the role of commanders, while others like firefighters always assume the role of operatives. In some situations, the commander of the fire department as well as other may assume one or the other role depending on their function at each moment. A logistics deputy is an example of a person who may assume both roles, acting as operative while performing the functions attributed to him but also consulting a general view in order to gain information regarding equipment. Depending on the occupation at each moment however, he performs tasks relevant to one or the other roles.

4.3 Tasks related to the commander

In order to fulfill his/her mission, the commander must be aware of the situation in the TO in what concerns the status of the occurrence and the availability of operatives in order to respond to each situation. The tasks that the platform must allow regard mostly two subjects: Situation awareness and team awareness, and several tasks have been identified:

Create a new mission – When the communication of a new occurrence is received, the commander is able to create a new mission related to that occurrence. This approach should allow different occurrences to be managed simultaneously regardless of their location, including overlapping missions and sub-missions. It becomes possible for the ANPC for example to command different forces while allowing the commander of one force to create a new mission that regards only to his/her teams. Organizing different situations in different missions also makes it possible for posterior analysis and the creation of training missions.

Assign operatives to missions – By assigning operatives to missions the commander makes sure that he/she can monitor, command and receive information from relevant operatives without redundancy. Ideally it should be possible to assign new operatives to an existing mission at any point in time for replacing operatives after twelve hours or adding specialists in specific situations.

Browse the Theater of Operations - The tool provided by the platform to commanders affords the possibility of browsing an area of the world into which the TO is included. The visualization in 3D of DEM (Digital Elevation Model) data, buildings and bridges allow the commander to plan strategies and paths, evaluate the spreading pattern of a fire and localize obstacles that operatives may not be aware of.

Visualize Events - While the knowledge of obstacles and types of terrain is of great importance, it is vital that the commander maintains an updated awareness of events, like the beginning of a fire, the location of dangerous substances or victims. The suggested tool superimposes information regarding these events over the view of the world.

Receive information - Task number three concerns the reception of the before mentioned information from operatives. When a fire fighter locates a victim, he is trained to provide emergency assistance and first care, but he must go on with his mission and the victim can be assisted by specific professionals. The platform receives information provided regarding the victim so that the commander can decide on how to proceed. Other relevant information like a new fire front or a collapsed structured must also be received in order to fulfill task number two.

Request Visual feedback – Although the command has access to a 3D representation of the TO, that view is far from updated in real time. In order to better access the situation, the commander may request a photograph of the surroundings. The analysis of this photograph can provide a better understanding of the situation in real time, including dimension of fire, blocked paths or stated of victims. The use of video has been ruled out due to bandwidth requirements, but it might be an important complement when wireless communications reach the necessary point. Like photos, video could be requested only when necessary.

Locate team members – When new information is received, the commander must handle any situation accordingly. If a new front of fire is detected it must be handled, but fire fighters may be busy on another position. Awareness of the location of each operative allows the commander to make an informed decision based on availability, proximity or accessibility and redirect the most relevant operative(s) to another mission.

Visualize information regarding units – While a vehicle may be available and close to a point where it is needed with a clear path to it, it may happen that its water reserve is nearly empty. In a situation such as this, this vehicle may be discarded as the best choice and another one may take its place in the job. Any unit has correspondent generic and specific information, like age, blood type, rank or specialty in the case of human units or fuel capacity and reserve, type or number of hoses in the case of a vehicle.

Issue orders to units – To complete the loop, the commander must issue an order to a moving object or human actor instructing it/him to attend to a certain location or flee from a place where fire has become uncontrollable. Since each operative knows beforehand of his/her function when arriving at an occurrence, relevant orders implicate movement from the current location to a new place. In certain situations, this movement must be urgent, when running away from an uncontainable situation. Orders should be cancelable by the command center as well.

Send messages to units – While orders described in the paragraph above concern preset actions like move or retreat, messages can have a more general usage. Orders must be accepted or rejected and marked as complete when possible, while messages can contain any text. Messages may be informative only, and in such cases they can be acknowledged but not necessarily marked as completed. Providing a tool in the platform to send messages to operatives allows the command to send the same message one or several operatives at the same time.

Replay a completed mission – After a mission is closed, it should be possible for the commander to evaluate performance in training and real missions, share views and advice with other personnel and analyze specific locations in time and space. Mission playback should therefore allow the user to jump to a specific moment in time and any location in the TO. By using a 3D computer generated world, is becomes possible for anybody with proper credentials to visualize the TO from a bird's eye view, a third person view or even a First-Person view, gaining better information concerning any sight available to any operative.

4.4 Tasks related to the operative

The operative's most important task is to attend to the occurrence, save lives and exterminate fires. The operative's tasks when interacting with the platform have thus been reduced to a minimum. These tasks focus on complementing the tasks related to the commander by sending and receiving information. Six relevant tasks have been acknowledged:

Accept/ Reject mission – When assigned by the commander to a mission, the operative must be able to confirm his/her availability. The first step when using the platform is accepting the mission, or if necessary, rejecting it.

Send event information – An event is any situation that may arise related to a certain place, like the location of a container of flammable or corrosive material, a victim or a new fire front. To allow the operative to maintain the maximum possible attention on his task, and due to the difficulty of interacting with electronic hardware, an event would be chosen from a list of possibilities. The chosen event is signaled on the map available at the command after it is communicated.

Accept/Reject/Mark as completed order – When a new order arrives from the command center, the operative must be able to accept it, or reject it the situation calls for it. Although orders like moving to a certain point can be automatically marked as completed when the GPS position of the unit matches the target location, there may be situations where this is not possible or even necessary.

Navigate to target – After receiving an order to move to a certain location, navigation becomes the most important contribution that the unit can receive from the system. This navigation consists of an arrow pointing at the target location as well as the distance to it. While this information might suffice in order to locate the target, a general idea of orientation can also prove valuable. If the operative is lost or disoriented due to stress, lack of points of reference or low visibility due to smoke or storms, the location of the north can provide some sense of direction.

Send information messages – Unlike events, which concern pre-formatted information attached to an absolute point in space, a unit may need to provide or request some more general information. While data input falls out of the scope of this dissertation, the proposed platform provides a way of sending messages that might contain anything from requesting backup to asking for information. Apart from pre-constructed text, these messages could rely on Speech-to-Text or any other kind of data input.

Receive messages – Messages received from command could include anything from replies to questions to alerts like a change in wind direction or further instructions necessary to complete a command. A message is displayed as text on a screen if available and haptic/sound alerts are generated. A text-to-Speech engine could also be used to read the message aloud. The operative must then be able to acknowledge reception of the message.

Team / Situation awareness – There have been cases of firemen being trapped between lines of fire. Knowledge of the situation and/or location of team members can prove to be a valuable asset. Team awareness delivers information of the whereabouts of other team members relatively to the unit's position, while situation awareness is assured by providing information regarding the whereabouts of close events.

4.5 RTS Interaction

With the main tasks defined, it becomes relevant to suggest the RTS interaction mechanics that will be used in the solution. Starting with the map sources relevant to represent the TO, this section continues by describing navigation, selection, organization and other pertinent solutions based on existing RTS games.

4.5.1 Maps, buildings and features

Although there are several types of Real-Time Strategy games, most of them – and the ones that relate to this study – rely on a map of the surroundings where the action is developed. Some games may have a pre-designed map, created by hand, while others rely on procedural maps that are generated based on rules and parameters. While the former allows for more specific details and a visual quality only limited by money and time, the latter allows for nearly instant generation of huge maps.

As mentioned chapter 3, three different types of maps are suggested. A purely mathematical model would be nearly impossible to achieve with current technology, due to the diversity of details present in the real world. However, a lot of information exists. Although more accurate sources may exist, these are usually paid services or accessible only by certain institutions. OSM (OpenStreetMap) is a crowd-sourced map repository with a lot of information. While some of this information may not be completely reliable, this service was used for the proof of concept. According to [73], the quality of OSM is comparable to commercial solutions with positional accuracy above 70% with occasional drops to 20%. The difference from commercial solutions, however, is the fact that errors do not show up at random geographic locations, but rather often depend on the source. In the proposed solution, however, accuracy was very good with procedurally generated buildings from OSM data matching data from other sources nearly perfectly.

Terrain elevation is based on SRTM data. By downloading the data related to each area of the world as a 16-bit TIFF file, a height map can be generated. Each pixel represents a height, with 16-bit allowing for 65536 discrete height values, providing a relatively accurate height information. The Bing maps service is then used to provide a texture that colors each pixel based on satellite photography.

For buildings and landmarks, three different sources are used: OSM, photogrammetry and manual models.

From OSM or other similar sources, it is possible to collect plots of land with meta-data. This information, at the most basic form, is download as polygons and height information (for example, four corners of a building and the building's height). By generating a polygon from the downloaded data and extruding it along the y axis, a building block is created. This type of building is described from here on as procedural. Since information is already available for most of the world, and always growing and improving, creating buildings for a great percentage of the world is effortless. This type of map is therefore used for any part of the world that does not have a more accurate model, and an example of the FEUP campus can be seen in figure Figure 19 - Procedural Buildings.

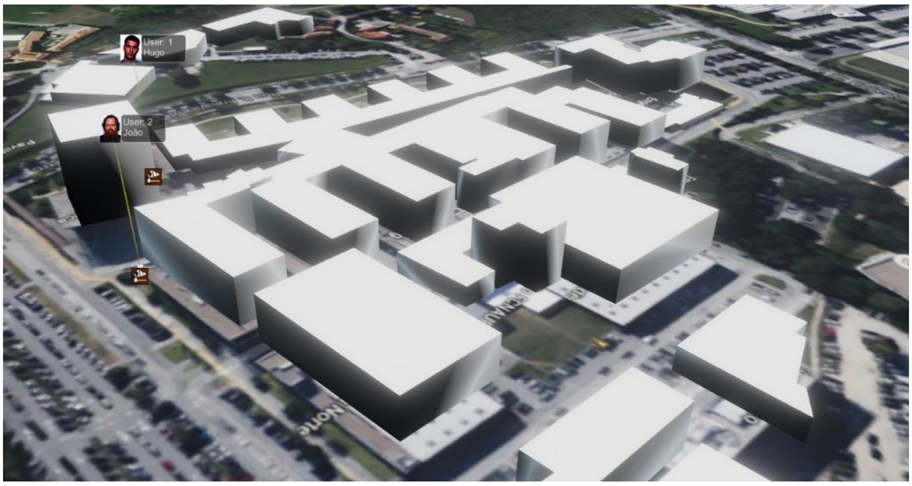

Figure 19 - Procedural Buildings

For the last few years, companies have been using photogrammetry – a method of measuring features from photos, which allows for the reconstruction of 3D models from photographs – to generate visually accurate models. Google Maps and Apple Maps contain examples of features inferred by photogrammetry. This type of data, if existing, can be used instead of procedural maps to bring more visual fidelity to the solution, as shown in Figure 20 - Reconstructed buildings with photogrammetry.

Figure 20 - Reconstructed buildings with photogrammetry

Lastly, hand modeled buildings can be used. This type of model can be extremely accurate, depending on the work that is dedicated to it. It is, however, a very time-consuming job. For the prototype, an existing 3D model of FEUP (the TO used in all the tests) was used, after fixing some problems like normal direction, due to the model having been developed for non-real-time rendering. The final model can be seen in Figure 21 - Buildings modelled manually. Due to the potential accuracy and visual fidelity, these models are proposed for infrastructures that maintain an emergency plan. These are usually airports, power plants, and other types of organizations for which a catastrophe is more likely to happen or potentially results in extreme losses.

Figure 21 - Buildings modelled manually

4.5.2 Units

A unit is any of the three types of actors previously presented. In fact, anything that can send or receive information from the commander is considered a Unit.

In RTS games a unit is usually a human or vehicle that can move, and fixed structures like buildings are not considered as one. In the parallel solution suggested in this document, a Unit represents any entity added to the TO voluntarily. This includes men, vehicles or structures as long as they did not exist in the TO prior to a mission. Some units move as a result of their own decision – usually operatives, while others move by a third party's action (like a vehicle or an animal) and others stay fixed in the same location. Among other data, the position of each unit is recorded at any given instant during the mission. This data can be used later for mission analysis and playback, but it can also be very useful during the mission. At any given point the commander can see a breadcrumb trail for each moving unit, which gives him an idea of what happened before the current instant, while giving him relevant information to infer a unit's next move before it happens.

4.5.3 Navigation

Navigating in the TO is achieved by rotating, translating and zooming a camera above the map. Different programs designed to work on 3D models present different navigation mechanics. Many use a combination of mouse and keyboard, with the ALT key being used very often in conjunction with the left mouse button to rotate. There is not a standard for 3D navigation and more often than not users try to keep using the navigation techniques they are used to, since a few programs provide means to change the way the user navigates. This is especially found by famous software houses like Autodesk, in order to maintain legacy navigation methods as well as adapt new ones to the problem we propose to solve.

For disaster management, it may be useful to have one hand free for taking notes or communicating over radio. With this fact in mind, a navigation method was developed for this task which allows for complementary tasks to be performed with the left hand while the right hand navigates and interacts with the software. A more traditional method was also implemented.

3D mice are part of a very niche market. They are very good at performing one task only, and this task can be handled with traditional keyboards and mice. However, for 3D graphics professionals, a 3D mouse speeds up operations and becomes second nature after a few minutes of use. Due to the complicated mechanical and electronic workings, as well as not being a mainstream product, this type of hardware can be quite expensive for the common user. However, the 3D mouse used for the prototype was very welcome by nearly all participants in the study who expressed their opinion that it would be a welcome addition.

Navigation with a 3D – shown in Figure 22 - SpaceMouse Pro (Left) and SpacePilot (Right), mouse was implemented to complement the other two navigation mechanics. The hardware used was the SpaceMouse Pro and SpacePilot, both by 3DConnexion, a joint-stock company that specializes in this type of hardware. Either of these products provide a nub that can be manipulated in several ways, by providing 6 DoF (Degrees of Freedom). The nub can be pulled or pushed up and down, forward and backward, left and right, and it can also be twisted. Furthermore, several shortcut keys are available, mimicking the keys with the same name on a computer keyboard. Some keys can also be redefined to provide additional functionality.

Figure 22 - SpaceMouse Pro (Left) and SpacePilot (Right)

The methods of interaction described above allow the commander to move freely around the map (pan forward-backward, left-right and up-down), rotate the camera (pitch and yaw) and zoom in and out. Roll is locked to a completely horizontal position. Although it would have been easy to implement, rotating the camera around its Z axis would result in a much more complicated navigation while not bringing any advantages to the interaction.

Besides from navigating freely in the TO, it may be necessary to quickly find a unit or the TO itself (if, for example, the commander needs to temporarily move to a surrounding area to analyze the shape of the terrain or location of close structures).

For focusing on the TO, a keyboard shortcut was added. The user can move the camera to focus on the centroid of the TO by pressing the key ‘F’. This function can also be mapped to any other key if necessary. Since free navigation is achieved by using the mouse only, one hand should be available at least most of the time to press this key. Most of 3DConnexion's 3D mice have dedicated keys that mimic the keyboard, and some of them even feature programmable keys. By using a 3D mouse, the commander does not even have to move his hand to focus on the TO.

It is also possible to bring any unit to the center of the screen. This may be useful in many situations, like checking the position of a unit who just sent a message. The Mission Log contains all the messages and events and will be described in the next section.

To locate a unit on the map, all the commander must do is click the right mouse button on that unit in the Unit List, which will be described on the next section. Alternatively, a right click on the Mission Log will center the view on the unit that triggered the event in question. Table 5 summarizes the axis and functionalities used.

Functionality / Device	Mouse	3D Mouse	Keyboard
Pan	Mouse Wheel (press and hold)	X, Y and Z axes - translation	N/A
Rotate	Right Button (press and hold)	X and Z axes - rotation	N/A
Zoom	Mouse Wheel (Roll)	Y axis - Zoom	N/A
Select	Left Button click (on unit, unit list), Left Button Drag (area selection)	N/A	N/A
Focus on Unit	Right Button (on Unit List, on Mission Log)	N/A	N/A
Focus on TO	N/A	Programmable Key	'F' (Remappable)

Table 5 - Navigation and Interaction

Units are represented by icons that represent its type. In many situations, a unit may be hidden behind the terrain, buildings or other features. In order to be able to quickly locate any unit regardless of what may be shown in front of it, the icon itself is drawn after everything else, so that it is visible in any situation. Due to the wide range of units that may be available, and the fact that the choice of icons to better represent each unit falls outside the scope of this work, only three icons were created to represent some of the most common human actors. The following table shows the icons used in the prototype as well as the unit they represent:

Icon	Description
	Fire Fighter
	Medic
	Police

Table 6 - Icons representing Units

From the icon that represents the unit and its correct position in the map, a line is drawn. This line, unlike the icon, may be occluded by geometry. At the top of the line, the photograph that represents the specific unit is shown along the unit's id and description. The fact that the line can be partly occluded provides a good indicator of where the unit is located.

4.5.4 Other interactions

Unit can be anywhere in the TO, and looking at it from a distance can help with situational awareness while being aware of where units are. It may, however, be important to locate a specific unit and have access to information regarding it. With this fact in mind, a list containing all the units is available. This list is located on the left side of the screen in the prototype, but it should be easy to make this list – as well as other elements of the interface – floatable, allowing for a personal workspace specific to each commander. The list could also be collapsed to provide more screen real estate and called up when necessary. Figure 23 - Unit List shows the unit list with the mouse hovering over the third unit (Pedro) and his information shown.

Figure 23 - Unit List

Besides from the main view of the TO, the commander has access to two other views. Like most RTS games, the interface provides a mini-map of the TO viewed from above. This functionality provides a way to see a broader picture especially while interacting with units at close range. The mini-map uses an orthographic camera perpendicular to the ground plane, which result in an image similar to a paper map. The orthographic view results in a map free of distortion since perspective is ignored. This map is centered on the mouse cursor, which results in a constant representation of what is showing on the screen. Due to perspective being used for the main view, by moving the mouse it is possible to see the map for a very large area.

The orthographic map can be zoomed in or out, which results in a larger area being shown if necessary, with some level of detail available by zooming in. Units and other information available in the main view is also reproduced here, in its correct location. This feature allows the commander to inspect close areas for collapsible structures, dangerous substances, among other features relevant to the successful completion of the mission.

The third view of the TO is presented in the form of a first-person view. By ticking the "1st Prs." Option box in the Unit List, the commander has access to the same view as the operative for whom the box was ticked. If the need arises for a photo or video in near-real time from the point of view of the operative, the commander can request that information. However, the amount of data for every unit may be very large. For this feature, only the position and orientation of a unit is being received, and this information would be available even if there was no need for a first-person view. As such, the commander can see what any unit is seeing without taxing the communications network. This dynamic first-person view can also be selected later at mission review, which can be a useful tool for analysis and training. Both the orthographic map and the 1st person view can be seen in Figure 24 - Minimap (Left) and 1st person view (Right).

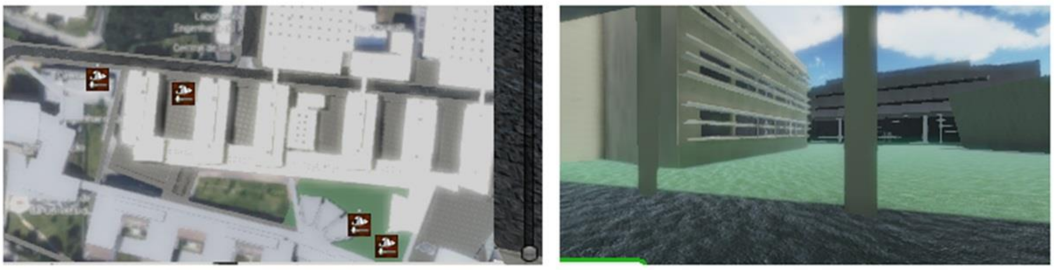

Figure 24 - Minimap (Left) and 1st person view (Right)

RTS games frequently make use of FoW (Fog Of War), a feature that can be used to focus attention on relevant known areas while hiding other spaces. For a disaster situation, however, it is hard to predict what is going to be relevant. Fog of War is not implemented to allow the commander to inspect any spot in or around the TO. This allows the commander to have complete access to the TO, but also inspect close areas for important assets or terrain features. The TO is nevertheless surrounded by a grid that represents its limits. This grid – the TO delimiter – can be thought of as the border between the visible area and the area hidden by FoW. Even as a grid, it would be easy to fall into a situation in which this feature might hide relevant features. To circumvent this problem, the grid is invisible when inside the TO. As the commander navigates further from the centroid of the TO, the grid appears smoothly in a transition from completely transparent to completely opaque, as exemplified by Figure 25 - TO Delimiter.

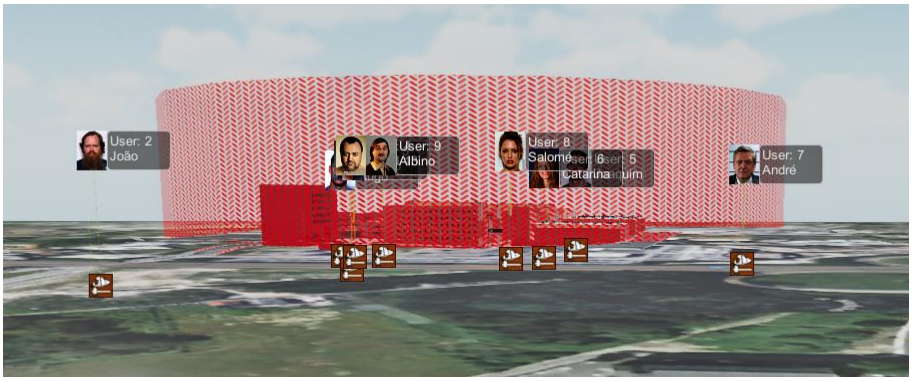

Figure 25 - TO Delimiter

While information is power, it must be filtered to optimize the way it is consumed. For this end, it is possible to hide information that may not be pertinent at any given moment. Some of the available information is presented by default, while the other is hidden. It is possible to selectively hide or show information either globally or per unit.

A small window at the bottom left of the screen provides the functionalities that concern to global visibility, as shown in Table 7 – Unit's feature visibility.

	Description	Default State
Unit Trail	Line connecting the discrete locations for each unit over time	Off
Order Status	Line connecting the unit's position to its target	Off
Unit Visibility	Unit's representation on the map	On
Unit Info	Unit's photograph and extra information above its position	On

Table 7 - Unit's feature visibility

Unit Visibility and Unit Info can also be toggled on a per-unit base. This can be achieved by checking or unchecking the boxes “Visible” and “User Info” respectively, next to the unit in the Unit List present in Figure 26 - Per unit (Left) and Global (Right) feature visibility.

Figure 26 - Per unit (Left) and Global (Right) feature visibility

Depending on the type of unit, information can be unidirectional or bidirectional. All units communicate their position, which may be enough for a dog, for example, while weather stations can provide further information. Human actors can both send and receive information. Two types of information require a more specific treatment and explanation: events and orders.

An event can be issued by an operative. While anybody in the TO must provide first aid to anybody they find to be injured, most of the times there is not much more a firefighter can do and medics must replace him, or the injured person or animal must be evacuated from the TO. Another example is a new front of fire appearing to a medic or the discovery of a previously unknown explosive substance next to a fire. In this case, a unit can mark an event at its current position. This event will be instantly communicated to command and it will appear in the Mission Log. Its position on the map is also marked on the map with a flag. While it was not implemented in the prototype, it might be pertinent to set events for units like weather station. In this case, an event would be triggered automatically when, for example, the air temperature rises above a certain predefined threshold.

If events are unidirectional from the TO to the command, orders follow the reverse path. The command can issue an order to any moving unit that he is hierarchically allowed to command. As shown by the analysis of the state of the art and the interviews with professionals, each person in the TO, regardless of the force or institution he belongs to, knows exactly what to do in each situation. Due to this fact, orders can be a lot simpler and take a lot less information – and valuable bandwidth – since only a target location is needed. Messages, descried below, can handle other types of communication. Three types of order were defined: Move [and handle the situation], End Mission and Flee. The first one would be used to handle the examples presented in the previous paragraph. End Mission is automatically sent to all units when the command closes the mission, and it tells the units that the situation has been handled and they can return to base. Flee was added in response to the conversations with the firemen, in which they explained that in some situations the only objective they have is to run away. This can happen, for example, when fire gets too close to explosive tanks or when operatives are trapped between two fronts of fire. When an order is issued it is automatically received by the selected unit or group of units.

The Mission Log is located on the right side of the screen. It provides a scrollable area that lists all the events, orders and other information regarding the mission. The commander can browse through the log to find any information that happened at any time in the mission. By right clicking an entry in the mission log, the view focuses on the unit that received or sent the entry. While not implemented on the prototype or tested, it could be relevant to provide a filtering mechanism that would only show entries that happened during a certain time slot, received or sent entries only or any entries that concern a certain unit.

The Mission Log, Figure 27 - Mission Log, shows all the key points of a mission. At its current iteration, entries are not grouped, but grouping them according to their type and source/destination might prove to be a very useful tool. Due to time constraints and the risk of losing focus, this mechanic was not tried or tested, but a group entry could be initiated for example when the commander issues an order to a unit. On that same group, entries would be created whenever the unit accepts or completes the order. In its current state, the application creates different entries, at the point in time in which they happen, for an order being issued, accepted or completed.

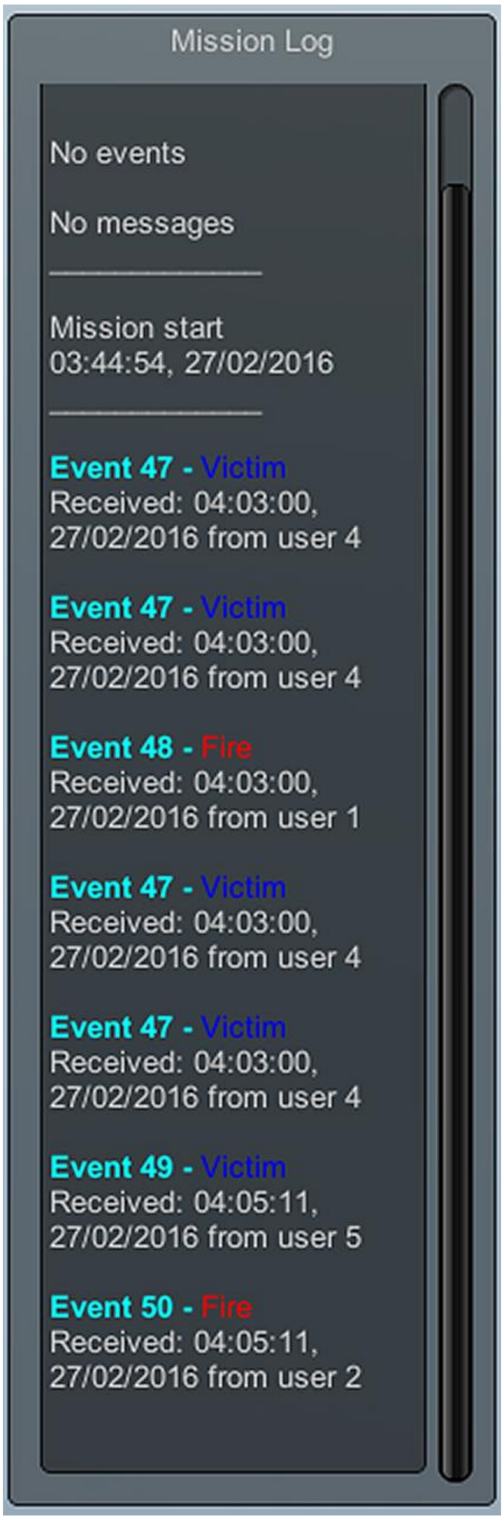

Figure 27 - Mission Log

4.5.5 Debriefing and Mission Analysis

Even within Real-Time Strategy games there are different definitions for "Real-Time". In most of them, the action develops in real-time when the user is actually playing the game, but a session can be saved at any time and continued from where it stopped at a later date. Only recently there has been a growth in games in which the action keeps developing even if the game is not being played, arguably for the benefit of collectibles and In-App purchases. In a real-life disaster situation, the action keeps developing even if the commander is not "playing the game". Therefore, there is no way to exit and continue later, only the option to not follow the action as it happens. Everything is recorded, always.

RTS games do usually provide a summary at the end of the mission, with information of what was gained, what was lost, and an overall performance index for the way the mission was played. This can be thought of as a simple debriefing.

In the proposed solution, debriefing is complemented by automatically generated reports. As previously mentioned, mission reports are currently as important as they are unreliable. Reports are filled in by operatives and therefore as only as accurate as the memory these operatives have of their performance. Furthermore, recording times or other specific data is not important when compared to the urgency of saving people and assets. This information is therefore compromised from the start. While it is hoped that it does not happen often, it is possible for an operative to fill their report with data that does not correspond to what happened in reality.

A simple web interface, shown in Figure 28 - Report Generator web interface, was developed to generate reports for any mission. The interface requires only one field, the mission itself, which can be selected from a dropdown list. Permissions have not been considered for the prototype that was implemented, but it is strongly advised that these reports are generated only by personnel with the right credentials. An optional field allows the filtering of the report by unit. This field can be left blank to generate a report for all units, or it may be filled with one or several unit separated by commas to generate a report for those units only. While these reports can often be more useful when presenting information relative to operatives (mobile units), they can also include other types of unit which generate events.

Due to the long size of a complete report, even for a small mission, a copy of the report generated for the first mission used in the tests in chapter 5 is available as an appendix to this document.

Figure 28 - Report Generator web interface

The last feature that was suggested and implemented does not have its origins in RTS games, although it can be found in many racing or fighting games, albeit for a different purpose. Since all the interactions with the platform, whether they originate from operatives, animals, structures or even the commanders are recorded along with the transform of every unit, any mission can be played back at a later time.

Anybody with the right credentials can replay a mission. When replaying, the view may be set to a free view similar to the one of the commander during the original recording of the mission, or even from the point of view of an operative. This study aims to provide solutions that are as hardware agnostic as possible, which means that the recorded mission can even be re-lived in Virtual Reality. While it is not the purpose of this study to dictate if replaying an operative's performance at a later stage, the tool has been suggested and implemented and can be adapted to fit the best workflow. Mission playback can be used for analysis and training. Like in the field of medical simulations, there are situations that a professional faces everyday and he can many times solve problems that regard to that situation without even thinking about it. However, some situations happen only once in a life time, and these are the ones that should be trained – preferably without endangering people or assets. Consequently, mission analysis can be a very useful tool. The technology can also be used for any simulacrum as a training tool.

A mission can be played back at any point in time, as long as it has been marked as closed by a commander. All of the pre-recorded events, orders and messages appear on the map and/or mission log. It is still possible to switch to the first-person view for any unit on the TO and all the visibility options remain available. The interface and interactions are the same as when the mission is running in real-time, with a few exceptions:

- It is not possible to issue orders
- It is not possible to send messages
- A section is added to the interface with timeline controls

Transport controls similar to a tape deck have not been implemented, in detriment of a mission timeline and a time speed multiplier. The mission timeline is represented in the form of a slider show in Figure 29 - Mission playback controls. At its leftmost position, the slider indicates the starting time for the mission, while the rightmost position represents the time at which the mission ended. The marker moves from left to right automatically, at a 1:1 time ratio, and it can be moved to any point at any time, in which case the mission will continue to playback from the position where the marker was dropt. Underneath this slider, another slider indicates the time step multiplier. The marker on this slider starts in its default position of 1 (100%), and may be dragged all the way to the left to 0.1 (10%) or to the right to the value 10 (1000%). When this slider is dragged, mission playback will continue at the set speed. The interface for mission playback is complemented by a "Reset" button, which sets the time scale multiplier to exactly 1 (100%).

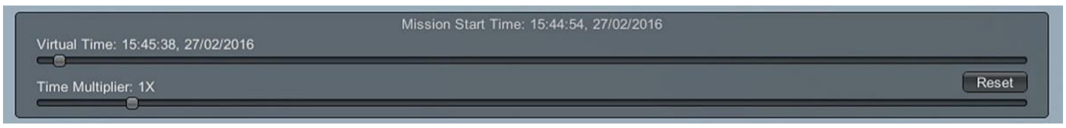

Figure 29 - Mission playback controls

4.5.6 Application for operatives

While the contribution of this work targets the command, an application for the operatives had to be developed in order to provide the necessary interaction between command and operative.

With the price of dedicated microcontrollers and electronic components dropping to very affordable values, it would have been easy to develop a small hardware module that could be added to non-autonomous units. Operatives, however, require bi-directional communications and they must be able to receive and understand the information they receive. While it would be interesting to provide the information to the operatives via Augmented Reality or something like Google Glass, for the current Proof of Concept and application was developed for Android Smartphones.

For the sake of simplicity, and since the focus of this study targets the command and not the operative, the application starts by asking the operative for the mission he is going to enroll as well as his id. The interface for this action is shown in Figure 30 - Mission and User selection. In a real case scenario, the application should save the operative's id after logging in for the first time, and notify him when he was added to a mission. After this information is provided, a large button at the bottom of the interface starts his collaboration in the mission.

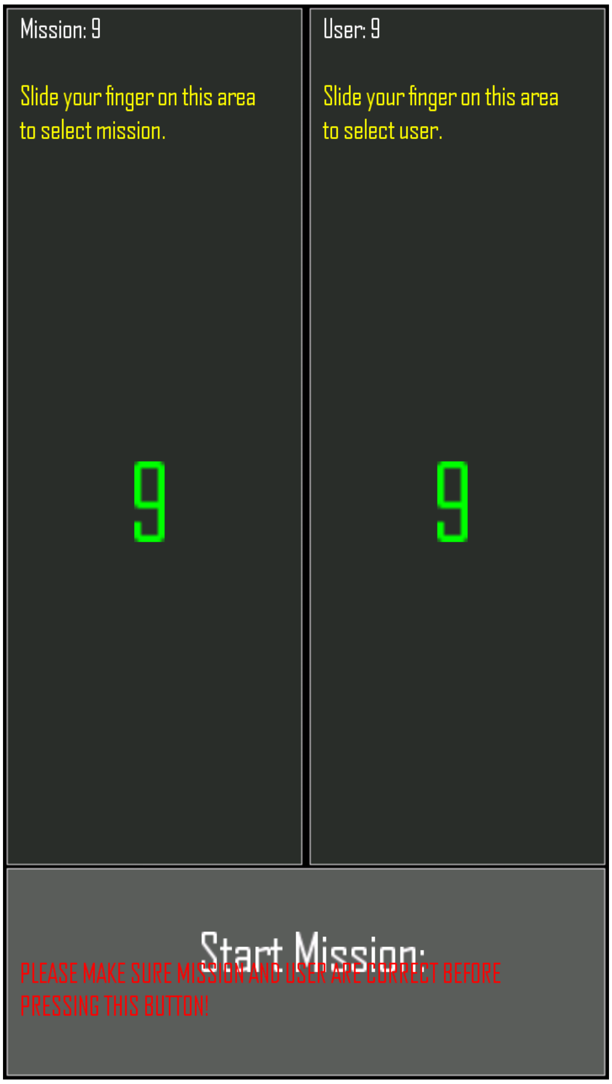

Figure 30 - Mission and User selection

At this point, the operative's contribution to the mission starts and the main interface is shown. Most of the elements, and especially the most relevant information, are presented in green over a black background. The green color was selected for two main reasons: It is a contrasting color with red, which is the most common color for low to medium temperature fires, and the photonic eye sensitivity function has a maximum sensitivity in the green spectral range, at 555 nm [74]. In this moment the application is in stand-by mode. By touching the screen at any point, the operative can report a new event to the command. Two types of event were considered for the prototype: new fire and new victim. By touching one of the large buttons that represent each event and shown in Figure 31 - Buttons for creating a new event, the operative initiates the operation that adds the event to the database, at the current position and current point in time. The command is instantly notified of the new event with a warning sound, a new entry in the Mission Log and a flag marking the spot of the event on the map.

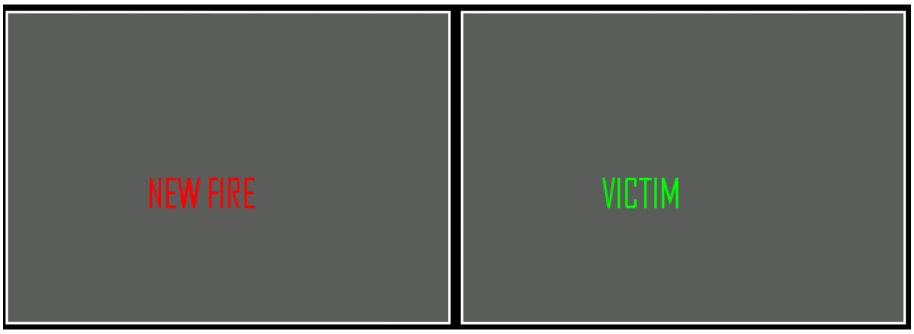

Figure 31 - Buttons for creating a new event

At any point in time, the operative can receive a new order from the command. When this happens, the device shakes for 0.25 seconds, emits a sound and shows the new order on the screen. This order can be one of the three predefined types: Move to position (and act according to the situation), end the mission or flee. The operative can now decide if he accepts or rejects the order. The option to reject an order has been added to answer to situations in which the operative is performing a vital task at the time. In this case the command can issue the same order to another unit. If the operative does not accept or reject the order within the allowed amount of time, the order is marked as “timed-out” as will be seen in the chapter describing the implementation.

A new order provides the operative with the information that a new order was received, the type of order, and in the case of a “Move” order, the location of the target and the current distance to it.

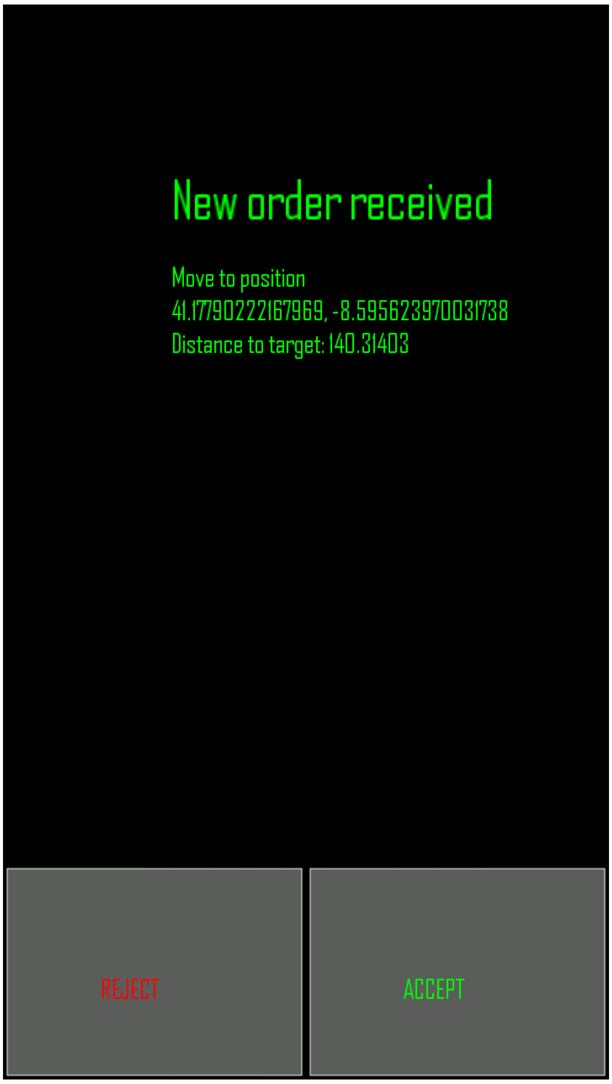

Figure 32 - Interface for new order

If the operative accepts the order by touching one of the buttons shown in Figure 32 - Interface for new order, the interface changes to navigation mode. In this mode, the operative can see his position in three dimensions, including latitude, longitude and altitude. The altitude information based on the GPS data is relatively imprecise especially in urban areas or other locations where the DoP (Dilution of Precision) is high. While this could be addressed by using more reliable military GPS systems, the prototypes that were implemented and tested rely on commercial smartphone hardware. To improve the reliability of the altitude values, altitude was calculated using the barometric pressure whenever the smartphone used was fitted with a barometer.

The navigation screen also provides information regarding the location provider, accuracy based on HDoP (Horizontal Dilution of Precision), the direction to the geographic north, magnetic declination in the area where it is being used and the number of samples acquired since starting the application. While these values can be very useful for debugging or confirming data, navigation can be more effective when graphical indicators rather than numerical values.

A compass takes most of the screen real estate. This compass is oriented in the direction of travel. Four blue lines indicate the four cardinal points, with a longer green line specifying North. A bright cyan arrow shows the direction to the objective. Bearing and distance to the objective are also shown as numerical values. Distance to the objective is shown graphically at the bottom of the screen in a bar graph. This bar is divided in two different color areas. The border between these areas represents the distance to the objective when the order was issued. A white line represents the current distance to the objective. When the line moves into the left area of the bar, represented by a different color, the operative knows he is moving away from the objective. This is useful because most of the time it is not possible to move to the target position in a straight line. When trying to find a better path to the objective the operative knows if is getting closer or further from it, as can be seen in Figure 33 - Navigation interface.

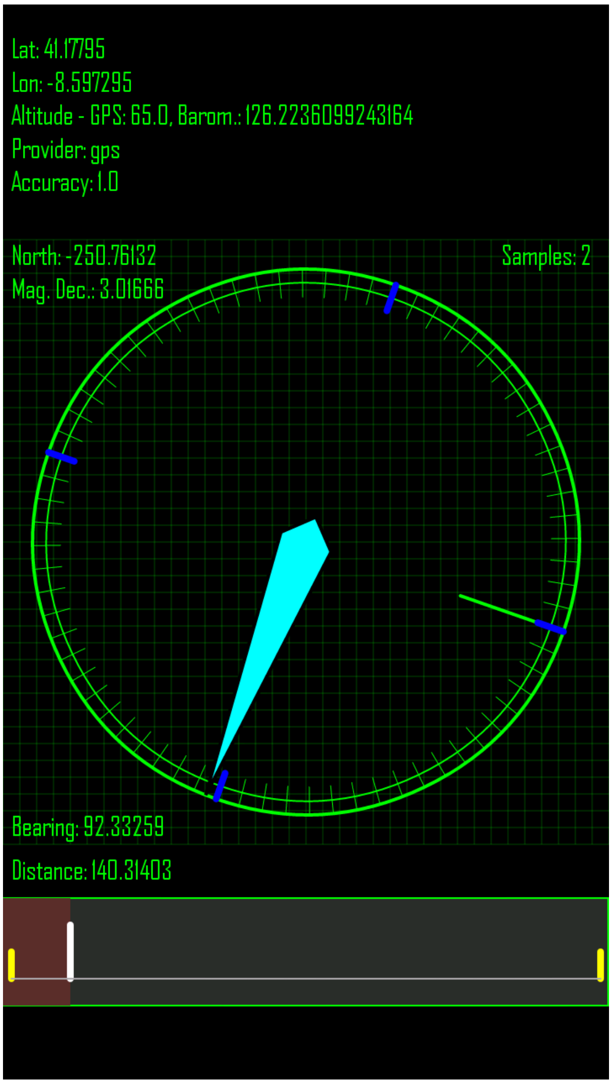

Figure 33 - Navigation interface

When the operative reaches the target, he can confirm that he is at the location and is ready to handle the situation. This can also be done automatically when the current location is within a predefined distance threshold from the target.

4.6 Conclusion

In this chapter, the involved actors were analyzed. It quickly became clear that roles matter a lot more than actors, and as such the roles of each user were defined. Tasks were defined for the two main roles: Commander and Operative. With the tasks defined, this chapter proposed the interaction techniques based on RTS games that were planned and executed for the whole solution to work as expected.

5 Implementation

The directives presented above were used to develop an initial prototype, which in turn was used to validate the hypothesis. The present chapter describes the implementation of the prototype.

The database supports the mechanics used by RTS-based solution, including all the communications of events, messages and other types of information, users and missions, as well as logs for every type of information collected or reported in a mission. The schema and data from the database could ideally complement those of existing solutions, but the database was also designed to provide a fully working environment for the prototype.

PHP services stand between the database and the clients. These services handle communications with the database while enforcing proper data communication and providing relevant translations, like the one between cartesian and spherical coordinate systems.

The Command application is the used to manage the operation, sectors, teams and other situations. Anybody who is in command, whether of a whole operation or of a single team, interacts with operatives and receives information from structures through this application.

The first-responder's application is used by operatives to receive and send data. It can also be easily adapted to handle and communicate information from vehicles, structures and all types of non-human actors.

The web application that generates reports is described in the end of this chapter. This application is responsible for filtering and organizing logs into a human-readable report format which can be used for debriefing or mission records.

5.1 Database

A C4i database is a very complex data structure. Although some information is available (e.g. [75], [76]), implementing a C4i database is no trivial task. Since no working database has been found which could be extended with the necessary requirements to implement the proposed solution, implementing a full database would consume more time and effort than is normally available for a dissertation.

A subset of a database has been developed to support the platform. Figure 34 - Database diagram represents a general diagram of the database created for the prototype. The full diagram can be found in Appendix I – Database diagram.

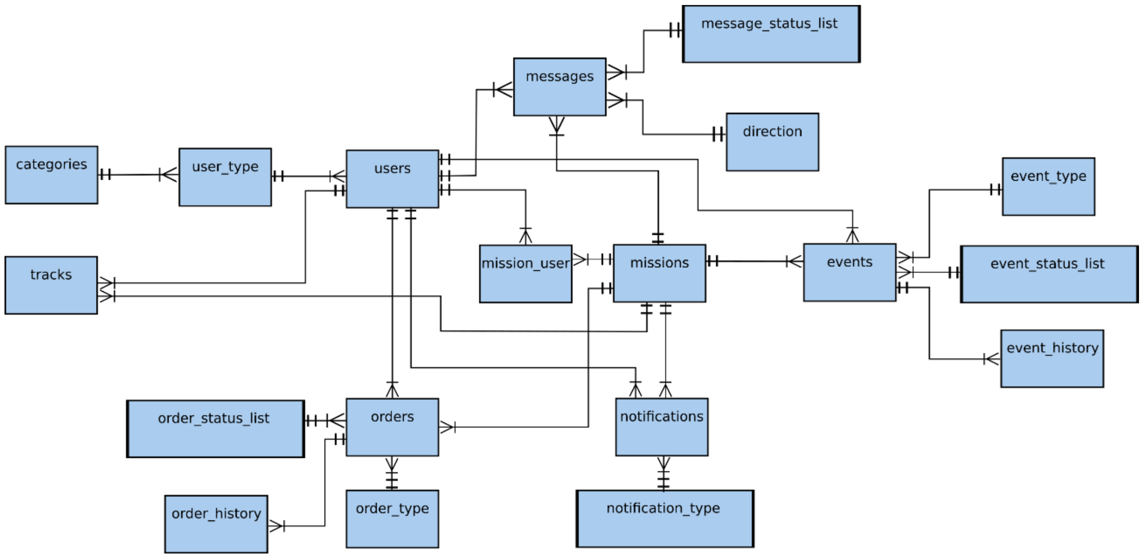

Figure 34 - Database diagram

Units are represented in the database as users. Each user has a type which represents the type of unit. Each type also corresponds to a category, which can be anything from animals to aerial assets. For example, unit 1 could be of type VUCI (*Veículo Urbano de Combate a Incêndios* – Urban Fire Fighting Vehicle) and unit 2 could be of type VSAT (*Veículo de Socorro e Assistência Táctico* – Tactical Assistant and Rescue Vehicle), and both of them would belong to the category Vehicles.

When a mission is created, users are assigned to it. The mission_user table is a pivot created to implement the many-to-many relationship required, as a user can be part of many missions, and a mission can have many users.

Messages, Tracks, Orders and Events are always related to a User and a Mission. The Notifications table contains information that is also tied to User and Mission, although it has a different function.

Messages are bidirectional. The direction of each message is stored in the Messages table by an integer, with the table Direction providing the description for each direction. The table Message_status_list contains the description of the different statuses a message can have. The status "Issued" signifies that the message was sent but there has been no acknowledge from the operative. After a preset time threshold, if there is no acknowledgement from the operative, the status automatically changes to "Time out". If on the other hand the operative acknowledges the message, its status changes to "Accepted".

The Tracks table stores the waypoints collected during the mission, and provides the breadcrumb data based on the history of stored positions. Each record represents a sample, and contains the mission-user pair, a timestamp, the position in 3D space, facing direction and speed.

Orders always flow in one direction, from command to operative. Like messages, orders have a status at any given in time. The following table describes the possible states of a message:

Order Status	Description
Issued	The order has been issued and there has been no acknowledgement
Accepted	The operative accepted the order and is currently following it
Rejected	The operative rejected the order
Canceled	The command canceled the order
Completed	The operative completed the order
Time out	No acknowledgement was given within the preset time threshold

Table 8 - Order Statuses

The Events table contains all the events reported to the command. Each record contains the mission in which it was recorded as well as the user who reported it, a time stamp that represents the exact moment of reporting, the 3D position of the event, the event's type and status.

Event type descriptions are stored in the Event type table, and the Event_status_list table stored the status of the event. These statuses are similar to order statuses and are described in table 9.

Event Status	Description
Reported	The event has been reported and there has been no acknowledgement
Accepted	The command accepted the event
Rejected	The command rejected the event (it may already have been reported by other unit)
Handled	The command handled the event
Time out	No acknowledgement was given within the preset time threshold

Table 9 - Event Statuses

The Event history table keeps a record of the different statuses an event can go through during its lifetime, recording timestamps for the moments the status changed, as well as the new status.

The Notifications table contains temporary data that is queried by the interface in order to find orders, messages and events that have been issued or changed state, but have not yet been communicated to the destination. Once the interface reads a record from this table, it acts accordingly and deletes the record.

5.2 PHP Services

None of the applications communicate directly with the database. Every database exchange is handled by PHP services, which provide an extra layer of protection, handle possible errors and convert data when necessary.

Position data is stored in the database as latitude, longitude and altitude values. However, the applications handle location data as UTM (Universal Transverse Mercator). UTM divides the world into 60 zones. Each zone provides a Cartesian coordinate system, unlike the spherical system used by latitude and longitude. Although the planification of the map introduces, the UTM projection provides simple ways to calculate distances, for example, using the Pythagoras theorem. All conversions are handled by the PHP scripts.

A mission is created by calling “createMission.php” with the parameters name and description. Time is handled by the server to enforce the same time scale to every operation. All three parameters, as well as a mission id, are added to the Missions table.

The script “addUsers.php” takes the mission id as a parameter as well as a list of users. From this point on, these units are assigned to this mission, and the mission is ready to be executed. When the mission finishes, “endMission.php” is called with the mission id as a parameter, in which case the current time is added to the mission’s record as the end time. From here on, the mission can be replayed and reports can be generated, but none of the applications is able to add further data to the database regarding this mission.

“getMissions.php” returns a list of missions in the server, including name and description, status (open or closed), start time and end time if available.

“getUsers.php” returns a list of all the units. If a mission id is provided, the script returns a list of units that are attributed to the mission. Unit photos are stored in the file system and referenced in the database by a file path and name, which is also returned by “getUsers.php”.

The scripts “setPosition.php” and “getPosition.php” handle the transactions of unit’s positions. These scripts can receive the positions in 3D space, whether as latitude and longitude or northing and easting used by the UTM projection. In the latter case, the script converts UTM coordinates to and from latitude and longitude. All the scripts that handle location have been written to support both projections. Altitude is also set or returned, and the timestamp is provided by the server within “setPosition.php”. This information, along with bearing and speed, are stored for each unit in each mission.

Several other scripts were created to provide the functionalities described before, and all of them work similarly to the scripts presented in this section. Scripts exist for creating or querying events, orders and messages, updating or reading statuses, as well as receive and store images. Several other scripts were also developed for debugging, like the conversion between coordinate systems, reading the server time or handling notifications.

While all these scripts serve as a layer between the interfaces and the server, a set of scripts were created to develop a web page that generates reports for closed (finished) missions. The front page is handled by a script that asks the user to select the mission for which the report should be generated, and one or a list of units, comma separated, for which the report should be generated (a report is generated for all the units in a mission if the users field is left blank). This information is sent to “report.php” which handles the generation and presentation of the report.

5.3 Command application

The command front end is the main application in this study, as it will be used to validate the hypothesis. The application was developed on Unity, a Game Engine that is widely used for games and simulations, as well as one of the most used development environments for Virtual and Augmented Reality Applications.

Most of the screen real estate is filled with a map of the TO and its surroundings. Units are represented in this map in their real locations, in real time. A screenshot of the main application can be seen in Figure 35 - Command application interface.

Figure 35 - Command application interface

The numbers in the figure represent the different areas of the interface. The number 1 represents the main navigation interface. When the application starts, the view is centered on the centroid of the TO. From there on, the commander can zoom in and out, drag the view (pan), rotate it, select units, issue orders, among the other mechanics that have been described in the proposal of the solution. Five units can be seen in the figure, represented by an icon and, above their position, a rectangle with the photo that represents the unit and basic information.

The unit list is represented by the number 2. This is a scrollable list with all the units that are part of the mission. Each slot also shows visibility of features for the unit, and an option box that selects the First-Person view (the area with the number 4) for that unit. A right mouse button click on the unit focus the main view on its position.

Number 3 represents the mission log. Once again, this panel is scrollable, and scrolling is automatic with every new log entry, so that the newest entries are always shown on top. Like before, clicking the right mouse button on a log entry focuses the main view on the unit that issued the entry, or the unit to which the entry was destined.

The small rectangle marked with the number 4 is the First-Person view for the unit that has the relevant check mark. This view is provided by an alternative camera positioned on the unity object in the application. Since the position in 3D space is provided by the unit, as well as the direction it is facing, the commander can have a very good idea of what the unit is “seeing”. This view is related to the model available and may not be exactly like the real view of the unit. If more realistic and real time images are required, the commander can request a photo of the visual field of the unit.

Number 5 shows the map of the TO and surrounding area. One more camera is used to provide an aerial view. This camera is positioned above the point where the mouse cursor intersects the ground, and it is perpendicular to the ground plane. Moving the mouse cursor allows the commander to inspect surrounding areas without having to change the view. The virtual camera that provides the map provides an orthographic projection, which results in the lack of distortion in the map view. Finally, a slider positioned at the right of the map can be used to zoom in or out. In reality, since the camera uses an orthographic projection, zooming is based on increasing or decreasing the area of the camera rectangle.

Global visibility affects all the units, and can be set with the controls in the box marked with the number 6. Underneath this box, the "Menu" button returns to the main menu of the application, where missions can be created or selected for real time command or analysis.

The area marked with the number 7 contains the playback controls. This area is only visible if the mission has already finished, was closed, and has been open for playback. At the top, the time at which the mission was started is shown. The virtual time represents the time in the mission, or the moment in which what is being reproduced actually happened. Th is virtual time flows at the same speed as normal time, unless the commander instructs it to behave differently. This can be achieved by moving the bottom slider, which results in the virtual time advancing from 10% to 1000% of normal time. The "Reset" button next to it brings the time scale back to 100%. The upper slider is the mission scrubber, which allows the commander to jump to a specific point in time.

Underneath the mission log, represented by number 9, a panel is provided to select the type of map, if available. The "M" button in the figure was mainly implemented for debugging, as it alters the behavior of the other three checkboxes. "M" stands for "Multiple", and allows for different types of maps to be used, overlapping each other. The three boxes stand for "Manual", "Procedural" and "Reconstructed". These boxes act as option buttons – only one option can be selected at any time – if the "M" box is not checked, or check boxes – more than one option can be selected at the same time – if the "M" box is checked.

Buildings and features were acquired from different sources. FEUP already had a model of its campus, which they provided to be included in this work. Although the model is accurate, it presented a few problems. Measures were correct in relation to each other, but the scale was wrong and different from the special sizes of the campus. The model was also not geo-located. To fix this problem, google maps was used to infer the distance between the academic services building and the corner of the library, as these two buildings are positioned at the extremes of the campus. This length was then used to rescale the model to its real dimensions. With the real location of three corners of the campus acquired, the model's rotation was also fixed in order to accurately position the model in 3D space.

Both the texture for the terrain and the procedural buildings and features were generated by GeoStream [77][78]. Geostream generates textures and 3D models from data sources like OpenStreetMaps or VirtualEarth. These textures and models are requested by providing location data, which results in the location of these features to be accurate without the need to reposition them.

While several companies have been generating models of a large part of our planet for several years, using techniques like photogrammetry and LIDAR, this data is not available for direct use. The reconstructed buildings used in this study were generated by photogrammetry with the source images originating from photogrammetry. Several screenshots were taken from Google Earth, each of them from a different point of view. At least one pair of screenshots overlap by about 40% for any given area. The screenshots were edited to show only the relevant part of the image, by removing the interface, and the final result was processed by Agisoft Photoscan, one of the leading applications for photogrammetry. While the results present worst quality than their Google Earth alternatives, they were accurately scaled and positioned on the map, and provide a visually recognizable image of the campus.

Positioning the units on the map turned out to be a more complicated challenge than expected. When creating a RTS game, the developer has complete knowledge and control over all the objects in the game. Wherever the ground is, a unit is positioned right above it. However, in this case, the units are not controlled by a computer. They are independent entities that can move anywhere in the real world, regardless of the features of its virtual analogue. X and Y positions are matched to the real world, either using latitude and longitude or zone, northing and easting. The problem arises from the altitude, and the large error introduced on this third dimension by the GPS system. Altitude reported by the GPS is normally unreliable, and its error is usually much higher than the error in the x/y surface. This problem is more noticeable when the unit is positioned inside a multi-level structure. For example, in the FEUP campus used for the TO, a pedestrian bridge connects the library to one of the canteens. The distance between the bridge tray and the ground is over four meters, which means that a unit can be located at the same horizontal position, but have one of two vertical positions: on the ground or on the bridge. The GPS error is enough to result in the unit jumping between over and under the bridge tray. Even on open ground, where no structures exist above or below, the GPS error would mean that the unit would be visible hovering over or buried under the ground.

To minimize this problem, two approaches were followed. One of them was to infer altitude information using the barometric formula whenever possible. The barometric formula relates air pressure to altitude [79].

While most methods of inferring altitude from pressure rely on base stations that report current pressure at sea level and calculate the altitude at a point based on the pressure distance, very accurate results were achieved using an alternative point for the reference pressure. Using previously collected accurate altitude information at a fixed point in the campus, the pressure at that point was measured before the start of every mission. The equivalent alternative in a real scenario could be based on military maps to find the pressure at any of the cells in the TO. With known altitude and pressure at a fixed point, the altitude for a unit's position can be inferred from samples of the barometric pressure at that time. While not all mobile devices integrate a barometer, the accuracy improvement justified implementing the barometric formula. Altitude is reported with higher accuracy if the device integrates a barometer, and defaults to GPS based altitude if not. The error measured using this method was constantly under two meters, and under one meter more than 50% of the time. It is important to note that pressure is affected by temperature, which means that this method might not be ideal for situations that present significant heat differences between the unit's position and the reference point.

The second approach taken works for both GPS and pressure-based altitudes, although its reliability varies with the accuracy of the altitude reported. To properly position the unit on a surface, a constant value was added to the reported altitude. The resulting point was then cast down to the nearest surface, and the unit was positioned at the intersection of the vector that starts on the resulting point and is directed straight down with nearest surface on the map. These methods resulted in the unit being positioned on a surface 100% of the time and avoided floating or buried units. While using altitude calculated from pressure, the result was correct every time, while some jumps between ground and bridge were noted at times when using GPS only.

The main section of the interface shows the TO in 3D. On the representation of the TO, the application adds the units involved in the mission and the events. Using the mouse only, the user can pan, rotate and zoom on any point of the TO and surroundings and select units. The interaction with a 3D mouse was also implemented, which resulted in a quicker and more natural navigation.

Dragging the mouse on the screen with the left mouse button depressed draws a gray rectangle on the screen. When the button is released, all the units inside the rectangle are selected. At this point, clicking on any part of the map opens a menu with the options "Move to", "Message" and "Cancel", which result respectively in sending an order to the selected units (move to the point where the commander clicked and act accordingly), send a message to the selected units or cancel the action. The first and last actions happen automatically when selected, while selecting the "Message" opens a text box to type and send the message. The units remain selected after the commander's action, at which time a new command can be issued, or the units can be deselected. Selected units can be seen in Figure 36 - Selected units and order/message menu.

Figure 36 - Selected units and order/message menu

Events are represented by a flag that represents the type of event. In the same way as units, a line rises from the flag and finishes with a smaller icon that represents the event. This line and extra icon help in identifying the position of the event, as it can be seen raising from behind buildings and other features.

Hovering the mouse cursor over the event shows extra information that concerns it, including the type of event, the user who reported it, the time it was reported and its status. The status can be changed by clicking on the event flag. At this point, a menu appears for selecting the new status, as can be seen in Figure 37 - Event information and status menu.

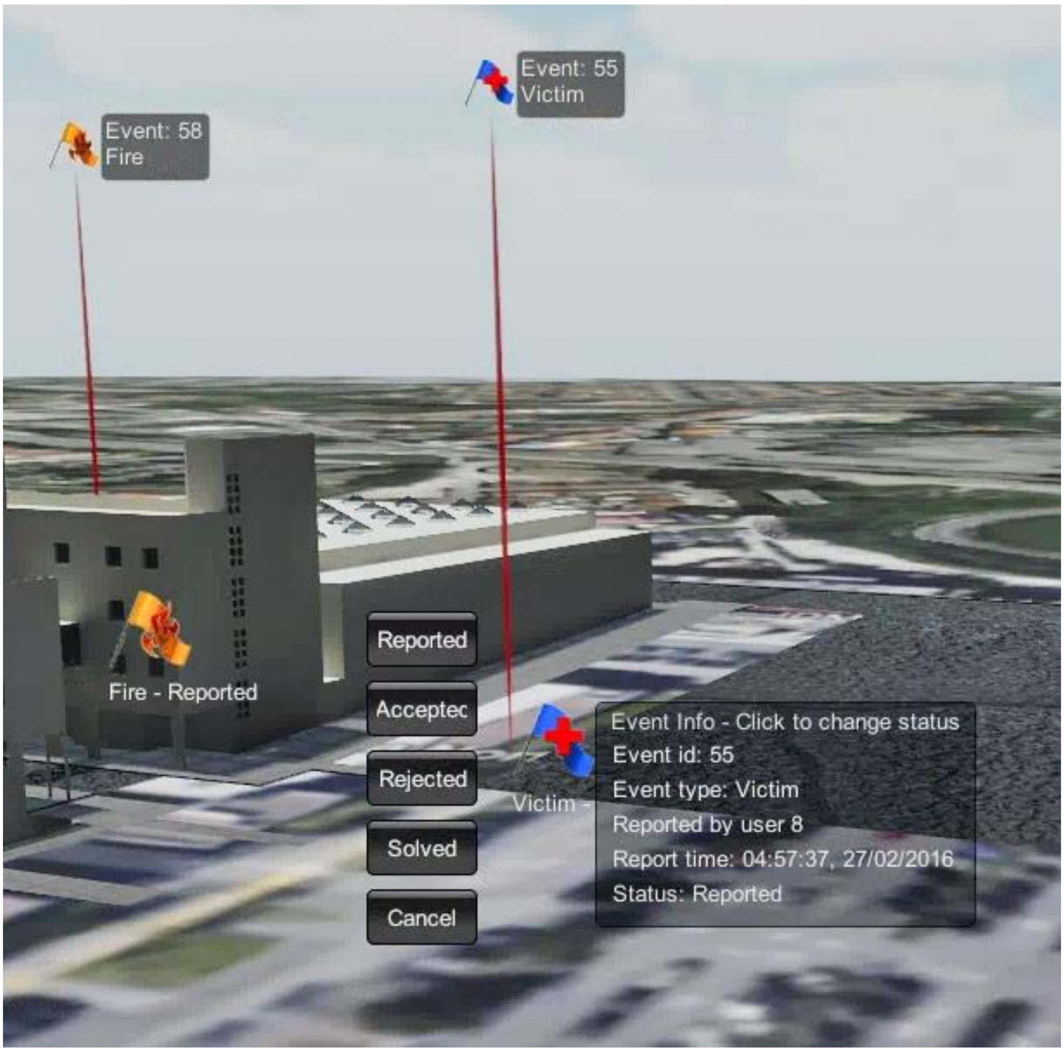

Figure 37 - Event information and status menu

Mission related data is available, either constantly on the screen or on demand by the commander. The time since the mission started is always shown, since this is extremely relevant information.

Weather information can be shown on demand by pressing the 'W' key on the keyboard. AccuWeather is usually a very reliable service that uses data from weather sources near each location. This service replies to GET requests with JSON a JSON formatted string. By sending the service the location of the centroid of the TO, along with an API key which is commercially available but also provides demonstration features, the AccuWeather sevice replies with basic or extended weather information. An example of the data available for the application is shown in Figure 38 - Weather Information.

Figure 38 - Weather Information

As mentioned before, every movement or event is parsed by PHP scripts and registered on the database. Excepting unit tracks, every transaction is reflected on the Mission Log. The information is presented to the commander as a long string with separated messages. However, each of these messages are internally stored on its own object, which fires an event when the mouse is clicked when the cursor is hovering over it. As already mentioned, the right mouse button centers the view on the unit from which the message originated or to which the message was directed.

The choice of Unity for the development of the application was based on the fact that most of the necessary tools for the generic functionality for the application are already integrated into Unity. One of these functionalities is the camera component. The application uses three cameras, one for the main view, one for the mini-map and one for the first-person view.

The main camera is controlled by the mouse or 3D mouse. A GameObject in Unity is any object that contains a transform. By manipulating the position vector, euler angles and quaternions for rotation, which are part of the Transform, the main camera moves and rotates over the TO.

The mini-map is based on a second camera for which the projection was modified. Instead of considering perspective, which shows the camera view as we see in the real world, the camera uses an orthographic projection. This projection results in an image free of distortion, comparable to a paper map. Unlike the main camera, which creates a pyramidal frustum and can zoom in or out by manipulating the 'FoV' (Field of View) property, zooming an orthographic camera is achieved by changing the 'Size' property. This property controls the area of the rectangle seen by the camera and, in the application, it is controlled by a slider positioned next to the mini-map.

The First-Person view camera used to report what a unit is seeing is similar to the main camera. When a unit is selected for monitoring its view, this camera moves to the object that represents unit, which becomes the camera's parent in the Unity's hierarchy. When an object is parent to another object, it follows the transform of the parent automatically. The First-Person Camera, therefore, can be left alone by the application until it has to be used for another unit, since Unity itself takes care of positioning the camera where it should be (at the point of view of the unit to which it is applied).

Requesting a real-time photograph was initially implemented but ended up not being used. This functionality would require that the physical camera on the operative was mounted on the uniform, facing forward. It would be possible to use an external camera connected to a mobile phone, but such cameras were not available for the development of the applications. Using the camera on the phone would require that operatives carried the phone in a vertical position at all times, which would make it hard for them to see the screen and interact. However, in order to implement this feature, an extra area was initially added to the database, very similar to the areas named 'Messages', 'Orders' or 'Events' in figure 30.

The request initiated by the commander was immediately added to the database, since it would later show in reports regardless of having a response or not. Every unhandled request for photographs would then be handled by the application for the first responder, which would take the photograph and send it to the server, where it was stored in the file system with the full path to the image stored in the database. Once the image became available, the command application retrieved it and showed it, as well as a notification, in the Mission Log.

5.4 First Responder application

The First Responder application was created to support the main application and help on tests and data collection. Since this application is not the focus of this work, it was developed to provide basic functionality. Further study would be suggested to unify the application between different types of units, improve the interface and functionality and even select the best platforms and hardware. For the present scenario, the application was developed for Android smartphones, which provide all the necessary functionalities. The application was developed in Processing [80] with the Ketai Sensor Library [81].

All the data required by the application is handled by the Ketai Library. This library provides methods for accessing the various sensors in Android devices. In the present case, this data is used in the form of GPS location, facing direction, barometric pressure and camera images. The sensors used are respectively the GPS radio, magnetometer, barometer and camera. The application requires permissions to access these sensors, as well as an internet connection.

The application starts by defining the minimum interval for position updates. This is initially set to 1000ms, which is the interval between samples used by most civil GPS receivers until recently. This variable is complemented by a minimum range of movement before registering a position update. These two values define that, for example, a sample is taken every 1000 ms or more whenever the device moved more than 5 meters. The combination of these two variables assures that data remains relatively accurate (there is no need to request a new position if the device did not move, nor need of continuous updates) while keeping bandwidth under control. Position updates for multiple units over multiple missions could also grow the database by a big factor.

The pre-defined interval is also used for querying the database for new orders, event statuses or messages. Every time the interval since the last query is equal or higher than the preset interval, the application queries the database for new information. If it exists, the application retrieves is and shows it to the operative. If a new position update is available, this is also communicated to the database via a PHP service. Position is communicated and stored in the application as latitude, longitude and altitude, and it is only converted to UTM by a PHP service when requested by the command application.

Ketai sensor access is initialized by instantiating a new KetaiSensor and passing the application context to the constructor, and calling the method 'start()' as follows:

```
KetaiSensor sensor;
sensor = new KetaiSensor(this);
sensor.start();
```

The KetaiLocation class handles the location sensors. The following code excerpt shows the initialization of a KetaiLocation object:

```
KetaiLocation location;
location = new KetaiLocation(this);
location.setUpdateRate(100, 1);
```

The 'setUpdateMethod' above tells KetaiLocation to get position updates every 10^{th} of a second (100ms) or more, if the device moved at least 1 meter.

`sensor.isPressureAvailable()` returns true if the device contains a barometric sensor, or false otherwise. If the method returns 'true', altitude throughout the lifespan of the supplication is calculated by use of the barometric sensor instead of GPS data. In this case, the application starts by sampling the current air pressure at the preset point to which the altitude is known. With this value, the reverse barometric formula is used to calculate pressure at sea level, which will from there on be used as the basis to calculate altitude from pressure. The barometric formula can be affected by temperature variations. Ideally, the device would contain a thermometer which could be used to measure temperature. Since most devices do not contain a thermometer, the current temperature is received from AccuWeather, similarly to the main command application.

Besides from collecting waypoints and communicating them to the server to create a breadcrumb track, the application also features orders, messages and events. If at any time an order is ready for the operative who is using the application, the order information is downloaded and the user is asked if he is available to complete the order. At this point, the screen shows the information that a new order is available, as well as the type of order. If the order tells the operative to move to a specific location (and act accordingly), the position and distance to the destination is also shown. The operative selects a reply – accept or reject – using large buttons, his input is communicated to the server and consequently to the command application. If the order is accepted, a compass is shown, with the direction to geographical north marked, as well as the direction to the objective and the distance.

The magnetometer inside mobile phones reports the direction to the magnetic north, which is slightly offset from geographic north. This offset depends on the part of the globe in which the smartphone is used. The application uses a service to find the magnetic declination at the TO, by sending its latitude and longitude. The complete URL, after parsing and inserting the values for the FEUP campus, is:

http://www.ngdc.noaa.gov/geomag-web/calculators/calculateDeclination?lat1=41.18&lon1=-8.59&resultFormat=csv

lat1 and lon1 contain the latitude and longitude of the point for which magnetic declination is needed. These values are based on the centroid of the TO, but they do not have to be that precise. The last value, *resultFormat* dictates the format that the resulting data should take. CSV (Comma-Separated Values) is used by every communication from and to the application. CSV formatting, despite the fact that it is not very human readable, results in very short strings compared to XML (eXtensible Markup Language) or even JSON (JavaScript Object Notation), which is beneficial in keeping traffic low.

If a message is available, this message pops up on the screen with a countdown timer. This timer shows the time left before the message is automatically dismissed (in which case the message is marked on the database as 'Timeout'. Otherwise, the operative can acknowledge or reply to the message.

At any time during the mission, the operative can touch any part of the screen to send a message or an event to command. When typing a message, a text field and the active Android keyboard are shown. It would be relevant to research other types of input like Speech-To-Text, since most of the time operatives need their hands available to complete tasks.

The above-mentioned functionalities provide a certain level of situation awareness, but the application also contains some features to help with team awareness. Team members show up on the screen as dots in the direction of their location. The center of the compass represents the location of the operative using the application, and team members are positioned around it with the distance to the center of the compass indicating a relative distance. The closest team member is highlighted, which may be relevant in a situation of danger in which an operative needs urgent help.

The application uses a simple and minimalist interface so that users can focus on relevant information. Most of the interface elements are drawn in green, since this color is easily distinguishable from fire, smoke or snow. As seen before, the human eyes are also more sensitive to wavelengths of 555 nm, which fall in the yellow-green spectrum. Since first responders usually wear gloves, buttons fill the biggest space possible. Using a smartphone with gloves requires a high sensitivity touch layer, which is only available for certain devices.

The application was developed to support the main mechanics and feed information to be used by the command application. Based on the same principles, an application could be developed for AR devices, which would free the operative from handling a smartphone constantly. In fact, a companion version of this application was developed for the Sony LiveView, one of the first smartwatches depicted in Figure 39 - Navigation of the Sony LiveView. While it helped freeing the operative's hands and did a good job showing information, interaction turned out to be very complicated.

Figure 39 - Navigation of the Sony LiveView

Interaction was also approached in a more natural way, which would have left operatives free to use their work tools without thinking of pressing buttons. For this end, a glove shown in Figure 40 - Prototype of the interaction glove was developed consisting of a micro-controller, flex-sensors for each finger and a 9DoF IMU, which would be used inside the firemen's fireproof gloves. The orientation of the operative's hand was inferred by the IMU, which could report pitch, roll and yaw angles. The flex-sensors measured the amount of bending on each finger, which would provide interaction by gestures. In combination with the methods described in 2C [4], the glove would allow an objective to be marked by pointing at it with the index finger. While this method might have proved very useful, it soon became clear that it deserved a thesis on its own and fell outside the scope of this document.

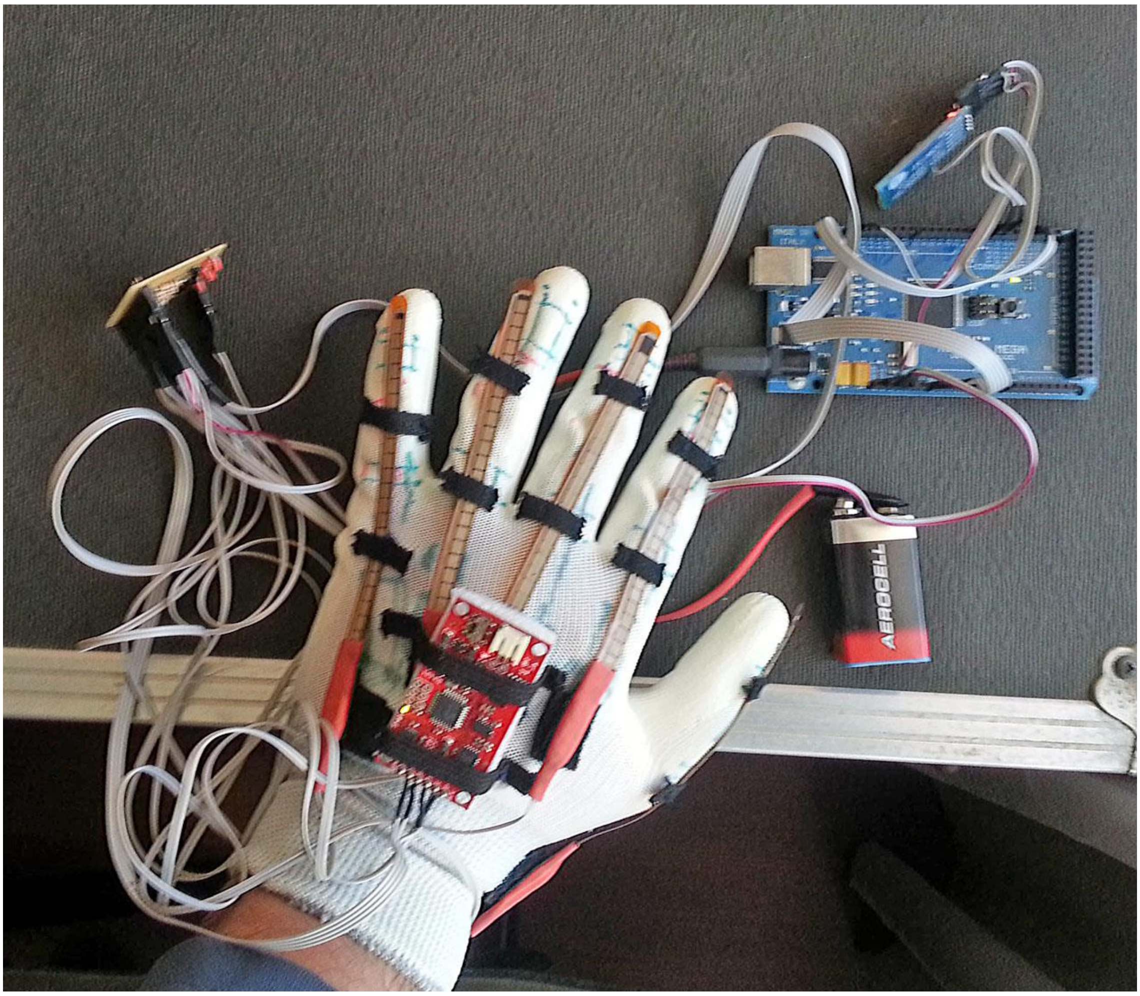

Figure 40 - Prototype of the interaction glove

5.4 Reports

Since all actions and communications are stored in the database, reports are generated from this data. These reports can be used for learning from experience, as well as training and analysis of what went well or less well. Examples of SQL commands used to access the data, as described in this section, are available in Appendix II – Sample SQL Commands.

Reports are generated from a web-based tool developed with PHP and HTML. The main page, *index.php*, is located in the *report* folder in the server. It is run automatically when the user types the URL for the report functionality.

The main page presents a from to the user, containing a list of all missions. In its current form, a list of missions is being used, since the number of missions recorded is very small. It is suggested that other filtering options be made available. The list of missions is collected from the database and used to fill a combo box.

Besides from the mission, the user may or may not add one or more units to filter the resulting report. In a commercial product it would be easy to implement a list box with only the units that were present in the selected mission. However, in its current form, the page accepts unit id's separated by commas in a text box. The only other element in the form and in the page is a submit button.

The form calls a second PHP script by the name of *report.php*, which generates the report taking the form fields as parameters.

In this script, id is the mission id in the database, whereas $missionId represents the id of the mission previously selected by the user. This value is contained in the $_POST and $_REQUEST associative arrays when *report.php* starts. The rest of the variables contain mission details: The name of the mission, the mission's description, the time the mission started and the time it was closed. These fields describe the mission and are presented at the top of the report.

This returns all the units that collaborated in the selected mission. If the field that filters the units was previously filled by the user, only units present in that field are selected.

For each unit returned from the database, the scripts retrieve the relevant messages, orders and events using the same methods as presented so far.

5.5 Conclusion

This chapter presented an application and server-based solution for the application of RTS game principles to emergency management. The development of the different modules necessary for the solution to work was also documented, including the database, support services and different applications.

While the solution works very well and produces the expected results, the work developed was done to support the command application and especially its mechanics. Some experiments were done with less attention demanding hardware, but these experiments fall outside the focus of the current document. It is suggested that further research is developed in the area of pervasive computing and wearables, as well as Augmented Reality. Furthermore, the application for operatives currently requires an Android smartphone. This is not the most cost-effective solution for a commercial application. Non-autonomous units could use a subset of the application running on a micro-controller, using different communication infrastructures like ZigBee or other peer-to-peer networks communicating with one of the cells, which in turn could relay the information through a 4G network or another alternative.

Finally, the automatic report generation was described. While these reports are not a requisite for the application of RTS game principles, their contribution was very welcome by professionals of emergency response.

6 Evaluation

The initial idea for the tests involved an invitation for the firemen to participate on a mission at FEUP, both as commanders and operatives. However, it soon became clear that this was not going to be possible. The proposal was presented to the GIPS, the Porto's professional firemen and the voluntary firemen from Porto, Leça do Balio and Marco de Canaveses. Their busy schedule and the hierarchical structure of these forces dictated that an alternative had to be developed.

Porto's professional firemen suggested that the TO would be recreated for their facilities, where they train regularly and participate in exercises. They even provided a floorplan of the headquarters with the objective of facilitating the task. While this would represent the manual modelling of their facilities – which would be a long and hard task to complete – an effort was made to complete the tests at the headquarters. However, due to the change in the chain of command, this option became impossible.

The tests were performed at the FEUP campus as initially proposed, by two teams of five voluntaries, none of them related to any emergency task force. The missions completed by these participants were recorded and presented to the voluntary firemen from Marco de Canaveses.

6.1 Test description

Ten voluntaries gathered at FEUP on a Saturday morning. After an introduction which explained the study and its objectives, they were instructed on how the platform works and received information about what was asked from them. Both the command and the first responder application were explained in detail and they were able to pose their questions to ensure that they would know how to proceed.

All the participants in all the tests signed an Informed Consent form and their details were added to the database. All the participants were photographed for the test missions, but their photos and personal details were deleted afterwards for privacy reasons. This temporary information was used by people at the command to provide clear information regarding every unit.

The information collected for each participant included age, gender, highest level of education, occupation, as well as their proficiency with computers, computer games and location systems. It was also registered whenever a participant knew in advance the FEUP campus.

The participants were distributed in two groups of five elements each. Group 1 would command one mission in which group 2 participated as first responders, while a second phase reversed the roles and assigned group 2 to command the mission taken by group 1.

Each element of the away team received an Android smartphone with a data enabled SIM (Subscriber Identity Module) card and the first responder application installed. The command application was used to create the two missions before it was passed to the command team.

UEQ (User Experience Questionnaire) is a standard validated questionnaire to evaluate User Experience available in different languages, including English and Portuguese [82]. This questionnaire evaluates factors like Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty, turning out to be the ideal tool to evaluate the proposal.

6.2 Description of missions

As described above, ten participants were part of two missions. All ten participated in both missions, but each group of five had different roles in each mission. By taking one mission only as example, the explanation of the mission design and objectives becomes easier and clearer. For the sake of clarity of the example, we consider that mission 1 had group A in command and group B in the TO.

With the mission created and started, group A left the command and placed five flags in random places of the TO while using the mobile application. Each element of group A was instructed to place a flag wherever they wanted to, and at this point mark an event with the help of the mobile application. Group B waited in a separate room for this task to complete, without any knowledge of where group A was placing the flags. They also did not have access to the command application so they could not see the events showing up, which would give them knowledge of the flag's location.

Group A took the role of the ERAS in this phase. While the ERAS would report events found in a real case scenario, for the tests they reported the events as if they had found them when in fact they were creating them. However, since group B had no knowledge of group A's actions, the result was comparable to the real scenario. As each flag was planted and the event reported, these events showed up in the command application.

At this point, group A returned to command and when they were ready, group B left for the TO with the mobile devices. Their mission was to find each flag (representing an event), pick up the flag (which represented an action), mark the event as handled and return to base with the flag.

Group A operated the command application. They could see all the units in the TO, as well as the events. They could also send and receive messages, browse the TO and manipulate the view, and emit orders to each unit.

Mission 1 finished when all the units returned to the TO with their objectives complete. At this point, roles were reversed for mission 2. In the end of both missions, all participants were asked to fill in the UEQ regarding different parts of the solution. By the time they all finished filling in the forms, an open conversation was held.

Five UEQ surveys were used, one for each component of this study. These surveys regard the collaborative metaphor (the whole proposed solution), the command application, and each of the three map types: Manually modelled, procedural and reconstructed from photographs.

6.3 Results from emergency response professionals

After running the two test missions with voluntaries not related to emergency management, the missions were played back at the headquarters of the Voluntary Firemen of Marco de Canaveses. The project was explained and they witnessed the missions happening, from the marking of events to the completion of the missions. As has been said before, mission playback does not allow the commander to issue orders. Every other functionality was available for the firemen to explore.

Sixteen firemen filled the survey. Their patents ranged from soldier all the way to the second in command, being that five of the sixteen people that took the survey had been in positions of command. The commander could not be present, but several members of the force had been assigned as COS on several occasions.

The UEQ does not produce an overall score for user experience, but rather different scales regarding Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. From these, the most relevant were identified as Efficiency and Dependability, followed by Perspicuity, Stimulation, Novelty and Attractiveness. The range of the scales is between -3 (horribly bad) to 3 (extremely good), but values below -2 or above 2 are extremely rare due to the calculation of means over a range of different persons with different opinions and answer tendencies. The example cited in the UEQ itself regards people avoiding extreme values when filling surveys.

The UEQ is distributed with its own analysis tools. It provides graphs within two different ranges: from -2 to 2 and from -3 to 3. The former is usually used to communicate results to people with little knowledge of the subject without going into much detail and provides a good idea of the test results in relative terms, where the latter gives accurate absolute results.

The UEQ also returns the results compared to a benchmark data set. This data set contains data from 4818 persons from 163 studies that relate to different products. While each product is different, this benchmark provides a quick idea of the levels of user experience provided by a product.

Based on the benchmark values, the UEQ defines five levels of quality, ranging from Bad to Excellent. The borders between these levels vary depending on the topic that they represent, from a list of six topics: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. Table 10 shows the values of lower and upper borders for each range.

	Attractiveness		Perspicuity		Efficiency		Dependability		Stimulation		Novelty	
Borders	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Bad	-1.00	0.65	-1.00	0.53	-1.00	0.50	-1.00	0.70	-1.00	0.52	-1.00	0.24
Below Average	0.65	1.09	0.53	0.90	0.50	0.84	0.70	1.06	0.52	1.00	0.24	0.63
Above Average	1.09	1.50	0.90	1.37	0.84	1.31	1.06	1.40	1.00	1.31	0.63	0.96
Good	1.50	1.72	1.37	1.82	1.31	1.64	1.40	1.60	1.31	1.50	0.96	1.34
Excellent	1.72	2.50	1.82	2.50	1.64	2.50	1.60	2.50	1.50	2.50	1.34	2.50

Table 10 – Quality ranges for each topic of UX

Figure 41 - Quality ranges defined by benchmarks presents the ranges defined in the previous table as a graph for reference.

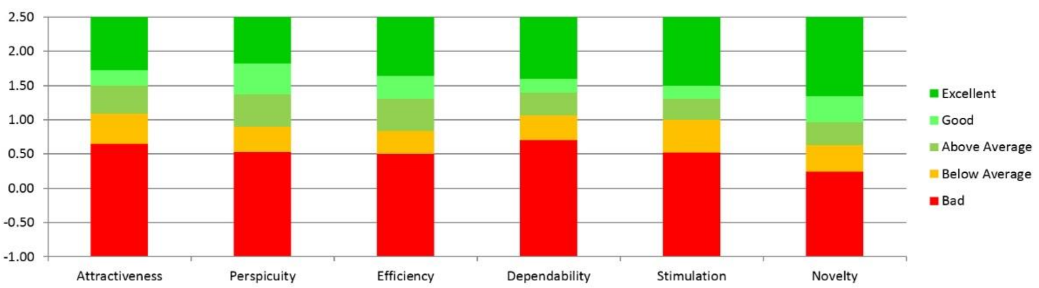

Figure 41 - Quality ranges defined by benchmarks

After understanding and using the proposed solution, the collaborative metaphor returned good results when compared to the benchmark. Mean values were 1.833, 1.458, 1.516, 1.484, 1.859 and 1.609 for attractiveness, perspicuity, efficiency, dependability, stimulation and novelty respectively. These values placed the proposed solution in the top 10% against the benchmark for attractiveness, while perspicuity, efficiency and dependability were below the top 10% but above 75%. Stimulation and Novelty were once again positioned in the top 10%. The resulting graph is presented in Figure 42 - Collaborative Metaphor compared to UEQ benchmark.

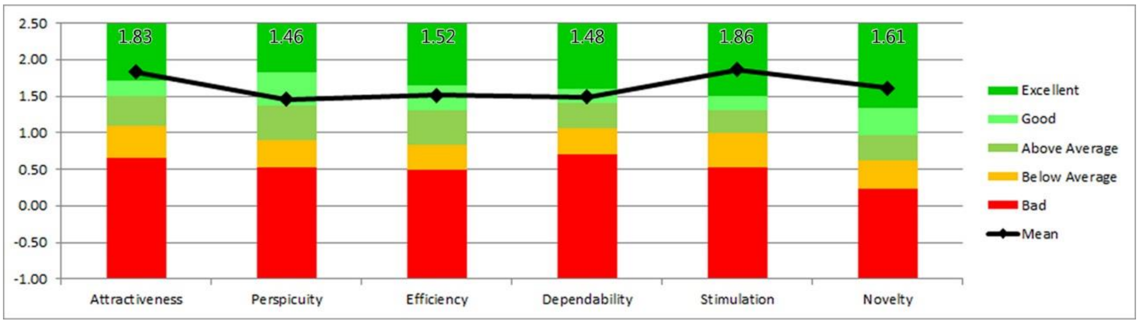

Figure 42 - Collaborative Metaphor compared to UEQ benchmark

While it scored slightly below the collaborative metaphor, the command application was evaluated with good results. Mean values for Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty were 1.542, 1.359, 1.516, 1.484, 1.672 and 1.302 respectively. These values place Perspicuity above average, bellow the top 25% results when compared to the benchmark. Stimulation values were comparable to its values in the collaborative metaphor, in the range of the top 10% when compared to the benchmark. All other values were placed above 75% of the benchmark results, but below the top 10%.

While each question in the UEQ contributes to a certain aspect of evaluation, the six areas described above represent the results. The UEQ is very well organized, and it does not ask, for example, if a product is beautiful or ugly. Instead it evaluates replies to questions like “how attractive is the product”. A concept, like the collaborative metaphor, can be attractive or unattractive, while it will not be beautiful or ugly. In what concerns to the application, there is a high chance that attractiveness will be judged based on its looks by many people. The values for this and other related areas that get their score from the same questions would likely be higher if a designer would recreate the interface. Figure 43 - Command Application compared to UEQ benchmark summarizes the information collected.

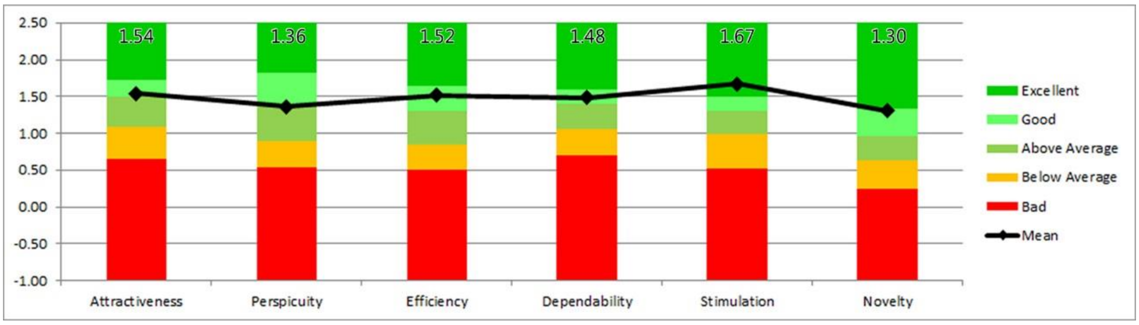

Figure 43 - Command Application compared to UEQ benchmark

The three different types of map were evaluated with one UEQ for each, in the same order as they appear in the command application.

The manually modelled map showed a mean value of 1.939 for attractiveness, a testament to the work of the author. This placed attractiveness in the excellent range when compared to the benchmark, a position that was shared by efficiency and novelty, which scored respectively 1.656 and 1.385. Perspicuity, dependability and stimulation received mean scores of 1,718, for perspicuity and 1.593 for both dependability and stimulation, placing these three factors above 75% of the products analyzed in the benchmark. Efficiency and dependability are probably the most relevant marks for the maps, as well as the rest of the solution, as Figure 44 - Manual Model compared to UEQ benchmark shows. At this point it becomes relevant to state once again that, although the model is very accurate, it was created with the aim of producing non-real-time rendered images. Although a lot of work went into improving the model for real-time use, a model created from the start with this objective in mind might score better than the one used.

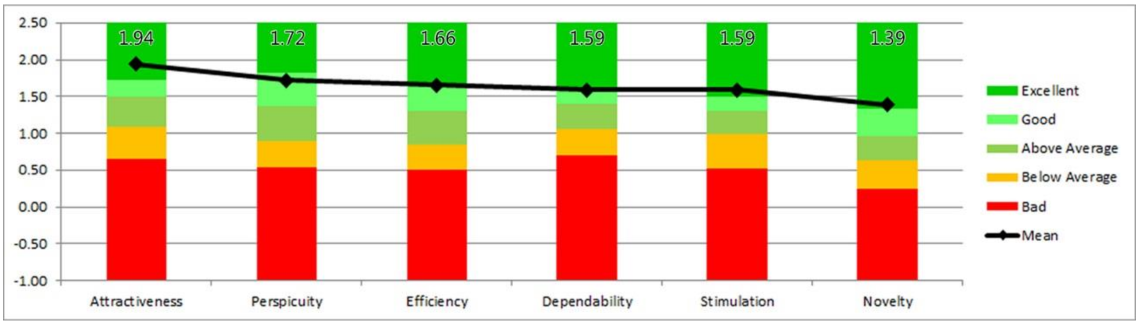

Figure 44 - Manual Model compared to UEQ benchmark

Unsurprisingly, the procedural model scored the lowest values of the three. The cube-like structure of the resulting buildings and features and the lack of textures lead to predict a lower attraction value, while a possible subconscious comparison to the graphics from twenty-year-old computer games would result in lower novelty values. More importantly, the lack of identifying features contributes negatively for all the other areas. Since this type of model was proposed to be used in the case that no other source was available, these lower results should show that the solution is acceptable, if not ideal. However, the evaluation of this type of map was placed below average for all areas, while novelty was actually considered bad by comparison to the benchmark.

With mean values of 0.729, 0.765, 0.781, 0.869, 0.75 and -0.046, novelty received bad marks and was placed among the worst 25% products. All the others were placed above the worst 25%, but still below the best 50%. The graph for this metric is shown in Figure 45 - Procedural Model compared to UEQ benchmark

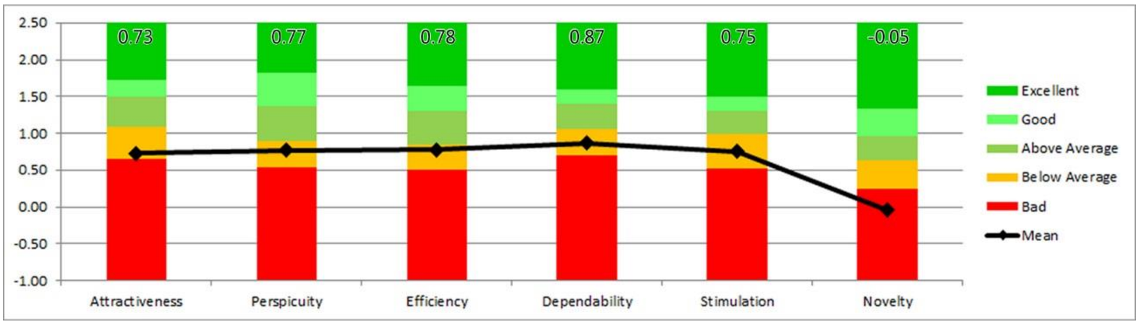

Figure 45 - Procedural Model compared to UEQ benchmark

The procedural model received good results again. The lower scores were related to perspicuity, stimulation and novelty. These results can be explained by the familiarity that most people currently have with Google Maps and Google Earth. Since the source of the data that generated these models was in fact Google Earth, the model looks similar to the ones in these offers from Google. In fact, the degradation of data when capturing screenshots and reconstructing the models again represented a large drop in quality. Nevertheless, attractiveness, stimulation and dependability results were considered excellent. This fact represents a big win, since they show that even with quality degradation, the models provide a good image of reality and the tools for the commander to do his job well.

Mean values of 1.729, 1.708 and 1.75 for attractiveness, efficiency and dependability are considered excellent, in the top 10% of all the products considered in the UEQ benchmark. Perspicuity, stimulation and novelty dropped their score comparatively to the other areas, while still maintaining a good rating. Stimulation was still placed in the top 10%, while perspicuity and novelty were considered good by comparison, above 75% but below 10% of the products from the benchmark. Figure 46 - Reconstructed Model compared to UEQ benchmark presents the graph for the opinions on this type of model.

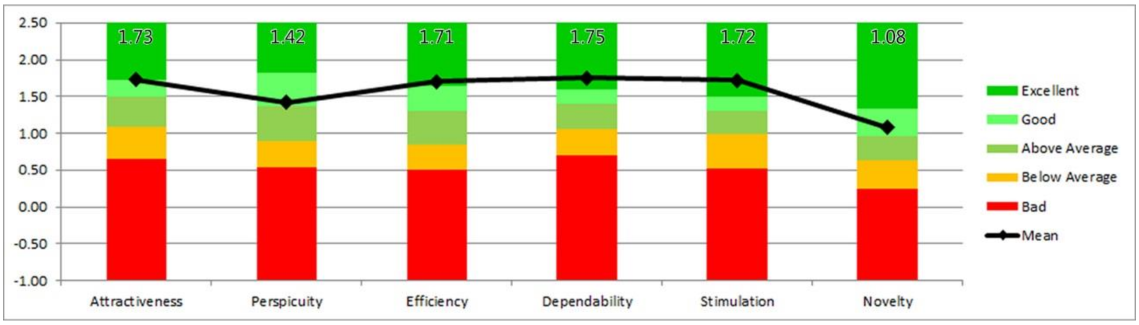

Figure 46 - Reconstructed Model compared to UEQ benchmark

6.4 Conclusion

It would have been relevant to have firefighters testing the proposed solution in real-time, and applying their hierarchical structure in the tests as they do in their job. While everybody who was contacted revealed to be extremely nice and helpful, their busy schedules and training as well as the constant restructuring of hierarchy dictated that this would not be the case. However, the extensive talk and the analysis of the solution in non-real-time provided valuable information. While the intervenients were strongly encouraged to leave comments on the surveys, which included specific fields for suggestions, no comments were submitted.

In the semi-guided interviews, it was stated that the proposed solution would be an extremely valuable tool for emergency professionals. Furthermore, the results gathered from firefighter analysis has led to pertinent conclusions. The interview lasted for a total of one hour and ten minutes. In this interview with one commander, it was mentioned that the proposal was very innovative, and it would complement very well the functionalities that the new radios provide. It was mentioned that the lack of GPS inside buildings and structures could be the biggest obstacle to implement the solution. While this topic falls outside the subject of this dissertation, it was approached in [5]. Another potential problem seen by the operative was the use of a mobile phone while wearing gloves. However, it was explained that the mobile phone was used only to test the proposed paradigm and that other techniques, while not fully developed, were studied in the scope of this study. He also agreed that having the information displayed in AR inside the helmet would be an amazing tool. He stated, however, that as long as other data input solutions were available, having the information displayed on a Smartwatch would already be a great benefit.

The commander stressed the importance of focusing on the hierarchy and praised the hierarchical infrastructure of the solution. According to his words, the proposal allows for the COS to command the team leaders who in turn command the team. This could be extrapolated to sector commanders, CDOS, civil protection and

General Staff. It was stated that the proposal would be even more important in situations where sectorization occurs.

A fact that was previously unknown was pointed out. The ERAS members currently use tablets to record their findings and communicate them to the COS. The automatic mechanism and the hierarchization of the proposed solution were seen as a major benefit to what has already started being used.

Also pointed out as major benefits were the replacement of the COS and consequent transfer of the POSIT. The fact that the COS can predict dangerous situations by having a general view of the TO and the 3D view of each element also received great merit. The commander explained that in the past there were cases in which that a COS gave the CDOS information that differed from what the previous COS had communicated, which results in complications. When the CDOS and the COS have real-time access to the POSIT, this problem is largely minimized or even becomes obsolete.

While the above comments are mainly a confirmation of the relevancy of the solution, two suggestions were given. The first suggestion is that every operative or member of the attack should be provided with real-time information about who is in charge of command. This would be developed in a hierarchical system like every other feature, so the operative would know at a glance who his team leader is, the team leader would know who the current COS is, and this would repeat all over the hierarchy. The other suggestion regarded overlaying the SITAC information over the map in the command tool.

User experience was evaluated as good to excellent, confirming the information received from talks and interviews. Very good results were also received regarding the command application, and some lower results confirmed that more attention to the user interface would be required, as well as a more carefully planned design. Yet, the functionalities and mechanics were considered to be useful for their profession. This makes a lot of sense, since being able to identify map features helps with mentally relating the visual feedback from the application to the location and situation of a unit.

The proposed models for buildings and features revealed that accuracy, detail and looks do matter. Manually created and reconstructed models were not ideal and would benefit from the work of a larger team with bigger funds. This would allow for the manual modelling of structures with the objective of emergency response in real-time from the start, which might lead to a higher concentration of work on more relevant areas, as well as the optimization of the model for real-time use. Although a lot of work was done to achieve fluid and consistent results in real-time, the original data did not have this objective. 3D reconstruction would have benefited greatly from the use of aerial photography captured by remote controlled or self-flying drones or even a helicopter.

Reconstructing models based on screenshots of reconstructed models is far from an ideal solution, but since the data is not freely available, this task turned out to be impossible. Despite these difficulties, the evaluation of these types of models was extremely positive, confirming that the proposal is valid.

Procedural models scored lower than the other two approaches in every regard. Although the test subjects were informed that this type of model was suggested only for situations in which no other data was available, it is true that these models present a lot less information than the alternatives. It was important for the tests that the subjects had all the information prior to filling the survey forms, but the comparison with more feature rich alternatives may also have led to responses below what would possibly be received otherwise. A few solutions would also have helped with this type of model. CityEngine, for example, is very versatile in the creation of procedural models and could have been used instead of GeoStream, but its high cost and steep learning curve turned this approach impossible. Another tool that could have helped in adding detail to the otherwise naked buildings is WRLD, which provides a Unity plugin for streaming buildings in real-time. Although this tool is still relatively basic, it improved a lot since launch. However, it only became available recently, when the tests were already finished and closed. Considering how hard it was and how long it took to find a time with the firemen for testing, taking the tests again would have been very hard. With this said, further study in this field is recommended.

7 Conclusions and Future Work

Completing this study turned out to be a lot harder than expected. It required the participation of a lot of well trained professionals and voluntaries, and the organization of events that needed to gather whole teams of busy professionals at the same time. However, these difficulties were mitigated by the fact that all of them were eager to help, knowing that any advances in the area would benefit the whole population of the globe.

Using game ideas for such an important mission did provide a feel of completion. Every time an improvement in the prototypes was shown to emergency responders, they responded very positively, and the joy that is usually found on gamers could be seen, although the happiness came from seeing a tool that they considered easy to use and powerful for their functions.

7.1 Conclusions

A lot was learnt from the interviews, the surveys and the analysis of the state of the art. These learnings were used to create and iterate on a fully functional prototype that could be experienced, and showed what things could become in the next few years.

While some functionalities planned in the beginning had to be left out, the resulting prototype managed to gather the ones that were considered more important, and the hands-on time that first responders managed to get was sufficient to see that if this work is not a solution, it at least contains valuable ideas that can be used to improve this area.

The collaborative metaphor was very well received. Getting POSIT information in real-time, at any time, just by looking at the representation of the TO and a mission log complemented the traditional POSIT boards and returned up-to-date information. Being able to see a new fire front or a victim as soon as the first operative became aware of it without the need for radio contact was also extremely welcome. The tests confirmed how welcome this metaphor was, after the interviews had already stated this fact.

While the command application focused on functionality rather than looks and kept a "function-over-form" approach, it still received very good comments and test results. A better interface design would have benefited the solution greatly, by improving its usability. Efficiency and dependability were taken from the beginning as two of the most important factors for the solution. They did compare favorably to benchmarks, but a better interface design might have pushed the standards even higher.

The approach presented here relies heavily on data that can reproduce the TO as faithfully as possible, for any point of the world. At its current state, world mapping is not advanced enough to have high standards for any spot in the world. The analysis of map sources and features confirmed what was already predicted: Carefully built models with attention to detail return a better understanding of the TO and better situational awareness. These models can easily exist for high-risk structures, or they can in many cases be collected from BIM (Building Information Modelling), at present this is only available for a very small percentage of the world.

It has become common for big companies to model buildings and features from aerial photographs or LIDAR information. Currently, however, no open sources could be found for this type of models. With the recent proliferation of private drones, a collaborative platform for terrain and buildings photogrammetry would benefit the cause. While this part of the study is probably not its strongest point, and the techniques used to recreate buildings were far from ideal, the tests returned the best feedback for s, dependability and stimulation. Proper reconstruction from the original photographs would probably improve attractiveness, perspicuity and novelty, even if the results showed an already good score.

Procedurally generated content received the lowest score of all the model sources. This could be easily explained by the lack of detail and many recognizable features. However, data that generates these models is widely available for a large percent of the globe. There are collaborative tools that use crowdsourcing to grow a huge database, and all hints tend to show that more these databases will grow immensely in the next few years. Furthermore, tools are available to generate better procedural content from the same data. Currently, this is the type of data that can better be collected by a community, due to the low investment necessary to collaborate in the augmentation of the databases.

The research questions on which this document developed did get an answer. The first research question, “What are the best map types and 3D feature sources for representing the TO?” resulted in the simple answer “Manual models created by teams of 3D artists”. While this would be ideal in a use scenario, it would be extremely expensive and time consuming if global coverage was to be expected. However, it was shown that, even if less realistic results, automatic reconstruction techniques can provide the solution with identifiable models. And in a situation where none of these solutions can be used, procedural geometry can still achieve better results than simple 2D maps.

Finding and improving the relevant RTS mechanics to respond to the second question, “What RTS mechanics should be implemented to respond to a crisis?” was a long iterative process. In the end, all the initially planned mechanics as well as the ones suggested by members of the civil protection forces, showed that they can improve the current scenario by providing real-time information on units and can act as a valuable complement to the POSIT.

As for the third and last research question, "What other functionalities become available by using RTS design principles to crisis management?", it was concluded that being able to know physiological information about an operative like his blood type, can reduce the time needed to provide medical support as well as improve efficiency. The automatic reports can provide reliable debriefing and mission analysis while minimizing the possibility of tampered information.

This work was hard, and it took a long time to complete. However, even the thought of making the lives of these untold heroes a little safer and easier maintained the strength to complete it. Every one of the few negative comments was welcome and used to improve on the solution, and every positive comment left a feeling of a job well done. A job that matters. This was one of the most, if not the most rewarding activity in the author's life.

Despite all the limitations and difficulties, the tests showed that the approach is valuable. A lot of work is still left to be done in this area, and until fully autonomous mechanical devices have the necessary functionality to replace human actors, a lot of work should be done.

7.2 Future Work

The INDIGO project did a great job at making emergency management more complete and a lot more user friendly. As a joint venture with large funds, INDIGO managed to integrate proven existing technology in its study. It is very hard for a single civilian to have access to existing systems and usable C4i databases. Testing some of the ideas brought from this study with formal existing emergency technologies would likely help in sanding some rough edges and in creating a self-contained, generic solution.

Further work would be required to connect units to missions, analyzing different non-moving units, or anything that could connect these ideas to a working solution. Surely a lot of new priceless ideas would be gathered from this approach.

Better usability, with the help from graphic design and interface design could move these ideas even further. This study aimed to bring down the learning curve with technology so that professionals can focus much better on their function. A lot of work is left to be done in this area, and this work should be done with complete access and knowledge of professional state of the art systems.

Mixed Realities are gaining a lot of traction at the time of completion of this work, and with good reason. They allow users to lose contact with the world, if relevant, and focus their complete attention on a task. While VR is not in itself a social experience, since it aims to transport a user to an alternative reality, it can be extremely helpful. It is not suggested that a commander would use a VR system only. VR can help focus on specifics, but it results in the loss of awareness of the general situation. At this point it cannot be recommended that a VR system allow a user to fly to see the entire TO and return to a specific area, because this would surely result in sickness, headaches, and so many other negatives that are attribute to VR. A motion simulator could help with these problems, but the benefits might not outweigh the disadvantages. Nevertheless, using a VR system would bring a commander – with all his experience – to the TO whenever necessary. Nothing prevents an application based on the principles studied to be used as proposed, but augmented with the functionality of jumping into the action. Whenever a firefighter needed to help a patient, a medic could use a VR system to stream 3D video from the fireman and guide him from his perspective.

In contrast to VR, AR can be a social experience. A person using an AR system does not lose touch with the real world. Further studies in integrating AR solutions with the findings from this study could be applied to first responders. A lot of work was done in this area, although it remained mostly undocumented because it was broadening the target of the study too much. This work maintains its relevancy. In the beginning of this project, a glove controlled by a micro-controller board was developed. This glove tracked position and rotation of the whole hand, as well as bending of the fingers. Its aim was to replace smartphones as a data input device. Further study in this area is suggested, since although the work done in this field was too heterogeneous to make it into this document, the results were very promising.

Visualizing information is another field that was approached in the beginning, but ended up not making it into the final document. Before even Google Glass had been heard of, some tests were done with a Sony Liveview wrist screen. This screen was used like a watch, but also worn on the head, projecting its image onto a piece of acrylic rotated 45 degrees in front of the right eye. At the time, this solution presented a double image (which might have been mitigated with the use of thinner Plexiglas) and was hard to get an image in focus. This was done in an attempt to free the hands of first responders so they could better complete their task. Since then, smartwatches have proliferated, and AR goggles have started to flood the market. Very recently, MagicLeap finally showed the prototype of its lightfield magic. The resulting product is lighter than anything ever seen and provides very believable content. Although this product is not yet commercially available, it will probably be possible to integrate the technology into first responder's helmets. Their gloves can also be fitted with sensors to improve data collection while keeping them protected from the elements. It is strongly suggested that further study is done in these areas, as the present study would greatly benefit from this type of advances.

Communications are the base for this technology to work on. For the tests, different solutions have been attempted, including getting access to the FEUP's WIFI communication infrastructure by removing the need for authentication. However, despite all the efforts, there were several dead periods with no communications due to transitioning between access points. In the end, mobile data connections had to be used. In a crisis situation, antennas may burn or collapse, and emergency teams cannot afford to lose such a vital component. It is advised that developments from mesh networks are analyzed in conjunction with parts of this study. When sectorization is needed, different cells can have communication hardware to provide a reliable solution. Technologies like ZigBee could result in a reliable communications network for emergency response.

Useable computer maps exist since about two decades ago. However, examples from that time are very limited in what they can do and how they can do it. Developments in this area have been really good since that time, but many techniques require a lot of money, work and effort. Available data for procedural building generation has been growing very fast, and the techniques used to generate models from this data have also improved greatly. Buildings reconstructed from photographs have shown to be the preferred type by emergency professionals. However, generating these buildings in large numbers is very costly. Anybody with a commercial drone and an average camera, as well as a license of any photogrammetry program can generate a building, but generating the buildings and features from a large area if far from reach of the ordinary hobbyist. On the other hand, wikis and public repositories, as well as crowdsourcing have been gaining traction for a lot of technological areas. It is recommended that future study targets this type of solution, since it would be extremely valuable for this and other areas.

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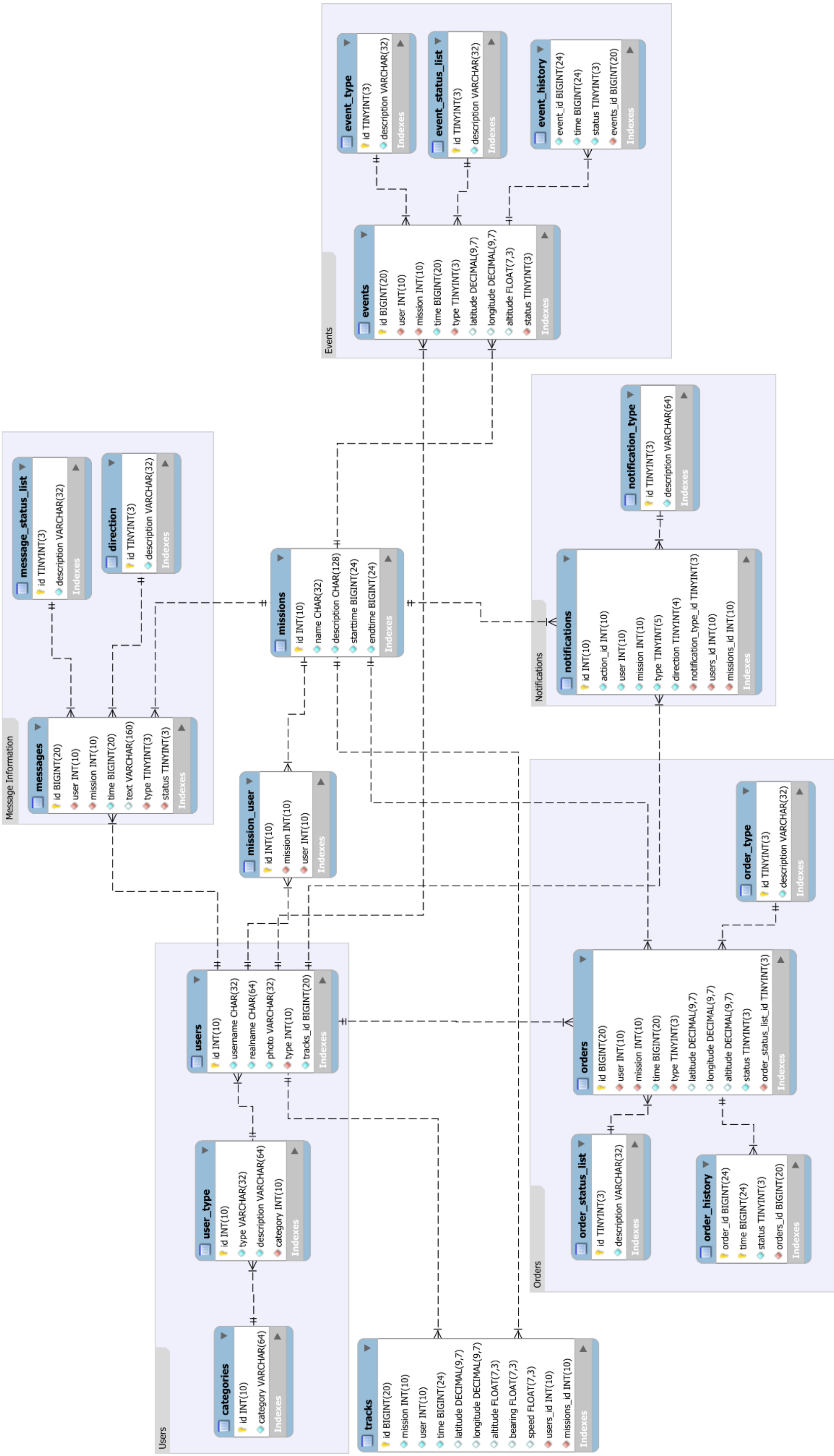
Appendix I – Database diagram



Appendix II – Sample SQL Commands

Get complete list of missions:

```
SELECT id, name FROM missions;
```

Get information on a specific mission:

```
SELECT id, name, description, starttime, endtime FROM missions
WHERE id=$missionId;
```

Get user information for users enrolled in a specific mission:

```
SELECT users.id, username, realname, photo, mission
FROM users INNER JOIN mission_user
ON mission_user.user = users.id
where mission=$missionId
```

Filter users in a mission - extend the previous command with:

```
AND users.id IN ($userIds);
```

Appendix III – Mission 5 Report

Mission Report

Mission: 5
Mission name: Testes 1
Mission description: Primeira Missao de Teste
Start: 27-02-2016 - 15:44:54
End: 27-02-2016 - 16:30:03
Events: 6
Users in mission: 5

Users:

Code: 1 **Username:** Hugo **Full Name:** Hugo da Silva	

Reported events:

Id	Time	Type	Latitude	Longitude	Current
48	27-02-2016 - 16:03:42	Fire	41.1779286	-8.5960508	reported

Orders Received:

Id	Time	Type	Latitude	Longitude	Status
30	27-02-2016 - 16:25:29	move	41.1792655	-8.5939556	completed
>>>	27-02-2016 - 16:17:50				accepted
>>>	27-02-2016 - 16:17:44				issued

Mensagens:

Id	Time	Direction	Text	Status
67	27-02-2016 - 15:56:01	From Command	Ja vos estou a ver, esperem por favor	timeout
69	27-02-2016 - 16:03:03	From Command	podem seguir	timeout
75	27-02-2016 - 16:03:58	From Command	podes voltar	timeout

Code: 2 **Username:** João **Full Name:** João Jacob	

Reported events:

Id	Time	Type	Latitude	Longitude	Current
50	27-02-2016 - 16:04:36	Fire	41.1792146	-8.5945883	reported

Orders Received:

Id	Time	Type	Latitude	Longitude	Status
31	27-02-2016 - 16:23:22	move	41.1791596	-8.5945894	completed
>>>	27-02-2016 - 16:20:38				accepted
>>>	27-02-2016 - 16:20:34				issued

Mensagens:

Id	Time	Direction	Text	Status
68	27-02-2016 - 15:56:01	From Command	Ja vos estou a ver, esperem por favor	timeout
70	27-02-2016 - 16:03:04	From Command	podem seguir	timeout

Code: 3 **Username:** Pedro **Full Name:** Pedro Flores	

Reported events:
No Events

Orders Received:

Id	Time	Type	Latitude	Longitude	Status
32	27-02-2016 - 16:23:00	move	41.1779307	-8.5960587	completed
>>>	27-02-2016 - 16:21:16				accepted
>>>	27-02-2016 - 16:21:12				issued

Mensagens:

Id	Time	Direction	Text	Status
71	27-02-2016 - 16:03:04	From Command	podem seguir	timeout

Code: 4
Username: VUCI 13
Full Name: Veiculo Urbano de Combate a Incêndios

Reported events:

Id	Time	Type	Latitude	Longitude	Current
47	10-03-2016 - 14:31:47	Victim	41.1777816	-8.5950633	timeout
>>>	05-03-2016 - 22:42:21				timeout
>>>	27-02-2016 - 16:21:25				timeout
>>>	27-02-2016 - 16:20:31				timeout
>>>	27-02-2016 - 16:04:04				accepted
>>>	27-02-2016 - 16:03:48				accepted
>>>	27-02-2016 - 16:03:38				timeout
>>>	27-02-2016 - 16:02:44				reported

Orders Received:

Id	Time	Type	Latitude	Longitude	Status
35	27-02-2016 - 16:38:20	move	41.1771544	-8.5955925	completed
>>>	27-02-2016 - 16:25:05				accepted
>>>	27-02-2016 - 16:25:01				issued

Mensagens:

Id	Time	Direction	Text	Status
72	27-02-2016 - 16:03:05	From Command	podem seguir	timeout
74	27-02-2016 - 16:03:33	From Command	podes voltar	timeout

Code: 5
Username: Joaquim
Full Name: Joaquim Madeira

Reported events:

Id	Time	Type	Latitude	Longitude	Current
49	27-02-2016 - 16:04:20	Victim	41.1771762	-8.5955926	reported
51	27-02-2016 - 16:22:20	Victim	41.1775427	-8.5946138	reported
52	27-02-2016 - 16:28:38	Victim	41.1776071	-8.5948010	reported

Orders Received:

Id	Time	Type	Latitude	Longitude	Status
33	27-02-2016 - 16:23:30	move	41.1771904	-8.5955863	overridden
>>>	27-02-2016 - 16:22:13				issued
34	27-02-2016 - 16:26:46	move	41.1771902	-8.5955339	overridden
>>>	27-02-2016 - 16:23:30				issued
36	27-02-2016 - 16:29:23	move	41.1776105	-8.5946478	overridden
>>>	27-02-2016 - 16:26:46				issued
37	27-02-2016 - 16:29:23	move	41.1779545	-8.5951309	issued

Mensagens:

Id	Time	Direction	Text	Status
73	27-02-2016 - 16:03:05	From Command	podem seguir	timeout
76	27-02-2016 - 16:25:42	From Command	sdgdshfjghsdgf	timeout

Report Generated On: 15:21:36 - 30/12/2017