ROBOTICS ASSISTANCE TO PROTECTION SERVICES: USERS REQUIREMENTS

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ABSTRACT

Mobile robots are beginning to be applied for search and rescue operations. These applications are related to security and environmental surveillance, for instance prevention of disasters, intervention during disasters, assisting in fire-fighting and other protection services. A central point for these various kinds of missions is to ensure the safety of the human rescue workers and where possible the safety of human casualties. Let us mention the well known EOD and IEDD missions already entrusted to military Units in charge of the localisation, neutralisation and/or removal of explosive devices: humanitarian de-mining campaigns and intervention/inspection by terrorist threats are typical examples of missions that may be conducted with the support of mobile robots.

The Guardians and View-Finder projects both are concerned with safe and rescue operations, though from different perspectives. Common for both projects is the need for information. In the early stage of an emergency, being it a fire or any other emergency, very little is known about the seriousness and scale of the crisis. Risk analysis is a necessary but time consuming pre-requisite, that could delay the real rescue operation. An obvious prerequisite is to establish whether the ground or area can be entered safely by human emergency workers.
The VIEW-FINDER and GUARDIANS projects are to develop robotics systems which have a major task in gathering data to support continuous risk analysis, by providing information to the incident commander and others concerned. Obviously, chemical sensors are an essential element in the battery of sensors needed to perform the task.

The VIEW-FINDER project looks at the more general aspects of crisis management. It investigates how robots supported by extensive automated data processing in a base station can contribute to managing a crisis, on the incident ground as well as the higher-level (municipal, provincial or national) Crisis Management Centres. The main task of the robots is information gathering while the base station has to represent and distribute the information at different levels of detail as required by the different roles of the users.

The GUARDIANS project focuses on a fire emergency in an industrial warehouse. These warehouses are of huge dimensions: 100x180 meters for a single compartment of a warehouse is not an exception. In case of a fire, it is expected that the fire (initially) is confined to a specific area but the smoke will cover the whole warehouse compartment. The GUARDIANS project applies a swarm of robots, which have to search the smoke covered warehouse. They are provided with mobile communication units and can perform ad hoc networking and position detection. A very particular task is that the robots also have to be able to assist and safeguard a crew of (usually two) human fire fighters.

In this paper we combine the user requirements listed in each of the projects, as they are complementary. We will first discuss the VIEW-FINDER requirements and in the second part go into the GUARDIANS applied for a warehouse and similar large sale buildings.

Part 1, Crisis Management Requirements

On site, both projects will deploy a *base station* as the central point where the robots deliver their data. In the base station developed in the View-Finder project will be connected onwards to a Crisis Management Centre, that is, if the situation requires (decision of the Operation and/or Incident Officer).

Robotics assistance should meet the following overall requirements, which we discuss below:

- Improvement of the **Security/Safety** of the Intervention Team
- **Rapid** Deployment of Intervention Team
- Operation in **Contaminated** Environments
- Implementation of Reliable Chemical **Detection** means
- Hazard Prediction Modelling (Mapping/Training/Testing through **Simulation** Tools)
- **Secure** Voice and visual **Data**

IMPROVEMENT OF THE SECURITY/SAFETY OF THE INTERVENTION TEAMS

Responsibles of the National Disaster Management Centres of Italy, Greece, Belgium and Poland (namely the Italian Ministry of the Interior, Fire Brigades Department of Public Rescue and the Civil Defence. Central Management of Logistic and Operational resources, the General Direction Crisis Centre of Belgian ministry of Interior, State Fire Protection of Poland) as well as End-Users directly involved in both projects (SYFIRE-UK or South Yorkshire Fire & Rescue Service, IGN-BE or National Geographic Institute, BFAST-BE or Belgian Fast Aid and Support Team, the Extra-departmental Office of Civil Protection, Municipality of Rome) and indirectly interested Fire-Fighting and Civilian Protection Services have been consulted and clearly defined the possible interest of Robotics Assistance (in the general sense of Robotics) in next fields:

a) Fire, Explosion, earthquake, buried people: transmission of remotely taken photography in dangerous or inaccessible areas (including underground areas)
b) Breaking up of a container of toxic material: remotely controlled manipulation in dangerous or inaccessible areas (including underground areas)
c) Nuclear Incident: remote measurement of radio-activity
d) Bacteriologic or Chemical Incident: remote measurement of toxic concentration and remote taking of samples
e) Gas-leak or inflammable liquid-leak : remote measurement of explosion risk
f) Terrorist threat: explosive detection
g) Aerial photography

The Fields c, f and the bacteriological aspect of the d task will not be treated by our projects. While VIEW-FINDER will essentially focus on the tasks a (excluding the sub-aquatic areas), b

(limited to the capacities of normal EOD-like robots), d, e and g (focusing on the exploitation of geographical information available from different sources and processed in order to deliver effective crisis management tools, including basic suitable intervention maps allowing the path planning of robots.

In VIEW-FINDER a reliable Network of Information connecting a dedicated Base Station (Crisis Operational Centre or COC located near the Operation Commander Post (PC-Ops)), the robots moving on the crisis-area and the municipal, provincial or national Crisis Management Centres (CRMC) plays a major role in the development of an Intelligent Information System (Crisis Management Information System or CMIS). The base station includes also the major processing unit which interprets and represents the data originating from the various sensors carried by the robots. This Network corresponds to the left side of figure 1 with robots sending and receiving data to/from the base station while the same base station send and receives information (2D/3D maps including data on the possible dispersion of a chemical plume) to and from the CRMC.

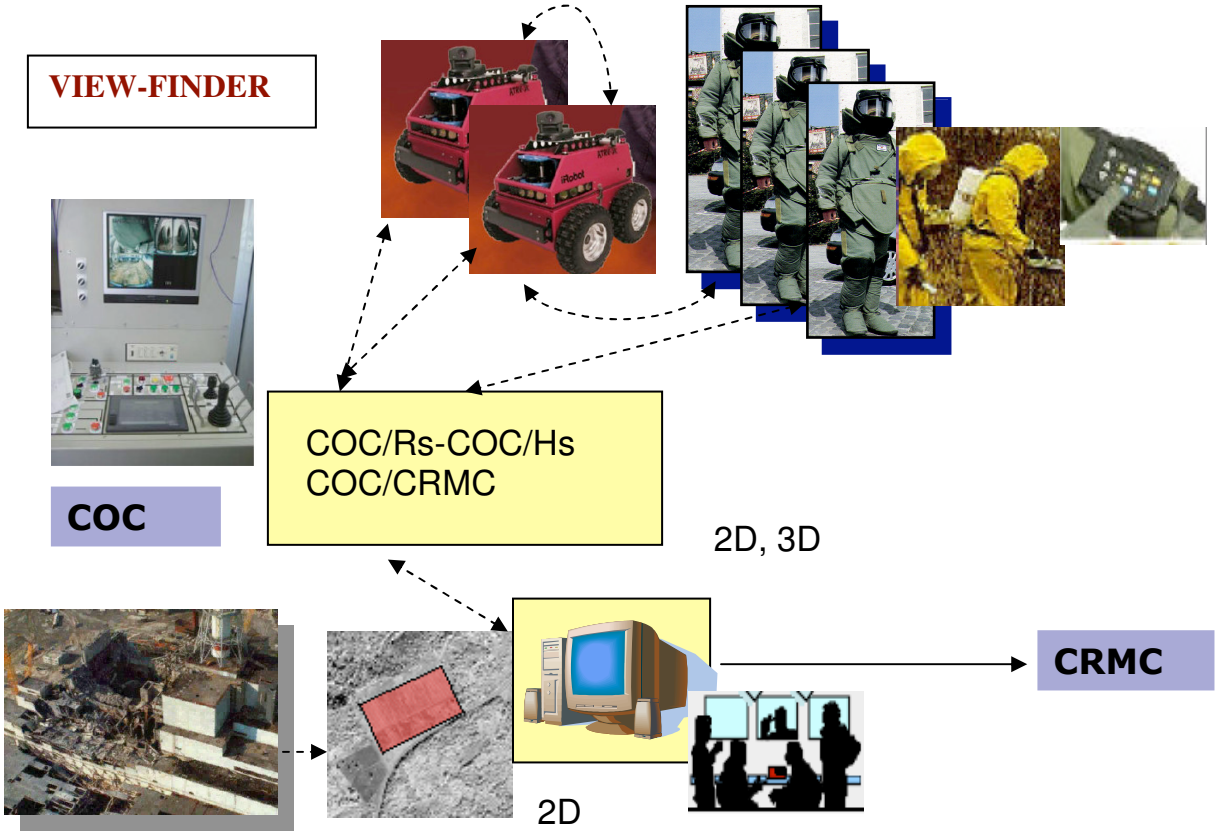

Figure 1. Crisis Information/Action Network

OPERATION IN CONTAMINATED ENVIRONMENT

Typical scenarios have consequently been proposed by/with the support of the End-Users, leading to first equivalent simulated scenarios aiming the assessment of the practical difficulties that would need to be overcome in order to realise effective robot assistance. They are:

(1) the crash of an airplane on/near an industrial zone (will be refined by January 2009 in accordance with the existing normalised procedures and in close cooperation with the Belgian DOVO (Intervention IEDD Service) , as illustrated by the fig 2

(2) the intervention in a SEVESO site where an explosion affects one industrial building inducing the risk of an extended fire as well as the dissemination of toxic plume (will be refined by December 2009 in accordance with the European 2003/105/EC (or subsequent) SEVESO procedures and in close cooperation with the Municipality of SENEFFE (the location of the final validation of the integrated modular V-F has still to be confirmed, and could be an extension of the first scenario), as illustrated by the fig 3

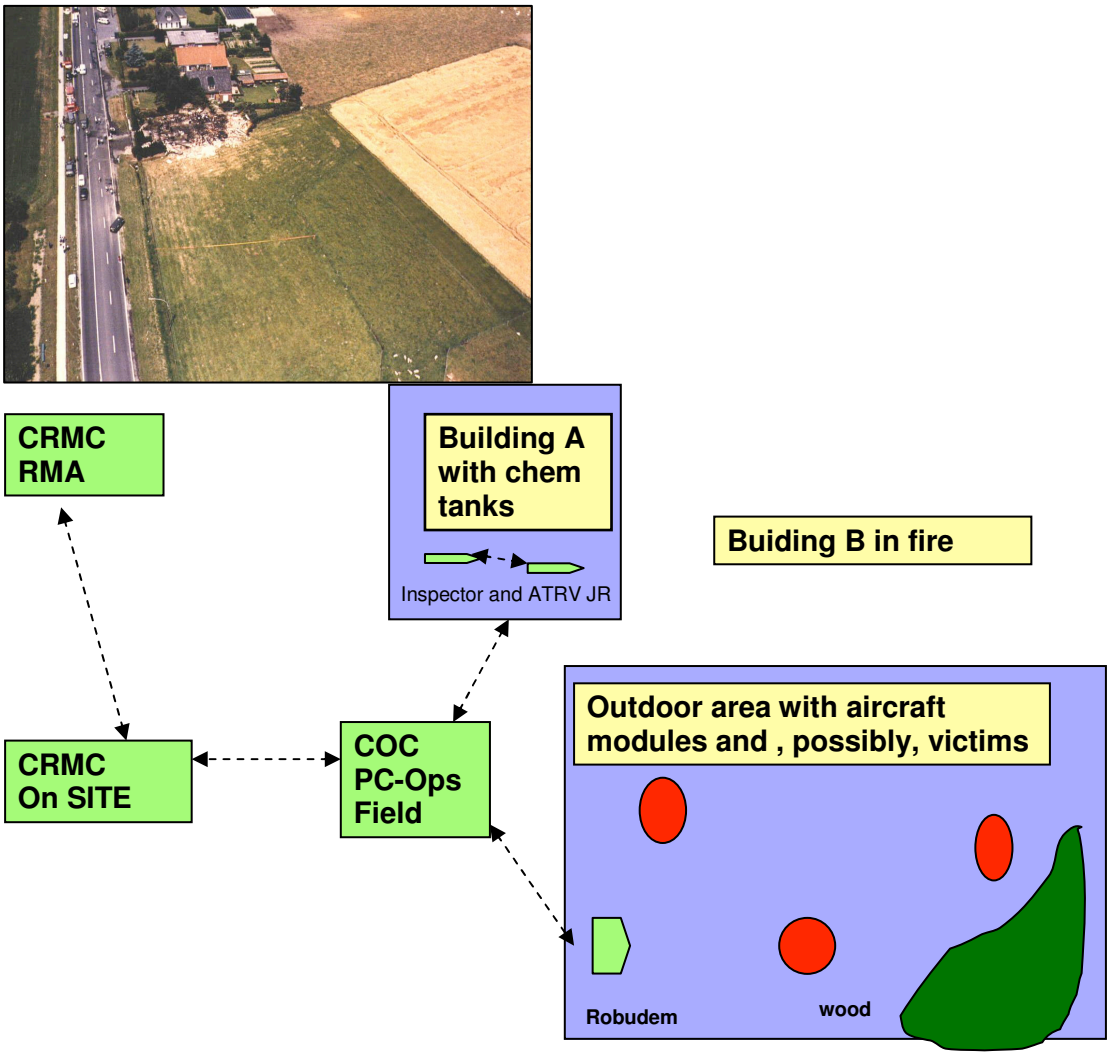

Fig 2. Example of the crash of a Mig 23 near Belleghem, in Belgium 1989, Schematic corresponding 2009 Network.

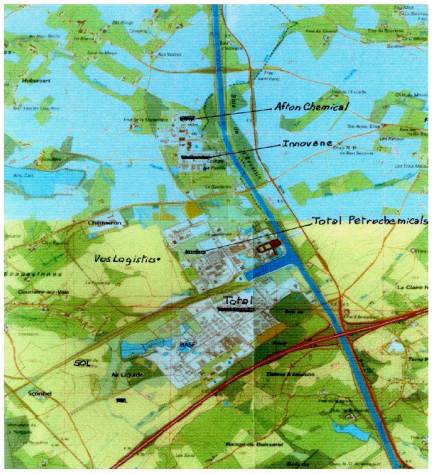

Fig 3. 2D Map of the Seneffe Zoning (including the permanent measurement points of chemical concentrations), 3D view of an industrial area in fire

IMPLEMENTATION OF RELIABLE CHEMICAL DETECTION MEANS

After discussions with South Yorkshire Fire and Rescue Services following gases and vapours were identified as the target analytes to be detected by the sensor arrays. The analytes can be split into two groups called vapours and gases. The first group includes the compounds which exist in both liquid and gaseous forms at room temperature and normal atmospheric pressure. In the thermodynamic equilibrium, the vapours can be characterised with the parameter of saturated vapour pressure. In contrast, gases could be condensed into the liquid form at low temperatures and/or high pressure

Vapours:
- Hydrocarbons (hexane, cyclohexane, octane, and higher hydrocarbons constituting petrol)
- Alcohols (methanol, ethanol, butanol, propanol)
- Ketones (acetone, ethylmethylketone)
- Ethers
- Aromatics (benzene, toluene, ethylbenzene, xylene,)
- Chlorohydrocarbons (chloroform, dichlormethane, dichlorethane)

Gases:
Electronegative (oxidising gases):
- Oxygen,
- Chlorine,
- Hydrogen Chloride,
- Hydrogen Cyanide (cyanide gas),

Electro-positive (reduction gases):
- Hydrogen
- Carbon Monoxide,
- Ammonia,
- Low hydrocarbons (methane, ethane, butane, propane constituting natural gas),
- Acetylene

It is to be noted that commercial detectors with possible computer interface now appears on the market. Dräger is a well known Gas detection manufacturer (USA) providing a lot of portable instruments allowing ‘hands-free’ measurement and alarm at hazardous levels of

gases or vapour ; In the previous list, some gases may already been detected by the most Civilian Protection Units with the portable HAZ-MAT Kit (Belgium, for instance). Obviously , the VF and G projects intend to improve the safety (of the Fire-Fighters) by providing a remote detection.

RAPID DEPLOYMENT OF THE INTERVENTION TEAM

Two real scenarios have been analysed: the Staniforth Road Fire Incident (UK) and the Feluy Incident (BE), both implying the involvement of a municipal Crisis Centre.

In both cases, after a first evaluation of the Fire consequences by the local Fire fighting service, the on-site Crisis Management Commando Post (under control of the appropriate Incident Commander) was ready at **H + 20 min**.
In both cases, several actions (for instance, the venue of an expert to evaluate the chemical pollution and suggest evacuation measures, as it was the case in Feluy, or, the request of additional appliances, as it was the case in Staniforth) were conducted between H+20 and **H+50 min**.
Both Fire-Fighting Services would then dispose of a VF or G-like appliance to further treat the incident under safe conditions.
As soon as a higher level crisis Centre is open (Municipality), graphical information should be exchanged between the higher level CRMC (provincial, national) and the COC, normally located at the regional level. It's however recommended that every Regional Intervention COC would have the GI of the Region. That problem is far from solved. Only 'sensitive zones' (as SEVESO) seem to be 'mapped' in Urgency Plans (available at all levels).
In both cases, the VF or G team should be ready to intervene **at H+20 at the soonest, at H + 50 min at the latest.**

Part 2, Warehouse Incident

The GUARDIANS project focuses on the particular event of an Industrial Warehouse under smoke. Below a brief review of the start and the development of the intervention by the Fire service. We look at the command structure, risk assessment and finally at deploying a robot swarm for searching.

COMMAND

The fire brigade responds to any alarm, not knowing whether it is real or false. Initially, when arriving at a real incident they have very little information. The first task of the arriving crew is to assess the incident, in particular from the point of view of safety. The team leader becomes the Incident Commander and reports; if the incident appears to be of a large scale the Incident Commander will call for further assistance.

With the arrival of more appliances and crew a further division of labor and command occurs and the role of Incident Commander is –depending on skills- passed on to senior officers. The division of command is made as simple and clear as is possible and usually also made visible by applying special role dependent jackets. Moreover, the span of control for any officer is arranged to be between 3 and 5 lines of communication, in order to avoid an overload (and consequently neglect of) information. To achieve this, SYFIRE makes a distinction between

the roles of Incident Commander and the Operations Commander (Ops Com). Currently the Operations Commander deals with the crews and appliances that are directly involved. The Incident Commander (IC) deals with the overall supervision of the incident, the operations support and the off site communication. Off site communications concern local authorities, ambulance, press etc, refer to Part 1 above.

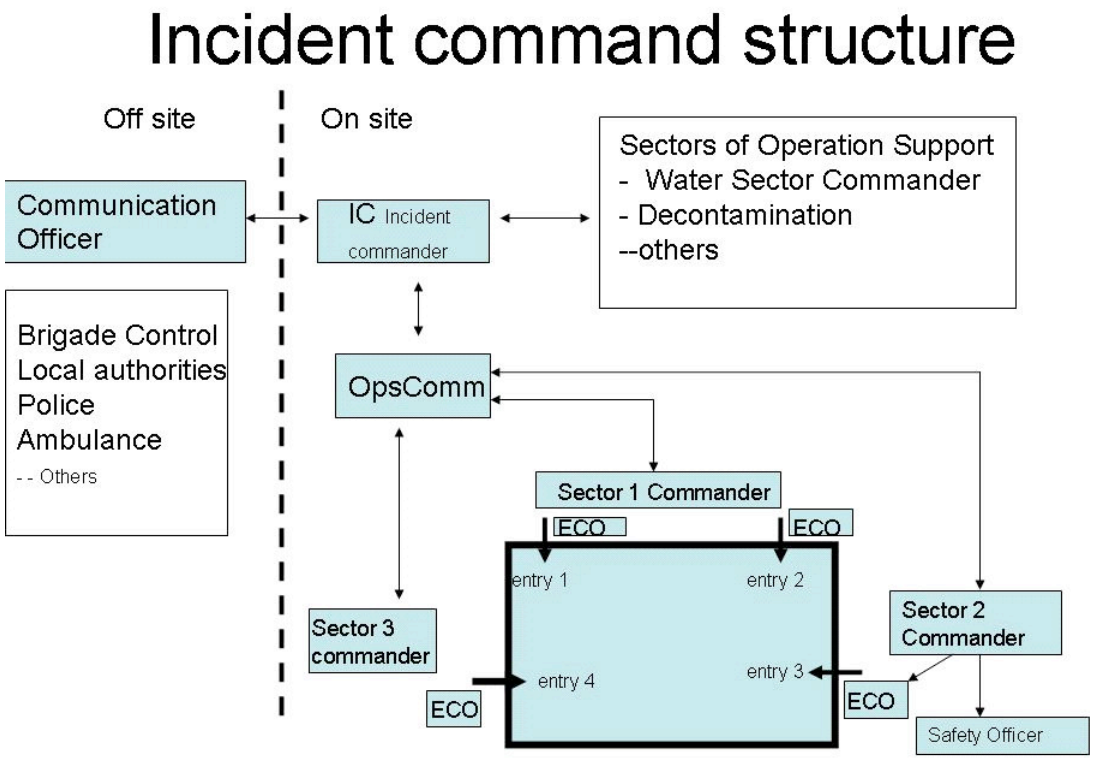

Figure 4, Fire service command structure

User Requirement: Important when applying robots and a base station is that the command lines should not be disrupted and that the level of detail of the information provided suits the role of the user.

RISKS AND SAFETY

A decisive factor for any intervention by fire fighters is safety; the risk and safety assessments. The key elements of any assessment of risk are:
- Identification of the hazards;
- Assessment of the risks associated with the hazards;
- Identification of who is at risk;
- The effective application of measures that control the risk.

Based on the assessment, a strategy will be chosen. The safety of the fire fighters is a priority and determines to a great extend the choice. Moreover, many of the procedures applied are aimed at ensuring the safety of the fire fighters. The overall rules for selecting the strategy are:

- Fire-fighters will take some risk to save saveable lives.

- Fire-fighters will take a little risk to save saveable property.
- Fire-fighters will not take any risk at all to try to save lives or property that are already lost.

Robots that gather information obviously can contribute to the risk assessment. Chemical and other sensors may provide valuable information to identify hazards. Moreover, robots can be applied in situations that are too dangerous for human beings and thus provide otherwise unavailable information.

Warehouse search procedure

Based on risk assessment a strategy will be chosen and a search of the warehouse might have been decided on. The commander will also decide about deploying robots and whether or not human fire fighters will be send as well. The GUARDIANS robot swarm is developed to be applied as an autonomous robot swarm as well as a swarm that assists and possibly guides a human crew.

A human crew will be wearing breathing apparatus and the procedures for searching a smoke ground are (in the UK) laid down in the breathing apparatus (BA) procedures. Breathing apparatus command and control procedures distinguish stage I and stage II incidents. A warehouse fire would probably classify as a stage II incident meaning that numerous control and safety procedures apply. Relevant here is the appointment of an Entry Control Officer for each entry point. Duties include:

- Updating of the Entry Control Board (who went in/out and when).
- Check BA 's 'Time of Whistle'. (The cylinders contain roughly 20 minutes of air supply).
- Liaison with other Entry Control Points.
- Liaison with Main Control.
- Maintain contact with the crew inside.
- Having a fully equipped emergency BA team standing by.

The BA wearers entering the risk area apply a guideline, which enables

-The team of BA wearers in a risk area to retrace their steps to the entry point;
- Subsequent teams to readily locate a team of BA wearers;
- Subsequent teams to locate the scene of operations.

Guideline procedure:
The 'guideline' is a special line which is used to indicate a route between the Entry Control Point and the scene of operations. At larger scenes branch lines [of the same type] may be used. The individual BA wearers attach themselves using a personal line (1.25m) to the guideline or to each other.

The guideline is secured to an object outside the risk area and is under control of the Entry Control Officer. Laying the guideline, the BA team would follow a wall or similar guiding structure, starting either to the left or the right of the point of entry. The guideline is secured at intervals to suitable objects and is kept off the floor, branch lines are connected to the main guideline.

Usually a two person squad is deployed. One fire-fighter (the squad leader) moves forward feeling for obstacles/survivors and testing the integrity of the floor as he goes. The other fire-

fighter holds on to the leader and communicates with him verbally. His job is to communicate with the Entry Control. At the firetraining (January 2007) we clocked an experienced crew of two firefighters following the guideline, they proceeded about 12 meters in one minute. This means that with full cylinders (20 minutes of air) they can advance 240 meters.

The GUARDIANS project applies a swarm of robots provided with wireless communication facilities that enable ad-hoc mobile networking; they perform position detection and carry chemical sensors. When the robots are to assist a BA crew they first of all should not increase the cognitive load of the human crew, the crew needs full attention to guard their own safety. Therefore the robots must be autonomous.

When applied, robots could have the following roles:
- ensure wireless connectivity;
- perform position detection of the crew;
- explore the area in advance of or in addition to the human crew;
-'replace' the guideline by positioning themselves in a secure route from the Human crew back to the Entry Point and guide the humans.

SOME CONCLUSION ON THE IMPORTANCE OF THE PROJECTS

It has been interesting to statistically evaluate the frequency of the proposed V-F and/or G teams; the next table summarizes the number of interventions of Fire-Fighting Services in 2005 in Belgium.

Nature of intervention	Number of interventions	Number of men/hours
fire	215	4244
flooding	196	7537
water supply	398	6474
pollution	1198	14868
pollution	1198	14868
road accident	248	1739
collapse	26	250
explosion	7	71
explosion	7	71
storm	43	464
water rescue	68	2360
bomb alert	3	62
bomb alert	3	62
nests of wasps	42	59
transports and roadwork's	261	4866
humanitarian intervention	174	12120
preventive intervention	76	2099
logistic intervention	375	9857
demonstration / exercise	104	5134
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legal aid	81	4023
other	116	5803
Total	**3631**	**81769**

A GUARDIANS Teams safe guarding Fire-Fighters facing dangerous conditions should be useful in the cases of fires, pollution and possibly 42% incidents (yellow), while VIEW-FINDER results - Network of Graphical data among Crisis Centres **and/or** Gathering of 'Visual' data on the field - should be requested in 38 % (blue).

The Human Life has no price and the basic objective of VIEW-FINDER and GUARDIANS really fits the needs of Fire-Fighting and Protection services which already lost a considerable number of members. That has been confirmed by the Panel Advisory Panel.

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