THE USE OF UGVs IN EARTHQUAKE RESPONSE OPERATIONS

Authors: EFFIE MAKRI, PHILIPPE CHROBOCINSKI

Affiliation: TELINT RTD Consultancy Services Ltd., CASSIDIAN SAS - DARIUS project FP7 SEC

Keywords: Disaster response, Earthquake, UGV, Generic Ground Station, sensors

Abstract

Most of existing UGVs have been designed to replace humans in hazardous environment (CBRNE hazards). These environments are however generally structured and accessible. DARIUS project (FP7 SEC, Use of unmanned platforms for SAR missions) is studying the usage of UGVs in highly unstructured environments resulting from large earthquakes and possibly associated with Seveso risks. This usage is studied not only to protect the first responders against the threats but also as a force multiplier that would allow to speed-up the search and rescue operations.
DARIUS have already identified the gaps and shortcomings of the existing solutions (obstacles crossing, navigability in rubbles, continuity of communications between outdoor and indoor segments, specialisation/customisation of sensors and payloads). The study also integrates the legal constraints and the environmental constraints. DARIUS system concepts and technological demonstrators will be tested in real environment to assess the added-value of the multi-agencies and multi-platforms interoperability solutions and to draw a realistic roadmap to offer quickly adapted and affordable UGVs for these missions.

Section 1 Introduction

The crisis management operations in case of large scale disasters are confronted with two major issues:

- The deployment of the forces, assets and systems;
- The coordination of the operations in a multi-National and multi-agency context.

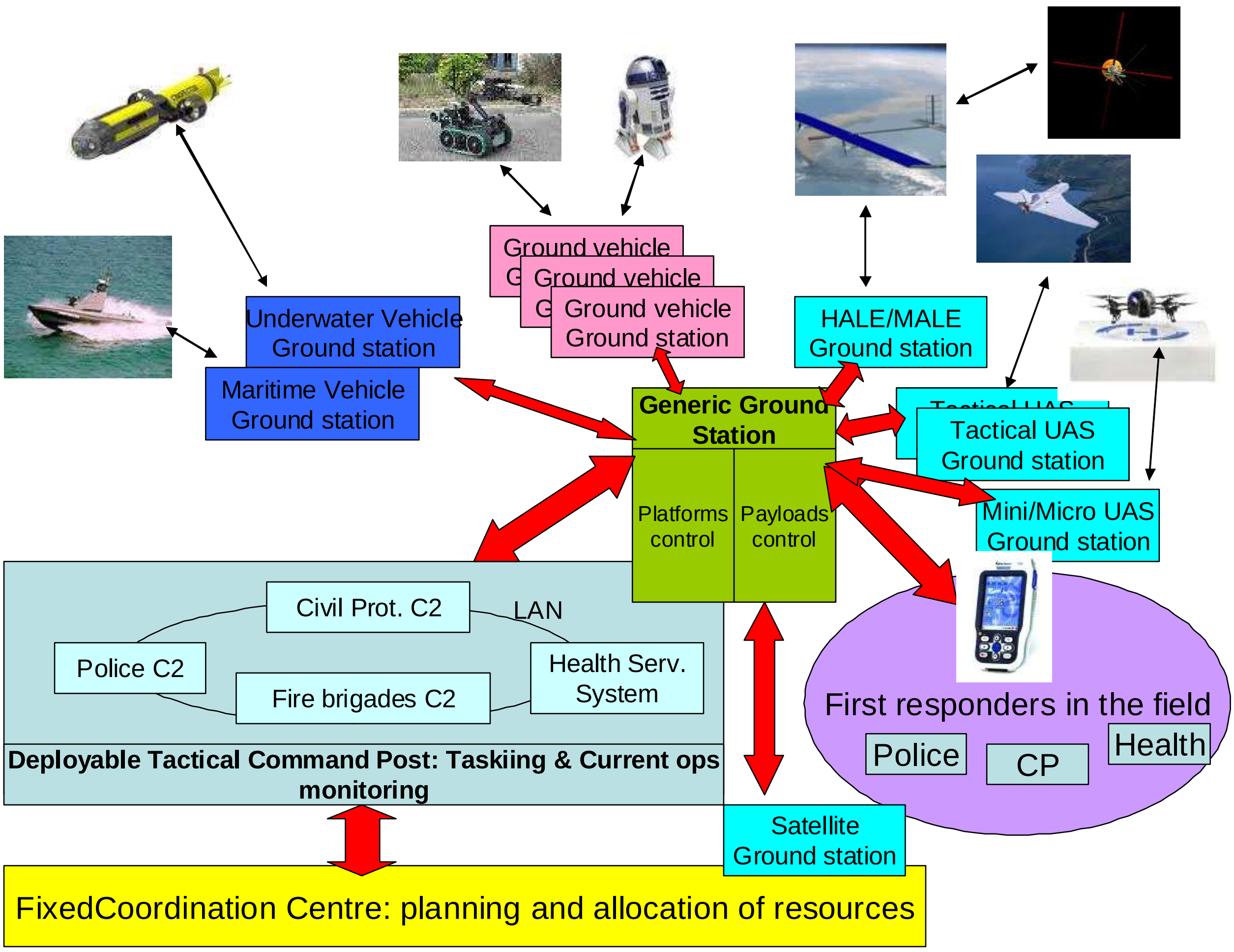
These two issues need to be addressed so as to allow a better reaction time to save more people and goods. When statistically 80% of life saving occur during the 48 first hours, the impact of improving the reaction delays is obviously essential.

For the Search And Rescue operations, which are the most urgent and important tasks during the crisis management phase, DARIUS aims at enhancing the situation by integrating Unmanned solutions which will allow:

- Quicker deployment capabilities to rapidly perform a first accurate damage assessment that will be the basic information to dimension the reaction;
- Enhance the research capabilities by complementing the forces with unmanned platforms where needed;
- Enable the research operations in hazardous areas (collapsed/weakened buildings, toxic/noxious environments);
- Speed-up the delivery of first aid kits in areas that are not easily accessible to classical vehicles;
- Provide a permanent capability to monitor the operations;
- Provide support for the recovery phase (interim communications capabilities through an airborne relay).
-

The project concept will be to integrate in a seamless way the unmanned platforms into the overall reaction forces system while aiming at enabling their management as wide assets that can be operated in a multi-agency and multi-National way.

The following figure illustrates the DARIUS concept:



3 scenarios have been envisaged for DARIUS project:

1. Earthquake in an urban area with important damages to buildings and a lot of missing persons (Haiti or L'Aquila type), including Seveso-type plant accident with Chemical cloud (or N hazards) and
2. Forest Fire
3. SAR in Maritime area - possibly linked to illegal immigration or combined with the earthquake in a sea border city/harbour.

The 3 scenarios will cover most of the possible use cases as they involve differently several types of unmanned platforms with specific constraints: more UASs for maritime issues and more robots/ground vehicles for SAR in collapsed or weaken buildings. Of course, for the real demos, we will certainly group the scenarios.. Where possible, DARIUS will use real demos.

Listed below are the major domains/technical objectives DARIUS wants to address (not in hierarchical order):

1. Provide a full and effective communication coverage of the area of interest: Satellite/Tactical Data Links/deployable wireless "bubble"/beacons;
2. Enhance the Situation awareness (damage assessment and current operations monitoring): - Unmanned platform sensors + dropped/abandoned sensors;
3. Integrate unmanned platforms in the overall operations planning: Command and Control systems;
4. Integrate unmanned platforms in the tasking process: Command and Control systems;
5. Integrate the unmanned platforms in the current operations monitoring: control of unmanned platforms with various levels of operators intervention;
6. Develop a generic ground station able to control any type of unmanned platform, to coordinate them with a strong link with the C2 system and to share the unmanned platforms between several agencies;
7. Provide smart solutions for the essential deployment issues (transport, and autonomy of use).

Section 2 Theory and methods

While the main objective of DARIUS is to provide interoperability solutions to integrate heterogeneous UGVs inside a large multi-National and multi-agency system, the UGVs will be tested in real conditions for their main functions considered in the project:

- Mapping of terrains and buildings,
- Research of casualties,
- Bringing support and first aid to trapped/wounded people,
- Communication relay (ad hoc meshed network) to warrant communication continuity in difficult terrain (indoor/tunnels).

In DARIUS, the UGV segment is composed of:

- The ground stations (piloting the platforms, the sensors, receiving and exploiting the sensors data);
- The data links between the ground stations and the platforms;

- The platforms (robots) themselves (represented in the project by ECA Cameleon and BAES Robovolc);
- The sensors and payloads that can be integrated to the platforms;
- And the link between the specific ground stations and the Generic Ground Station (GGS) (DARIUS concept) that acts as an interface between the C2 systems and the unmanned segment. The GGS has been designed both to manage a large fleet of heterogeneous unmanned systems (UAVs, UGVs and USVs) and to implement the capability to connect all the ground stations in a standardised network to share the relevant data between all the agencies.

DARIUS being an integration projects, the test campaign will be two-fold:

- Factory testing: the robots will be integrated to the Command & Control system and the GGS and tests will be conducted on realistic simulated simulation, using the factory site buildings as a real crisis environment;
- Trials: A complete detailed scenario has been elaborated to test the UGVs in real conditions. The scenario will be played in 2 sites: 1. A Seveso site in Sorgues near Avignon to test the operability of the UGVs in underground conditions (communications connectivity, mapping and research) and a trial site in Vaucluse for all SAR functions testing. The trials are supported by SDIS 84.

The trials will combine the tests of the intrinsic capabilities of each UGV (navigation, obstacles handling, research capabilities with the various sensors, Rescue/Support capabilities) and a broader interoperability test between heterogeneous systems.

UGVs presentation

DARIUS will use two UGVs: The CAMELEON developed by ECA and the ROBOVOLC developed by BAE Systems.

Figure 1 CAMELEON Vehicle

Robovolc description

In order to facilitate real-world demonstrations, BAE Systems' Robovolc is provided by a team at the Advanced Technology Centre (ATC). Originally designed for volcanic exploration as part of a collaborative European project of the same name [1], Robovolc offers proven all-terrain capabilities with its six wheeled skid steer drive train, in addition to fully articulating front and rear axles designed with 3 degrees of freedom through roll, pitch and linear travel.

The drive train consists of six, high torque gear-head motors and custom tyres with the capability of traversing the expected terrain types, maximising mobility. The system control software provides the versatility to operate in the range between 0.1 - 1m/s, catering for the ability to autonomously navigate at speed as well as performing delicate manoeuvres through narrow paths. The option of using an external generator further provides the capacity for continuous operation for seven hours.

The platforms physical architecture and software systems have been designed to allow the rapid integration and validation of 3rd party hardware payloads and software components. The ATC software implements an Autonomous Systems Architecture (ASA) [2] framework, which permits inter-process communications through CORBA using TCP/IP or UDP. The ASA design architecture further promotes the ability for rapid integration though 'plug and play' capabilities, using a common interface language between software components.

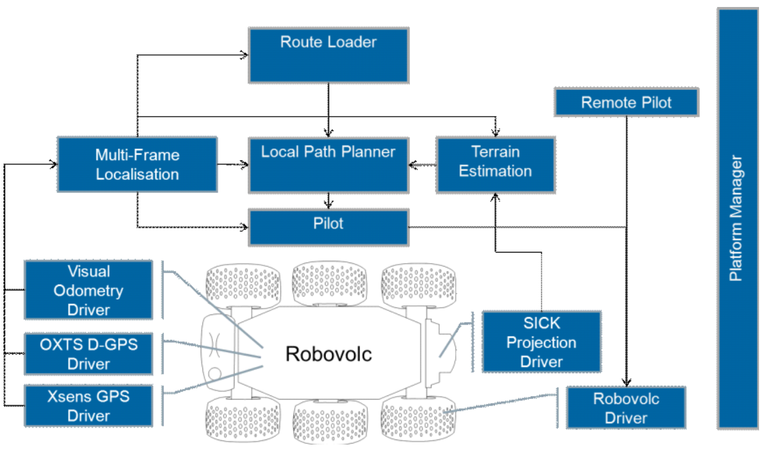


Figure 2- Hierarchical design of ATC - ASA system components

As part of the ATCs Autonomous Navigation System (ASA-NS), Robovolc is equipped with a number of software components to enable the localisation, planning, terrain estimation and control of the platform. Furthermore a Control Station interface has been specifically designed for the DARIUS project, to permit the integration of external Control Stations using a defined UDP protocol.

Robovolc is outfitted with a number of state of the art sensors that included high resolution encoders for Wheel Odometry, Point Grey Bumblebee XB3 for Visual Odometry, Point Grey Ladybug for 360° Teleoperation video streaming and an OXTS RT3003 D-GPS for attitude and heading measurement. A Wi-Fi infrastructure is also provided, which enables a Control Station to maintain point-to-point communications over a 2km range.

Robovolc has participated in a number of projects proving its reliability and robustness, and providing the capability to effortlessly traverse difficult and varied terrain; ensuring maximum time for software integration and experimentation. The most recent of these projects include:

- Demonstrating GPS Denied navigation for the Office of Naval Research [3].
- Participating in airport security under a European Framework 7 program named Total Airport Security System (TASS) [4].
- Performing autonomous long range rover navigation for the European Space Agency in the Atacama Desert, Chile [5].

Figure 2 – Robovolc located at BAe Brabazon Hangers, Bristol

Section 3 Results

The real trials will take place in June 2014. The tests that will be conducted are described in the following table.

The Urban/Indoor scenario phases and response are presented to the following table:

Stages	Response scenario
I. Victims	DFRC UAV localize the victims by using the phone detector ReSSAC ONERA confirms the victims by post-analyzing his recorded information (low altitude)
II. Hot spot	TANAN UAV is patrolling above the plant area (medium/high altitude) to identify a pollution DFRC UAV localize precisely the pollution origin (very low altitude)
III. Mapping	CAMELEON maps the bunker by using the LIDAR and send the data by using ROBOVOLC as a relay. CAMELEON identify the pollution source and the concerned products
IV Monitoring	ROBOVOLC survey the presence of victims by using the phone detector tool CAMELEON and ROBOVOLC monitor the firefighters missions inside and outside the bunker (video, sensors).

During the scenario a special case in terms of interoperability will be tested. A UGV will enter a building that its construction does not permit the communication of the UGV with the outside world and the communication bubble. In order to solve this problem the following will be implemented: The UGV will be equipped with a WiFi module and will be able to communicate through WiFi with another UGV located at the front entrance of the building that maintains its connection to the communication bubble. This UGV will act as a relay by having a WiMAX module. The sensor data coming from the vehicle inside the building will be transmitted through WiFi to the relay-UGV and then retransmitted to the network using WiMAX. The data will be received by the GGS and any mission commands for further action will be transmitted through the network in both GCSs, the one of the vehicle located outside the building and the one located inside it. So, in this special case, in order to solve a situation that a vehicle do not access the network a vehicle is used as a relay having installed both WiMAX and WiFi modules beside any WiMaX module installed in their GCSs for transmitting data and receive mission commands. The following figure shows the communication links between the entities found under the communication bubble.

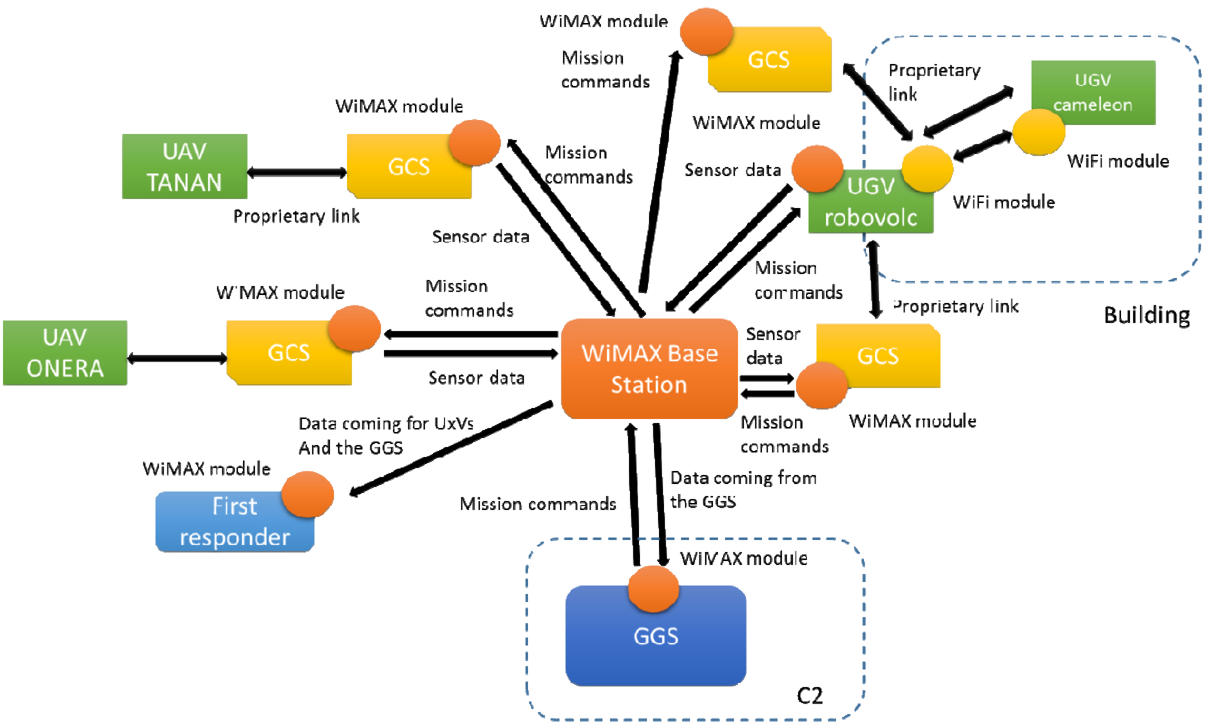


Figure 3 Communication flow for Earthquake/Seveso scenario

The systems are currently in the adaptation phase and the integration phase will start in January 2014.

Section 4 Discussion

Since the trials are still in their definition phase, DARIUS partners continue to work with end-users (already in the User Advisory Board or invited) to make the best possible tests to provide answers about the operability and added-value of the UGVs in this type of situation.

References

University Of Catania (Italy), Robots and Volcanoes. 1st March 2000. http://www.robovolc.dees.unict.it/system/system.htm

G. Callow, ‘Engineering Autonomous Systems Architecture’, SEAS DTC, 2008. http://www.seasdtc.com/events/2008_conference/downloads/pdf/systems_engineering_research/SER013_presentation.pdf

C. Smith, ‘Autonomous Navigation and Localization in GPS-Denied Environments in support of Expeditionary Capability’, BAE systems White Paper

http://www.tass-project.eu/

M. Woods, A. Shaw, E. Tidey, B. V. Pham, U. Artan, B. Maddison, G. Cross, ‘Seeker-Autonomous Long Range Rover Navigation for Remote Exploration’, i-SAIRAS 2012.

Alexander, D.E. 1985. Death and injury in earthquakes. Disasters 9(1): 57-60.

Alexander, D.E., 1986. Landslide damage to buildings. Environmental Geology and Water Science 8(3): 147-151.

Alexander, D.E. 2002. Principles of Emergency Planning and Management. Terra Publishing, Harpenden, UK and Oxford University Press, New York, 340 pp.

Alexander, D.E. 2008. Emergency command systems and major earthquake disasters. Journal of Seismology and Earthquake Engineering 10(3): 109-118.

Alexander, D.E. 2010. Mortality and morbidity risk in the L'Aquila, Italy, earthquake of 6 April 2009 and lessons to be learned. In R.S. Spence and E. Ho (eds) Proceedings of the Second International Workshop on Disaster Casualties, 15-16 June 2009, University of Cambridge, Cambridge, UK.

Barbolini, M., F. Cappabianca, B. Frigo and R. Sailer 2006. The vulnerability of buildings affected by powder avalanches. In W.J. Ammann, S. Dannenmann and L. Vulliet (eds) Risk 21: Coping with Risks Due to Natural Hazards in the 21st Century. A.A. Balkema, Taylor and Francis, London: 227-235.

Buck, D.A., J.E. Trainor and B.E. Aguirre 2006. A critical evaluation of the incident command system and NIMS. Journal of Homeland Security and Emergency Management 3(3): article 1.

Coburn, A. and R. Spence 2002. Earthquake Protection (2nd edition). Wiley, Chichester, UK, 420 pp.

Cooper, A.H. 2008. The classification, recording, databasing and use of information about building damage caused by subsidence and landslides. Quarterly Journal of Engineering Geology and Hydrogeology 41(3): 409-424.

Drabek, T.E. 1986. Human System Response to Disaster: An Inventory of Sociological Findings. Springer-Verlag, New York, 509 pp.

Mays, G.C. and P.D. Smith (eds) 1995. Blast Effects on Buildings. Thomas Telford, London.

McDonald, J.R. 1993. Damage mitigation and occupant protection. In Church, C. (ed.) The Tornado: Its Structure, Dynamics, Prediction and Hazards. Geophysical Monograph no. 79. American Geophysical Union., Washington, D.C.: 523-528.

Mileti, D.S. 1975. Disaster Relief and Rehabilitation in the United States: A Research Assessment. Natural Hazards Research and Applications Information Center, Boulder, Colorado.

Movahedi, H. 2005. Search, rescue, and care of the injured following the 2003 Bam, Iran, earthquake. Special issue on the 2003 Bam, Iran, earthquake. Earthquake Spectra 21(S1): S475-S485.

Palm, J. and E. Ramsell 2007. Developing local emergency management by co-ordination between municipalities in policy networks: experiences from Sweden. Journal of Contingencies and Crisis Management 15(4): 173-182.

Peek-Asa, C., M. Ramirez, H. Seligson and K. Shoaf 2003. Seismic, structural, and individual factors associated with earthquake related injury. Injury Prevention 9: 62-66.

Petrucci, O. and G. Gullì 2009. A support analysis framework for mass movement damage assessment: applications to case studies in Calabria (Italy). Natural Hazards and Earth System Sciences 9(2): 315-326.

Quarantelli, E.L. 1993. Organizational response to the Mexico City earthquake of 1985: characteristics and implications. Natural Hazards 8(1): 19-38.

Sharkansky, I. 2007. Local autonomy, non-governmental service providers and emergency management: an Israeli case. Journal of Homeland Security and Emergency Management 4(4), Art. 1.

Stewart, M.G., M.D. Netherton and D.V. Rosowsky 2006. Terrorism risks and blast damage to built infrastructure. Natural Hazards Review 7(3): 114-122.

UNDAC 2006. United Nations Disaster Assessment and Coordination (UNDAC) Handbook. Section H: Urban Search and Rescue. United Nations Office for the Coordination of Humanitarian Affairs, Geneva.

UN-OCHA 2008. International Search and Rescue Advisory Group (INSARAG) Guidelines and Methodology. Field Coordination Support Section (INSARAG Secretariat), United Nations Office for the Coordination of Humanitarian Affairs, Geneva, 153 pp.

Zuccaro,G. and D. Ianniello 2004. Interaction of pyroclastic flows with building structures in an urban settlement: a fluid-dynamic simulation impact model. Journal of Volcanology and Geothermal Research 133(1-4): 345-352.

Authors biography

Ms. Effie Makri holds a degree in Informatics Engineering from the Technological Educational Institute of Athens (1994) and a M.Sc. degree in Electronic Engineering from the University of Dublin, Trinity College (1996). She is the Director of TELINT RTD and she has been actively involved in a number of EU funded projects (DARIUS, SAVASA, PERSEUS, ACRIMAS, TASS, DITSEF, STARRS, COMANCHE, LIAISON, etc). Her research interests include management in Wireless LANs, middleware technologies, Wireless Ad□hoc and Sensor Networks and development of semantically enhanced knowledge management systems using ontological models.

Philippe CHROBOCINSKI has been working for 17 years in large system design, development and integration. He has been involved as a project manager in systems of systems military projects (C4ISR) and large civilian crisis management systems, for National, European and exportation customers. He is now the head of R&T for border surveillance and protection of critical infrastructure within CASSIDIAN.