ECA ROBOTICS, PROJECTS FOR FUTURE

overview on a six year R&D end users project

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Abstract

New threats and growing Cbrn risks have increased the advantages of robotic systems for inspection or intervention, especially in harsh environments.
For many years, French research programs have been developing a Land robotic system called Cameleon® in such context, under direct requirements of end users.
In fact, Bouches-du-Rhone fire department is the initiator and the operational leader of the program. A 'top-down' analysis and scenarios implementation have allowed the definition of robotic concept and its evaluation. This UGV ongoing project and its prototypes give now significant benefits to emergency services facing to unusual missions, giving really a good support.
After six years studies and development, this solution consists in a modular robot integrating a large choice of sensors and task modules: infra-red imaging, high definition camera, liquid and gas sampling, gamma spectrometer … The main idea is not to develop new dedicated detection systems, but to integrate the sensors previously detained by emergency services.
Complementary partners allowed this achievement: the ECA Company specialized in robotics, the national alternative energies and atomic energy commission, Cea, bringing its knowledge in gas and radioactivity detection technologies, and the research agency Ineris improving the device safety, regarding potentially explosive atmosphere.
Today, the ongoing program is to optimise the thermal resistance, create and test new mission modules, and enhance human / machine interface, enlarging the operational spectrum of the tool from Eod to military Cbrn defense.
This new tool is now in duty in some specialised squads, giving a good support to human Cbrn missions, and sometimes increasing the safety of first responders.

1. INTRODUCTION

The current evolution of threats and emergence of new, mainly Chemical, Biological, Radiological, Nuclear and Explosive (CBRNe) risks, have led to new requirements, which must be studied and taken into account in order to define the operational resources available to today's emergency teams.
Considering that robots available on the market just a decade ago were incapable of handling a relatively wide range of interventions and measurements in multiple and complex environments, Bouches-du-Rhône Fire department (Sdis 13) set many years ago its first studies on the topic. In addition, as these UGVs were developed for military applications or Explosive Ordnance Disposals (EOD) clearing, they were not fully adapted to the needs of civil protection first responders.
After choosing a designer and manufacturer, with deep expertise in robotics and system integration, ECA robotics company, some pluriannual projects were therefore launched in the aim of providing a response to current requirements. This program brought together various partners with complementary operational and technological skills:
Two firms (SMEs) in charge of developing accessories (e.g. detector integration),

Two national research institutes (CEA and INERIS) with expertise in radiological and chemical-related technologies and hazard management,
An ergonomics firm,
The French Academy for Fire, Rescue and Civil Protection Officers, and the Bouches-du–Rhône Fire Department (Sdis 13), possessing user experience and operational expertise.

2. THE PROTOTYPE

2.1 The mobile platform, invariant elements

The mobile base consists of a platform with caterpillar wheels. Its main characteristics are described in Table 1 below.

Table 1. *Technical characteristics*

Length:	670 mm (flippers stowed) +200 mm if flippers deployed
Width:	520 mm
Height:	200 mm (excl. antennes)
Ground clearance:	60 mm
Empty weight:	26,5 Kg
Load capacity:	25 Kg
Low speed:	from 0 to 0.8 m/s (3 Km/h approx)
High speed:	from 0 to 1.7 m/s (6 Km/h approx)
Spin turn:	Yes
Incline:	40° (88%)
Cant:	30° (66%)
Steps:	35° (77%)
Obstacle crossing:	16 cm forwards 25 cm reverse
Autonomy:	from 2 ½ to 8 hrs 2 ½ hrs locomotion on flat ground 8hrs on standby with cameras on.

It is fitted with:
A forward driving camera and reverse driving camera (colour cameras with automatic B/W switching in case of low lighting).
A microphone for ambient noise feedback.
A loudspeaker for message broadcasting.
An external temperature sensor.
A radiation meter (cf. 4.2) developed by the CEA is incorporated in the platform body for the detection and transmission of a radiological alert threshold. Similarly, a sensor (cf. 4.3) developed by INERIS assesses explosion hazards. If the explosion hazard threshold is overstepped, the platform transmits an alert message then switches off automatically.

2.2 Radiation meter

Due to size constraints, the radiation monitoring system was specially designed and customised for the purpose, as shown on Fig. 1. A Geiger-Müller sensor polarized at 600V was selected.

Figure 1. *Radiation meter*

The system is piloted using a PIC® microcontroller with an intrinsic on-board calculation capability suitable for integrating a high-performance filtering algorithm.
This algorithm has a variable and self-adapting depth according to the intensity of photon and gamma fluxes received by the sensor. It therefore provides high measurement stability and is quasi-insensitive to vibrational-type environmental phenomena, which are considerable when the mobile base is in motion. After air-Kerma rate calibration, this radiation meter provides reliable information on the gamma dose received by the mobile base.
The system's main radiological performances are as follows:
No mobile base malfunctions are observed at dose rates of between **325 µGy/h and 520 mGy/h** with photons of **662 keV**.
The radiological indicator is green in public areas (dose rate lower than 2.5 µSv/h) and red in the marked-out area (dose rate above 2.5 µSv/h).
At dose rates higher than 1 µSv/h, the alert indicator switches to red intermittently (due to measurement fluctuations); the fluctuations increase when the dose rate approaches 2.5 µSv/h. This disadvantage is weighted by the sensor's quasi-instantaneous response.

Future users must be aware that due to the radiation meter's position on the mobile base, the meter's response is not isotropic; it is therefore more sensitive to radiological risks located directly in front of the robot (no screening phenomenon) than to side-facing risks. This is especially true for gamma fluxes approaching the 2,5µSv/h alert threshold.

2.3 Explosion hazard detector

As explosion hazards must be detected in a reliable manner, it was necessary to design a detector capable of detecting explosive atmospheres in the various environments encountered by the robot.

The prototype combines 4 detectors: two catalytic detectors dedicated to measure gas and explosive vapours and two (electrochemical) detectors used to measure ambient oxygen and hydrogen sulphide levels, in order to correct the measurements provided by the two catalytic detectors if necessary.

The algorithm used to process signals from the four detectors was determined on the basis of numerous experimental trials. These trials also enabled determination of the most appropriate calibration gasses. The assembly is managed by a Rabbit® module.

The user's graphic interface features an icon that changes colour, associated with an audible beep; **green**: no gas; **orange**: gas concentration below relay trigger threshold; **red**: the trigger threshold has been reached and power supply to the robot is cut off. Trigger thresholds are factory-set and cannot be user-modified.

The explosion hazard detector was approved on an experimental basis by means of laboratory tests and assessment trials.

2.4 Command & control unit, transmissions

The platform and mission modules are piloted and controlled using a Tablet PC (Fig. 2).

The command & control unit is fitted with a touchscreen for status and measurement displays, video feedback and various commands. It also comprises two units for controlling platform movements and the various axes of the mission modules if installed.

The remote command & control unit and platform are linked via a 802.11b radio link, forced to 1Mb/s.

Data (commands, status feedback and measurements), as well as audio and video feedback, are incorporated in a single flow.

Fiber-optic transmission (250 m fiber optic drum) is also available.

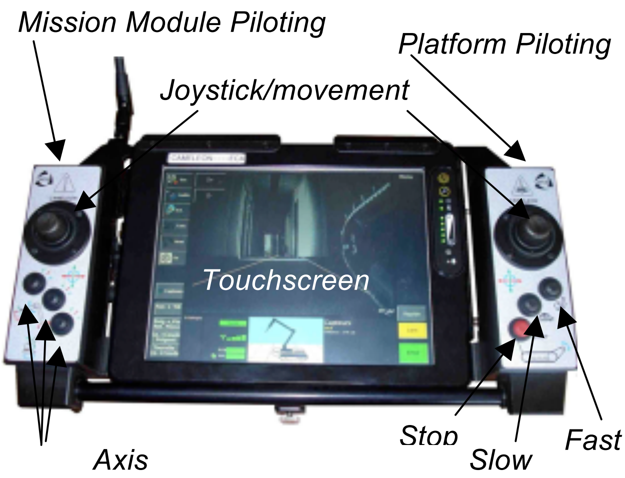


Figure 2. *Command & control unit*

2.5 Mission modules

The various mission modules are mounted on the robot by means of a special interface. In addition to providing mechanical and electrical links, this interface also incorporates the on-board calculator used to manage the various mission modules (see below Fig. 3).

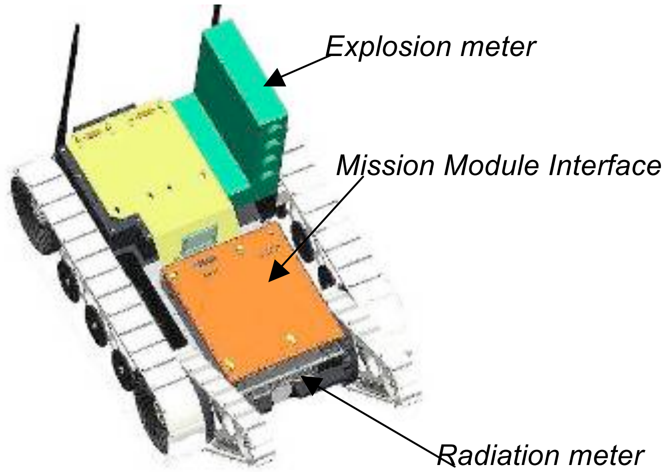


Figure 3. *Multi-purpose platform*

2.5.1 Observation camera

Colour camera (4X digital zoom) fitted with a Pan&Tilt device installed on a tipping mast. The device is also equipped with LED lighting.
In full-forward position, the camera provides a lined-up front view of the robot.
An infrared pyrometer is built into the camera body and follows camera movements.

2.5.2 High-Definition camera

Colour-B/W camera (ICR filter) fitted with a 10X optical zoom and digital zoom (2X to 10X)
It is mounted on a Pan&Tilt device.
Pan: 360° non-stop
Tilt: - 45°/190°
The camera base is fitted with LEDs providing hemispheric lighting.

2.5.3 Colorimetry and sampling

A colorimetric measurement and gas and liquid sampling module was developed specially for the project (Fig. 4).
This module enables the simultaneous deployment of colometric measurement tubes, including gas sampling tubes and one liquid sampling tube.

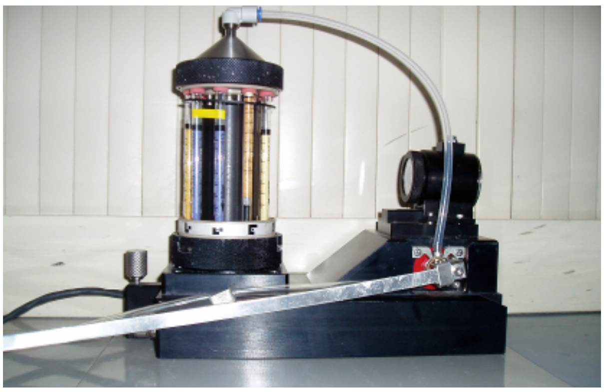


Figure 4. *Measurement and Sampling module*

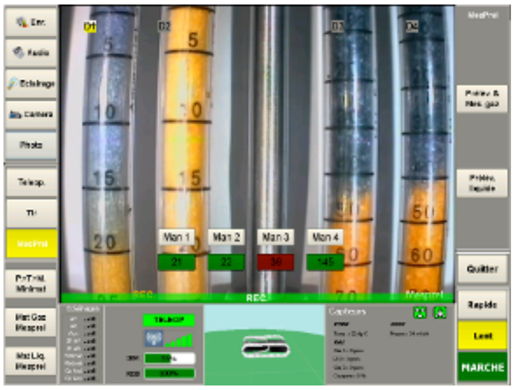


Figure 5. *Screen view of colometric tubes*

The module is equipped with two sampling rods: one gas rod and one liquid rod. Gas sampling can be performed to a height of 90 cm (vertical rod) above the platform, or 50 cm to the fore.
Suction through the colometric tubes can be performed automatically (in this case the quantity of gas processed is indicated by the tube supplier), or manually as required, also in respect of the specified quantity of gas / suction rate.

A video image of the tubes is fed back to the operator and displayed on the remote command & control unit (Fig. 5)

2.5.4 Sensor fixtures

The system is fitted with a series of fixtures enabling the rapid deployment of a large number of chemical and/or radiation sensors (Fig. 6).

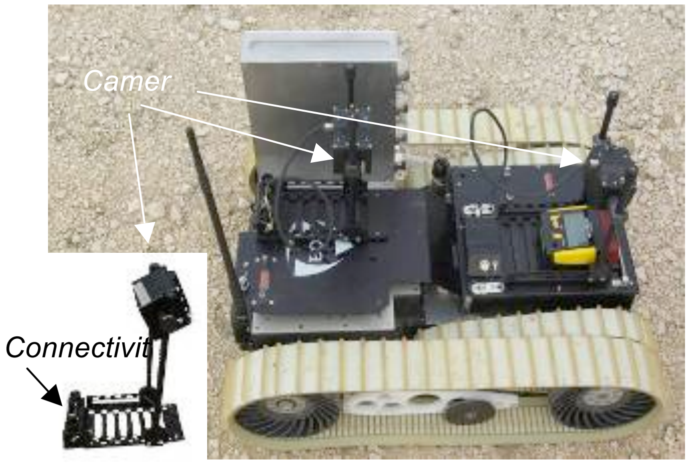


Figure 6. *Sensor fixture*

Two modes are available for sensor data feedback and operator information, according to the capabilities of the relevant sensor:
Insertion of sensor data in the data flow fed back to the remote command & control unit by the platform if the sensor is fitted with a suitable output (serial link or equivalent).
Image acquisition and insertion of the sensor screen image in the video feedback in other cases.
One to three sensors can be installed on the platform simultaneously.

2.5.5 Thermal imaging camera

A directional mount (0°/+40°) is provided for installing a thermal imaging camera on the platform (Fig. 7).
The camera video output is inserted in the system video feedback and can be viewed on the command & control unit.

2.5.6 EOD manipulator arm

ECA has developed an innovative and user-friendly manipulator arm. Pre-defined positions and movements are stored in the system. The user can call up pre-saved movements using the touch screen on the command & control unit.
The screen can display four video cameras at the same time for manipulator arm control and assistance.
The manipulator arm possesses the following special features:

- Automatic management of arm positions
- Anti-collision safety device to avoid collisions between arm axes and other equipment
- 1 firing channel on elbow & 1 firing channel on wrist
- 1 video channel with lighting on wrist, for the disrupter support camera.

Although the arm was first designed for EOD configurations, it is now used for CBRN missions.

3. ASSESSMENT AND FUTURE

3.1 Scenarios

Around 15 scenarios were drawn up initially in order to assess the robot's ability to satisfy operational needs. They were then combined and synthesized to form 5 reference scenarios [9] giving a good scope of robot's various missions and for their relevancy regarding to robot expected performances.

- Potential chemical or radiological incident in underground environment.
- Hazardous Materials Transportation involving multiple incompatible products.
- Fire involving surface treatment facility of an industrial site.

- Reconnaissance in restricted environments.
- Reconnaissance in a Harbour container Storage zone.

3.2 Trials and assessment

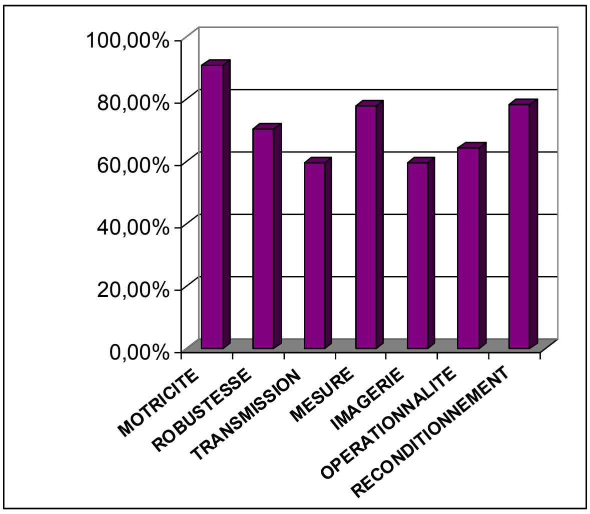
A robot performance evaluation grid was then drawn up; this grid was completed by the assessment team (5-man team or more) during a series of trials. Trials were performed throughout 2009 at various sites made available by their respective users, including technical training centres, railway and subway stations, underground car parks (Fig. 7) and industrial sites. All trials involved the robot and its operational tools, in high concentrations of authentic industrial chemical toxics atmospheres, authentic radioactive sources and significant heat fluxes.

These scenario-based trials were completed with laboratory tests, in particular aimed at testing the robot's resistance to corrosive and oxidizing chemical products and to high radioactive dose rates.

Figure 7. *Trials at car park with thermal imaging*

Once the results had been compiled, the highest and lowest scores were eliminated and the average score was calculated per criteria. These results were then used to establish a basic calculation for the rate of coverage of the requirements expressed previously and approved by a panel of users.
Using this method, in addition to its general performance, the robot's ability to satisfy established requirements was confirmed on a per criteria basis, taking into account the specific characteristics of each mission.
This technique was used to assess 7 main criteria (Mobility, Ruggedness, Transmission, Measurements, Imaging, Operationality and Reconditioning) and 106 sub-criteria. The results showed the robot to able to match with 78% of the requirements expressed (Table 2)
by potential users working in emergency services [8] in 2009-2010.

Table 2. *Test recap*



4. CONCLUSIONS

Although all remains to be perfected, the remote-operated mission aid system developed on the basis of needs expressed by users has proved to be satisfactory. This device has shown itself to possess a high functional potential, and is capable of improving numerous aspects of the missions of emergency teams. In particular, it has proved its ability to provide multiple feedback data relative to incident scene, giving tactical information prior to all human intervention. Moreover, the various trials and initial interventions have confirmed the need to define and approve operational processes to integrate this tool in incident first responder's teams.

The robot is now in duty and operational service since March 2012, integrated in Hazmat and usual emergency teams with an enlarged spectrum, exceeding CBRNe risks.

Even if it's the short beginning of a fruitful cooperation between humans and UGVs [10], future (security) challenges are also to deal with robots cooperation and to manage and discriminate their data flow to give a real progress in Crisis management.