Coll. Antropol. **38** (2014) Suppl. 1: 71–75
Original scientific paper

Detection and Neutralization of Threats from Improvised Explosive Devices (types CBRN-CIED)

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A B S T R A C T

Various forms of threats, technological accidents, especially in the chemical industry and military complexes which cause major damages to humans, assets and environment, draw attention to development of new technological means to eliminate danger without the risk for human life. This determines the equipment logistic for the protection and rescue system. In line with this, the article presents the development of a robotized system for detection of chemical, biological, radiological and nuclear threats (CBRN), and for detection and neutralization of improvised explosive devices (CIED). In addition, a prototype model of a robotic vehicle is constructed. Reconnaissance, terrain and object mapping are of great importance so that the operators and technicians have at their disposal an option of multiple analysis of a problem. The basic feature of using a robotized machine is the replacement of EOD and CBRN technicians in various life-threatening situations. Citizens' trust is of greatest and crucial importance for providing safety in such extraordinary situations. In order to meet the strict tactical and technical requirements, the robotised system comprises the stealth platform, working tools, a control console, a manipulator arm for complex actions, a CBRN detector, an additional EOD robot for terrain scouting and sample taking, an unmanned reconnaissance aircraft and a mobile command center. The prototype model of a robotic vehicle shows that the project is both technically and economically feasible on the basis of a tracked machine with battery propulsion, the Ultra Low Profile dozer. Existing resources and experience in development of specialized machines are significant for the development of a robotised system.

***Key words**: threat detection, danger neutralisation, elimination of improvised explosive devices, robotised system, CBRN-CIED project*

Introduction

Modern warfare and new forms of terrorism by way of various CBRN improvised devices condition the development of new contra-devices which can conduct remote detection and neutralisation. The task of an automatised remote controlled robotic vehicle CBRN-CIED is reconnaissance, recording and overview of terrain and objects in order to enable operators and technicians with greater option of multiple analysis of a given area. One of the principal advantages to using the stated robotic vehicle is certainly the replacement of EOD and CBRN technicians in different life-threatening situations so as to reduce the injury risk to the lowest level attainable. The initiative for lowering the danger of threats was strenghtened by the feasibility study for the development of a robotic vehicle for detection of Chemical, Biological, Radiological and Nuclear hazards (CBRN) and for detection and neutralisation of improvised explosive devices (CIED – Counter Improvised Explosive Devices)[1,2].

To successfully fulfill the set tactical and technical requirements, the automatised remote-controlled robotic vehicle CBRN-CIED comprises a basic stealth platform, working tools, a steering console for remote control, a robotic manipulator arm for the performance of complex manuevers, a CBRN detector, an additional EOD robot for terrain scouting and sample taking, additional unmanned reconnaissance airplanes, a transport vehicle and a command centre. The robotic vehicle is feasible on the basis of a tracked machine Ultra Low Profile – ULP doser with battery propulsion (Figure 1).

Received for publication November 29, 2013

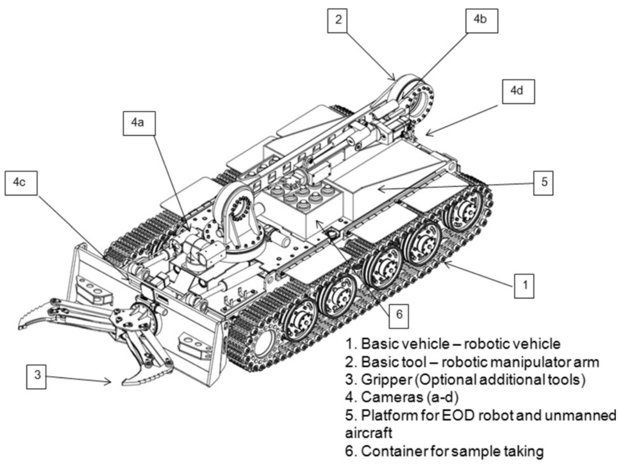

Fig. 1. Project solution of the CBRN-CIED system.

IED (Improvised Explosive Devices) are lethal weapons used by terrorist and rebels in areas of crisis for committing acts of terror. IED usually explode on either side of a road in close range of vehicles or people[3,4]. Attacks using various IED devices cause numerous casualties among members of peace-keeping missions and the local community. NATO forces procure and utilise the devices for detection and destruction of IEDs.

Analysis of terrorist activity considers the development of modern solutions which would serve to detect the presence of CBRN devices as well as detect and remove IEDs using a sophisticated robotic vehicle. Extraordinary situations are known to happen often, therefore the citizen's safety and trust need to be ensured. The remote-controlled CBRN-CIED type vehicle is equipped with sophisticated electronic monitoring gear which comprises: CBRN sensors, a couple of functional camreas and video supervision. Equpment is mounted on a reduced--noise tracked or wheeled platform and a 3 m high hydraulic hand. 3D remote control system for supervision is configured on a support airplane. This multifunctional robotic vehicle is useful in various incidental situations.

Robotic vehicle prototype model

CBRN-CIED type remote-controlled robotic vehicle prototype model provides the future investor with an insight into all tactical-technical features, to evaluate material-financial expenses to the project. Criteria and key parameters to the technical possibilities and material-financial expenses of creating a test model are provided, such as the financial payout of a robotic vehicles in the CBRN and CIED variant.

Apart from its military purpose, the robotic vehicle can serve in situations where it's necessary to ascertain the degree of threat to human life, detect and remove dangerous objects. Examples of such situations are spillage of dangerous chemical substances, nuclear assembly malfunction, natural catastrophies (quakes, fires etc). Robotic vehicle carries a mini mobile robot with accurate tools and an unmanned airplane for terrain reconnaissance. Unlike armoured scouting vehicles, which generally require one to six members of staff, this vehicle is autonomous, remote-controlled, and all the crew members (commander, operator, service officer, driver etc.) in a safe area and physically separated from the location where life-threatening operations are performed. This vehicle can work in stealth mode. Batteries and electric motors with permanent magnets, with low termal emission and low noise characteristics, are just the ones that provide an almost silent working mode and significantly low termal footprint. The existing autonomy of the basic platform is sufficient for performing CBRN-CIED tasks. On request, the autonomy can be additionally increased. The robotic vehicle, due to its dimensions and weight, is the smallest and shortest of all scouting vehicles, which facilitates its stealth approach to dangerous targets as well as providing it with easier access and shelter in its surrounding (such as tall grass, bushes etc.).

The CBRN-CIED robotised system comprises its main parts[2]:

a) Basic vehicle – robotic vehicle, serves as a mobile platform to carry basic and optional systems and tools
b) Remote control console
c) Basic tool – robotic manipulator arm enabling the handler to perform simple and complex manuevres
d) Gripper located on the robotic manipulator arm
e) Optional additional tools – plough, gripper, roller, tiller
f) EOD robot for terrain scouting and sample taking
g) Unmanned reconnaissance aircraft
h) Reconnaissance video system
i) CBRN detectors and sensors
j) Additional equipment – Command centre, transport and terrain vehicle

The mobile platform is the result of long-standing experince in constructing similar platforms (Figure 2). Battery-tracked propulsion ensured soil trafficability in the harshest of conditions. Its shell made of Pantsir armoured steel protects systems inside the machine from explosion of improvised explosive devices. Basic technical characteristics of the robotic vehicle are:

Operative Mass: 3870 kg; Vehicle Speed: 0–5 km/h; Dimensions: length: 2700 mm, width: 1500 mm, heigth: 590 mm

Batteries: Lithium Iron Phosphate ($LiFePO_4$) in a serial connection. Total of 80 batteries, Capacity per Cell: 200 Ah, Total Battery Capacity: 200 Ah, Voltage: 3.2 V, Cell Mass: 5.6 kg, Battery Package Mass: 500 kg, Battery Life Expectancy: 2000 Cycles; 2 AC Motors, Power: 22 kW, Torque 95Nm, 2000 RPM, Voltage 288 V, Power of Current: 57 A

Manipulator arm (Figure 3), assists technicians in activities of manipulating certain suspected objects, collec-

Fig. 2. Prototype model of the remote-controlled robotic vehicle.

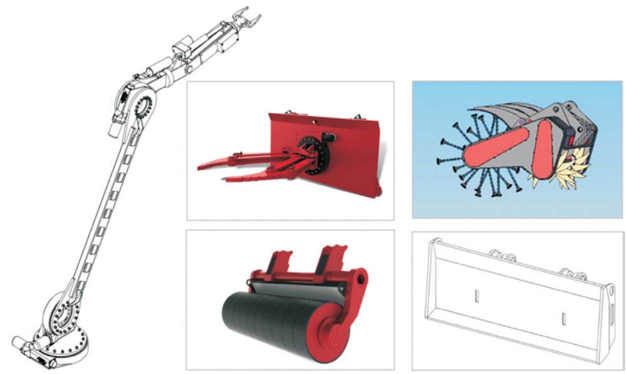

Fig. 3. Manipulator arm and working tools (gripper, tiller, roller and plough).

tion and sampling as well as detection and research of unidentified and suspected objects. In so doing, the technician is not exposed to danger nor risk. Maximal carrying capacity of the arm is 50 kg, reaches 3 m up and 1 m below soil, while the extended length of arm reaches 2,5 m in front. The arm carries a camera by default, which enables close object surveillance. As the arm is conceived as a modular assembly, it's possible to add additional tools, cameras, scanners and other gear. Electric motors used in the robotic arm enable precise and neat control of the arm. Its main tool comprises a gripper and work surveillance camera (a working and a thermal one). There is an option of upgrading a detector (chemical, radiological) as well as a weapon for destruction of dangerous objects (water gun, shot gun) depending on the needs of the robot's task.

Additional working tools are mounted from the front side of the machine. They can be used for various purposes depending on the task set. The tools are equipped with a universal joint for fast connection.

- Gripper – a tool for moving and transfering hard suspected loads otherwise impossible to lift with a manipulator arm gripper (with a 1000 kg limit). The gripper can rotate 360° and open wide up to 180°. Supervision over the gripper's work is done via camera mounted on the very gripper.
- Plough – a tool for moving hard loads to open up access and clear pathways.
- Roller – a tool for clearing roads from residual mine-explosive devices. Independent roller segments apply pressure to the soil and detonate or destroy residual mine explosive devices[5].
- Tiller and flail – a tool for mechanical demining of mine-suspected area through soil treatment[5].

Command centre is the central point or cabin of a terrain vehicle from which tasks are being solved, as a result of accidental events. Serving as a central base in the communication with headquarters, it is the place where all relevant terrain information is gathered and transfered. Operators of the robotic vehicle and other additional gear are located in the cabin, where they have a complete view of the situation with all the parameters relevant for decision making.

The remote-controlled CBRN-CIED robotic vehicle is controlled via mobile control benchboard (operator hand-held unit). The control benchboard enables the operator to control the vehicle and perform monitoring over all the functions and tools from a distance of 1000 meters in open clear environment, or 350 meters in urban areas. The operator who controls the robotic vehicle is situated at a safe distance or in the command centre. The mobile control benchboard is used on occasions when the operator is leaving the command centre, or when the visualisation of the robotic vehicle is indispensable.

The CBRN variant

Modern forms of terrorism with CBRN improvised devices have conditioned the development of new resources (robots etc.) that can perform detection from a distance, using a detector mounted on a remote-controlled vehicle. The CBRN vehicle variant comprises a mobile platform, a robotic manipulator arm, additional tools, cameras, a platform for a lesser EOD robot and aircraft, and a sampling container.

A platform to accommodate a lesser EOD robot for additional terrain scouting and sample taking is located in the rear part of the robotic vehicle. A small unmanned aircraft serves for terrain reconnaissance. Immediately behind the EOD robot and aircraft there is a tank for sample taking. The tank contains capsules for sample taking, in liquid, gas and solid state. The capsules are taken by a robotic arm and placed into the tank.

Four high resolution cameras are used, positioned on these locations: the main camera at the front of the vehicle, the second one at the rear, the third one on the additional tool – gripper, and finally a thermal camera on the manipulator arm.

The chemical detection equipment enables detection of:

- War gas – Tabun, Sarin, Soman, Cyclosarin, Agent VX and Vx
- Toxic industrial chemicals – Hydrogen Cyanide (HCN), Phosgene, SO, NH, and other
- Various types of explosive – RDX, PETN, TNT, Semtex, TATP, NG, Ammonium Nitrate, H_2O_2, and other)
- Various kinds of narcotics (cocaine, heroine, THC, Methamphetamine, and other) – optional availability.

Radioactive radiation detection equipment enables detection of substances which can damage human health and environment, and which emit very dangerous and long-lasting contamination difficult to decontaminate. A high sensitivity detector enables detection and dosimetry of Y and X radiation, as well as the option of neutron detection and dosimetry.

Biological detection equipment, by using the NIDS model (Nano Intelligent Detection System), identifies various biological agents and toxins in standard configuration.

Decontamination of the robotic vehicle is performed using an on-the-spot mobile station. The vehicle drives through a system of shower nozzles that spray decontaminant matter. The construction is light and the assembly quick. It is adjustable per heigth and width, providing with decontamination of a wider spectre of the vehicle. The station contains a tank for waste fluid (water) in order to prevent the spread of contamined water across its surroundings.

EOD robot and unmanned aircraft

A lighter version of iRobot »PackBot« serves for mobile operations outside the vehicle, a robot that proved itself in military operations (310 SUGV iRobot)[3,4]. The robot enters areas unaccessible or posing threat to humans and collects information for infantry, engineering, mobile technicians for the elimination of unexploded devices, and other personnel. In such conditions the robot gathers data about the situation on terrain and does not expose soldiers and other professionals to any danger. Unmanned aircraft can be of the T-HAWK Micro type. It is controlled from the Commanding centre and assists operators and technicians in additional scouting operations, monitoring and terrain surveillance. It is equipped with cameras for terrain recording and GPS navigation.

Economic and financial analysis

The project is subjected to the economic and financial analysis stressing on the project's static evaluation of efficiency and overall dynamics assessment. Sensitivity of analysis ends with presenting basic indicators of financial payout (justifiability) and the project's profitability. 31 produced units are expected to be approved with a rentability index.

Machine life cycle costs are derived through integral analysis of the product's technical logistics. Life cycle costs represent the sum of assessed expenses from the beginning of the project's gear procurement process all the way to its write-off. Cost monitoring is conducted in accordance with an analytical approach. Based on evaluation of mean time before failures (MTBF) of its main components, the machine's working life cycle up until its more serious preventive repair service is determined (mid-way remount – including the requirement for modernisation), which is considered a highly significant indicator of vehicle's validity maintenance within its life cycle.

Competence, skills and testing

It is necessary to form a team, required expert knowledge, competence and skills, as wells as logistic support, to operatively perform all set tasks in accidental cases.

Predicted are the following team members:

- Team Commander
- Operator, three persons – each operator controls a particular system – the first one controls the basic robotic vehicle, the second one the sensors for CBRN detection, and the third one controls the lesser robot and unmanned aircraft.
- Service officer, two persons – physical support to the team.

Members of the team are trained through the following courses:

- CBRN course – reconnaissance, detection, decontamination
- Pyrotehnical course (exploseives and explosive devices)
- Maintenance and control of the robotic vehicle
- Maintenance and control of other additional systems

To conduct verification of the remote-controlled robotic vehicle's function along with additional systems and gear, it is necessary to perform thorough testing, along the phases of prototype testing, which include testing performance, survivability and acceptability[6,7] (Figure 4).

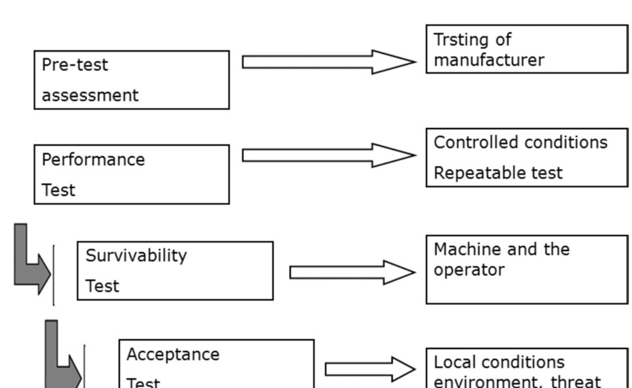

Fig. 4. Phases of prototype testing.

Conclusion

The following items are significant for development of the robotic vehicle and its serial production:

- experience in using the battery powered mobile tracked platform for performing difficult mining operations,
- enterprise that carries forward the development owns the most complex and expensive part of robot technology, has the finalisation ability for the basic vehicle which means in fact governing the whole entirety of production, and as such its development perspective,
- value participation in robot construction is expected to be over 70% by final price criterion (technical-economic indicators of robot production contain an overview of robot subsystem and individual subsystem manufacturers). The investments are evaluated to yield return after production surpasses 31 unit.

The reference from a robotic vehicle of the CBRN-CIED type is of most relevance to the future investor and manufacturer. This is the foundation for coopeartion with NATO partners and ensurance of interoperability (demand for and supply of services from partners). Current mobile platform with manipulatory activities is not a programme in need of rebooting and large asset investment, rather a programme which to be continued onwards. Technical-economic analysis indicated the need and justification of developing a robotic CBRN-CIED vehicle and financial payout.

A feeling for various events and accidental answers are nonexistent without the development of technic and technology. These machines are intended for extraordinary situations and providing citizens' safety.

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OTKRIVANJE I NEUTRALIZACIJA UGROZA OD IMPROVIZIRANIH EKSPLOZIVNIH NAPRAVA (TIPA CBRN-CIED)

SAŽETAK

Razni oblici ugroza, tehnoloških akcidenata, posebice u kemijskoj industriji te vojnim kompleksima koji uzrokuju veliku štetu za ljude, imovinu i okoliš, upućuju na razvoj novih sredstava i tehnologija koje mogu otkloniti opasnost bez ljudskog rizika. To sustavu zaštite i spašavanja određuje logistiku opremanja. U tom cilju, u članku je prikazan razvoj robotiziranog sustava za otkrivanje kemijske, biološke, radiološke i nuklearne ugroze (CBRN), kao i za otkrivanje i neutralizaciju improviziranih eksplozivnih naprava (CIED). Također, izrađen je prototipski model robotskog vozila. Izviđanje, snimanje terena i objekata je vrlo važno kako bi operatori i tehničari imali mogućnost višestruke analize problema. Osnovna značajka korištenja robotskog vozila je zamjena EOD i CBRN tehničara u različitim po život opasnim situacijama. Od najveće i presudne važnosti je povjerenje građana za pružanje sigurnosti u takvim izvanrednim situacijama. Kako bi se ispunili strogi taktičko-tehnički zahtjevi, robotizirani sustav se sastoji od stealth platforme, radnih alata, upravljačke konzole, manipulatorske ruke za obavljanje složenih radnji, CBRN detektora, dodatnog EOD robota za izviđanje terena i uzimanje uzoraka, bespilotne letjelice za izviđanje, te mobilnog zapovjednog centra. Prototipski model robotskog vozila pokazuje da je projekt tehnički i ekonomski izvodljiv na bazi gusjeničnog stroja baterijske propulzije, Ultra Low Profile dozera. Za razvoj robotiziranog sustava značajno je iskustvo u razvoju specijalnih strojeva.