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CONTEMPORARY ENGINEERING PERSPECTIVES REFLECTED IN THE PRACTICAL REALIZATION AND IMPLEMENTATION OF THE AVANGARD Robo SilMih ROBOTIZED TECHNOLOGICAL DEMONSTRATOR

Silviu-Mihai PETRIȘOR, Antonia-Renata COROIU

Abstract: *The authors of this scientific demarche want to highlight some scientific contributions that are shaped around some patented robotized tracked technological products and that have led to the practical realization of a technological demonstrator, TRL 6 level. The paper highlights a summary of all the execution phases of a Sectoral Research-Development Plan-type of research grant of the Ministry of National Defence regarding the practical realization and implementation of a technological product of a tracked mini-robot intended for engineering applications. We briefly present some elements regarding the identification of those components specific to NATO interoperable engineering systems, an example of good practice regarding both the realization, on a 1:1 scale, of a technological demonstrator intended for the detection and clearance/demining of UXO and IEDs, as well as the possibility of its implementation within the engineering missions (operational environment – verified prototype system), the formulation of proposals and recommendations regarding the initiation of the process of homologation of the technological product.*

Key words: *technological demonstrator, human-artificial partnership, responsible intelligence, engineering missions, patent*¶

1. PREAMBLE

The revolution in military technologies has led to a change in strategic thinking, nowadays the robotization of the combat environment being deemed necessary for the missions of the armies of all the states to be carried out at normal parameters. The main aspect that modern robotized military technologies aim at is the prompt response to battlefield threats, reacting rapidly and efficiently to attacks on critical infrastructures [Rom 19]. The use of these technologies to quickly obtain the necessary information about threats to critical structures represents an advantage for the armed forces, because with the help of robots, the potential threats could be avoided or removed. The need to use advanced technological systems is essential for the protection and safety of military personnel, because they, in addition to carrying out monotonous missions that involve maximum physical and mental concentration, are also subjected to high-risk missions in which their physical moral integrity and are affected [Zech 19].

The communication routes of any type, which connect two important military objectives, are particularly vulnerable in the event of an attack by the enemy. Being considered critical infrastructures, the military field focused its attention on their permanent research and surveillance [Pet 22].

Taking all these aspects into account, developing a robotic product that exhibits reliability and ensures full user confidence is vital for the success of military land reconnissance operations.

2. PRACTICAL REALIZATION OF THE Avangard Robo-SilMih ROBOTIZED TECHNOLOGICAL DEMONSTRATOR

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The technologization of the battlefield has imposed on the states the need to design and implement some robotic systems in order to be able to respond to the requirements of the external and internal security environment, which directly influences their military actions.

Thus, terrestrial research robots end up being used more and more often in missions, especially by EOD teams, in the theaters of operations, due to the advantages they bring, protecting thus the military and civilian personnel from certain risks related to IED (Improvised Explosive Device) detection, UXO (Unexploded Ordnance) or different types of mines.

The robotized technological solutions used in theaters of operations must represent vanguard elements of the human factor in risky or dangerous areas and they must be able to develop a nature-friendly behavior by reducing/eliminating the consumption of fossil fuels to reduce pollution.

Next, we present the constructive solution of a technological demonstrator, resulted from the association of two patents, presented in detail in the papers [Pet 16], [Pet 21], and which refer to two tracked mini-robots intended for engineering applications.

The patent-technological demonstrator association is presented in Figures 1 ... 4, and they represent: Figure 1a, b - the structural kinematic diagram of the mini-robot and the industrial production of the technological demonstrator, Figure 2a, b - the general structure of the mini-robot (side view) and the industrial production of the technological demonstrator, Figure 3a, b - the general structure of the mini-robot (view from above) and the industrial realization of the technological demonstrator, Figure 4a, b, c - overview of the technological demonstrator, the electrical installation and the control of the servomotors .

The technological demonstrator consists of two main components, namely: the *MRo* rotation module (consisting of the *CRo* rotation coupler and the *Pro* rotation plate) and the robotic modular arm (consisting of: the *Br1* arm, the *Br2* arm, the *MPO3* orientation and positioning module, the *DP* gripping device), each having at least one degree of mobility, to which the *MB* basic module is added (Fig. 1, Fig. 2) [Pet 17].

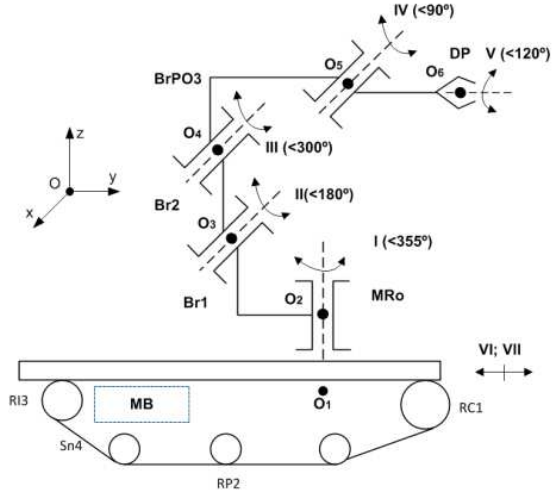


Fig. 1a. Concept

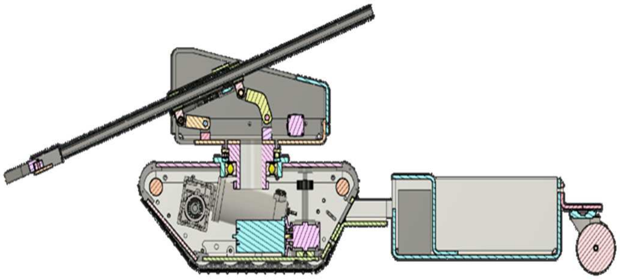


Fig. 1b. Industrial production

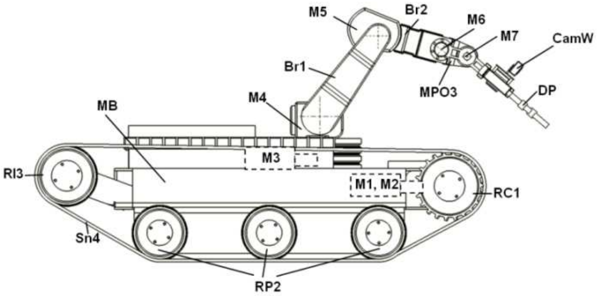


Fig. 2a. Concept

Fig. 2b. Industrial production

The gripping device is equipped with sliding gripping fingers that have a pivoting joint of the wrist, this favors the grasping of any object with dimensions of up to 4.30 cm.

The degree of mobility *I* (Fig. 1) (the rotation of the rotation coupler and of the robotic modular arm) are achieved by means of an *M3* step-by-step electric motor.

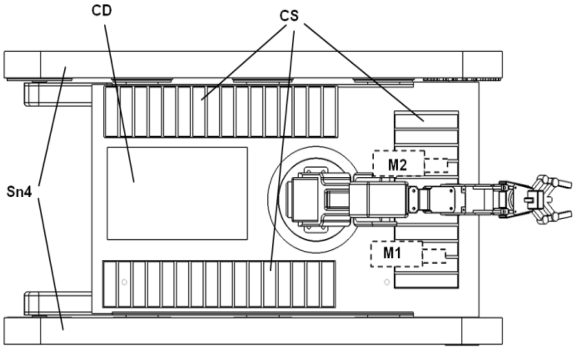


Fig. 3a. Concept

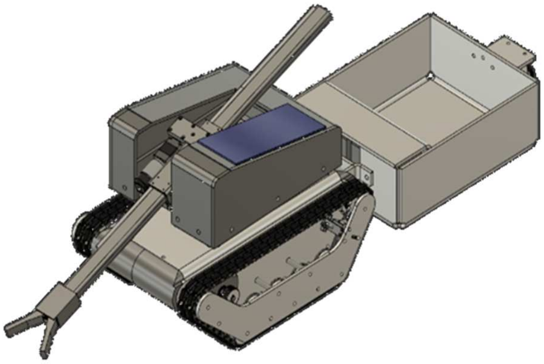


Fig. 3b. Industrial production

The mobility degrees *II, III* and *IV* (Fig. 1, Fig. 2, Fig. 3) (the rotation of the *Br1*, *Br2* arms and of the orientation and positioning arm along the *x* axis) are obtained with the help of the electrical step-by-step motors *M4*, *M5* and *M6*.

Fig. 4a. Technological demonstrator overview

The degree of mobility *V* (Fig. 1, Fig. 2, Fig. 3) (vertical pivoting of the fingers in the structure of the gripping device) is obtained with the help of the *M7* step-by-step electric drive motor.

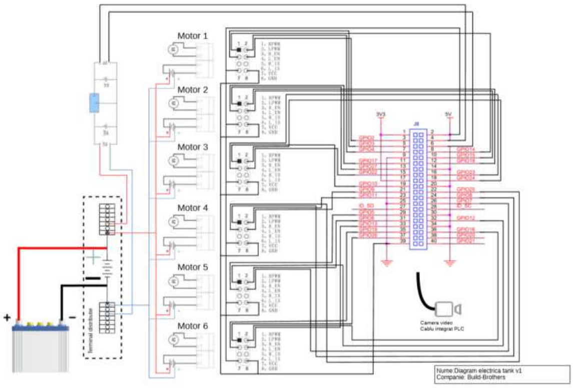
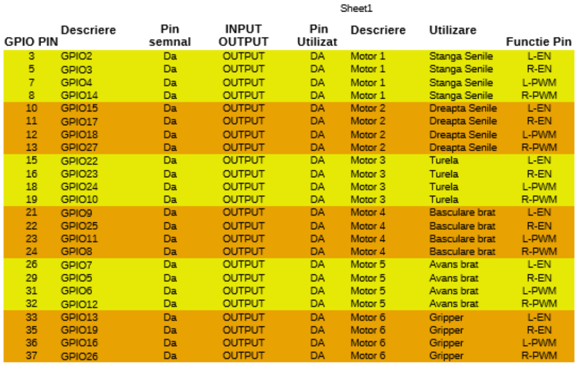


Fig. 4b. Electric installation



Sheet1

GPIO PIN	Descriere	Pin semnal	INPUT OUTPUT	Pin Utilizat	Descriere	Utilizare	Functie Pin
3	GPIO2	Da	OUTPUT	DA	Motor 1	Stanga Senile	L-EN
5	GPIO3	Da	OUTPUT	DA	Motor 1	Stanga Senile	R-EN
7	GPIO4	Da	OUTPUT	DA	Motor 1	Stanga Senile	L-PWM
8	GPIO14	Da	OUTPUT	DA	Motor 1	Stanga Senile	R-PWM
10	GPIO15	Da	OUTPUT	DA	Motor 2	Dreapta Senile	L-EN
11	GPIO17	Da	OUTPUT	DA	Motor 2	Dreapta Senile	R-EN
12	GPIO18	Da	OUTPUT	DA	Motor 2	Dreapta Senile	L-PWM
13	GPIO27	Da	OUTPUT	DA	Motor 2	Dreapta Senile	R-PWM
15	GPIO22	Da	OUTPUT	DA	Motor 3	Turela	L-EN
16	GPIO23	Da	OUTPUT	DA	Motor 3	Turela	R-EN
18	GPIO24	Da	OUTPUT	DA	Motor 3	Turela	L-PWM
19	GPIO10	Da	OUTPUT	DA	Motor 3	Turela	R-PWM
21	GPIO9	Da	OUTPUT	DA	Motor 4	Basculare brat	L-EN
22	GPIO25	Da	OUTPUT	DA	Motor 4	Basculare brat	R-EN
23	GPIO11	Da	OUTPUT	DA	Motor 4	Basculare brat	L-PWM
24	GPIO8	Da	OUTPUT	DA	Motor 4	Basculare brat	R-PWM
26	GPIO7	Da	OUTPUT	DA	Motor 5	Avans brat	L-EN
29	GPIO5	Da	OUTPUT	DA	Motor 5	Avans brat	R-EN
31	GPIO6	Da	OUTPUT	DA	Motor 5	Avans brat	L-PWM
32	GPIO12	Da	OUTPUT	DA	Motor 5	Avans brat	R-PWM
33	GPIO13	Da	OUTPUT	DA	Motor 6	Gripper	L-EN
35	GPIO19	Da	OUTPUT	DA	Motor 6	Gripper	R-EN
36	GPIO16	Da	OUTPUT	DA	Motor 6	Gripper	L-PWM
37	GPIO26	Da	OUTPUT	DA	Motor 6	Gripper	R-PWM

Fig. 4c. Actuator control

Mobility degrees *VI* and *VII* (Fig. 1, Fig. 2, Fig. 3) (movement and direction of the designed technological demonstrator) are provided by the electric step-by-step motors *M1* and *M2*, respectively.

The drive motors in the componence of the technological demonstrator are powered by solar cells encapsulated in *CS* panels (Fig. 2), when the demonstrator operates during the day and by means of accumulator batteries, respectively, when it is desired to operate at night.

Furthermore, the technological demonstrator has in its composition a *CD* storage compartment for the explosive as well as a *CamW* web camera that provides information from the field, in real time, to the human operator at the control desk.

The movement possibilities related to the technological demonstrator can work simultaneously and/or independently, and its operating system can include 24 commands, the working modes can be in automatic mode or the programming of movements by learning/manual (Fig. 4).

3. IMPLEMENTATION SCENARIO OF THE TECHNOLOGICAL DEMONSTRATOR IN ENGINEERING APPLICATIONS

By resorting to robotized technologies, the decision-making structures have the possibility to decide on an optimal course regarding the conduct of military actions in a much shorter time. Most of the robotized technologies are used for the purpose of searching urban areas, areas that are difficult for military personnel to access, or areas with rugged terrain or open fields that present suspicions during these missions. In order to mark the engineering reconnaissance actions of the respective ensemble, the technological demonstrator was used in educational-applicative activities with the students of our institution. Following these tests, the hypotheses and operational objectives were validated. Moreover, this implementation process helped to accurately establish its main technical-tactical characteristics, which are highlighted in Table 1.

Tab. 1. *The main characteristics of the Avangard Robo - SilMih robot*

Destination	- obtaining information on the entire set of communication paths
Weight	95 kg
Size	1582x448x188 cm
Autonomy	6 h
Travel speed	5 km/h
Range	maximum 1 km
Control system	- autonomous, - manual (remote control).
Masking	- camouflaged, - detectable by high-performance devices.
Use	- tactical, - operative, - strategic.

Both the constructive and the technical-tactical characteristics demonstrated that the technological demonstrator can be used in all three operational fields, namely - tactical, operational and strategic.

Due to the high-performance electronic components and to the programming based on two modes (manually controlled or autonomous), the operator has the possibility to choose one of these modes depending on the difficulty of the mission.

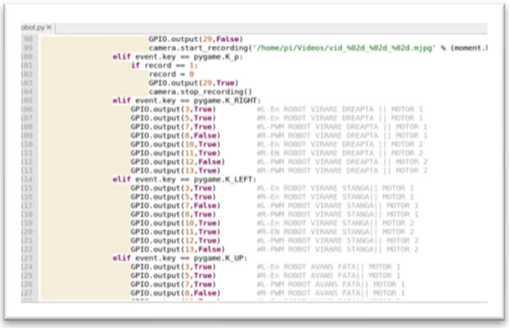
At the same time, the safety mode, i.e. in the event of video camera malfunctions, during autonomous operation, offers the possibility of stopping the technological product only after it has fulfilled its mission. By combining the two types of assembly actuation — one intended for the motors and one intended for the development board, it was possible to increase the autonomy of the product, which is of approximately 6 h. A disadvantage that the functional prototype presents and which is desired to be eliminated is the range. The wireless module of the robot is not powerful enough to give it a very large viewing range. The operator can only control the robot within a radius of 1 km, and in its autonomous mode the operator can obtain information related to the area in which it operates up to the same distance. It is believed that this problem can be reduced by using a high-performance antenna to capture the signals transmitted by the operator. The integrated GPS module provides accurate data about the location of the mini-robot, but in case of bad weather conditions, another GPS system must be used. Thus, by simulating the model in adverse weather conditions with the GPS system with antenna, it was found that such a system integrates perfectly in the unfavorable situation.

The technology demonstrator was programmed using the Python programming language. In this sense, from the control unit, the technological product, with the help of the specified keys, performs the possible movements. A part of the instruction used to control the remote demonstrator is represented below (Fig. 5 a), b)) where you can identify the motors operated at the time of the execution of the requested movements and the infrared color video camera that provides information in real time to its operator.

The testing and validation of the mini tracked robot involves guidance according to the following operational objectives: determining the standard procedures for the operation of the mini tracked robot in order to execute access to an objective and in open field, to investigate the objective and the open field presenting the specific threats of the presence of UXO/IED, real-time recording and transmission of data from the investigated area using the infrared video camera, identification and removal of UXO/IEDs by means of the mobile arm and transport in the specially designed bin for neutralization in a safe area.

```
                    GPIO.output(7,True)         #L-PWM ROBOT AVANS FATA|| MOTOR 1
                    GPIO.output(8,False)        #R-PWM ROBOT AVANS FATA|| MOTOR 1
                    GPIO.output(10,True)        #L-En ROBOT AVANS FATA|| MOTOR 2
                    GPIO.output(11,True)        #R-EN ROBOT AVANS FATA|| MOTOR 2
                    GPIO.output(12,True)        #L-PWM ROBOT AVANS FATA|| MOTOR 2
                    GPIO.output(13,False)       #R-PWM ROBOT AVANS FATA|| MOTOR 2
                elif event.key == pygame.K_DOWN:
                    GPIO.output(3,True)         #L-En ROBOT AVANS SPATE|| MOTOR 1
                    GPIO.output(5,True)         #R-En ROBOT AVANS SPATE|| MOTOR 1
                    GPIO.output(7,False)        #L-PWM ROBOT AVANS SPATE|| MOTOR 1
                    GPIO.output(8,True)         #R-PWM ROBOT AVANS SPATE|| MOTOR 1
                    GPIO.output(10,True)        #L-En ROBOT AVANS SPATE|| MOTOR 2
                    GPIO.output(11,True)        #R-EN ROBOT AVANS SPATE|| MOTOR 2
                    GPIO.output(12,False)       #L-PWM ROBOT AVANS SPATE|| MOTOR 2
                    GPIO.output(13,True)        #R-PWM ROBOT AVANS SPATE|| MOTOR 2
                elif event.key == pygame.K_a:
                    GPIO.output(15,True)        #L-En TURELA ROTIRE STANGA || MOTOR 3
                    GPIO.output(16,True)        #R-En TURELA ROTIRE STANGA || MOTOR 3
                    GPIO.output(18,False)       #L-PWM TURELA ROTIRE STANGA || MOTOR 3
                    GPIO.output(19,True)        #R-PWM TURELA ROTIRE STANGA || MOTOR 3
                elif event.key == pygame.K_d:
                    GPIO.output(15,True)        #L-En TURELA ROTIRE DREAPTA || MOTOR 3
                    GPIO.output(16,True)        #R-En TURELA ROTIRE DREAPTA || MOTOR 3
                    GPIO.output(18,True)        #L-PWM TURELA ROTIRE DREAPTA || MOTOR 3
                    GPIO.output(19,False)       #R-PWM TURELA ROTIRE DREAPTA || MOTOR 3
                elif event.key == pygame.K_q:
                    GPIO.output(21,True)        #L-En
                    GPIO.output(22,True)        #R-En
                    GPIO.output(23,True)        #L-PWM
```

a)



```
                        GPIO.output(29,False)
                        camera.start_recording('/home/pi/Videos/vid_%02d_%02d_%02d.mjpg' % (moment.
                elif event.key == pygame.K_p:
                    if record == 1:
                        record = 0
                        GPIO.output(29,True)
                        camera.stop_recording()
                elif event.key == pygame.K_RIGHT:
                    GPIO.output(3,True)         #L-En ROBOT VIRARE DREAPTA || MOTOR 1
                    GPIO.output(5,True)         #R-En ROBOT VIRARE DREAPTA || MOTOR 1
                    GPIO.output(7,True)         #L-PWM ROBOT VIRARE DREAPTA || MOTOR 1
                    GPIO.output(8,False)        #R-PWM ROBOT VIRARE DREAPTA || MOTOR 1
                    GPIO.output(10,True)        #L-En ROBOT VIRARE DREAPTA || MOTOR 2
                    GPIO.output(11,True)        #R-EN ROBOT VIRARE DREAPTA || MOTOR 2
                    GPIO.output(12,False)       #L-PWM ROBOT VIRARE DREAPTA || MOTOR 2
                    GPIO.output(13,True)        #R-PWM ROBOT VIRARE DREAPTA || MOTOR 2
                elif event.key == pygame.K_LEFT:
                    GPIO.output(3,True)         #L-En ROBOT VIRARE STANGA|| MOTOR 1
                    GPIO.output(5,True)         #R-En ROBOT VIRARE STANGA|| MOTOR 1
                    GPIO.output(7,False)        #L-PWM ROBOT VIRARE STANGA|| MOTOR 1
                    GPIO.output(8,True)         #R-PWM ROBOT VIRARE STANGA|| MOTOR 1
                    GPIO.output(10,True)        #L-En ROBOT VIRARE STANGA|| MOTOR 2
                    GPIO.output(11,True)        #R-EN ROBOT VIRARE STANGA|| MOTOR 2
                    GPIO.output(12,True)        #L-PWM ROBOT VIRARE STANGA|| MOTOR 2
                    GPIO.output(13,False)       #R-PWM ROBOT VIRARE STANGA|| MOTOR 2
                elif event.key == pygame.K_UP:
                    GPIO.output(3,True)         #L-En ROBOT AVANS FATA|| MOTOR 1
                    GPIO.output(5,True)         #R-En ROBOT AVANS FATA|| MOTOR 1
                    GPIO.output(7,True)         #L-PWM ROBOT AVANS FATA|| MOTOR 1
                    GPIO.output(8,False)        #R-PWM ROBOT AVANS FATA|| MOTOR 1
```

b)

Fig. 5. *a) Lines of code for moving forward, backward and turning the turret left and right, b) Lines of code for recording with the built-in camera and for the turning right and left of the technological demonstrator*

When accessing an objective, the EOD intervention team will take shelter in a safe place approximately 300 m from the targeted objective. With the indications of the sapper or the witness who announced the incident, the mini-robot will be placed on a corridor where it will move under the command of the operator up to 50 m from the objective, while transmitting in real time information about the environment it crosses. At the mentioned distance, it will stop and check at 180° for the presence of signs that would reveal the existence of other dangerous elements such as wires, upturned earth, unusual objects for the investigated area, on a stretch of 5 m. In the absence of such signs, the movement will continue for another 5 m and the procedures will be repeated until the distance of 25 m from the objective. At the distance of 25 m, the mini-robot will stop and analyze the terrain and the possible threats. In their absence, it will begin to survey the objective, both horizontally and vertically. The objective will be divided into three parts so that the investigation is carried out thoroughly. If no threats are identified after investigating the edges of the objective vertically and horizontally, the mini-robot will proceed to collect and transmit data on the UXO/IED device to the EOD operator. Based on these, the next steps to be taken and the necessary resources, respectively will be determined and it will also be decided if the mini-robot can take the device or if the scenario needs to be supplemented with the help of human intervention.

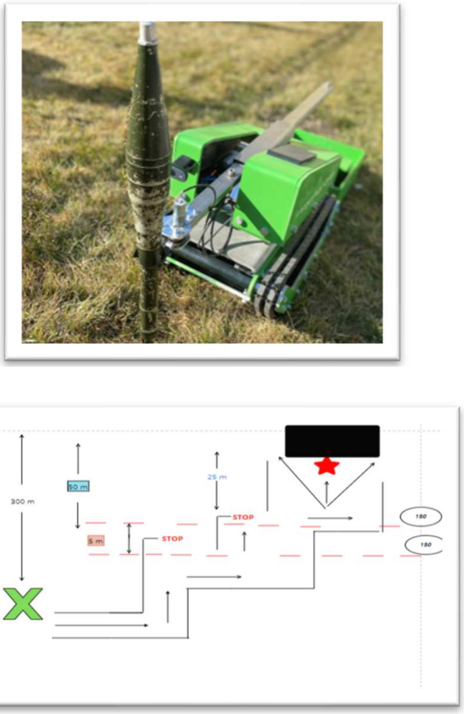


Fig. 6. Procedure for accessing a target and picking up the AG-7 rocket

This stage is carried out in the same way as in the case of the access into buildings and is illustrated in the figure materialized in the *Visual*

Paradigm program, used for modeling scenarios in different structures and domains (Fig. 6).

This diagram graphically materializes the procedure for accessing an objective that the operator follows using a mini-robot intended for the missions of the EOD groups. Based on the information collected with the help of the mini-robot, the operator will decide whether he can continue his mission with the mini-robot he operates or proceed to withdraw it and supplement the forces with other techniques or with the human factor.

Similar to the procedure of access to an objective, a robot can be sent to scout and inspect an open field where a UXO/IED device is suspected. The distance at which the operator must take cover is between 200 m and 300 m. The mini-robot will move along the corridor established by the operator and the witness or the EOD agent up to 50 m from the possible threat. At this distance, the mini-robot will check over the terrain up to a distance of 10 m both lengthwise and widthwise. This last step will be repeated up to a distance of 10 m from the investigated threat, after which the robot will approach up to a distance of 5 m following the investigation of the UXO/IED threat, in the form of a described imaginary square or by a circularly executed movement, as one can see in Figure 7.

Once the necessary information is obtained from the UXO/IED contaminated area, the EOD operator will determine how the course of action will be carried out: either the mini-robot will be withdrawn and the necessary technique, equipment and resources will be used in order to accomplish the mission, or he will continue to operate with the robot sent after the investigation is completed.

Analyzing the course of the intervention, it was found that the demonstrator was able to transmit the necessary information to facilitate the taking of a decision.

This aspect could also be noticed in the case of the demonstrator's access in the open field where the steps specified in the procedure were followed.

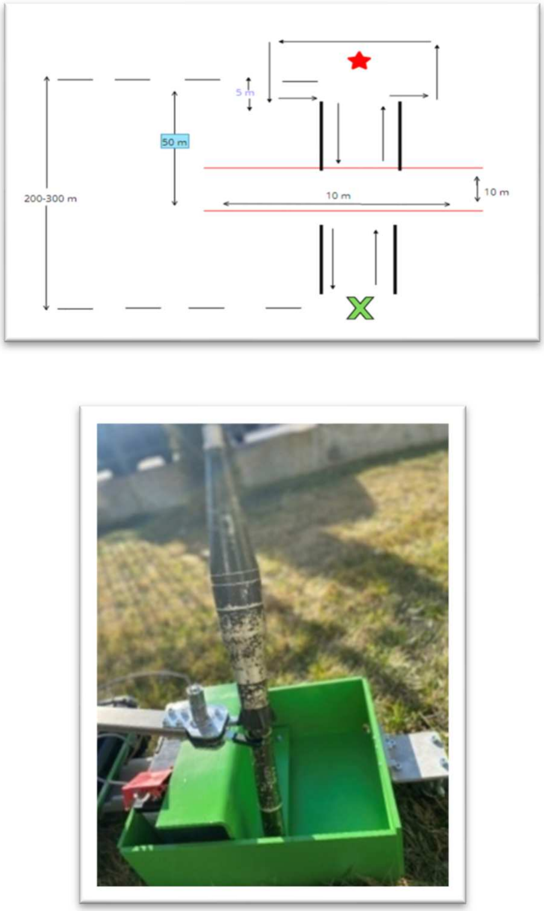


Fig. 7 Procedure for access in open field and placing the rocket in the transport bin

3. THE FORMULATION OF SOME PROPOSALS AND RECOMMENDATIONS REGARDING THE INITIATION OF THE HOMOLOGATION PROCESS

The point where both the advantages and disadvantages of using the technological product converge allows for highlighting and formulating some suggestions and recommendations for improving its endowment, and, on the other hand, some suggestions regarding the development of engineering activities assisted by the robotic component: the use of lighter materials, but resistant to shocks for the organological construction of the mini-robot, the mounting of auxiliary video cameras on the support of the mechanical arm or in other points where they are considered necessary, the use of high-definition video cameras, the use of encrypted connections, the storage of recorded data, the development of the software component so that, based on the recorded data, calculations can be made regarding the mission failure rate related to the provided equipment.

The current stage reached in the construction of the technological demonstrator in question could be augmented by moving to the homologation stage and its actual production in industry, according to all the engineering and economic rigors.

Taking into consideration the characteristics of the contemporary operations environment (a special case is represented without a doubt by the Russian-Ukrainian crisis), but also by the trends of technological renewal of the military field, otherwise subsumed to an irreversible development of the technical dimension of security, making substantial steps towards the specialized market is a must.

Under the conditions of the current security challenges, the issue of endowing the forces, especially the land forces, with such a system (mini-robot), in a standardized, mass way (for example – one for each battalion-type structure), as a manner of equipping, which is also of interest from the point of view of the agreed production load after homologation.

An important point in determining the final solution will also be represented by ensuring the possibility of updating and upgrading and by ensuring the necessary logistical support (the involvement and co-interest of the manufacturer) during the life cycle.

4. ACKNOWLEDGEMENT

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PERSPECTIVE GENISTICE CONTEMPORANE REFLECTATE ÎN REALIZAREA PRACTICĂ ȘI IMPLEMENTAREA DEMONSTRATORULUI TEHNOLOGIC ROBOTIZAT – AVANGARD Robo SilMih

Rezumat: *Autorii prezentului demers științific doresc să reliefeze câteva contribuții științifice care se conturează în jurul unor produse tehnologice robotizate, pe șenile, brevetate și care au condus la realizarea practică a unui demonstrator tehnologic, nivel TRL 6. Lucrarea evidențiază un sumar al tuturor fazelor de execuție aferent unui grant de cercetare tip Plan Sectorial Cercetare-Dezvoltare al M.Ap.N. privind realizarea practică și implementarea unui produs tehnologic de minirobot șenilat destinat aplicațiilor engineeringe. Sunt prezentate, pe scurt, câteva elemente privind identificarea acelor componente specifice sistemelor engineeringe interoperabile NATO, un exemplu de bună practică privind atât realizarea, la scară 1:1, a unui demonstrator tehnologic destinat detectării și asanării/deminării UXO și IED, cât și posibilitatea implementării acestuia în cadrul misiunilor engineeringe (mediu operațional – sistem de prototip verificat), formularea unor propuneri și recomandări privind inițierea procesului de omologare a produsului tehnologic*

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