Unmanned Ground Military and Construction Systems Technology Gaps Exploration

Eugeniusz Budny[a], Piotr Szynkarczyk[a] and Józef Wrona[b]

[a]Industrial Research Institute for Automation and Measurements
Al. Jerozolimskie 202, 02-486 Warszawa, Poland
Email: ebudny@piap.pl, pszynkarczyk@piap.pl
[b]Military University of Technology
Ul. Gen. Sylwestra Kaliskiego 2, 01-476 Warszawa, Poland
E-mail: jozef.wrona@wat.edu.pl

Abstract

There are found the answers to the scientific question whether it is possible to figure out the methodology to explore technology gaps looking through Operational Requirements (ORs) defined for military systems, to apply it to construction industry applications technology gaps exploration. In this paper were specified the (ORs) that enabled a preliminary analysis on Unmanned Ground Systems (UGSs): which kind of platforms might be developed and shared between the systems devoted to different military and construction industry applications. In this paper are presented technology gaps identified by comparing the ORs with the state of play of technologies that are currently available in the military and construction equipment applications. Then the challenges and measures are identified and associated to the gaps that should be taken in order to bridge each specific gap. There are identified technological and non-technological aspects that may hamper development of UGS solutions that fully achieve the ORs, and thus would need to be further studied and/or elaborated. As a next step actions are specified. They represent the research and development initiatives, steps or activities that should be done in order to be in the position of developing UGS solutions achieving the specified ORs and requirements of construction site. The actions need to be completed to bridge the technology gaps to make required new capabilities available. One of results of such a methodology are schedules based on the roadmap aimed to guide the development of the future UGS solutions towards the achievement of operational and construction site requirements.

Keywords –

unmanned ground systems (UGSs); construction industry applications; operational requirements; technology gaps

Introduction

The article is based on the work carried out on Unmanned Ground Systems Landscaping and Integration Study (UGS-LIS) (GMV 24150/14 V2/15) that was done by international consortium: GMV AEROSPACE AND DEFENCE S.A. (Spain), Industrial Research Institute for Automation and Measurements PIAP (Poland) and Military University of Technology (Poland) for European Defence Agency (EDA) as an owner of the study results (EDA Project 13.CAP.OP.592) [1]. It concerns the work carried out within the project PBS No 936 on Development of design, technology and effectiveness of Unmanned Ground Platforms teleoperation systems.

The purpose of the study was to support the development process of ORs for military Unmanned Ground Systems (UGSs), expounding the implications for military structures and proposing a detailed *roadmap* (with a focus on autonomy) that guide future developments towards the achievement of the ORs.

Being supported by the study results of the above mentioned project, the purpose of this article is to find the solutions to the scientific question whether it is possible to figure out the methodology to explore technology gaps looking through operational requirements defined for military systems to apply it to construction industry applications technology gaps exploration.

Operational Requirements

The main objective was to select the military tasks suitable for UGSs and define a set of Operational Requirements for them coming from Concept of Operations (CONOPs) [2]. Then, there were identified the potential implications derived from these requirements. Next, there were identified legal challenges and ethical implications of using UGS in military operations [2].

What was essential to do that? First there were established a series of definitions regarding the UGSs to guarantee a clear common understanding of the meaning of most relevant terms, provided a rationale for the use of UGSs to highlight the main advantages posed by them. Then there were established a clear criteria for selecting military tasks most suitable for UGSs._

As a next step there was selected a set of military tasks based on the previous criteria, task survey guided by the Generic Military Task List (GMTL) defined in the EDA's Capability Development Plan (CDP) [3].

Then there were specified the operational capabilities an UGSs should possess to perform each task to be specified in the form of ORs. High levels of autonomy were assumed, although leaving in some cases the door open for intermediate remotely controlled solutions. Platform-specific requirements were also included, enabling a preliminary analysis on UGSs platforms [2].

At the end of this process there were identified the potential implications on the military structures of UGS solutions. There were done some analysis of the implications considered in the light of the NATO's DOTMLPFI model. – Assessment of the ethical and legal issues posed by UGSs [4].

In opinion of the Authors of this article, the same approach could be applied to unmanned construction machinery not only in the military area of applications to find their newest functionalities, that are needed looking through the requirements of the market. Defining the list of new tasks resulting from the market needs, using the well defined criteria, it is possible to fulfil these requirements reaching new capabilities of the newest unmanned construction systems.

State of Play

At the beginning of the process there was analysed the global & European UGS market (Figure 1). Then there were discussed the main research areas to be focused on detailed analysis of the autonomy area [2].

Next, to describe the state of play there were defined application areas like: EOD/IED robots, inspection/reconaissance robots, engineering robots, combat robots [2].

Then there were defined UGSs research areas like: high mobility, manipulators, power supply and drive, perception and sensory systems, communication, Human-Machine Interfaces, standards and interfaces, autonomy [2].

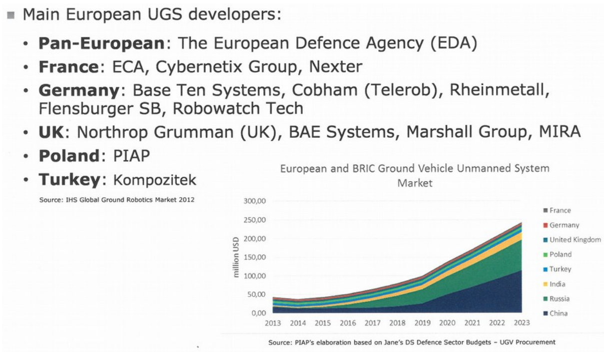

Figure 1. European UGS market [2]

In case of autonomy, there were considered three main levels of UGS autonomy:
1. Non-autonomous robots: decisions are made by an operator, who is also responsible for controlling the movements;
2. Semi-autonomous robots: perform some of their tasks autonomously, but under the supervision of an operator; the task may also be interrupted at any time and control can be taken over; applies to all the robots which partly support the decisions of an operator;
3. Fully autonomous robots: do not require operator supervision and their functions are performed independently in a dedicated environment [2].

Being focused on autonomy it was considered and then described in such areas like: operational autonomy, mapping, perception, global path planning, local movement planning, manipulator autonomy, robot swarm and their cooperation, partial autonomy-following a human/vehicle/robot [2].

Gaps Identification

There were defined steps to find technology gaps.

First, there was defined the list of fields that covers Operational Requirements in the following fields: general, communication nodes, area surveillance, reconnaissance, casualty extraction, CBRNE (Chemical, Biological, Radiological, Nuclear and Enhanced Conventional Weapons) reconnaissance, explosive detection and disposal, convoying for the distribution of supplies, follower mule, route clearance.

Next step was to define field requirements divided into specific fields. There were defined technological: *high mobility base platform, Human-Machine Interfaces and Machine-Machine Interfaces and teleoperation and control systems, data transmission systems, environments recognitions (sensors), manipulation capabilities, autonomous operation, supply and engine* *systems* and non-technological fields: *command structure, ethical, legal, personal and cultural*. In each of these fields the technology gaps were figured out and described. For the field of *high mobility base platform* there were defined following technological gaps: platform capable of making fast moves conditions and operation in urban areas. For *Human-Machinery Interfaces, Machine-Machine Interfaces and teleportation and control systems* there was defined such technology gaps like: multi-purpose shared tactical map interface, console access and authentication, interactive overview of autonomous systems. In the field of *data transmission systems* there were defined following technological gaps: elimination of interference between radio waves on small objects, taking the co-site effects into consideration, effective methods of electrical equipment shielding (including drive systems) and electronic devices. For *environments recognitions (sensors)* there were defined such technological gaps like: environment awareness, visual recognition, identification and tracking, combat situation awareness. In the field of *manipulation capabilities* there was indicated a lack of low power hydraulic components and need to establish safety measures for powerful manipulators. But in the field of *autonomous operation* there were defined following technological gaps: malfunctioned motor robot navigation, recovery mode switching logic and path planning maximizing tracked objects' visibility. And finally in the field of *supply and engine systems*, electric and hydraulic drives were pointed out as a technological gaps [2].

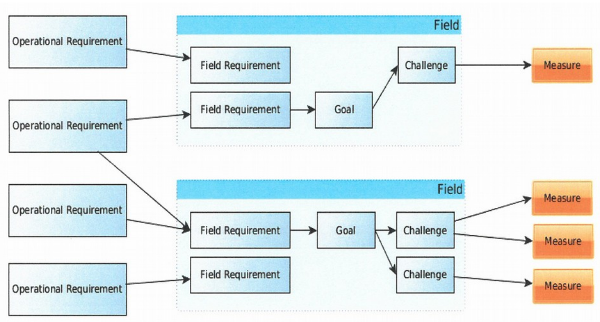

Figure 2. Process and terminology [2]

There were also defined gaps in non-technological fields. In the field of command structure there were defined lack of Concept of Operations (CONOPs) of usage of UGSs at the all level of command and technology gaps that hamper fulfilment the Operational Requirements, lack of procedures in the area of education, training, use and methodology to test them. In the ethical field there was defined the need to establish ethical and legal frameworks of UGSs usage and also decision-making procedures. In the legal field there were pointed the needs to figure out system security (Unauthorized Use) and proliferation. While, in personal and cultural fields there was defined the need to figure out best Human-Robot Interaction solution. There was also pointed out technology dependency [2]. Each gap was finally described in the Final Report [1].

As a third step, there were identified the field requirements that have already been met within the existing solutions and those to be met in future as a goals that were considered in step fourth (Figure 2). For each Goal, there was analysed the related gap and provide appropriate measures. Finally, there were provided summary, measures and traceability matrix [1].

It seems to be obvious that very similar approach can be applied to explore technology gaps in the fields of construction systems considering requirements resulting from technological the same way as were considered ORs coming from CONOPS. So, we can say that the above described approach could be a solution to the scientific question whether it is possible to figure out the methodology to explore technology gaps looking through Operational Requirements (ORs) defined for military systems to apply it to construction industry applications technology gaps exploration.

Actions plan

There were defined methodology and then within it - steps and process. Then there were done actions identification and their descriptions, actions analysis and conclusions [2].

The objective of this process was to define the research and development initiatives, steps or impulses that should be done in order to be in a position of developing autonomous unmanned vehicles in a medium term and to provide both a methodology and a tool to define the actions to make possible development of UGS basing on technologies defined in the process of gaps identification.

There were defined four steps to create an actions plan:

1) create a matrix of actions to be confronted with identified gaps including technology gaps grouped in the fields with attached adequate and corresponding Operational Requirements being additionally screened through three mentioned in below step 3 aspects of UGSs issues;
2) create action descriptions for each of identified gap;
3) specify separate developments for work on:
   - the base platforms,
   - efforts dedicated to payloads, sensors and effectors,
   - the system level components;

4) include some result of studies for chosen technologies - the interoperability options with other developments [2].

Within the actions analysis process there were defined 179 actions confronted with identified technological gaps that are adequate and corresponding with Operational Requirements.

It was possible to analyse defined actions looking through three aspects of UGSs' issues defined in above described step 3, finding the importance of the actions.

Actions considering *autonomy* being a main issue of these analysis have been considered within the following fields: *Human-Machine Interfaces and Machine-Machine Interfaces and teleoperation and control systems, data transmission systems, environments recognitions (including sensors), manipulation capabilities, autonomous operation.* Considering autonomy it was also very important to analyse: *high mobility base platform* and *supply and engine systems.*

Roadmap

Unmanned Ground Systems Landscaping and Integration Study (UGS-LIS) was centred also on establishing a roadmap that guide the future development of UGSs in the European context [1].

Roadmapping can be defined as a strategic planning process whose main objective is to provide both a methodology and a tool to promote sound planning of technology development against capability needs. In particular, capability roadmaps are aimed at supporting the processes leading up to the development of the user requirements, being the capability needs the primary unit of analysis [1]. It applies not only to the area of unmanned ground military but also civilian – construction systems.

As described above, in the UGS-LIS study capability needs were defined in the form of Operational Requirements, and then analysed in order to find out the existing (technological and non-technological) gaps and specify the set of actions to be performed to bridge them (and thus, satisfy the capability needs). The roadmap produced as result of the work linked those actions with the corresponding capability needs into a timeframe. Two main parts may be distinguished in the roadmap:

- The first one showed the estimated schedule for bridging the technology gaps. It was organized by field and presented in the form of timed charts, where each gap was associated a timeline representing the estimated time to bridge it. In the case of the *Autonomous operation* technology field, a more detailed schedule was provided including the time to complete each specific action associated to the identified gaps.
- The second part showed the derived capability acquisition schedule. This part was organized by military task and included, for each associated required capability, the time in which that capability would be acquired according to the schedules established in the first part of the report.

The resulting roadmap may be seen as a basis to plan and arrange the future projects and R&D initiatives that lead to the development of UGSs that possess the required operational capabilities [1]. In the area of civilian applications (construction systems) such a roadmap could be based on very similar analysis in the context of required capabilities resulting from new tasks that the newest construction systems have to fulfil.

Conclusions

The Final Report of Unmanned Ground Systems Landscaping and Integration Study (UGS-LIS) contains thorough analysis of actions assigned to technological and non-technological gaps (organizational, political and legal aspects).

Division of the problem into the different series of UGSs is in line with military representatives approach to implement the UGS into structures basing on specific operational needs. Due to different conditions and requirements the actions to support implementation of UGSs will be different for each scenario and associated platform type.

Action Plan Report together with Matrix create a clear guidance for decision makers to establish necessary initiatives and actions that will support implementation of autonomous UGSs into military structure.

This analysis provides knowledge concerning current level of technology development in each gap defined in the fields, by highlighting how far each of the presented philosophies is in achieving full autonomy level and how much work (and what type of work) still needs to be done to reach desired levels.

Each action defined is accompanied by a justification or rationale of the need to execute that action, the actors who could execute it and the priority of that action.

Using Action Plan Report and Matrix it is possible to do multispectral analysis of actions in the area of defined gaps within the fields and assigned for them Operational Requirements to reach capability needs such as for example autonomy of the systems or interoperability of them.

The planned actions are dedicated to specific technologies or applications. It is one of the key parameters to keep all activities in boundaries of reconfiguration and modularity approach as a priority. With regard to all implementation support actions the main focus is on keeping the interoperability of emerging UGS as an important added value for future use of that systems in military structures. [2].

Autonomy which was a focus area in the presented approach is a common field for unmanned ground military and construction systems that is being developed just now.

Described in this paper approach could be a solution to the scientific question whether it is possible to figure out the methodology to explore technology gaps looking through Operational Requirements (ORs) defined for military systems to apply it to construction industry applications technology gaps exploration.

References

[1] Final report of the project on: Unmanned Ground Systems Landscaping and Integration Study (UGS-LIS) (GMV 24150/14 V2/15), that was done by international consortium: GMV AEROSPACE AND DEFENCE S.A. (Spain), Industrial Research Institute for Automation and Measurements PIAP (Poland) and Military University of Technology (Poland) for European Defence Agency (EDA) as an owner of the study results (EDA Project 13.CAP.OP.592), European Defence Agency, Brussels, Belgium, 2015.

[2] Unmanned Ground Systems Landscaping and Integration Study (UGS-LIS), EDA Supported Project -EDA Project 13.CAP.OP.592, FINAL STUDY REPORT - GMV-UGS-LIS-PRS-001-15 – Presentation prepared by Héctor Naranjo Setién on behalf of Consortium Members presented to the EDA by international Consortium: GMV AEROSPACE AND DEFENCE S.A. (Spain), Industrial Research Institute for Automation and Measurements PIAP (Poland) and Military University of Technology (Poland), Brussels, 11th February 2015.

[3] Capability Development Plan. On-line: https://www.eda.europa.eu/docs/default-source/eda-factsheets/2015-05-07-factsheet-cdp351D4CB6EDE5, Accessed: 16th March 2017.

[4] Lieutenant General Jeffrey G. Lofgren. NATO CAPABILITY DEVELOPMENT INTEROPERABILITY. On-line: http://www.jwc.nato.int/images/stories/_news_items_/2016/LT_GEN_Lofgren_interview.pdf, Accessed: 16th March 2017.