

Ergonomic Convergence of a Modular Integrator in Aspect of Soldier's Situational Awareness on the Battlefield

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Abstract

Herein article describes the result of analysis of fitting the Modular Integrator (M-ITG) to a man operating in a given environment-the battlefield. Applying the Modular Integrator is one of main methods of increasing soldier's situational awareness on the battlefield through using advanced technical and electronic devices to manage its C4I system. Functional aspects of the M-ITG support a soldier in everyday combat operations, while increasing soldier's situational awareness. Main tasks of this device are to provide the soldier with maximum safety during performing his combat missions. It also integrates the electronic and optoelectronic equipment, improves commanding the battle team, ensures a flow of voice information, sending data and images and displays the tactical situation on its screen. Centralizing the device lets to reduce the number of actions that a soldier would have to perform, and thus shortens the time of concentration loss on the battlefield. The dependency system between the battlefield the soldier and the Modular Integrator has been described in this material as a classic ergonomics system (a man-a technical object-the environment). The indication of convergence between the Modular Integrator and the user, as well as other elements of the environment, contributes to increasing the situational awareness on the battlefield, which is confirmed by the prepared matrix of dependencies. The results shown, that the examined equipment meets the specific ergonomics requirements in the triangle between a man-a technical object and the environment of the battlefield.

Keywords: Ergonomics; Situational awareness; Ergonomic convergence; Functional polymorphism

Introduction

Changes taking place on the battlefield determine new method of gaining the dominance over an opponent. A particular attention is to be drawn to soldier's equipment, which should support the increase of his situational awareness, combat capabilities, and as a result, should provide access to reliable and up-to-date information. A man, equipped with the most modern technical gear to support his actions, he gains more chances to succeed in his mission. It should be noted that all devices dedicated to a man must be adapted to him. They have to meet functional needs, but also, and perhaps above all, to fit all individual psycho-physiological conditions of a person and comply with the specific environment in which soldiers operate. Particular attention should be drawn to those devices that directly support the soldier in completing his tasks. Among many elements of soldier's individual equipment, we focus our interest on the Modular Integrator (M-ITG), which is used to manage the C4I system (Command, Control, Communications, Computers and Intelligence) and is a subject of a research and development project. The main aim of project titled Modular Integrator to manage the soldier's C4I system" was to develop and construct the Modular Integrator (M-ITG) on the 9th level of technology readiness. The project and construction of the device turned out to be an interdisciplinary issue, which required knowledge and experience in the field of telecommunication, signal processing, mechanical engineering, aerial technics, software

engineering, materials and ergonomics. Due to the significant specialist requirements the above task was performed in the interdisciplinary Scientific-industrial Consortium including: WB Electronics S.A., consortium leader, Military Institute of Aviation Medicine – a member and PCO S.A., a member.

The aim of this publication is to present results of the analysis of the Modular Integrator's economic convergence in aspect of soldier's situational awareness on the battlefield.

In order to perform the analysis, a classic ergonomic system-a tripartite system including a man-a technical object-the environment was used. The human centric system of dependencies defines a need of adapting technical means (objects) to a user, with taking into account the conditions in which the person is located, namely the environment.

Human Conditioning: Situational Awareness

Concerning the aspect of fitting the technical equipment to a man, both general and specific psychophysiological requirements, resulting from the nature of performed task, must be taken to account. General ones are defined by device's ergonomics. The literature shows a number of aspects to be considered when describing characteristics to be met by a product which relates to a man. Jabłoński J [1] formulated nine principles that guarantee to construct a product adapted to a man:

- Anthropocentrism principle
- Ease of use principle
- Convenient and effortless use principle

- Principle of appropriate size and space maintaining
- Accounting the mental capacity principle
- Principle of adequate environment for usage
- Information legibility principle
- User error tolerance principle
- Principle of hierarchy of ergonomics objectives

Wieczorek S [2] adds another four characteristics appearance (shape, proportions, graphics and colour solutions) and workmanship.

Górska E [3] indicates a significant role of an expert system in a general approach to ergonomics, but also to the role in evaluation of representatives in the target group, which shows the importance of subjective assessments.

However, Horst W [4] draws attention to a role of user's perception and his individual features.

Detailed, specific guidelines and ergonomic recommendations, dedicated to electronic devices for special purposes can be found in the standard NO-06-A104: 2005 – Armament and military equipment. General technical requirements, methods of testing and inspections. Construction requirements. The standard draws special attention to soldier's surroundings, work environment, purpose, characteristic features of construction and function of the device, anthropometric indicators, control units, information display, sound indicators, visual effectiveness and recommendations for technical aesthetics and color solutions.

Requirements that result from the performed tasks of a professional soldier are concentrated around the situational awareness on the battlefield.

The situational awareness can be defined as a perception of elements of the surrounding environment performed in a specific time and space, including understanding their meaning and being able to imagine them in the nearest future. Thus it is a thorough knowledge of what is happening around us and what can be expected [5]. In other words, it is a constantly updated "knowledge of where I am, where are my companions, where is the enemy". Possessing current, updated and reliable information helps to make accurate decisions, react quickly and change, what increases security and task performance. Thanks to getting feedback on performed actions one can change their decisions. While paying particular attention to situations where what is thought does not comply with what is seen. Cognitive stressors that are formed on the information platform, play a significant role in this aspect.

A study of Alberts DS, et al. [6] define a hierarchy of terms that are used when building the situational awareness. According to the authors the data used are: individual facts, measurements and observations that can be sufficient (or not) to work out a particular, detailed decision, information is formed through data collection and processing which means its reduction, analysis, synthesis, adjustment etc., knowledge comes from the ability to use information to build a model of concept, it is based on understanding the phenomenon, what allows operation results to be forecasted and situation control to be increased, while awareness and wisdom are results of merging the crucial information of clear and equivocal for all users. The above can

be illustrated on a diagram showing a connection between "information hierarchy (Data Information Knowledge Wisdom) with the general model of observation and taking actions OODA (Observe Orient Decide Act). This model has been developed by a retired American colonel John Boyd, who claimed that anyone can show all human rational behaviours and his organization as a continual cycle of four changing and different tasks: to observe, to orientate, to decide and to act.

The situational awareness constitutes of internal and external information. The first are drawn from own observations – soldier's senses and elements of his personal equipment. They are sets of cameras installed in the helmet system, as well as his binoculars, scopes, microphones, etc. Devices that can be fully controlled provide information which is located in the soldier's Personal Combat System. It is quickly accepted and interpreted. However, it should be noted that the above described information are less valuable if they are forwarded only in their original form. Without additional data, like for example location of their acquisition-soldier's coordinates (individual reference system) they will be less possible to be read (for example an image from a camera which does not specify the position, or the pointing direction of the camera is information which is hard to be used).

The second group of acquiring information is external sources-soldiers operating in the task unit along with their equipment and their direct commander or a higher level commander. This information can be local and global. Local information is derived from colleagues from the unit and is given in the local reference system, for example in relation to local coordinates. In a direct contact they can be transformed by a person passing them on his own individual frame of reference, for example using words like: on your left, 12 o'clock, etc. Their interpretation is their additional distinctive feature. One should not forget that people cooperating together possess a way of communication that is distinctive to this specific group. This fact should be used for interpreting incoming information. During training, the soldiers exercising together work out an own group communication system which uses no words. The information communicated with non-verbal signs carry more information for members of the team, than for those outside it. Using this custom-"altered" form of communication provides distinct opportunities for the whole team. This information is formulated in a local reference system and has a group form [7].

Information are also transmitted with use of technical means that support the battlefield – for example manned and unmanned aircrafts, land or sea devices, satellites, etc. To say briefly, the situational awareness boils down to possessing up-to-date knowledge of the situation prevailing in our environment-the battlefield, that in turn is a component of two types of elements (Figure 1):

Natural elements-terrain form, geographical coordinates, climate, fauna and flora and prevailing conditions -including dustiness, pollution and environment contamination.

Artifacts-artificial objects built by a man. They include widely understood infrastructure and equipment on the battlefield-all technical equipment of both the allied and the enemy units.



Figure 1: Soldier's surroundings on the battlefield. Source [5].

Increase of Situational Awareness of a Soldier in Aspect of Functionality of the Modular Integrator

In order for the described above situational awareness to be maximized, the system of perception of a soldier must be provided with the optimum number of information. Its interface should be simple and intuitive in order to not to become troublesome in a situation of extreme stress. A device, which in the soldier's Personal Combat System (PSW) can combine functionality of a few devices in one housing, will be the key to improve and extend the functionality, increase the ease of use and efficiency, and thus ergonomics in terms of adapting soldier's tasks to his psychophysical capabilities. The Modular Integrator to manage the soldier's on the battlefield is such device [8,9]. The Modular Integrator integrates features of a mobile phone (smartphone), a personal computer (PDA) and soldier's personal radio station within one housing (Figure 2). Its functional multiform can also be called a functional polymorphism – because of the fact that a single, autonomous device combines functions of many different appliances. Considering the definition of "functionality", by defining mechanisms that allow the use of the M-ITG in several different ways one comes to the conclusion of polys (Greek for "many") – morphe (Greek for "form") [10]. The task of the Modular Integrator is to provide the user with simple and intuitive way of presenting visual

signals received from various sources and sensors of the C4I system. Various wired interfaces that enable the above functionality are placed on the device's housing, which is shown in Figure 2. Access to the optoelectronic and radio electronic equipment, a legible display of tactical situation, control of data, video and audio transmission were put on an interactive display, shown on Figure 3.

The device provides access to soldier's C4I optoelectronic and radio electronic components using a single interactive display, which performs following functions: audio-visual, navigational, sensorial, gives comprehensive picture of a tactical situation and controls data transmission as well as image processing. M-ITG also performs the functionality of a mobile phone basing on the global telecommunication infrastructure (GSM). The built-in radio station module forms and configures MESH network, provides simultaneous data and voice transmission, passes the information of the current GPS position and transmits a video from a selected station. The cooperation of the Modular Integrator with tablets and smartphones (visualization and configuration is conducted via USB or Ethernet), a built-in AES 256 encryption and optimization of the range of operating frequencies and modulation scheme make the M-ITG a fully webcentric solution [11-14].

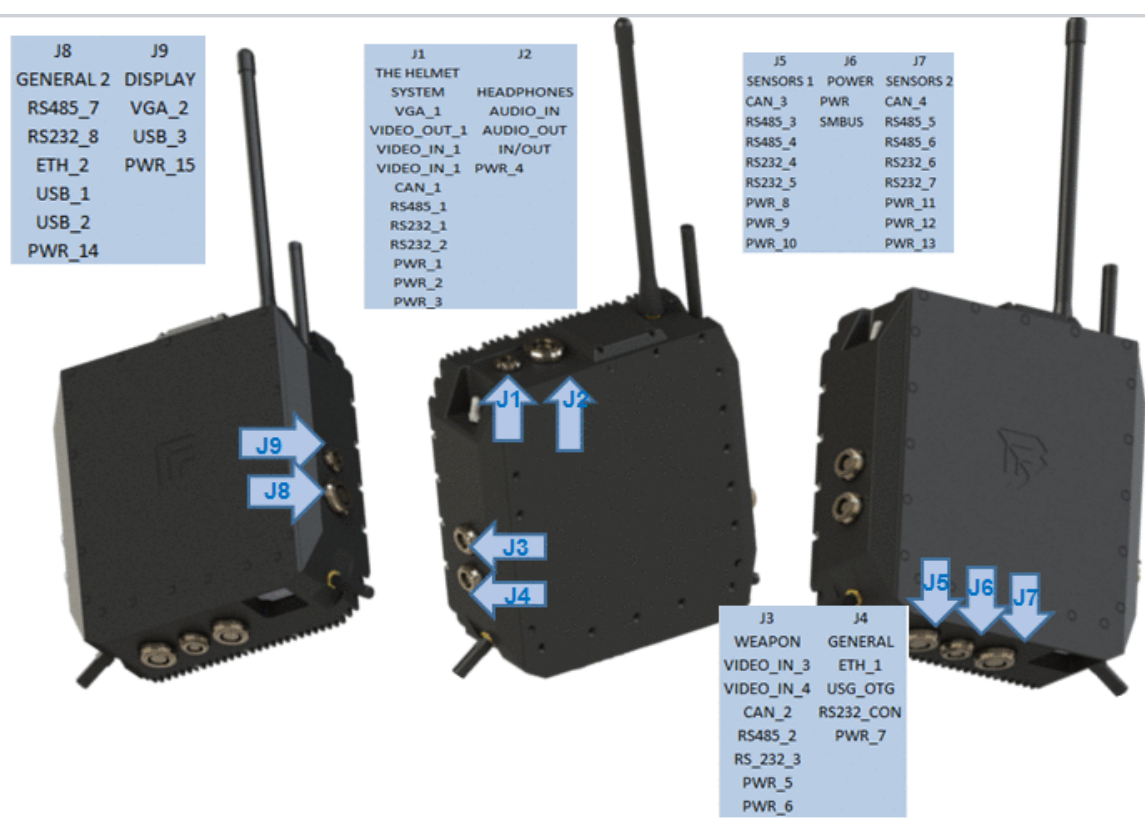


Figure 2: Modular Integrator to manage the C4I soldier system-designation of the interface's.

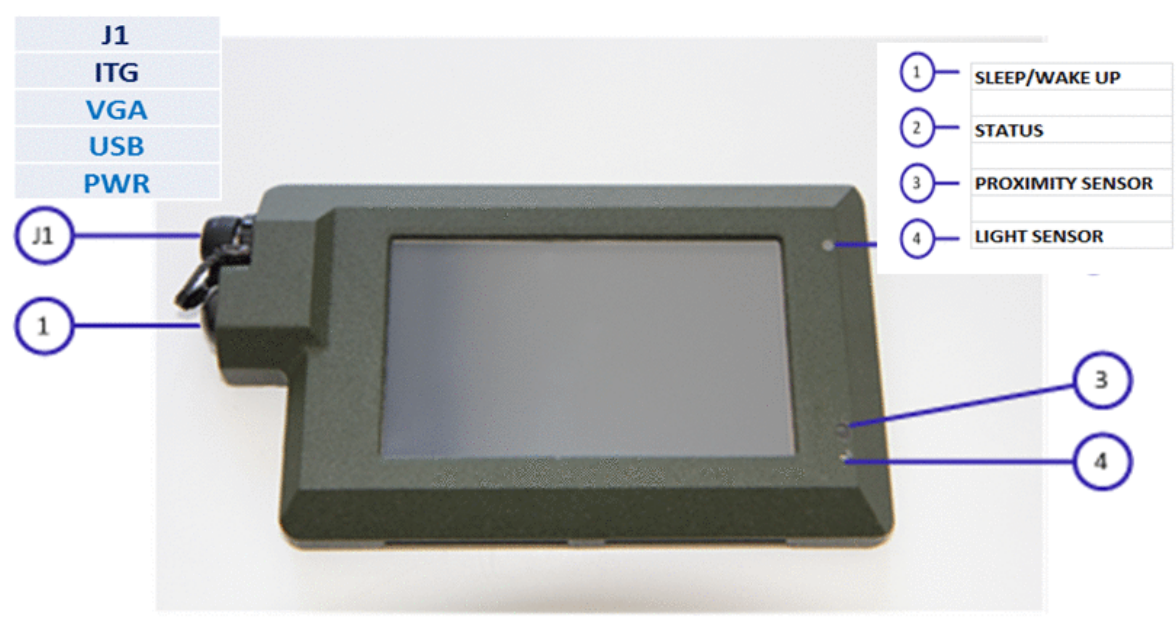


Figure 3: Display of Modular Integrator-designation of the interfaces.

Centralizing the entire device in a single housing reduces the number of actions that a soldier would do if he was supposed to use each appliance separately. As a consequence using the Modular Integrator reduces the loss of concentration on the battlefield and helps to improve safety.

As a result, controlling and using the Modular Integrator is intuitive and simple enough not to cause problems in the situation of a severe stress. It is also noteworthy that the mobile phone, broadband soldier's personal radio station and a personal computer (PDA) with battery module which allows an eight-hour work, complement each other, forming a fully functional device, which, although is well spread among users of smartphones, has no counterparts within the military equipment – both on Polish and foreign markets.

It should be added that above mentioned self-phone, soldier's radio station and PDA constitute a convergence and form a fully functional device. The process of integrating multiple devices in a single device

and making a synergy out of them, points out to the innovative nature of the product.

MITG Ergonomics Convergence Analysis

MITG ergonomics: Conditions of a man

Adapting the MITG to the psychophysical conditions of the user has been analysed within an expert evaluation with a participation of a research group, using a method of subjective tests. The aim of the study was to assess if the M-ITG complies with the requirements and expectations of its users in accordance to rules of ergonomics.

Tests were performed by eighteen users' representatives. Most of them consider their competences in use of the device as good or very good. Respondents' age ranges from 31 to 41 years old. The average age of the research group was 36 years old - Figure 4.

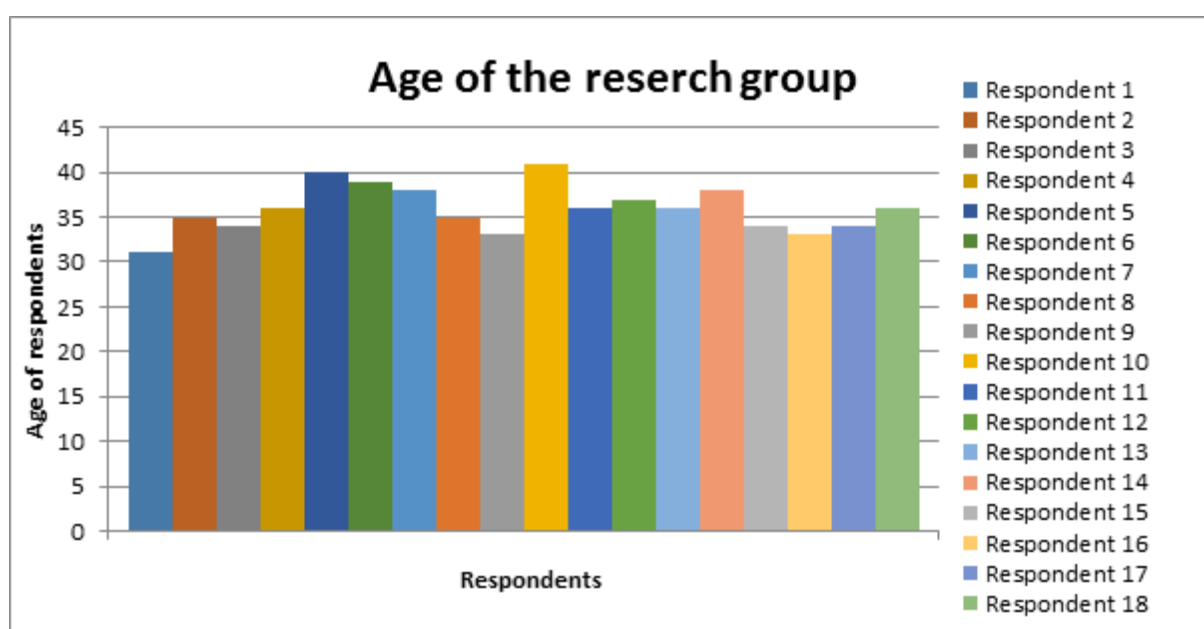


Figure 4: Age of the research group. Source: Own study based on data from Military Institute of Aviation Medicine.

Questions asked in the survey carried out in the form of an interview were open-ended. Evaluation was rated with five-point rating scale, where 1 was the lowest note and 5 the highest note.

Most of the respondents assessed locating the M-ITG on human body as good (44% rated it 4, 38% rated it 3). The equipment gives a soldier the ease of use which was confirmed by 55% of respondents (11% rated it very good, 44% rated it good). It does not collide with any other element of the soldier's equipment (11% rated is very good, 44% rated it good).

The weight of the device is acceptable (55% rated it 3), however it still need improvements in terms of optimization. The device does not limit its users movement or action (55% rated it good, 44% rated it sufficient, which can be a result of previously asked question considering the device's load on human limbs and the whole body). The results are shown on a Figure 5.

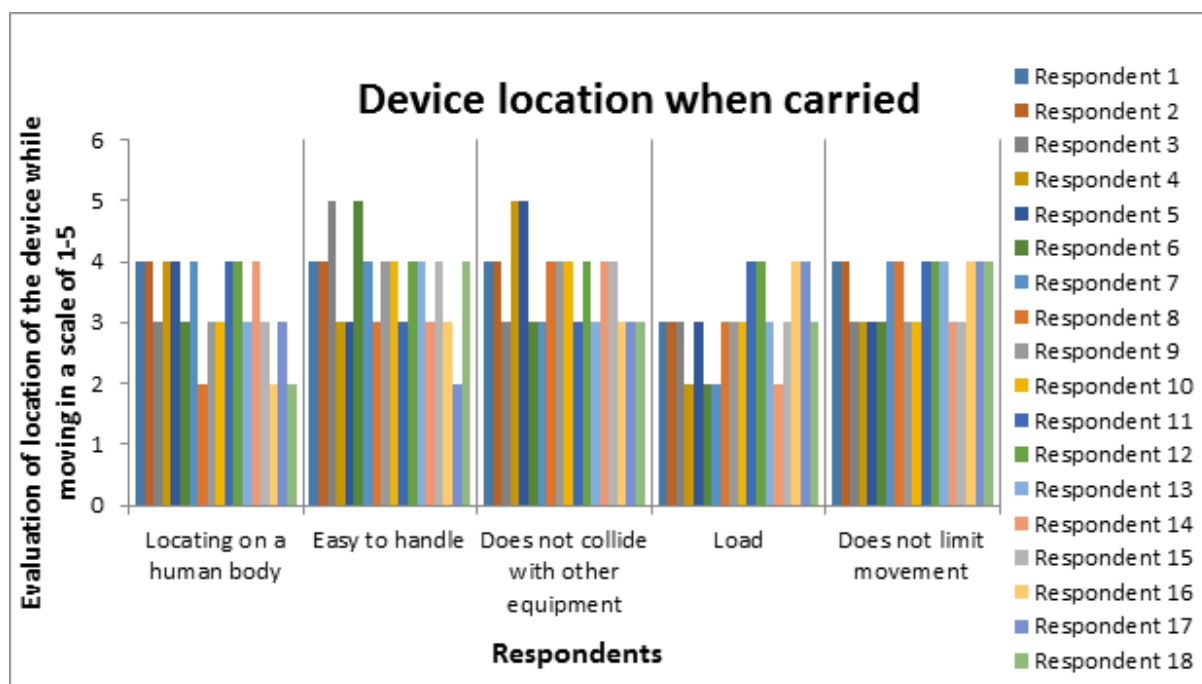


Figure 5: Results of questionnaire device location when carried.

The second part of questions focused on the requirements and recommendations of product's ergonomics described in the second chapter of this publication. Results shown on Figure 6 indicate that the MITG device rather fits human body size (50% responded well). Its ease and comfort of use were rated mainly good (61% rated it very good and 50% it good). The size of the device was generally rated as sufficient (83%), which indicates that Modular Integrator's size should be minimized.

Information presented by the device were rated legible (67% rated it good). It should be mentioned that Modular Integrator software can be modified and configured according to one's needs.

The shape of the device is suitable (50% responded well and 37% rated it very good). Graphic solutions as well as the colors used both of hardware and software is suitable (55% rated the graphics as good, 72% rated the colors as very good). The device was manufactured in a rather decent way (50% rated it good) and can be configured according to individual needs of its user (50% responded good).

The survey performed on the group of respondents, who represented the target group clearly show that the device meets user's requirements in terms of using it in the modern battlefield.

Therefore, it can be concluded that the Modular Integrator is ergonomic. However, according to the principle of constant improvement-Deming Cycle-the device should undergo constant development and adaptation to the newest achievements of technology.

According to the respondents the device fulfils its functions and is accepted in terms of its ergonomics. Its functionality remains maintained. However it is advised to seek for optimization of its weight and size.

An attention should be drawn to the fact, that any device of such type becomes an additional weight to the limb it is attached to thus can become troublesome depending on the time it is used. The location of the Modular Integrator on a human body is good; it does not limit soldier's moves and does not collide with other elements of his equipment.

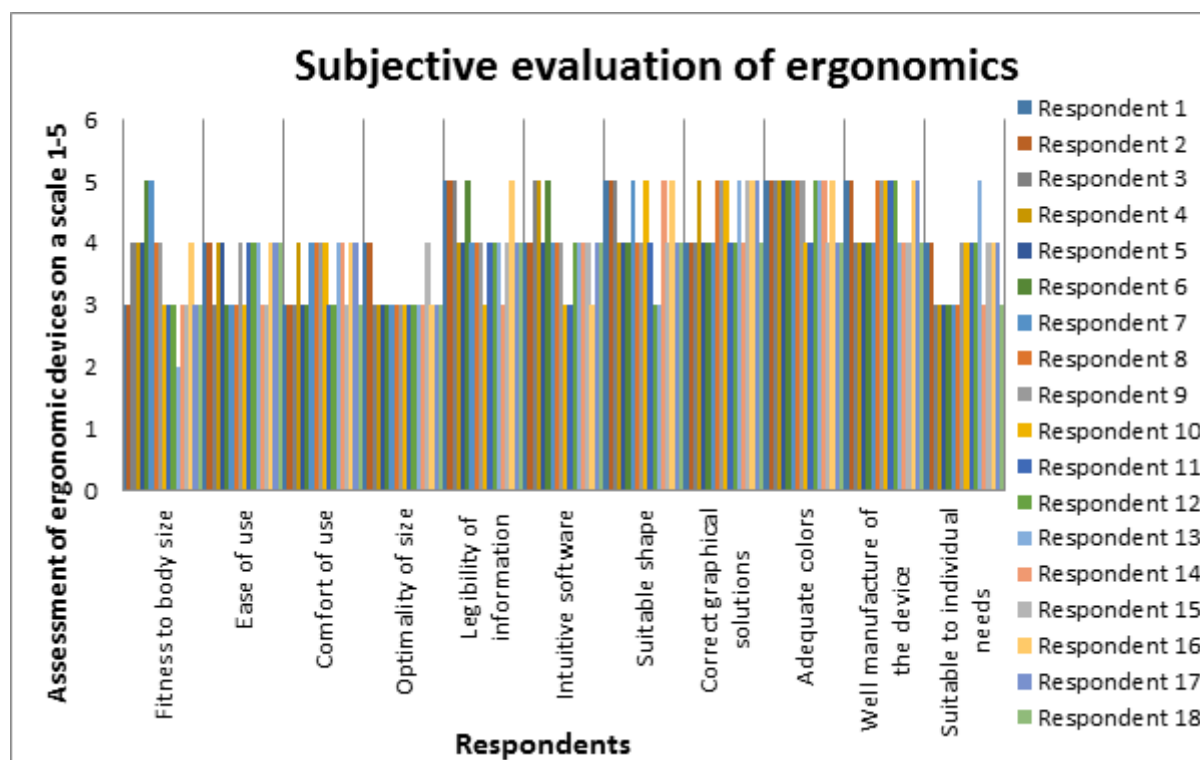


Figure 6: Result of questionnaire. Subjective evaluation of ergonomics.

MITG ergonomics: Situational awareness

The second part of analysis presents functions that MITG has in terms of improving the situational awareness of the soldier. It was widely presented in chapter two of this article. Features, functions and

possibilities presented in the below table fit into the work ergonomics of the soldier operating in his “work environment”, namely the battlefield (Table 1).

Description	W-M-ITG	M-ITG	B-C4I	Sending	Receiving
Basic information display: time, location, battery status, device status		x	x		x
Enable / disable of equipment from the system environment, detecting the connection to M-ITG	x	x	x	x	x
Display mode change (day / night), brightness adjustment	x			x	
Turning system and other devices on / off	x	x	x	x	
Alarm triggering, contamination alarm					x
Alarm information sending		x		x	
Receiving the alarm about the loss of command by the commander, taking over the command of the former commander and the higher level of command		x		x	x
Receiving the alarm from another member of the unit, from the car of the unit		x			x
Visual alarm signal, acoustic signal	x			x	
Electronic compass orientation reading		x			x
Radio module parameters setting, radio connection diagnostics		x		x	
Coordinates information using build-in GPS receiver in the radio module		x			x

Map and tactical situation visualization, photos and audio receiving, video reception	x	x		x	x
Picture taking, receiving, non-formal report (SMS)		x		x	x
Information the main battery charge			x		x
FFI information (ally-enemy)					x
Measuring the distance to a given object					x
Measuring vital signs of a soldier, an MMZ alarm (for example: wounded, dead)					x
Video and photos transmitting				x	x
Transmitting/Receiving the own position of a soldier, tactical position of troops (BFT), enemy troops (RTF), and unknown troops				x	x
Defining the criteria to filter/prioritize the received tactical situation				x	
Transmitting / receiving alarm and orders				x	x
Reports and demands transmission, exporting the combat journals				x	x
Importing maps to system		x			x
Measuring losses within own unit / the enemy unit, preparing and sending logistic reports				x	
Ordering the subordinate		x		x	

Table 1: M-ITG functionality in aspect of increasing the soldier's situational awareness.

The above table shows a number of possibilities and functions that contribute to improvement of soldier's situational awareness. They are assigned to the appropriate module built in the M-ITG providing information about the possibility of receiving or sending data. After the analysis performed by the interdisciplinary group of respondents it was concluded that the Modular Integrator improves the situational awareness of the soldier in a significant way, it complies with latest trends of managing the future army and becomes a base to further development work and improving the device.

Results

As pointed out by Czeszejko S [15], activities in the electronic environment gained more significance over the last ten years. The reason for that are gathering more experience in the field of recently managed military conflicts, colloquially known as information age conflicts. The constant battlefield digitalization, focusing "the information flow" in one point and having access to all data thank to just a "click" increases the situational awareness of the battlefield and accelerates combat operations. Also, the constantly increasing degree of integration of electronics, and a related miniaturization leads the fact that electronics become ubiquitous. It allows it to be applied not only in the field of electronics but other environments too (land, sea, air and outer space). Although we are the witnessing consistent changes, the next several years are expected to be characterized with a revaluation of the contemporary solutions to electronic systems and devices. However, it should be noted, that most of this equipment is used by a human, and should be adapted to his requirements and expectations [16].

Conclusion

In this article the authors presented possibilities offered by the Modular Integrator to manage the C4I soldier system in aspect of

increasing soldier's awareness and meeting users' requirements and expectations both considering the human and the battlefield. By means of using the tripartite evaluation system: a man – a technical object – the environment, the device meets the standards of widely understood ergonomics. Thanks to performed research a kind of Modular Integrator's ergonomics convergence of the soldier's situational awareness was formed. The analysis carried out with participation of users' representatives and the interdisciplinary evaluation team confirmed device's ergonomics pointing out to its strengths as well as showing features to be improved.

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References

1. Jabłoński J (2006) Product's ergonomics. Ergonomic principles of product design. Published by Poznań PP.
2. Wieczorek S (2010) Ergonomia: Tarbonus. Kraków-Tarnobrzeg.
3. Gorska E (2002) Ergonomia. Projektowanie, diagnoza, eksperymenty. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa.
4. Horst W, Dahlke G, Górny A, Horst N, Horst WF, et al. (2011) Ergonomia z elementami bezpieczeństwa i ochrony pracy [Ergonomics using the elements of safety and work protection]. Wydawnictwo Politechniki Poznańskiej, Poznań.
5. <http://coat.ncf.ca/ARMX/C4ISR.jpg>

6. Alberts DS, Garstka JJ, Stein FP (2000) Network Centric Warfare: Developing and Leveraging Information Superiority, CCRP publication series.
7. Dudczyk J, Mirosław T (2012) Polish Soldier of Future Program. In Naukowe P (ed) *Kwartalnik Bellona*, Scientific journal issued by the Ministry of national defence, Poland. 2: 207-215.
8. Dudczyk J (2011) The IT heart of the future soldier's C4I system. *Miesięcznik* 9.
9. Dudczyk J, Mirosław T (2012) Information relativism on the contemporary battlefield. *Military technics* 10.
10. Dudczyk J (2011) Functional Polymorphism of radio electronic devices in the aspect of individual communicator for the future soldier. The evolution of military teleinformatic systems and Lessons Learned in terms of peacekeeping and stabilization missions 23: 165-170.
11. Dudczyk J, Kawalec A (2014) Technical parameters optimization of a personal radio with the use of OFDM modulation and UHF band. *Electronics – construction, technology, use Magazine* 4: 77-80.
12. Dudczyk J (2011) Optymalny dobór parametrów radiostacji szerokopasmowej żołnierza. *Miesięcznik* 9.
13. Dudczyk J (2014) Wideband personal radiostation PERAD as an innovative way of soldier's communication in XXIst century, X: International Conference on Armament New aspects of arm security.
14. Dudczyk J, Tyma G (2014) Ożarów personal radiostation merges requirements of contemporary battlefield in a communication device. *Miesięcznik NTV* 2.
15. Czeszejko S (2011) Operations in electronic environment and situational awareness. *Journal of Konbin* 2: 18.
16. <http://www.hems.info.pl/wp-content/uploads/2012/12/%C5%9Awiadomo%C5%9B%C4%87-sytuacyjna.pdf>