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New Perspectives on the Use of Satellite Information in Contemporary Armed Conflicts and Crisis Management

Abstract: Among current global threats, the risk of developing an emergency requires a comprehensive approach from all entities involved in crisis management. Despite the advanced technologies available to predict each threat, taking appropriate countermeasures is often impossible. Often the best solution is to prepare in advance and act efficiently after the occurrence of a given threat event. It is also crucial to implement the latest methods and solutions that allow for better preparation and response in case of an emergency. This article presents the results of the analysis of the use of modern satellite systems aimed at, among others, improving security in the event of armed conflicts and crises. This perspective is written for two reasons. Foremost is to present the potential of the existing Polish security system, which aims to reduce the risks and minimise the problems of crisis management associated with natural disasters. Secondly, to foster a discussion and create a basis for exchanging information and advances within the countries implementing similar solutions. It is especially crucial in joint actions with neighbouring countries in case of emergencies and disasters in border areas.

Keywords: *satellite data, disaster preparedness, remote sensing, disasters, conflicts, crisis management*

Introduction

Currently, the military effectiveness of both public administration and armed forces, among others, depends on the speed of collecting, processing, and delivering information. This effectiveness translates into social satisfaction, which is important for the functioning of a democratic state. Following the example of other developed societies, Polish society demands a continuous increase in security in every area of life (Marszałek-Kawa, 2019; Borowski & Patuk, 2021). This task is performed by central and local government authorities, which in Poland results because of two reasons. First, the public sector can accumulate human, financial, and logistical resources on a scale inaccessible to any inhabitant, community, or private sector entities.

In today's increasingly globalised world, remote sensing techniques are currently the most effective and fastest way to monitor areas at risk (Yuan et al., 2020). In the analysis of this phenomenon, both optical and radar imaging can be used (Tang et al., 2020). Radar images use microwaves, which permeate through clouds and can be registered day and night, allowing for the ideal material for analyses (Tang et al., 2020). On the other hand, when imaging various types of threats optically, cloudiness is a frequent obstacle (Zhong et al., 2020). At the same time, the high frequency of return visits over a given area, offered by some systems using optical sensors, allows for ongoing monitoring of any given phenomenon.

Information plays a key role in every armed conflict (Ojala et al., 2018). The war in Ukraine is probably the first conflict in which modern technology developments are used on a large scale (Zheng et al., 2022). Modern warfare is characterised by a constantly flowing, swift stream of data that is as important as the supply of fuel or ammunition. A regular, near-real-time look deep into the enemy's backstage can provide vital intelligence. Before the development of devices such as radar, military forces used reconnaissance aircraft primarily to recognise the movement of enemy troops and provide support to their own ground forces (Schleper, 2022). After World War II, many reconnaissance aircraft were built to perform highly specialised intelligence tasks, for example, the U-2 or the super-fast SR-71 Blackbird, decommissioned at the end of the 20th century (Ziyong, 2018). Today, their role is increasingly taken over by various types of unmanned systems, such as the Global Hawk or radio-electronic reconnaissance aircraft. Reconnaissance machines circulate on the border of safe airspaces in search of any electromagnetic emissions related to the activity or the mere presence of various types of military equipment. The missions of the Swedish Gulfstream S102B aircraft flying along the eastern border of Poland or the British RC-135W Rivet Joint aircraft flying near Crimea are the best examples of this asset (Molkentin, 2018). In many cases, however, a look "from above" made possible by various types of satellites turns out to be irreplaceable. For many years with the development of space technologies, such possibilities were reserved for the greatest powers who can build and launch large, heavy, and very expensive devices into orbit (Christaki et al., 2019). The progressing miniaturisation and the decreasing costs of launching payloads into orbit have also attracted private entities to space imaging. What distinguishes modern satellites' capabilities is that their constellation is not limited to taking ordinary photos. Satellites have unique capabilities provided by the SAR (Synthetic Aperture Radar) they are currently equipped with (Al-Dujaili & Zazlzala, 2021). This solution allows for the virtual increase in the size of the antenna by sending a signal from a mobile transmitter, thus increasing the resolution of the image obtained. It allows for the possible replacement of huge structures with a radar small enough to be placed in a microsatellite (Zhang et al., 2022). It represents a huge qualitative leap because a satellite with radar can do much more than a satellite with even the best camera. Information from the war in Ukraine confirms that satellites with radars work well during military operations, where a precise picture of what is happening here and now is important (Borskina, 2022).

The article's focus is to present the possibilities of using modern satellite systems aimed at, for example, improving security in the event of armed conflicts and crises and to describe current trends in the implementation of satellite technologies in anti-crisis systems.

Methodology

The article presents a retrospective analysis, including a review of the literature on preparedness in the use of satellite information in conflicts and crisis management, as well as an analysis of legal acts, programs, and documents of government and non-governmental organisations regarding civil-military cooperation, including public policy and strategies at the national level.

Modern Military Use of Satellite Systems

Satellite imaging of the terrain is basic to modern warfare. During military operations, where a precise picture of the current military situation is important, climatic conditions must not impair the operational capability of the troops (Yongzhen et al., 2020). In difficult weather conditions (clouds, night), satellites with radars are the preferred solution. Unlike optical satellites, radar satellites "track" the Earth through clouds and at night. The idea of "observing" the Earth from satellites using radars is not new. The basics of the SAR technology were developed in the 1950s, and in 1964 the first satellite with such radar was launched into space (Vehmas & Neuberger, 2021).

Synthetic Aperture Radar

The Synthetic Aperture Radar [SAR] is an Earth observation technology used to obtain high-resolution images of stationary objects. Radar is used to create images of the land surface, the Earth, and other planets using remote sensing techniques. The military uses such radars for intelligence, surveillance, and reconnaissance. The SAR technology allows for taking pictures of both land and sea, regardless of the degree of sky cloudiness and lighting conditions, which means that radars work with the same efficiency both during the day and at night (Shen et al., 2019).

In using classic radar to increase the resolution (narrowing the beam), the size of the antenna is increased. It leads to the construction of radars with large antennas, the dimensions of which can reach several dozen meters. The antenna size is limited by design possibilities, especially when the radar is mobile. The synthetic aperture radar method increases the antenna's virtual size by transmitting and receiving probing signals using an antenna placed on a mobile platform. The recorded signals are then combined (synthesised) so that they come from the components of one large antenna, often several hundred meters or even several kilometres in size (Shen et al., 2019). As a result, very high-resolution radar images can be obtained. The theoretical SAR resolution in the direction of movement of the platform (aircraft or reconnaissance satellite) is equal to half the length of the antenna (in the direction of movement). Therefore, it is possible to increase the SAR resolution by reducing the antenna size. The distance resolution is determined by the width of the probing pulse or its bandwidth (when using a composite signal) (Mahafza, 2017). Currently, in the space SAR method, meter resolutions are obtained in aircraft technology–decimetre resolutions. In order to obtain high-quality SAR images, it is necessary to know the platform's trajectory precisely (with an accuracy of more than 0.1 wavelength). Since the trajectory of movement is usually not so precisely known, it is necessary to use automatic focusing techniques (Le Chevalier, 2002).

In the initial period of development of the Synthetic Aperture Radar technique, analogue optical computers, using laser light and holographic techniques, were used to create images. Currently, SAR images are obtained using digital techniques: matrix computers (usually built as matrixes of signal processors). In many systems, raw radar data (received signal samples) are transferred to ground-based computing centres, where synthetic aperture images are created using supercomputers (Le Chevalier, 2002). A synthetic aperture radar image is a monochrome image that only contains information about the reflectivity of the observed area. This image can be enriched by using more complex processing methods, polarisation techniques, and interferometric techniques (Le Chevalier, 2002).

The SAR System in Ukraine

Clouds cover the sky over Ukraine for most of the year. It hinders reconnaissance and weakens the military's operational capabilities. The Ukrainians recognised that the information advantage over the Russian aggressor is one of the pillars of an effective defence. In addition to the data provided by the countries supporting Ukraine, they decided to use their own satellite reconnaissance data (Freedman, 2022). The result of such an approach was an agreement signed between Serhiy Prytula Charity Foundation and the ICEYE company (Borskina, 2022). It provides the Ukrainian side access to data from an entire constellation of 21 microsatellites. This equipment has been designed and built primarily in Poland. Also, in Poland, there is the management centre for the entire swarm of those "space detectives". Instead of offering single images of a given area daily, as in the case of individual satellites, ICEYE can provide images of the same place taken, for example, every two hours (Borskina, 2022). It allows for tracking changes for space reconnaissance with a very small delay. It is difficult to overestimate the importance of such capabilities for the military.

According to the information from the Ministry of Defence of Ukraine, during the first two days of operation, the ICEYE satellite detected over 60 units of Russian combat equipment (Borskina, 2022). Although the Russian offensive began on February 24, the Poles began to support the Ukrainians with their photos in January, and a week after the invasion, permanent cooperation was established (Stojanović, 2022). It was quickly learned that the SAR satellite is extremely useful in war conditions in several modes of operation. While an optical satellite takes pictures all the time and covers huge areas with the lens, a radar satellite is tasked with taking a specific picture in a specific area. That allows it to photograph the given area more precisely (Johnson, 2022).

The radar works in three modes: the widest provides images of 400 km per 100 km in size. Such photos tend to be of poor resolution, but they are crucial for obtaining a broader picture of the situation. For example, they perfectly track ships at sea, Russian warships and cargo ships that illegally export grain stolen from Ukraine. Such ships usually have transponders turned off, such as devices emitting signals that allow tracking of all maritime traffic within the Global Maritime Distress and Safety System (GMDSS) (Grispos & Mahoney, 2022). While the switched-off transponder allows one to hide from GMDSS, it is still perfectly visible to SAR satellites.

These are not the only advantages of the SAR system. Both sides of the conflict set up dummy equipment to confuse the opponent. Unlike most optical satellites, SAR can distinguish mock-ups from real machines so that artillery can only direct fire at the latter. In addition, the SAR system can locate military equipment camouflaged under tree crowns, although often without precise data on its parameters (Grispos & Mahoney, 2022).

Satellite Systems in Crisis Management

In addition to military use, satellite systems play an important role in the period of response, prevention, and minimisation of risk in the crisis management system. Crises are natural disasters, military, social or religious conflicts, information, and political terrorism (Ma et al., 2022). Poland has a crisis response structure according to administration units (provinces, districts, communes), related management centres, and central, nationwide crisis coordination teams. In addition, there are teams with rescue coordination specialists and emergency notification centres (Goniewicz & Burkle, 2019). In the aspect of services, inspections, and guards, which remain on 24/7 readiness in case of disasters, the information system has become the foundation of the command support system. Since 2013, this system has been improving the actions of the Police in emergencies, mainly in police interventions, and optimised the management of activities, human resources and information (e.g., in the National Police Information System). In addition, with this system, it was possible to image the activities of the Police (Universal Map Module), use mobile terminals (mainly in official vehicles), automate reporting or statistics (quantitative analysis), and exchange information with the emergency notification centre and the State Fire Service. In 2014, it was decided that emergency notifications to the 997-telephone number would ultimately be transferred to the police command support system by the operators of the Rescue Notification Centre. Currently, the Polish Police are facing the task of system modernisation, mainly in responding to notifications, personal data management or advanced cooperation with external entities (State Emergency Medical Services, State Fire Service, Voivode) (Goniewicz et al., 2020).

The situation is similar to the Rescue Notification Centre (a uniform 112 system that handles emergency calls throughout Poland). Operators mainly use satellite systems to automatically obtain information about the caller's location (geographical coordinates), obtain their data, and submit the notification electronically to the appropriate services. The command support system, apart from the Police, is also used by the State Fire Service and the State Emergency Medical Services in conjunction with the GIS. It is possible to locate the scene of the incident (determining the fastest access), track company vehicles (locate a free medical rescue team), analyse data about the environment (e.g., infrastructure), or determine the consequences of the event due to the zone of occurrence (possible evacuation). GIS also supports the Mountain Volunteer Search and Rescue in its operations. Thanks to the geoinformation system, it is possible to increase the effectiveness of search and rescue operations in difficult weather conditions, which increases the social sense of security in the mountains. It is mainly used for developing statistics on the behaviour of missing persons, navigation, planning activities, locating patrols in the field, and remote tasking or field updating. It is also worth emphasising the importance of the "National Map of Security Threats" based on the infrastructure of the National Geoportal system, in which information on crimes, offences and threats can be reported free of charge. This initiative fits perfectly into the need for social activation (according to the idea of civil society) or public safety management within the institutional and social partnership framework to optimise the equipment and staff resources of the services (Goniewicz & Burkle, 2019b).

Discussion

Currently, "in the most general sense, security can be defined as the certainty of an entity's existence and survival, ownership, functioning, and development (Kośmider, 2021). The confidence is not only the result of the absence of threats (their non-occurrence or elimination), but also arises primarily as a result of the creative activity of a given entity and is variable over time, and therefore has the nature of a social process" (Koopman, 2011). In the past, traditional maps, in which data was added manually, were used to describe geographical space. Computerisation and the development of GIS systems enabled the digital visualisation of space for interactive analysis of multiple data (vector, raster, mixed, etc.) in the form of models or simulations. On the other hand, the computerisation of the environment has become a source of new threats to the state, society, or the individual itself, especially in personal data protection (privacy). However, technical and technological progress now seems indispensable due to the possibilities it provides, for example, in geoinformation. Currently, the spatial information system enables the collection, storage, processing, and visualisation of spatial data, which gives a new dimension to public administration activities (Chen et al., 2017). In crisis management, the readiness of services, inspections and guards in the event of disasters is currently incomparable to the previous state. A spatial information system needs appropriate computer hardware, software, stored spatial databases and appropriate information processing and sharing procedures. It requires costly modernisation and the maintenance of professional human resources (Wiśniewski, 2022).

Implementing new satellite systems would certainly increase the institution's potential for crisis management and rescue in Poland. Remote sensing allows imaging a large area in a short time, which is a crucial asset in crises. However, the implementation process requires multilateral coordination and significant financial outlays, which is currently difficult in today's Polish conditions. First, in general, most public administration is prepared to use new technologies, but employees are concerned with the portal's lack of intuitiveness and software compatibility, which will generate adaptation costs (Borowska-Stefańska et al., 2022). Secondly, the lower the local government level, the greater the chance of training (implementation) difficulties. Thirdly, there is scepticism in the administration towards satellite technology as a free, compatible, and universal system. The use of satellite systems in crisis management could also be used for forecasting and recovery after an extraordinary event.

Limitations

In the case of any new proposals, especially those which involve a large section of the population, concerns have arisen regarding their limitations. It is understandable, and what has been proposed here is only the first step leading to a wider system implementation potential. The author believes that this proposal is only the first step towards alleviating the consequences, which must also weigh in on the immediate debate between citizens and governments to ensure universal and transparent opportunities to monitor the use of the technology.

There are also gaps in the ethical, social, and political issues raised by information systems. The ethical issues also include the accuracy of the information, accessibility of information, ownership of the information, and IT employees' occupational health, safety, and quality of life. These factors can affect information system quality, such as reliability and security (Mason, 2017).

Conclusions

SAR is a solution that allows to "virtually increase the size of the antenna, thus increasing the resolution of the image obtained". It is a significant qualitative leap, as a microsatellite with a SAR radar provides much greater possibilities than a satellite with even the most advanced camera (Chippalkatti et al., 2022). The war in Ukraine shows that the technology used in ICEYE perfectly fulfils its tasks. Using satellites with a synthetic radar aperture is important in the context of the Russian-Ukrainian war because this area is often cloudy, preventing optical satellites from conducting effective reconnaissance (Choi, 2022). In addition, SAR satellites allow for additional performance of similar operations at night over the monitored territory.

The experience gained during the war in Ukraine confirms how critical it is for the state's security to have these capabilities provided by the forces of industry and entities operating within their own borders (Goniewicz, 2022). Poland already has such capabilities. However, it takes political will to translate them into necessary operational decisions. Satellite image reconnaissance must be one of the priority operational capabilities of the Polish army, including access to SAR imagery.

In summary, satellite systems' fundamental impact on the public sector's effectiveness in crisis management in Poland is visible, especially for preparedness in the event of disasters and armed conflicts. From decade to decade, the advantages of satellite systems increase the sense of security in Polish society, while admittedly, they generate costs for public administration and require additional support in modernisation related to the implementation of new technologies. Modern technologies are required to counter the effects of crises and other threats in the 21st century.

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