Proceedings of 4th International Conference CNDCGS'2024
ISSN 2669-2023 (print) / ISSN 2538-8959 (on-line) / DOI 10.3849/cndcgs.2024.550

Specific Activities in the Electromagnetic Spectrum and their Relevance in Future Military Operations

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Abstract

This article examines specific activities in the electromagnetic spectrum that are discussed in the context of electromagnetic operations of which these activities may be a part. The subject of discussion is the impact of the operational environment on ongoing military operations conducted in accordance with the North Atlantic Treaty Organization principles, with emphasis on the importance of the electromagnetic environment. The operational environment is presented in terms of physical and non-physical battlespaces. It formulates and explains what the categories of military forces in terms of their utilization of the electromagnetic spectrum and their dependence on its use are.

KEY WORDS: *battlespace, electromagnetic energy, electromagnetic environment, electromagnetic spectrum, intelligence preparation of the operating environment, joint intelligence preparation of the operating environment, military forces, military operations, operating environment, specific activities in the electromagnetic spectrum.*

Citation: Hlavizna, P., Vasicek, R. (2024). Specific activities in the electromagnetic spectrum and their relevance in future military operations. In Proceedings of the Challenges to National Defence in Contemporary Geopolitical Situation, Brno, Czech Republic, 11-13 September 2024. ISSN 2538-8959, DOI 10.3849/cndcgs.2024.550.

1. Introduction

The 21st century is characterised by considerable dynamism. It manifests itself in all areas of human activity and raises myriad dilemmas facing humanity. These are caused not only by opportunities but also by challenges that can come from virtually anything and anyone. These dilemmas, which also concern security and defence, are then, in the light of the real experience of the wars of recent decades, the source of revisionist attempts to change the art of war. In direct relation to the activities of military forces, it is thus a response to the possibilities and challenges associated with the operating environment (OE) and its changing, multidisciplinary and interdisciplinary nature. However, it is questionable whether these revisionist efforts are desirable at all times and in all circumstances.

The nature of the OE, which the North Atlantic Treaty Organization (NATO) defines as *"a composite of the conditions, circumstances and influences that affect the employment of capabilities and bear on the decisions of the commander"* [1, rec. 874], is constantly influenced by the interaction of countless variables. This does not mean, however, that efforts to analyse, describe, estimate, and predict the OE can be ignored, neglected, or in any way suppressed. Understanding the OE is critical to current and future military operations (MILOPs) and/or campaigns. The analysis and description of the current state of the OE serve as the foundation for both its estimation and prediction. The term "estimation" is used to describe the process of assessing the near-future appearance of the OE. In contrast, the term "prediction" is employed to describe the assessment of the OE's appearance over the medium to long term. The prediction of the OE therefore takes into account mainly trends and megatrends, while the estimation reflects primarily the influence of current factors shaping or having the potential to shape the OE. Indeed, the conduct of operations, which is defined as *"the art of directing, coordinating, controlling and adjusting the actions of forces to achieve specific objectives"* [1, rec. 14799], must not only reflect this OE but also respect the principles of operational art, i.e. *"the employment of forces to achieve strategic and/or operational objectives through the design, organization, integration and conduct of strategies, campaigns, major operations and battles"* [1, rec. 15720].

Although much has been written about operational art, it is not an easy subject to navigate. A multitude of sources of information, including military doctrines, publications, and manuals, some of which are accessible to the general public, frequently address operational art issues without providing detailed interrelationships.

Peer-review under responsibility of General Jonas Žemaitis Miltitary Academy of Lithuania and University of Defence, Czech Republic

This often results in information gaps where it is challenging to comprehend the interrelationships without further clarification. Paradoxically, when it comes to the OE estimate and MILOPs and/or campaigns, the details seem less difficult to understand than the interrelationships and overall functionality of the mechanism of external and internal interconnectedness. This may be due to the fact that the discussion of the OE focuses on individual phenomena, opportunities and challenges in relative isolation, with the relationship to the various levels of command and control (C2) and the products they produce being addressed horizontally rather than vertically. This is not helped by the occasional tendency to sometimes glorify the activities of military forces at the tactical level and/or downplay the importance of the operational level of C2. In practice, there is a risk of encountering misconceptions that could have serious consequences. These misconceptions include the idea that the OE is solely a matter for operational level C2, and that it need not be addressed at all for tactical level forces. To eliminate or at least reduce these negative consequences, it is necessary to define the missing dependencies and at least modify the unclear ones. Therefore, understanding the interdependencies between the activities of military forces at the operational and tactical levels, including their attitudes toward the OE estimates, is critical to the effective engagement of military forces in MILOPs and campaign.

The OE is inherently complex and continuously changing. It also includes the electromagnetic environment (EME), which is sometimes not given enough attention, although it can even have a fatal impact on MILOPs and campaigns. Since this environment is defined as *"the totality of electromagnetic phenomena existing at a given location"* [1, rec. 18831], its final form is determined by the interaction of electromagnetic (EM) energy at a given place and time. The sources of EM energy that shape the final form of the EME can then be both natural and artificial, with unintentional or intentional emission. Progressive scientific and technological development is contributing to the introduction of new equipment and advanced technologies in all areas of human activity, including the military sector. The military forces are equipped with a wide range of military equipment, such as radio-electronic and electro-optical devices, which are mainly based on the use of EM energy. Military personnel using this equipment within their duties automatically become users of the electromagnetic spectrum (EMS). To some extent, the freedom of action of military personnel is affected by their dependence on the availability of the EMS. If this availability is reduced or eliminated, these military EMS users cannot adequately perform their combat tasks. The situation is further complicated by the fact that even when the EMS is available, military forces can be targeted with EM energy.

It is a fact that in terms of MILOPs, EM energy can be used as a *"potent force multiplier"* [2, p. I-3]. By concentrating military forces in the EMS, EM energy can then be used to deliver non-lethal effects caused by specific EMS activities. These can then be used to affect the audience of the OE. This can be done either separately or as an integral part of electromagnetic operations (EMO). Accordingly, the current question is whether all NATO Allies should begin to consider EMO as a necessary capability for their own forces, and whether such operations must inevitably become a national aspiration. Similarly, how specific EMS activities will be viewed in the implementation of EMO, and whether there should be internal changes that alter their nature as a result of some integration into EMO, need to be answered. These issues should be discussed not only in the context of the OE and the operational level, but also the tactical level of C2. Particular attention must then be paid to the EME and understanding what EM activities are and why it is appropriate to categorize so-called specific EMS activities.

2. Methodology and limitations

The first part of the article deals with MILOPs in the context of operational and tactical levels of C2. The term "MILOPs" should not be understood as a substitute for a campaign, as a campaign is defined as *"set of MILOPs planned and conducted to achieve a strategic objective"* [1, rec. 5536]. Only non-classified information concerning the current NATO approach to the conduct of MILOPs is presented. It is focused on the planning framework, designated areas and selected products of the operational and tactical levels of C2, generated by individual headquarters (HQ) and units in relation to the OE. Reflecting on the OE, it explains and visualises the differences in the selected products in terms of the detail and quantity of information contained in them, clarifying the way in which these products should be disseminated. It also discusses some of the less clearly defined approaches of operational and tactical C2 levels to the OE, placing the formulations in the context of publicly available NATO documents. It is also based on the authors' 2021 research on "*The role of joint intelligence preparation of the operational environment in support of future military operations"* presented at the NATO Science and Technology Organization (STO) conference [3].

The second part of the article partly reflects research results in the field of specific EMS activities, in particular electromagnetic warfare (EW), conducted by one of the authors in the period 2017–2020. It is a doctoral thesis entitled *"The development of EW in the Czech Armed Forces providing combat support in the EME during operations in the near future"* [4]. This thesis was developed using a combination of qualitative and quantitative methodological approaches. The methods used were literature research, field research through individual informal interviews, identification of key issues, causal analysis, risk assessment and brainstorming. This part of the article also generalizes some results of the author's final thesis from the General Staff Course, prepared in 2022, on the topic *"Conduct of EMO from the perspective of the strategic level of C2 of the Czech Armed Forces"* [5]. This result was created by applying a qualitative methodological approach using a systematic literature search, a prognostic method – the futures wheel, brainstorming, questionnaires, interviews with experts and field research using the method of semi-structured interviews.

Selected findings from the above two theses were placed in the context of current and publicly available information on the issue of specific EMS activities of the military forces in the area of MILOPs. Findings on the current opportunities and

challenges that the military may face in relation to the issues raised were also taken into account. Although in this article it is not possible due to its sensitivity to discuss all the details of the findings, the presented results are a relevant basis for the subsequent professional debate on the issue of the EMS and the operational art from the perspective of the activities of military forces in the EME. The results of the authors' research are presented in the form of a consolidated text, which is complemented by its own visualization through images accompanied by explanatory text.

3. The operating environment in the context of current military operations

Much has been written about the OE, its changes and the resulting opportunities and challenges. Because *"commanders make decisions based on their understanding of the OE"* [6, p. 3-6], the ability to not only analyse and describe but also estimate the OE is critical to planning, executing, and sustaining current and near-future MILOPs and campaigns. In order to gain as much insight as possible into the above quote, it should be emphasised that the OE is not just a matter for the operational level commander and staff. Therefore, there must be a process to continuously describe, analyse, and validly estimate the nature and changes in the OE. A clear understanding of the OE is essential to assess and estimate the impact of this environment on all military activities and to create the conditions for achieving the desired end states of MILOPs and campaigns.

It is a fact that a comprehensive analysis, description, and estimation of the current and near-future of the OE is carried out at the operational level. In light of the aforementioned considerations, NATO has implemented the term "comprehensive preparation of the operating environment" (CPOE) with the goal of *"comprehensive understanding of the operating environment (CUOE)"* [7, p. 96]. The CUOE represents the primary and continuous process through which the joint task force (JTF) staff oversees the analysis and development of products designed to assist the commander and key staff in understanding the OE. [7, p. 96] It is also stated, that *"the CPOE may also take into account the assessments of non-military and non-governmental organizations, the joint intelligence preparation of the operating environment (JIPOE) and the joint intelligence estimate support."* [8, p. 3-2]. Consequently, commanders and staff, particularly those at the operational level of C2, or those who have undergone extensive training for JTF HQ, must be able to produce and work with both the CPOE and JIPOE. To prepare the CPOE, the staff can use the PMESII (political, military, economic, social, information, and infrastructure) analytical framework to identify relationships and interdependencies relevant to a particular MILOP or campaign [9, p. 55, 145]. When relevant OE facts are identified, they are used at the same level for JIPOE, *"the analytical process used to produce intelligence estimates and other intelligence products in support of the commanders' decision-making and operations planning"* [1, rec. 12313]. JIPOE is also generated product which must be designed to provide the commander and staff with a comprehensive view of the crisis background, root causes and specific dynamics, and to holistically describe the main characteristics of the OE in which MILOPs will be conducted. While JIPOE product is intended primarily for the operational level commander, it is also shared with tactical level C2. Similarly, the CPOE can be shared with the tactical level, but information critical to the MILOPs should be included in JIPOE. Although JIPOE is focused on the conduct of a specific MILOP, as opposed to the broader CPOE, the PMESII analytical framework is also employed. [8, p. 3-2] The above-mentioned facts are visualised in Fig. 1.

Fig. 1 also illustrates a JTF HQ, as an operational level command, generating the CPOE and JIPOE. The CPOE may contain information about the OE related to the entire theatre of operations (TOO), i.e. *"a designated area, which may include one or more joint operations areas"* [1, rec. 25356]. JIPOE is focused on the OE within joint operations area (JOA), which is defined as *"a temporary area within a theatre of operations defined by the Supreme Allied Commander Europe, in which a designated joint force commander plans and executes a specific mission at the operational level"* [1, rec. 6762]. Both of these products support the operations planning process (OPP) at the operational C2 level. Additionally, primarily JIPOE, but alternatively the CPOE is shared with the component commands (CC) to facilitate their military decision-making process (MDMP). At the tactical level, information on the OE related to their area of operations (AOO) is processed at the HQ of CC, divisions (Div), brigades (Bde) or regiments (Regt), with the resulting product being the intelligence preparation of the operating environment (IPOE). As shown in the figure, IPOE of a superior HQ is provided to a subordinate HQ. In the case of battalion, due to the smaller HQ intelligence staff, IPOE is usually no longer processed, and the intelligence preparation of the battlespace (IPB) is generated. The IPB is subsequently used to specify the mission variables, i.e. the information on mission, enemy, troops, terrain - time and civilians (METT-TC). These are used in troop leading procedures (TLP) to properly prepare activities of companies (Coy), platoons (Plt) and squads.

The left part of Fig. 1 shows not only the products generated by each HQ, but also the level of detail and quantity of information contained in each product. It is evident that IPB or IPOE contains more detailed information about the OE, but in terms of quantity it is much less than in JIPOE. This is because tactical level units need more detailed information to conduct *"activities, deployments, and engagements that are planned and executed to achieve the military objectives assigned to tactical formations and units"* [1, rec. 16309] contrary to JTF HQ, which must plan, conduct, and sustain campaigns and major operations *"to accomplish strategic objectives within theatres or areas of operations"* [1, rec. 16311]. By comparing the content of the rectangles of the individual products (CPOE – light red coloured, JIPOE – yellow coloured, IPOE of CC HQ – blue coloured, etc.) to the volume of the rectangle of the OE (grey coloured) and to each other, it is possible to get a proportional idea of the amount of information from the OE that the individual products work with.

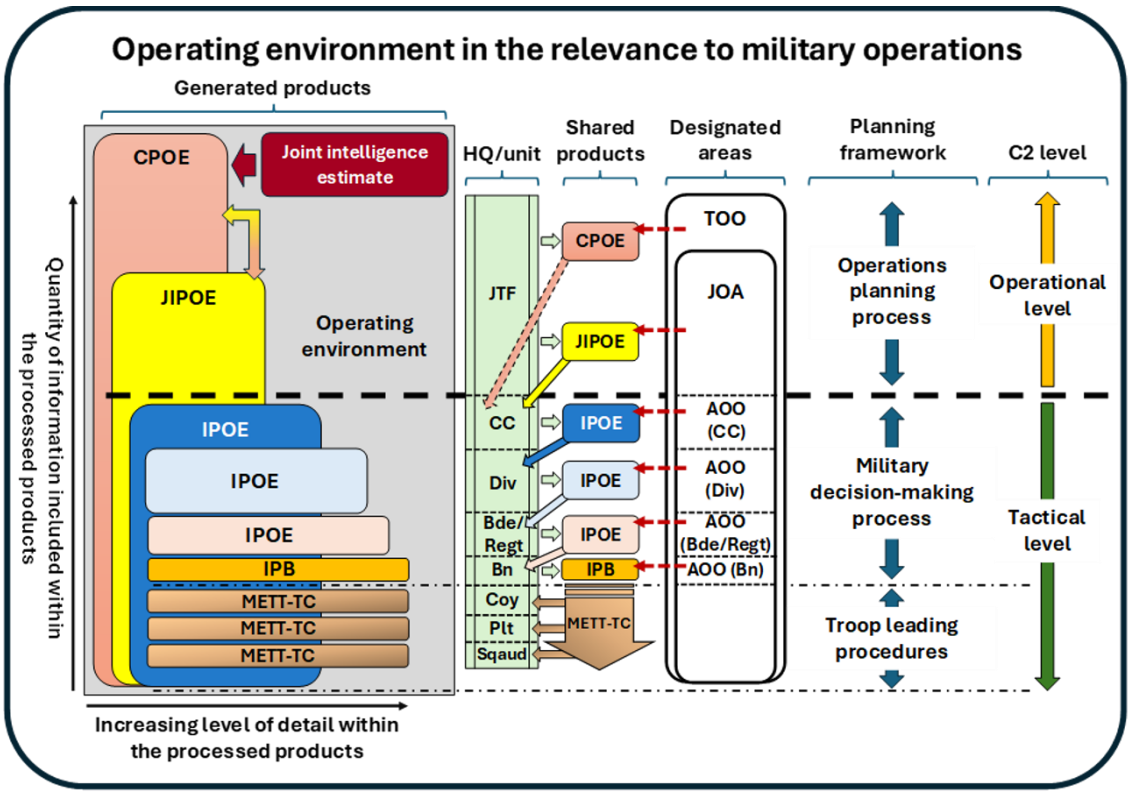

Fig. 1. Visualization of the OE in the relevance to MILOPs [by the authors based on [3], [6], [10]]

4. Perception of the operating environment estimation based on physical and non-physical battlespace

Continuous development of understanding of the OE, in which MILOPs are then carried out, represents an application of a holistic approach to all relevant conditions, circumstances and influences that affect or may affect the environment. As shown in Fig. 2, NATO currently recognises a total of five operational domains (land, air, maritime, space and cyberspace) that reflect MILOPs and the activities of military forces. The capabilities and activities of the forces within the operational domains create physical, virtual, and cognitive effects in the engagement space. The engagement space is synonymous with the "battlespace", defined as *"the portion of the OE where actions and activities are planned and executed"* [1, rec. 15752]. A clear understanding of the interactions producing effects enables commanders to coordinate and organize available capabilities to achieve desired MILOP's and campaign's end states through flexible, agile, and integrated actions while maintaining resilience to disruptive or hostile actions. Beyond all of the above, NATO has explicitly stated that information is not a separate operational domain, which is identical to the approach to the acoustic spectrum and the EMS. However, this statement does not exclude the acoustic spectrum, the EMS or information from the OE assessment, as all these variables directly or indirectly affect all five operational domains. [7, p. 2, 97–98] In addition to the above, contemporary operational art also emphasizes the importance of not overlooking the OE in the context of the audience. *"The audience may consist of publics, stakeholders and actors"* [1, rec. 40605], and is defined as *"an individual, group or entity whose interpretation of events and subsequent behaviour may affect the attainment of the end state"* [1, rec. 40605]. It is therefore very important to include the attitudes and behaviour of all relevant actors, stakeholders, and the public in the estimation of the OE. It is also required to take into account the relevant relationships and interdependencies that have been identified through the PMESII analytical framework, or the meteorological and oceanographic (METOC) aspects of the OE. [10, p. IV-8]

Fig. 2 illustrates the perception of OE estimation when OE is accessed through battlespace, more specifically physical and non-physical battlespaces. The physical is defined as maritime, land, air, and space, while the non-physical as cyberspace, the EME, information, and time. The separate components of a physical or non-physical battlespace can sometimes be called domains or environments, i.e., physical or non-physical domains or environments. The ambiguity of the terminology employed in the context of battlespaces is frequently problematic in practice. This is primarily due to the lack of clarity surrounding the term "domain" in military practice, which has resulted in a lack of consensus on its definition. It is proposed that it is not possible to consider a single physical or non-physical battlespace in isolation, as the actions carried out in one separate component of the battlespace can have implications for others. This is demonstrated by the components of the non-physical battlespace that permeate the entire physical battlespace and have the potential to influence the activities of all audiences in the land, air, maritime, space and cyberspace. [6, p. C-1–C-7] It is evident that the requisite conditions for the planning, implementation, and maintenance of MILOPs cannot be created without prior awareness of the battlespace division. Closely related to this, however, is the ability to manage, synchronize, and orchestrate the activities of military

forces, which must be understood not only in the context of the overarching MILOPs, but in the details provided by the conditions, circumstances, and influences of the OE, including the details of the physical and non-physical battlespace.

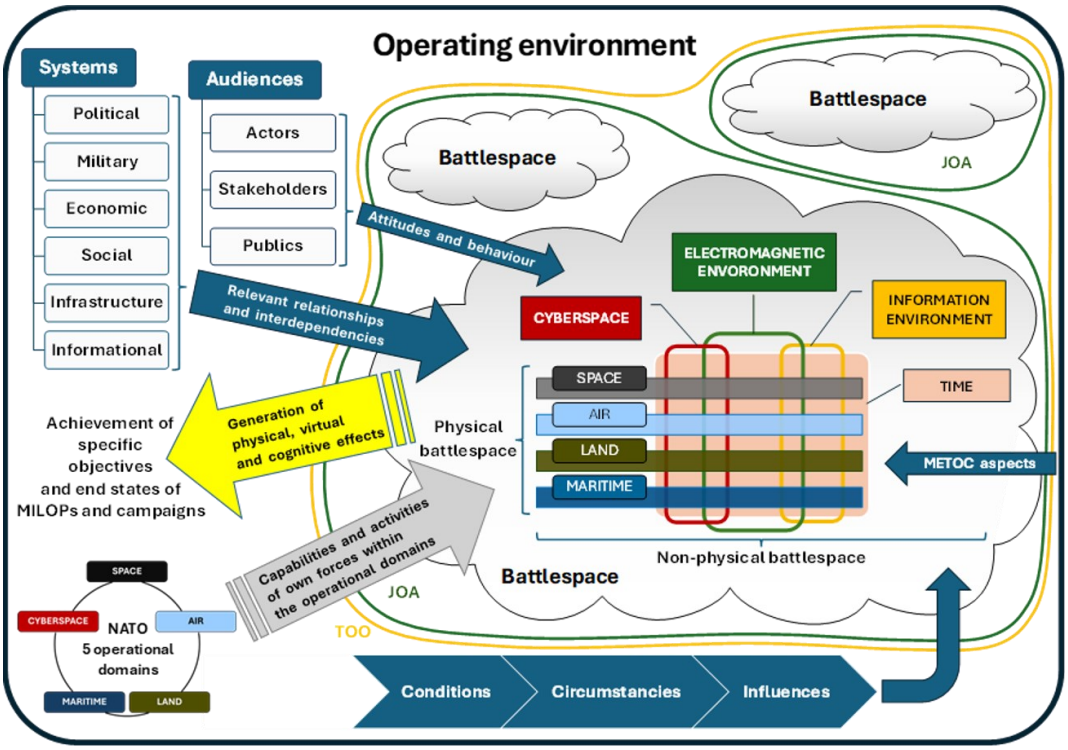

Fig. 2. Perception of the OE estimation [by the authors based on [6, p. C-1–C-7]], [7, p. 79]], [10, p. IV-8]]

Fig. 2 also shows that one TOO can contain multiple JOAs and one JOA can include multiple battlespaces. Although the distribution of the AOO of a given unit, as outlined in Chapter 3, is not shown in relation to the battlespace, it is understood that it will in fact replicate the unit's allocated space. The assigned AOOs, in which military forces will conduct their own combat and other activities, will then dimensionally divide the physical battlespace, while the non-physical battlespace will influence the activities of military forces within them. Although NATO has defined an approach to OE estimation, it is evident that the implementation of these provisions will vary in practice. The manner of OE estimation will depend on several variables, including the product being processed, the time and number of personnel devoted to analysis, description and estimation, the type and conditions of MILOPs planned and executed, desired end state, and so forth.

The issues outlined in this chapter have the potential to affect both the JIPOE and the CPOE. It is therefore critical not to underestimate, but also not to overestimate, any conditions, circumstances or influences that affect or may affect the resulting character of the OE and, ultimately, the conduct MILOPs or campaigns. *"It is assessed that the current way, in which JIPOE is conducted, provides a solid foundation but it needs to be improved to better accomplish requirements and effectively support of future operations. In order to make JIPOE more relevant and adequate for future MILOPs, it will be necessary to consider all of the physical and non-physical domains, including the EME, as a combination of tools for achievement of future operational objectives."* [3, p. 3-6] This quotation is based on extensive research by authors who have dealt with military forces' specific EMS activities and who have often emphasised the importance of EM energy and the impact of the EME on military forces' activities, as this has not always been fully acknowledged and understood. Although the EME is not the only non-physical domain of the battlespace, a brief discussion of this specific issue will be conducted in the following chapter.

5. The electromagnetic environment and specific activities of military forces in the electromagnetic spectrum

The EME and the activities of military forces in the EMS play a very significant role in influencing, affecting and shaping the nature of the OE. The ever-increasing capability of NATO adversaries and competitors to win without fighting relies, among other things, on the use of EM energy [11, p. 8]. One of the key challenges currently facing military strategists and practitioners is how to mitigate the effects of EM energy on their own forces, as well as how to establish superiority in EMS, which is an integral part of the modern approach to operational art. Therefore, experts are discussing many areas related to EM energy, such as management of the EMS and electromagnetic warfare (EW), development of navigation warfare (NAVWAR), adaptation of commercial technologies based on EMS exploitation, disruptive EMS capabilities, specialised intelligence to achieve EMS superiority, overall EMS force readiness, the form and manner of EMO planning and execution, etc. [12]. Despite differing views and approaches to individual solutions, military theorists agree that gaining and maintaining superiority in the EMS and achieving freedom of action within the EMS is vital for MILOPs. This makes highly developed assets and technologies based on EM energy a so-called "potential game changer" [13, p. 11–14], [14, p. 1–2].

As shown in Fig. 3, it is inevitable that current and future MILOPs, regardless of whether they are combat or crisis response operations, will require the use of EM energy. Military forces are composed of personnel and assets that, in terms of their utilisation in the EMS and their dependence on its use, can be divided into three interconnected categories [5, p. 26–28]:

- Category 1 – personnel and assets dedicated to the implementation of specific EMS activities: Their primary role is to plan and conduct special activities in the EMS that are directly related to their predetermination. These include EW (including electromagnetic attack (EA) realized through electromagnetic countermeasures (ECM), electromagnetic surveillance (ES) realized through electromagnetic support measures (ESM), and electromagnetic defence (ED) realized through electromagnetic protective measures (EPM)), NAVWAR, signal intelligence (SIGINT), EMS management or intelligence, surveillance, target acquisition, and reconnaissance (ISTAR), suppression of enemy air defences (SEAD), protection against radio-controlled improvised explosive device (RCIED), directed energy weapon (DEW), etc. These personnel and assets are also dependent on the EMS in compliance with Category 2 and Category 3;
- Category 2 – personnel and assets directly dependent on the use of EMS: These use EM energy to provide support of their own predetermination. These include radars, positioning, navigation and timing (PNT) signals, electrooptical (EO) / infrared (IR) sensors, satellite communication (SATCOM), radio frequency (RF) sensors, amplitude modulation (AM) / frequency modulation (FM) / television (TV) broadcast, identification friend or foe (IFF) signals, etc. These personnel and assets are also affected by specific EMS activities as Category 3 but are not predetermined to implement special EMS activities as Category 1;
- Category 3 – personnel and assets affected by specific EMS activities: They do not use EM energy for their activities. Personnel and assets that are neither Category 1 nor Category 2, whether or not they use electronic components. Nevertheless, their activities related to their predetermination can be affected by specific EMS activities.

The above categorised dependency of military forces on EM energy clearly shows that all military personnel and assets can be affected by specific EMS activities. Consequently, EW, at least in the context of ED and EPM, is a matter for all military actors in the battlespace. However, the affectability by specific ESM activities is not only on military actors, but on all audiences of the OE (see Fig. 3). It is therefore clear that those, who are able to achieve freedom of action within the EMS and to gain and maintain superiority in the EMS, will be in a position to create the appropriate conditions for achieving the desired end states of MILOPs and campaigns.

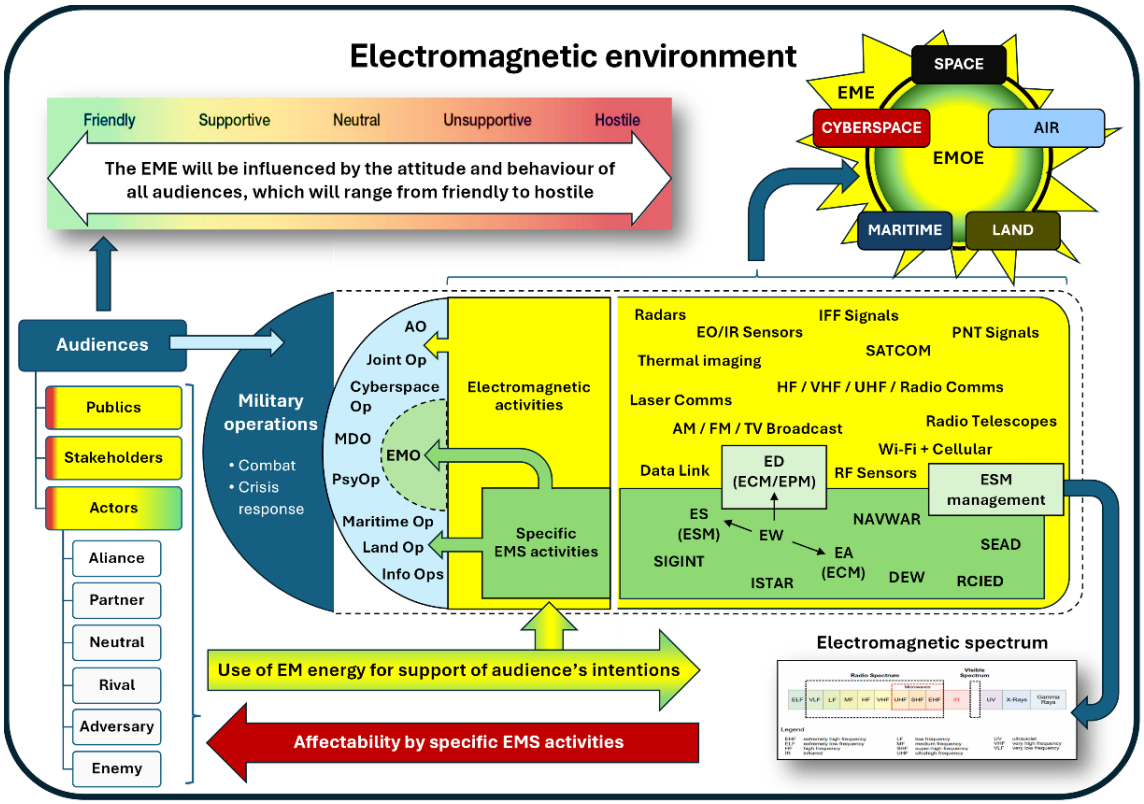

Fig. 3. The EME and EM activities of military forces in the modern battlespace [by the authors]

As visualised in Fig. 3, this article treats the specific EMS activities of military forces as a subset of EM activities. Implementing these specific EMS activities allows one to reinforce one's own EM hardiness in the EMS and to affect any actor in MILOPs. Because the EME permeates all physical and non-physical battlespaces, it is possible via the EMS to affect

the audience in any operational domain where that audience is predetermined to act. Separate specific EMS activities can be conducted independently or in a coordinated manner with one another. An alternative approach would be to manage them as an integral part of EMO, which NATO define as "*all operations that shape or exploit the EME or use it for attack or defence including the use of the EME to support operations in all other operating environments"* [1, rec. 26254]. In accordance with NATO, *"EMO include, but are not limited to, EW; SIGINT; ISTAR; NAVWAR and battlespace spectrum management"* [1, rec. 26254].

The NATO approach to EMO, for instance, differs from the United States (US) approach to so-called electromagnetic spectrum operations (EMSO), which are described as *"military actions to exploit, attack, protect, and manage the electromagnetic operational environment"* [15, p. 4]. The electromagnetic operational environment (EMOE) is then *"a composite of the actual and potential EM radiation, conditions, circumstances, and influences that affect the employment of capabilities and the decisions of the commander. It includes the existing background radiation (i.e., EME) as well as the friendly, neutral, adversary, and enemy EM systems able to radiate within the EM area of influence. This includes systems currently radiating or receiving, or those that may radiate, that can potentially affect joint operations."* [2, p. I-2] Another difference is that the US only includes two coordinated efforts in EMSO, namely EW and EMS management [16, p. 8].

Despite the fact that both EMO and EMSO are operations in the EMS, it is clear from the above quotations that there are differences in the understanding of both their content and subsequent implementation leading to the fulfilment of the vision – freedom of action in the EMS. As stated in the US EMS Strategy *"freedom of action in the EMS, at the time, place, and parameters of our choosing, is a required precursor to the successful conduct of operations in all domains. Forces in 2030 and beyond will be ready to fight and win through the deliberate, institutional pursuit of EMS superiority"* [12, p. 2]. Unfortunately, with regard to NATO and EMO, or specific EMS activities, there is no publicly available information on when NATO will be ready to fight and win through the deliberate, institutional pursuit of EMS superiority. The absence of this proclamation gives the false impression to NATO personnel not familiar with EMO issues, specific EMS activities, EMS management, etc., that these areas do not need to be addressed. A lack of attention to the EM activities of military forces, and in particular to specific EMS activities, may lead to an undesirable degradation or even elimination of those capabilities predetermined to conduct deliberate activities within the EMS if any of the functional areas of *"doctrine, organization, training, materiel, leadership development, personnel, facilities, and interoperability (DOTMLPFI)"* [1, rec. 36370] will be underestimated.

Answering the questions posed in Chapter 1 of this article is challenging due to the complex and evolving nature of the OE, changes in operational art, the necessity for military forces to acquire the capability to conduct MDO, and other factors and variables. In order to respond to these questions, it is first necessary to present the authors' findings regarding the specific EMS activities that may or may not be part of EMO. From the authors' perspective, it is important to note that if military forces are able to conduct these specific EMS activities, or any part of them, this does not necessarily mean that they have acquired the capability to conduct EMO. The capacity to conduct EMO is not only about the ability to conduct individual specific EMS activities and to be able to coordinate them. EMO are also about the ability to organize specific EMS activities in which military forces are able to expose adversaries and enemies to dilemmas in any of the currently recognized operational domains and gain and maintain freedom of action in the EMS, by creating synergistic effects on the adversaries and enemies through the EMS. All of these activities must equally be inextricably linked to the ability to manage the entire EMS, not just a select portion of it. Furthermore, the military force itself must be able to refrain from using the portion of the EMS at a given time and space. The research also shows that all NATO allies should start thinking rationally about EMO, i.e.:

- EMO is one of NATO's capabilities under construction. When NATO conducts EMO as part of MILOPs, individual Allies and all their forces and assets participating in those MILOPs will always be part of NATO EMO. This is true whether the forces are using EM energy (i.e. conducting specific EM activities, even separately or as part of EMO – see Category 1, or just conducting EM activities – see Category 2) or not using EM energy at all, but possibly being affected by specific EMS activities of enemies or adversaries – see Category 3);
- The ability to conduct EMO must also be seen through the prism of a capability that our enemies or adversaries may possess. This creates real threats and risks to all forces in the Alliance, to which we must be prepared to respond appropriately in all operational domains, both through ED/EPM and effective management of the overall EMS, as well as through the conduct of our own specific EMS even separately or as part of EMO;
- Not all Allies necessarily have national C2 EMO ambitions, although they must have the capability to participate in NATO EMO when they are conducted. On the other hand, all Allies should at least have the ambition to develop specific EMO activities, including coordination among them.

It follows that if individual NATO nations decide to develop their own C2 capability for own EMO, they must respond by being prepared to integrate all own specific EMS activities into EMO. If there is no such ambition and alliance member states will only participate in NATO EMO, it will be necessary to implement this readiness only with personnel and assets that are assigned for NATO operations. However, the EMO must be understood consistently across the Alliance at all levels of C2, regardless of the ambitions of individual Allies. All functional areas of the DOTMLPFI must be adapted to this and can only be developed in parallel and symbiosis with each other. Similar coherence must exist between all specific EMS activities and other MILOPs in which these specific EMS activities can be implemented separately or as part of an EMO (see Fig. 3).

6. Conclusions

The continuous use of EM energy will be closely linked to the availability of modern technical equipment and the introduction of emerging disruptive technologies, as well as to the rising standard of living, which will further lead to a greater dependence of the population on the EMS. The availability of the EMS will be subject to competition, which will limit its availability not only to the private and public sectors, but also to the military. Therefore, the availability of EMS for security and defence purposes is already the subject of expert discussions. These discussions need to be continued with national EMS regulators, because even in peacetime we see hostile specific EMS activities on a daily basis that affect not only the security and defence of Alliance nations, but also their populations, public services, and so on [17]. The congested and contested nature of the EMS and the resulting implications for shaping the EME will have a lasting impact on the changing nature of the OE at any given place and time.

As previously mentioned, EM energy has the potential to fundamentally affect the fighting power of any military force in any operational domain. Appropriate use of EM energy, achievable through specific EMS activities at particular places and times, can contribute significantly to the end states of MILOPs as well as to the reduction of friendly combat losses. The development of EM activities, especially specific EMS activities, brings with it a number of opportunities but also challenges. In order to use EM energy properly, it is necessary to continuously assess the capability of military forces in relation to the use of the EMS and their affectability through it. However, the assessment must always be realistic, both for friendly forces and for adversaries and enemies. It is crucial to highlight that underestimating the capability to exploit or be affected by EMS activities can have as many negative implications as overestimating them. It is of the utmost importance that military forces are able to conduct their own ED and provide their own EM hardening through EPM to defend against the non-lethal effects of adversaries' and enemies' specific EMS activities. The execution of specific EMS activities must then be built in accordance with operational art by seamlessly integrating them into the real MILOPs.

The nature of the current OE and the trends that will shape it in the near future underscore the need for military forces to have realistic capabilities to gain and maintain superiority in the EMS. To achieve this goal in major operations or campaigns, however, having only the capability to conduct specific EMS activities will not be sufficient in the future. The development of the concept of MDO makes it clear that military capabilities will need to be addressed in all operational domains in the future. This means that the operational level of command will necessarily have to deal with both planning and conducting EMO, despite the fact that the task of conducting specific EMS activities that will be incorporated into EMO will remain at the tactical level. EMO will therefore have to be an indispensable capability for those military forces or political-military formations whose ambition will be to conduct military operations independently, not just to participate in them. However, it should certainly be the ambition of all NATO member states to understand the concept of EMO, as their military forces can participate in NATO EMO. Similarly, the issue of EMO should not go unnoticed for reasons of defence necessity, as the ability to plan and conduct EMO can hypothetically be acquired by adversaries or enemies.

In order to prevent this from happening, it is necessary to realistically appreciate the importance of the EMS to MILOPs, as evidenced by an unambiguous assertion of Air Chief Marshal the Lord Stuart PEACH KG GBE KCB DL, former Chairman of the NATO Military Committee and former UK Chief of Defence Staff, that *"We need to spend time understanding warfare, including EMS activities."* [17]. His clear statement was made at a conference organized by the Association of Old Crows in Oslo, Norway, on 14–15 May 2024. The objective of this conference was to present the most recent findings and to engage in discourse regarding the matters of EW and other activities related to the EMS, including EMS management and EMO, among other topics. The expert community, comprising representatives from the military, industry, and academia, discussed upon the genuine threats that we are already confronted with in the EMS on a daily basis. It is necessary to be able to explain to the population and the political representation that the EME, due to its permeability to other operational domains, is an extremely effective tool not only for the acquisition of situational awareness, but also for the projection of offensive effects against NATO and its member states. This affects not only the military and security forces, but also the public sector and the population. The necessity of readiness to face the action of adversaries by deterrence and defence was particularly emphasized. In this context, it is important to be able to implement the capabilities of our own activities in EMS. Furthermore, the necessity for addressing significant challenges was highlighted, including the necessity for broad-spectrum education of soldiers in the field of electromagnetic activities, encompassing special EMS activities. It was noted that the effects of EME are not limited to a single domain, but rather operate across the entire matrix of domains, including land, air, space, and cyberspace, where MILOPs and campaigns are conducted. The necessity for the specification of real operational tasks and closer interaction between military, industry and academia has also been acknowledged. Dissemination of needs, knowledge and experience is the only possible way to ensure that the EMS is prepared to face current and future threats. It is notable that neither the necessity for the development of interoperability, which is one of the functional areas of DOTMLPFI, as outlined in this article, has been addressed. [17]

It is evident that the EMS, EM activities and specific EMS activities will continue to play a pivotal role in the current and future warfighting environment. While they may not become the last resort solution in the immediate future, their significance in modern warfare must not be overlooked!

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