THE POTENTIAL REPRESENTED BY MISSILE DEFENCE – EMERGING AND DISRUPTIVE TECHNOLOGY – IN THE GLOBAL POWER BALANCE

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The rapid exploitation of the scientific research results for military purposes, implementing them in new weapon systems, has become a key factor in the global power relationships. The possession of the nuclear weapon has a relevant contribution to maintaining the high-power status by placing the states having it in the first positions of global military power hierarchy. Emerging technologies, in this case the missile defence, have the capability to threaten or strengthen strategic stability.

Missile defence represents a complex system of armaments that includes a variety of capabilities designed to protect different objectives against missile attacks in different ways. The integrated missile defence system (IMDS) entails tracking weapons/missiles to know their location during the travel trajectory, assessing the missile nature and capability, detecting (sensors, radars – early warning), identifying (sensor- or procedure-based), selecting the type of response (rules of engagement), selecting the weapon system to engage the missile (air/ground based-tracking, weapons) and destroying the missile (lethality – tactics and weapons effectiveness). Low observability aircraft – stealth/invisible and network-centred warfare are technologies affecting IMDS performance. The missile defence is largely determined by the improvement of the detection (radars), the assets of engagement (weapon range, tracking, sensor fusion, situational awareness) and the degree of destruction (tactics).

Keywords: missile defence; ballistic missile; sensor; radar; detection;

PRELIMINARY CONSIDERATIONS

The security environment has changed deeply in recent years, both globally and regionally. There have been outlined quite relevant tendencies and actions regarding the revival of the dispute for superpower status, the redefinition of the relationships between actors with global interests, the reconfiguration of the power balance, the amplification and diversification of the fields of competition and geopolitical rivalry, nuclear deterrence becoming more present and relevant in the relationships between the great powers. (*White Paper on Defence*, 2021, pp. 10-12). The features of the security environment have undergone dramatic changes, especially after 24 February 2022, when Russia invaded Ukraine, affecting the rules-based international order. In this context, NATO has diversified deterrent and defence measures, including by deploying response forces, to strengthen the posture and presence on the eastern flank. The consequences of the war have already been felt at global level, the strategic and systemic competition has intensified, involving operational aspects of defence and deterrence, consolidating and diversifying capabilities, the technology and industry development, prioritizing and redefining the multilateral strategy. The employment by the Russian Federation of conventional, cyber and hybrids assets to undermine the rules-based international order represents the most significant and direct threat to the security of NATO allies as well as to peace and stability in the Euro-Atlantic area.

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The new challenges with an impact on the security environment are generated by: the increasing tendency of state and non-state adversaries to exploit the limited ability to protect against hostile complex actions; the economic crisis caused by the Covid-19 pandemic; the strengthening of the Russian Federation military potential on NATO eastern flank, namely on NATO border, through which offensive operations can be carried out, amplifying and causing major challenges against national strategic interests aimed at securing

EU and NATO borders and ensuring energy security and stability; the delays in the Alliance's adaptation processes to the threats in its eastern and southern neighbourhood; the volatility of the security status in the Western Balkans, the instability of the Middle East and North Africa; the terrorist threat; the hostile informative actions; the cyber-attacks; the integration of emerging and disruptive technologies; the proliferation of weapons of mass destruction and delivery systems; the phenomenon of organized crime and, last but not least, the distortions in energy markets. (Presidential Administration, 2020, pp. 24-27).

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The global strategic situation, which has never been so uncertain, volatile and constantly evolving, is influenced by many dynamics, including the political-social, demographic, environmental, economic, military, and technological ones. There are threats that potentially have an impact on the global strategic balance and on the new world order established after the Second World War. The armed forces of a great power and of any country, in general, must meet the emerging challenges that, in terms of size and nature, are unprecedented. (Italian Army Headquarters, 2019, pp. 3-10). Missile defence represents a decisive and challenging military mission, and its relevance has evolved because NATO adversaries continue to develop new and disrupting attack capabilities intended to threaten the Allies. The threat represented by the hypersonic missiles, together with the ballistic and cruise missiles capabilities arsenals, increasingly complex, under development and modernization, of the Russian Federation and China clearly demonstrates the prominence the adversaries place on long-range strike capabilities. In response to these developments, NATO must ensure that the missile defence mission is planned, organized, budgeted and managed properly in order to be effective in this new and demanding security environment. (Department of Defense, 2022, pp. 4-8).

In order to cope with the new security environment characterized by an unprecedented strategic competition, NATO must improve the degree of global awareness and the deterrence, defending and contesting capacity, as well as deny access and dominance in all domains and directions, in accordance with the 360-degree approach. NATO's deterrence and defence posture is also based on missile

defence capabilities. (NATO, 2022, p. 6). Investment with dedication in hypersonic capacities is not only a strategic advantage but also a risk for opponents. NATO adversaries also invest in missiles, while allies have not invested enough in the assets for defending against missiles, an aspect highlighted by the excessive use of missiles by the Russian Federation in the invasion of Ukraine and the massive use of missiles by the Houthis movement in Yemen, supported by Iran, during the attacks on the United Emirates and Saudi Arabia. NATO states must invest now to ensure that they can defend themselves against missiles and to eliminate any strategic advantage taken into account by adversaries. (Department of Defense, ib.).

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Considering the missile's massive use in the latest conflicts, the consequences that this threat represents, the effectiveness of these emerging offensive capabilities, and their contribution to fulfilling the objectives of NATO adversaries military operations, missile and air defence missions have become decisive during a war. Therefore, the armed forces services must treat missile defence capabilities as a primordial task, in order to respond to the changing security environment features we are facing now, having the consequence of highlighting the missiles and means of air strikes as a mainly used battle form by adversaries. (Department of Defense, 2022, p. 6).

Two of the main problems that have caused frictions between the great powers lately are represented by the NATO member states' missile defence and the strategic balance stability, aspects highlighted since the Cold War era. The contradictions were generated by the fact that the deployment of the missile defence systems could substantially diminish the capacity of the adversary forces that use strategic assets and survived a first strike to penetrate the missile defence, thus offering an incentive for both sides to trigger a nuclear war in a contingency crisis. Moreover, the deployment of the missile defence systems could generate a nuclear arms race, because the parties involved developed their missile forces to favour the penetration of the adversary's missile defence system. (Sankaran, p. 55). Ballistic missile defence has lately represented the most important topic that generates tensions between the USA, on the one hand, and Russia and China, on the other hand, regarding strategic stability. (Ib., p. 54). Emerging technologies, which favour great powers to use the global connection, to easily influence migration and to compete for resources, result in the distribution of centralized power and the change in traditional identities. These significant changes make effective the reflection on the character of the war and on the anticipated shifts that the evolving trends at this time will have on the future battlefield. (Amerson, 2016, p. 1).

The challenges generated by emerging and disruptive technologies in the arms realm can be represented by five significant and potentially disruptive technological developments: hypersonic weapons, missile defence, artificial intelligence, counter-space capabilities, and computer network operations (cyber). (Futter, 2021, p. 1). This article will highlight only the nuances specific to missile defence, assessing the comparative influence of missile defence, particularly in the following domains: intercontinental ballistic missiles; hypersonic missiles; missile defence systems; command and control systems; coverage and protection; ballistic missile defence architecture; proliferation of ballistic missile capabilities; effects on international stability and security.

Missile defence represents an emerging technology that has a significant potential for substantially dangerous or disrupting effects on strategic nuclear stability and global and regional security. The great powers seek modalities, techniques and strategies to address, or at least mitigate, the impact and risks caused by the use of this new technology and the potential to disrupt the calculation of deterrence.

The gap between the speed ay which the shape and identity of threats change and the sometimes slow adaptation of the armed forces to the needs of transformation and modernization of the response capabilities clearly highlights the difficulties the states must meet during the process of transforming forces. The importance of defence against ballistic missiles has increased in recent years, especially after North Korea tested ballistic missiles that could threaten the territory of the United States of America (Watts, 2020, p. 1).

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THE SITUATION OF MISSILE AND AIR DEFENCE SYSTEMS ARCHITECTURE

The renewal of super power status competition has led to prioritizing the defence planning of the great powers on the capabilities for conducting so-called *high-end conventional warfare*, meaning large-scale war, high-intensity, technologically sophisticated conventional warfare against adversaries with similarly sophisticated military capabilities.

The defence capabilities against ballistic missiles, hypersonic and cruise missiles and attacks with other aerial means as well as land and anti-ship weapons with a longer range than the previously deployed systems also represent emerging technologies with the potential to influence the global strategic balance. (Congressional Research Service, 2022, p. 10). The war in Ukraine has validated in a convincing way the entry into a new missile era. This era is characterized by global messages amplification regarding the supply and demand for both missile delivery systems and for systems to counter them. In addition to the morale of the Ukrainian people, the support of intelligence for determining the targets and the sustained logistical support from the West, the conflict is defined by the mass use of precision fires. (Karako, 2022, pp. 1-3). In the latest and most relevant war, among other things, it is highlighted the fact that the Russian Federation uses the missiles, the means of air striking and the artillery in Ukraine, leading to the conclusion that we should accept them as predominant in the future military actions of this century. The emerging threats represented by the ballistic, cruise and hypersonic missiles, as well as by other lower-level ones, including unmanned aircraft systems, are rapidly amplified and evolving risk for NATO forces and countries. Identifying the ways and effective means of counteracting the threats and effects generated by the use of such weapons is a primordial mission for NATO. (Plumb, 2022, pp. 3-5).

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The missile defence system is a generic term used for a missile defence shield that is designated to protect a country against any types of missile – conventional, cruise or nuclear – that enter the national airspace, including intercontinental ballistic missiles (IBMs) or other ballistic missiles. (MDA, 2023, p. 1). The USA, Russia, India, France, Israel, Italy, the United Kingdom, China and Iran have developed such defence systems. Any mechanism that can detect and destroy a missile before striking the target is assimilated to the missile defence system. (Ib.).

Integrated Air Defence System (IADS) generally consists of sensors (inputs, what is put in, taken in, or operated on by any system), command and control, and effectors (a weapon that acts in response to a stimulus). The ***Kill chain*** of IADS integrates the following six steps:

1. tracking weapons release;
2. assessment;
3. detection (sensors);
4. identification (sensor- or procedure-based);
5. reaction selection (rules of engagement), selection of weapon system;
6. engagement. Details are presented in *figure no. 1*.

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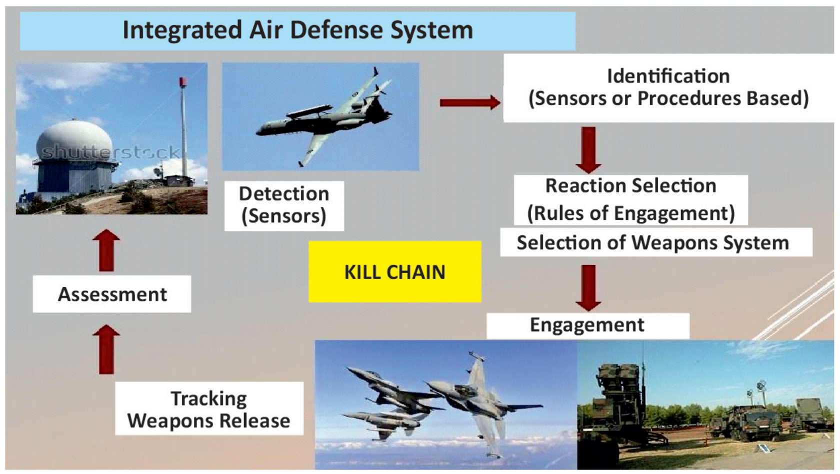

Figure no. 1: The Kill Chain of Integrated Air Defense System (Ib.)

In this process, the detection is determined by the early warning, the engagement (air/ground means), which is influenced by supervision and the technical-tactical characteristics of the armament and the degree of neutralization, which is determined by the tactics used and the efficacy of the armament.

Interception of missiles involves:

1) identifying and tracking the missiles or warheads;

2) discriminating the missiles or warheads from other false missiles;

3) determining the coordinates of the missile hitting point on the trajectory;

4) recording the fire elements and launching the missile interceptor (or directed energy) to destroy the missile or warhead. The ballistic missile flight trajectory has the following ***phases***: *boost* (the most advantageous phase for detection and monitoring), *ascending* (rocket motor is burned out and downrange sea-based systems can be effective to intercept), *midcourse* (the longest flight phase, most interception opportunities, and the decoys are released) and *terminal* phase (final opportunity for missile intercept). Currently, there is no asset to target ballistic missiles during the initial, or *"boost"* phase of missile trajectory. (American Foreign Policy Council, 2015, pp. 1-8).

Unmanned aircraft vehicles (UAVs) have the ability to intercept rockets during flight trajectory. The ability to quickly detect a launch and react to it significantly increases interception opportunities. Land, sea, and space-based sensors, including satellites and radars, provide the Ballistic Missile Defence System (BMDS) with the ability to detect, track and destroy incoming ballistic missiles. Details are presented in *figure no. 2*.

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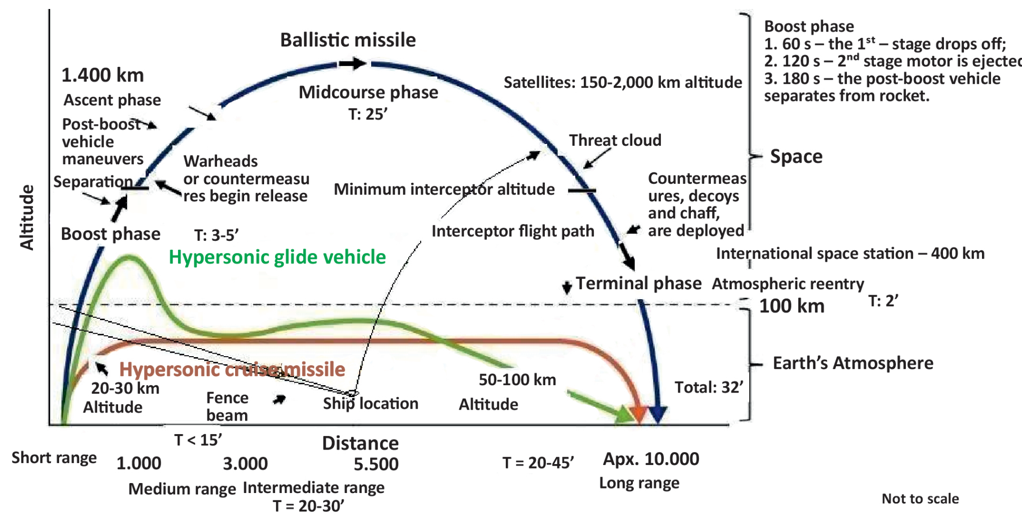

Figure no. 2: Missile trajectories, their actions during the flight and the reaction of the air and missile defence system
(Kunertova, 2021, p. 55, Williams, 2022, p. 3, Karako, 2022, p. 3, Boord, 2016, pp. 36, 63, 99, Speier, 2017, pp. 2, 11-12).

The NATO Integrated Air and Missile Defence System (NATINAMDS) represents an integration of the capabilities and overlapping operations of all services to deter and defend the Alliance' territory, population and forces to ensure freedom of action by denying the adversary's ability to achieve destructive effects due to its air and missile assets. It includes a network of interconnected systems to detect, track, classify, identify and monitor air assets and, if necessary, intercept them by using terrestrial or air weapons systems, as well as the necessary procedures to employ these systems. NATINAMDS is a foundation stone of NATO air defence and defence policy, which was implemented in the 1970s. Generally, it has the following components: command, control, communications and intelligence; surveillance; active air defence and passive air defence (dispersal, hardening, shelters, camouflage, decoys, electronic protection measures). NATO Air Policing, part of active air defence, is a peacetime mission that requires an Air Surveillance and Control System, an Air Command and Control structure, Quick Reaction Alert interceptors, and aircraft to be available on a 24/7 basis. It enables the Alliance to detect, track and identify to the greatest extent possible all aerial objects approaching or operating within NATO airspace, so that the violations can be recognized and the appropriate actions can be performed.

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The architecture of the NATO Ballistic Missiles Defence System has as a central part the NATO Command Centre in Ramstein, Germany, which leads the activity of the following elements: satellites providing early warning for NATO BMD; Aegis Ashore *"Sensors Shooter"*, Deveselu, Romania, operational since 2016; four US Aegis BMD capable ships – *"Sensors Shooter"*, Rota, Spain; air defence systems – PATRIOT (Phased Array Tracking Radar for Intercept on Target – a US theatre-wide surface-to-air missile defence system) and SAMP-T *(sol-air moyenne portee-terrestre* – the main French medium-range air defence system for theatre protection); sea-based radars; land-based radars; Aegis Ashore, *"Sensors Shooter"*, Redzicowo, Poland, 2023; BMD tracking radars *"Sensors"* Kurecik, Turkey, and Ship Force Protection. (NATO, 2019).

The European Phased Adaptive Approach (EPAA) represents a NATO missile defence project, whose implementation started in 2011, in which the USA has a decisive contribution, being designed

to protect Europe against short, medium and intermediate range potential ballistic missiles, launched from Iran. This initiative is based on the missile defence system Aegis configured for terrestrial and naval employment and has as its essential means the standard SM-3, missiles interceptor designed to engage short and medium range, ballistic missiles in the mid-course and terminal phase of trajectory, a system that will be progressively integrated into a network of land and space-based sensors. All of the SM-3 variants fire from the Mk 41 vertical launching system. An overview of different EPAA phases is provided by the following three phases with reference to: *missile platforms and number*, *SM-3 variant and number*, *sensors and combat system*.

Phase 1 – deployed. In phase 1, EPAA consists of the command centre arranged in Germany, the radars deployed in Turkey, the ships of the US Navy in Monterey and 29 other ships with Aegis ballistic shield capabilities in Spain and 129 SM-3 Block IA and IB interceptors. The system has been operational since the end of 2011. Starting in 2014, Spain has hosted four of those ships (equipped with SPY-1 radar) at its naval base in Rota. The sensors and interceptors operate under the Aegis combat system. This is a system capable of tracking 100 simultaneous targets. US and European BMDS are integrated for battle management at Ramstein Air Force Base in Germany.

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In ***Phase 2***, the system has been operational since May 2016. At the July 2016 Warsaw Summit, NATO declared the Initial Operational Capability of the NATO BMDS. In May 2016, NATO declared operational the Romania Aegis Ashore site at Deveselu as part of EPAA Phase 2. Interceptors were also mounted on an increasing number of Aegis BMD ships in support of global missions. The first Aegis Ashore site in Romania (which completed an update in August 2019) is equipped with one land-based Aegis SPY-1 radar and 12 missile tubes for 24 SM-3 Block IB interceptor missiles. Phase 2 obtained the Technical Capability Declaration in December 2015, certifying that the system operates according to the project.

Phase 3, having 2022 as planned implementation date, includes the deployment and operationalization of the Aegis Ashore system in Poland, operational probably in 2023 (Costea, 2023), which was initially scheduled in 2018. Thus, the assets deployed at sea and those existing in Romania will be supplemented and the European area protected by the system will be expanded. Phase 3 provides equipment with the most efficient interceptor SM-3 Block III. This interceptor provides the system with an increased capacity to engage intermediate-range ballistic missiles and a restricted capability to employ IBMs. One last test on a destroyer equipped with Aegis IBMs having SM-3 Block II A interceptor, in November 2020, completed the development phase and confirmed the production phase. In 2022 it was planned the production of eight SM-3 Block II A interceptions for deployment in Romania and Poland, as well as on some Aegis ships, along with 60 others produced in 2021. In Phase 3, the United States of America planned to deploy two new tracking systems to support early interception: the airborne infrared sensor platform (ABIR), a system designed to track a significantly larger number of missiles launched by the enemy and the Precision Tracking and Surveillance System (PTTS), which would provide up to 12 satellites. Both the ABIR and PTTS programmes were provided in the budgets of 2013 and 2014 respectively. (Arms Control Association, 2022, pp. 1-5). Space-based sensors represent the most effective means with operational capabilities for ballistic missiles in flights persistent global surveillance. The PTTS was designed to strengthen the BMDS, by using a constellation of infrared sensors to exploit all the benefits of space deployment for precision missile tracking. The PTSS satellite programme corresponds to the needs of the warfare forces, by ensuring persistent tracking, post the first stage of missile flying, used to give initial acceleration, the ballistic missiles elements tracking, and provides assistance to the description and discrimination of the elements. Although the necessity and efficiency of a space layer, part of BMDS are of great topicality, in October 2013, the programme was officially interrupted. (US Department of Defense, 2013, p.1). Phase 3 of EPAA was planned to comprise a capability that can only be accessed by means of a network, the Aegis interceptors to perform operations based exclusively on the information provided by radar, thus extending the range of Aegis systems. In this capability, the interceptor can be launched and guided to intercept sensors deployed at a distance from the launching platform.

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Phase 4 was cancelled in March 2013. The Aegis platforms for SM-3 interceptors would have remained the same, namely the naval platforms, and the terrestrial platforms deployed in Romania

and Poland and the SM-3 block IIB interceptor missiles, which were only in the design phase, were designed to be used to neutralize the medium, intermediate range missiles and IBMs. These missiles were scheduled to have an improved detector and an initial engine with higher performance and speed. The planned mission of *"early interception"* without adequate technical support was appreciated as being not realistically achievable. According to the initial project, the space-based sensors would have played a decisive role in this phase. Aegis Ashore – is a land-based component of the BMDS and is the achievement implementing' decisive element of the EPAA, respectively the US military support to the NATO Missile Defence. (Everson, 2022, p. 1).

If North Korea launches a ballistic missile, the sensors located in space will begin tracking it in seconds. The ground-based radars, located on different continents, will continue tracking it even after the rocket engine is removed and the warhead continues the movement. The radars will guide the interceptors to a planned interception point. (Sankaran, 2022, p. 52).

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THE DESIGN AND DEVELOPMENT OF THE MISSILE DEFENCE SYSTEM TO MEET THE OPERATIONAL REQUIREMENTS

The emerging threats represented by the ballistic, cruise, hypersonic and lower-level systems, as well as by Unmanned Aircraft Systems (UAS) constitute an expanding risk for NATO and great powers. NATO adversaries, in order to create a favourable course of action in a potential conflict, are developing, deploying, and integrating emerging technology in the field of missiles and missile defence capabilities. The missile defence is decisive to deny the implementation of the plans by the adversaries, the conventional and nuclear military power projection creating uncertainties regarding the success of employing missiles of any kind and UAVs in battle. It highlights the importance of the so-called high intensity, technologically sophisticated conflict that includes ballistic missiles defence capabilities and longer-ranged land and naval-attack and anti-ship weapons and offers possibilities that have a lower escalation potential than other offensive means.

The amplification of the dimension and complexity of the capabilities and effects of the missiles possessed by Russia, China, North Korea and Iran determines the United States of America and NATO to develop new capabilities and strategies to neutralize these threats for their territories through actions that result in stopping the development, acquisition and proliferation by adversaries as well as in denying their current and potential employment of offensive missiles of any type and diminishing the effects caused by such use.

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Theoretically, the armed forces try to develop systems for neutralizing rockets in all phases of their flight. However, most of them guide their efforts, almost exclusively, on intercepting ballistic missiles or other types of missiles in their midcourse and terminal stages of the trajectory. There are sufficient technical, operational arguments or results from the latest conflicts that support this approach. The analysts conclude that the programmes and concepts of striking in the trajectory' ascending or boosting phase would be expensive, strategically destabilizing, technologically unfeasible, or operationally unrealistic. The United States of America has tried to achieve several

boost-phase defence systems but none has passed the development stage. (Williams, 2022, p. 1). Details are presented in *figures no. 1* and *no. 2.*

The operational requirements fulfilment and the achievement of an efficient and performing Missile Defence System entail an optimal balance between the air defence armament platforms, the sensor systems and their performance as well as between the system's requirements, possibilities and ballistic missile and air defence needs. Today, many countries have offensive missile capabilities deployed on terrestrial, naval and air platforms.

The operational requirements fulfilment and the achievement of an efficient and performing Missile Defence System entail an optimal balance between the air defence armament platforms, the sensor systems and their performance as well as between the system's requirements, possibilities and ballistic missile and air defence needs. Today, many countries have offensive missile capabilities deployed on terrestrial, naval and air platforms. The need for missile defence systems to defend against more capable and diversified offensive missile system capabilities is increasing. (Boord, 2016, pp. 1-2). Generally, a missile defence system has to respond to the clearly defined or identified operational requirements that are approached together to provide an effective defence. The functional requirements are: intelligence, surveillance and reconnaissance (ISR); detection and tracking; weapons control; and engagement. Ballistic missile defence is carried out in three stages: boost, midcourse, and terminal intercept engagement phases. (Ib., p. 23). Missile defence entails a range of actions to counteract the development, acquisition, proliferation, real and potential use by adversaries of any type of missiles and limiting the effects of their use. (US Department of Defense, ib., p. 1/62).

Cruise missile defence is usually separated into three sections: *defence stage area, self-defence stage,* and *point defence stage.* Self-defence and point-defence stages may employ the same system elements but with various mission requirements. These components and missions are integrated to assure a layered defence capability to increase defence efficiency. Also, in order to counteract the penetration of the missile defence system, it is necessary to employ higher-speed missiles, aerial and more efficient information, surveillance, recognition sensors and radars connected to data networks and sophisticated signal processing techniques to counter these offensive techniques. (Boord, ib.). In order to be effective, the air and missile defence system (AMDS) is necessary to have the ability to neutralize advanced aerodynamic and ballistic missiles, aircraft and UAVs in a complex, multidomain operations theatre. All military operations are multidomain operations on land, sea, air, space, and cyberspace. AMDS will involve theatre defence – provides protection to any other military or civil element throughout the operation theatre, area defence – air defence assets area, point defence – the mission to defend military or civil assets from within the immediate area of the missile attack, and self-defence. (Boord, p. 49).

Analysts specialized in weapons consider that the trajectory of a ballistic missile has three phases: the boost phase, the missile is most vulnerable few minutes, from ignition through launch to engine shut off at the edge of the atmosphere; the midcourse phase, the missile is now on the flight trajectory, it includes the highest point of the trajectory in space, located between the ascending and the descending branch of the trajectory, and the terminal phase that includes the last minute.

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An important stage is ballistic missiles interception. After the adversary launches a ballistic missile for a target on the NATO's states territory, the reaction time is reduced to a few minutes. NATO's BMDS employs sensors and interceptors' networks integrated into a layered defence. It determines the missile trajectory, assesses the threat, and calculates the most effective variant for the interception. At the same time, it issues rapid warnings regarding the possible impact areas in order to warn the national authorities. Thus, the threat is identified and it is selected the optimal interceptor for launching from land or naval platforms to annihilate the opponent's missile and finally to assure the protection of NATO populations, territories and forces. A simple algorithm and landmarks from the adversary's missiles launching to destroying are presented below: time zero, launching the missile representing the threat; the tracking sensors convey the signal and threat missile trajectory computing. The total flight time is assigned as follows: 25% into the flight represents burnout stages, the fuel is consumed; at 50% of the trajectory flight, the interceptor is launched; at 75% of the trajectory flight, the threat missile is destroyed by the interceptor. BMDS must cope with tactics that may include jamming and manoeuvres either combined or separately. Jamming is used to delay the detection by the radar and the search missile or to prevent

an accurate range and angle estimation. Details are presented in *figures no. 1* and *no. 2.* According to realistic scenarios, radars and missile detectors have to be able to function in complicated environments that comprise mixed consequences of various trajectories, jamming and clutter. Missile seekers have to also cope with the terrain bounce jamming and towed decoys. Both of these deceptive techniques are designed to confuse the seeker angle estimates for the target. (Boord, p. 29). The advantage of intercepting a missile at the beginning of the flight is unanimously acknowledged. The neutralization in the boost or ascent phase can make less severe and critical certain technical requirements generated by the interception in the final phases of the trajectory, where the missiles can trigger certain countermeasures and can perform manoeuvres to avoid interception. (Williams, p. 1). Achieving effective fighting capability in defence against missile attack is conditioned by ISR; detection and tracking; weapons control; engagement process addressed in the circumstances of the complete area where the mission of the defence system is performed. Once a missile is detected, through the battle management process is carried out an assessment of potential targets or hostile actions.

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The characteristics on which the ***mission's fulfilment*** depends are the following: 1. *Reaction time* – executing fire within the available engagement timeline, consisting of target detection and transfer of target location from the sensor to shooter, combat identification, and missile launcher response time; 2. *Firepower* – the ability to launch missiles at the target when and where it is required to be done with adequate quantity to guarantee the fulfilment of the mission. It has two components: a) adequate *range* to detonate the target missile, not at the end of the trajectory and, b) *homing* – requirement to achieve the desired single-shot probability of a kill; 3. *Defence penetration technique resistance* – the denying of the missile's characteristics designed by adversaries in their offensive air and missile systems that are intended to defeat the defensive systems of targets to be destroyed. Missile defence has to eliminate the missile counteract measures regarding: search and surveillance, detection and tracking within a fire-control system, engagement – considered the sensitive or most vulnerable phase in the engagement chain and counterpoint defence – when short-range systems will be used to achieve a self-defence layer against the missile. In this phase, fluctuations in trajectory and altitude, jamming, signature dilution, masking schemes and speed are taken into account. The system computes the likely point in time and space where the engagement will fulfil; 4. *Environmental resistance* – maintain AMDS performance in hostile environments; 5. *Continuous availability* – refers to the AMDS ability to be in the operating state, according to the designated parameters, permanently; and 6. *Contiguous coverage in the theatre* – involves the perfect coverage of the objective to be defended from all directions from a certain range and altitude. (Boord, pp. 43, 49).

The functional requirements that define the ***system architecture*** decompose into the following functional elements or systems: (1) the *central defence system* has as missions – detect and track, discriminate, compute the engagement doctrine and decisions, compute engagement solution, clarify, handover and communicate; (2) the *intelligence, surveillance, and reconnaissance system* – compute target origin, compute and update target geoposition, estimate target geospatial and temporal final objective and exchange information; (3) the *target system* – a form of identification/signatures, dynamics, time/space correlation, physical characteristics; (4) the *engagement system* – flyout, midcourse guidance and control, terminal homing, lethality mechanism, exchange information; and (5) the *communication link system* – frequency, bandwidth, word content and format, data rate, reference frames (spatial, temporal). (Ib., p. 50).

CONCLUSIONS

Air and missile defence is one of the toughest missions the great powers' armed forces have faced in the past period, an aspect particularly highlighted in the war in Ukraine. They must find a balanced approach to neutralize a missile in both standard and electronic attack environments. It must also improve the key performance parameters that determine the capabilities of AMDS, respectively weapons and sensors systems. AMDS is necessary to exploit new technologies and innovative architectures to make certain that they are exceeding those of targets. The importance of missile defence will increase, as long as there will be offensive missile capabilities, as a guarantee against missile strikes.

In order for the air and missile defence to be effective, at least three actions are needed: improve targets detection by equipment with performance assets, very high-frequency radars, passive radars, over-the-horizon radars, radars with the ability to detect targets at very long distances; improve engagement by employing long-range weapons that have the ability to engage at long distances, tracking, fusion sensors, which have the ability to combine sensor data or data obtained from disparate sources, so the resulting information has less uncertainty, infrared searching, and tracking radars; and, situation awareness through networks that process a large amount of data and finally improve the kill probability by adopting adequate tactics.

The missile interception efficiency in the initial part of the trajectory is unanimously accepted. Missile interception in the trajectory impulse or ascending phase can eliminate many of the technical challenges specific to the final stages of the trajectory, in which certain misleading, counteracting interception actions are triggered and manoeuvres difficult to forecast are carried out. At the same time, engagement missiles in the boost phase are largely influenced by the short-length exposure as well as by certain delays in the detection and tracking process. Selecting the boost stage to neutralize a missile is considerably impeded, among others, by the reduced reaction time in relation to the other phases, the release frequency of the support penetration elements against missile defence, and the time required to position itself on the final ballistic trajectory. As a result of missile neutralization costs and benefits analysis, it can be concluded that it is effective to engage them in the trajectory midcourse phase at the same time with the improvement of the actions to missile tracking and the discrimination capacities.

The Ukraine war has shown that the threat of missile and aircraft employment has accelerated lately. In order to counter these threats, the AMDS must be layered with terrestrial-based and space-based sensors, comprehensive, mobile, with integrated command and control system, and capable of suppressing, neutralizing, and destroying the adversaries' missiles in any situation and in all phases of the trajectory based on tactics that emphasise manoeuvre and dispersion to give it resilience in a disputed theatre by adversaries and where multidomain operations are conducted. The presence of flexible capabilities

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that ensure a permanent and detailed situation awareness and are integrated into a layered defence network supports the fulfilment of the air and missile defence missions. The reliability of the missile defence system is given by the engagement of missiles launched on any platform, terrestrial, naval or air. There is a gap between the development and evolution of ballistic missiles and the development and evolution of air and missile defence assets, including their roles and missions. The air and missile defence systems are outrun, in particular situations, by the missile threat and other modern equipment for striking from the air.

For the great powers, the only deterrence viable element in the short term remains nuclear missiles, which no other power element can replace. Missile defence remains the main priority not only for the defence of national territories but also for deterrence. In order to be effective, AMDS must integrate all defeat capabilities, offensive, defensive, passive, kinetic, and non-kinetic, in a large, cohesive, combined, and joint headquarter.

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