Article received in March 2017 and accepted for publication in May 2017

BALLISTIC MISSILE DEFENSE: A MULTIDIMENSIONAL CAPABILITY

DEFESA CONTRA MÍSSEIS BALÍSTICOS: UMA CAPACIDADE MULTIDIMENSIONAL

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Abstract

At the end of the last century, everything led to the belief that ballistic missiles would lose their relevance, but the proliferation of pariah states and the technology associated with the production and development of ballistic missiles have kept the topic on the agenda. Thus, this paper characterises the threat and analyses anti-ballistic missile defence in its different dimensions, from its genesis to the current path mapped out by NATO and the US, both politically and militarily, while taking into account the problems associated with interceptions management and the integration of efforts and capabilities.

Keywords: Missiles, ballistic, defence, interception.

Resumo

Quando no final do século passado tudo levava a crer que os mísseis balísticos perderiam relevância, a proliferação de estados pária e da tecnologia associada à produção e desenvolvimento de mísseis balísticos, garantem a atualidade deste tema. Assim, este trabalho caracteriza a ameaça e analisa a defesa contra mísseis balísticos nas suas diferentes vertentes, desde a sua génese até ao caminho atualmente apontado pela NATO e pelos EUA,

How to cite this paper: Leitão, F., 2017. Ballistic missile defense: a multidimensional capability. *Revista de Ciências Militares*, May 2017 V (1), pp. 205-226.
Available at: http://www.iesm.pt/cisdi/index.php/publicacoes/revista-de-ciencias-militares/edicoes.

quer ao nível político quer no domínio militar, tendo em conta a problemática associada à gestão das interceções e à integração de esforços e capacidades.

Palavras chave: Mísseis, balístico, defesa, interceção.

> *The theory of ballistic missile defense is not to provide a perfect shield, but to degrade an attack to the point where it becomes unprofitable, as our riposte will unfailingly ruin the attacking country.*
>
> Ron Lipsman, *The unintended consequences of missile defense*.

Introduction

Man's need to defend himself from the attacks of his opponents is as old as war itself. In early warfare, shelters would have consisted of rocks, vegetation or terrain features, but these were quickly forced to evolve in order to respond to the development of weapons systems. Infantry responded to the range that archers were able to cover by developing better shields. The increasing lethality of artillery was met with a corresponding increase in the ability to resist enemy fire by building walls and fortifications. However, these forms of passive defence have been proven to have significant limitations and are quickly overcome by the constant advancement of technology. Thus, from early on, an active type of defence proved to be a more attractive proposition, especially one that could prevent enemy projectiles in flight from reaching their target.

Although artisanal rockets have been used for a number of different purposes since the Middle Ages, more recently rockets have extended the range of ground combat systems, especially artillery, and were, along with the development of the reaction engine, at the genesis of the missiles we know today. Used in various military capabilities, the missile era reached its apex during the Cold War, when missiles played a key role in the nuclear deterrence strategy of the US and the North Atlantic Treaty Organization (NATO), becoming one of the elements of a well known triad that also included strategic bombers and nuclear submarines.

After the fall of the Berlin Wall and with the ensuing agreements for the reduction of nuclear weapons, it was believed that ballistic missiles would lose relevance as weapons systems, but due to the proliferation of so-called pariah states and of technology related to the production and development of ballistic missiles, the issue has remained on the agenda as a credible threat to the west. Thus, this paper aims to characterise that threat, to describe and analyse ballistic missile defence in its various facets, from its genesis to the current path mapped out by NATO and the United States of America (US), both politically and militarily, while taking into account the problems associated with interceptions management and the integration of efforts and capabilities.

1. Threat proliferation

The use of "bombs" or, more accurately, V1 cruise missiles, and especially Germany's V2 ballistic missile in the final stages of World War II, was a milestone for the development of new military capabilities as well as for the space race, and some features have survived in other weapons systems used today. In all, more than 8,600 missiles were launched against England, of which 7,500 were V1 missiles, the remainder being V2 (*All World Wars*, n.d.).

Although they had rather different ways of operating, these missiles spread terror across English cities, and specific missions were carried out to combat their use by the Germans. These missions were integrated in the Combined Bomber Offensive and had the effect of preventing missiles from being produced in enough numbers for effective use. The bombing of launch sites and production centres, coupled with technical difficulties that stemmed from the pioneering nature of these weapons systems, and the gradual reduction of German industrial capacity rendered this battlefield innovation ineffective (Idem).

Alongside these conventional attacks, which were predominantly offensive in nature, the Allies also used defensive countermeasures that closely resembled the defensive aerial combat already practiced at the time, as the V1, which were essentially cruise missiles, rather resembled small reaction engine aircraft. Thus, there were anti-aircraft artillery bases on the coast of England, around London and at the Thames estuary, as well as in other locations determined by the most likely V1 approach routes. Balloons were also used to prevent overflight of certain routes, but were unsuccessful as those missiles had wings fitted with cable cutters. Additionally, unsuccessful interceptions using fighter aircraft were attempted, based on early warning given by observers with radios (Idem). Finally, deception proved vital as a way of preventing the Germans from correctly assessing their attack accuracy and the damage their attacks had done. Against the V2, a ballistic missile with a range of 200 NM (379,4 km), a warhead capacity of 2,200 lb. (998 kg) and inertial guidance system (Hickman, 2015), no countermeasures were effective in preventing them from reaching their targets (ETHW, 2015).

It is therefore relevant to analyse how we went from a context where ballistic missiles were almost exclusively owned by the major powers to the current context of proliferation of these systems.

During the Cold War, proxy wars[1] were responsible for the large-scale proliferation of weapons of varying technological complexity, which nevertheless allowed some states to come into contact with new weapons systems that had been unknown to them up to that point. The provision of Chinese and Russian missiles and rockets to North Vietnam during the war with the south (*The Blade*, 1968) or, in another operational context, the supply of US

[1] Proxy War refers to the armed conflicts where belligerent states were more or less explicitly supported by the United States and by the Soviet Union. There was thus an indirect confrontation between the two powers.

Stinger missiles to the *mujahedin* in Afghanistan during the Soviet invasion are examples of this. Similarly, even though Iran could rely on its Soviet-inspired SCUD missiles during the war with Iraq, the country was forced to develop its own capabilities in order to extend the range of its systems and become independent vis-a-vis the geopolitical climate at the time. To that end, Iran had the support of China, Libya and North Korea, which had not only sold the country missiles but also provided components and expertise (*Iran Watch*, 2012). At the same time, the US tacitly accepted the development of nuclear weapons by its allies, such as Pakistan (Chakma, 2009, p. 26) in response to India's nuclear program, and failed to adequately respond to the use of chemical weapons by Iraq in the war with its neighbour to the east. One possible conclusion that can be drawn is that, with a few exceptions, as long as allies are useful in conflicts with rivals, non-proliferation efforts have been superseded by broader security concerns (Idem). More recently, in the 2006 Lebanon war, Syria and Iran showed clear support to Hezbollah by supplying the organization with short and medium-range rockets and missiles (Cordesman, Sullivan and Sullivan, 2007, p. 60).

In addition to the proliferation brought about by the Cold War and other related limited armed conflicts, the transfer of technology and arms systems between states and the support of pariah states to terrorist organizations also contributed decisively to the proliferation of the threat posed by ballistic missile weapon systems.

After the Cold War ended, it could be thought that the anti-missile defence system announced by Ronald Reagan in 1983, the Defense Strategic Initiative, or Star Wars[2] as it is widely known, and earlier efforts such as the Safeguard programme, would, regardless of their feasibility, become an addition to the shelf of mementos where ideas and experimental systems that have never seen the light of day in terms of operational use are stored. However, the relevance of missile defence systems did not end with the Cold War, nor are the missiles themselves the cause for concern. The nuclear era was followed by new irregular threats that, together with the use of weapons of mass destruction, could become the greatest threats to global stability in the post-Cold War era. There is no evidence that a country that acquires the ability to use weapons of mass destruction behaves less responsibly in the geopolitical arena, although recent North Korean behaviour appears to indicate otherwise. However, states are not currently the only stakeholders in international relations, as the global importance of non-state actors is increasing. The different types of missiles take on new prominence as delivery vehicles for weapons of mass destruction or, in the case of more accurate missiles, for conventional high explosive charges.

Given the nature of terrorist organizations, it is possible, if rather unlikely that any of these organizations has the technological capability to develop its own missile systems in combination with weapons of mass destruction[3]. If this assumption is true, there are

[2] The name Star Wars came from the programme's goal of mounting lasers on satellites in order to intercept Soviet ballistic missiles in flight.

[3] In his book *On Nuclear Terrorism* (2007), Michael Levi outlines in detail the difficulties and obstacles that terrorist organizations face in producing a nuclear weapon.

two ways to obtain these systems: either they are supplied by countries that support those organizations' causes, or they are acquired using criminal means, either through the violent theft of materials or technology or through corrupt government forces of fragile or failed states. It came as no surprise, then, that George W. Bush, in his 2002 Union address (*The White House*, 2002), identified attacks with ballistic missiles and weapons of mass destruction by states or by organizations sponsored by those states as a priority threat[4]. This concern becomes particularly pertinent when one considers how difficult it is to deter stateless fighters without fixed bases of operation or known modes of operation. Eleven years later, President Obama maintained the same level of concern regarding North Korea and Iran, suggesting new avenues to suppress weapons of mass destruction, also referring to the need to strengthen US and allied missile defence systems (*The White House*, 2013).

The threat posed by the proliferation of ballistic missiles can be described in three dimensions: first, as a platform for weapons of mass destruction; second, as a tool for terrorist attacks; and finally as a potential feature of anti-satellite weapon systems through nuclear detonations in space and the associated effects of the electromagnetic pulse (IWG, 2009, p.1). However, the operational use of ballistic missiles is not exclusive to these models and may take on more conventional forms.

In recent conflicts, Air and Space Power has been an asymmetric advantage of the west vis-a-vis its opponents. Although western air capabilities are technologically and numerically superior, especially in terms of projection capability and precision strike, a fact that becomes even clearer when those capabilities include the North American military structure, strategies have emerged to counter this western superiority.

Called Anti-Access/Area Denial, these strategies are a response to western air superiority. On the one hand, they entail limiting freedom of action and operation in a given area through the use of aggressive air defence systems, and, on the other, denying access to a particular area of interest by using the ability to fire ballistic and cruise missiles over long distances. They may be aimed at naval targets, as is the case of the Chinese strategy, but they can also be aimed at other mobile targets with equal precision (Corbett, 2013). Thus, a state becomes capable of counterbalancing a superpower's ability to project military power while maximising its ability to coerce its neighbours or influence the course of events at the regional level. This effect, as well as the concerns it elicits, is maximised when accompanied by the development of nuclear capability, as with North Korea and Iran. At its core, it is a struggle for territory where the lack of occupation capacity is compensated by the enemy's ability to deny the domain and use of that space, be it in the air, on sea or on land. These strategies include aggressive measures to protect one's ballistic missiles against preemptive strikes. As the Cold War showed, when it comes to balancing defensive, coercion and influence capabilities, ballistic missiles are effective weapon systems.

[4] In his 2002 State of the Union Address, the President of the United States of America included North Korea, Iran and Iraq, and terrorist organizations supported by those states in the same group of international actors he dubbed the "Axis of Evil".

2. Ballistic Missiles

Ballistic missiles are missiles that follow a ballistic trajectory during the major portion of their flight profile. They differ from cruise missiles in that they are not primarily governed by the laws of aerodynamics but by the laws of ballistics. While ballistic missiles undergo an initial thrust, after which they are affected by the force of gravity, making them follow a ballistic trajectory, and can spend part of their flight path at near-orbit altitudes or even in space, cruise missiles remain in the atmosphere on their path to the target, usually along non-linear routes, similar to manned or unmanned aircraft, at approximately constant speed. Thus, ballistic missile routes can be more easily predicted than those of their cruise counterparts. The latter may also include deception measures to counter air defences and avoid detection, while ballistic missile launches, due to their characteristics, are easily detected by space-based systems and intercepting them requires dedicated systems.

Their trajectories and guidance systems make ballistic missiles less suited to conventional precision attacks than their cruise counterparts or manned aircraft, but particularly suited to deliver weapons of mass destruction. Although they also possess this unconventional warhead delivery capability, cruise missiles and aircraft, manned and unmanned, effectively serve a dual role, and are therefore highly unlikely to be removed from modern arsenals. This has been shown in the recent proliferation in number and diversity of unmanned aerial systems of different sizes and capabilities.

Ballistic missiles can be classified according to several criteria (Figure 1), such as type of propellant, warhead, accuracy, or more commonly, range. Although the exact figures for the different categories are not consensual, Short Range Ballistic Missiles are often classified as those with ranges up to 1000 km, Medium Range Ballistic Missiles have ranges from 1000 km up to 3000 km, Intermediate Range Ballistic Missiles, from 3000 km up to 5500 km, Intercontinental Ballistic Missiles have ranges over 5500 km, and Submarine Launched Ballistic Missiles include all ranges (Koft, 2012).

With regard to their payload, ballistic missiles may have the capacity to deliver single or multiple warheads with nuclear weapons, conventional high explosives, or chemical and biological weapons, in the latter case with limitations as to their effectiveness due to the temperatures generated during the missile flight. As for the type of propellant used in the missile engines, it differs essentially in the thrust produced, liquid propellant being the most advantageous in that aspect, and in the caution that must be taken with handling and storage, and thus its suitability for military purposes, solid propellants offering the most advantages in this case. In order to increase their range, ballistic missiles are composed of several stages or sections, which are released during their flight towards the target to reduce their weight (Fought, n.d.).

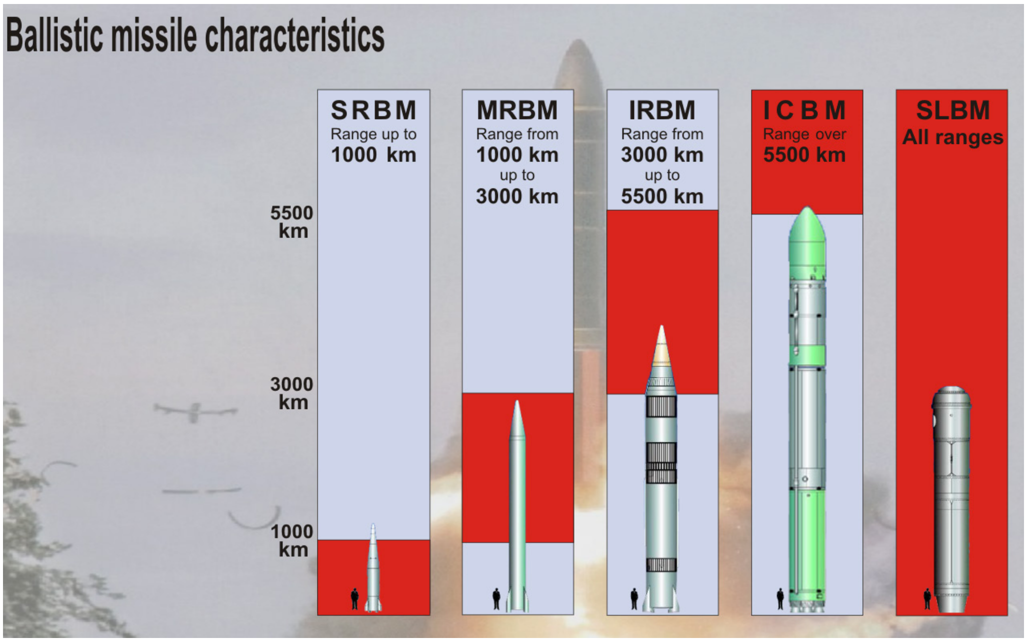

Figure 1 – Ballistic missile classification

Source: (Koft, 2012)

A typical flight profile of a ballistic missile comprises three distinct phases. In the first phase, called Boost Phase, the motor or motors convey the necessary thrust to push the missile into a ballistic trajectory. During this phase the missile travels at relatively low speed and the exhaust cloud is very noticeable. Furthermore, the infrared signature resulting from the engine temperatures can be easily detected by infrared sensors. During the next phase, the Midcourse Phase[5], the booster burns out, the missile separates the final module from the remaining sections and all elements acquire a ballistic trajectory. This intermediate phase takes place in space or near-space. The last phase, called Terminal Phase, begins when gravity drives the final module into atmospheric reentry and down towards the target, which is why this module, which can be multiple and contain submunitions, is also called Reentry Vehicle. In this final stage of its trajectory, the original missile retains only its military payload, that is, the main warhead, explosive or otherwise, the guidance system, which is usually inertial, and decoy and countermeasure devices such as electromagnetic jammers to elude enemy defences (Idem).

[5] Some authors also mention an Ascent Phase that begins when the missile's powered flight ends and ends immediately prior to the apogee, followed then by the Midcourse Phase.

3. Ballistic Missile Defence

Having analysed how the threat emerged and how it operates, it is now necessary to consider how to counter it. The US approach to the threat posed by the use of ballistic missiles is based on five dimensions: dissuasion, deterrence, offensive operations (or conventional counter force), active defence and passive defence (Burke, 2012).

In its narrowest sense, dissuasion or non-proliferation focuses on measures and incentives designed to discourage the development of a particular capability or to compel states to avoid behaviours that are in some way contrary to a desired outcome. Ultimately, this course of action can consist of implementing restrictions or imposing limitations on an opponent's capabilities. Furthermore, persuasion can be positive - when measures or resources that are in some way advantageous to the adversary are used-, or negative - when measures are taken to restrict the use of resources designed to prevent the achievement of the interests at stake.

At the other end of the spectrum from isolated actions by states, international arms control or non-proliferation treaties such as the Missile Technology Control Regime[6] garner broad international support, although this is not always relevant because adherence to these treaties is voluntary and the ability to enforce them is limited.

When deterrence relies on intimidation, the use of force as a last resort is implied. Much like the previous course of action, it aims to modify the behaviour of adversaries and can be used when the opponent has already acquired hostile capabilities in order to prevent them from being used. Based on an opponents' perception of their coercer, these courses of action require capabilities, credibility, and communication consistent with the end goal. These two courses of action are aimed primarily at eliminating the threat and, at a later stage, at preventing missile launches.

In a different phase, the aim of offensive operations is to prevent missile launches by opponents who already have that capability, or at the very least to prevent a second launch from occurring. Employing conventional forces, usually precision air strikes carried out by stealth fighters or cruise missiles, but also special operations forces, this is the most extreme course of action aimed at limiting the threat posed by ballistic missiles. This is due to the difficulty in obtaining accurate and detailed information for planning the attacks, whose past effectiveness has yet to be proved. Furthermore, and most importantly, it poses a dilemma to the attacker: the possible consequences of failure to destroy the enemy's capabilities could trigger an immediate attack by the same weapons that one wished to destroy, leading to the escalation of the conflict. These operations can have a punitive nature and their implementation is strongly associated with the credibility required for effective deterrence, therefore they must remain on the list of options that can be adopted by policy makers. Much like the second course of action, this option aims to prevent missile launches by entities that already have that capability.

[6] Established in 1987.

Active defence systems are reactive in nature since they respond to a missile launch. These anti-ballistic missile defence systems have a complex architecture, not least because no known system can protect an area against all known threats, whatever their number, and will be discussed in more detail further on in this paper. Ultimately, the aim of these systems is to prevent the missile from hitting its target.

Finally, passive defence aims to mitigate the effects of a ballistic missile impact on friendly territory, on its population, or on its military forces. Thus, the use of prediction tools to assess impact points, degree of destruction, and the consequences of non-interception or of a failed attempt to intercept is of vital importance. Early warning is equally vital, as it boosts the ability of civil authorities to both warn the population and mitigate post-attack damage. The aim of this dimension of anti-missile defence is to achieve an ideal state of no consequences.

Thus, the four effects to be obtained by implementing each dimension, or functional area, of anti-missile defence are: no threat, no launch, no impact and no consequences. Although it is a key element of deterrence, most military activity in this area consists of offensive operations, active defence and passive defence, supported by a robust battle management, command and control, communications, and intelligence collection, processing and dissemination structure.

4. Architecture of a (layered) Integrated Ballistic Missile Defence System

A typical ballistic missile defence system consists of a triad of systems. In addition to the Command and Control, Communications, Computers and Intelligence (C^4I) structure, this system also includes a set of sensors and one or more types of interceptor missiles.

NATO's centralised Command and Control of air defence and ballistic missile operations is carried out from the Head Quarters Allied Air Command in Ramstein, Germany. The Ballistic Missile Defence Operations Cell was created at the Operations Centre to reinforce C^4I capabilities. The goal is that the entire air operations structure, NATINADMS[7], will be working from the same image of the air environment for both air and missile defence. Thus, networking all the elements of the sensor systems is crucial. In the future, data-sharing capability at distances beyond the line of sight should be acquired by extending the traditional capabilities of the Link 16 network[8], or Joint Range Extension Application Protocol[9] (Ploeger, 2012).

The most suitable systems for early detection of ballistic missile attacks are satellites equipped with infrared sensors[10], since missiles emit a large thermal signature during the launch and initial acceleration phases. High-definition radars (Figure 2) that can be

[7] NATO Integrated Air and Missile Defence System.

[8] Link 16 is a secure data exchange system in which all components must be in one another's line of sight, and as such it has limitations when some components of the same network are geographically apart.

[9] Joint Range Protocol to Extend the Range of data links.

[10] Space Based Infra-Red System – SBIRS.

deployed and positioned in response to a threat are also used for detection, classification, identification, tracking, and impact point estimation (MDA, 2014). Some sensors are space-based, but they can also be found on land and sea bases or aboard aircraft. The interceptor weapon system will also be equipped with its own sensors, both for guidance and to allow it to detonate its charge when in close proximity to the intended target.

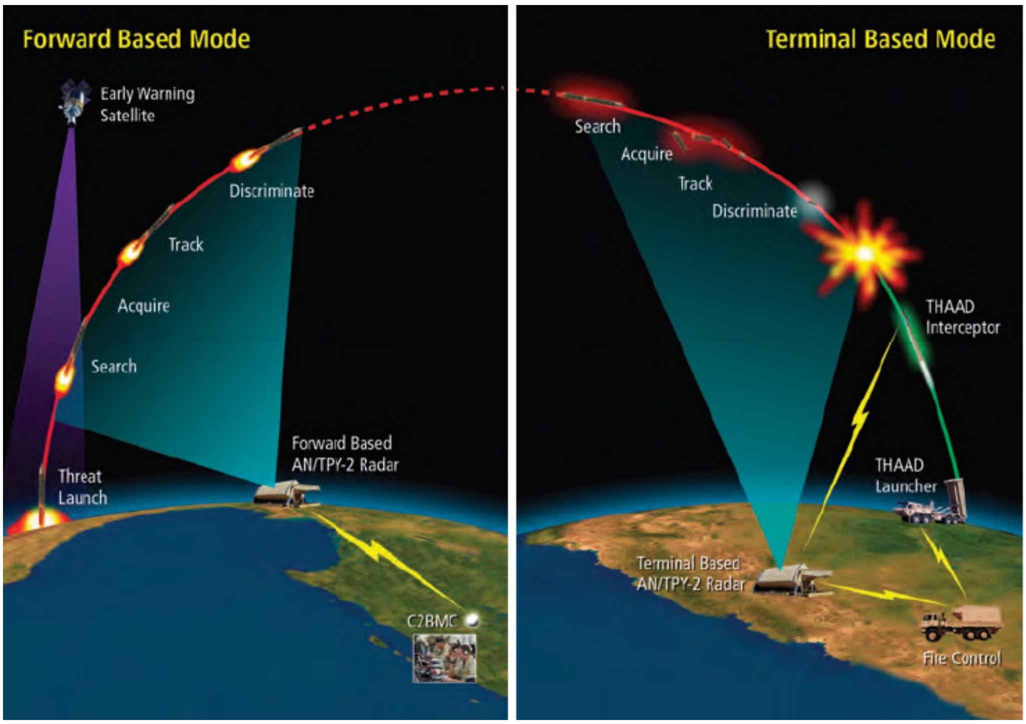

Figure 2 - Use of An/TPY-2 radar

Source: (Pakistan Defence, 2015).

The announcement by the US Secretary of Defence in March 2013, concerning the installation of a second TPY-2 radar in Japan following threats by North Korea, is an example of how this type of radar can be used (Pereira, 2013). Sharing and integrating the intelligence collected by the various sensors will increase the likelihood of successful interceptions across a wider area.

The different types of interceptors have distinct purposes and employment concepts, depending on which ballistic missile trajectory phase they are meant to interrupt. An interception will be all the more effective the earlier it occurs. In addition to the advantage of allowing new attempts at interception, an early interception effort minimises the consequences of intercepting over friendly or third party territory, especially in the case of failed interceptions or of debris fallout. Ideally, all interceptions would take place during the boost phase; however, such interceptions have proved difficult either because of the short response time required or because it would be necessary to position the sensors and the interceptors in geographical proximity to the potential threat. Thus, the types of interceptor are usually distributed according to a layered defence. For NATO, this atmospheric stratification is divided into three altitude layers (Figure 3): lower layer, upper layer endoatmospheric, and upper layer exoatmospheric.

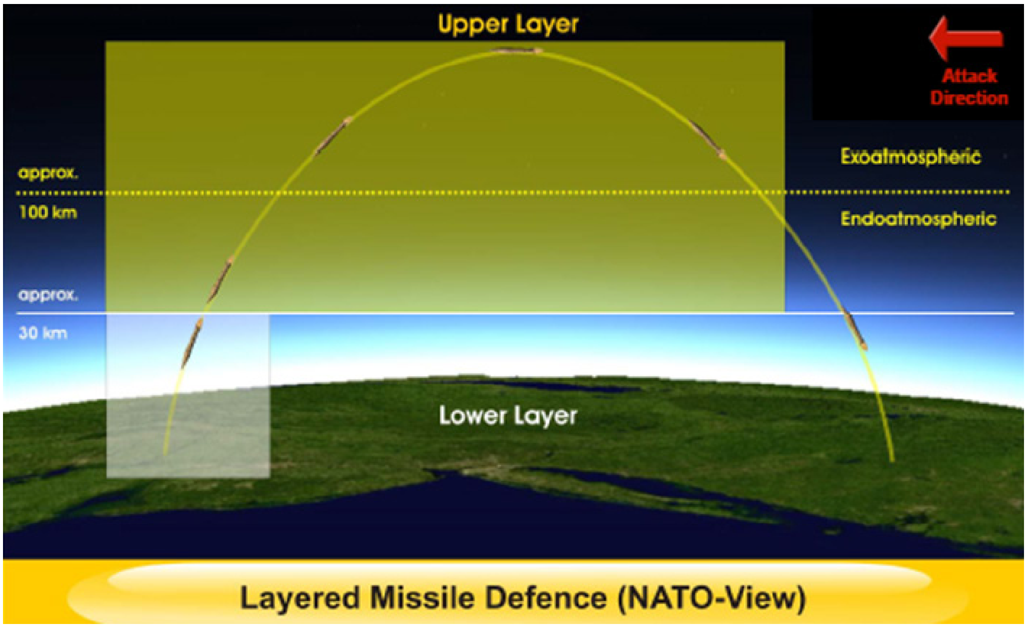

Figure 3 - Layered Anti-missile Defence

Source: (SAF, 2012).

In this configuration, a given two-dimensional area protected by one of these systems is associated with a three-dimensional battle space.

Interceptors devised for the system's lower layer protect a given site or piece of equipment, that is, they provide site protection. These systems are designed to intercept ballistic missiles at their terminal phase, are installed near the sites or equipment to be protected, and have engagement envelopes with altitude and range up to 30 km and 40 km, respectively. The US Patriot Advanced Capability-2 (PAC-2), the European-made Aster 30, with high explosive warheads and proximity fuse, and the more recent Patriot Advanced Capability-3 (PAC -3), with hit-to-kill warhead[11] and improved missile guidance systems through a dedicated radar, are examples of this type of interceptor (SAF, 2012).

[11] Hit-to-kill technology relies on the destruction caused by the collision between an animated object infused with high kinetic energy and its intended target, rather than on using explosives to inflict the desired degree of destruction.

The upper endoatmospheric layer or, more simply, the intermediate defence layer is designed to provide area defence and is based on interceptors that can operate at altitudes from 30 km to 100 km and across 300 km ranges. Due to these capabilities, these interceptors are used to intercept short- and medium-range missiles at the terminal phase of their trajectory. The North American and Israeli Arrow missile, equipped with explosive warhead, and the US system Terminal High Altitude Area Defense (THAAD) with hit-to-kill technology are typical upper atmospheric layer interception systems (Idem).

Finally, the upper exoatmospheric layer provides a broader area of defence. The interceptors used in this defence layer can be used for interceptions at altitudes from 100 km to 400 km and across ranges of more than 400 km. These systems typically target intermediate range ballistic missiles and intercontinental ballistic missiles, and therefore allow the establishment of an anti-missile defence in depth. Standard SM 3, Block I and II missiles integrated in the Aegis combat system, both ground-based and ship-based, are the most recent systems developed for this type of interception (Idem).

Figure 4 depicts the envelope of a layered missile defence system and presents, in addition to the systems mentioned above, the Ground Based Interceptor - Exoatmospheric Kill Vehicle (GBI EKV).

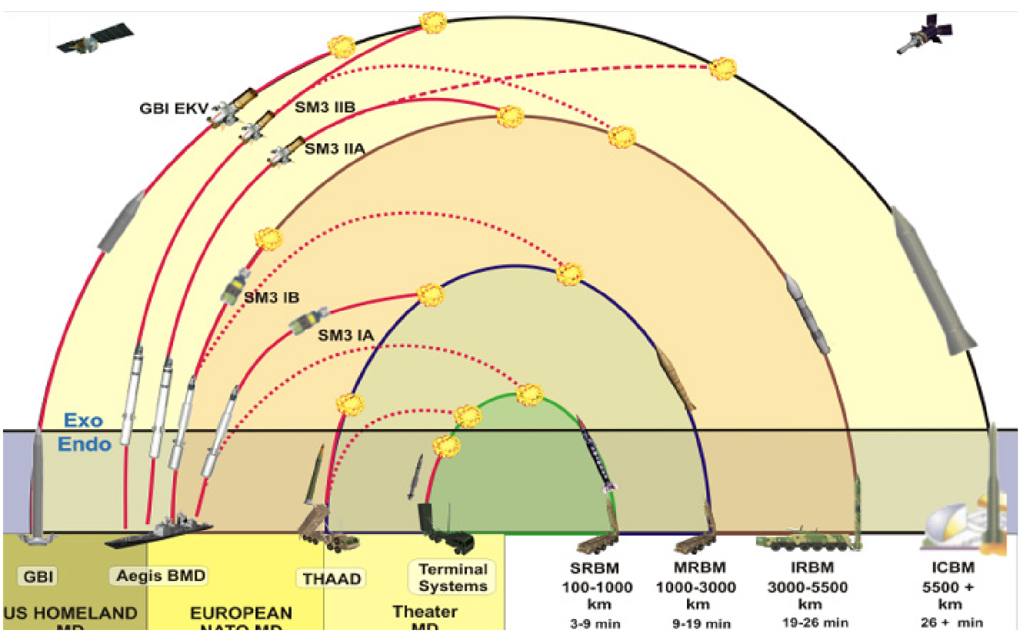

Figure 4 - NATO Layered Anti-missile Defence

Source: (SAF, 2012).

An example of a clearly tactical employment system - a mid-sized launcher/city - that provides specific protection against mortars, artillery and rockets, as well as short-range air defence (Rafael, n.d.), is the widely publicised success of the Israeli Iron Dome system in intercepting rockets launched from the Gaza Strip into Israel. Although the level of success achieved can be questioned, the system has clearly proved its deployability and ability to respond promptly to irregular threats. However, the price of one battery, which can come up to $50 million, combined with the price per round, $50,000 to $80,000 (*Missile Threat*, 2013a), puts this system at a disadvantage in comparison to a potential attacker, for whom the price of artillery or rocket ammunition is incomparably lower.

Furthermore, no ballistic missile defence system would be complete without a set of procedures and solutions to minimise the consequences of a missile impact on its intended target. In the effects to mitigate are include not only those that result from enemy missiles successfully hitting their targets, but also the effects of both successful and failed interceptions. Thus, the ability to receive and disseminate early warning is vital, as is close coordination with each country's civil protection structures.

5. New Technologies

Ballistic missile defence architectures involve extensive assets and cutting-edge technology. Furthermore, the costs of defence are much higher than those of offensive means. In the current anti-missile defence context, $13-15 million interceptors are used to intercept missiles worth $1 million. Due to the costs and resources involved, there is the need to add or create a new air-based defence layer with interception capability at the different phases of the missile trajectory. Cheaper weapons, such as lasers, are a necessity (SAF, 2012). The Airborne Laser (ABL) system[12], a North American programme spearheaded by Boeing worth $ 1.4 billion, was one such system that has since been discontinued. Equipped with a chemical laser, it would have had limited autonomy and required installing heavy equipment aboard a Boeing 747-400EF. In addition to being designed to destroy missiles in flight during the boost phase, it could detect and follow their route and transmit the intelligence collected to other interceptor systems (Boeing, 1999). Although it was discontinued in 2012, the programme to develop this system boosted research for lighter and more powerful systems capable of integrating other weapons systems with greater survivability, especially for employment immediately after the missile launch. Successful tests using lasers mounted aboard ships to target unmanned drones and fast boats (Osborn, 2013) suggest that the field offers a wide range of possibilities. Similarly, the development by the US Navy of an electromagnetic cannon with non- explosive projectiles that can reach exit speeds of over 8,000 km/h (Vlahos, 2012) also shows promise in this respect.

6. Space

Defence against ballistic missiles depends to a large extent on space capabilities. Not only is space a part of this defence component's three-dimensional battlefield, since it

[12] Laser mounted aboard a Boeing 747-400.

is traversed by attacking missiles, and therefore there is the possibility of interceptions occurring, defence and surveillance systems operating in or through space confer unique capabilities in this respect through early warning, positioning, navigation and temporal synchronisation of communications and the weaponization of space, which, although limited by treaties, is considered inevitable by authors like Everett C. Dolman[13].

Early warning is vital to the effectiveness of Ballistic Missile Defence (BMD) systems[14]. In that respect, nothing beats the capabilities of space-based sensor systems. The ability to recognise, identify, track and anticipate behaviours by objects or events, especially thermal ones, through the characteristics that distinguish them from other phenomena or from similar targets, is a key advantage. On the other hand, although land or sea-based systems such as radars are more flexible in how they can be employed, especially if they are deployable, they also have limitations in the three-dimensional cover they provide, which can be exploited by opponents (Figure 5). Thus, these systems alone cannot guarantee the early warning required for the earliest possible interception attempt.

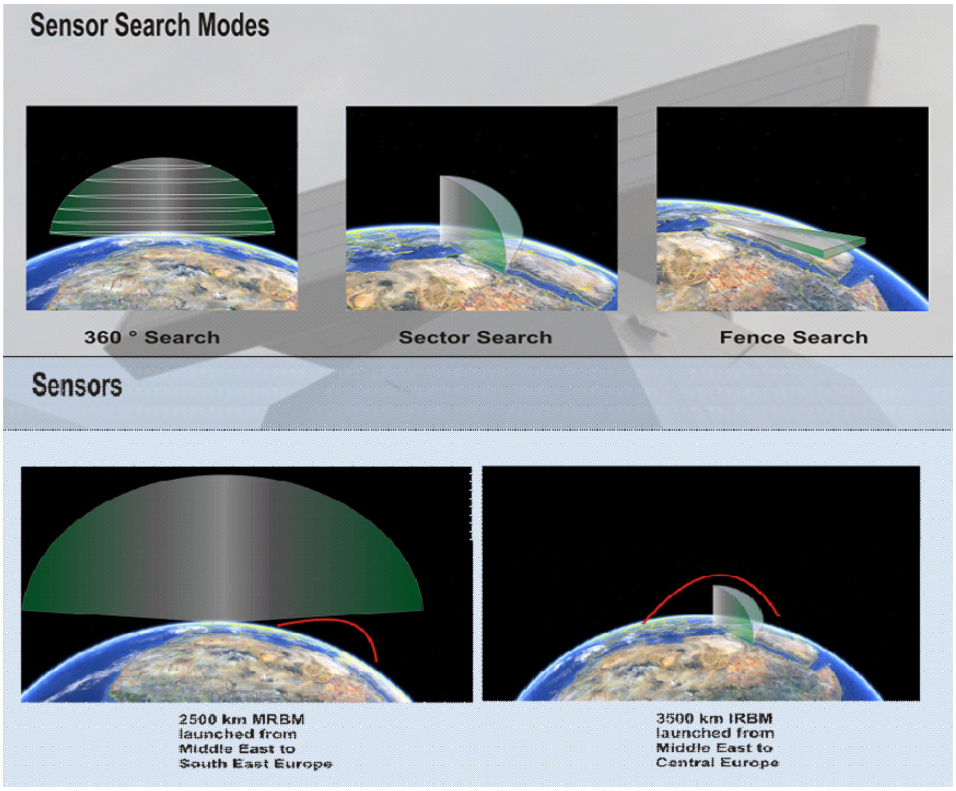

Figure 5 - Limitations of Radar coverage

Source: (SAF, 2012).

[13] See *Astropolitik: Classical Geopolitics in the Space Age*, Everett C. Dolman, 2002.

[14] General designation for the system architecture.

Positioning, navigation and timing capabilities are useful for tracking and controlling the interceptors as well as for integrating the data collected from all the sensor systems of a given BMD architecture.

Similarly, with regard to intelligence control and sharing, satellite communications have proved vital to bypass the line-of-sight limitations of surface systems. This capability not only allows information to be received continuously, be it from sensors in space or from land-based radars, but also to respond in a more flexible manner to a threat in flight.

Finally, while some authors argue that the weaponization of space has not yet occurred, others state that it has already happened[15], since some components of weapon systems are space-based and the area is already traversed by armed platforms, at least in parts of the lower orbital space and on a temporary basis. Space-based weaponry - as foreseen in the Brilliant Pebbles constellation[16] - has always raised concerns, especially from Russia, due to its threat to the balance of forces, which was based more on perception than on reality (*Missile Threat*, 2013b).

On the other hand, a BMD architecture based solely on space presents some obvious weaknesses. First of all, the cost of the systems precludes their acquisition by most NATO-allied countries. On the other hand, their vulnerability to anti-satellite weapons or nuclear explosions in space raises questions about their resilience.

In view of these limitations, other alternative systems are seen as complementary to space systems. The idea is to have space capabilities through near-space platforms or systems, using both manned and unmanned aircraft. Thus, NATO does not explicitly rule out the possibility that E-3A AWACS and UAS AGS[17].aircraft will be used in the future for early warning Of course, this solution also entails some obvious limitations: it is less permanent than satellites, with lower sensor coverage, requiring risk analysis and assessment due to the need to bring the orbits of these systems close to the threat's geographical origin. In addition to these surveillance systems, conventional forces and special operations forces can be employed to dissuade opponents or even to destroy their launching capabilities on the ground.

7. Interceptions management

When everything else fails, the success of anti-missile defences depends on their ability to prevent a missile from reaching its intended target. However, intercepting missiles in flight is not without its risks, and it is important to address some aspects that may influence decision making. Time quickly runs out from the moment a launch is detected until it is

[15] See Michael E. O'Hanlon, *Neither Star Wars nor Sanctuary: Constraining the Military Uses of Space*, for further on the first stance, and Everett Dolman, *Astropolitik*, for a more aggressive stance on space weaponization.

[16] Brilliant Pebbles was the name given to a constellation of 4,000 low orbit satellites designed to use tungsten projectiles to target missiles during the boost phase. Born in the early 1980s and christened by the Reagan administration in 1988, the project was cancelled by Bill Clinton in 1993.

[17] Unmanned Aerial System – Alliance Ground Surveillance

identified, tracked, its trajectory calculated, and a shooting solution is determined and an interceptor launched. Bearing in mind the above, it is paramount that an analysis of the outcomes for each option be conducted in advance.

Although there is no universally accepted definition, the term Consequences of Engagement (COE) refers to the outcomes or effects of a successful interception (COI, as well as to the effects of an unsuccessful interception attempt (CONI), which are not limited to the physical effects of the actions undertaken. In fact, given the possible scattering of the assets involved in a complete BMD system, it is necessary to reflect and consult with all objectively involved or geographically relevant states.

The granting of rights to base BMD systems will itself be an indication of a state's stance on a given threat. Involvement in an international missile defence architecture may even lead to regional imbalances and to the proliferation of more effective counter-defensive systems, and thus merits a reflection. However, in strictly military terms, the exploitation of BMD systems alone ensures greater flexibility of options and time saving while taking pressure off decision-making due to the increased protection they provide (Nin-Nun, 2013, p. 21). Similarly, actions involving follow-up or even attempts at interception should be considered carefully in light of their effects on regional geopolitics. An interception over third-state territory will certainly have foreign policy consequences. Furthermore, should any actions taken lead to an act of self-defence, its consequences will be rather different from those resulting from the interception of a missile on its way to an allied country.

COI often go beyond an already significant impact on relations between states. Objectively, the effectiveness of a BMD system is related to its ability to prevent enemy missiles from reaching their intended targets. What no system can do is prevent the debris created by an interception from hitting the ground. Predicting the behaviour and magnitude of the debris resulting from an interception is currently done based on experimental models that do not garner consensus regarding the planning factors they employ. If weather conditions at altitudes above 30 km altitudes are relevant for some, others believe that this is not significant due to the low air density at those altitudes. Equally important is the domain where the interception occurs: in interceptions in space, there is some possibility that smaller debris will not survive atmospheric re-entry, but when they do, determining the landing site is extremely difficult. Furthermore, as one can easily deduce, the size, shape and behaviour of the debris is affected by the angle of interception and the area of the missile that takes the impact.

Equally important is the need to assess the consequences of a failed interception, especially if it occurs over the territory of neighbouring countries. The damage caused by a failed interceptor that hits the ground can affect regional support for defence systems and place the burden of aggression on the side of the defender, rather than assigning it to the aggressor. Thus, the need to consider effects and consult with allies and neighbouring states can lead to the decision of not intercepting a missile during certain phases of its flight, opting instead for a later interception that poses less risk in terms of international relations between states. Also regarding the consequences of no interception, it is important to include those that result from the missile hitting its target and those that result from the kind of warhead it is carrying. Given the role of time constraints for decision making, including civil protection institutions and early warning to populations in the decision cycle is of vital importance. Evacuations of large population clusters will normally not be feasible, so initial damage mitigation will mainly involve seeking shelter and protection inside buildings or facilities, followed by capable assistance by civil protection capabilities (Levi, 2007).

8. European Phased Adaptive Approach

In 2010, in the closing declaration of the NATO Summit in Lisbon, the attending Heads of State announced the Alliance's decision to "develop a missile defence capability to protect all NATO European populations, territory and forces" (NATO, 2010). This declaration immediately raised new challenges, since NATO has expeditionary forces that often operate outside Alliance territory. At the same time, protecting entire allied populations and territories would not be a short-term task.

Later, at the 2012 Chicago summit, NATO reiterated its commitment to develop BMD capability. However, in an early indication of the strategic impact of developing and implementing these systems, the final summit declaration showed the Alliance's willingness to adapt its systems to lower threat situations should international efforts be successful (NATO, 2012).

The United States of America also acknowledge the proliferation of sophisticated technology and armament, not only among states, such as China and Iran, but also among non-state actors, as well as the need to expand protection against threats to its entire territory, its interests abroad and its allies (DOD, 2012, p. 4). Identifying the threat contributes significantly to the effectiveness of the systems to be developed and implemented, since without that knowledge it is not possible to predict the adversary's behaviour and the courses of action against which defence is required.

The European Phased Adaptive Approach is a US initiative to develop the Alliance's BMD capability in Europe that goes along with NATO's layered defence architecture - which was initially designed to protect NATO forces - to extend protection to the population and territory of allied countries.

While not explicitly devised to minimise Russia's strategic deterrence capabilities nor, according to NATO, directed against those capabilities, this North American and NATO vision for Europe's anti-ballistic missile defence takes upon itself the responsibility of defending NATO's European territory, disagreeing with that country on a joint sector defence in this respect (Rose, 2013).

The initial capabilities will undergo technological developments and will be expanded, providing protection against longer range missiles in the transition to a new phase that will culminate in the defence of the United States against intercontinental ballistic missiles launched from the Middle East into its territory.

Phase 1 of this initiative was completed in 2011 with the deployment of multi-role vessels with Aegis BMD capability to the eastern Mediterranean and with the deployment of an AN/TPY-2 radar to Turkey. With the Interim Operational Capability declaration at the Chicago summit, this radar was transferred to NATO control.

In combination with these systems, and as part of Phase 2, in 2014, Spain received at its Rota naval base the first of four North American vessels equipped with the Aegis system with standard SM-3 missiles. The flexibility offered by basing these missiles on mobile platforms cannot be ignored, be it aboard ships, which have virtually global reach, or mounted on land vehicles, which have more limited mobility but are nevertheless important to position the missiles according to a given threat. This second phase also included the implementation at the Deveselu Military Base in Romania of a land-based Aegis system - SPY-1D(V) radar and SM-3 Block IB North American interceptors- which went operational in May 2016 (USNI , 2016).

Phase 3 includes the implementation of a system similar to the one installed in Romania, this time based in Poland, equipped with SM-3 Block IIA interceptors, which is expected to be completed in 2018. At that time, together with other existing systems, it will ensure BMD coverage of the entire NATO territory and populations against medium-range ballistic missiles launched from the Middle East (Rose, 2014).

A fourth phase had been predicted at one point. Its main component would be the SM-3 IIB interceptor missile that would intercept intercontinental ballistic missiles launched from the Middle East into the US. Due to the difficulty in securing funding from Congress, the US abandoned this acquisition programme and opted for reinforcing by about 50% the number of GBI in its anti-missile defence base in Fort Greely, Alaska (Rose, 2013).

Conclusion

In face of this increase in BMD system capabilities, a corresponding strengthening of political responsibility by the governments of the nations involved and by NATO as a whole is to be expected. In addition to the usual guidance on policies and directives to be implemented, it is crucial that Rules of Engagement be established at the North Atlantic Council in order to expedite decision-making procedures for the use of interceptors.

It is widely accepted that, like other military capabilities, the threats faced by NATO that stem from the proliferation of ballistic missiles cannot materialise in all countries simultaneously, nor attack all the assets of one of those countries. Furthermore, it is also true that it is impossible to protect everything and everyone against a ballistic missile attack, especially if they are fired in a salvo to saturate BMD systems. It is also a known fact that some areas and assets of a country are more vital than others to ensure that country's sovereignty and survival. It will be up to each state to draw up a Critical Areas List and a Critical Asset List for protection. Given the nature of the decision on what to include in the list - as this is a risk management exercise that will have consequences at the domestic policy level - it must be made by the highest possible instances. The exclusion of national areas and assets from these lists does not mean the unprotected areas and infrastructures will be abandoned or are not as important, rather it is a consequence of the nature of the threat and of the costs and capabilities of protection systems: it is simply not possible to protect everything and everyone. Thus, the risks must be taken at the policy level, and the decision must be made to invest either on deterrence or on eliminating the aggressor's ability to conduct a second launch. As a consequence, there will be an increasing integration of early warning capabilities with civil protection agencies.

The scientific research conducted in a broad range of fields, the ongoing technological advances and the increasing integration of efforts by the various countries will surely lead to new ballistic missile defence capabilities. However, updating and modernising these powers' nuclear weapons systems, some of which are decades-old, and the constant changes in the global security environment will pose new challenges to those who wish to defend themselves.

The justification for investing in these defensive systems has been underpinned by the instability in the Middle East, and not even the nuclear deal with Iran appears to have toned down western concerns in this regard. This perspective on the problem is compounded by the behaviour of North Korea, with its many missile tests and frequent threats to western interests and to those of its allies, South Korea and Japan. And the US at least cannot ignore China's capabilities in this area and its claims to the status of undisputed power in its geographic area of influence, where territorial disputes and sovereignty are of particular importance. We are not only referring to Taiwan, but also to other disputes with Japan and with the Philippines, Indonesia, Malaysia and Vietnam.

No power whose greatest strategic deterrence capability is based on its nuclear or non-nuclear ballistic missile systems will welcome the installation of BMD systems near its borders. On the other hand, in light of the possibility of a Cold War 2.0, the first steps of which seem to have already been taken, considering the crisis in Crimea or the recent Russian involvement in Syria, these defence systems will become increasingly relevant, as they expand the range of military response options, and, as a consequence, their entry into service will elicit reactions from international stakeholders.

The economy will always play a key role in developing and acquiring new weapon systems. Small powers that are not able to acquire complex and costly systems by themselves can still play an important role in containing a threat. Collaboration in non-proliferation efforts by enhancing land and air, but especially maritime border controls, combined with control of illegal transfers of technology, can and should be ongoing. Permissions to base systems and to cross through territorial waters, like in the cases of Romania, Poland and Spain, provide important contributions, and the sharing of sensor signals, especially air defence radars, which will be merged into a single air picture, are also contributions that should not be downplayed.

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