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COUNTERING HYPERSONIC THREAT

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Hypersonic missiles represent the new class of threats, capable declaratively and in a way that has not been proven in a theater of operations, to annihilate air and anti-missile defences that exist at this time. The sum of the new threat's characteristics, high speed, increased maneuverability, and low flight altitude, get major concerns for air and missile defence, as effective detection and combat are reduced by compressing available time. Rethinking how to combat the new threats thus represents the main concern of military specialists in countries that want to complete their arsenals with new weapons.

Keywords: hypersonic speed; threat; countering hypersonic missiles; missile, hypersonic vehicle; anti-missile systems.

Introduction

The hypersonic threat[1] is no longer an element of novelty since the daily vocabulary of the military and the media is quite often improved with references describing this threat, tests with such missiles are frequent, and the conflict in Ukraine has already made known their use. Possessing hypersonic missiles is neither simple nor achieved in a short period of time. Countries that engaged in the such weaponsresearch and development were forced to identify substantial funds for this challenge, especially when the defence industries generally had limited technologies in the missiles.production

Hypersonic weapons may have been designed to exploit traditional air and missile defence system limitations. Their defining characteristics, sustained flight at hypersonic speed and maneuverability in- or -out- of the atmosphere, can compromise today's air defence principles by limiting reaction time.

However, the problem is that up to this point their features are stated and less demonstrated. In this way, hypersonic weapons add a new dimension to existing threats through their ability to rapidly engage key strategic level elements or infrastructure, their use in the early stages of a conflict resulting in potentially blocking or paralyzing planned operations. They could provide long-range, relatively short-time strike options against immediate, heavily defended, and/or time-sensitive threats or in case other forces are not available or preferred.

However, the simple idea of developing such weapons amplifies the concept of threat in a way that was no longer necessary. At the NATO level, threat is defined as a measure *of an attack likelihood or probability of being attempted against a particular target within a specified time frame*. As a rule, threats are considered deliberate and intentional acts carried out by individuals or organizations, generally with a hostile purpose (NATO Term 2022).

The new weapons systems development creates unknown challenges for stakeholders, both in their use or counteraction. Actually, the of great powers` desire is to update the already developed arsenals with the new threats, their quantity and performances being again challenging details. However, hypersonic missile programs are still in their infancy and must reach the maturity acquired by other weapon systems, be them used or not, over time. In other words, they must be able to identify both the skilled operating personnel resources and the ability to develop, produce, and test the above mentioned ones. For example, in the U.S., reasons for concern have been identified[2] regarding the

[1] *** N.A.: As a rule, the hypersonic threat is most often related to various hypersonic missile development programs. The debates in this field, specific to virtual space, have as their subject both the hypersonic missile or weapon in general, and the hypersonic vehicle. Thus, throughout the article the terms hypersonic missile, weapon or hypersonic vehicle will be used interchangeably.

[2] *** N.A.: These issues were detailed by Mark J. Lewis, Executive Director of the National Defence Industrial Association's Emerging Technologies Institute, and presented by John A. Tirpak in the article *Catching Up on Hypersonics*, published in the April 2021 issue of Air Force Magazine.

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development of hypersonic infrastructure, related to test facilities or locations, the actual propulsion testing or the availability of flight-test range (Tirpak 2021, 45). Another problem identified in the development of hypersonic weapons, again in the U.S., is given by the fact that they do not have clearly defined mission requirements (Sayler 2022), being somewhat developed as a result of technological progress and less as part of a strategy (Acton 2018).

At this point, the systems capable of using hypersonic technology are at a relative advantage since both space-based sensors designed to detect ballistic missiles and surface-based radars are unable to counter this threat.

What is a hypersonic missile?

Regarding the name of ballistic missiles and hypersonic missiles, there are opinions according to which *ballistic* or *hypersonic* does not define a type of missile or a type of propulsion and that, actually, *ballistic* describes a parabolic trajectory defined by gravity while *hypersonic* refers to a quality of supersonic flight (Karako and Dahlgren 2022, 7-8). Beyond this point of view, the literature presents hypersonic missiles as those aerial vehicles capable at a certain moment of the trajectory to fly at a speed of at least five times the speed of sound (over Mach 5)[3] and which have a maneuverability component higher than the ballistic missiles.

The approach to hypersonic missiles must be made through the speed, point of view because the aerodynamic phenomena around Mach 5 are different from those that occur at supersonic speeds or outside the atmosphere. Thus, hypersonic speed together with lower altitude and increased maneuverability provide a qualitative combination that makes it difficult to predict hypersonic missile trajectories, especially with surface-based sensors.

Various reports or articles in the field of hypersonic missiles present other weapons systems that are capable of such velocities, and in these cases long-range ballistic missiles are just one example. Under these conditions, military analysts appreciate that a lower altitudes with increased maneuverability and a hypersonic speed development inferior to the ballistic missiles[4] case, make hypersonic missiles both attractive and in high demand (Karako and Dahlgren 2022, 5). The presentation of the characteristics of hypersonic missiles, most of the time compared to ballistic or cruise missiles, led to the situation where they became the main threat in the case of possession but, above all, of use.

Based on the concerns main countries have to get such weapons, there are two main categories of hypersonic weapons (Sayler 2022, 2):

- Hypersonic glide vehicles/HGV that are launched aided by another air vehicle before gliding to a target;
- Hypersonic cruise missiles/HCS that are powered by high-speed engines, or ”scramjets”, after acquiring their target.

For example, Figure no. 1 shows a comparison between the ballistic and hypersonic missiles trajectories (Karako and Dahlgren 2022, 6).

Interest in the hypersonic threat

While the United States, Russia, and China are recognized as having the most advanced hypersonic weapons programs, a number of other countries, including Australia, India, France, Germany, South Korea, North Korea, and Japan[5], are interested in hypersonic weapons technology (Sayler 2022, 20).

Much of the attention given to the hypersonic threat focuses on the programs developed by Russia and China. According to online sources, the first hypersonic weapons equipped the Russian forces in December 2019, while some experts believe that, the first hypersonic weapons entered China’s service as early as 2020. According to the same open sources, the United States is not expected to

[3] *** N.A.: More details on the types and characteristics of hypersonic missiles can be found in the RAND Corporation study, *Hypersonic Missile Nonproliferation, Hindering the Spread of a New Class of Weapons*, Published by the RAND Corporation, Santa Monica, 2017 as well as in Tom Karako, Masao Dahlgren, *Complex Air Defence, Countering the Hypersonic Missile Threat*, A Report of the CSIS Missile Defence Project, CSIS, 2022.

[4] *** N.A.: The flight altitude is unusual for these missiles (between a few tens and 100 kilometers) in terms of the speed developed, according to the RAND Corporation study, Hypersonic Missile Nonproliferation, Hindering the Spread of a New Class of Weapons, Published by the RAND Corporation, Santa Monica, 2017.

[5] *** N.A.: A summary of these states’ concerns regarding hypersonic technology can be found in Kelley M. Sayler, *Hypersonic Weapons: Background and Issues for Congress*, Updated May 5, 2022, available at https://crsreports.congress.gov

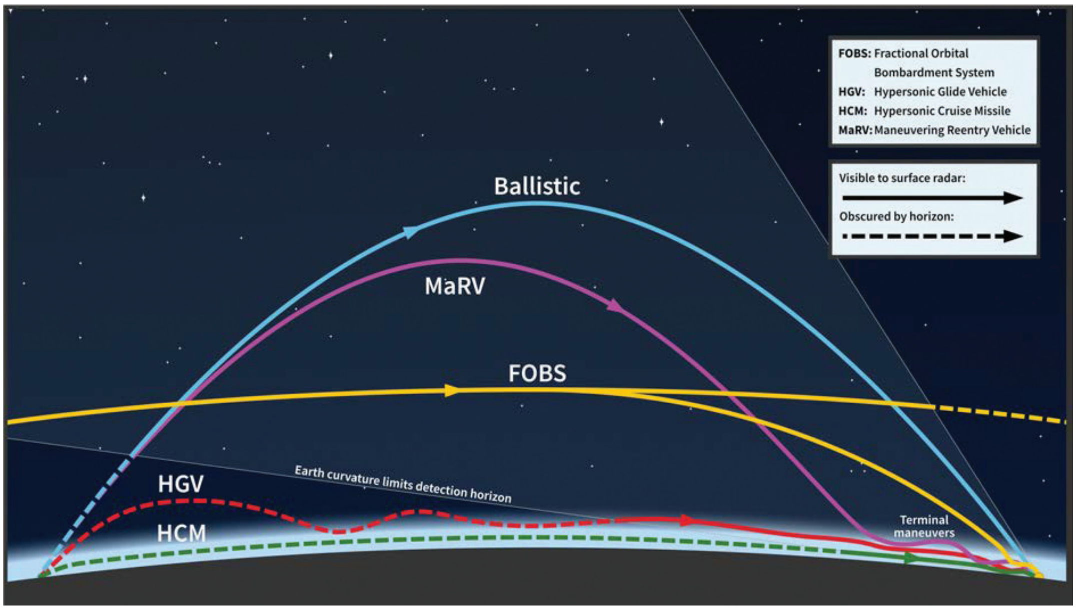

Figure 1 *Comparison between ballistic and hypersonic trajectory*

field hypersonic weapons before 2023 (Sayler and McCall 2022).

To provide a general idea, China, the United States and Russia's concerns in the field of hypersonic missiles are briefly presented below[6]:

China

- China's race to develop hypersonic weapons, as is the case with Russia, reflects its concern that the U.S. hypersonic weapons could allow them to carry out a pre-emptive strike on China's nuclear arsenal and supporting infrastructure (Sayler 2022, 16);

- In 2020, the PLARF[7] began its first operational hypersonic weapon system development called the DF-17, a medium-range ballistic missile equipped with a hypersonic glide vehicle/HGV (Annual Report to Congress 2021, VII). At the same time, it made steps towards scramjet engine development that can be used in the hypersonic cruise missiles development (Annual Report to Congress 2021, 144);

- Simultaneously with the DF-17, it tested the DF-41 intercontinental ballistic missile, which could be modified to carry an HGV, conventionally or with a nuclear payload, which would significantly increase the Chinese forces' nuclear threat (Sayler 2022, 17).

United States

- Congress designated MDA[8] as early as 2016 as being responsible for the of hypersonic defence concepts' development and implementation. Thus, the MDA established a *Hypersonic Defence Program* in 2017, and in 2018 requested 21 white papers to explore hypersonic missile defence options, including interceptor missiles, hypervelocity projectiles, laser guns, and electronic attack systems (Sayler 2022, 11);

- The first MDA funding program was presented in the fiscal year 2018. In a short term, MDA aimed to develop a limited terminal defence, proposing also a longer-range defence for the future, to detect and counter hypersonic weapons in their glide phase of flight. At the same time, MDA will improve the existing surface-based radars to ensure hypersonic engagement support, in time developing space-based radar prototypes capable of tracking a hypersonic threat throughout flight (Karako and Dahlgren 2022, 18);

- In January 2021, MDA awarded contracts to L3Harris Technologies and Northrop Grumman to develop *Hypersonic and Ballistic Tracking Space Sensors/ HBTSS*, as well as contracts for a Glide

[6] *** N.A.: The measures adopted and presented in this article are not exclusive and only have the role of drafting in the interest shown by the three states in the field of hypersonic weapons. Details regarding the allocated funds, approximate completion dates and technical characteristics, declared for open sources, can be consulted in Kelley M. Sayler, *Hypersonic Weapons: Background and Issues for Congress*, Updated May 5, 2022, available at https://crsreports .congress.gov

[7] *** People's Liberation Army Rocket Force.

[8] *** Missile Defence Agency.

Phase Interceptor/ GPI.The former will be surface-based radars integrated, to track hypersonic missiles anywhere on the globe, A two-prototype satellite HBTSS demonstration is planned by 2023 (Mahshie 2022);

- At the United States Armed Forces' branches level, concerns for the hypersonic domain are various. Thus, the Air Force has requested funds for the *Air-Launched Rapid Response Weapon / ARRW* system research and development, one of the first U.S. hypersonic weapons scheduled to enter service in fiscal year 2023, and for the *Hypersonic Attack Cruise Missile/HACM* program (Bugos 2022). While, attention is directed to the two hypersonic weapons programs running at the Navy level, the *Conventional Prompt Strike/ CPS* system and the H*ypersonic Air-Launched Offensive Anti-Surface Warfare/HALO* system, scheduled to be equipped in 2028 (Bugos 2022), the Army is currently developing the *Long-Range Hypersonic Weapon/ LRHW* program, scheduled to be equipped in fiscal year 2023 (Bugos 2022);

- In terms of infrastructure, the U.S. had 48 critical hypersonic test facilities and mobile assets in 2014, needed for the defence systems development with hypersonic technologies maturation by 2030 (Sayler 2022, 12).

Russia

- Although Russia has conducted research on hypersonic weapons technology since the 1980s, its efforts were accelerated in response to both the U.S. missile defence systems deployment in United States and Europe and the U.S. withdrawal from the ABM[9] Treaty in 2001 (Sayler 2022, 14);

- Russia has two hypersonic missile programs under development: the Avangard, which is a hypersonic glide vehicle/HGV, launched with an intercontinental ballistic missile which gives it a declaratively unlimited effective range, and the Zircon 3M22, a ship-launched hypersonic cruise missile, capable of striking both ground and naval targets (Wilson 2021, 2) (Sayler 2022, 14). At the same time, it is assumed that the Kinzhal missile, a maneuvering air-launched ballistic missile, included by military analysts in the category of hypersonic threats due to its stated characteristics (Sayler 2022, 14-15);

- The Kinzhal missile was used in the Ukraine conflict on March 19 and 20, 2022, against warehouses in western Ukraine, the first use of a hypersonic weapon in a conflict (Woolf 2022, 3). Even though the missile was used against ammunition and fuel depots, which are not targets for such weapons and do not have a solid air defence, the Russians' objective was achieved: to demonstrate that the missile is operational and that the first use was a success. However, assessments of the usage effectiveness for the first hypersonic missiles in the Ukraine conflict are not entirely positive. General Mark A. Milley, Chairman of the Joint Chiefs of Staff, stated: "*Other than the speed of the weapon, in terms of its effect on a given target, we are not seeing really significant or game-changing effects to date with the delivery of the small number of hypersonics that the Russians have used*" (Bugos 2022).

Defence against hypersonic missiles

The U.S. understanding is that the safe way to prevent a war is by being prepared to win one (Department of Defence 2018, 5). Thereby, preventing a missile-dominated conflict can consist of a comprehensive approach to identifying and training forces to deter their use and counteract them.

The possession of hypersonic missiles is a growing trend among nations that want to complete their missile arsenal, and purely ballistic and somewhat predictable trajectories are being replaced by ones in which the flight time is shorter and, much more importantly, less predictable. By understanding the environment in which it operates and the characteristics necessary to evolve in that environment one can anticipate the defence needs future development. Budgets allocated to the hypersonic threats development force their usage against important targets in order to justify their use. Air bases, naval forces groups, air and missile defence, command and control or force projection elements etc., represent possible targets whose elimination can substantially limit the way military actions are conducted.

Generally, the threat, similar to an action, is anticipated to create some effect aimed at obtaining a strategic, operational, or tactical advantage over an adversary, At the opposite pole, the measures adopted for defence are directed against a distinct

[9] *** Anti-Ballistic Missile Treaty.

threat or a spectrum of threats. If until now, deterrent or combat measures have been identified, for the threats generated by ballistic or cruise missiles, or unmanned aerial systems/UAS, the hypersonic threat represents an area that is too little covered, the measures against it being currently subject to identification and implementation.

Since the hypersonic threat exists, adequate and acceptable countering means must be identified. Great powers' interest in this area has demonstrated that a defence against hypersonic missiles is militarily necessary and technologically possible. The resources allocated over the last few years have emphasized that there are, and will be, funds for various programs to combat the hypersonic threat. Reality has shown that this is difficult to achieve, as the approaches are much more complex than those used in ballistic or cruise missile defence. Hypersonic defence will not be easy, yet not impossible, nor should we assume that hypersonic missiles are unstoppable.

The hypersonic missile specific features are actually a sum of ballistic and cruise missile characteristics, since it combines the ballistic missiles speed and range with the cruise missiles flight profile and maneuverability. If systems have been developed for countering ballistic and cruise missiles, the sum of a hypersonic missile characteristics requires new vision, concepts, and systems.

A question that arises is also related to the type of defence. Can we consider a pure defence against hypersonic missiles, or should it be investigated in the broader spectrum of air and missile defence, taking into account the missile's flying environment? Experience and investment in air and missile defence can be the starting point for hypersonic missile defence, which must evolve from the current air defence framework, rather than being developed independently from scratch.

The challenges of hypersonic missile defence are multiple and relate to warning, interception type, interceptors type and quantity, timing, command and control, deployed resources, etc. In the the U.S. level field of command, control and communications, the MDA approach has been to develop and adapt the existing Command, Control, Battle Management and Communications/ C2BMC system to the new challenges and requirements, instead of developing a new system (Karako and Dahlgren 2022, 27). Viable solutions can also be provided by artificial intelligence use, which can optimize the use of sensors and resources for future defence architectures (Karako and Dahlgren 2022, 30). It should not be forgotten that ballistic missile defence has in turn generated the same type of challenges, which in time have been overcome with research and testing generous investments.

The effectiveness of air and missile defence systems is determined by existing sensors and interceptors performance. Because the threat will always be ahead of countermeasures, it is highly unlikely that there will be systems available at that time to combat threats from the full range heights and speeds. Particularly for the hypersonic threat, it is possible that some systems radars may ensure their timely discovery, and others', interceptors of their combat. But again, it will be a matter of time for integration, joint operation, testing, delegation of authority, command and control relationships, etc. The common point between ballistic and hypersonic defences is that you cannot defend everything, just as you cannot combat all threats. Under these conditions, the problem of prioritizing the objectives or infrastructure to defend returns[10].

The starting point in countering hypersonic missiles can be the *point defence systems* that ensure small targets or areas' missile defence. The PATRIOT and THAAD systems are the first systems in this regard, suported by the fact that speed itself is not an insurmountable barrier for defence against hypersonic missiles.

The most advanced missile defence system in the field is currently the Patriot Advanced Capability (PAC)-3 system, whose missile can reach hypersonic speeds to hit its target. Hypersonic experts believe that current missile defence capabilities could protect high-value targets against hypersonic threats if they are placed in the right location (Mahshie 2022). The Patriot and THAD systems can be adapted in a way to provide defence against hypersonic missiles, on the terminal phase of the missile's trajectory, the obvious disadvantage being the size of the defended space (Acton 2018). If the *point defence* may appear approachable,

[10] *** N.A.: In the study *The Hypersonic Missile Debate*, Robert S. Wilson presents a well-researched point of view on the hypersonic missile debates, in which elements regarding the prioritization of defence against them are also presented. See Robert S. Wilson, *The Hypersonic Missile Debate*, Center for Space Policy and Strategy, 2021.

defending theaters of operations, countries or continents is already challenging.

In the current security architecture, the Patriot Advanced Capability (PAC)-3 system is seen as a solution to combat hypersonic missiles in the terminal phase of flight when they are quite maneuverable. Current air defence and missile interceptors, designed for slower or more predictable targets, do not have the kinematic performance to favorably intercept a terminal-phase hypersonic missile.

More favorable options are aimed at employing hypersonic missiles in the gliding flight phase where they are less likely to consume energy for evasive maneuvers. Thus, a long-range interceptor that is warned by a space radar offers a much larger battle space and also increased early warning in compliance with the *Shoot-Look-Shoot* doctrinal principle. In this way, the countering missiles challenge in the flight final phase is avoided, but it also influences the missile flight (adjacent trajectories, successive maneuvers) in the sense of performance loss (Karako and Dahlgren 2022, 24-25). MDA Director, Vice Admiral John Hill, stated that: *”We have a program that we are working toward … that takes us further back into that trajectory for a layered defence against hypersonic [threats], and that would be in the glide phase”* (Mahshie 2022).

The characteristics of hypersonic missiles that have created this impossibility of flight interfering myth, also constitute opportunities for those who develop strategies to counteract them. According to hypersonic flight researchers and specialists, organizing the defence against the hypersonic threat must take into account several elements:

- Missiles are not invisible, their flight at very high speed and at an altitude of up to 100 km, creates a thermal footprint that can be detected by early warning satellites;

- The hypersonic flight normal physical phenomena over longer periods of time provide vulnerabilities that should be taken into account when designing hypersonic missile defences (Karako and Dahlgren 2022, 10). The challenges inherent in hypersonic flights can provide interesting possibilities for defence against the hypersonic threat, making it more approachable, but not easy;

- Detection remains central to achieving a an infrastructure, defence capability against a hypersonic threat. Because the current surface-based radars are limited by the horizon and the curvature of the earth, existing capabilities can only provide the missiles counteraction in the flight terminal phase. In this case, the missiles speed ensures very little time available to identify the optimal combat solution, communicate the necessary dispositions and, last but not least, the combat itself. The current radars and interceptors vulnerabilities in the fight against hypersonic missiles can be limited by masking, increasing the number of capabilities or deploying them in depth.

Prolonged flight through the atmosphere can generate unpredicted or unidentified failure modes while the ability to maneuver will have an impact on the autonomy and power consumption. A hypersonic missile consumes energy while maneuvering, which can be exploited by providing a layered defence that requires frequent maneuvers[11]. Also, during hypersonic flight, missiles can be affected by impact with objects, no matter how small, by disturbances or changes in their structure or in the surrounding airflow (Karako and Dahlgren 2022, 14). Every maneuver executed in the air has a cost, and air and missile defence forces must take advantage of this by deploying to locations that force the adversary to frequently use the maneuver or an undesirable flight profile. In this way, the time required for warning and combat will be increased, the performance of the threat will be reduced and all these results will generate some uncertainty regarding the hypersonic weapon system.

There is a possibility that influencing the evolution conditions of a hypersonic missile will not allow the desired performance to be achieved. If we consider that the flights in the conditions specified for a hypersonic missile often require exotic materials and an extremely integrated design (Karako and Dahlgren 2022, 11), a question arises related to how many such systems can be developed. It is a premise that is currently favorable for the military that are thinking about defence against such missiles. However, quantity should

[11] *** N.A.: Some suggestive calculations regarding the influence of maneuver on flight characteristics are presented in Abraham Mahshie, *Hypersonics Defence, How hypersonic weapons maneuver and what to do about it*, available at https://www.airforcemag.com/article/hypersonics- defence/, accessed on 22.06.2022.

not be put before effectiveness, still to be proven. Even if hypersonic weapons will be designed that are not affected by varied and harsh environmental conditions, new technologies (particle and directed energy) may force the development of hypersonic systems that are more traditionalist in terms of construction, heavier or with lower performance (Karako and Dahlgren 2022, 34-35). All these contribute to achieving the missile defence objectives.

If detection, hypersonic missiles identification and tracking are possible, the next step is to combat them. This can be done under an active defence cover, as kinetic interceptors or blast-fragmentation interceptors. The alternative is future technologies, with varying levels of maturity, such as lasers, high-power microwave technologies or particle clouds designed to disrupt hypersonic flight (Shaikh 2021). Some analysts have suggested that surface-based and space-based sensors, arranged in a layered structure, integrated with tracking and fire control systems to direct high-performance interceptors or directed energy weapons could theoretically represent viable defence options in the hypersonic weapons future war (Sayler 2022, 3).

Active defence alone may not be able to cope with a hypersonic missile attack, to which the existing ballistic and cruise missiles can be added. In this case, passive defence is also necessary to be considered and an increased role in the wider context of counteracting the hypersonic threat shoulg be granted.

Early warning, camouflage, concealment, deception, and dispersion are just some of the passive defence forms that can be used in this context and that can deter the use of hypersonic missiles. The actions of decentralizing command and control, prioritizing the objectives to be defended, the existence or establishment of reserve command points to take over the attributions of the basic ones in the shortest possible time, the improvement and application of tactics, techniques and procedures that make the most of forces mobility, are equally important (Chiriac 2020, 55). In the long term, the transition from a large, centralized, well-protected infrastructure to smaller, dispersed, adaptive basing with the ability to use active and passive defences may represent a viable solution to the hypersonic threat (Department of Defence 2018, 6).

Conclusions

Speed, which is the core of this threat, can be exploited to identify the vulnerabilities needed to build defences against hypersonic missiles. Speed and low-altitude air friction problems, and the design challenges, exotic materials required, maneuverability-to-performance ratio are all considered in building the robust defence against hypersonic threats.

The characteristics of hypersonic missiles could define the future war in which they become the main actor, and how the defence mission against them is accomplished may shape the missile defence future. Otherwise, giving up active or passive defences against hypersonic missiles can cause missile defences to fail in general.

At the same time, we must not see hypersonic weapons as the *miracle weapons* capable of winning a war or the *technological marvel* that will improve the leaders` .less inspired decisions. What is certain is that the hypersonic weapon will provide one of the tools, vital if we are to consider the efforts made for research and development, which will ensure the psychological comfort and that extra necessary to achieve victory. The varied defence architectures and the existence, of different mechanisms for countering hypersonic missiles, at least theoretically, (missile, physical destruction, electronic warfare systems, various classes` directed energy systems and types) may pose new problems to hypersonic missile designers, who must take into account their optimization against more or less implemented threats.

The issue of hypersonic missiles is frequently seen as a debate in which technology is the predominant element. The reality is much more nuanced. Once the technological barriers are overcome, attention will be directed to production capacity, logistics, command and control structures and relationships, i.e. the entire chain necessary for their use. We must not lose track of the fact that their use should ensure those effects for which they were developed. This is an easy thing to establish, but difficult to achieve. What is certain is that the approach to hypersonic combat must be different because the threat is different. Consequently, we cannot pretend to achieve a fulminant success in tomorrow’s conflict by fighting with yesterday’s weapons.

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