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Hypersonic Weapons

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ABSTRACT:

In the field of military technology, the creation and application of hypersonic weapons have attracted a lot of attention lately. Weapons that can go faster than Mach 5 are known as hypersonic weapons, and they open up new possibilities for combat. The purpose of this research paper is to examine the specifics of hypersonic weapons and how they differ from conventional supersonic weapons in terms of their powers and characteristics. This research aims to give a thorough grasp of the effects of hypersonic weapons on contemporary warfare and geopolitical dynamics by analyzing their benefits and drawbacks. As countries compete to improve their military prowess, the development of hypersonic weapons poses both opportunities and problems that require careful thought and study.

Keywords: Hypersonic Weapon Systems, South Asia, Indian Ocean, deterrence, and strategic balance.

Introduction:

Global militaries are developing a new class of weaponry called hypersonic weapons. Five times the speed of sound, or Mach 5, is not the top speed at which these weapons are intended to fly. They can now move faster over vast distances and in ways that are not possible with conventional weaponry. Although they are still in the early phases of development, hypersonic weapons have the power to completely change combat. There has always been a direct correlation between combat dominance and military technological innovation and improvement throughout the history of warfare.

What distinguishes supersonic weapons from hypersonic weapons?

When compared to their supersonic predecessors, hypersonic weapons are a formidable leap in military technology because of their unique characteristics. These weapons are extremely nimble and able to alter their direction mid-air because they are made to fly at speeds faster than Mach 5 Hypersonic missiles, which move at least five times the speed of sound, or Mach 5, traverse enormous distances in a matter of minutes, in contrast to supersonic weapons, which fly at speeds below that threshold. Because of their extraordinary speed and dexterity, hypersonic weapons are difficult to intercept or counter, giving them a major tactical advantage in contemporary conflict. Moreover, military authorities view the development and use of hypersonic missiles as crucial.

The advent of hypersonic weapons has introduced a new dynamic to the realm of military technology, with both advantages and disadvantages. These weapons, defined as those capable of traveling at speeds between 5 and 25 times the speed of sound, are considered to have game-changing capabilities due to their unmatched speed and maneuverability. Flying at speeds of at least Mach 5, hypersonic weapons can cover vast distances in a matter of minutes, making them difficult to intercept and highly agile in-flight, able to change course swiftly. Companies like Lockheed Martin are at the forefront of harnessing the power of hypersonic missiles, showcasing the potential for these weapons to revolutionize modern warfare with their engineering prowess and speed capabilities. However, the proliferation of hypersonic missile systems poses a significant challenge to global strategic stability, potentially upsetting the delicate balance between nuclear states as countries like China heavily invest in this technology for regional dominance. As such, while hypersonic weapons offer unprecedented speed and agility in military operations, their widespread adoption may introduce new risks and uncertainties in the international security landscape.

The emergence of hypersonic weapons represents a pivotal advancement in military technology, introducing a new dimension of speed, maneuverability, and strategic capabilities that have the potential to reshape global security dynamics significantly. These weapons, capable of traveling at speeds ranging from 5 to 25 times the speed of sound, possess unparalleled agility and the ability to change course mid-flight, rendering them extremely challenging to defend against using traditional systems. The remarkable speed at which hypersonic weapons operate, surpassing Mach 5, allows them to traverse vast distances in mere minutes, offering a strategic advantage that could potentially revolutionize modern warfare tactics. While the unique capabilities of hypersonic weapons present opportunities for enhanced military operations and deterrence, their proliferation also raises concerns regarding international security and stability. The widespread adoption of hypersonic missile systems by nations like China underscores the potential for these weapons to disrupt the delicate balance between nuclear states and introduce new uncertainties in the global security landscape. As countries invest heavily in the

development and deployment of hypersonic technologies for regional dominance, the implications for strategic stability and arms control agreements cannot be overlooked. The advent of hypersonic weapons heralds a new era in military strategy, underscoring the need for robust international dialogue, cooperation, and regulatory frameworks to address the challenges and risks associated with their proliferation. Moving forward, continued research and analysis are essential to better understand the implications of hypersonic weapons on global security, defense strategies, and the broader geopolitical landscape**.**

Literature Survey:

Paper 1

Title : Hypersonic Weapon Systems – A New Wave Of Arms Race In The Indian Ocean Region

Authors : Imran Raza and Nasir Mehmood.

Published on : June 15, 2023

Description : This paper explores how Technological advancements and tactical applications have always played a significant role in determining the outcomes of military conflicts. The emergence of Hypersonic Weapon Systems is considered a game-changer in contemporary and future warfare, as it can potentially dominate the early stages of conflict. Major powers like the US, China and Russia are pursuing technological superiority by developing hypersonic weapons, which could undermine conventional strategic capabilities and render even the most advanced air and missile defences obsolete. However, there has been limited discussion on the impact of deploying hypersonic weapons in the Indian Ocean region and its implications on strategic stability in the Pakistan-India military matrix.

Paper 2

Title : Hypersonic: Past, Present, and Potential Future

Authors : David M. Van Wie

Published on : November 2022

Description : This paper explores how Hypersonic technologies have been investigated for more than six decades, and important operational capabilities exist in the form of re-entry, space lift, and interceptor systems. Today, new classes of hypersonic weapons capabilities are emerging throughout the world. This article provides a brief overview of the history, today's state of the art, and the future potential for hypersonic.

Paper 3

Title : Hypersonic Weapons

Authors : Maya Brehm, Anna de Courcy Wheele.

Published on : February 2023

Description : This paper explores about Hypersonic weapons have in recent years attracted attention from militaries, governments and, increasingly, multilateral institutions following reports of successful prototype testing. In 2018, the UN Secretary-General highlighted hypersonic glide vehicles and cruise missiles in a report on the role of science and technology in the context of international security and disarmament, and called on the international community to 'remain vigilant in understanding new and emerging weapon technologies that could imperil the security of future generations'. The development of hypersonic weapons is said to pose a challenge to strategic missile defences and raise wider international security concerns due to their 'considerable potential to further complicate strategic relations, encourage new arms competition and endanger stability'.

Paper 4

Title : Study on Optimal Guidance Method for Intercepting Hypersonic Weapons

Authors : Wang Zhigang , Han Xu, Shi Lianzi.

Published on : 17 July 2023

Description : This paper shows hypersonic weapon interception scenarios, the interception guidance problem for hypersonic targets with known manoeuvre escape strategy is studied based on the adaptive optimal control principle. The nonlinear interception guidance problem is converted into an optimal control problem, the neural network is used to design the evaluation network and the execution network, the neural network weight correction update is realized, and the interception of hypersonic weapons with large manoeuvring measures is achieved by solving the constructed Hamilton-Jacobi-Bellman (HJB) equation. The simulation results show that the adaptive optimal control-based guidance method can intercept hypersonic targets more effectively than the generalized proportional guidance law and the adaptive sliding mode guidance law.

Paper 5

Title : Detection of Hypersonic Missiles in presence of Plasma Stealth

Authors : Vangipurapu Lakshmi Harshitha, James A Baskaradas.

Published on : February 2023

Description : This paper explores about The hypersonic missiles are the type of missiles which can travel above Mach 5 that is 5 times the speed of sound. The hypersonic missiles with nuclear or non-nuclear warheads causes threat not only nationally but also globally. Due to their high speed, heat is produced which breaks down the molecules in the atmosphere causing formation of ionized gas layer called as Plasma stealth. So, it is very challenging to detect hypersonic missiles but few vulnerabilities of hypersonic missiles make it possible for its detection. The Plasma Stealth itself can be used to detect the hypersonic missiles. By detecting the Plasma footprint which will last for few milliseconds, the hypersonic missiles can be detected.

Technologies

A simple logical approach to understanding how, over the years, hypersonic technology has developed is by scanning earlier developments in various aircraft and missile technologies which led to the development of this technology. Since hypersonic technology is about reaching the five Mach speeds, it would be prudent to check when and how the sound barrier got broken and how further developments in this field took place.

Hypersonic weapons are a new class of weaponry being developed by several countries, including the United States, Russia, and China. These weapons are distinguished by their extreme speeds, which can reach Mach 5 (five times the speed of sound) or greater. This extreme speed makes them difficult to track and defend against, potentially revolutionizing warfare.

There are two main types of hypersonic weapons:

Hypersonic glide vehicles (HGVs): These weapons are launched by a rocket booster that accelerates them to hypersonic speeds. Once at speed, the glider separates from the booster and glides towards its target, manoeuvring to evade defences.

Hypersonic cruise missiles (HCMs): These weapons use scramjet engines to propel themselves at hypersonic speeds throughout their flight. Scramjet engines are a type of air-breathing jet engine that can operate at hypersonic speeds.

The technologies used in hypersonic weapons are complex and cutting-edge. Some of the key technologies include:

High-temperature materials: Hypersonic weapons experience extreme heat due to the friction of traveling through the atmosphere at high speeds. New materials are being developed that can withstand these temperatures without melting or losing their strength. Like Silicon Nitride can withstand extremely high temperatures; that is the core reason it is being used in structural parts of hypersonic flight vehicles. Dense silicon nitride is an exceptionally tough, abrasion-resistant, and corrosion-resistant solid material.

Advanced propulsion systems: Scramjet engines are a critical technology for hypersonic cruise missiles. These engines are incredibly complex and difficult to develop, but they offer the potential for sustained hypersonic flight.

Navigation and guidance systems: Hypersonic weapons must be able to navigate through the atmosphere at high speeds and maneuverer to avoid defences. This requires sophisticated navigation and guidance systems that can operate in a challenging environment.

Hypersonic Aerodynamics: Designing the shape of the vehicle to manage hypersonic airflow is crucial. This involves complex computational fluid dynamics simulations to optimize lift, drag, and manoeuvrability at extreme speeds.

Heat Management Systems: Managing heat is a constant battle. Advanced heat exchangers and radiative cooling technologies are used to dissipate heat and protect sensitive components.

Advanced Control Systems: Since hypersonic vehicles experience significant aerodynamic forces, sophisticated control systems using rudders, elevons, or other control surfaces are necessary for precise manoeuvring and target acquisition.

Sensor Technologies: High-performance sensors are essential for navigation, guidance, and target identification. This may involve heat-seeking sensors, radar, or electro-optical systems that can function in the harsh hypersonic environment.

Communication Systems: Maintaining communication with hypersonic vehicles during flight can be challenging due to the extreme speeds and potential for plasma blackout. Specialized communication technologies that can withstand these conditions are being developed.

Methodology

1. Hypersonic Glide Vehicles (HGVs):

Boost Phase:

•A powerful rocket booster ignites, propelling the HGV to hypersonic speeds. This initial acceleration can be achieved using a separate missile or a booster integrated into the HGV itself.

•The booster relies on the combustion of fuel and oxidizer (often liquid oxygen) to generate massive thrust. This phase is critical as it needs to overcome atmospheric drag and reach the desired hypersonic velocity.

Glide Phase:

•AOnce at high speed, the HGV separates from the spent booster.

•The HGV utilizes its carefully designed shape to generate lift from the atmosphere, similar to an airplane wing but at much higher speeds. This allows it to glide towards the target on a flatter trajectory compared to a traditional ballistic missile.

•Control surfaces like fins or rudders enable maneuvering during the glide phase, making the HGV's path less predictable for missile defense systems.

Terminal Phase:

•As the HGV nears the target, it may perform final maneuvers for precise targeting. This could involve sharp turns or adjustments to ensure the warhead hits the intended location.

•The HGV can carry either a conventional or nuclear warhead. Upon reaching the target zone, the warhead detaches and detonates.

Fig 1 Hypersonic Glide Vehicles [3]

2. Hypersonic Cruise Missiles (HCMs):

Launch Phase:

HCMs can be launched from various platforms like aircraft, ships, or ground launchers. They may use a rocket booster for initial acceleration similar to HGVs.

Scramjet Propulsion:

•The heart of an HCM is the scramjet engine, a marvel of engineering that operates at hypersonic speeds.

•Unlike traditional jet engines that require an onboard oxidizer (like oxygen), scramjets are air-breathing engines. They scoop in atmospheric air at hypersonic speeds using a special inlet design.

•This air is then compressed through a series of ramps and shocks within the engine, heating it significantly. Fuel is then injected and combusted with this hot air, generating thrust to propel the missile forward.

•Since scramjets use atmospheric oxygen, they can potentially achieve sustained hypersonic flight compared to HGVs which rely on a limited rocket fuel supply.

Cruise Phase:

The scramjet engine allows the HCM to maintain hypersonic speeds throughout most of its flight, making it extremely difficult for traditional radar systems to track and intercept. This high-speed cruise phase gives defenders less reaction time.

Terminal Phase:

Similar to HGVs, HCMs may perform final maneuvers for precise targeting before delivering their payload. The warhead detaches and detonates upon reaching the target zone.

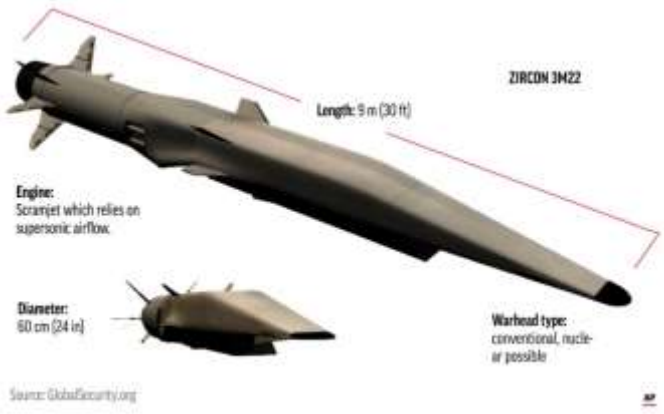

Fig 2 Hypersonic Cruise Missiles

ADVANTAGES

Extreme Speed and Maneuverability: They travel at least five times the speed of sound, making them difficult to intercept with traditional missile defense systems. Their maneuverability during flight adds another layer of challenge for defenders.

Penetrating Defenses: Their speed and low-altitude flight path allow them to potentially bypass high-altitude missile defense systems designed for ballistic missiles.

Faster Response Times: Their immense speed translates to quicker strike times on targets across vast distances. This could be crucial for time-sensitive missions.

Non-nuclear Option: Hypersonic weapons can be equipped with conventional warheads, offering a potentially less destructive alternative to nuclear weapons.

APPLICATIONS

Military Applications:

Strategic Deterrence: HGVs launched from rockets can hold any point on the globe at risk, deterring potential adversaries from aggression.

Time-Sensitive Strikes: Hypersonic missiles can deliver conventional warheads to high-value targets (enemy bases, mobile launchers) much faster than traditional options, allowing for quicker response in critical situations.

Penetrating Defenses: Their speed and maneuverability may allow them to bypass existing missile defense systems designed for slower ballistic missiles.

FUTURE SCOPE

Military Applications:

Advanced Capabilities: We can expect advancements in hypersonic technology leading to weapons with even greater speed, maneuverability, and range. This could significantly alter traditional warfare strategies.

Counter-Defense Systems: The development of hypersonic weapons will likely be met with the development of sophisticated counter-defense systems, potentially leading to an arms race. This race could focus on advanced missile defense systems capable of intercepting hypersonic threats.

Proliferation: There are concerns that hypersonic technology could proliferate to more countries, potentially destabilizing global security. International treaties or agreements might be necessary to manage this risk.

Beyond Military Uses:

Hypersonic Passenger Travel: While futuristic, hypersonic technology could pave the way for high-speed passenger aircraft, drastically reducing travel times between continents. This would revolutionize global travel.

Space Launch Systems: Hypersonic scramjet engines might be used to develop cheaper and faster space launch vehicles, making space exploration more accessible.

Conclusion

Throughout the annals of warfare, adversaries have gained combat superiority by judicially fusing advanced weaponry with strategic utilization. Successful mission accomplishment during combat depends upon the correct employment of armed forces and technologically advanced weaponry to get synergetic effects. The US, China and Russia are acquiring HSWs to seek a technological edge over their adversaries. Similarly, other states like France, Germany and India are venturing into this field.

With the induction of hypersonic weapons in South Asia, the security calculus of the Indian Ocean region has obtained a new strategic dimension, leading to an intensified arms race. Given this, Pakistan needs to carefully decide its course to preserve South Asia's strategic stability. Finding viable options that can match India's HSWs capabilities becomes essential for maintaining this delicate equilibrium. Due to Pakistan's constrained fiscal space, it is important to seek an equalising response while staying within the bounds of available resources to prevent the opponent from fully utilising technical advances in its Favor.

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