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THE OPERATIONAL AND STRATEGIC RAMIFICATIONS OF HYPERSONIC WEAPONS

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Hypersonic weapons are reshaping the high-altitude air battle, challenging traditional missile defence systems and creating both operational dilemmas and strategic opportunities. For middle powers, sustaining sovereign air defence against these fast, manoeuvrable threats is increasingly difficult, yet hypersonics also offer a limited but potent offensive counter-air capability. By exploiting seams in existing air and missile defence architectures, these weapons can compress decision timelines, complicate interception, and threaten hardened targets that were previously resistant to conventional strikes. This paper examines how middle powers can navigate these challenges, assessing both the defensive limitations and the strategic value of hypersonics in mitigating vulnerabilities and reinforcing deterrence.

Keywords
Hypersonic weapons, Hypersonic cruise missiles, Missile defence, Airpower, Strategic deterrence, Major powers.

Introduction

The advent of hypersonic glide vehicles and hypersonic cruise missiles has been a subject of considerable interest to defence communities around the world. The ability of these missiles to combine very high speeds with manoeuvrability and accuracy is viewed by many observers as being of potentially great consequence (Sugden, 2021). Other observers have treated the emergence of hypersonic missiles with somewhat more scepticism, noting that many of the most important qualities of hypersonics can be emulated with less novel technology including ballistic missiles (Oelrich, 2024).

Part of the reason for this discussion is a lack of specificity regarding precisely what hypersonics bring to the modern battlefield. Discussions of hypersonic missiles tend to focus on the qualities of the missiles themselves rather than the operational use cases which might guide their employment which in turn makes an examination of the trade-offs involved in fielding these capabilities vis-à-vis other possible means of achieving similar outcomes more difficult.

Secondly, there is a false dichotomy which currently pervades discussions regarding whether hypersonics are unique. Hypersonic missiles are either treated as an entirely novel capability which will fundamentally

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alter the battlefield or a capability which adds little that other more anodyne systems do not. It might, however, be more germane to view hypersonic weapons as being a symptom of a wider shift towards weapons which are built to operate at the seams of currently existing air and missile defence architectures in a way that problematises radar-based detection and tracking and reduces defenders' warning times. In other words, hypersonics do not necessarily need to be sui generis to be consequential. Rather their role should be understood within the context of a wider spectrum of emerging capabilities which will significantly challenge existing approaches to air and missile defence.

A final consideration which is more specific to hypersonics, given their costs and the enablement which they require, is whether the barriers to entry for fielding these missiles as an effective weapons system (including not only the missile but its enablers) as well as credible defences against them is beyond the reach of the international system's major powers. In other words, how can middle powers cope with some of the barriers to entry posed by both hypersonics and defences against them on a sovereign basis?

Defining a Hypersonic Missile

Typically, when the term hypersonic missile is used, it tends to be in reference to one of two capabilities either a hypersonic glide vehicle (HGV) or a hypersonic cruise missile. Hypersonic glide vehicles are unpowered weapons which rely on the power imparted by a rocket booster from which the vehicle separates before it manoeuvres towards its target. In a sense, HGVs are an evolution of manoeuvring re-entry vehicles (MARVs), with the salient difference being that they manoeuvre for the majority of their trajectory rather than just their terminal phase.

Hypersonic cruise missiles, by contrast, are powered weapons which rely on a scramjet engine to propel them towards their targets. Scramjet engines force oxygen through a nozzle to achieve combustion at supersonic speeds. In order to operate at these speeds, a hypersonic cruise missile has to first be accelerated to a supersonic speed before the scramjet engine begins to operate. This can either be achieved using a rocket booster or the missile can be accelerated to a supersonic speed by a launch platform such as an aircraft which effectively acts as the first stage booster (Kaushal 2023).

The two types of missiles have specific advantages. Hypersonic glide vehicles are less complex than hypersonic cruise missiles given the challenges inherent to operating a scramjet engine. They are also typically longer ranged. However hypersonic cruise missiles are more manoeuvrable and since they are powered, they face fewer trade-offs between manoeuvrability and velocity in the terminal phase than HGVs (which bleed energy for every manoeuvre performed). Like HGVs, hypersonic cruise missiles are an evolutionary tool which represent a natural progression from supersonic ramjet powered supersonic missiles.

However, it must be remembered that travelling at hypersonic speeds, manoeuvring and achieving high levels of accuracy are all qualities which missiles other than those which sit in these two categories of weapon possess. For example, quasi-ballistic missiles are able to manoeuvre at speeds of over Mach 5 for parts of their flight and can achieve very low circular error probable (CEP) (Ellman 2020; Kaushal and Evans, 2023). Similarly, conventionally armed MARVs which can pose a challenge for missile defences are fielded on a growing number of ballistic missiles.

Thinking in Terms of Outcomes, Not Capabilities

What we describe as hypersonics might be better understood as part of a trend that relates to a specific portion of the air threat. Both hypersonic glide vehicles and cruise missiles are largely high-altitude systems (the latter must cruise at around 20 km to operate it's scramjet) and thus create a middle category between low altitude threats such as cruise missiles and high-altitude ballistic missiles. This category is also populated by MARVs and quasi-ballistics. This trend poses several challenges to air defences as currently constructed.

The first aim is challenging traditional air and missile defence systems by operating at the seams between the layers of these systems. This imperative is one that capabilities such as quasi-ballistic missiles share with HGVs. By virtue of operating at altitudes of around 40 km, these missiles fly above the engagement envelopes of most surface-to-air missile (SAM) systems but below the altitudes at which infrared (IR) interceptors optimised for ballistic missile defence would perform optimally (Dean 2023). Weapons operating on this trajectory also complicate the existing two-tier distinction between air and space channels (the latter relating to ballistic targets which operate above the air defence envelope), since they straddle both channels for the longest period of their flight. The absence of a neat mode of threat categorisation against threats which operate across channels can rob defenders of valuable time needed for the allocation of sensors and effectors.

The second related aim is compressing the decision time available to a defensive system. What the combination of speed and manoeuvrability provides a system such as a hypersonic glide vehicle or a hypersonic cruise missile is the capacity to evade detection for long enough to compress a defender's decision-making times. This can be achieved by, for example, underflying the horizon of a surface-based radar. A HGV, for example, is likely to be detected by surface-based radar used for ballistic missile defence, but it will be detected far later in it is trajectory than a higher-flying ballistic missile, which in turn means that the defender has considerably less time to react. There are several other capabilities which can achieve the same effect, however. For example, the warning time which a ballistic missile provides a defender can be shortened by firing the missile on a depressed trajectory whereby range is traded for a shorter time to impact (Oelrich 2016). Ballistic missiles also offer the advantage of, ceteris paribus, having more kinetic energy and higher velocities in their terminal phases than hypersonic give vehicles or cruise missiles since they are not subject to aerodynamic drag for as long (Acton 2013, pp. 71-78).

Finally, the very low circular error probable of hypersonics as well as their high kinetic energy on impact means that they can be employed against hardened targets which might previously have required a nuclear weapon. This means that passive defences such as hardening have less value which in turn compels an active defensive layer to aim for a very high SSPK – which can likely only be achieved through the expenditure of a disproportionate number of scarce interceptors in less efficient shot doctrines (Boord 2016, p. 135). Different estimates have suggested that the potential penetration through REBAR concrete of a HGV with a very low CEP of <10m could be between 17-40 m (Acton, 2013, p. 85; Kaushal and Dolzikova, 2025, p. 40). The latter, higher end, estimate would however likely require a larger glide vehicle with a kinetic penetrator which typically exceeds the known dimensions of existing hypersonics. However, even the lower bound estimate would exceed the known penetration through hardened concrete of munitions such as the Massive Ordnance Penetrator (MOP). This would place a range of hardened targets at risk. In addition, highly accurate hypersonics can be employed against high value operational targets such as naval carrier groups at sea. However, the quality of high accuracy is one shared by both ballistic and quasi-ballistic missiles. For example, some anti-ship ballistic missiles have CEPs which enable the engagement of dynamic targets such as naval carrier groups. Similarly, quasi-ballistic missiles s can achieve very low CEPs and can penetrate hardened concrete structures as can some MRBMs (particularly if equipped with tungsten penetrators to optimise them for this role) (Newdick, 2024).

What is most significant about hypersonics as described is not, then, their intrinsic qualities important though these are. Rather they should be considered within the context of wider trends in how attackers are seeking to overcome air and missile defences by challenging existing approaches to threat categorisation, reducing decision times and limiting the effectiveness of passive mitigations such as hardening.

Each of the trends described has considerable ramifications for the future of warfare and in particular questions regarding the ability of forces to protect their operational and strategic rear areas. While hypersonic weapons may not represent the entirety of each trend they are an important constituent part.

The Defender's Dilemmas in an Expanding High Altitude Air Battle

We might begin with the problem of detection and engagement. Hypersonic missiles and in particular HGVs, complicate the process of engagement both by shortening defender's warning times and through the ability to manoeuvre- making calculating their trajectories more difficult than would be the case for a ballistic missile on a parabolic trajectory. As mentioned, this can be achieved by other means as well. While none of these modes of attack makes interception impossible, what they problematise is the ability of the defender to operate on the basis of an efficient 'shoot-look-shoot' or 'shoot-shoot-look-shoot' doctrine whereby follow on intercept is attempted after observing the impact of an initial attempt (Boord 2016, p. 220). By making tracking during the longest phase of a missile's trajectory more difficult, these capabilities impose a greater burden on terminal phase defences which must often expend interceptors in larger numbers to achieve certainty of effect.

There is thus an inverse relationship between the manoeuvrability of a missile and the ability of a defender to conserve interceptors-something of particular importance during an extended conflict. For example, it has been observed that intercepting short range ballistic missiles can require the expenditure of all the missiles in a SAM battery (GB Wolff et al. 2025, p. 25). Hypersonics do add another dimension to this challenge, however. Surface launched hypersonics provide a defender with even shorter warning times than aero-ballistic missiles since the preparatory stage of an aircraft accelerating to supersonic speeds at a high altitude is missing. Moreover, hypersonics (both cruise and glide vehicles) are typically more manoeuvrable than a quasi-ballistic missile.

The ability of a missile to manoeuvre in its final stages also makes terminal phase intercept more difficult. The difficulty of terminal phase defence has been understood since the incorporation of multiple independently targetable re-entry vehicles (MIRVs) on ballistic missiles but the interception of ballistic missiles in midcourse- before a re-entry vehicle began its terminal phase manoeuvres- had provided at least a partial solution to this challenge (Larson and Kent, 1994, pp. 1-10). Though not hermetic, midcourse defences substantially reduce the strain on terminal phase defences particularly if ballistic missiles carrying MIRVs can be identified early (based on factors such as the IR plume of the booster used) and prioritised for the allocation of midcourse interceptors (Epstein 2025).

The addition of hypersonic glide vehicles substantially reduces the value of existing midcourse interceptors. Ballistic missile defence interceptors typically employ infrared seekers to detect a hot ballistic target against the cold background of space. Within the earth's atmosphere, the impact of aerodynamic friction at high speeds makes these interceptors either unusable or at a minimum reduces their effectiveness. Moreover, hypersonic missiles are liable to underfly the long-ranged surface-based radar upon which missile defences depend. Midcourse interceptors remain vital against ballistic targets which will likely be combined with hypersonics. However, the previously valid assumption that a fast medium or intermediate ranged target could in the first instance be engaged using an exo-atmospheric interceptor is now problematised.

This in turn generates a requirement for an additional midcourse intercept layer in the form of glide phase interceptors which can engage hypersonic glide vehicles during the longest phase of their flight in which they expend much of their energy (Judson 2024). For most states the risk that having to add new layers to an air and missile defence system creates is twofold. Given the costs associated with each layer, it is possible that what emerges from an effort to create a multi-tier missile defence system is one in which each layer is both bespoke and poorly resourced. Secondly the space-based sensors needed to track hypersonics in their glide phase are beyond the reach of most states. In all likelihood, then, hypersonics will increase the portion of the defensive battle which terminal phase defences must conduct. This necessarily implies higher levels of interceptor expenditure.

In conjunction, then, more manoeuvrable ballistic missiles and hypersonics might be viewed as being mutually reinforcing capabilities that make defence prohibitively costly in terms of interceptor expenditure. Their existence in a state's arsenal also imposes conflicting dilemmas on a defender regarding interceptor design- the radar equipped blast fragmentation warheads which might be best suited to counter-hypersonics being suboptimal for ballistic missile defence (BMD). This in turn makes scaling more difficult by forcing defensive investments down multiple channels. Furthermore, the fixed longer ranged sensors upon which BMD systems depend for early warning and cueing more granular X-band radar are themselves vulnerable to attack by missiles which can underfly them including but not limited to hypersonics (Khryapin and Evsukov, 2023, p. 27). In addition, ballistic missiles and hypersonics can be combined in multi-azimuth attacks which, by virtue of their differing altitudes, can saturate a defensive system.

Finally certain qualities of hypersonics make them uniquely difficult targets for radar. Among these are the plasma layers which hypersonic flight generates and the challenge they pose for classification. The problem posed by plasma layers is an essentially physical one- plasma tends to absorb radar, making the returns from a hypersonic glide vehicle somewhat weaker. By contrast the issue of classification is more organisational. Targets which fly at altitudes of 40km exploit a seam between air defence and BMD and in a multinational context different approaches to classifying these targets can rob critical seconds from a defensive systems time to engage (Kaushal, 2025 p.25).

For middle powers, the addition of another defensive layer that circumvents midcourse BMD makes the already expensive problem of missile defence even more challenging. The addition of an additional layer to the already costly high altitude air battle, with hypersonics forming an important part of this layer, could make sovereign air defence an impossibility for middle powers. Because of the limitations of surface-based radar against hypersonics, a glide-phase interceptor requires enablement through additional capabilities such as space-based sensors. While middle powers can field these sensors, they must typically do so in a collaborative context either in tandem with one of the major powers or on a multilateral basis. As such, the addition of an additional layer to the already costly high altitude air battle, with hypersonics forming an important part of this layer, could make sovereign air defence an impossibility for middle powers.

It might of course be viable for nations to opt for more sovereign solutions at a cost in terms of coverage and some lower altitude BMD systems which use radar to track ballistic targets in the atmosphere can also be used as terminal phase defences against hypersonics, (IAI, Suciu, 2025). Since hypersonic glide vehicles are slower in terminal phase than comparably ranged ballistic missiles, it is plausible that high altitude endo-atmospheric ballistic missiles would be capable of engaging hypersonic targets. However, given the lower warning times provided by hypersonics and their potential to manoeuvre between first detection and terminal phase, this is likely a second-best solution. In all likelihood, terminal phase interception can be achieved only with a very inefficient (and thus unsustainable) shot doctrine. If one were to assume an opponent with a relatively limited number of hypersonic missiles that could only be used against key targets, this could be a viable (if high risk) approach that provided a sovereign defensive capability. However, any approach built around the principle of a layered defence would likely require some form of collaboration- limiting the prospects for sovereign air and missile defences for all but the most powerful states.

The Use Cases for Hypersonics as an Offensive Capability

Despite the utility described, it remains the case that hypersonic missiles are prohibitively expensive to an extent which limits the number of targets against which they may be rationally used. For example, known programmes currently at full operational capability have had development costs of approximately $10 billion as well as a unit cost of $40 million (Zheynalov, 2025). In this context use cases which are sometimes mooted for hypersonics for example, the destruction of adversary launchers or air defence radar are implausible except in contexts where a state has relatively few mobile offensive or defensive systems (in which case other means of attack could likely be employed). In a context where potentially hundreds of launchers or radars need to be destroyed to impact an opponent's integrated air defence system (IADS) or long range strike complex as a whole, hypersonics cannot be rationally employed.

For middle powers, this raises an additional consideration. Even if the unit costs of hypersonics themselves can be afforded (and given the high unit costs this will likely result in limited arsenals), the reconnaissance strike complexes upon which the ability to track dynamic targets depends likely cannot be built on a sovereign basis by nations other than the two major powers which field hundreds of satellites. The same dynamics apply to other sensors such as high-altitude long-endurance UAVs which are also more vulnerable in contested airspace. In addition to gathering data, building the networks to move and fuse data from across multiple sources in a timely manner also represents a challenge for most states.

There are however several use cases which might justify the extremely high unit and development costs, which effectively preclude the use of hypersonics against most tactical or even operational targets. First, concentrated static targets of value might be considered. It should be recalled that the challenge most middle powers face is a defensive challenge writ large in which credible defence against cruise and ballistic missiles will prove as difficult as defending against hypersonics over an extended campaign.

Missiles are very difficult to track once they begin to move but they typically have to be stored in consolidated sites with temperature-controlled storage and appropriate maintenance. These sites represent a limited, static target set but are likely to be both robustly defended and hardened to a degree which makes most missiles (for example subsonic cruise) less useful. While stand in airpower can be employed as was the case during recent conflicts in the Middle East, this requires a level of successful suppression of air defences as well as enablement through capabilities such as tankers which cannot typically be guaranteed against a robust adversary air defence network. Particularly in the early stages of a conflict, stand-off capabilities will likely be needed to suppress an adversary missile threat.

Hypersonics could both have a higher likelihood of avoiding adversary air defences. They could penetrate hardened storage bunkers and could be employed against specific parts of underground bases (for example silo doors and entrances). Engaging targets that are static, limited in number but also hardened and well defended represents a viable use case for middle powers which will field limited numbers of missiles with modest enablement. Indeed given the difficulty of engaging large-scale missile threats over time something underscored by the sheer costs observed in recent conflicts a prolonged defensive campaign is unlikely to be feasible for most middle powers. The offensive capability to strike concentrated storage sites could thus be viewed as mitigating a middle power vulnerability. Similarly, certain hardened and buried targets such as the bunkers that serve as operational or strategic level command nodes may well justify the employment of hypersonic missiles equipped with kinetic penetrators. In this context, a limited number of hypersonic missiles would likely represent a means of mitigating a middle power's defensive vulnerabilities which would become apparent in a protracted missile war.

The second category of target against which the employment of hypersonics would prove a rational choice is defensive systems which undermine the deterrent value of a middle power's (typically smaller) nuclear arsenal. While tracking large numbers of targets over an expansive battlefield may exceed the capacity of middle power ISR, this is less true when the search area is well defined (New York Times, 2023). The capacity for hypersonic missiles supported by modest nationally owned ISR constellations (perhaps augmented by a growing commercial ISR sector) to engage critical targets in well-defined search areas is both realistic and might make them a critical extension of middle power nuclear arsenals. Hypersonic missiles as a breaching capability can restore the credibility of smaller nuclear arsenals against which limited missile defences could pose a threat.

Conclusion

Hypersonic weapons are part of a broader trend in high-altitude strike capabilities, combining speed, manoeuvrability, and precision to challenge conventional defensive layers. Middle powers face constraints in achieving comprehensive, sovereign air defence, particularly given the sensor and interceptor requirements needed to track and engage these systems. In this context, hypersonics can serve as a force multiplier enabling states to mitigate vulnerabilities, protect critical assets, and manage operational risk within limited defensive and offensive resources. The use of these systems underscores the importance of viewing defence as a temporal and layered construct rather than an impenetrable shield, and highlights the growing strategic significance of precision, rapid decision-making, and integrated sensor networks.

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