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LESSONS FROM THE PAST, HORIZONS FOR THE FUTURE: **INNOVATION AND THE HYPERSONIC AGE**

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This paper assesses hypersonic missiles in an historical perspective, focusing on two questions: do they represent a revolution in military affairs? And does their introduction threaten the relevance of air power? Historical patterns show that few innovations fully replace prior technologies; instead, they reshape and diversify force structures. Cavalry and infantry adapted to gunpowder, navies incorporated aircraft, and missiles complemented aviation. Hypersonics are therefore unlikely to eliminate existing domains but will alter their interaction. What distinguishes hypersonics is the extreme compression of decision time. Their speed makes rational deliberation or allied consultation nearly impossible, forcing states toward automated or pre-emptive responses, potentially involving artificial intelligence. This dynamic destabilises deterrence by privileging offence, recalling Cold War fears of "launch on warning". Unlike earlier innovations mitigated by defences or adaptation, hypersonics expose a structural fragility in nuclear command and control. Addressing this requires not only technological integration but renewed thinking on arms control, resilience, and the ethical role of AI.

Keywords
Hypersonic missiles, weapons, innovation, military technology, warfare, air force.

It may at first seem counter-intuitive to look to the past to gain a better understanding of the strategic change effected by hypersonic missiles. But there are two questions on which a look at the past history of the development of weaponry can throw light. The first is whether the introduction of such missiles that move faster than the fastest plane can fly will bring about a revolution in some aspect of, or all of, military affairs. The second question is whether these missiles will replace aviation. Leaving aside answers from an aviation or missile expert's point of view – which I am not – this is an attempt to take a long-term historic view: how has military technology evolved over the past, and have new technologies ever made older ones entirely redundant, and if so, to what extent?

This approach requires a disclaimer. In the complexity of human and social developments, a pattern repeatedly found in the past can nevertheless not predict the future. Nevertheless, patterns of the past can help ask the right questions about conditions required for them to repeat themselves in the future. And that is all this contribution can endeavour to provide. We shall see that in few cases, weapons, weapons systems and technologies disappeared entirely in the past millennium, but instead, tended to be adapted

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to new contexts and in reaction to technological innovation and the appearance of new weapons and weapons systems.

A Revolution in Military Affairs?

It seems that all weapons developed before nuclear weapons found their relative match in the form of defensive technologies mitigating their effects – until nuclear weapons came along. No hardened shelters or bunkers or food and water stocks have so far led anyone to feel confident that they could ride out a nuclear attack. Nuclear weapons have been the one exception so far. But we are facing what is potentially a further turning point: the speed at which hypersonic missiles travel makes it well-nigh impossible for rational – let alone consultative – human decision-making to take place between the moment of launch alert and the moment of impact.

If an Avangard-class missile can travel 15,000 kilometres per hour—covering approximately 2,500 kilometres, or the distance between two major capitals on different continents, in ten minutes—this allows hardly enough time to reach a head of government by phone let alone for him or her to make a considered decision.

A recourse to automated responses – or responses delegated to Artificial Intelligence (AI) – is needed, but might prove ethically unacceptable if interception is impossible and it becomes a matter of retaliation (McNamara, 2024). If so, we may be up against an offensive technological innovation without its defensive match.

Whether it is useful to keep AI out of nuclear relations is a question of interest to all sides, as governments explore whether AI will bring helpful or catastrophic options within range for themselves and their opponents. - During the Cold War, the Soviet Union developed an automated command-and-control system known as Perimetr—popularly referred to as "Dead Hand"—designed to ensure a retaliatory nuclear strike in the event that national leadership and communication channels were destroyed (Stillwell, 2022). Some analysts suggest that similar automated deterrence concepts have persisted in modified forms since that period. Decades before such systems were created, however, the idea had already appeared in fiction through Peter Bryant (the pen name of Peter George), author of the novel *Two Hours to Doom* in the late 1950s, later adapted by Stanley Kubrick when he wrote and directed his 1964 film, *Dr Strangelove* (Smith, 2007, pp. 403–407).

While such a "Doomsday Machine" supposes that an automated retaliation would occur once there is evidence suggesting that no central command has survived to take the decision to retaliate, the concept could be "speeded up", so to speak, by ordering a counter-strike once it is clear that enemy missiles have been launched and are approaching.

Prior to the advent of hypersonic weapons, the time it would take intercontinental missiles to traverse the space between two nuclear-armed states was already considered to be one of few hours, so short as

to exclude consultation of allies. What is revolutionary with hypersonic missiles is that consultation even *within* the government of a nuclear power may no longer be feasible, and the automated response imagined by Bryant is now the only revenge option available (and thus the keystone needed for the fragile construct of deterrence).

Since the first screening of *Dr Strangelove*, other technological advances suggested that there was an alternative to vengeful retaliation aiming to destroy what the enemy cherished. And that alternative was anti-missile defence, still largely a pipedream when it was proposed during the presidency of Ronald Reagan. By and by it became feasible in response not only to incoming planes (which to counter *Flak – Flug Abwehr Kanonen*, or air-defence cannon – had already been developed in the Second World War), but also to drones and missiles. We have seen the effects of air defences during various episodes of missile attacks on a state in the Middle East in recent conflicts, always aware that the cost of defensive missiles and the support system to go with them greatly exceeds the cost of incoming missiles or drones. A hypersonic missile, such as the Kinzhal system, was reportedly intercepted by an air-defence battery during operations over Ukraine in May 2023. While such incidents invite scrutiny of hypersonic weapon performance, they do not necessarily justify dismissing broader claims about their disruptive potential as mere "hype" (Montgomery and Nelson, 2023).

Fears articulated decades ago are translating into realities. More than anything ever before, hypersonic missiles are shortening the time to respond to their launch, tipping the balance of responses from interception to pre-emption (launching one's own weapons on warning of enemy launch, and thus before the enemy launch, to be able to destroy them while they are still on the ground) or else automated responses, as reaction times are too short for assured interception let alone human decision-making. And all gloating about the effectiveness of Patriot missiles and other missile defences should not let us forget that, when charged with a nuclear warhead, even one missile getting through would be a catastrophic tragedy, whereas one conventionally-armed missile getting through would cause a fraction of the damage or suffering. In short, hypersonic weapons may have tipped the equation irredeemably in favour of the aggressor.

Do past patterns of obsolescence apply to the relationship between hypersonic weapons and aircraft?

Turning now to the question how the introduction of hypersonic weapons will affect the air forces, we might ask, will they make air forces redundant? Looking at military technological innovations in the past millennium, there have been many – or imports from other cultures – that challenged the technological preponderance of one military format, but generally, new technologies tended to be added to old, rather than replacing them completely.

Casting our minds back to the Middle Ages, the skill of constructing stone fortifications in Europe had been largely forgotten after the fall of the Roman Empire in the West. But its rediscovery at the turn to the second millennium was crucial in the spread of Viking and Norman rule in large parts of

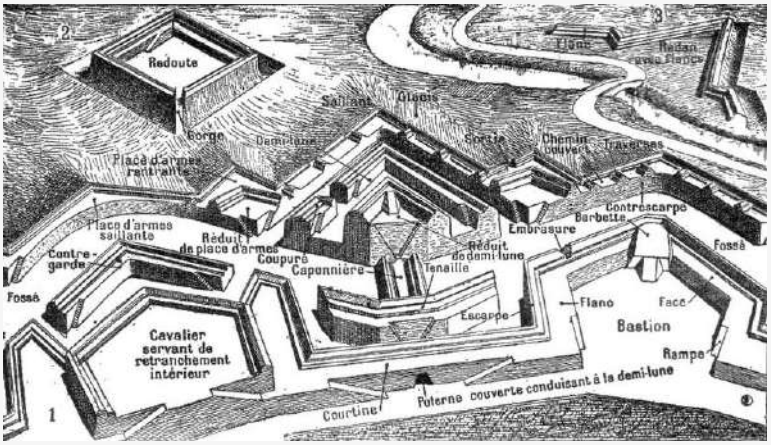
Europe's western coastal areas, up to and including the largest part of Britain. But by the 13th century, Roman siege engine technology had been either rediscovered or reinvented, and all but the strongest castle walls found their counter-technology already in trebuchets and other means of propelling stones and fire into fortifications. Equally, foot soldiers and cavalry found their countermeasure in artillery – the introduction to the battlefield and to the siege of longbow and crossbow in the High Middle Ages necessitated a response, at least by those who could afford it – in part the reason for the evolution of armour. In parallel, new infantry formations were invented in Scotland and the German-speaking lands, with the Scottish schiltron and Swiss-German *Haufen* of pikemen who could defend themselves very successfully even against charging cavalry. Later developed into the Spanish *tercio*, they were used into the mid-17th century and only became obsolete when they could be mown down by firearms. Thus in the 13th to 15th centuries, a willingness to experiment and innovate predicted the Renaissance.

Curtain walls, here the gate towers of Llawhaden Castle, Wales © the Author.

While longbow and crossbow had already had a considerable impact on warfare, the introduction of gunpowder would lead to change on a very much greater scale. It took centuries, however, to have its full effect. Where hauling heavy stones or even fire at vertical fortifications (curtain walls) could be answered by building stronger, thicker walls, no such wall could long withstand battering with gunpowder-propelled cannonballs.

Cannon, invented in Asia in or by the 12th century, were first mentioned in Europe in the early 14th, and by 1453 they brought down the strongest walls of Christendom, those of Constantinople, bringing Christian rule in the Eastern Mediterranean to its end. Henceforth, more of the same was not enough,

a fundamental change in the architecture of fortifications was required: the adoption of flat, spacious fortifications, famously taking star-like shapes to allow cross-fire on forces approaching the walls that in turn had to resort to tunnelling in order to approach walls.



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One might have expected fortifications with curtain walls to disappear completely, but they did not, entirely. As wooden forts they would reappear in America when European forces confronted native populations not in possession of gunpowder and similarly, they would reappear as comparably small "block houses" in colonial wars of the late 19th and early 20th centuries. Even in the face of high-technology adversaries, they would make a comeback as overground bunkers of steel and concrete that now mar the cityscape of Vienna, Hamburg, and other central European cities. Thus older technologies may be overtaken by others in some form, but may be revived in turn by technological innovations – here concrete and steel as building materials.

Bunker in the centre of Hamburg

https://pixabay.com/de/photos/flak-tower-iv-hamburg-bunker-3622160/

Then came the Gunpowder Revolution on the battlefield. While cannon revolutionised siege warfare and forced a change in the architecture of fortifications, gunpowder led to changes also in the configuration and character of the soldiery. Densely packed formations of pikemen could keep cavalry – even knights in heavy armour – at bay but were helplessly exposed to cannon and to the hand-held firearms that slowly emerged from the late 16th century. But the knight in full body armour also became obsolete, and yielded to lighter forms of cavalry, from those still wearing partial armours to armour reduced to breastplates – used by the cuirassiers – to the very light Hussars and similar formations, each used for particular purposes. Yet neither foot soldiers nor cavalry became extinct, much to the contrary: both adapted. Indeed, armies grew again until in the 17th and 18th centuries, they once again reached sizes we read about in battles of Antiquity. Mobile cannon deployed on battlefields massively increased battlefield fatalities, and still, this did not lead to the total elimination of infantry or cavalry.

Similarly, bowmen – longbowmen, crossbowmen, or other archers – yielded to musketeers and formations with other handheld weapons, but they took a long time to do so entirely. In the 1590s, the war-experienced Englishman Sir John Smythe still deemed bow and arrow more effective than hand-held guns (Hale, 1964, xxxvii–lxi). Even around 1800, Tecumseh still used bow and arrow effectively to ambush redcoats in the forests of North America.

Evolving in lockstep with their technology, soldiers initially had to be intensively drilled when the reloading of firearms had to be performed to precision timing while standing in the back while soldiers in the front fired and then changed places, without the risk of friendly fire. By the time of the French Revolution, however, handheld firearms had evolved to the point where these choreographed movements were no longer an absolute requirement, and with little drill, the volunteers levied in France could prevail over their adversaries' drilled formations.

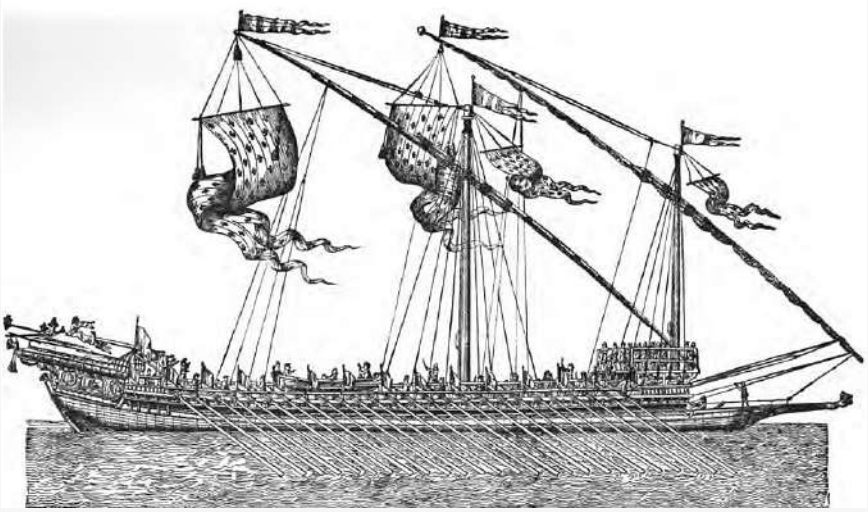
Turning to the Naval Revolution in early modern Europe, multiple technological innovations came together to allow naval navigation and then warfare to undergo profound change in a similarly lengthy period. One of these would be loading cannon aboard ships and using them against ports or other ships. But other innovations were crucial. From Antiquity until the Battle of Lepanto in 1571, naval battles were almost exclusively carried out by primarily muscle-powered, oar-propelled boats: triremes or galleys. It was with the invention of the compass and vessels with deeper keels – galleons or *taforeias* – that could sail away from the coast, across the choppier seas of the Atlantic, that a revolution of naval warfare could occur. While naval battles continued to be fought over access to land, added to these were now lines of communication in the more open seas, even if navies could still miss each other well into the 19th century if they sought battle away from key thoroughfares. As Vice-Admiral Philip Colomb put it, writing in the mid-19th century,

"The operations of military warfare have at all times been conducted with a view to territorial conquest… The sea-fight of ancient times was but the contention of armies on the water, not to hold the field of battle and surrounding waters, but simply as the encounter of one army with another which was barring its way to the conquest of territory. Permanent occupation of the water, as of the land, was a thing

undreamt of, because impossible to the trireme of the ancients, or to the galley of the Middle Ages." (Colomb, 1891, pp. 1–3)

Here is one of the rare examples where one technology – ships powered by wind – would almost entirely replace another – oar-propelled vessels, at least in the open waters and for large-scale transport of goods and men.

With preponderant use of sail, and the new structure of the vessels derived from the northern *kogge*, ships could extend their areas of operation, and navies could widen their contribution to commerce and warfare. This innovation in shipping opened up sea routes of far greater distances, and across oceans to the "new world" and to the Far East.



16th-century galley https://archive.org/details/barbarycorsairs01kellgoog, Wikimedia Commons from (Lane-Poole, 1890).

Replica of the Golden Hinde, source https://pixabay.com/de/photos/golden-hinde-replik-schiff-galeone-219818/ public domain.

It was a small step to contest these spaces, and to aim for something that already Thucydides had described as of major importance, namely the "rule of the sea".[1] Until the 16th century, this had at best meant local preponderance. But from then onwards, imagiznative thinkers picked up Thucydides' *Peloponnesian War*, newly translated into vernacular languages, and could dream of a universal monarchy based on dominion of the sea. Among them was Sir Francis Bacon (1561–1626), who was later credited with the possibly apocryphal dictum that "He that commands the sea is at great liberty and may take as much and as little of the war as he will" (Olivier, 2004, p. 38). Similarly his contemporary, the great seafarer Sir Walter Raleigh (1555–1618), in his *History of the World*, which he began to write in 1607 while a prisoner in the Tower under James I, and which therefore was published only in 1614, pondered the strength of the Phoenicians, who were "absolute kings of the Mediterranean Sea", and their main city of Carthage, which was "invincible while it commanded the sea", and how Rome wrested the "absolute masterie of the sea" from it (Raleigh, 1614, pp. 314, 360, 696). The saying is attributed to him that "Whosoever commandeth the sea commandeth trade; whosoever commandeth trade commands the riches of the world," and thus the world itself (Olivier, 2004, p. 38). Voyagers and thinkers in Portugal, Spain, and above all Italy had similar dreams, and the Italian friar Tommaso Campanella (1568–1639) postulated audaciously, "Che è signore del mare è signore della terra" – who is lord of the sea is lord of the world.

With this began a new pattern of thought that is of relevance to us here, namely, the idea that one sole service, one sole form of technology might be sufficient to produce such military-strategic predominance without needing recourse to any other forms of armed forces. Could it suffice to rely only on a navy, to dominate an entire sea, or even the globe? This idea gained further support as steam replaced wind as the main means of naval propulsion in the 19th century.

Thus British General Sir Howard Douglas enthused in the mid-19th century,
"We are now at the commencement of a new era in naval warfare, in consequence of the introduction of steam as a propelling power for ships, and its application, by all the maritime powers of Europe, to vessels of war, from those of the lowest class to line-of-battle ships of the greatest magnitude. This new power will necessarily modify, and, to a great extent, overturn, the present tactics of war on the ocean. Hitherto the execution of naval evolutions has depended on atmospherical conditions…; while now, an elaborate system of appropriate machinery, put in motion by the expansive force of steam, by enabling a vessel to be moved at pleasure, … will enable the commander of a ship or fleet to put in practice, without risk of failure, whatever manoeuvre he may have determined on… This … should enable British commanders to preserve their present superiority over those of the Continent…" (Douglas, 1860, p. ix)

Yet while in some respects Venice and Genoa had come close to doing so in the Mediterranean in the later Middle Ages, and while in modern times, Spain, England/Britain, the Netherlands and France

[1] "Μέγα γαρ τὸ της θαλάσσης κράτος"
"For the rule of the sea is [a] great [thing]."
(Perikles, quoted by Thukydides I.143,20)

did indeed establish global colonial empires thanks to their navies, armies – or at least contingents of soldiers – never became redundant. Whether it was by means of expeditionary forces, locally raised troops or hired armies, to pursue their aims on land, whether to enforce commerce on unwilling partners or turn lands into colonies, all these naval powers needed soldiers and armies.

Even at the height of British naval power, there were British authors who were sceptical of any aspiration to rule all seas of the globe. With bluff and overstretch, little Britain had indeed secured an empire with colonies around the globe, but others were there to challenge it. While Spain, Portugal, and the Netherlands, the early competitors, fell away, others arose later, notably the United States Navy in the 20th century, the German *Kriegsmarine* at the end of the 19th, and later the Soviet navy. In the official *Soviet History of Military Art* of 1966, the authors note triumphantly, "Our fleet has become an ocean fleet and has acquired ocean-going qualities closing the era of undivided rule of the oceans by the American and English Navies." (cited in Cable, 1981, pp. 161–162)

In any case, the dream of gaining the status of world power by means of just one service, the navy, remained just that at all times: a dream. Even at the beginning of the 20th century, the British Foreign Secretary Sir Edward Grey described the army as "a projectile to be fired by the navy" (Fisher, 1919, p. 18), which can be turned around to say that without soldiers to project ashore, the navy's uses are limited. True, gunboats could threaten to bomb ports and those capital cities situated not inland alongside big rivers but right upon the shore; Lisbon or Copenhagen thus at various points in their history suffered direct bombardment from the sea. Nevertheless, today perhaps more than ever, navies serve as platforms to project other forces – ground forces, planes and missiles – and do not purport to replace them.

Finally, then, let us look at the Air Power and Missile Revolutions. Naval enthusiasts' dream of the all-powerful new domain was taken up by the pioneers of air power. Early aviators began to claim that aircraft could win wars on their own, that they could indeed replace the other two services. Adapting Bacon and Raleigh, the French aviation pioneer General Jean-Henri Jauneaud opined soon after the First World War, "Whoever is master of the air will be master of the world." (Arztet, 1999, pp. 46–47)

General Jean-Henri Jauneaud (1892–1976), © the descendants.

On a scaled-down version, aviators attempted to convince their political masters that air forces were the ideal – because economical – means to keep colonies under heel, as unruly insurgents could be bombed from the air without the cost of boots on the ground. Air power continues to be the cheaper means of military intervention. As a senior U.S. military leader put it during the NATO intervention in Afghanistan in the 2000s, "Without air and space power, 500,000 to 600,000 troops would be needed in Afghanistan to achieve the same effects as the 40,000 soldiers, sailors, marines and airmen we have there today." (Dalton, 2009)

The development of missiles in the Second World War reawakened the dream of a weapon that could replace all others. This came in several waves – right after the First World War in the writings of Giulio Douhet, who enthused about the rule of the air (Douhet, 1921), or again in the 1950s to 1970s, usually in combination with nuclear warheads, when French General Pierre-Marie Gallois opined that one could say goodbye to all the other armed forces (Gallois, 1963) – and again after Western air interventions in the conflict between Serbia and Kosovo in 1999 or in Libya in 2011. These let French strategists fantasise about "la guerre zéro morts" – war without casualties (Dumoulin, 2001) – on one's own side – and Russian strategists about "no contact warfare", fought in a stand-off mode by aircraft – and missiles (Romanchuk, Dulnev and Orlyansky, 2020).

But instead of replacing armies or navies, both other services found ways to make aircraft serviceable to them. Nor did missiles replace aircraft. Missiles either complemented them, or were incorporated into air forces as air-ground missiles. The general pattern is one of diversification and the increase of options, rather than that of replacements as seen with galley and galleon.

Conclusion

The history of military technology shows a consistent pattern: few innovations ever fully displace what came before. Cavalry adapted to gunpowder; navies absorbed the aeroplane; missiles did not replace aircraft but were incorporated into them. New technologies tend to diversify the portfolio of options rather than render older systems obsolete. From this perspective, hypersonic weapons are unlikely to eliminate the need for air forces, navies, or ground forces. Instead, they will alter the balance of their interaction, forcing adaptation and integration.

What sets hypersonics apart, however, is not simply their speed or manoeuvrability, but the way they compress time itself. Decision-making windows collapse from minutes to seconds, making rational deliberation, allied consultation, or even intra-government coordination nearly impossible. This creates a qualitatively new problem: the risk that retaliation or escalation may be automated, delegated to artificial intelligence, or launched on warning with dangerously little human oversight. What we all must worry about is the return of the dynamics identified and feared in the 1950s and 1960s, by which the "delicate balance of terror", as Albert Wohlstetter put it in a famous warning in 1959, can all too easily be upset and turned into a nuclear catastrophe (Wohlstetter, 1959).

Looking to the past, three lessons stand out:

1. Continuity through adaptation: Like earlier innovations, hypersonics will be absorbed into existing force structures rather than replacing them outright.

2. Compression of decision time: Unlike most earlier technologies, hypersonics challenge the very capacity for human decision-making, forcing states to reconsider the relationship between humans, machines, and deterrence.

3. Strategic fragility: In the nuclear context, even a single successful strike can have catastrophic consequences. Here, the historical pattern of adaptation may not be sufficient; fresh thinking on arms control, command-and-control resilience, and AI oversight is essential.

In this sense, hypersonics are both familiar and unprecedented. They remind us of a millennium-long pattern of innovation and adaptation, yet they also threaten to undermine the fragile balance of terror that has defined the nuclear age. The challenge is not whether hypersonics will "replace" air forces or other domains of power, but whether political and military leaders can adapt fast enough — doctrinally, technologically, and ethically — to preserve stability in a battlespace where time itself has become the most contested resource.

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