



SMART DRONES AND FAST MISSILES: EMERGING TECHNOLOGIES AND THEIR IMPACT ON WARFARE

A new generation of weapons is changing the face of warfare. Cold War-era systems – which once themselves displaced World War II-era platforms – are themselves being replaced by new systems.

In particular, two technologies stand out as both transformational weapons on the battlefield, and as symbols of future warfare in the popular imagination. Drones and hypersonic missiles have generated a great deal of buzz, as well as bluster as Russia and others boast of undefeatable new weapons.

But every offensive weapon ever invented, from chariots and tanks, to battleships and bombers, has eventually confronted a countervailing weapon that could destroy it. History suggests that drones and hypersonics will be no different.

THIS PAPER WILL EXAMINE TWO MATCHING SETS OF OFFENSIVE AND DEFENSIVE TECHNOLOGIES:

- Hypersonics and counter-hypersonics
- Drones and counter-drone defenses

PART I

HYPERSONIC MISSILES

Hypersonic missiles refer to missiles that travel faster than Mach 5, or five times the speed of sound. This compares to traditional subsonic missiles such as the U.S. Tomahawk -- with a speed of around 550 miles per hour -- and supersonic missiles such as the U.S. Sidewinder, the Russia-Indian BrahMos, and Japan's ASM-3, with speeds of Mach 2.5 to Mach 3.

If hypersonic missiles were merely faster missiles, then their impact would only be evolutionary. But the speed of hypersonic weapons changes fundamental aspects of warfare, especially lack of time to detect and destroy these missiles.

HYPERSONIC WEAPONS CURRENTLY COME IN TWO TYPES:

Hypersonic Glide Vehicles (HGV)

Hypersonic Glide Vehicles are launched atop a rocket -- such as Russia's Avangard HGV, which is boosted to high altitudes by an ICBM. But instead of ascending into outer space as an ICBM does prior to releasing its warheads, the HGV booster ascends as high as 100 kilometers (62 miles) -- about where outer space begins -- and then releases an unpowered glider that descends toward the target at speeds of Mach 20 or more (Russia claims its Avangard HGV can reach Mach 27, or 20,552 miles per hour).

Hypersonic Cruise Missiles

Hypersonic cruise missiles are more like traditional missiles, albeit powered by air-breathing scramjets. While boost-glide HGVs descend on their targets from high altitudes, a hypersonic cruise missile flies at lower altitudes. However, these cruise missiles must accelerate to a minimum speed of about Mach 5 before the scramjet kicks in, so they need to be mated to an air- or ground-launched booster.

Several nations are developing hypersonic weapons. The U.S. is taking both a common and service-specific approach, with the Navy developing a common glide vehicle that the Army and Navy will mate to boosters launched from land and sea. The Air Force is developing its own air-launched HGV as well as an air-launched hypersonic cruise missile, while DARPA has multiple projects to create HGVs and hypersonic cruise missiles.



Russia has tried to turn hypersonics into a propaganda coup, with President Vladimir Putin extolling the "unstoppable" power of Russian hypersonic missiles. Indeed, Russia is developing multiple hypersonic missiles, including the Avangard (which has already been declared operational), the Mach 8-capable Zircon anti-ship cruise missile, and the Mach 10 Kinzhal air-launched cruise missile.

China has deployed the land-mobile DF-17 HGV, and is reportedly developing an air-launched HGV. Other nations that are developing hypersonic weapons include Britain, France, India, Japan, Australia, North and South Korea, and Pakistan.

KEY TRENDS FOR HYPERSONIC WEAPONS:

Hypersonic Missiles Will Become Favored Weapons for Time-Sensitive Targets

A Mach 5 missile travels 64 miles per minute – the equivalent of Boston to New York in under four minutes -- while a Mach 20 glider descends at 256 miles per minute (New York to Los Angeles in under 12 minutes). This makes these weapons extremely valuable for destroying time-sensitive or mobile targets such as mobile missile launchers.

Hypersonics Will Vex Missile Defense Systems

Boost-glide vehicles fly at high altitudes – but below the altitude bands covered by ballistic missile defense radars. Hypersonic cruise missiles fly too low for radar detection, just like subsonic cruise missiles. And unlike ballistic missiles or even mortar shells – which follow predictable trajectories – hypersonic missiles can maneuver in the atmosphere, allowing them to exploit gaps in radar coverage and evade interceptors.

Artificial Intelligence Will Become Vital

Autonomous missiles maneuvering at high-Mach speeds will require advanced AI to optimize flight paths.

The U.S. Air Force Has Competition for Long-Range Fires

Since 1945, it was the U.S. Air Force – and to a lesser extent the Navy -- that struck long-distance targets, while the Army tended to focus on the immediate battlefield. But hypersonics threaten to blur that distinction. For example, the Army's ground-launched Long Range Hypersonic Weapon (LRHW) boost-glide weapon will reportedly have a range of more than 2,775 kilometers (1,724 miles). Not only does this raise the issue of interservice rivalry, but it also suggests there will be a multiplicity of hypersonics weapons programs across the military services.

Hypersonics Creates New Business Opportunities

Hypersonic weapons development will generate research and manufacturing demand in several areas, including propulsion, flight control systems, heat-resistant materials, and modeling and simulation.

POTENTIAL OBSTACLES TO HYPERSONICS:

Engineering

The price of hypersonic flight is an array of engineering challenges, such as developing heat-resistant materials, as well as flight control systems to maintain stability. For example, a 2012 DARPA test flight of an HGV crashed due to extreme shockwaves caused by hypersonic flight.

Targeting

Fast missiles aimed at mobile or time-sensitive targets – such as aircraft carriers – require precise and up-to-date targeting data. This applies particularly to anti-ship missiles, because the ocean is big, ships are relatively small and constantly change location, and missile sensors have a limited field of view. Thus a capability to collect and transmit real-time targeting information is necessary.

Lack of Combat Testing

For all the publicity and hubris about hypersonics, they have yet to be used in combat, let alone against a sophisticated adversary equipped with missile defense systems.

Political Issues

Hypersonic missiles could be powerful first-strike weapons to destroy an opponent's key installations – including nuclear weapons sites. In turn, this prospect could spur an adversary into launch a preemptive strike to mitigate hypersonic attack. While the range of hypersonic weapons – from tactical anti-ship missiles to thermonuclear-armed gliders – makes arms control difficult, hypersonics could be a political issue.

PART II

COUNTER-HYPERSONIC DEFENSE

While history suggests that hypersonic weapons are not unstoppable, that doesn't mean stopping them will be easy. The closest parallel is ballistic missile defense: more than 70 years after anti-missile systems were first discussed, there is no working defense against a massive ICBM strike, while even successfully intercepting a few ICBMs launched by a minor state is a questionable proposition.

Ballistic missile defense has been likened to shoot down a bullet. Imagine that bullet taking evasive action as you shoot at it, and the problem of hypersonic defense becomes evident.

COUNTER-HYPERSONIC DEFENSE ESSENTIALLY BREAKS DOWN INTO TWO CATEGORIES:

Kinetic Weapons

This mostly comprises anti-missile interceptor rockets, but it could potentially include exotic kinetic weapons such as electromagnetic rail guns. Noteworthy is DARPA's Glide Breaker program, which aims to develop a long-range interceptor that can destroy HGV gliders descending from the upper atmosphere.

Non-kinetic Weapons

The most likely candidate would be directed energy weapons (DEW) such as lasers, but this could include other technologies such as cyberwarfare.

KEY TRENDS FOR HYPERSONIC DEFENSE:

Counter-Hypersonic Defense Will Be Multi-Layered

As with ballistic missile defense, U.S. counter-hypersonics may rely on multiple layers of interceptor rockets, drones, manned interceptors and directed energy weapons. For example, a June 2021 MDA animated video depicted Navy Aegis destroyers destroying four hypersonic gliders using both MDA's proposed Glide Phase Interceptor (GPI) for long-range kills, and an SM-6 interceptor for terminal defense kills.

Hypersonic Defense Will Begin in Outer Space

The current U.S. National Defense Space Architecture (NDSA) will have seven layers including a Tracking Layer of satellite-based sensors to detect hypersonic weapons, a Transport Layer to connect sensors and weapons, and a Battle Management Layer to control the kill chain. If completed as scheduled by 2025, the NDSA will encompass a staggering 550 satellites of various types.

Hypersonic Defense Is a Boost for JADC2

For a hypersonic defense system to function optimally – or function at all – will require a C3 network. This could be a key selling point for the Pentagon's technically ambitious Joint All-Domain Command and Control (JADC2) program, which aims to connect sensors from all the military services into a single network.

AI Will Be Important

AI for interceptors and ground stations will be needed to quickly perform the complex calculations required for hypersonic interception.

Hypersonic Defense May Be Offensive

The U.S. may embrace the axiom that the best defense is a good offense: American hypersonic missiles could preemptively knock out an adversary's hypersonic weapons, while U.S. aircraft could lurk near HGV launch sites to destroy boost-glide vehicles during the boost phase.



OBSTACLES:

Vulnerability to Mass Attack

As with ballistic missile defense, hypersonic defense runs the risk of being overwhelmed by a grim equation: it may be cheaper to launch more hypersonic missiles than to build sufficient interceptors – and their associated sensor and communications systems – to stop them.

Defense is Complicated

The more moving parts in a system, the greater the chance of failure. At this stage, hypersonic defense requires precise and unforgiving coordination between sensors, shooters and command and control elements.

Political Constraints

An offensive counter-hypersonic strategy raises questions of if and when a nation should launch a preemptive strike to destroy a potential adversary's hypersonic weapons.

PART III

DRONES

Drones have become so ubiquitous in both military and civilian use that the question isn't whether they will change warfare, but by how much.

What is remarkable about drones is how their capabilities have expanded. What began as simple robotic aircraft in World War II (Nazi Germany's V-1) now includes a seemingly endless array of unmanned craft in the air, on the ground and at sea. It is no longer science-fiction to envision battles fought by – and between -- robot tanks, submarines, and jet fighters. Indeed, the U.S. MQ-1 Predator and MQ-9 Reaper UAVs have already become cultural memes.

A glimpse of a drone-centric future was the 2020 Nagorno-Karabakh conflict, where an Azerbaijani army equipped with Israeli and Turkish attack and reconnaissance drones decimated an Armenian army equipped with Cold War-era tanks, artillery and air defense systems. There was also Iran's devastating 2019 drone/cruise missile strike against Saudi oil facilities guarded by air defense systems including Patriot missiles.

The world took notice. If a minor military power like Azerbaijan could achieve this capability, what about other nations? Even more disturbing, how vulnerable are the conventional forces of advanced military powers America, Russia, Britain and so on – to drone strikes?

DRONES AND ROBOTS – THE TWO TERMS ARE NOT IDENTICAL BUT ARE OFTEN USED INTER-CHANGEABLY – COMPRISE SEVERAL TYPES:

Unmanned Aerial Vehicles (UAV)

UAVs are the most common drones, ranging from insect-sized quadcopters, to backpack-carried loitering munitions ("kamikaze drones"), to airliner-sized ISR aircraft. A recent but significant addition to this category is the ongoing development of Unmanned Combat Air Vehicles (UCAV), which are expressly designed to carry weapons like manned warplanes do.

Unmanned Ground Vehicles (UGV)

UGVs encompass a range of models, from bicycle-sized, tracked vehicles to haul an infantry platoon's gear, to jeep-sized wheeled patrol vehicles, to robot tanks armed with cannon and missiles.



Unmanned Surface Vessels (USV)

These currently tend to be small boats, such as speed-boats, tugs or patrol craft. They can be equipped with sensors, cannon and missiles, or even explosive charges for suicide missions. Examples include the DARPA/U.S. Navy Sea Hunter, a yacht-sized autonomous vessel designed to detect and track ultra-quiet diesel submarines, and the Navy's Large Unmanned Surface Vessel, a robotic missile boat.

Unmanned Underwater Vessels

Essentially robotic submarines, these include Autonomous Underwater Vehicles (AUV) and Remotely Operated Vehicles (ROV), which are controlled by a human operator.

These can be used for non-combat tasks such as reconnaissance, surveillance, minesweeping and hydrographic mapping, or can be armed with mines, torpedoes and other weapons.

KEY TRENDS FOR DRONES:

Drones Will Be Used for More Tasks

In theory, robots can perform most missions currently executed by manned platforms or foot soldiers. While robot aircraft carriers may be a bit of a stretch for now, it is entirely possible that unmanned ships, aircraft and armored vehicles will eventually comprise the majority of combat platforms. Whether or not robots actually perform better is immaterial: as machines replace humans, it will become politically difficult to justify risking human lives on hazardous missions that can be performed by a machine.



Drones Will Become More Autonomous

Despite political and ethical complications – especially regarding use of lethal force -- robots cannot reach their full potential if humans are actively in the loop making decisions. For example, drones controlled by human operators through communications satellites face signal latency issues. At the same time, drones will become more collaborative as they operate in swarms to overwhelm a target.

AI Will Be Vital

Concepts like autonomous drones and drone swarms will require sophisticated AI, either to enable unmanned craft to function independently or to coordinate with other unmanned vehicles.

Robots Will Replace Manned Platforms

For example, it is significant that the U.S. Army's Next Generation Combat Vehicle (NGCV) program includes an Optionally Manned Fighting Vehicle – which can be manned or remotely operated – as an M-2 Bradley troop carrier replacement, as well as Robotic Combat Vehicles capable of limited autonomy.

Drones Magnify the Power of Smaller Nations

The success of Israel, Turkey and Iran in developing combat drones points to an uncomfortable fact for major powers: smaller or less developed nations can afford to design and manufacture armed drones (and export them, as Israel and Turkey are doing). These craft don't have to be as sophisticated as American or Russian models: they just need to be good enough.

Drones Will Become the Poor Man's Firepower

Even the weakest militant or extremist group can fit explosives on off-the-shelf quadcopters purchased for a few hundred dollars on Amazon or eBay.

OBSTACLES TO DRONES:

Humans May Want to Be In the Loop

It remains to be seen whether how much control humans will cede to robots in the name of efficiency. The day a missile-armed UCAV mistakes a school bus for a tank is the day that a backlash will begin against autonomous vehicles.

Some Technologies Have Yet to Be Proven

Drone yet have yet to be tested in combat, while there are only a few autonomous drones -- such as Israel's Harpy anti-radar loitering munition – that have been deployed. Until these systems have been fielded in combat, questions will remain:

- Can autonomous UCAVs be trusted to attack the correct targets?
- Can a swarm of drones work together amid jamming, spoofing and a GPS-denied environment?
- How well will unmanned craft perform against counter-drone defenses?

PART IV

COUNTER-DRONE DEFENSE

The global counter-drone industry is booming: from \$614 million in 2020, the market will soar to more than \$1.6 billion by 2026, with a compound annual growth rate of 27.8 percent, according to a recent estimate. Some of this has been spurred by demand from civilian users such as law enforcement, but the most cutting-edge counter-drone technologies will be driven by military requirements.

As the Nagorno-Karabakh war showed, mechanized armies cannot operate – or even survive – when they lack protection from hordes of drones flying continuously over the battlefield. Nor can traditional air defense systems, such as long-range surface-to-air missiles, destroy drones. The prospect of a \$4 million tank being destroyed by an explosive charge strapped to a \$1,000 quadcopter bought on Amazon will be a powerful incentive for armies to invest in counter-drone technology.



COUNTER-DRONE SYSTEMS COMPRISE TWO TYPES:

Kinetic Weapons

“Hard kill” systems are the sort of traditional cannon and missiles found in air and missile defense.

Non-Kinetic Weapons

“Soft kill” systems include jammers and other radio frequency (RF) equipment to disrupt or hijack drone control systems and datalinks. They also include directed energy weapons such as lasers and microwave beams.

TRENDS IN COUNTER-DRONE DEFENSE:

Layered Defense

U.S. counter-drone defenses will likely consist of multiple types of countermeasures, including guns, missiles, directed energy weapons and RF countermeasures. The U.S. Army’s IM-SHORAD air defense system, for example, is a Stryker armored vehicle armed with anti-aircraft/anti-drone missiles, cannon and machine guns.

Soft Kills Will Be as Important as Hard Kills

While air defense systems have historically been kinetic, soft-kill defense will become important as future

warfare is fought in an increasingly urbanized world. DARPA’s Mobile Force Protection project, for example, launches small interceptor-drones that shoot streamers to foul UAV propellers without harming nearby civilians.

Defenses Must Be Mobile and Portable

Heavy counter-drone weapons, such as lasers, will be mounted on vehicles such as the Stryker, to keep pace with mechanized formations. The U.S. Army also envisions heavy systems like lasers and microwaves being operated by air defense units, while small units will be equipped with man-portable RF countermeasures.

AI Is Needed to Fight Drone Swarms

No matter how well-trained, human operators cannot cope by themselves with detecting, identifying, tracking and defeating hundreds of drones in a swarm. They will need assistance from AI.

OBSTACLES TO COUNTER-DRONE DEFENSE:

Vulnerability to Mass Attack

As with missile defense, counter-drone systems can be swamped by drone swarms that appear with little warning and overtax sensors and human operators.

Economics

Given the low cost of drones and the ease of launching large numbers at a target, counter-drone systems must be capable of stopping multiple targets at an affordable price.

CONCLUSIONS

“Revolutionary” has been a word applied to new weapons throughout history, sometimes correctly and sometimes not. Whether drones and hypersonic missiles, and the defensive systems that will be their nemeses, will revolutionize warfare remains to be seen. But it is clear that the era of World War II and Cold War weaponry is drawing to a close, replaced by a new generation of equipment.

What is interesting is the commonalities between the new technologies. In particular, advances in Artificial Intelligence, for example, are necessary for both hypersonic weapons and drones, and counter-hypersonic and counter-drone defenses.

Either way, warfare in the remainder of the 21st Century is unlikely to be the same.