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Science, Technology Assessment, and Analytics

SCIENCE & TECH SPOTLIGHT:

# HYPERSONIC WEAPONS

**SEPTEMBER 2019**

## WHY THIS MATTERS

Hypersonic weapons, once developed, would fly faster than 3,800 mph and be extremely difficult to defend against. Advances in hypersonic technologies have significant implications for national security, as well as for transportation and space systems. Research and development of offensive and defensive capabilities in hypersonics is and will remain critically important.

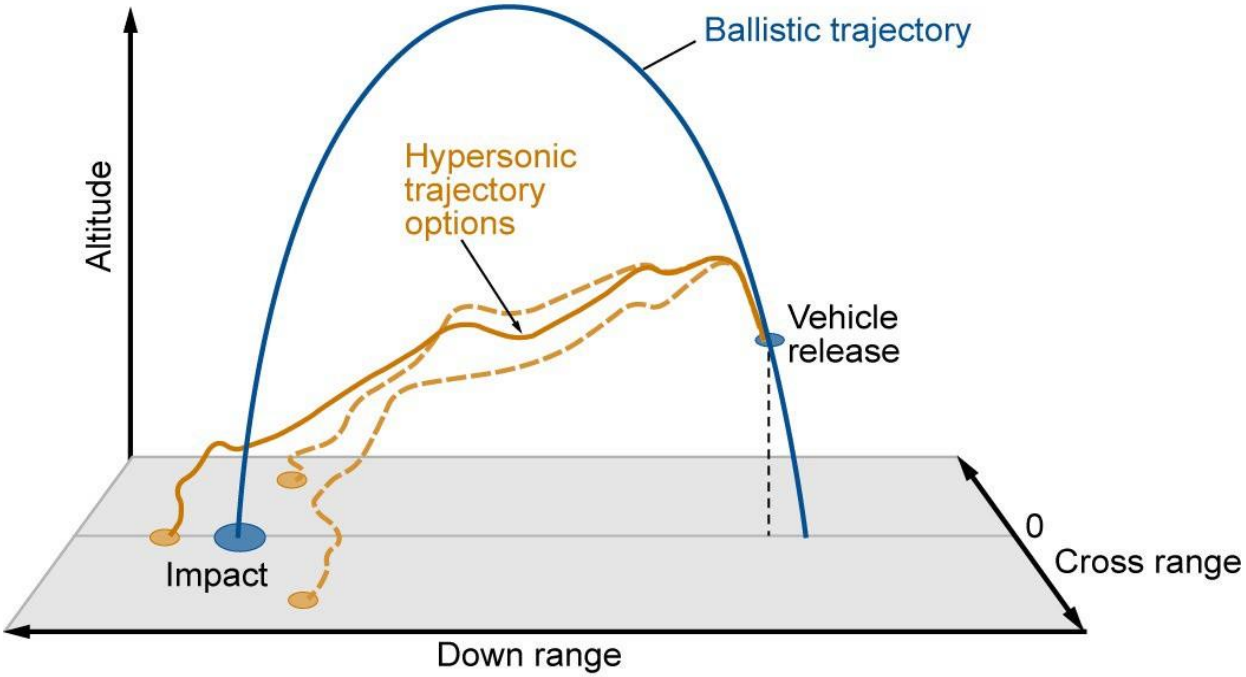
## THE TECHNOLOGY

What is it? Hypersonic weapons fly at least Mach 5 – five times the speed of sound, or approximately 3,800 mph. Unlike ballistic missiles, which can reach similar speeds but have a relatively fixed flight path, hypersonic weapons, once developed, would fly at lower altitudes, be highly maneuverable, and may be able to change targets during flight. This will make them extremely difficult to defend against.

How does it work?

Most hypersonic weapons fall into two categories, hypersonic glide vehicles (HGVs) and hypersonic cruise missiles (HCMs).

**Figure 1. Ballistic Reentry Vehicle (RV) Versus HGV Trajectories.** An RV follows a parabolic trajectory determined mainly by its launch characteristics, its target, and gravity. An HGV can take a variety of trajectories and leave its final destination ambiguous.



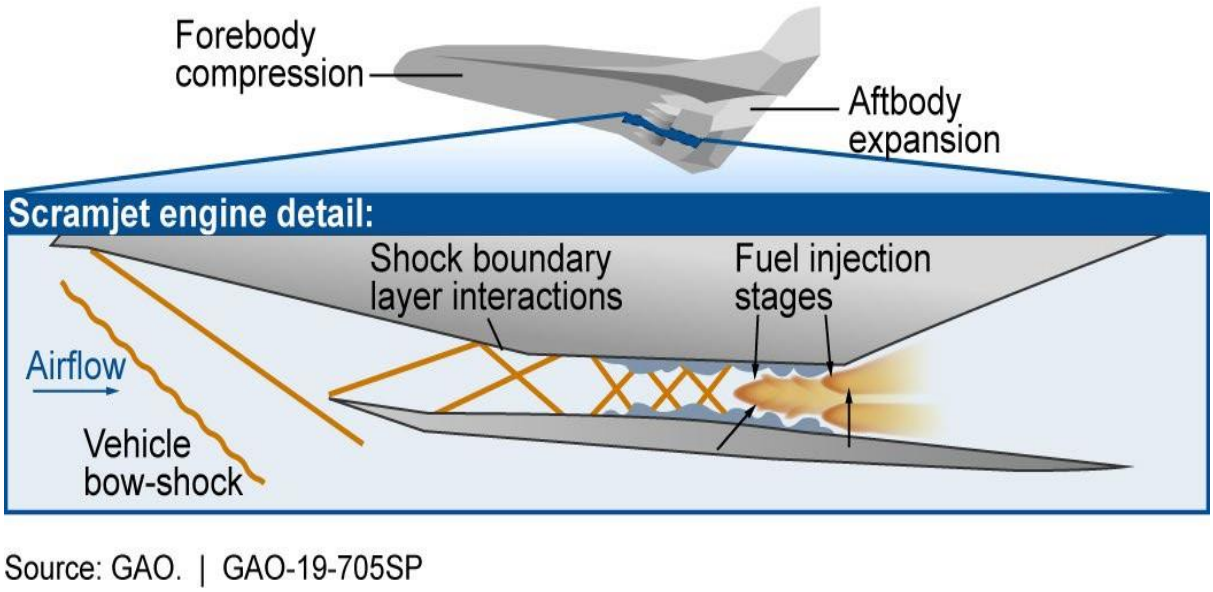

Source: GAO. | GAO-19-705SP

HGVs are unpowered and glide to their targets from a high altitude after initial launch by a rocket. They are expected to fly at altitudes between 25 and 60 miles.

HCMs are powered by high-speed engines during their entire flight. They are expected to fly at altitudes between 12 and 19 miles.

For most HCMs, a rocket would accelerate the missile to Mach 3 or 4, and then the HCM's own ramjet or supersonic combustion ramjet (scramjet) engine would take over. A ramjet uses the speed of the vehicle to "ram" and compress air with fuel, which is burned to produce thrust. A scramjet is similar, with air moving at supersonic speed.

**Figure 2. Scramjet Engine.** The air enters the inlet at a speed greater than Mach 1. It is then compressed by the engine geometry, and combustion occurs at supersonic speeds.




Source: GAO. | GAO-19-705SP

How mature is it?

According to a U.S. Air Force Scientific Advisory Board report, domestically, the core technologies needed for the development of a tactical range HGV have reached Technology Readiness Level (TRL) 5 out of 9. The board expected the remaining subsystems for such a weapon to reach TRL 6 or higher by 2020. According to GAO best practices, TRL 7 is the level of technology maturity that constitutes a low risk for starting system development. It indicates that a technology has achieved form, fit, and function, and has been demonstrated in an operational environment.

## OPPORTUNITIES

- **Penetrate defenses.** Hypersonic weapons would likely enable U.S. warfighters to penetrate existing adversary anti-aircraft and anti-missile systems because of their speed, maneuverability, and altitude (above typical anti-aircraft defenses and below interception points for ballistic reentry vehicles).
- **Strike fleeting targets.** The speed of hypersonic weapons would allow them to hit targets that are only vulnerable for a limited time, such as mobile, high-value military targets and adversary weapons systems.
- **Agile targeting.** A traditional missile needs to be launched with a target in mind, but a hypersonic weapon could be maneuvered later in flight. This could provide U.S. decision-makers more time and make it extremely difficult for adversaries to prepare.
- **High travel speeds.** Piloted hypersonic vehicles would allow for very short travel times and may have commercial applications. Such vehicles have essentially been limited to certain spacecraft reentering the atmosphere and experimental aircraft.

## CHALLENGES

- **Heat-tolerant materials.** At hypersonic speeds, the exterior temperature of a hypersonic vehicle or weapon can exceed 2,000°F, necessitating advanced materials that will protect interior electronics. Such materials also need to be mechanically strong and efficient.
- **Propulsion technology.** Refinement of engine technology is needed for HCMs. This includes increasing the reliability and efficiency of scramjet engines. New types of engines that allow for propulsion from standstill to hypersonic speeds are also being developed, which would eliminate the need for rockets to provide the initial launch.
- **Weapon tracking.** Defense against a hypersonic weapon would involve tracking and intercepting it, but current radar and satellite systems

are inadequate for this task.

- **Limited testing resources.** There are limited places to perform ground tests and flight tests of hypersonic weapons and vehicles in the United States. Currently, there are limited wind tunnel facilities in the country capable of running propulsion tests of hypersonic weapons and vehicles.
- **Safety and control.** Hypersonic velocities require additional improvements of aircraft control and guidance to help ensure the accuracy of hypersonic weapons and to avoid in-flight accidents or loss of control of hypersonic vehicles.

## POLICY CONTEXT AND QUESTIONS

Within the Department of Defense (DOD), multiple programs by the Defense Advanced Research Projects Agency (DARPA), the Air Force, the Navy, and the Army are leading research or developing hypersonic weapons for a variety of applications and launch methods.

NASA also conducts work related to hypersonics for vehicles and spacecraft reentry into the atmosphere, both for NASA programs and in support of DOD. This includes research to safely control and guide hypersonic vehicles.

With U.S. investment in hypersonics increasing, and key technologies not yet mature, some questions for consideration include:

- What is the status of U.S. efforts to advance the science and technology needed to develop hypersonic weapons and vehicles?
- What measures are needed to ensure timely and efficient development?
- Are the development goals realistic given the current status of key technologies?
- Which federal agencies are investing in hypersonic weapons, vehicles, and related technologies, and how are these efforts coordinated?
- What are the implications of the proliferation of hypersonic weapons? What are the implications of the commercialization of hypersonic technologies and vehicles?

## SELECTED GAO WORK

- DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight, GAO-19-439
- National Security: Long-Range Emerging Threats Facing the United States As Identified by Federal Agencies, GAO-19-204SP
- Technology Readiness Assessment Guide, GAO-16-410G

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## GAO SUPPORT:

GAO meets congressional information needs in several ways, including by providing oversight, insight, and foresight on science and technology issues. GAO staff are available to brief on completed bodies of work or specific reports and answer follow-up questions. GAO also provides targeted assistance on specific science and technology topics to support congressional oversight activities and provide advice on legislative proposals.


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