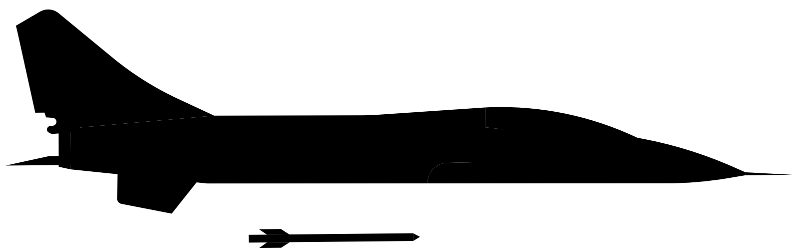
PLOUGHSHARES
SPOTLIGHT

THE RISKS OF **HYPERSONIC WEAPONS**



BY MARK McWHINNEY

DECEMBER 2020

More states are investing in hypersonic weapons capabilities. These weapons have the potential to travel faster and farther than current intercontinental ballistic missiles (ICBMs), with the added benefit of increased manoeuverability. While not all hype around hypersonic missiles is justified, the pursuit of such capabilities is changing the defence landscape and raising concerns about the future of nonproliferation and arms-control regimes. Because of their destructive potential and the alarming geopolitical context that informs their development efforts, the peacebuilding and disarmament communities must pay attention to these weapons.

WHAT IS HYPERSONIC FLIGHT?

Hypersonic flight is defined as flight through the atmosphere at altitudes below 100 kilometres (km) and at speeds above Mach 5 (~3,800 miles per hour, or roughly 5 times the speed of sound).

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MILITARY HYPERSONIC VEHICLE DESIGNS

Two types of hypersonic vehicle (see below) are being developed to serve military functions. Both can deliver conventional or nuclear payloads at speeds between Mach 5 and Mach 20, offering virtually unlimited global strike range when coordinated with existing weapons delivery systems.

Hypersonic glide vehicles (HGVs)

- are launched from existing missile systems
- are released from rocket boosters
- glide through the air toward targets

Hypersonic cruise missiles (HCMs)

- are powered by scramjet engine
- manoeuvre at low altitudes
- fly at hypersonic speeds toward targets

HOW DO HYPERSONIC VEHICLES WORK?

HCMs and HGVs can be delivered in two ways. They can be launched from ICBMs or Submarine-Launched Ballistic Missiles (SLBM) and skip along the top of the atmosphere to accelerate to hypersonic speeds (between Mach 5 and Mach 20). They can also be launched independently or released from a supersonic bomber before accelerating to hypersonic speeds using a supersonic combustion ramjet (scramjet) propulsion system.

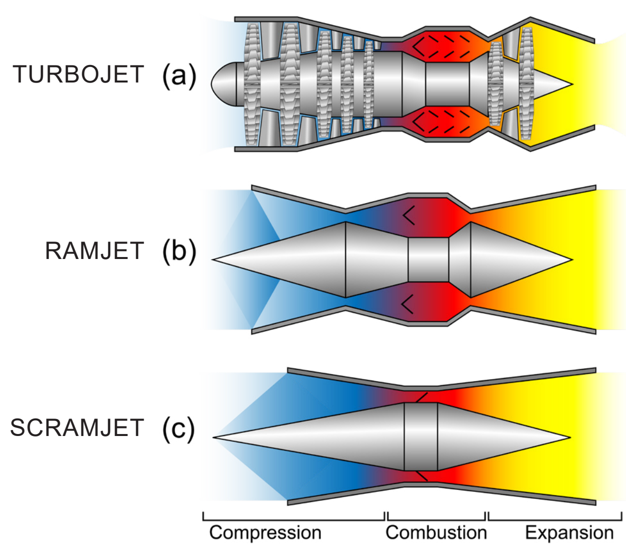

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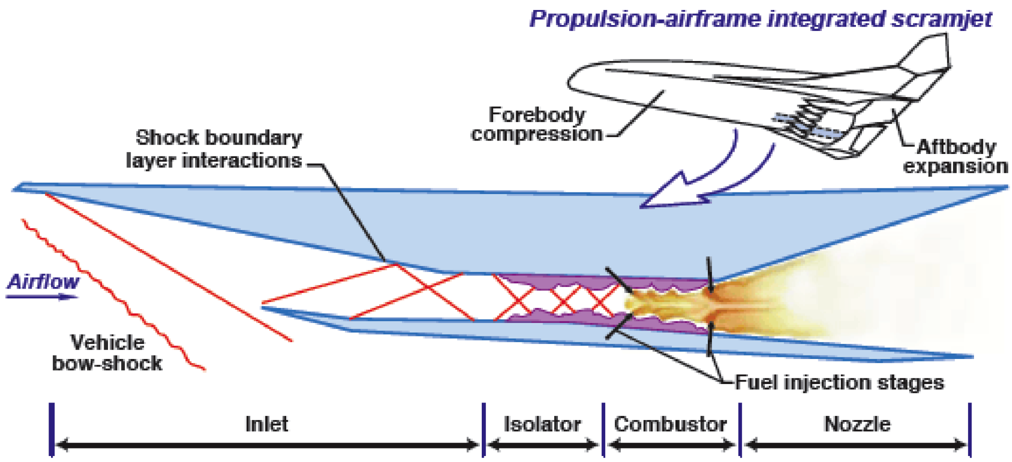
Figure: How scramjets work



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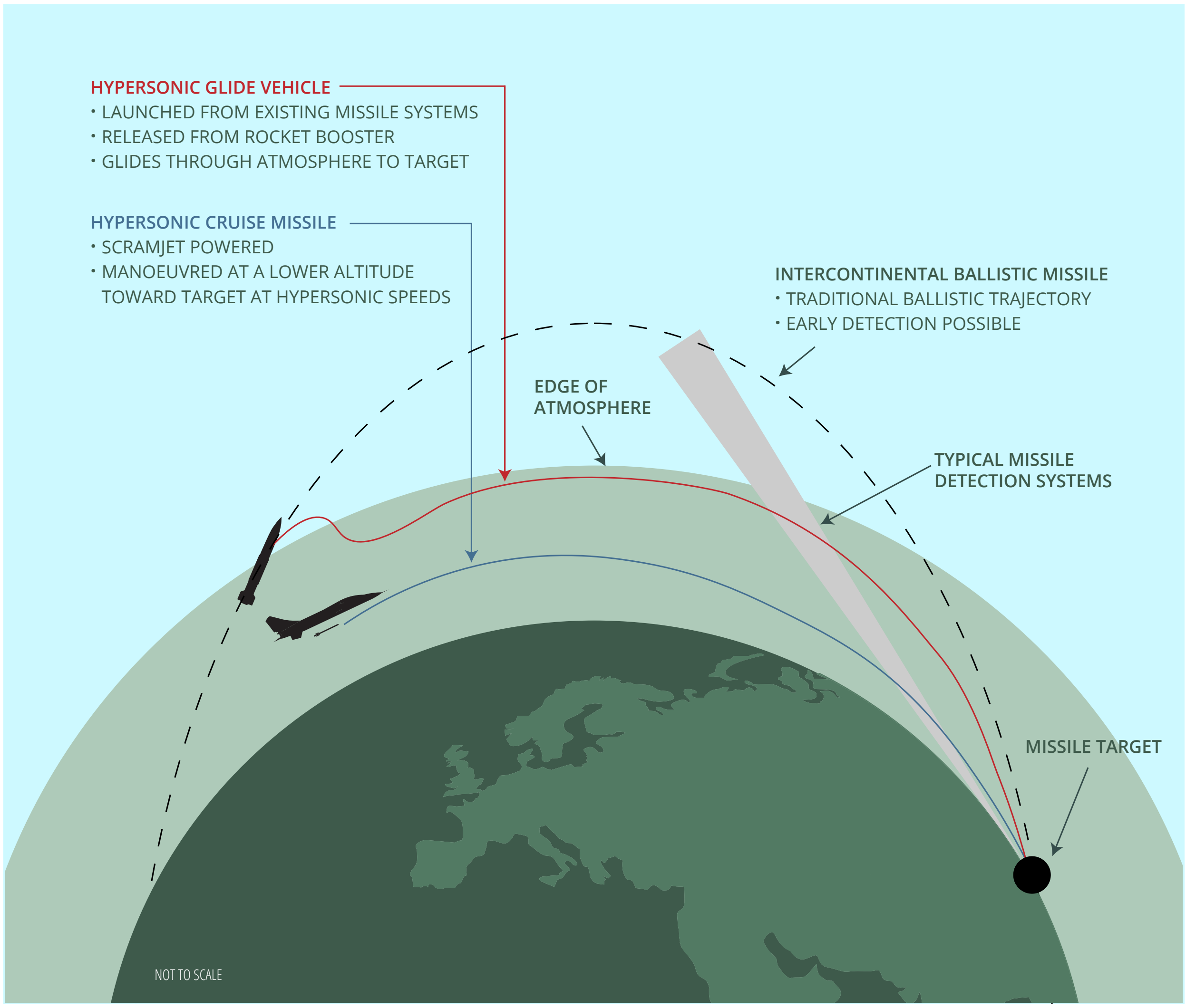
Instead of using a rotating compressor like a turbojet engine, the scramjet relies on forward velocity and aerodynamics to compress air into the engine before hydrogen fuel is introduced and subsequently combusted. It is, in effect, an “air breathing” technology with no moving parts. Whereas a ramjet decelerates the air to subsonic velocities before combustion, the airflow in a scramjet is supersonic throughout the entire engine.

WHAT IS THE MILITARY VALUE OF HYPERSONIC WEAPONS?

In theory, the key advantages of hypersonic vehicles are speed, evasiveness, and manoeuvrability. Hypersonic missiles and glide vehicles are designed to combine the manoeuvrability of a cruise missile with the speed of a ballistic missile. Unlike ICBMs, which travel in predictable paths at high altitudes in a parabolic arc toward their target, hypersonic weapons take unpredictable paths at low altitudes with higher speeds. As a result, these weapons have the potential to render modern ballistic missile defence systems obsolete. Able to deliver conventional, nuclear, or biological payloads at high velocities over long ranges, hypersonic weapons, if operational, could strike with little notice, enabling unprecedented global first-strike capabilities.

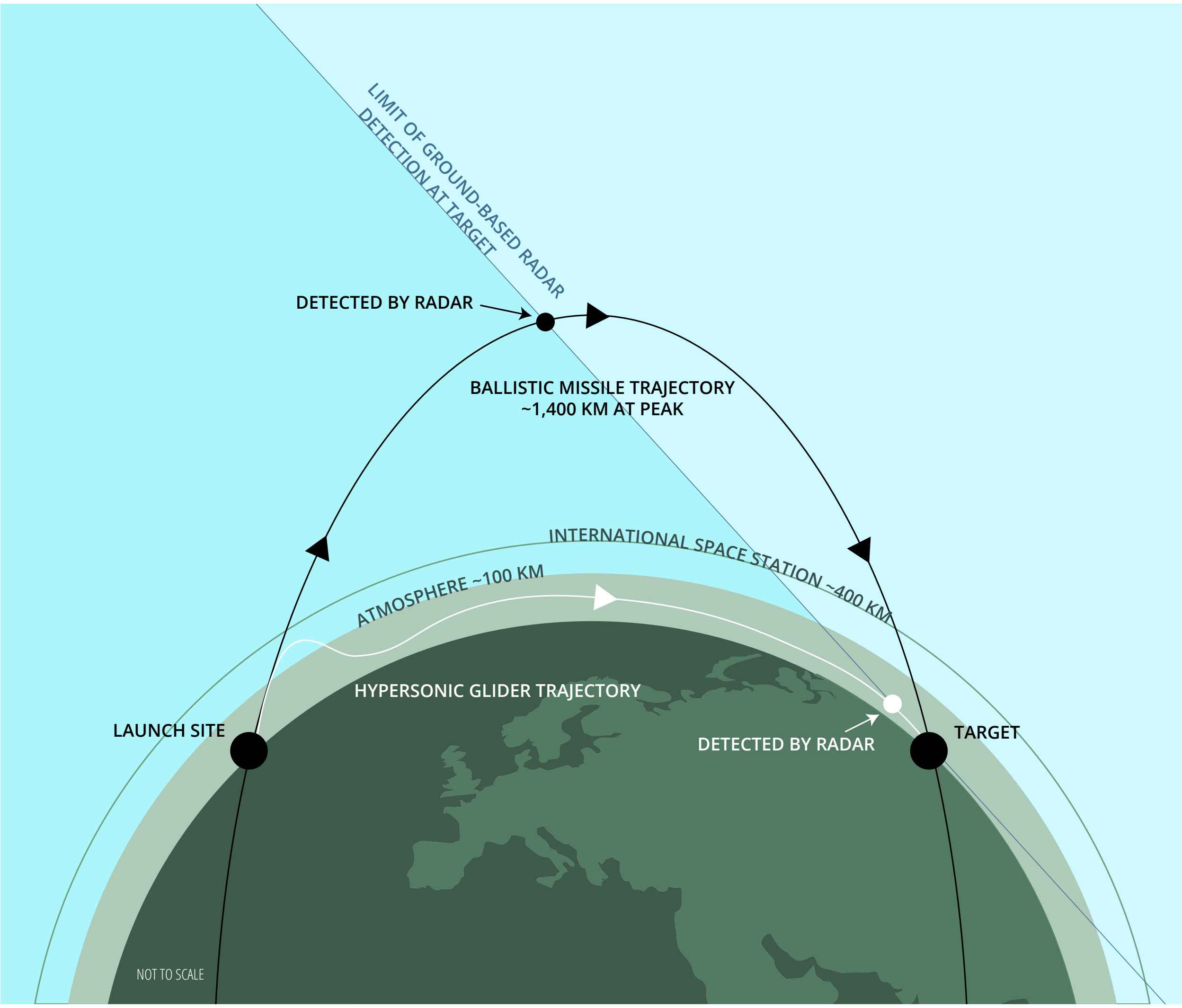
FIGURE: HYPERSONIC MISSILES AND THE CHALLENGE FOR MISSILE DEFENCE SYSTEMS



Sources: RAND Analysis, Stratfor, The Hankyoreh

WHICH STATES ARE PURSUING HYPERSONIC WEAPONS CAPABILITIES?

Russia, China, India, and the United States lead in the development of hypersonic weapons applications. Russia and China focus on hypersonics to deliver nuclear payloads, while the United States has stated that it is pursuing hypersonics to deliver only conventional (kinetic, incendiary, explosive) payloads. India has conducted a successful test of their HSTDV system, but they have yet to achieve long-range sustained hypersonic flight akin to that of their competitors. Australia, Israel, France, Japan and Brazil have also begun to develop hypersonic weapons capabilities, both as sole proprietors of unique technologies, and as partners working in conjunction with allied states. See table below for a current list of military developments.



DOES HYPERSONIC TECHNOLOGY HAVE CIVILIAN USES?

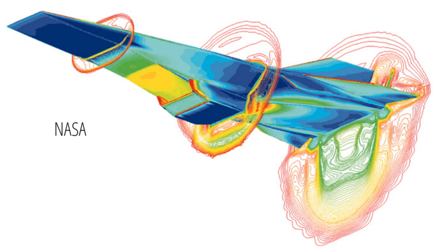
Hypersonic technology can be considered dual use. Propulsion systems originally used by the military could be adapted to meet civilian and commercial needs. Some members of the European Union are pursuing high-Mach propulsion systems for use in projects conducted by the European Space Agency (ESA) and in commercial transport capacities.

Singapore, Norway, and the United Kingdom have expressed interest in commercializing hypersonic technology, while Iran and Canada have funded projects that aim to achieve a better understanding of hypersonic flows. But research and development remain enormously expensive and require sophisticated research facilities that can model hypersonic conditions (speed, temperature, and pressure) and accurately assess material behaviour/degradation.

WHAT ARE THE LIMITATIONS OF HYPERSONIC TECHNOLOGY?

As a next-generation military technology, hypersonic weapons face a number of technical challenges going forward that may impede their effectiveness, particularly when compared with established weapons systems. It is possible that their promise and potential may not be realized.

1. Withstanding heat



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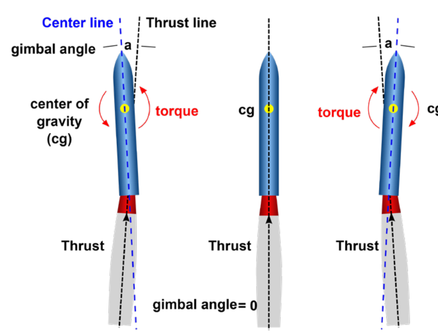
The enormous amount of thrust and speed generated by scramjets produce air friction and intense heat from molecular dissociation, imposing constraints on system design and materials. Hypersonic technology must be composed of materials that can withstand temperatures of up to 2200 degrees Celsius. Woven silicon carbide (SiC, very similar to carbon fibre), coupled with an oxygen-resistant ceramic coating, is currently one of the best available options for thermal management, but is expensive. Another problem is that these materials currently work only with design profiles that lack aerodynamic efficiency.

New metal alloys, coatings, and material compositions need to be developed to avoid the costly repairs that repeated vehicle use would require.

2. Flight controls

Gimbaled Thrust



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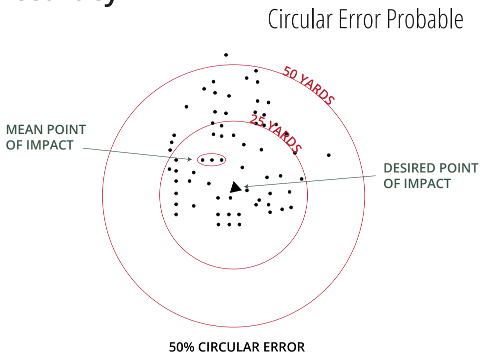
Hypersonic vehicles are more manoeuverable than ICBMs, but less so than cruise missiles. Because aerodynamic flight controls are ineffective in low density atmospheric conditions, traditional flight course correction controls, like fins, do not work as intended. However, using rocket engines alone to make major course changes creates directional forces strong enough to destroy the missile or vehicle by putting exceptional stress on the fuselage. The remedy is to set up the main engines to gimbal (allowing them to swivel) or to place deflection vanes within the rocket exhaust to allow for only minor course corrections.

3. Atmospheric conditions

Guidance systems are designed to cope with unpredictable atmospheric conditions by considering multiple trajectory options and adapting to environmental factors like wind and cloud cover. Cruise missiles rely on either radio or inertial/internal guidance systems that monitor their position, velocity, and acceleration. Radio guidance experiences line-of-sight-issues and can be subjected to jamming or spoofing.

Hypersonics use inertial guidance systems that consist of gyroscopes and accelerometers that feed data to an onboard computer. These systems tend to become less effective over long-range flights. Hypersonics might need to rely on external guidance systems such as satellites.

4. **Accuracy**



Each of the three main kinds of accuracy errors for ballistic, cruise, and hypersonic missiles has a different solution. Aim-point (targeting) and launch errors can be solved by greater diligence in surveying methods. Guidance errors, which occur while a vehicle is in flight, are measured by a missile's circular error of probability (CEP) and deviation of the mean impact point from the actual aim point. These errors are typically resolved by iterative tests and design corrections.

Hypersonic weapons have a significant chance of missing their target because they operate at high speeds over extended ranges. While hypersonics are not new technology, they continue to experience problems with unknowns in aerodynamics. Ballistic and cruise missiles seem more reliable. Both are incredibly accurate.

WHAT ARE THE DANGERS OF HYPERSONIC TECHNOLOGY?

Despite the limitations noted above, military hypersonic development continues, with some technologies already in service (see table below). We must therefore consider the dangers of hypersonic technology.

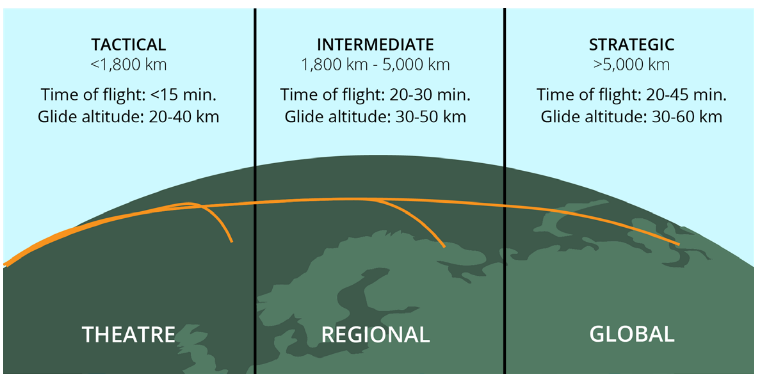
Hypersonic military systems can deliver conventional or nuclear payloads. Thus, hypersonic weapons are characterized by "warhead ambiguity." This means that it is not clear to adversaries if the weapons are nuclear-armed or armed with conventional payloads. In such a situation, the tendency is for adversaries to assume that the weapons are nuclear-armed. Combined with minimal reaction time afforded by hypersonic missiles, in the event that one is launched, a nuclear-armed adversary might well assume that it is under nuclear attack and respond accordingly. The result could be nuclear war, even if unintended.

Hypersonic weapons are contributing to an emerging arms race that extends beyond the missiles themselves. Intended to outpace existing anti-ballistic missile defence systems currently operated by states such as United States, Russia, Israel, and India, their development encourages the acceleration of new defence capabilities, potentially spurring a security dilemma and causing further arms escalation and instability.

Gaining dominance in the application of offensive hypersonic weapons capability could have significant geopolitical consequences, creating a power imbalance, the like of which was not seen in the Cold War. Guaranteed first strike capability would upend current nuclear deterrence strategies and surely heighten international instability.

HYPERSONICS, GOVERNANCE, AND ARMS CONTROL AGREEMENTS

Hypersonics weapons are not covered by any existing arms control agreements, nor by voluntary measures that restrict the development and proliferation of missile technology, such as the International Code of Conduct against Ballistic Missile Proliferation and the Missile Technology Control Regime. An international commitment to inspection protocols and information sharing could be a way forward. However, there are no indications that major powers are interested in pursuing agreements to prohibit or limit the use of such weapons at this time.



The Intermediate-Range Nuclear Forces (INF) Treaty, signed in 1987 by the United States and the then Soviet Union, led to significant reductions in nuclear warhead stockpiles. Until the United States withdrew from this treaty in 2019, the INF framework could have served as an effective model to prohibit or limit hypersonic weapons.

Another nuclear arms control treaty between the United States and Russia, New START (Strategic Arms Reduction Treaty), contains a provision for parties to restrict the development of new arms. However, this treaty is set to expire in February 2021 and a reprieve seems unlikely in the current political environment.

Any new agreement to control hypersonic weapons must include all major players, not the United States and Russia alone. All states with advanced military capabilities must be brought to the table.

But this must be only the beginning. Ultimately, the need is for inclusive and global arms control treaties. Without them, proliferation is bound to continue, heightening geopolitical tensions as a new, and very dangerous arms race revs up.

CURRENT DEVELOPMENT OF MILITARY HYPERSONIC CAPABILITIES

Nation	Program	Type	Explanation	Delivery date
United States	CPS	HGV	Conventional Prompt Strike (combines glide vehicle with submarine-launched booster system)	2028
United States	LRHW	HGV	Long-Range Hypersonic Weapon (combines glide vehicle with Navy's booster system; combats A2/AD capabilities, suppresses LRFs, engages sensitive targets)	2023-2024
United States	ARRW	HGV	Air-Launched Rapid Response Weapon (leverages DARPA's Tactical Boost Glide technology; Mach-20 speeds with a range of 575 miles; Concept vehicle)	2022
United States	TBG	HGV	Tactical Boost Glide (aims to develop and demonstrate technologies to enable future air-launched, tactical-range boost glide systems at Mach 7+)	2021
United States	OpFires	HGV	Operational Fires (leverages TBG to develop a ground-based system for air defence penetration and critical time-sensitive target engagement)	2021
United States	HAWC	HCM	Hypersonic Air-Breathing Weapon Concept (air-launched; designed for a wider range of platforms; possible seeker implementation)	2021
United States & Australia	HIFiRE	HGV	Hypersonic International Flight Research Experimentation Program (experimental Mach-8 scramjet; three-launch system fueled by hydrocarbons instead of hydrogen)	Testing
United States & Israel	Arrow 3	HCM	Exoatmospheric hypersonic anti-ballistic missile (has divert motor capability; may be repurposed for antisatellite use)	Testing
Russia	Avangard	HGV	Mach-20 HGV (launched from ICBM with effectively unlimited range; capable of sharp horizontal and vertical manoeuvres; nuclear potential of 2 megatons)	Potentially n service*
Russia	Zircon	HCM	Mach-6 to Mach-9 HCM with semi-ballistic trajectory (can be deployed by supersonic aircraft or through naval vertical launch systems)	Testing
Russia	Kinzhal	HCM	Mach-10 air-launched HCM (manoeuvrable at all stages of flight trajectory; evidence of effectiveness not available)	Potentially n service*
Russia & India	BrahMos II	HCM	Mach-7 HCM (for ship, submarine, aircraft, and land-based systems)	2025-2028

TABLE CONTINUED ON NEXT PAGE

Nation	Program	Type	Explanation	Delivery date
India	HSTDV	HCM	Hypersonic Technology Demonstrator Vehicle (Mach-6 carrier vehicle for hypersonic and cruise vehicles, with planned CubeSat launch capabilities)	Testing
China	DZ-ZF	HGV	Mach-5 – Mach-10 HGV (mounted to existing DF-17, DF-21, and DF-31 ICBMs; capable of complex vector manoeuvring with nuclear or precision payloads)	2020
China	DF-41	HCM	Modified ICBM (for conventional or nuclear HCM delivery)	Testing
France	V-MaX	HGV	Experimental Maneuvering Vehicle (stresses high-speed manoeuvrability and nuclear potential)	Testing begins in 2021
France	ASN4G	HCM	Air-sol nucléaire 4eme generation (nuclear payload air-to-surface HCM; replacement for ASMP-A nuclear cruise missile)	2035
Japan	DMSJ	HCM	Dual-Mode Scramjet Engine (Mach 5-15 ramjet and scramjet propulsion system; satellite and inertial guidance system; employs explosively formed penetrator (EFP) warheads to target naval and ground-based assets)	2030s
Japan	HVGP	HGV	Hyper-Velocity Gliding Projectile (ground-launched glider with minimal radar cross-section. 90° incidence vector)	2026-2028
Brazil	14-X	HGV	Mach-7 air-breathing jet concept (uses Waverider design)	Testing

* CLAIMS ARE DIFFICULT TO SUBSTANTIATE

RESOURCES AND FURTHER READING

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