PUGWASH WORKSHOP
on
HYPERSONIC WEAPONS

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SUMMARY
and
RECOMMENDATIONS

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Introduction

The Pugwash Foundation supported an international Pugwash workshop on hypersonic weapons, which took place in Geneva on 9 and 10 December 2019. The meeting brought together 30 international participants from various continents, including current and former government officials, scientists, engineers, academics and experts from think tanks and other non-governmental organisations. All discussions were held under Chatham House rules.

The workshop aimed at fostering a constructive exchange of views on hypersonic weapons. Participants discussed factors driving the development, roles and purposes of hypersonic weapons, as well as the risks associated with their deployment and use. The following provides a summary of these discussions[1].

What is a hypersonic weapon?

While in recent years hypersonic weapons have featured prominently in various media, academic publications and official statements, publicly available technical information about such weapons remains scarce. Their characteristics, the consequences of their introduction into the arsenals of major military powers and their eventual proliferation need to be better understood. Today, it is still unclear what precisely the term 'hypersonic weapons' refers to. In order to get closer to a working definition, the workshop identified the following criteria:

Criterion	Description
Speed	Greater than Mach 5
Trajectory	Non-ballistic and atmospheric for part or all of the flight
Manoeuvrability	High
Target accuracy	High

What distinguishes Hypersonic Cruise Missiles (HCMs) and Hypersonic Glide Vehicles (HGVs) from traditional cruise and ballistic missiles is the combination of all those criteria: HCMs and HGVs a) fly at hypersonic speed, b) have a high manoeuvrability, c) offer high target accuracy, and d) follow a non-ballistic atmospheric trajectory for part or all of their flight. Because of the underlying physics, reconciling all these characteristics proves difficult and may involve trade-offs.

[1]This report was prepared by two rapporteurs, Amb. (ret.) Sergey Batsanov and Kevin Miletic. Please note that the views presented here represent opinions expressed in the meeting. They do not necessarily reflect the personal views of the rapporteurs, nor of the Pugwash Foundation or its sponsors.

What are the technical challenges?

The development of hypersonic weapon systems raises a number of technical challenges. These include:

- an aerodynamic design that reduces drag and guarantees stability throughout the gliding phase for HGVs and the cruising phase for HCMs;
- materials that withstand high temperatures, have a high tensile strength, have low-density, and have good resistance to oxidation;
- propulsion systems with stable combustion at hypersonic speed for HCMs;
- navigation, communication and guidance systems that withstand high temperatures, high G-forces, and can get through plasma;
- testing facilities and simulation modelling that can reproduce hypersonic conditions.

Due to the lack of open data on HCMs and HGVs testing, it is unclear whether those technical issues have been resolved. Without a proper technical understanding, it is impossible to accurately evaluate the real capabilities of HCMs and HGVs and assess the risks they pose.

What are the current hypersonic weapon development programmes?

Hypersonic programmes are not new. The U.S. and the Soviet Union did work, with some discontinuity, on hypersonic programmes during the Cold War. With very few exceptions, for example the X-15 (U.S.), those old programmes almost never materialized, but they informed and guided the current development of HCMs and HGVs.

It is public knowledge that countries, including China, India, Russia and the U.S., are working on hypersonic programmes. However, only little information is available on their:

- range
- speed
- types of playload
- types of platform
- deployment dates

That information is absolutely crucial for an accurate assessment of a country's hypersonic capability. While some secrecy around hypersonic programmes is understandable, greater transparency would help correct erroneous assumptions and reduce dangerous misunderstandings.

Why do States develop hypersonic weapons?

Reasons behind the development of hypersonic weapons seem to be manifold and specific to each country. Without any attempt to attribute more importance to one reason over another, the workshop identified the following key drivers:

- *The current techno-military context* – It creates concrete opportunities for hypersonic weapon development. A permissive R&D environment combined with progress in spacecraft and ballistic missile technologies has provided in several instances such favorable conditions. Over time, lower production costs also helped drive the development of hypersonic weapons.

- *Geopolitical tensions* – They have prompted some countries to upgrade their overall military capabilities and/or introduce new technology.

- *Changing threat perceptions* – Some countries may feel threatened by decisions or actions taken by other nations. They can see the pursuit of a more assertive security policy or the development /acquisition /deployment of new weapon systems as leading to the erosion of their own military capabilities and hence perceive it as a threat. The development of ballistic missile defence systems, for example, may have triggered an interest in developing hypersonic weapons. This, in turn, may have prompted other countries to invest in similar programmes and upgrade their missile defence systems.

- *Strategic calculations* – Some countries may have considered their current nuclear deterrent capability insufficient to keeping the strategic balance. In this regard, the acquisition of HGVs and HCMs may boost confidence in the effectiveness of one's second-strike capability, thereby enhancing their nuclear deterrent capability.

- *Tactical calculations* – Some countries may expect HGVs and HCMs to provide them with an advantage in certain theatres of operation. In this regard, the acquisition of HGVs and HCMs may enhance a country's anti-access/area-denial capabilities and/or the ability to hit protected high-value targets or “fleeting targets” deep into another country's territory.

- *Status* – Hypersonic weapons, as symbol of technological advancement, can provide their owners with an exclusive status and a sense of belonging to the technologically more advanced powers.

What are the roles and missions of hypersonic weapons?

Most HCM and HGV programmes are still in their design and experimental phases and will not be operational for some time. Building an understanding of their potential roles and missions ahead of their deployment could give policymakers and practitioners a head-start in dealing with possible future problems.

At the moment, it seems that HCMs and HGVs are not being built to take on new missions. Rather they seem to be integrated into the existing operational framework to support pre-existing missions.

Tab.1: Overview of possible strategic and tactical missions for hypersonic weapons

Hypersonic Glide Vehicles (HGVs) and Hypersonic Cruise Missiles (HCMs)			
Strategic Missions		**Tactical Missions**	
Defensive	Offensive	Defensive	Offensive
Enhancing second-strike capability	Enhancing first-strike capability Enhancing ability to eliminate targets that are perceived to pose a threat to national security wherever their geographic location.	Enhancing anti-access/area- denial capability.	Enhancing ability to eliminate targets, in an attempt to gain operational superiority in a given context.

HGVs and HCMs are more likely to be used in a conflict involving two or more countries with advanced missile defence systems and missile programmes. The use of HGVs and HCMs in conflicts involving countries with less technologically advanced missile and anti-missile programmes would represent a waste of resources.

However, as long as countries do not lay open in their military doctrines the intended use, uncertainty will remain as to their true defensive and offensive purposes in strategic and tactical contexts.

Many questions will still have to be answered before countries feel confident in using hypersonic weapons. For example, the impact of physical phenomena on their navigation, guidance and other supporting sub-systems represents an array of challenges. It is also unclear to which extent HCMs and HGVs are compatible with existing sub-systems, such as launch-platforms, satellites and C4ISTAREW (Command, Control, Communication, Computer, Intelligence, Surveillance, Target Acquisition, Reconnaissance and Electronic Warfare).

For all these reasons, HCMs and HGVs are unlikely to replace traditional cruise or ballistic missiles very soon. Traditional missiles will, in all likelihood, remain the preferred military choice in the near to medium term.

Hypersonic technology could also be used for Intelligence, Surveillance and Reconnaissance (ISR) missions. However, speed, aerodynamic forces and high temperatures were seen as significant challenges to the gathering of accurate and exploitable information. While hypersonic vehicles hold an important future potential for ISR missions, conventional aircrafts and satellites are currently still more effective.

What are the risks associated with hypersonic weapons?

Increased risk of nuclear war

HCMs and HGVs contribute to an increased risk of nuclear war for several reasons:

- *Warhead ambiguity* – The uncertainty of whether a hypersonic delivery system carries a conventional or a nuclear warhead is referred to as 'Warhead ambiguity'. Warhead ambiguity thus involves the risk of confusing a conventionally tipped HCM or HGV with a nuclear one.

- *Target ambiguity* – The high manoeuvrability of HCMs and HGVs allows them to change course after launching. This makes it impossible for other countries to forecast the final target.

- *Heightened threat perceptions* – Depending on their number and location, HCMs and HGVs could constitute a threat to a country's nuclear or strategic conventional forces. These heightened threat perceptions create additional pressures for nuclear weapon states to lower the nuclear threshold by delegating authority to low-level officers, adopting launch-on-warning postures or even using or threatening to use nuclear weapons for fear of losing them.

- *Shortened reaction time* – It is currently unclear if and how much the use of HCMs and HGVs would compress the response time in the event of an attack. However, any compression of the timeline across the detection, assessment and response process, even if it were only a few minutes, would provide less time for accurately assessing the origin, destination and payload of a HCM or HGV. Yet, this information is critical for selecting the appropriate type of response. Thus, a shortened reaction time would not only result in increasing uncertainty and risk, but also the need for greater reliance on automation and artificial intelligence (AI) in critical decision-making process, including the decision to launch nuclear weapons.

- *Encouraging nuclear brinkmanship* – Hypersonic missiles, because they are difficult to detect by early warning systems and difficult to defend against, may transform the behavior of nuclear weapon states and lower the threshold for some of them to engage in nuclear brinkmanship.

- *Fueling an arms race* – The introduction of HCMs and HGVs, even if it were only for defensive purposes, may be perceived by some countries as threatening their own national interests and might therefore fuel a new arms race.

Increased proliferation risks

While horizontal proliferation was considered less likely than vertical proliferation in the near to medium term, some horizontal proliferation risks remain. These include:

- development of indigenous hypersonic programmes which would be immensely challenging
- downhill transfer of hypersonic technology to lower-tier military countries with already established missile programmes
- sales of hypersonic systems to allies
- transfer of commercial hypersonic technology to lower-tier military countries with already established missile programmes.

How to mitigate the risks?

Workshop participants considered several measures in order to mitigate the risks associated with the introduction of HCMs and HGVs. These involved:

Reducing proliferation risks

Most technologies required for the development, production and maintenance of HGVs and HCMs are controlled by the Wassenaar Arrangement[2], and the Missile Technology Control Regime (MTCR)[3]. Open issues that need to be addressed include:

- a more inclusive participation in existing export control and non-proliferation fora that involves all relevant stakeholders: China currently participates neither in the Wassenaar Arrangement nor the MTCR.
- HCMs are Unmanned Area Vehicles AVs (cruise missiles) according to MTCR, and are missiles under the Wassenaar Munitions List.
- under the MTCR, depending on national interpretation, HGVs might be considered either as re-entry vehicles or UAVs
- the accounting for commercial/civilian use of hypersonic technology requires clarification.

[2] The Wassenaar Arrangement (1996), is a voluntary export control regime. The 42 participating states exchange information on transfers of conventional weapons and dual-use goods and technologies. Through such exchanges, Wassenaar aims to promote "greater responsibility" among its members in exports of weapons and dual-use goods and to prevent "destabilizing accumulations."

[3] The Missile Technology Control Regime (MTCR) (1987) is a voluntary export control regime. It is an informal political understanding among 35 member states that seek to limit the proliferation of missiles and missile technology. The regime was formed by the G-7 industrialized countries.

Reducing risk of nuclear war

Confidence-building and arms control measures could contribute to reducing nuclear risks. Some may require a level of political will that is lacking at the moment. However, it is useful not to limit the field of possibilities and consider a wide-range of measures for policymakers to choose from:

Enhancing transparency and predictability

- *Communication on roles and missions* – Gaining better understanding of the defensive and offensive purposes of HGVs and HCMs in strategic and tactical contexts.

- *Notification of test-launches and deployment* – Enabling a more accurate assessment of another country's hypersonic capability and its operational level.

- *Warhead clarification* – Reducing warhead ambiguity and the likelihood of miscalculations.

- *Numerical and geographical limitation* – Reducing the perception of vulnerability that an otherwise uncontrolled deployment of HCMs and HGVs might generate.

- *Non-targeting of critical assets* – Reducing the incentive for a first strike and enhancing strategic stability

Making use of and strengthening the bilateral and multilateral regulatory framework

- *New START* – While existing HCMs and non-strategic HGVs are clearly outside the framework of New START, there is a strong argument for the application of New START to strategic nuclear HGVs as a variant of Intercontinental Ballistic Missiles.

- *Multilateral Export Control Regimes (MECRs)* – Abiding by and implementing relevant provisions applicable to hypersonic technology.

- *Multilateral Export Control Regimes (MECRs)* – Because of their relatively limited politicisation and strong emphasis on technical aspects, MECRs may provide conducive platforms to initiate dialogue on hypersonic weapons.

- *Hague Code of Conduct (HCoC)* – Applying relevant HCoC provisions to HCMs and HGVs test-launches.

- *Test Ban* – Freezing current testing programmes and prohibiting future flight-testing of HCMs and HGVs suitable as weapons (commercial HGVs would stay outside the remit of a test-ban) would considerably slow down any arms racing in the field of hypersonic weapons.

HCMs and HGVs are also linked to other weapon systems, which provide reasons for their development, support for their use, or response to their use. Therefore other relevant weapon systems should be taken into account when dealing with HCMs and HGVs. In parallel to stand alone measures, HCMs and HGVs should be considered in a broader context of confidence building/arms control, strategic/regional stability and nuclear risks reduction.

How to counter hypersonic weapons?

Countering HCMs and HGVs is a two-step process. The first step is to detect and track the missile either before it is launched or during its flight, and the second step is to intercept the missile:

- *Detection and Tracking* – It is doubtful whether existing systems are capable of detecting and tracking a HCM or HGV for the entire duration of their flight. Due to the earth's curvature, the low cruising and gliding altitude of HCMs and HGVs make them visible to ground-based radars only a few minutes before arriving on the target. Whereas, over-the-horizon radars may prove more effective at detecting and tracking HCMs and HGVs as they are not as much affected by the earth's curvature. It was not clear whether existing space-based sensors would be able to pick up the infrared radiation of a HGV or HCM or whether new sensors, especially in the infrared spectrum, would be needed.

- *Interception* – In-flight interception of HCMs and HGVs would also present some serious technical challenges. HGVs and HCMs manoeuvrability could allow them to evade existing ground-based interceptors (with the caveat that incoming interceptors be detected and that the manœuvre be initiated in time). Space-based interceptors could be an option but they are technically very challenging to do in practice. In addition, they would raise several legal and strategic issues, and they would also have a high cost and be very vulnerable. While a laser would be fast enough to intercept HCMs and HGVs, there are too many question marks around their accuracy, mobility and power to contemplate laser-technology as a reliable countermeasure. Spoofing and jamming of navigation and guidance systems would also be technically challenging, especially considering that the layer of plasma around the missile may reduce the effectiveness of any spoofing or jamming attempt.

At this moment, it seems that no effective defence against HCMs and HGVs exists. Given the difficulties existing missile defence systems face with traditional ballistic and cruise missiles, developing effective defence systems against HCMs and HGVs would require an enormous and sustained investment with speculative guarantees of success.

Preliminary recommendations

Table 2: Overview of preliminary recommendations

Addressed to	Nr	Recommendations	Nr	Possible avenues for implementation
States developing and/or possessing HGVs and HCMs	**1**	Explore opportunities for opening a dialogue on hypersonic weapons focusing on areas of concern and possibilities for reducing tensions, misperceptions and misunderstandings that increase the risk of inadvertent outbreak of armed conflict.	a)	Including HCMs and HGVs in broader strategic/regional stability processes, such as the P-5 process, and nuclear risk reduction talks.
	2	Enhance transparency through the adoption of reciprocal measures that provide for sharing timely information	a)	Adopting a more explicit definition of roles and missions of HGVs and HCMs in Defence White Papers and other official and publicly available documents
			b)	Communicating actual and/or planned deployment locations and dates
			c)	Communicating the type of warheads they can be fitted with
			d)	Notifying test-launches, possibly under HCoC umbrella

	3	Enhance predictability through the adoption of measures that decrease the destabilizing effects of HCMs and HGVs	a)	Adopting numerical and geographical limitations
			b)	Adopting measures about the non-targeting of certain critical assets, such as satellites with a view to long term sustainability in outer-space
	4	Make use of and strengthen the bilateral and multilateral regulatory framework	a)	Including strategic nuclear HGVs under the limits set by New START and extending this measure to non-parties
			b)	Abiding by and implementing Multilateral Export Control Regimes with regards to civilian and military hypersonic technology covered by those regimes
			c)	Applying HCoC provisions to HCMs and HGVs test-launches
			d)	Exploring to what extend a test-ban could be applicable to HCMs and HGVs
States interested in contributing to regional and international security	**5**	Explore opportunities for expanding and broadening the use of existing multilateral frameworks for export control and non-proliferation	a)	Ensuring inclusive participation of all relevant stakeholders, especially China, Russia and the U.S.

			b)	Ensuring respect for and implementation of provisions dealing with HCMs and HGVs
			c)	Encouraging the use of export control regimes as initial platforms where relevant stakeholders can exchange information on HCMs and HGVs for an enhanced understanding of hypersonic technology and its impact
			d)	Reviewing and sharpening where necessary the terminology used in existing export control and non-proliferation regimes in order to eliminate definitional ambiguity in relation to HCMs and HGVs
	6	Explore opportunities for increasing transparency and predictability with regards to hypersonic weapons	a)	Encouraging States possessing or acquiring or developing HCMs and HGVs to share information about the deployment and intended use
			b)	Promoting the opening of an open-source hypersonic weapons registry with a mechanism for possessors and/or developers to contribute

			c)	Encouraging research institutions to develop research programmes on hypersonic weapons and their impact by providing them with financial and political support
			d)	Forging discreet channels with a view to encourage, initiate and facilitate track 2 talks on HCMs and HGVs that help enhance understanding of common security issues and overcome differences
Organisations with an interest in international security	**7**	Contribute to an enhanced understanding of hypersonic weapons by developing a research agenda and publishing data and information covering technical and doctrinal aspects, as well as their intended civil and military use and their expected impact		
	8	Foster interest in research related to hypersonic technology, its applications, and its impact on international peace and security		

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