The Chinese FOBS operation and the intricacies of hypersonics

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The *Financial Times* was the first to publish an article about the Chinese Fractional Orbital Bombardment System (FOBS) in the summer of 2021.[1] Supposedly the Chinese space programme demonstrated a new concept of space weapons and the use of hypersonic technology herein. In 2020 the *Militaire Spectator* published an article by Ruben Aarten on hypersonic weapon systems and their threat to international stability.[2] The seemingly rising popularity of hypersonic weapon systems is commonly seen as a most disturbing development within the current great power competition.

Now with gradually more information surfacing on the Chinese demonstration and on hypersonic weapons as a whole, it is time to separate facts from fiction and discriminate between promises and practices. The *Financial Times* news item is used to explore the wider issue of hypersonic weapons and in this article I try to explain the current state of play concerning the development, fielding and implications of hypersonic weapons. Although the matter is highly technical, I try to refrain from the use of too much jargon. This article first gives some information on how the space domain is becoming more and more a mainstream environment for the military, but also for commercial purposes. Next it addresses FOBS as a concept and its history. Then some light will be shed on what the Chinese operation was and how it was conducted. What follows is a short description of hypersonic weapons and some inherent peculiarities. Next, the unraveling from hype to reality and how the technology and knowledge is spreading across the world is discussed. A new threat has its own vulnerabilities, which are also described, and, lastly some reflections and conclusions are presented. Of course the article also reflects on what the Netherlands can do in the field of knowledge development concerning the military applicability, security and safety issues surrouding hypersonic technologies.

Some background on the increasing (military) use of space

In recent years, the second space race has come to full bloom.[3] The first space race was in the 1950s to 1960s when the US and the USSR were competing for access to space and landings on the moon. Now with new technology and ever cheaper access to space[4] not only governments

A US Air Force B-52H Stratofortress undergoes pre-flight procedures at Edwards Air Force Base before conducting a captive-carry flight test of the AGM-183A Air-launched Rapid Response Weapon, 2020

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are looking to space, but commercial firms are extending their views even further to find business cases through the use of space outside earths' atmosphere. In the last twelve years in the US alone, the turnover of space business has more than doubled.[5] Companies such as Blue Origin, Virgin Orbit, SpaceX, Onweb, Firefly, Galactic Energy, Rocket Labs, Dawn Aerospace, et cetera are all either already present in space and have launched satellites or are on the verge of doing so.

However, also in a military sense the increasing use of the space domain can be observed. The oldest application is using space to observe the earth and spy on military developments of opponents. In order to provide for long range, over-the-horizon communication, satellites have become indispensable for military operations as well. Ballistic missiles (BMs) use the space domain and in order to provide early warning for launches of opponents' BMs, infrared observing satellites have been put into orbit. For positioning, navigation and timing (PNT) purposes the US was the first to develop and

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1 Demetri Sevastopulo and Kathrin Hille, 'China tests new space capability with hypersonic missile', *Financial Times*, 16 October 2021. See: https://www.ft.com/content/ba0a3cde-719b-4040-93cb-a486e1f843fb.

2 S.R. Aarten, 'The impact of hypersonic missiles on strategic stability. Russia, China, and the US', *Militaire Spectator* 189 (2020) (4) 182-193. See: https://www.militairespectator.nl/thema/strategie/artikel/impact-hypersonic-missiles-strategic-stability.

3 S. Fawkes, 'The Second Space Race', *Journal of the British Interplanetary Society*, Vol. 59 (2006) 364-367. See: https://ui.adsabs.harvard.edu/abs/2006JBIS...59..364F.

4 Hugo van Manen, Tim Sweijs and Patrick Bolder, *Towards a Space Security Strategy. Action Points for Safeguarding Dutch Security and Prosperity in the Space Age* (The Hague, *The Hague* Centre for Strategic Studies, 2021). See: https://hcss.nl/report/strategic-alert-towards-a-space-security-strategy/.

5 Global turnover of the space economy from 2009 to 2020 (Statista, september 2021). See: https://www.statista.com/statistics/946341/space-economy-global-turnover/.

deploy the Global Positioning System (GPS) satellites in a Medium Earth Orbit (MEO) some 20,000 kms above the surface of the earth, soon followed by Russia, China and the EU. Furthermore, with all these systems in space which are essential for military superiority and the conduct of military operations, they become targets themselves. Anti-satellite weapon development and operations have been added to the military use of space. With these developments it is no surprise that more nations are developing their own military space forces, following Russian, Chinese and US initiatives.

Many of the military space systems are designed and produced within the military-industrial complex, in the US as well as in Russia and China, leading to multi-billion dollars of business. Not surprisingly, the competition in space, its military implications and vulnerabilities led to NATO's decision to label the space domain a military domain in December 2019.[6] The EU, now in the process of updating it's security agenda with the Strategic Compass also considers the space domain as essential for security.[7] And to add to the already complex picture of who is conducting space activities for whom, many commercial firms mentioned above are also offering their research and development, technology, products and services to governments and military customers.[8] Where the exploration of the space domain started as an environment for the military and to support military operations, space is now becoming a domain where commercial firms are expanding their activities much more quickly than the military worldwide are doing. The dramatic reduction of launch costs will further accelerate this development.[9]

History and working of FOBS

Although the *Financial Times* article seems to want to make the public aware of a totally new application of weapon systems in the space domain, FOBS was already considered in the 1960s as a way to exert deterrence on a geostrategic competitor. The USSR was well aware of the capabilities of the Ballistic Missile Early Warning (BMEW) radars of the US and what they were 'looking' at. Nuclear armed ballistic missiles fired at hypersonic speeds from Russia with a direct trajectory over the North Pole or from the northeast would be detected at an early moment and destroyed before impacting on US soil. These nuclear armed missiles were deemed necessary to deter the US from using its own nuclear arsenal against the USSR and Warsaw Pact countries in Europe. In 1962 the Soviets developed a way to bypass the BMEW system and were building the 'fractional orbital bombardment system' as it was called by the West. In general it consists of a rocket body partly orbiting the earth and capable of releasing its deadly load at the will of the attacker. This made it possible to attack the US from its 'blind side': the southern hemisphere. When the US expanded its radar network with improved radars and satellites capable of detecting missile launches, the surprise element was mainly lost. In 1982 under the SALT II Accords the weapons at the ready in silos at Baikonur were decommissioned.[10] Both the Chinese and Russians have taken up the challenges to renew the development of hypersonic weapons anew as the capable US missile defences are perceived to have a dual use as anti-satellite weapons.[11] This would create unwanted deterrence and even endanger the current power balance, leading the Chinese and Russians to find ways to restrict the US from using space for power projecting purposes.

6 *Press conference by NATO Secretary General Jens Stoltenberg following the meeting of the North Atlantic Council at the level of Heads of State and/or Government* (Brussels, 4 December 2019). See: https://www.nato.int/cps/en/natohq/opinions_171554.htm.

7 Daniel Fiott and Gustav Lindstrom, *Strategic Compass. New bearings for EU security and defence?* (Brussels, European Union Institute for Security Studies, 2021). See: https://www.iss.europa.eu/content/strategic-compass.

8 Sandra Erwin, 'Commercial spy satellites put Russia's Ukraine invasion in the public eye', *Space News*, 27 February 2022. See: https://spacenews.com/satellite-imaging-companies-increase-profile-as-they-track-russias-invasion-of-ukraine/.

9 Bruno Venditti, 'The Cost of Space Flight Before and After SpaceX', *Visual Capitalist*, 27 January 2022. See: https://www.visualcapitalist.com/the-cost-of-space-flight/.

10 Miroslav Gyűrösi, 'The Soviet Fractional Orbital Bombardment System Program', *Air Power Australia*, January 2010. See: http://www.ausairpower.net/APA-Sov-FOBS-Program.html.

11 Theresa Hitchens, 'Hypersonic Space Test Fuels Sino-American Arms Race', *Breaking Defense*, 21 October 2021. See: https://breakingdefense.com/2021/10/hypersonic-space-test-fuels-sino-american-arms-race/.

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Ballistic Missile Early Warning System site at Clear Air Force Station, Alaska: already in 1962 the Soviets developed a way to bypass the BMEW system and were building the 'fractional orbital bombardment system'

The use of the word 'orbit' suggests the use of space in order to circle the earth. But orbiting the earth multiple times would give away the fact that something is circling and attracts the attention of defensive systems. So a fraction of an orbit means that the space domain is being used, but only for a limited part, not a full orbit around the earth. Moreover, where ballistic missiles soar to a height of 1,000 to 12,000 kilometres above the surface of the earth, before coming down with excessive speeds, a missile used as a FOBS will cruise at an altitude of as low as approximately 150 kilometres. To reach this altitude and speed the rocket boosters of ICBM's are mostly used. This relatively low altitude results in a late ascent above the radar horizon of the defensive systems, thus resulting in a late detection. Late detection decreases the reaction time for defensive actions. Under the 1967 UN Treaty on Outer Space, under ratification by the Soviet Union, China and the US (and some 130 other countries), it is prohibited to put weapons of mass destruction into orbit or on celestial bodies (Article IV).[12] This limits the use of fully orbiting nuclear weapons whilst fractional orbiting of such systems is, with some creative reasoning, not

12 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* (New York, UN General Assembly, 19 December 1966). See: https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

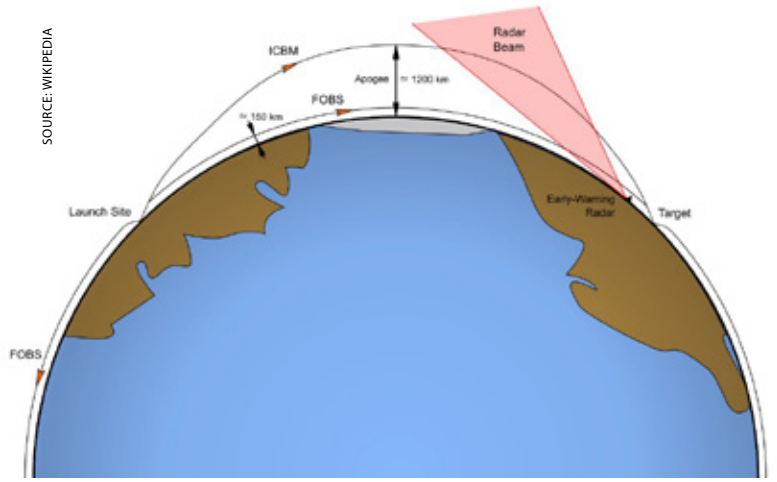

Figure 1 Fractional Orbital Bombardment System

prohibited by the Treaty. Following this reasoning a nuclear tipped FOBS weapon falls outside the Treaty and would be permitted. The trajectory of the 'classic' FOBS is rather predictable, which aids the defender a bit although the de-orbiting is at the will of the instigator of the attack. The surprise element of FOBS consists of four parts: The unexpected direction from which the attack takes place, the late visibility because of its depressed trajectory, the high speed of the missile itself and the location of de-orbit (so also where the projectile will hit the earth) which is only known to the operator of the missile. These four elements confront the defender with the challenge of overcoming the short time between detection of the missile and taking defensive actions against it.

What the Chinese did

The gradually emerging reports tell us that in July and/or August 2021 – the sources are not fully in agreement – the Chinese launched not only a missile on top of a rocket booster, but apparently it was a hypersonic glide vehicle (HGV).[13] It did a partial orbit of the earth, similar to that of a normal booster rocket propelling a satellite into space. After some time the Chinese de-orbited the object or missile, sending it back to earth, but missing its presumed objective by several dozens of kilometres.[14] Later information indicates that the test was even more complex and that the hypersonic vehicle released another vehicle that afterwards made a safe landing in China.[15] American research in 1966 was halted as the release of a projectile from a highly supersonic flying plane led to the death of the crew members.[16] The shockwave of both vehicles interfered and led to the destruction of the launching plane. So making such technology work is a considerable technological breakthrough by the Chinese. According to the Chinese themselves this was just an experiment to achieve hypersonic commercial travel into space. The spaceplane itself was presumably launched from Jiuquan and landed safely at Badajilin airport.[17] Looking at the launch number of Long March rockets there seems to be one lacking, which adds to the secrecy of what really happened.[18] So the exact events remain rather cloaked and we still have to guess what, why and how things developed during this test.

What are Hypersonic weapon systems and how mature are they?

Hypersonic weapon systems are primarily developed to decrease the time between observation by the defender and his possibility to deploy countermeasures, thus drastically

13 Sandra Erwin, 'China's hypersonic vehicle test a 'significant demonstration' of space technology', *Space News*, 22 October 2021. See: https://spacenews.com/chinas-hypersonic-vehicle-test-a-significant-demonstration-of-space-technology/.

14 Mike Wall, 'China successfully tested hypersonic weapon in August: report', *Space.com*, 18 October 2021. See: https://www.space.com/china-hypersonic-weapon-test-august.

15 Sakshi Tiwari, 'China's Missile Program Far Exceeds The Capability Demonstrated By US, Russia So Far – US Intelligence Report', *The Eurasian Times*, 25 November 2021. See: https://eurasiantimes.com/chinas-missile-program-far-exceeds-the-capability-demonstrated-by-us-russia-so-far-us-intelligence-report/.

16 Theresa Hitchens, 'China's mysterious hypersonic test may take a page from DARPA's past', *Breaking Defense*, 24 November 2021. See: https://breakingdefense.com/2021/11/chinas-mysterious-hypersonic-test-may-take-a-page-from-darpas-past/.

17 'China Says 'Hypersonic' Object Put Into Orbit Was Space Vehicle', *Bloomberg*, 18 October 2021. See: https://www.bloomberg.com/news/articles/2021-10-18/china-says-hypersonic-object-put-into-orbit-was-space-vehicle.

18 'Wat als China de hele wereld onder schot houdt?', *BNR* radio podcast, 10 November 2021. See: https://www.bnr.nl/podcast/spacecowboys/10458428/wat-als-china-de-hele-wereld-onder-schot-houdt.

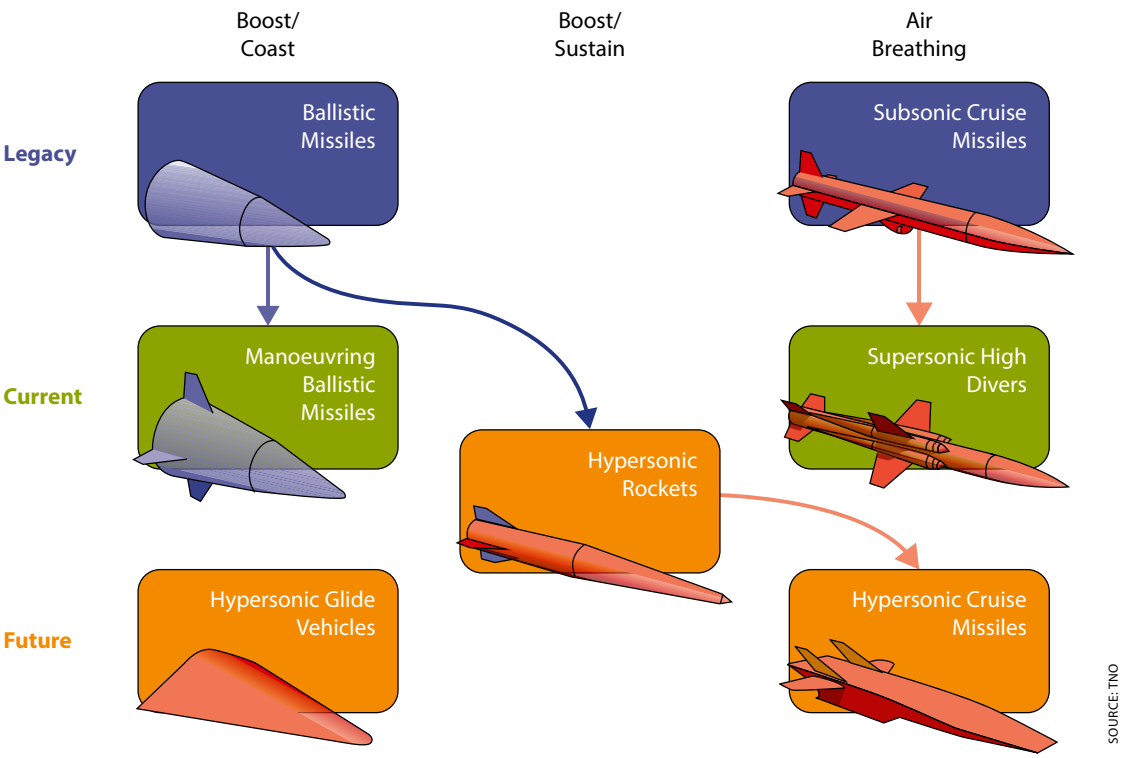

Figure 2 Overview of current hypersonic technology and developments

lowering the time available for decision making and possible retaliation. Another advantage as opposed to ballistic missiles is that the use of the (very thin) atmosphere also allows evasive maneuvers and its lower altitude for smaller boosters. Furthermore, the extreme high speeds of the missiles, when precisely aimed, require little to no explosive power to have devastating effects at the point of impact, although the terminal speeds will have been reduced to about Mach 3, due to air density at sea level. The weight not used for the warhead could be used to carry more fuel, thus adding to the speed and reach of the missile. However, lacking real explosive power requires great accuracy of the missile in order to create the desired effect at the desired point. Probably, however, these types of missiles will be armed. The weaponization can be either conventional or nuclear and will be a surprise to the attacked party. This ambiguity presents challenges of its own for the defending party. Figure 2 provides an overview of current hypersonic technology and developments and where they originate from.

There are several ways to characterize hypersonic vehicles. Generally speaking they come in two kinds, hypersonic cruise missiles and hypersonic glide vehicles. Hypersonic glide vehicles use a booster rocket to reach the required speed and altitude and then coast on top of the atmosphere as a 'glider', using the atmospere's upper layer (at an altitude of around 100 kilometres) to skip and change course. HGVs are launched by potent rocket bodies, often comparable with, or the same as those used to bring Inter Continental Ballistic Missiles (ICBMs) to an altitude of more than 1,200 kilometres above the surface of the earth at great speeds. HGVs will be launched with a more depressed angle than BMs and when the HGV itself is released from the rocket it comes back into the atmosphere, maintaining its excessive speed. When it approaches somewhat denser atmospheric conditions, it is able to maintain its high speed and maneuver in lateral directions. This capability adds a fifth surprise factor to the already challenging defence against FOBS, as the perceived point of impact remains a further mystery to the defending party.

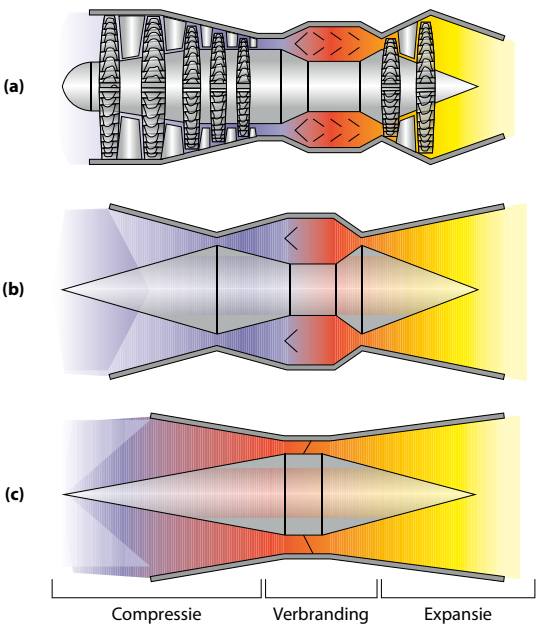

Figure 3 The three different types of engines, schematically illustrating the different internal geometry of each type

Reaching and maintaining hypersonic speeds sounds easier than it is, as most engine types (see figure 3) have their own operational velocities. For air-breathing engines, for example, a jet engine can operate from subsonic to supersonic velocities. Going faster from supersonic towards hypersonic velocities, a ramjet can operate effectively in this speed regime (from Mach 2 to Mach 6). Going into the hypersonic speeds regime above Mach 5, a scramjet is required. The downside of these engines is that the slightest change in angle of attack towards the incoming airflow might lead to engine stall. Apart from air-breathing engines, non-air breathing propulsion systems, such as solid fuel rocket motors, are also used to reach the supersonic and hypersonic regimes. The transition from one speed regime to the next and thus from one engine system to the next requires exact engineering and development. Instead of using three different engine-types, extensive research is going on in the field of the Turbine Based Combined Cycle (TBCC) which can change its internal geometry during flight to accommodate the varying speeds.

The extremely high speeds within the atmosphere come with some trade-offs. These high speeds result in extremely high temperatures within the boundary layer of air around the missiles and on the skin of the missile itself. These high temperatures may even lead to the formation of a plasma layer around the missile. Here the first problems on usability occur. The composition of the material of the projectile has to withstand these high temperatures for a prolonged time. Furthermore, any steering vanes or flaps will have to continue to operate under these high temperatures and shockwaves. These shockwaves especially influence the scramjet engine performances. On top of this, the high speeds introduce extreme dynamic pressure, resulting in gigantic lateral forces to enable maneuvering. These forces induce additional drag which costs energy, either influencing its forward speed or its altitude. HGVs losing altitude enter a more dense atmosphere, increasing friction and heat, which reduces the forward speed even further.

As for sensors, the high temperatures and the plasma layer (occuring at speeds around Mach 10 and higher) degrade their effectiveness or even make it impossible to use them. As for electromagnetic signals, these are also greatly hampered by the plasma layer, although China claims that their newly-developed 6G connectivity standard overcomes this.[19] This results in the limited ability for terminal guidance based on outside steering inputs. Probably a hypersonic vehicle will be used for static targets mainly, whose coordinates are loaded into the projectile prior to launch or re-entry into the atmosphere. The Chinese, however, seem to have experimented in order to overcome this feature and threaten to deploy their DF17 hypersonic gliders against US aircraft carriers.[20] In order to operate within the hypersonics flight regime, however, it is highly probable that they operate in an automatic and partly autonomous mode.

19 Sakshi Tiwari, 'China's new 'Super 6G tech' can penetrate Hypersonic Missile shield, boost country's near-space defense - Top Scientist', *The Eurasian Times*, 31 January 2022. See: https://eurasiantimes.com/chinas-new-super-6g-tech-can-penetrate-hypersonic-missile-shield/.

Maneuverability must not be exaggerated. Due to the laws of physics the extreme speeds and connected forces mean that a Mach 15 glider at 40 kilometres altitude drops by 2,5 kilometres to turn 30 degrees. With the US experimental HTV-2 this takes about seven minutes during which it travels along a vast arc of about 4,000 kilometres. In the meantime both the maneuver and the denser air at lower altitudes reduce the glider's speed by more than one Mach number and its range by some 450 kilometres.[21] A lot of technological problems have to be overcome in order to deploy hypersonic weapons as a useful military tool. The failed US experiments are indicators of the associated technological challenges, not only concerning the engines but also all technical hypersonics aspects.[22]

The accumulation of all characteristics leads to observation that these weapons will have the most effect when they are used against heavily defended strategic targets in order to create a shock, leading to a new, decisive phase in a battle.

State of play and international cooperation

Russia

Russia was most vocal about their progress and at the end of December 2018 claimed a huge success with their Avangard glide vehicle flying over 6,000 kilometres at Mach 27 and hitting its target in the Kamchatka province.[23] After introducing this technology in the operational units as of September 2019, presumably nuclear armed as well, Russia is the first to openly claim to have military operational hypersonic capability. According to President Putin, Russia had to develop hypersonic weapons after the US withdrawal from the Anti-Ballistic Missile Treaty in 2002 because the American Anti-Ballistic Missile shield would in future be capable of virtually neutralizing all Russian nuclear potential.[24] In the meantime, further Russian research has been conducted, which led to the 3M22 Zircon HCM to be used against big naval vessels.[25] Another development is the air-launched Kinzhal ('Dagger', Kh-47M2, mainly an air-launched Iskander BM) which can be launched by a MiG-31 aircraft and has a combined range of approximately 2000 kilometres. During the Ukraine war, started in February 2022 , it looks like so far only on the 25th day a hypersonic weapon (a Kinzhal) was employed. Allegedly it was used to strike an underground ammunition store in southwestern Ukraine. This weapon deployment raises questions about the true capabilities and current military usefulness of Russian hypersonic technology and missiles. The strategic messaging and battlefield testing which accompanied this event have probably more value than the military goal connected to this attack.

China

During the October 2020 military parade China demonstrated a considerable arsenal of hypersonic missiles of different kinds. During the summer of 2021 the experiment earlier mentioned in this article took place. At the 2019 military parade, China had already demonstrated for the first time, amongst others, numerous DF17 hypersonic glider and DF100 cruise missiles. There is international doubt about the DF100's speed and it is in general not classified as hypersonic. Undoubtedly international cooperation takes place between countries in developing hypersonic projectiles. Russia and China are known for their close

20 Kris Osborn, 'One Shot: All It Would Take For China to Sink a U.S. Aircraft Carrier?', *The National Interest*, 3 June 2021. See: https://nationalinterest.org/blog/buzz/one-shot-all-it-would-take-china-sink-us-aircraft-carrier-186698.

21 David Wright and Cameron Tracy, 'The Physics and Hype of Hypersonic Weapons. These novel missiles cannot live up to the grand promises made on their behalf, aerodynamics shows', *Scientific American*, 1 August 2021. See: https://www.scientificamerican.com/article/the-physics-and-hype-of-hypersonic-weapons/.

22 Joshua Pollack, 'Why Do US Hypersonic Missile Tests Keep Failing? They're Going Too Fast', *Defense One*, 3 January 2022. See: https://www.defenseone.com/ideas/2022/01/why-do-us-hypersonic-missile-tests-keep-failing-theyre-going-too-fast/360276/

23 Richard Stone, ''National pride is at stake.' Russia, China, United States race to build hypersonic weapons', *Science*, 8 Januari 2020. See: https://www.science.org/content/article/national-pride-stake-russia-china-united-states-race-build-hypersonic-weapons.

24 'Putin named the reason for the development of hypersonic weapons – Rossiyskaya Gazeta', *Tekdeeps*, 19 September 2020. See: https://tekdeeps.com/putin-named-the-reason-for-the-development-of-hypersonic-weapons-rossiyskaya-gazeta/.

25 Brian Wang, 'Russia Claims Mach 8 Zircon Hypersonic Missile Is Operational', *RealClear Defense*, 25 November 2017. See: https://www.realcleardefense.com/2017/11/25/russia_claims_mach_8_zircon_hypersonic_missile_is_operational_298502.html.

PHOTO ANP/EPA

A handout still image from video footage made available 19 July 2018 by the Russian Defense Ministry shows the Russian Avangard hypersonic strategic missile system equipped with a gliding hypersonic maneuvering warhead

26 Andrea Kendall-Taylor, David Shullman and Dan McCormick, Navigating Sino-Russian Defense Cooperation', *War on the rocks*, 5 August 2020. See: https://warontherocks.com/2020/08/navigating-sino-russian-defense-cooperation/; Minie Chan, 'China and Russia's push to develop hypersonic weapons raises fears of arms race with US', *South China Morning Post*, 19 January 2020. See: https://www.scmp.com/news/china/military/article/3046667/china-and-russias-push-develop-hypersonic-weapons-raises-fears.

27 Ryan Browne and Barbara Starr, 'Pentagon reveals some details of Trump's 'super duper' hypersonic missile', *CNN*, 16 July 2020. See: https://edition.cnn.com/2020/07/16/politics/pentagon-hypersonic-missile/index.html.

28 Jon Harper, 'Pentagon Want 'More Affordable' Hypersonics, *National Defense*, 29 November 2021. See: https://www.nationaldefensemagazine.org/articles/2021/11/29/pentagon-wants-more-affordable-hypersonics#:.

29 Jeremy Chin, 'US Army, Navy, Air Force, and MDA Jointly Developing Hypersonic Weapon', *Missile Threat*, 29 October 2018. See: https://missilethreat.csis.org/us-army-navy-air-force-and-mda-jointly-developing-hypersonic-weapons/.

30 'The U.S. Army's Long-Range Hypersonic Weapon (LRHW)' (Washington, D.C., Congressional Research Service, May 2022). See: https://crsreports.congress.gov/product/pdf/IF/IF11991.

31 'Department of Defense Tests Hypersonic Glide Body' (Washington, D.C., U.S. Department of Defense, 20 March 2020). See: https://www.defense.gov/News/Releases/Release/Article/2119458/department-of-defense-tests-hypersonic-glide-body/.

32 'Pentagon Official: Army, Navy Hypersonic Missiles Likely to be Fielded Soon', *Potomac Officers Club*, 18 November 2021. See: https://potomacofficersclub.com/pentagon-official-army-navy-hypersonic-missiles-likely-to-be-fielded-soon/#:~:text=A%20Department%20of%20Defense%20official,is%20expected%20to%20follow%20suit.&text=DOD%20is%20ramping%20up%20efforts,missiles%20to%20beat%20its%20adversaries.

military cooperation and probably also in this field.[26]

United States

In the Spring of 2020 President Trump boasted that the US had developed a 'super-duper weapon traveling 17 times faster than the Russians and Chinese have'.[27] This was a reaction to Russian and Chinese claims to having acquired advanced hypersonic capabilities. The US has recently decided to increase its R&D budget (in 2022) for hypersonics to 3,8 billion dollars from 3,2 in 2021 and make the research into hypersonics a top R&D priority.[28] The US Army, Navy, and Air Force are conducting their own concept development and studies into this issue, whereas the US Army seems to be the first service to operationally field such a missile.[29] The US Army (Conventional Prompt Strike project)[30] and US Navy will use the hypersonic glider concept,[31] whilst the US Air Force is developing its AGM-183 Air-Launched Rapid Response Weapon, a hypersonic scramjet powered cruise missile.[32]

North Korea and other countries

North Korea is apparently making progress, probably with the support of China's technology and knowledge.[33] In January 2022 alone North Korean leader Kim Jong Un commanded the firing of at least ten missiles at seven launches. Two of them are claimed to have been hypersonic and maneuverable.[34] India and Pakistan have their own hypersonics programmes in which Pakistan is sponsored by China and India by Russia. The cooperation between India and Russia led to the development of the short-range anti-ship supersonic missile BrahMos, which has also been sold in the region, namely to the Philippines to counter Chinese threats.[35] Currently development takes place to produce the hypersonic BrahMos II in India, a spin-off of Russia's Zircon. Australia also has its research and funding on hypersonics in place,[36] and, as expected, works in close cooperation with the US.[37] In Europe mainly France and the UK are developing advanced hypersonic capabilities.

How invincible are hypersonic weapons?

The extreme speed, low trajectory and maneuverability are seen as the best defenses of the system itself as these characteristics should reduce its visibility and thus their vulnerability. In general, detection, identification, tracking and taking action against hypersonic threats has to be done in a minimal amount of time. In combination with the lack in capable defences in the West over the past 30 years and the total neglect of the Integrated Air and Missile Defense (IAMD) landscape, a rather bleak picture arises of European and US capabilities to defend themselves against these weapons in particular.[38] Another complicating factor is that air defence is organised in a layered manner, consisting of very low level, medium level, higher level and exo-atmospheric level (midcourse and upper tier). The higher level often has its upper boundary at around 100,000 feet (some 30 kilometres) or for the Theater High Altitude Air Defence (THAAD) system up to 80 kilometrers for BMs. HGVs and HCM are designed to operate above that, whilst midcourse and upper tier ballistic defenses aim to destroy their targets well above the altitude of 100 kilometres. The operational gap between these altitudes is thus exploited by hypersonic missiles.

The launch of HGVs, however, must still be conducted with rocket boosters similar to those of ICBMs. The US Ballistic Missile Defence system consists of Space-Based Infra-Red (SBIR) detection satellites, especially designed to detect and track these ballistic rockets. The extreme heat generated by the hypersonic missiles provide for a specific heat signature, which is less detectable by the SBIR system. However, the US is studying the creation of a Low Earth Orbit (LEO) constellation of satellites to better track hypersonic vehicles (the so-called tracking layer) as they expect the thermal signature of the hypersonic missiles had better be followed by new technology.[39] Russia has presumably been testing a nuclear propelled Cruise Missile.[40] This system will probably need less booster capability and will thus be less visible for the US SBIR satellites. Detection will therefore be problematic. However, once airborne it will continuously eject radio-active gasses and

33 Gijs Moes, 'Kim Jong-un steekt hypersonische middelvinger op naar VS en buurlanden', *Trouw*, 11 January 2022. See: https://www.trouw.nl/buitenland/kim-jong-un-steekt-hypersonische-middelvinger-op-naar-vs-en-buurlanden~b834e8f3/

34 'North Korea missile tests: Photos from space released', *BBC*, 31 January 2022. See: https://www.bbc.com/news/world-asia-60193714.

35 'Philippines to buy India's BrahMos supersonic missile', *Global Security*, 14 January 2022. See: https://www.globalsecurity.org/military/library/news/2022/01/mil-220114-rfa01.htm?_m=3n%2e002a%2e3228%2eox0ao44795%2e2zp0.

36 'Australia opens hypersonic centre to support defence research', *Air Force Technology*, 26 January 2022. See: https://www.airforce-technology.com/news/australia-hypersonics-centre/.

37 'SCIFire Hypersonics', Air Force, see: https://www.airforce.gov.au/our-mission/scifire-hypersonics

38 Paul van Hooft and Lotje Boswinkel, *New HCSS report on Air and Missile Defense* (The Hague, The Hague Centre for Strategic Studies, November 2021). See: https://hcss.nl/news/new-hcss-report-on-air-and-missile-defense/.

39 Qinglin Niu et al, 'Infrared radiation characteristics of a hypersonic vehicle under time-varying angles of attack', *Chinese Journal of Aeronautics*, Vol. 32, No. 4, April 2019, pp. 861-874. See: https://www.sciencedirect.com/science/article/pii/S1000936119300512#.

40 Franz-Stefan Gady, 'Russia Reveals 'Unstoppable' Nuclear-Powered Cruise Missile', *The Diplomat*, 2 March 2018. See: https://thediplomat.com/2018/03/russia-reveals-unstoppable-nuclear-powered-cruise-missile/.

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Press conference by European Commissioners Jyrki Katainen (left) and Elżbieta Bieńkowska on the European Defence Industrial Development Programme (EDIDP) and the European Defence Fund: EU-funded research ultimately should lead to an advanced European Air and Missile Defense system

particles. Sensors to detect this radioactivity will also be available in due course, making it possible to have another tracking indicator available built-in to the 'tracking layer' LEO constellation. Although it is questionable if this type of missile moves at hypersonic speeds (probably high subsonic or low supersonic), its almost limitless energy makes it possible to remain airborne for infinite periods of time, keeping the defender continuously on his toes.

Taking hypersonic weapons down during flight poses enough challenges. A counter-missile fired 'from behind' will have a hard time overtaking the hypersonic vehicle because of its high speed. As that is practically impossible, it means that a defensive missile must come from a direction more or less ahead of the projected course. This reduces the reaction time even more. As the hypersonic projectile itself is structurally quite strong to withstand high temperatures and pressure, it is unknown if a nearby explosion will have any effect. On the other side, high thermal stresses may make the missile more vulnerable to even a 'scratch' on its surface by a direct hit, creating a weak spot where the hot air might enter the projectile head and destroy it internally. So probably a hit-to-kill missile and fragmentation missiles more effective in taking down the hypersonic projectile, are required. But it is also feasible that the shockwave of a nearby explosion will cause an engine stall, making a HCM less effective or even a harmless threat. Experiments with high power lasers are taking place, but how effective these are against already structurally strong and heated up missiles, is still unclear. Regardless of the effectiveness of counter measures, both for the use of hypersonic weapons as for the defence against them, the shortened timelines demand a high level of autonomy within the offensive and defensive systems.[41]

41 'Hypersonics and Autonomy in Near Space', April 2019. See: https://www.osti.gov/servlets/purl/1639841.

In the European Union, the Permanent Structured Cooperation on Defence (PESCO) initiative has its TWISTER project launched.[42] TWISTER stands for Timely Warning and Interception with Space-based theaTER surveillance and should become an advanced European Air and Missile Defense system, also capable of guarding against hypersonic missiles. It is still in its infancy and results will take at least 5 to 10 years to crystallize. Within the EU Defence Industrial Development Program (EDIDP) another missile defence project has been identified: Odin's Eye which stands for: multinatiOnal Development INitiative for a Space-based missilE earlY-warning architecturE.[43] It has recently started and aims to deliver a space based missile early warning (SBMEW) capability to create a situational threat awareness against ballistic and hypersonic threats. The study phase has just started and real results will take some 10 years to emerge.

Conclusions

The development of hypersonics is in full bloom. Possessing such a capability adds a certain standing to a state, underpinning state power versus geopolitical opponents and clearly is a demonstration of being a technologically advanced state, capable of exerting power over feebler states. The arms race involving hypersonics has taken flight and worldwide research and development and investments are on the rise. As the attacking side currently has the upper hand, the development of defensive systems will increase as well to counter the current asymmetry in capabilities and power.

Developments in the US, meant to make the US safer against attacks from ICBMs combined with the ending of verification regimes, have accelerated the development of new technologies by Russia and China. The need for security in the US has led to a situation where the deterrence towards Russia and China has tipped the scales. Absolute security for the US is seen as a threat to the other geopolitical players, especially Russia and China. US advanced missile defence systems, also static Aegis Ashore sites in Europa and Japan have increased the sense of vulnerability felt by Presidents Putin and Xi.[44] Distorted personal relations between world leaders further exacerbate mutual trust and fire up research into systems to change the power balance.

For the power balance, one might imagine that the current advantage the Russian Federation and China seem to have over the US might seduce them to the early use of such weapons. Next, there is quite an ambiguity concerning the use of hypersonics. They can be armed both with conventional (or none) warheads and with nuclear arms. As reaction times more or less evaporate, action for countermeasures comes under pressure which might lead to mistakes. When the defender thinks the hypersonic missile coming his way emptively contains a nuclear load, he might respond to the impact in launching (parts of) his nuclear arsenal towards the attacker. If the attacker, however, did not use nukes, the defending side started the nuclear onslaught, a position nobody wants to find himself in. If the defender does not respond with nuclear arms, but finds out he is confronted by a nuclear device, his second strike capability might be decreased considerably after the impact of the hypersonic weapon. The defender is thus faced with quite severe strategic decisions in a short period of time. Until now it looked as if the US was the only country to have the capability to project global coverage and global power. By exploiting the space domain with hypersonic weapon systems global reach has also come within the grips of the US' main competitors, Russia and China.

The military application and usability of hypersonic weapons seems not established yet and are still limited, but a state capable of

42 'Timely Warning and Interception with Space-based Theater Surveillance (TWISTER)'. See: https://pesco.europa.eu/project/timely-warning-and-interception-with-space-based-theater-surveillance-twister/.

43 Factsheet *ODINs EYE* (Brussels, European Commission, June 2021). See: https://ec.europa.eu/defence-industry-space/odins-eye_en.

44 Theresa Hitchens, 'Hypersonic Space Test Fuels Sino-American Arms Race', *Breaking Defense*, 21 October 2021. See: https://breakingdefense.com/2021/10/hypersonic-space-test-fuels-sino-american-arms-race/.

Hypersonic weapons require a rigourous redesign of the Integrated Air and Missile Defense architecture

employing such weapons creates a form of deterrence as there is currently no complete and good response to any air- and missile threats, including hypersonics. In the course of time and after more funding has been poured into R&D, production of hypersonics will become easier and cheaper and the technical hurdles of today will have been overcome. However, when the tempo of development of defensive measures exceeds that of making the weapon more potent, a new balance will be reached in which the need for extra development will have to be weighed again. Currently Russia and China seem to have the upper hand vis-a-vis the US. Momentarily no adequate defensive systems can deter the offensive use of hypersonic weapons, which might make it attractive for immediate use. However, the US still maintains a superior nuclear force with a strong second strike capability and will continue to counter the deterrence scales again.

Both the cost of hypersonic missiles as their specifics will determine their use which will be based in a doctrinal approach in order to enhance their effectiveness. Therefore, it can be reasoned that hypersonic weapons, either HGM or HGVs, with *conventional* payloads will mainly be employed during the first days of armed conflict. Its use against C2 nodes and well defended other targets of strategic value such as air defence systems are most logic. Not only is thus an operational advantage achieved, also a strategic shock (the opponent uses hypersonics, so he is serious to reach his goals) can be established. Hypersonic weapons with a *nuclear* warhead will mainly be used as a measure of last resort, to try to tilt the scales and deter further escalation. This last application might however unleash a full nuclear war if used against a peer competitor which is also nuclear capable.

Hypersonic missiles, due to their operating altitudes close the gap between the air domain and the space domain, which probably requires a new look to responsibilities and capabilities, both for the offensive side and for defence. The Von Karmán line, where the air domain and space domain (arbitrarily) have their upper and lower boundary respectively at 100 kilometres above the earth, should be no planning or responsibility divider anymore. A ballistic missile can either be that or the booster of a HGV. They require different counter measures and thus decision making procedures. As the reaction times for defensive actions are short, there should only be one agency in planning countermeasures, regardless of the weapon being a space weapon or one acting high in the atmosphere. For HCMs operating at around 40 kilometres altitude, probably a whole new defensive system has to be developed, supported by AI and placed in an overall Air and Space Defence infrastructure.

Dependency on the space domain is further increased by the development of hypersonic weapons, as timely detection, identification and warning can be almost exclusively be organised from space.[45] Detection satellites such as the new Hypersonic and Ballistic Tracking Satellite System (HBTSS) will play a crucial role in defending against hypersonic missiles.[46] But as they are the main elements of the defensive chain, the HBTSS itself will also be targeted in order to deny the US this capability. As a consequence the HBTSS should be protected and easily updated with new satellites and capabilities. This requires a responsive architecture, from operational need to development, production and launch.

45 David Vergun, 'Agency Addresses Hypersonic Vehicle Detection, Satellite Survivability' (Washington, D.C., U.S. Department of Defense, 12 January 2022). See: https://www.defense.gov/News/News-Stories/Article/Article/2897665/agency-addresses-hypersonic-vehicle-detection-satellite-survivability/.

46 Kristin Huang, 'US satellite could detect Chinese hypersonic missiles, but could it stop them?', *South China Morning Post*, 23 December 2021. See: https://www.scmp.com/news/china/military/article/3160869/us-satellite-could-detect-chinese-hypersonic-missiles-could-it.

What the Netherlands can do

In general the Netherlands, as well as NATO and the EU should put more effort in Integrated Air and Missile Defence, not only for existing threats, but also with a view to the threats as addressed in this article.

Although the Netherlands is only a small player in the defence arena when it concerns capabilities, the research and development landscape is well organised. Royal NLR and TNO, universities of Delft and Eindhoven have advanced technological knowledge and research appetite. The Netherlands participates in the EDA and EDIDP projects in order to strengthen the knowledge base further. The international cooperation brought together in the research projects mentioned further establishes a European wide understanding. This research can help find solutions to the defense challenges posed by hypersonic projectiles. A better understanding of airflows, plasma and materials will aid in finding methods for early detection and timely identification, the two first stages in the kill chain to negotiate the threats. New hypersonic wind tunnels to conduct such research should be developed and existing ones should be improved. Royal NLR already has knowledge of wind tunnels as it hosts the German-Dutch Wind tunnel (DNW) at their venue at the Noord-Oostpolder in the Netherlands.[47]

Space observation and detection should be enhanced to observe, identify, track and predict (courses) of hypersonic weapons. Thales NL with its SMART L-ER radars offers an excellent starting point for the Netherlands knowledge and industrial institutions to expand upon.

Further development of responsive space capabilities and hardening of satellites is another field where the Netherlands can work upon. Small satellites, produced in the Netherlands, a.o. by ISISpace[48] and Satellogic[49] can perform a crucial role in expanding the amount of small satellites and constellations. These knowledge and production facilities are already present in the Netherlands.

PHOTO ANP/EPA

A picture released by Xinhua News Agency shows military vehicles carrying the Chinese DF-17 hypersonic ballistic missile: currently Russia and China seem to have the upper hand in hypersonic weapons vis-a-vis the US

Furthermore, enhanced knowledge on hypersonic techniques might be beneficial in finding new modes for the launch of satellites. This would further aid in reaching responsive and autonomous access to space. Also time-sensitive strategic transport of critical assets over long distances might in future be conducted with the aid of hypersonic transport capabilities.

With a view to increasing security and safety, regulations and verification regimes should be developed, for instance by the legal department of the University of Leiden's Law Faculty which specializes in the field of Space Law. Currently faculty staff are working on an international programme to live up to previous treaties obligations.[50] Based on regulations and definitions the academics are working upon, efforts should be made to create new weapon restriction regimes and confidence building measures. ■

47 See: https://www.dnw.aero/.
48 See: https://www.isispace.nl.
49 See: https://satellogic.com.
50 See: https://www.universiteitleiden.nl/en/law/institute-of-public-law/institute-of-air-space-law/the-hague-space-resources-governance-working-group.