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HYPERSONIC WEAPONS – A TECHNOLOGICAL CHALLENGE FOR ALLIED NATIONS AND NATO?

Draft General Report

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I. INTRODUCTION

1. One of the highlights of Russian President Vladimir Putin's March 2018 State of the Nation address was the presentation of two new nuclear delivery systems, which, he claimed, could evade US anti-ballistic missile defences. About 1 ½ years later, on 27 December 2019, Russia announced that Avangard, a nuclear-armed hypersonic boost-glide weapon invulnerable to interception by any current ballistic missile defence system, had become operational.

2. Since then, hypersonic[1] weapons have received considerable attention, grabbing the headlines, and generating considerable hype. Even seasoned security experts have not been immune to this hype. Some have argued that hypersonic weapons will ignite a new arms race that promises to upend traditional strategic stability calculations (Smith, 2019). The Munich Security Report 2019 described hypersonic vehicles as "potentially game-changing weapons" that could "bypass any current missile defences and radically reduce the warning time for a targeted actor" (Munich Security Report 2019).

3. Hypersonic flight is not new, a large number of projects have been conducted in the past, including, for example the American X-15 in the 1960s, or the development of ballistic missiles. Much of the current experience regarding propulsion, aerodynamics and materials comes from hypersonic space flight. The increased attention to hypersonic flight is due to the technological progress made which now allows controlled hypersonic flight, including in the atmosphere. Addressing the issue of hypersonic weapons has taken on a sense of urgency. Russia and the People's Republic of China (PRC) appear to be moving from research and development to deployment more quickly that the United States and other Allies of this new class of weapon system which some consider to be a game changer. Funding for hypersonic programmes has significantly increased in many countries, including Russia, the PRC, and, recently the United States.

4. There are two types of hypersonic weapons: hypersonic glide vehicles (HGV) and hypersonic cruise missiles (HCM). Hypersonic glide vehicles are launched on top of a rocket booster, like those used in Intercontinental Ballistic Missiles (ICBM), which boosts the hypersonic glide vehicle to an altitude below that of the trajectory of a long-range ballistic missile (Oelrich, 2019). The weapon is then released, re-enters the upper atmosphere, and glides towards its targets at hypersonic speed, using aerodynamic lift as it descends (Sayler, 2020; Wilkening, 2019).

5. Hypersonic cruise missiles (HCM) are launched similarly to cruise missiles by using a booster rocket in their initial launch phase and then a Supersonic Combustion Ramjet (Scramjet) engine. Once the Scramjet ignites, the missile follows a cruise trajectory at a relatively constant speed and altitude (Sayler, 2020; Wilkening, 2019; MDAA, date unspecified). Hypersonic cruise missiles fly at lower altitudes (20-30 km) than hypersonic glide vehicles and have a shorter range because they must carry fuel (Klare, 2019).

6. The main advantages of hypersonic weapons are their speed, manoeuvrability, and range which makes them difficult to track, target and defeat. Combined with their high speed, the lower trajectory and their manoeuvrability results in shorter warning time for adversaries to respond. HGVs also have the potential advantage over ICBMs that their range can be significantly greater,

[1] Hypersonic speeds are typically speeds that are at least five times greater than the speed of sound, or Mach 5 (Ernst Mach was a late 19th century physicist who studied gas dynamics). The speed of sound varies depending on the temperature of the air through which the sound moves. At sea level and an air temperature of 15 degrees Celsius (59 degrees Fahrenheit) the speed of sound is 1,225 km/h (761.2 mph)

as they glide towards the target while ICBMs fall to the earth in a ballistic curve after the end of the boost phase.

7. This draft report offers a brief overview of the current state of hypersonic weapons development, including key technology and actors. Your Rapporteur also discusses possible implications of the development and deployment of hypersonic weapons for NATO and NATO Allies. The paper concludes by raising the question of the impact of hypersonic weapons for strategic stability. This draft report will be updated for the Science and Technology Committee's meeting at the 2020 Annual Session.

II. HYPERSONIC WEAPONS – STATE OF PLAY

8. Hypersonic weapons fly at speeds of Mach 5 (five times the speed of sound) or above and combine the high manoeuvrability and accuracy of a cruise missile with the long range and speed of an ICBM. Unlike normal ballistic missiles, hypersonic weapons do not follow a ballistic trajectory after their initial ballistic boost phase but travel typically in the higher atmosphere (Wilkening, 2019). They are significantly harder to track than ICBMs because their lower flight path and the curvature of the Earth delay their detection by ground-based radar. HGVs coast towards their targets in the stratosphere, 30–50 km above ground (Sayler, 2020), while a ballistic missile has a high arching path that lies mostly above the atmosphere and reaches altitudes of well over 1,000 km. Currently deployed satellite-based early warning sensors are optimised for elevations much higher than the flight paths of hypersonic weapons and ground-based missile defence radar systems can detect ICBMs from as far as 3,000 to 4,000 km. Moreover, according to Michael Griffin, Undersecretary of Defense for Research and Development at the US Department of Defense, “hypersonic targets are 10 to 20 times dimmer than what the United States normally tracks by satellites in geostationary orbit” (Vergun, 2018).

9. Another feature that makes hypersonic missiles difficult to detect by radars is that they can change their flight path after their initial ballistic boost phase - unlike an ICBM whose trajectory can be easily calculated from the missile’s powered ascent. By contrast, hypersonic weapons can be detected at launch, and possibly at several points along, but not throughout, their flight paths. As the defender cannot predict the endpoint of a hypersonic missiles leaves him with only little, if any, time to react.

10. Currently deployed ballistic missile defence interceptor systems are also not designed to operate at altitudes of the flight paths of hypersonic weapons. The interceptors of the US Aegis ship-based and the ground-based Terminal High-Altitude Area Defense (THAAD) anti-missile systems operate in the near vacuum of space but do not perform well in the thin upper atmosphere. Ground-based air defence systems, such as the US Patriot, are designed to intercept missiles with a lower flight path than hypersonic weapons (Smith, 2019). NATO’s ballistic missile defence system, which is built around the US’ European Phased Adaptive Approach (EPAA) and Aegis Ashore, is also neither designed, nor capable, to intercept hypersonic missiles.

11. Hypersonic weapons can be armed with nuclear or conventional warheads. Alternatively, hypersonic weapons can also use their immense kinetic energy, derived from their high speed, to destroy their targets.

12. As mentioned above, there are two kinds of hypersonic missiles. **Hypersonic glide vehicles (HGVs)** are launched with a booster rocket on an arching trajectory into space or the higher atmosphere where the warhead is released and glides towards the target at hypersonic speeds.

The HGV surfs on the atmosphere at an altitude below 100 km and reaches its destination by leveraging aerodynamic forces.

13. **Hypersonic Cruise Missiles (HCMs)** are launched with traditional booster rockets or from an aircraft. Once they have reached hypersonic speed the scramjet engine is activated which powers the missile to its target. Scramjet engines use air-breathing technology, i.e. they scoop up and compresses oxygen from the atmosphere and inject hydrogen fuel to create the combustion needed to travel at hypersonic speeds. Like a sub-sonic cruise missile, an HCM can change its flight path when approaching its target. The flight path of an HCM is lower than that of an HGV.

14. While hypersonic weapons have advantages over ballistic missiles, their development poses significant technological challenges. These are primarily related to the heat management, communication, manoeuvrability, and accommodation for payload and other internal systems (Claus, 2019).

15. At speeds of Mach 5 hypersonic weapons generate a lot of heat, shock, and vibration as they travel through the atmosphere (Stone, 2020). The temperatures, which can reach 2000°C or higher, and the shockwaves created by hypersonic speeds generate a sheath of superheated ionized plasma surrounding the missile that can block radio communications during the flight. This would make flight control of the missile and updating targeting data post-launch impossible. Devising a method to communicate targeting data to a missile that flies at Mach 5 or above that is surrounded by a plasma sheath is a key technical challenge in developing hypersonic weapons (Claus, 2019). Moreover, the extreme heat generated at high speed could actually change the shape of the delivery system in-flight.

16. The extreme environmental conditions of hypersonic flight put a lot of stress on the missile's guidance systems, sensors, sensor processing, communications, and electronic systems. Due to the research that has been conducted in different countries considerable progress has been achieved in addressing the engineering issues, but a lot remains to be done, particularly in the areas of advanced materials and composites.

17. In addition to the technical challenges that still need to be addressed, hypersonic weapons would rely on a reliably support system. This would require a robust intelligence, surveillance, target acquisition and reconnaissance (ISTAR) network, particularly if used in the conventional precision strike role.

18. Developing and operating an HCM is even more challenging technically than an HGV. For a scramjet to work the air introduced into the engine must already be at supersonic speed. The air-hydrogen mix is then ignited, which is technically very difficult. Operating a scramjet has been likened to "keeping a match lit in a hurricane" (Creech, 2004).

19. Moreover, while the ballistic booster of an HGV is separated outside the atmosphere the booster of an HCM is separated endo-atmospheric, i.e. in the more challenging conditions of the atmosphere.

20. The development of hypersonic technology therefore requires considerable resources and time. While China, Russia, and the United States have made a lot of progress in addressing the manifold issues, it will take several years before the technology is rife for deployment.

21. Moreover, although (offensive) hypersonic weapons offer several advantages, i.e. increased speed and range, and the ability to delay detection until late in the flight path, it is debatable if these advantages cannot be achieved with existing ballistic missiles. For example, ballistic missiles

that are launched on a depressed trajectory with manoeuvrable warheads can do almost everything claimed for hypersonic gliders (Oelrich, 2019). There are also trade-offs between these advantages. For example, there is a trade-off between speed and range for HGVs: The farther they glide the slower they become when approaching their target. There is also a trade-off between speed (and range) and manoeuvrability as the drag caused by jinking at high speed slows the missiles down significantly. Regardless, several nations consider the potential that hypersonic weapons can offer for both offence and defence worth to be evaluated.

22. Among the countries now pursuing hypersonic technology, Russia, China, and the United States are considered to have made the biggest progress towards developing and deploying these weapons. In addition, India, Australia, Japan, and France are also at various stages of studying and developing hypersonic technology, while countries such as Germany, Iran, Israel, Pakistan, South Korea, Taiwan, Singapore, Brazil, and Canada are showing signs of academic interest in the applications of hypersonic technology (Varilek, 2019; Sayler, 2020).

A. RUSSIA

23. Russia has been conducting research on hypersonic technology since the 1980s; it accelerated its efforts after the United States' withdrawal from the Anti-Ballistic Missile (ABM) Treaty in 2002. In his 2018 State of the Nation address, Russian President Vladimir Putin explicitly linked the forthcoming deployment of hypersonic weapons to the US abrogation of the ABM Treaty and the US missile defence programme. He reiterated this view in a TV interview in late February 2020 (TASS, 2020).

24. Russia perceives the United States' continued improvement, development, and deployment of anti-ballistic missile defence as a threat to its nuclear deterrent. For Moscow, hypersonic weapons are a means to restore its sense of strategic stability (Sayler, 2020), as well as assert regional dominance (Cummings, 2019).

25. Russia is currently pursuing several hypersonic weapons programmes: Avangard is a hypersonic glide vehicle capable of carrying a nuclear warhead of up to two megatons (The Guardian, 2019). It was successfully tested twice in 2016 and once in 2018 and is reported to reach a speed of Mach 20 or higher and can hit targets as much as 6,000km away. It has been tested using the SS-19 STILETTO. Russia reportedly deployed the first two Avangard systems, fitted on SS-19 STILETTOs, in December 2019 (Mizokami, 2019) although analysts are unsure if the system has actually entered service, or if it is just in advanced phases of field testing (CNN, 2019). It is unclear if Russia also plans to mount HGVs on the SS-X-30 SARMAT ICBM which is still in development and will replace the SS-18.

26. The 3M22 Tsirkon is a ship-launched HCM capable of travelling between Mach 6-Mach 8. It is capable of hitting both ground and naval targets up to a distance of 1,000 km. The most recent successful test was carried out in 2018. In December 2019, President Putin also announced that Russia will develop a ground-based version of the Tsirkon as a response to the US withdrawal from the Intermediate-range Nuclear Forces (INF) Treaty.

27. Russia has also reported that it is working on the development of a third hypersonic missile system, designed to be launched from submarines, although there is no information on this topic yet. Russia is also investing heavily in the development of new materials for hypersonic flight. According to the Russian news agency, Sputnik International, more than 40 state laboratories are doing research to find solutions to materials, communication, and propulsion systems faced in hypersonic flight (Claus, 2020).

28. While developing its own missile warning system, Russia is also helping China enhance its capability. TASS reported on 4 October 2019 that Russia is supporting China to create a missile warning system (Claus, 2020).

29. Russia is also working on the development of a system to defend against hypersonic missiles. A 15 May report of the Russian news agency TASS quoted President Vladimir Putin as saying, “Russia should develop systems against hypersonic weapons before such weapons are developed in other countries” (Claus, 2020).

30. During 2018 and 2019, Russia conducted a series of tests related to ABM interceptors. The A-235 ‘Nudol’ system is due to replace the existing A-135, providing defensive coverage to the Moscow region. The missile element of the system, the PRS-1M, is reportedly able to reach up to Mach 12 and can engage targets travelling at up to Mach 10. Moreover, according to Izvestija, Moscow is studying the development of a super long-range air-to-air missile with a splitting warhead which could be mounted on an aircraft such as the MiG 31 (Defense World Net, 2020).

B. PEOPLE’S REPUBLIC OF CHINA (PRC)

31. Since 2014, China has been engaged in the development of hypersonic technology. It has made significant progress in developing both hypersonic glide vehicles and hypersonic cruise missiles and has conducted extensive tests. According to Michael Griffin, Undersecretary of Defense for Research and Engineering of the US Department of Defense, China has completed 20 times as many hypersonic tests as the United States. (Ng, 2020). The Munich Security Conference Report 2019 noted that China was leading the way on academic research in hypersonics (Munich Security Report, 2019). The US Defense Intelligence Agency’s 3 January 2019 ‘China Military Power’ report included hypersonic technology in a list of “[o]ther areas where China is concentrating significant R&D [research and development] resources” (Claus, 2019).

32. Compared to its relatively secretive information policy on defence technology, China has been surprisingly open about its hypersonic research. Beijing has invested heavily in facilities, including sophisticated wind tunnels and shock tubes that use blast waves to study hypersonic flows. Although it is difficult to verify the official claims about the progress they have achieved, it appears that China has caught up technologically with the United States and with Russia, thanks to its considerable investments (Stone, 2020).

33. The PRC’s activities in this area are part and parcel of its efforts to modernise its armed forces to become a world class military power by 2050. The latest defence white paper of July 2019, titled *China's National Defence in the New Era,* emphasises the importance of emerging technologies for future warfare. *China's National Defence in the New Era* is a response to US strategy and signals a future positioned for geopolitical competition in the Asia-Pacific region (TSC Intelbrief, 2019). China is also increasing its capabilities in space and is likely to possess operational anti-satellite weapons within the next few years.

34. The focus of China’s hypersonic activities is on the development of medium-range conventional missiles which would complement Beijing’s deterrence capabilities. Beijing considers its nuclear deterrent, which is relatively small in comparison to that of the United States and Russia, vulnerable to a catastrophic first strike.

35. More generally, the PRC considers the US military presence in Asia and the Pacific, particularly in the South and China Seas as a threat to its security. While the People’s Liberation Army (PLA) and People’s Liberation Navy (PLAN) already have an arsenal of increasingly sophisticated anti-ship missiles, hypersonic vehicles would expand China’s anti-access/area denial

(A2/AD) capability significantly. From China's perspective, conventionally armed hypersonic weapons could prevent the United States from interfering in the areas of the Western Pacific which Beijing considers as its privileged sphere of influence. Hypersonic weapons would improve China's ability to hit high value targets like aircraft carriers as well as other US forward base units simultaneously and with very little warning (Cummings, 2019).

36. China wants the United States to conclude that the benefits to maintaining its regional interests are not worth the costs of armed confrontation. In addition, hypersonic weapons could increase China's leverage over its neighbours. In the past, Taiwan, Japan, the Philippines, and Vietnam have been targets of Chinese intimidation (Cummings, 2019).

37. China is developing both HGV and HCM technology. The Starry Sky-2 (Xing Kong-2) is a nuclear-capable HCM prototype which, according to the China Academy of Aerospace Aerodynamics (CAAA), was successfully tested in August 2018. The CAAA claims that the missile reached Mach 6 and was able to conduct complex manoeuvres (Claus, 2019). Some reports suggest that the Starry Sky-2 might become operational by 2025 (Varilek, 2019).

38. The DF-ZF (WU-14), a hypersonic glide vehicle, has been tested at least nine times since 2014 and can reportedly reach the top speed of Mach 10. US defence officials estimate that the DF-ZF has a range of approximately 1,900km. Some analysts believe the vehicle will be operational as early as 2020 (Sayler, 2020).

39. As stated above, China's hypersonic weapons programme currently focuses on shorter-range systems. Beijing is not focusing on the development of a global strike capability using an HGV. According to available open sources information there are no indications that China plans to mount its HGV on an ICBM like the DF-31A or the newer DF-41 (Claus, 2019). Shorter range missiles would be less technologically challenging to build, among others because they do not have to endure high temperatures as long (Smith, 2019).

40. The claimed success of the August 2018 Xing Kong-2 test would suggest that China has also made progress in overcoming some of the technological challenges in building an HCM (Claus, 2019).

41. China is also developing a rocket booster for its hypersonic missiles, including the medium range ballistic DF-17 (Dong Feng 17). The missile was tested twice in 2017; it has an estimated range of 1,700 to 2,400 km and can reportedly reach Mach 10. It is expected to be operational by 2020 (MDAA, 2018; Sayler, 2020). Furthermore, China has tested the DF-41 (Dong Feng 41) ICBM, which could be modified to carry a conventional nuclear-armed hypersonic glide vehicle (Sayler, 2020). There have also been uncorroborated reports that China has flight-tested a Scramjet engine (Acton, 2017).

C. THE UNITED STATES

42. The United States has been engaged in hypersonic research since the 1980s. It has resumed it activities in 2003 the context of the George W. Bush administration's Prompt Global Strike (PGS) programme that aimed at providing the United States with the capability to launch attacks against targets around the world in under an hour (Woolf, 2020). Until recently, though, the funding for US hypersonic projects has been quite limited.

43. Meanwhile, hypersonic research has become one of the R&D priorities of the US Department of Defense. Funding for the development of this technology has accordingly been increased significantly. Unlike Russia, which has already deployed the Avangard system, the US hypersonic

activities are designed to produce operational prototypes that can be used for the subsequent development of advanced tactical hypersonic weapons. Moreover, according to publicly available sources, the United States is not currently considering or developing hypersonic weapons for use with a nuclear warhead. For now, US hypersonic efforts prioritise the development of short and intermediate range conventional precision strike. This focus requires more accurate hypersonic weapons which will be more challenging technically compared to nuclear-armed weapons where accuracy is not so important (Sayler, 2020).

44. The various hypersonic technology and weapon development programmes pursued by the United States are conducted by the US Navy, US Army, and the US Air Force as well as the Defense Advanced Research Projects Agency (DARPA).

45. The US Navy and the US Army are jointly developing a Common Hypersonic Glide Body (C-HGB) that each military service will adapt to its purpose. The US Army will use the common glide body for its Long-Range Hypersonic Weapon and the US Navy for its Conventional Prompt Strike (IISS, 2020). According to public sources, the current programmes are being pursued:

46. The Intermediate Range Conventional Prompt Strike Weapon (IRCPS) programme of the US Navy focuses on the development of the C-HGB and a 34.5 inch two-stage booster. Initial operational capability of this missile is expected for 2028 when the missile will be fielded on a Virginia class submarine (Eckstein, 2020).

47. The US Army is working on the development of a land-based hypersonic missile (also known as the Long-Range Hypersonic Weapon). The goal is to develop a prototype for a missile that can eliminate enemy A2/AD and other high value targets up to 1,400 miles away. Moreover, the US Army also pursues the Advanced Hypersonic Weapon programme. The weapon, which has been tested successfully in 2011, will use boost-glide technology to carry conventional warheads at a theatre-level range (Klare, 2019).

48. Hypersonic efforts of the US Air Force originally focused on the Hypersonic Conventional Strike Weapon (HCSW - "Hacksaw") and on the AGM-183A Air-Launched Rapid Response Weapon (ARRW - "Arrow"). Both are HGVs, with the latter being launched from large aircraft (e.g. B-52s). The US Air Force has meanwhile terminated the HCSW programme to focus on the ARRW. The "Arrow" is a medium-range missile which will be capable of reaching up to Mach 20, which is considerably faster than any weapon currently in development in Russia and China. The "Arrow" project is designed to produce a prototype that will allow making informed strategy and resource decisions for future hypersonic programmes (Sayler, 2020).

49. DARPA is working on the development of technologies for tactical air-launched hypersonic boost glide systems together with the US Air Force. The longer-term activities of the US Air Force and DARPA are directed at developing the Hypersonic Air-Breathing Weapon Concept (HAWC - "Hawk"), the development of key technologies that will allow to build effective and affordable air-launched hypersonic cruise missiles (Sayler, 2020). The United States is using various medium-range rockets in order to boost its boost-glide vehicles into space, as opposed to ICBMs (Klare, 2019).

50. While most of the United States' hypersonic R&D mainly focuses on developing offensive capabilities, the United States is also working on counter-hypersonic weapons technology. In 2018, it created a new Space Development Agency, tasked with putting a network of sensors in low-earth orbit that would track incoming hypersonic missiles and direct US hypersonic attacks (Smith, 2019). Moreover, in January 2019, DARPA announced that it awarded USD13 million to

Northrop Grumman to develop the experimental "Glide Breaker" programme, which focuses on developing interceptors for hypersonic weapons (Tucker, 2020).

D. OTHER COUNTRIES

51. Since 2011, the Royal Navy and the French Navy have also been co-developing a hypersonic missile designed to replace the ageing Harpoon and Exocet missiles, respectively.

52. Australia is collaborating with the United States on a Mach 8 HGV, and India with Russia on a Mach 7 HCM. France intends to field an HCM by 2022, and Japan is aiming for an HGV in 2026, the US Congressional Research Service noted in a July 2019 report (Stone, 2020).

III. HYPERSONIC WEAPONS – ISSUES FOR NATO

53. The development of hypersonic weapons and the deployment of systems like Avangard are part and parcel of Russia's investments in new, modern military capabilities, including in modern missiles, both nuclear and conventional ones.

54. NATO Allies and partner countries are concerned about Russia's actions and posture which is challenging security and stability in the entire Euro-Atlantic area. Russia violated the Intermediate-Range Nuclear Forces (INF) Treaty with the development and deployment of the 9M729 missile system (called SSC-8 by NATO), which caused the United States to formally withdraw from the treaty in 2019. This decision was supported by all Allies. While the INF Treaty was a bilateral agreement between the United States and Russia, it was important for NATO because it eliminated all land-based intermediate-range nuclear missiles that threatened primarily European Allies.

55. The demise of the INF Treaty allows Russia to station new intermediate-range missiles on NATO's periphery. The 9M729 is a cruise missile with a range between 500 and 5,000 km that can be launched from a road-mobile launcher. At their December 2019 meeting in London, NATO Heads of State and Government agreed on a defensive, coordinated, and measured response to Moscow's action. They also decided to strengthen NATO's ability to deter and defend by further adapting the mix of nuclear, conventional, and missile defence capabilities, as necessary. In this context, it is planned to improve existing conventional air and missile defences. NATO leaders also stressed that they remain fully committed to the preservation and strengthening of effective arms control, disarmament, and non-proliferation, taking into account the prevailing security environment (NATO, 2019d).

56. The development and deployment of hypersonic weapon systems enhances Russia's strike capabilities significantly. While Avangard is a part of Russia's strategic nuclear deterrent, tactical/intermediate-range hypersonic weapons create far greater risks for European NATO member countries. Because of their speed and their ability to evade detection tactical HGVs and HCMs significantly shorten the warning time during a possible attack. A hypersonic weapon can reach a target 2,000km away in roughly the same time that a subsonic weapon can reach a target 150km away (Cummings, 2019).

57. The reduced reaction time also increases the risk for miscalculation and misunderstanding. Even if a hypersonic missile is detected shortly after launch, decision-makers would have a few minutes to consider the nature of its payload. The speed of delivery is particularly relevant during the early phases of a military conflict, and Russia might attack command and control assets.

Moreover, tactical hypersonic weapons would allow Moscow to leverage the threat of an attack against critical targets to coerce a neighbour or a NATO Ally.

58. What is more, the proliferation of hypersonic capabilities to third countries would undermine regional stability and that of NATO Allies and partners. NATO's ballistic missile defence would be incapable to intercept tactical HGVs and HCMs.

59. The deployment of Russian tactical hypersonic weapons therefore raises the question whether NATO's Integrated Air and Missile Defence system (NATO IAMD) will still be adequate. The system, which consists of a network of sensors, command and control facilities, as well as weapons systems, is designed to defend against currently deployed threats (NATO, 2019a). Hypersonic weapons could be used to take out critical components of NATO's IAMD architecture with little or no warning.

60. However, an effective defence against hypersonic weapons will depend on the ability to detect incoming missiles as early as possible and the ability to defeat incoming weapons at much longer distances than today's technology allows. Therefore, on the defence side, NATO should evaluate the technical feasibility of devising a system that can be effective against hypersonic weapons. Updating or replacing the existing technology would obviously require significant investments which would raise the question of burden and cost sharing among the Allies. With regard to the radar system, the United States is currently evaluating the possibility of deploying a system consisting of airborne high-altitude or space-based infrared tracking systems that can track hypersonic vehicles at greater ranges (Keller, 2019).

61. Moreover, NATO Allies could develop interceptors to destroy incoming hypersonic missiles either by colliding with it or by detonating a warhead in their flight path. A possible alternative are directed energy weapons such as lasers or microwave weapons which can shoot down incoming hypersonic weapons. The US Missile Defense Agency is currently evaluating the possibility to develop a space-based neutral particle beam (Stone, 2020).

62. On the offensive side, NATO Allies could consider the development and eventual deployment of hypersonic weapons. These systems could be deployed on land or mobile on sea. This could signal reassurance and resolve to NATO Allies – and thereby strengthen deterrence. Conventionally armed hypersonic weapons could enable NATO forces to tackle the A2/AD assets of potential adversaries from afar in a conflict.

63. At this point, hypersonic weapons are only a small blip on NATO's radar screen. However, hypersonic weapons can pose a qualitatively new security challenge to NATO member states. Therefore, NATO as an organisation needs to evaluate and discuss the implications of hypersonic weapons for deterrence, capability adoption, interoperability, and arms control. This also includes the proliferation of operational hypersonic systems as the availability of these weapons will clearly complicate the security environment on NATO's south-eastern and eastern flanks. Therefore, NATO should identify means to hinder their proliferation.

IV. HYPERSONIC WEAPONS AND STRATEGIC STABILITY

64. There is an ongoing debate on the impact of hypersonic weapons on strategic stability. While some consider these weapons to be a game changer, others disagree. The greatest difference between ICBM and hypersonic missiles is the manoeuvrability at low altitudes which results in an increased degree of unpredictability, as the target of an incoming hypersonic missile is

uncertain. The uncertainty of the target and their ability to manoeuvre at high speeds make it more difficult, if not impossible, to defend against an attack with hypersonic weapons. However, in the view of your rapporteur, the impact of long-range hypersonic weapons on strategic stability is only limited. There is only little, if any, advantage that strategic hypersonic weapons bring to existing nuclear arsenals. Russia already has a large number of nuclear-capable ICBMs and adding a strategic hypersonic weapon like Avangard does not fundamentally change the strategic calculus. The existing US and NATO missile defence systems are incapable of defending against an ICBM attack consisting of a large number of missiles. Allied missile defence systems are designed to intercept a very small number of ballistic missiles. As in the past, NATO's nuclear strategy is based on deterrence. Missile defence can only complement the deterrence role of nuclear weapons, it cannot substitute for it.

65. However, as outlined above, tactical hypersonic weapons can significantly increase the threat to NATO Allies because they can be inherently destabilising. Because they can reach their targets within minutes and because the reaction time is so compressed these weapons would raise the potential threat of attempted decapitation strikes during a crisis and create the pressure to "shoot first and shoot fast". The possibility of pre-emptive strikes would place NATO's air defence and its command and control infrastructure in danger.

66. The abrogation of the INF Treaty could lead to an increase in missiles and it is likely that, once they become operational, a good number of these weapons will be hypersonic ones.

67. Hypersonic weapons may also be problematic in terms of escalation control in the context of confrontation between NATO and Russia or between the PRC and the United States or partner countries Japan or South Korea. This concerns dual-capable systems, i.e. missiles that can be armed with either a conventional or a nuclear warhead. If a missile can be armed with either a conventional warhead or with a nuclear one, how should a defender react to an incoming missile? In the context of hypersonic threats, this is compounded by the reduced time available to decision-makers to respond to an incoming threat.

68. In the future Russia and China will have the capability to hit carrier groups with hypersonic missiles before their aircraft will be in range to launch airstrikes. The combat radius of current and future fighter aircraft is limited (e.g., the F-35 stealth fighter has a combat radius of up to 600 miles while hypersonic missiles are likely to have a range of approximately 1,200 miles or more). If, or rather when, China acquires an arsenal of hypersonic surface-to-surface, missiles the balance of power in the Western Pacific region would shift significantly. For example, in a confrontation over Taiwan or the South China Sea China might be tempted to launch pre-emptive strikes with conventional hypersonic weapons which could cripple US forces in the region (Stone, 2020).

69. Hypersonic technology is disruptive. The development and deployment of hypersonic weapons has the potential to upend the strategic stability that has been in place since the end of the Cold War. It would therefore be necessary to consider the option for reaching possible agreements that limit, or potentially outlaw, this class of weapons. However, while the Cold War was characterised by the power struggle between two dominant world powers, the world of today is multipolar, which will complicate reaching arms control agreements.

70. A hypersonic weapons programme can be used as leverage in pursuing arms control agreements beneficial to the security of NATO Allies. This could be analogous to the role that NATO's double track decision played in the negotiations that led to the INF Treaty. Hypersonic weapons could serve a similar purpose today in tamping the threats posed by Russian and Chinese weapons or in trade for other strategic interests. However, reaching an agreement on hypersonic weapons would require to develop, and possibly deploy, the same kind of weapons as

Russia and China. Failing this, neither Russia nor China would have an incentive to negotiate an arms control agreement. Only be developing and deploying the same capabilities will adversaries be forced to consider the negotiations seriously (Cummings, 2019).

71. Unlike conventionally armed strategic missiles hypersonic weapons do not count as strategic ballistic missiles under the New START Treaty which is up for renewal in 2021. They are new types of offensive strategic weapons which are not subject to an existing arms control regime. As the technology is maturing it is likely that hypersonic weapons will be introduced by Russia, China, and the United States in the second half of the 2020s, just as major arms control treaties are expiring and weapons proliferation is increasing.

72. The short warning times may eventually lead the major powers to introduce automated interceptor systems to a degree not previously acceptable, up to and including firing without human approval. Because of the difficulties to shoot down hypersonic weapons after launch, these weapons may invite an adversary to launch pre-emptive attacks in order to neutralise them prior to larger hostilities.

73. Although it is difficult to predict when hypersonic weapons will become fully operational, available open source information leads to conclude that this will be the case in the mid-to-late 2020. Perhaps the greatest danger is that of proliferation which will become an issue in the future. Russia or China could be tempted to selling export versions of these systems, or pass on the know-how to produce them, to third countries. Russia, for example, is already developing a hypersonic missile in cooperation with India, which has a long-standing confrontation with Pakistan, another nuclear power. The director of the Missile Defense Agency, Lt. Gen. Samuel Greaves, considers the likelihood that countries like North Korea or Iran obtain hypersonic missile technology as “extremely high” (Sherman, 2018).

74. The New START, the last major arms-control treaty still in force, was signed by the U.S. and Russia in 2010 and caps the size and number of their nuclear warheads, ICBMs and submarine-launched ballistic missiles. The treaty will expire in February 2021, unless Washington and Moscow agree to an extension. Russia has suggested it is willing to do so, and the Russian foreign ministry has said that it considers Avangard to be bound by the treaty’s missile limitations. The Trump administration has been sending mixed signals about whether it supports the renewal of the treaty or whether it would prefer creatingnew agreement to limit the proliferation of new types of weapons. China is unlikely to agree to any constraints on its ability to develop new weapons, even if they are destabilising. A new arms control regime will have to address new technologies, including hypersonics, and new actors, including China – which is both developing hypersonic weapons and fielding operational missiles with ranges that can reach Europe and the United States (NATO, 2019c).

V. PRELIMINARY CONCLUSIONS

75. A number of nations are devoting increasing attention and resources to advance research on hypersonic technology. These hypersonic programmes that are being pursued are at various stages of maturity and have, according to open source information, produced only experimental missiles, with the possible exception of the Avangard. However, it is likely that operational hypersonic weapons can be deployed in the mid-to-late 2020. An additional concern is the spread of knowledge about this technology among other nations like Iran or North Korea.

76. As outlined above, the arrival of hypersonic weapons on the battlefield is likely to have an impact only on the tactical, not the strategic field. From the perspective of NATO member states, hypersonic weapons can produce both opportunities and challenges. On the one hand, hypersonic weapons can enable to defeat enemy A2/AD capabilities which are threatening NATO Allies on Europe's north-eastern and south-eastern flanks. Therefore, hypersonic weapons would strengthen NATO's deterrence capability. On the other hand, hypersonic weapons could, if unmatched, provide an adversary with the means to coerce NATO Allies and partners in times of crisis.

77. Though it is too early to have a clear picture of the security implications of hypersonic weapons the Allies should therefore use NATO as a forum for evaluating the challenges and opportunities that these weapons generate. On the general level, the evaluation should concentrate on the implications of hypersonic weapons for NATO's deterrence posture and defensive architecture. On the practical level, NATO should help advance research on critical issues like propulsion systems, materials, Command and Contol (C2), and guidance systems. To that end, Allied nations should leverage their national research and activities by facilitating the exchange of intelligence, research, and design activities and by encouraging close cooperation among their national research programmes. The NATO Science and Technology Organisation (STO) could and should play a pivotal role in this process.

78. As the research activities of numerous nations will lead to the development and possible deployment of hypersonic weapon systems NATO Allies also need to find ways to limit the risk of proliferation. This will require both national and international measures. NATO and partner countries should examine ways to strengthen the Missile Technology Control Regime (MTCR). NATO Allies and partners should also devise measures that help to prevent the dispersion of know-how over hypersonic weapons further. This would also be in the interest of Russia, China, and the other nations that are currently developing these weapons and could be an incentive to eventually reach an agreement over an arms control treaty. This draft report will be updated for the Assembly's 2020 Annual Session.

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