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HYPERSONIC MISSILE PROLIFERATION: AN EMERGING EUROPEAN PROBLEM?

TIMOTHY WRIGHT

I. INTRODUCTION

Hypersonic boost-glide vehicles (HGVs) and hypersonic cruise missiles (HCMs) are two distinct types of missile systems, but they are often discussed synonymously as 'hypersonic missiles'. They have sometimes been characterized as an 'exotic' or 'novel' missile technology that is 'unstoppable' or a 'game-changer' for deterrence and warfighting.[1] They have also been expounded as being an exaggerated technology, unable to equal expectations.[2] These epithets and characteristics capture some of the hype (or lack thereof) around Mach 5+ systems, which can be misleading for policymakers when considering how to best respond to their development. So far, much of the analyses of this technology and its possible implications for stability have focused on competing Chinese, Russian and US programmes.[3] Although undoubtedly valuable, many of these assessments do not address the prospect and implications of hypersonic missile proliferation within regional contexts, particularly in Europe.

This oversight in focusing on Europe should be redressed for four reasons: Firstly, the details and implications of unilateral and collaborative European Mach 5+ missile programmes are typically less well-discussed than Chinese, Russian and US efforts, despite the availability of open-source material on the former. Although European research and development programmes are modest compared to those of China,

[1] Smith, R. J., 'Hypersonic missiles are unstoppable. And they're starting a new global arms race', *New York Times Magazine*, 19 June 2019; Simon, S., 'Hypersonic missiles are a game changer', *New York Times*, 2 Jan. 2020; and Oelrich, I., 'Cool your jets: Some perspective on the hyping of hypersonic weapons', Bulletin of the Atomic Scientists, 1 Jan. 2020.

[2] Oelrich (note 1).

[3] Bugos, S. and Reif, K., 'Understanding hypersonic weapons: Managing the allure and the risks', Arms Control Association, Sep. 2021.

SUMMARY

The supposed benefits of hypersonic missile technology and the reconsideration of the European security landscape following Russia's 2022 invasion of Ukraine may act as a catalyst for multiple European states to acquire or develop high-speed systems. Although these systems are currently challenging to develop, trends in other missile technology point towards a gradual diffusion of explicit and tacit knowledge that ultimately lowers production costs, resulting in greater affordability and accessibility. Coupled with inefficient non-proliferation barriers and the gradual erosion of the cold war arms control architecture, it is likely that these systems will be fielded by several European countries in the next 10 to 15 years. Reflecting this projection, this paper considers in detail various European hypersonic missile programmes and explains the applications of these systems and their possible implications for European stability, including existing technical and policy barriers that impede proliferation. In unravelling these, the paper proposes how policymakers can strengthen these mechanisms, achieve deterrence without undermining stability and better manage this emerging security issue.

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Russia and the United States, it is likely that at least two European states will possess or act as the host nation for these systems within the next 10 to 15 years. Given this projection, greater attention needs to be paid to these projects and their implications for regional stability. Secondly, although developing HGVs and HCMs is undoubtedly challenging, the prospect of technological and knowledge diffusion may mean that Mach 5+ systems could become easier to produce or more accessible to less advanced countries in the future, potentially mirroring the proliferation trends of other hitherto advanced missile technologies, such as cruise missiles.[4] Thirdly, given the very likely prospect of EU and European NATO member states revising their defence and deterrence policies in response to Russia's 2022 invasion of Ukraine, how these technologies could impact European stability must be better understood. Finally, given that many of these weapons do not fall under legally binding arms control agreements, greater attention needs to be given to understanding how states can achieve deterrence through their deployment without increasing the risk of conflict or escalatory nuclear use.

Considering this, policymakers in the European Union (EU) and member states should reflect further on the possibility and potential implications of hypersonic missile proliferation in the region. While HCMs and HGVs might provide states with a means of deterrence, their deployment in periods of competition and possible use in a conflict also creates risks. To prevent or manage these, policymakers in EU institutions and member states would benefit from a comprehensive analysis explaining the types of technology under development, their applications, and ways to mitigate risks that are distinctly associated with Mach 5+ missiles. This paper begins by briefly explaining the characteristics of hypersonic flight, HCMs and HGVs and their military applications. It proceeds by providing an overview of current hypersonic missile programmes underway in Europe and considers the possible implications for European security and stability should these missiles proliferate. In assessing how HCMs and HGVs might proliferate, the paper considers current technical barriers and the strengths and weaknesses of non-proliferation mechanisms that hinder states from developing or procuring this technology. Finally, the paper proposes policy recommendations that policymakers in the EU and member states could pursue to strengthen existing non-proliferation mechanisms and offset potential risks should HCMs and HGVs nonetheless proliferate.

[4] Vershbow, A. R., 'The cruise missile: The end of arms control?', Foreign Affairs, Oct. 1976.

II. HYPERSONIC FLIGHT, TECHNOLOGY, AND APPLICATIONS

Hypersonic missile technologies are an area of increasing focus and concern for policymakers, analysts, and the media. Although the parameters of hypersonic flight can be identified, 'hypersonic missiles' are sometimes misidentified or misunderstood.[5]

Hypersonic flight

Hypersonic flight refers to an aerodynamic phenomenon whereby an object travels at speeds greater than Mach 5 within the Earth's atmosphere. In this environment, depending on atmospheric conditions such as temperature and the object's altitude, the true airspeed of Mach 5 can vary from 4934 km/h to 6125 km/h.[6] Mach 5+ flight has a number of characteristics that separate it from subsonic (less than Mach 1) and supersonic (between Mach 1 and 5) speeds due to the creation of distinct physical effects on the vehicle's airframe when travelling beyond Mach 5. As a result of aerodynamic heating, the temperature around the travelling object's airframe can reach temperatures greater than 1000°C, depending on variables such as the vehicle's Mach number and its altitude.[7] At speeds near Mach 10, the intense heat can ionize the atoms of the surrounding air, breaking them apart and creating an electrically charged field called plasma. This generates electromagnetic forces around the vehicle which absorb radio waves, thereby at least partially blocking communications between the system and external guidance inputs, such as GPS.[8] Travelling at hypersonic speeds also generates intense stress on

[5] Smith (note 1).

[6] Brockmann, K. and Schiller, M., 'A matter of speed? Understanding hypersonic missile systems', SIPRI Topical Backgrounder, 4 Feb. 2022.

[7] Heppenheimer, T. A., *Facing the Heat Barrier: A History of Hypersonics* (US National Aeronautics and Space Administration (NASA): Washington DC, 2006).

[8] Gillman, E. D., Foster, J. E. and Blankson, I. M., 'Review of leading approaches for mitigating hypersonic vehicle communications blackout and a method of ceramic particulate injection via cathode spot arcs for blackout mitigation', US National Aeronautics and Space Administration (NASA), Feb. 2010.

the airframe due to the creation of shock waves. These distinct phenomena require engineers to develop extremely strong and specialized heat-resistant materials and components to withstand the intensely hostile environment.

Hypersonic missile taxonomy

The blanket use of the term 'hypersonic missiles' creates some problems when defining them, as some missiles and re-entry vehicles already travel beyond Mach 5 within the earth's atmosphere for portions of their flightpaths. The aerodynamic phenomena of heat and shock waves (among others), however, provide two useful preliminary criteria for identification.[9] First, as objects travelling in the vacuum of space are not subjected to these phenomena, 'hypersonic' flight must therefore by association take place within the earth's atmosphere. Although longer-range intercontinental ballistic missiles (ICBMs) travel at speeds beyond Mach 5 when they re-enter the Earth's atmosphere, they typically do so for extremely short periods of time. Depending on the warhead's re-entry angle, this can be for as little as one minute.[10] Comparatively, HGVs and HCMs spend the vast majority and entirety of their respective flightpaths within the Earth's atmosphere. Secondly, as a recent study observed, 'hypersonic is an attribute, not a thing—an adjective, not a noun'.[11] Rather than being characterized solely by their speed, some analysts have proposed that hypersonic missiles should also be defined by other characteristics, such as their ability to conduct significant cross-range manoeuvres within the Earth's atmosphere throughout their flightpaths.[12] As a practical definition, a hypersonic missile could be described as a weapon that spends most of its flightpath within the Earth's atmosphere, where it can conduct significant lateral and vertical manoeuvres while travelling at speeds greater than Mach 5. Considering these three parameters eliminates some systems which fall into a definitional grey area, such as aero-ballistic missiles and ICBM reentry vehicles, as both have limited time and/or manoeuvrability within the earth's atmosphere.[13] This leaves two distinct types of missile systems that can be classed as HGVs and HCMs. While this may be an oversimplification of the taxonomy of Mach 5+ systems—especially as engineers are likely to further develop designs that will stretch current definitions—it nonetheless provides a practical explanation of an emerging class of weapons which policymakers may attempt to address through risk mitigation measures.[14]

Hypersonic boost-glide vehicles

As with 'traditional' ballistic missiles, HGVs utilize rocket boosters for acceleration beyond the Earth's atmosphere, which is generally defined as being 80 km above the surface of the Earth, although the exact altitude is debated.[15] At this point though, the similarity between the two types of missiles ends. While 'traditional' ballistic missiles travel along arced exoatmospheric ballistic trajectories towards the target under the influence of gravity, HGVs are designed to quickly re-enter the Earth's atmosphere after separation from the booster. At this point, the glider uses aerodynamic lift generated by airflow to stay aloft and glides towards its destination.[16] A supposed benefit of HGV flightpaths is that operators can utilize this to manoeuvre vertically or laterally to evade an adversary's ground-based radar and missile defences by flying below radar horizons (thereby avoiding detection) and complicate tracking and interception by missile defences.[17] Manoeuvrability also creates target ambiguity for defenders. This means that defenders may be uncertain as to the incoming system's ultimate destination, therefore providing operators with the ability to hold large areas of an adversary's

[9] This includes other phenomena such as isentropic flows, multiple shock interactions and boundary layers. See Urzay, J., 'The physical characteristics of hypersonic flows', Center for Turbulence Research, Stanford University, July 2020.

[10] Adams, J. C., 'Atmospheric re-entry', Purdue University, June 2003.

[11] Karako, T. and Dahlgren, M., *Complex Air Defense: Countering the Hypersonic Missile Threat* (Center for Strategic and International Studies (CSIS): Washington DC, 2022), p. 8.

[12] Dunham, S. T. and Wilson, R. S., *The Missile Threat: A Taxonomy for Moving beyond Ballistic* (Aerospace Corporation: El Segundo, CA, Aug. 2020).

[13] Two examples of this are Russia's 9K720 *Iskander*-M (RS-SS-26 *Stone*) short-range ballistic missile (SRBM) and *Kinzhal* (RS-AS-24 *Killjoy*) air-launched ballistic missile (ALBM). Iskander's speed is noted as 2100 metres per second, which equates to a speed of 7560 km/h (Mach 6.1). See Arms Expo, 'Dmitry Rogozin: Iskanders will be stationed in Kaliningrad', 10 Nov. 2011, (in Russian) ; and Brown, L., 'Hypersonic missiles: Deadly weapons that fly at five times the speed of sound', *The Times*, 5 Apr. 2022.

[14] China, for instance, conducted two tests in 2021 that apparently stunned US officials due to their complexity. See Sevastopulo, D., 'China conducted two hypersonic weapons tests this summer', *Financial Times*, 21 Oct. 2021.

[15] McDowell, J. C., 'The edge of space: Revisiting the Karman Line', *Acta Astronautica*, vol. 151 (Oct. 18), pp. 668–77.

[16] HGV flight profiles can be broken down into six distinct phases: boost, ballistic, re-entry, pull-up, glide and terminal. See Tracy, C. and Wright, D., 'Modelling the performance of Hypersonic Boost-Glide Missiles', *Science & Global Security*, vol. 28, no. 3 (2020), pp. 135–70.

[17] Karako and Dahlgren (note 11), p. 8.

territory at risk throughout the missile's flight. This makes defending against HGVs harder than a standard ballistic missile, as the latter mostly travels along predetermined flight paths which can be ascertained by defenders once the missile is detected.[18]

Hypersonic cruise missiles

HCMs also share several attributes with existing types of cruise missiles. All subsonic, supersonic and hypersonic cruise missiles remain within the Earth's atmosphere for the entirety of their flight path and are powered throughout this by onboard propulsion units. This may initially involve the use of a short-burn rocket booster to launch the missile from its firing tube or launch platform.[19] However, whereas all subsonic or supersonic cruise missiles utilize either turbojet, turbofan, or more rarely, ramjet engines, to achieve their desired speed, HCMs use advanced ramjet, or more likely, scramjet (supersonic combustion ramjet) engines, to reach hypersonic speeds. A ramjet works by combusting fuel with subsonic airflow inside the engine. In a scramjet engine, combustion takes place in a supersonic airflow.[20] To achieve this, HCMs need to be equipped with rocket boosters to propel them to the appropriate transition speed whereby sustained combustion in the ramjet or scramjet engine can take place.[21]

Military applications of HCMs and HGVs

Given their dissimilar flight paths and methods of propulsion, HCMs and HGVs have different military applications. HCMs can only carry a limited amount of fuel; therefore, the emerging designs are more suited to theatre roles, as most systems have ranges that are less than 2000 km, which is similar to those of many types of existing cruise missiles.[22] Indeed, many HCMs are being envisaged to fulfil comparable roles to current cruise missiles, for instance for conducting land attack and anti-ship missions but with the advantage of a faster engagement time to complicate a defender's ability to avoid or intercept the incoming system. As such, the improved lethality and survivability of HCMs could erode the capabilities of states to project power, as their military assets would be at greater risk of being targeted and destroyed by an adversary. Almost all known HCM designs will be armed with conventional warheads, although developers can arm these with nuclear warheads if desired. Alternatively, HCMs can be designed so they can be equipped with either conventional or nuclear warheads, which is known as a 'dual-capable' weapon. In the European context, no state except for Russia currently possesses dual-capable cruise missiles.[23] One major issue is that dual-capable weapons can create warhead ambiguity and risk unintended or miscalculated escalation, as a defender might be uncertain whether the incoming system is armed with a conventional or nuclear warhead. Like existing cruise missiles, HCMs will be deployable from air, land and sea platforms.

HGVs have different military applications than HCMs, as rocket motors are less restricted by fuel constraints than ramjet or scramjet engines, thereby providing the option for HGVs to be used either in deterrence or warfighting capacities. Depending on the size of the rocket booster used to launch the glider, HGVs can have either theatre or strategic roles. Historically, intercontinental-range conventionally armed missiles have been rejected by some countries, such as the USA, as being insufficiently accurate with existing guidance technology to conduct long-range precision strikes (among other reasons).[24] However, it may be possible to develop very long-range conventionally armed HGVs that are much more accurate than their ballistic counterparts due to enhanced manoeuvrability in the terminal phase of the flight. If long-range conventionally armed HGVs were developed, it would create an entirely new weapons category. Like HCMs, HGVs can be deployed from various types of platforms and can be fitted with either conventional or nuclear warheads or be dual-capable. A designer might also choose not to fit a warhead and

[18] Rumbaugh, W. and Karako, T., *Extending the Horizon: Elevated Sensors for Targeting and Missile Defense* (Center for Strategic and International Studies (CSIS): Washington DC, Sep. 2021) .

[19] 'Technical manual Tomahawk Cruise Missile RGM/UGM109: System description', Public Intelligence, 27 Mar. 2009, p. 70.

[20] Barrie, D., 'Trends in missile technologies', IISS, 11 Mar. 2019.

[21] Airman Magazine, 'Dr. Mark Lewis: Hypersonics and the need for speed', 7 July 2021.

[22] Brockmann, K. and Stefanovich, D., 'Hypersonic boost-glide systems and hypersonic cruise missiles: Challenges for the Missile Technology Control Regime', SIPRI Report, Apr. 2022, pp. 9–10.

[23] This consists of the Kh55 family, including the nuclear-armed Kh55SM (RS-AS-15-B *Kent*) and the conventionally armed Kh555 (RS-AS22 *Kluge*).

[24] The United States assessed the feasibility of conventionally armed long-range missiles in the early 2000s but rejected the idea due to high costs and the risk of warhead ambiguity and inaccuracy. See Woolf, A. F., 'Conventional warheads for long-range ballistic missiles', Congressional Research Service, 26 Jan. 2009.

rely on the system's kinetic energy alone to destroy the target.[25]

III. EUROPEAN HYPERSONIC MISSILE PROGRAMMES

Several European states have active HCM and HGV programmes. However, differences in national priorities and the level of resources dedicated to these programmes means that there are significant disparities in their respective levels of progress. Some European states, such as Russia, already have developed and deployed hypersonic missiles, whereas others have made few inroads into the development of this technology.

Russia

Russia has conducted research and development of HGV technology since the late 1970s.[26] Although many of Russia's known hypersonic systems are revisions of older Soviet designs, its ability to revive and adapt these programmes demonstrates a utilitarian and cost-effective approach that makes use of the Russian government's concentrated investments in military research and development of new technologies.[27]

Russia's historic emphasis on aerospace technologies and its extensive defence industrial base has benefited its development and production of HCM and HGV systems. This is evident, for instance, through the availability of hypersonic wind tunnels, expertise development and the production of various types of components and equipment that are necessary for hypersonic systems, such as composite alloys, sensors and advanced fuels, liquid-fuelled and solid-propellant rocket motors, and suitable launch pads and ranges for testing purposes.[28] Considering these existing capabilities, Russian defence officials have claimed that the price of developing its hypersonic systems has not been exorbitant, costing between 70–140 billion roubles from 2001 to 2007 ($834m–1.67bn).[29] The amount that Russia spent prior to 2001 or since 2007 is unknown.

Of Russia's active hypersonic projects, the foundations of its current HGV programme were laid in 1987, when the Soviet Union began experimenting with an ICBM-range and nuclear-armed HGV named Albatros. This programme continued until budget cuts forced the project to be shelved in the early 1990s.[30] It appears that the development programme was restarted around 2004 and acted as the precursor to Russia's now deployed HGV, the RS-18 Avangard (RS-SS-19 Stiletto mod 4). Avangard is developed by the defence manufacturer NPO Mashinostroeniya, and it reached initial operational capability in 2019.[31] Since 2019, six units have been delivered to the 13th Missile Division's 621st Missile Regiment, which is based in Dombarovsky. Russia's defence ministry has stated that it plans to begin equipping another regiment with Avangard in 2022 at a rate of around two systems per year.[32] The system has a range of at least 10 000 km and is armed with a single nuclear warhead, the yield of which is unknown.[33] In the future, Avangard will also be fitted aboard Russia's new ICBM, RS-28 Sarmat (RS-SS-X-29), which Russian officials claim will be in service by the end of 2022.[34] Sarmat missiles will reportedly be capable of carrying several Avangard HGVs. Due to its survivability and limited numbers, Avangard would likely be used to destroy high-value targets, such as command and control centres.

NPO Mashinostroeniya is also developing another missile capable of travelling at Mach 5+ speeds, the 3M22 Zircon. Although the Russian media have referred to it as a hypersonic cruise missile, the system does not appear consistent with what might be expected of a HCM design.[35] Imagery analysis of a test

[25] Taylor, L. and Barrie, D., 'Hypersonics and hyperbole: The marathon to develop very-high-speed cruise missiles', IISS, 15 Mar. 2018.

[26] Dvorkin, V., 'Hypersonic threats: The need for a realistic assessment', Carnegie Moscow Center, 9 Aug. 2016.

[27] Engvall, J., 'Russia's military R&D: A primer', Swedish Defence Research Agency, Apr. 2021, p. 16.

[28] Central Aerohydrodynamic Institute, 'Wind tunnel T-117'; Aviaport, '60 Years. TsAGI – Space: Hypersonic Wind Tunnel T117', 15 Apr. 2021 (in Russian); Podvig P., 'UR100NUTTH launch from Dombarovskiy, most likely with Project 4202 payload', Russian Strategic Nuclear Forces, 25 Oct. 2016; 'Ministry of Defense: Russia has created a recipe for fuel for hypersonic aircraft', TASS, 17 Feb. 2015; and Topwar, 'Day of the Fuel Service of the Armed Forces of the Russian Federation', 17 Feb. 2018.

[29] RIA, 'Named the cost of developing the latest Russian weapons systems', 2 Nov. 2021.

[30] Raygorodetsky, A., 'Proekt MBP "Albatros" (SSSR)' [Albatross ICBM project (USSR)], Dogs of War, 15 Aug. 2011 (in Russian).

[31] 'First regiment of Avangard hypersonic missile systems goes on combat duty in Russia', TASS, 27 Dec. 2019.

[32] 'Russia to put 2nd regiment of Avangard hypersonic missiles on combat alert by yearend', TASS 11 Feb. 2022.

[33] Defense Intelligence Ballistic Missile Analysis Committee, 'Ballistic and cruise missile threat 2020', 11 Jan. 2021, p. 29.

[34] Russia 1, '"Sarmat" will ensure the security of Russia for 30–40 years', 24 Apr. 2022 (in Russian).

[35] 'Testing of Tsirkon missile about to end, supplies to begin 2022', TASS, 21 Dec. 2021

launch of Zircon during Russia's 2022 *Grom* (Thunder) strategic nuclear exercise reveals a lack of obvious air inlets that are necessary to sustain a ramjet or scramjet engine.[36] Other images purportedly of the system seem to show a front-end section that appears contrary to expected designs of an air-breathing design. These inconsistencies suggest that it is questionable whether Zircon is a true HCM. Russian officials have said Zircon will be delivered to the Russian Navy from 2022, but US defence officials believe that the system is already in service.[37,38] Zircon is thought to be capable of striking targets up to 1000 km and at speeds up to Mach 8. It was originally designed as an anti-ship missile (AShM) to be launched from the Russian Navy's Project 22530 Gorshkov-class frigate and the Project 08851 YasenM class nuclear-powered submarine with a secondary land-attack capability, although Russian President Vladimir Putin has said a ground-launched version is also forthcoming.[39] Footage released from the 2022 *Grom* exercise purportedly shows Zircon striking a shore and ground target and the system's multi-platform and targeting compatibility is consistent with other high-speed Russian and Soviet AShM designs, such as the 3M55 Oniks (RS-SS-N-26 Strobile), which was also adapted to be launched from both maritime and land platforms and strike ground and naval targets.[40'41]

Russia is also believed by US defence officials to have several classified hypersonic missile programmes underway, including systems 'which have no counterpart in the world' that incorporate 'new hypersonic warheads to expand the range of threats against the US our Allies and partners'.[42] One of these programmes may be known as Gremlin, which is allegedly an air-launched missile that utilizes an advanced ramjet engine. Few details are known about this project beyond a limited number of Russian sources.[43]

France

France is the leader of high-speed research within the EU, considering its extensive hypersonic testing infrastructure and its history of developing ramjet and scramjet engines, rocket propulsion systems, and heat- and stress-resistant materials.

France has been developing advanced propulsion systems and materials technology since at least the 1990s through government-funded programmes such as PREPHA (Programme de la Recherche pour la Propulsion Hypersonique Avancée).[44] Lessons learned from early programmes likely influenced subsequent French efforts, such as Prométhée and JAPHAR (Joint Airbreathing Propulsion for Hypersonic Application Research), both of which were vehicle concepts on hypersonic scramjet powered airtosurface missiles.[45] France has also successfully conducted research and development of advanced fuel-cooled composite materials through programmes such as PTAHSOCAR (Paroi Tissée Application Hypersonique – Simple Operational Composite for Advanced Ramjet), which would likely apply lessons learned and provide materials for future French hypersonic missile designs.[46] France has also conducted bilateral research and development on hypersonic projects, for instance with Germany on JAPHAR around 1995 and with Russia through a project known as LEA from 2003.[47] Analysts have stated LEA is an acronym for the Russian phrase for 'flight test vehicle' (which might translate as 'Летно-испытательная Автомобиль' or 'LEtno-ispytatel'naya Avtomobil' in Russian).[48] France has

[36] Wright, T., 'USSTRATCOM provides a pulse check on Chinese and Russian missile programmes', 24 Mar. 2022; and [Studio of Alexander Rogatkin, 'Firing with hypersonic Zircon from the frigate *Admiral Gorshkov*'], YouTube, 27 Feb. 2022 (in Russian).

[37] 'Russia's Tsirkon sea-launched hypersonic missile enters final stage of trials – top brass', TASS, 20 Jan. 2022,

[38] Richard, C., 'Statement of Charles A. Richard Commander United States Strategic Command' House Armed Services Committee on Strategic Forces, 1 Mar. 2022

[39] Ministry of Defence of the Russian Federation, 'The frigate Admiral Gorshkov successfully fired a hypersonic missile Zircon at a ground target', 19 July 2021; and 'Putin: Russia developing land-based version of Tsirkon hypersonic missile', TASS, 24 Dec. 2019

[40] [Studio of Alexander Rogatkin] (note 36).

[41] NPO Mashinostroeniya, 'History', 2021.

[42] Richard, C., 'Statement of Charles A. Richard Commander United States Strategic Command' House Armed Services Committee on Strategic Forces, 1 Mar. 2022.

[43] Lavrov, A., and Ramm, A., '[Hypersonic 'Su': The Russian military will receive a compact missile], 7 Oct. 2021 (in Russian).

[44] Falempin, F. et al., 'French Hypersonic Propulsion Program PREPHA: Results, lessons and perspectives', AIAA, 8th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, Apr. 1998.

[45] Moxon, J., 'Prométhée goes to second phase', Flight Global, 24 Nov. 1999; and Dessorenes, O. and Scherrer, D., 'Tests of the JAPHAR dual mode ramjet engine', Aerospace Science and Technology, vol. 9, no. 3 (Apr. 2005), pp. 211–21.

[46] Falempin, F., 'Propulsion systems for hypersonic flight', NATO, 10 May 2004.

[47] Bouchez, M. et al., 'French–Russian partnership on hypersonic wide-range ramjets', *Journal of Propulsion and Power*, vol. 17, no. 6 (Nov. 2001), pp. 1177–83.

[48] Speier, R. H., Nacouzi, G., Lee, C., and Moore, R. M., *Hypersonic Missile Proliferation: Hindering the Spread of a New Class of Weapons*

also collaborated with European partners on various hypersonic projects through the auspices of the EU, including with Belgium, Germany, Italy and the UK.[49]

Considering its current programmes, France has two known hypersonic missile projects and is pursuing both HCM and HGV technology. The former is a nuclear-armed hypersonic air-launched cruise missile known as the ASN4G (Air-Sol Nucleaire 4eme Generation), which will replace France's current nuclear-armed cruise missile, the ASMPA (Air-Sol Moyenne Portée-Amélioré), by 2035.[50] The ASN4G is being developed by ONERA in collaboration with MBDAFrance. Analysts have suggested that the system will likely have a range greater than 1000 km and will feature a scramjet engine enabling travel at speeds beyond Mach 5.[51] LEA is likely the test-engine design for the ASN4G. It appears the system has been tested several times by its developers, ONERA and MBDAFrance.[52] At least one of these tests may have taken place in Russia, as the Russian aerospace firms, Raduga and Rosoboronexport (among others), were contracted by ONERA and MBDAFrance to provide the HCM with a rocket booster adapted from a Kh22 (RS-AS-4 Kitchen) AShM, a suitable test range, and the use of a Russian Tupolev Tu22 M3 Backfire bomber aircraft from which to launch the missile.[53] Whether this test took place in Russia as planned is uncertain and the extent to which France and Russia continue to cooperate on the project is unknown, but it is highly unlikely given EU restrictions between member states and Russian defence entities. Rosoboronexport, for instance, was added to the EU's list of sanctioned entities in 2022 due to the firm's instrumental role in developing Russian military technologies.[54] The LEA programme still appears to be operational, however, as a test flight was planned to take place in the USA in 2021.[55]

ONERA is also cooperating with another French aerospace manufacturer, Ariane Group, on an experimental hypersonic glide vehicle referred to as VMAX (Véhicule Manœuvrant Experimental). Few details are known about the programme beyond its announcement by France's Defence Minister, Florence Parly.[56] France has earlier experimented with hypersonic glide designs through programmes such as the Dassault Aviation-directed VEHRA (Véhicule Hypersonique Réutilisable Aéroporté) project, however this effort had a commercial purpose.[57] If France were to eventually deploy VMAX , it is likely Ariane Group will focus on the development of the system's rocket booster, given the organization produces the booster for France's M51 submarine launched ballistic missile (SLBM), which acts as the delivery vehicle for the sea-leg of France's nuclear dyad. Which platform will launch VMAX and the system's ultimate configuration are unknown, but considering France only operates a single type of ballistic missile—the M51 SLBM—it is possible that the glider will be an intercontinental-range system equipped with a nuclear warhead.

United Kingdom

Despite overseeing several research and development projects to explore Mach 5+ propulsion in the early 2000s, most British programmes were cut by 2010 as part of the United Kingdom's reconsideration of high-speed missile technologies.[58] The UK appears to be reversing this trend, however, considering developments in adversary and ally programmes.

Trials of a collaborative Australian–British programme named Hyshot successfully tested a scramjet engine in 2002 and 2006, but a follow-up programme known as SHyFE (Sustained Hypersonic Flight Experiment) was cancelled.[59] Other programmes considered but not developed further include the Future Long-Range Cruise Missile and the Future Long-Range Deep Fires Capability. An Anglo–

(RAND Corporation: Santa Monica, CA, 2017), p. 22.

[49] European Commission, 'High-speed experimental fly vehicles – international', CORDIS, 6 Nov. 2020.

[50] Directorate General of Armaments, 'Inauguration of the new MBDA data center', 29 Mar. 2019.

[51] AirForce Technology, 'MBDA opens data centre in France for missile development', 5 Apr. 2019.

[52] Tran, P., 'French hypersonic cruise missiles: A work in progress', SLD info, 22 July 2021.

[53] Falempin, F. and Serre, L., 'French flight test program LEA status', NATO.

[54] European Council, 'Council Decision (CFSP) 2022/429', 15 Mar. 2022.

[55] Tran (note 52).

[56] French Republic, 'Déclaration de Mme Florence Parly, ministre des armées, sur la politique de défense, à Paris, le 21 janvier 2019', [Statement by Ms Florence Parly, Minister for the Armed Forces, on defence policy, in Paris, January, 21, 2019], 21 Jan. 2019 (in French).

[57] Dassault Aviation, 'La Famille de Véhicules Suborbitaux Vehra (Véhicule Hypersonique Réutilisable Aéroporté)', [The Vehra family of suborbital vehicles (airborne reusable hypersonic vehicle)], [n.d.], (in French).

[58] Barrie. D., 'UK cuts hypersonic ramjet launch test', Aviation Week, 1 Sep. 2008.

[59] Coppinger, R., 'Hyshot 3 aims for March flight', Flight Global, 7 Mar. 2006.

French collaboration to design a next-generation anti-ship and land-attack cruise missile—the Future Cruise/Anti-Ship Weapon (FC/ASW)—was agreed in 2017 and may have yielded a hypersonic design, but in early 2022 the missile's designer announced they are opting for two complementary missile concepts instead, neither of which will travel beyond Mach 5.[60] The British government is collaborating with the USA on an HGV project named Thresher which is projected to run until 2023, but no operational capability is currently envisaged.[61] As part of the AUKUS security pact, the UK announced in April 2022 that it was 'to commence new trilateral cooperation on hypersonics' with Australia and the USA.[62] British officials, however, noted that the UK would decide at a later date whether to pursue offensive systems following an assessment period.[63] This could potentially result in the UK pursuing only defensive rather than offensive systems. British defence officials have also indicated that the UK could purchase an off-the-shelf system from an international partner, such as the USA.[64] Given that the UK has been successful in procuring other restricted US missile technology, the possible British procurement of a Mach 5+ missile within the next decade is a realistic probability.

Germany

Apart from France, Germany is the only other EU member state that has conducted noteworthy research into developing technologies for Mach 5+ flight, albeit on a much more limited scale and with civilian applications in mind. Beginning in 2005, the German Aerospace Center began the SHEFEX (Sharp Edged Flight Experiment) programme to investigate the aerodynamic performance and the thermal problems of a conical re-entry vehicle that strongly resembles an HGV.[65] Two test flights of the vehicle were organized in 2005 and 2012, of which the latter was a controlled re-entry. Although follow-on programmes were envisaged, it is uncertain whether the project has continued beyond 2012.[66]

More immediately, however, media reports state that Germany is a possible host nation for future US HGV deployments to Europe, following the reactivation of the US Army 56th Artillery Command and 2nd Multi-Domain Task Force in Wiesbaden, Germany.[67] The 56th Artillery Command previously served as the headquarters for the European command's Pershing medium-range ballistic missiles (MRBMs) and its role will be to 'enable the synchronization of joint and multinational fires and command future long range surface-to-surface fires'.[68] The US Army plans for its Multi-Domain Task Forces to provide deterrence in competition and crises and strike options during conflict through the deployment and use of long-range and high-speed systems.[69] While each Multi-Domain Task Force can be tailored for specific theatre requirements, each group is expected to incorporate a strategic fires battalion which will consist of one battery of the US Army's LRHW (Long-range hypersonic weapon) HGV, among other systems.[70] The LRHW is a conventionally-armed ground-launched HGV that is in development, with a planned initial operating capability of 2023.[71] Its intended range of over 2775 km places targets across western Russia within range from potential launch sites in western Germany.[72] Whether Germany would approve of the deployment of ground-launched HGVs is currently unknown.[73]

[60] MBDA, 'UK and France advance future cruise/anti-ship weapon project', 18 Feb. 2022.
[61] Trimble, S., Norris, G. and Osborne, T., 'Hypersonic threshold', Aviation Week, 6 Apr. 2020.
[62] Prime Minister's Office, 10 Downing Street, 'AUKUS leaders' level statement: 5 April 2022', 5 Apr. 2022.
[63] Sevastopulo, D., Rathbone, J. P. and Fildes, N., 'Joe Biden announces US, UK and Australia co-operation on hypersonic weapons', *Financial Times*, 5 Apr. 2022.
[64] British House of Commons, 'Oral evidence—The Navy: Purpose and procurement, HC 168', Defence Committee, 2 Nov. 2021.
[65] German Aerospace Center, 'Controlled re-entry from space – DLR develops custom flight control system for SHEFEX II', 18 Aug. 2010.
[66] German Aerospace Center, 'Shefex Programme', Feb. 2011.
[67] Evans, M., 'American hypersonic missile plan for Europe has echoes of Cold War', *The Times*, 9 Nov. 2021; Ensor, J., 'US reactivates nuclear artillery unit in Germany—Why Russia should be worried', *The Telegraph*, 10 Nov. 2021; and Dickey C., 'Multi-domain task force activates in Wiesbaden', US Army, 17 Sep. 2021.
[68] US Army Europe and Africa, 'Media Advisory: US Army Europe and Africa reactivates the 56th Artillery Command', 3 Nov. 2021.
[69] US Army, 'Army multi-domain transformation: Ready to win in competition and conflict' Chief of Staff Paper #1, 16 Mar. 2021.
[70] US Army (note 69), p. 12.
[71] Judson, J., '"Dark Eagle" has landed: US Army finishes equipping first unit with hypersonic capability—Minus the missiles', Defense News, 7 Oct. 2021.
[72] Freedberg Jr, S. J., 'Army Discloses Hypersonic LRHW Range Of 1,725 Miles; Watch Out China', Breaking Defense, 12 May 2021.
[73] US Army, 'Army awards mid-range capability other transaction agreement', 6 Nov. 2020.

Collaborative European programmes

European states have collaboratively invested in several hypersonic programmes, each of which have explored different aspects of hypersonic flight as well as the potential commercial and military applications of this technology. Both commercial and military projects are considered, as many of the intrinsic technologies used in both are inherently dual use. Most research within the EU has been conducted through partnerships with a limited number of member states, primarily France, Germany, Italy and the UK, until its departure from the bloc in 2020. The EU has also collaborated on high-speed projects with non-member states, including Russia up until 2019. However, the amount of funding provided to these programmes is small when compared with other national efforts. Nonetheless, they demonstrate a willingness and means for collaborative development that EU states might utilize in the future.

One of the EU's earliest hypersonic endeavours, ATLLAS I (Aerodynamic and Thermal Load Interactions with Lightweight Advanced Materials for High-Speed Flight), ran from 2006 to 2009 and sought to identify and assess advanced heat-resistant and lightweight materials for vehicles travelling at speeds up to Mach 6.[74] A subsequent programme, ATLASS II, ran between 2011 and 2015 and received around €6.5 million in funding. The project incorporated 14 participants from France, Germany, Italy, Romania, Sweden and the UK and resulted in the development of several high-temperature materials that could be used for hypersonic flight.[75]

Of other EU projects, two successive projects, LAPCAT I and II (Long-Term Advanced Propulsion Concepts and Technologies) ran between 2005 and 2008, and 2008 and 2013 respectively. The purpose of these projects was to identify and evaluate advanced air-breathing engines that could be used in commercial aircraft at speeds between Mach 4 and Mach 8. The amount of funding available to LAPCAT I was around €7 million, and project partners included aerospace firms from Belgium, France, Germany, Italy and the UK.[76] LAPCAT II was a follow-up programme that ran between 2008 and 2013, and it retained two of the most promising designs from the earlier study: A Mach 5 vehicle using a turbo-ramjet and a Mach 8 airframe utilizing a hybrid scramjet.[77] The programme was able to improve the initial design of the Mach 5 aircraft proposed in LAPCAT I, resulting in the production of a detailed roadmap for developing the vehicle.[78] However, designers found that the Mach 8 concept was problematic due to high fuel consumption and limited range.[79] The programme's total budget was around €10 million, with participating firms based in Belgium, France, Germany, Italy and the UK.

Building on the LAPCAT programme, two other EU-funded programmes aimed to create new experimental hypersonic vehicles for commercial use. HEXAFLY (High-speed Experimental Fly Vehicles) ran between 2012 and 2014 to prepare the way for larger experimental flight-test platforms and to identify the risks of candidate technologies before a testing regime began. The project's total funds were less than €1 million and brought together aerospace firms from France, Germany, Italy and the UK.[80] A follow-up and broadened programme known as HEXAFLY-INT ran between 2014 and 2019 and received around €11.5 million in funding, most of which came from France and Italy.[81] Non-member states also participated in this project, with four Russian and three Australian aerospace firms contributing expertise. The project's objective was to continue earlier work from LAPCAT in establishing the viability of a Mach 5+ hypersonic glider as a passenger aircraft. The project anticipated using a modified one-stage solid-fuel rocket to boost the glider to an altitude of around 30 km, whereupon the glider would glide towards its destination, much like a military hypersonic boost-glide vehicle.[82]

HEXAFLY-INT aimed to develop commercial high-speed technology to avoid what the project report identifies as the 'great risk to allow the USA in particular to obtain a certain monopoly and control with respect to very high-speed transport'.[83] Despite

[74] European Space Agency, 'Facts and figures: Aerodynamic and thermal load interactions with lightweight advanced materials for high speed flight', [n.d.].

[75] European Commission, 'Aero-thermodynamic loads on lightweight advanced structures II', CORDIS, 1 Aug. 2019.

[76] European Commission, 'LAPCAT: Long-term advanced propulsion concepts and technologies', 5 Aug. 2009.

[77] European Space Agency, 'LAPCAT II', [n.d.].

[78] European Commission, 'Long-term advanced propulsion concepts and technologies II', CORDIS, 24 Feb. 2015.

[79] European Commission (note 78).

[80] European Commission, 'High-Speed Experimental Fly Vehicles', CORDIS, 27 Nov. 2015.

[81] European Commission, 'High-Speed Experimental Fly Vehicles – International', CORDIS, 12 June 2017.

[82] European Space Agency, 'HEXAFLY – INT: Project Final Report', 30 Sep. 2019, p. 8.

[83] European Space Agency (note 82), p. 46.

the project's commercial ambition, the appropriateness of working with Russian aerospace firms that are closely linked to its defence sector to compete with a strategic partner is questionable. One of the four Russian aerospace organizations participating in the project, the Moscow Institute of Physics and Technology (MIPT) was labelled as a Military End-User by the US Treasury in 2021 because of its production of military equipment and technology for the Russian armed forces.[84,85] MIPT was subsequently added to the Treasury's Entity List following Russia's invasion of Ukraine in 2022.[86] Other Russian organizations involved in HEXAFLY-INT are also prominent members of Russia's military–industrial complex. The Central Aerohydrodynamic Institute (TsAGI), for instance, is Russia's leading hypersonic wind tunnel tester and a regular and active participant at the International Military–Technical Forum, an annual arms fair organized by the Russian Ministry of Defence to stimulate the development of Russia's defence industry.[87] Demonstrating its intimacy to Russia's armed forces, TsAGI's Director-General remarked at the 2021 exhibition that, 'throughout its history, TsAGI has contributed to stronger national defence capability; gratifyingly, we are a part of this vital work ensuring Russia's security'.[88] Since Russia's 2022 invasion of Ukraine, the EU has sanctioned multiple Russian entities involved in the development of military aerospace technologies.[89] However, it appears that none of the Russian aerospace firms involved in HEXAFLY-INT have been targeted as of May 2022.

The inherent dual-use nature of hypersonic glider technology makes the EU's decision to partner with organizations that are closely linked to Russia's defence apparatus doubly contentious. Indeed, the project's final report noted the certainty of transfer between the military and civilian sectors, stating that 'it is clear that currently the major impetus comes from its [glide vehicle's] potential military use. It is, however, also clear that once the technology is sufficiently mastered for military application, the corresponding industries will also apply their knowledge also to the design of civil high-speed commercial transport vehicles'.[90] As dual-use products can be adapted from military–civilian applications, the reverse is also true, and the export of many technologies developed in this project to Russia are now restricted under EU sanctions that have been implemented since Russia's 2022 invasion of Ukraine, as listed in annex VII of Regulation 833/2014.[91]

IV. IMPLICATIONS FOR EUROPEAN STABILITY

Russia's invasion of Ukraine in 2022 has created a European *Zeitenwende* that might accelerate missile proliferation in Europe, either through the indigenous development of these systems by European states or their deployment in Europe by NATO allies, particularly the USA. Russia is highly likely to continue developing and deploying high-speed systems, and while the development and deployment of corresponding capabilities could provide EU member states and NATO with enhanced conventional and nuclear deterrence options, these gains need to be measured against the potential risks their deployment poses for European stability in times of competition and potentially in conflict. Against the backdrop of a more confrontational relationship between NATO and Russia, the unmanaged proliferation of Mach 5+ systems in Europe could create significant risks for regional security and stability.

Given some EU and NATO member states' interest in developing high-speed technologies and Russia's deployment of these systems, unfettered further development of these systems could exacerbate an already warming regional arms race. Following the collapse of the INF Treaty in 2019, there are no legally binding arms control agreements in Europe (or globally) that limit national or collaborative developments or deployments of any type of

[84] These are Baranov Central Institute of Aviation Motor Development (CIAM), Gromov Flight Research Institute (LII), Moscow Institute of Physics and Technology (MIPT) and The Central Aerohydrodynamic Institute (TsAGI).

[85] Federal Register, 'Addition of entities and revision of entries on the entity list; and addition of entity to the Military End-User (MEU) list', 26 Nov. 2021.

[86] Federal Register, 'Implementation of sanctions against Russia under the Export Administration Regulations (EAR)', 3 Mar. 2022.

[87] International Military–Technical Forum, 'Army 2022: General Information'.

[88] Central Aerohydrodynamic Institute, 'Army–2021: TsAGI at the Forum', 2 Sep. 2021.

[89] European Council, 'Council Decision (CFSP) 2022/429', 15 Mar. 2022.

[90] European Space Agency, 'HEXAFLY – INT: Project Final Report', 30 Sep. 2019, p. 46.

[91] European Council, 'Council Regulation (EU) 2022/328 of 25 Feb. 2022 amending Regulation (EU) No 833/2014 concerning restrictive measures in view of Russia's actions destabilising the situation in Ukraine', 25 Feb. 2022.

conventionally armed missile system.[92] Although the cost of developing HCMs or HGVs places them out of reach of many EU members for the time being, some states have both the financial and political capital needed for their development. France and increasingly the UK are either making investments in developing this technology or advocating for its acquisition, rejecting other EU members' calls for restraint.[93] Although France and the UK have both warned of the stability implications of high-speed weaponry in recent defence and security reviews, their respective ambitions to acquire hypersonic weaponry illustrates an apparent lack of a joined-up government approach specifying the role, requirements, and ramifications of developing high-speed weaponry.[94,95] How British and French policymakers will reconcile warnings that hypersonic missiles are destabilizing while at the same time making efforts to acquire them is, for the time being, unknown.

France may not be alone for long among EU member states in unilaterally developing this technology, however. German Chancellor Olaf Scholtz's vow that Germany must 'must invest much more in the security of our country' to create 'a powerful, cutting-edge, progressive Bundeswehr'[96] epitomizes the wake-up call felt in some EU and NATO member states that greater military capabilities are needed as part of a 'longer-term adaptation of NATO' to deter Russia.[97] Indeed, in addition to Germany, five other EU members—Belgium, Italy, Poland, Romania and Sweden—as well as NATO member Norway have pledged to increase defence funding as of April 2022.[98] Although these individual increases are insufficient to unilaterally afford the high costs of hypersonic missile development (except for Germany's €100 billion windfall) and new funds will likely be used to procure off-the-shelf equipment to fill existing capability gaps, greater funding and a degraded security environment might provide a means and motive for some EU and NATO states to consider strengthening collaborative Mach 5+ projects through the EU's Permanent Structured Cooperation (PESCO) or NATO's recently created DIANA (Defence Innovation Accelerator for the North Atlantic) project in response.[99] It is unlikely, however, that any indigenous European capability could be delivered within at least the next decade. Whatever acquisition decisions are made by EU member states, Russia is highly likely to continue developing and deploying new HCM and HGV systems, as indicated by President Putin and US government assessments.[100]

Beyond arms race instabilities, the advantages of HCMs and HGVs, namely their speed, survivability, manoeuvrability and ability to hold large areas of an adversary's territory at risk might create instabilities in moments of crises due to pre-emptive fears. Existing systems such as land-attack cruise missiles already somewhat provide users with this capability.[101] However, HCMs and HGVs provide an evolutionary advancement of this capability due to shorter engagement times and being harder to intercept. In a crisis, a state might be concerned that an adversary will use HCMs or HGVs to launch decapitating pre-emptive strikes. HCMs and HGVs could be used to pre-emptively strike high-value targets, such as civilian and military leadership sites, nuclear command-and-control, or nuclear forces. Should a state become concerned that pre-emptive targeting would diminish its capability to defend itself, it might pre-empt the assumed pre-emption and strike first. Russian officials have condemned the USA for pursuing what it calls 'prompt-strike non-nuclear high-precision weapons'

[92] Russia and the US appeared to be making some progress towards a Russian-proposed moratorium on restricting missile deployments of a certain range in Europe in late 2021; however, these efforts appear to have collapsed following Russia's invasion of Ukraine. See Aza, H. B. and González, M., 'US offered disarmament measures to Russia in exchange for de-escalation of military threat in Ukraine', *El País*, 2 Feb. 2022.

[93] German Federal Foreign Office, 'Speech by Foreign Minister Heiko Maas at the opening of the first Missile Dialogue Initiative', 18 Oct. 2019.

[94] British Government, 'Global Britain in a competitive age: The integrated review of security, defence, development and foreign policy', July 2021, p. 29; British Ministry of Defence, 'Defence in a competitive age', Mar. 2021, p. 9; and Ministère des Armeés, 'Strategic Update', Jan. 2021, p. 17.

[95] Brown, L. and Philip, C., 'Admiral Sir Tony Radakin warns of Russian threat at sea', *The Times*, 7 Jan. 2022; and French Republic (note 56).

[96] Bundesregierung [Federal Government], 'Regierungserklärung von Bundeskanzler Olaf Scholz am 27. Februar 2022', [Government statement by Federal Chancellor Olaf Scholz on February 27, 2022], 27 Feb. 2022 (in German).

[97] Malnick, E., 'Jens Stoltenberg: We need a beefed-up NATO to face down threats to European security', *The Telegraph*, 9 Apr. 2022 .

[98] Mackenzie, C., 'Seven European nations have increased defense budgets in one month. Who will be next?', Breaking Defense, 22 Mar. 2022.

[99] NATO, 'NATO sharpens technological edge with innovation initiatives', 7 Apr. 2022.

[100] President of Russia, 'Presidential Address to Federal Assembly', 1 Mar. 2018; and Richard, C., 'Statement of Charles A. Richard Commander United States Strategic Command' House Armed Services Committee on Strategic Forces, 1 Mar. 2022.

[101] Gormley, D. M., 'Cruise Control', Bulletin of Atomic Scientists, Mar. 2006.

which President Putin has said were 'comparable in their effect to nuclear weapons' and could be used in a 'disarming first strike'.[102,103] These assessments are concerning, as Russia's declaratory policy provides it with the option to use nuclear weapons 'in the event of aggression against the Russian Federation with the use of conventional weapons when the very existence of the state is threatened'.[104] A broad interpretation of this could potentially include decapitation strikes against Russia's leadership or undermining its nuclear deterrent. Russia has not, however, addressed how its missile programme similarly generates destabilizing implications for EU and NATO member states.

Beyond pre-emption fears, target ambiguity provides a further escalatory pathway. Russian officials have also expressed concerns that existing and future European- and NATO-deployed conventional precision-guided munitions could be used to target Russia's nuclear deterrent or its command-and-control infrastructure, thereby undermining its nuclear capability and credibility.[105] As HGVs in particular can utilize circuitous flightpaths, a defender will likely have little certainty of the detected system's ultimate target and may assume a worst-case analysis. Mixing pre-emption fears with declaratory ambiguity and target ambiguity would create a potent risk combination in a crisis—one that could push Europe closer towards the nuclear threshold in the event of a wider European conflict.

V. TECHNICAL AND POLICY BARRIERS TO HYPERSONIC PROLIFERATION

Developing HCMs and HGVs is a substantial engineering challenge which requires producers to commit significant resources and energy to their development. This creates—at least for now—development barriers that are surmountable by only a handful of technologically advanced states. Supply and norm-setting mechanisms also create roadblocks that may stymie proliferation. However, as this technology becomes less monopolized and there is a diffusion of explicit and tacit knowledge on production techniques, some of these impediments may become less challenging, thereby decreasing development costs and facilitating proliferation either through procurement or production. Although widescale horizontal and vertical proliferation is unlikely within the next decade, HCMs and HGVs are likely to proliferate beyond current possessors given the number of states seeking their development, the potential for fewer development barriers and costs, and the possibility of collaborative development. It is therefore a realistic probability to expect burgeoning proliferation in the next few decades, which would mirror trends in other hitherto advanced missile technologies. Land-attack cruise missiles, for instance, were once restricted to only a handful of nuclear weapon states but have become a mainstay in the arsenals of many regional powers and even non-state actors due to technological diffusion, the inadequate scope and implementation of export controls, and 'conditional proliferation' by some states to their allies.[106]

Financial and technical challenges

A pronounced barrier for developing either HCMs or HGVs is their sheer cost. The estimated $15 billion price of the USA's various high-speed missile programmes between 2015 and 2024 is roughly the same amount as Poland's entire 2022 defence budget.[107] Apart from France, Germany, Russia and the UK, it is unlikely that any other European state will have sufficient resources to unilaterally develop this capability. Multinational programmes coordinated through cooperative mechanisms such as PESCO, however, provide one possible means for cheaper collaborative development. This approach has already been utilized by EU member states to develop other expensive related technologies, such as the hypersonic missile defence project TWISTER (Timely Warning and Interception with Space-based TheatER).[108]

[102] Ministry of Foreign Affairs of the Russian Federation, 'Answer by Foreign Ministry Spokeswoman Maria Zakharova to a RIA Novosti question on the build-up of the United States' global missile defence system and its readiness to discuss the missile defence agenda in a dialogue with Russia', 3 May 2021.

[103] President of Russia, 'Meeting of the Valdai International Discussion Club', 22 Oct. 2015.

[104] Ministry of Foreign Affairs of the Russian Federation, 'Basic principles of state policy of the Russian Federation on nuclear deterrence', 8 June 2020.

[105] 'Russia concerned over US Prompt Global Strike concept—Russian diplomat', TASS, 15 Feb. 2016.

[106] For further discussion of 'conditional proliferation', see Alberque, W. and Schreer, B., 'AUKUS, US allies and the age of conditional proliferation', IISS, 29 Oct. 2021.

[107] Popescu, A.R., 'Poland to increase defence spending to 3% of GDP from 2023', Janes, 4 Mar. 2022.

[108] PESCO, 'Timely Warning and Interception with Space-based TheatER (TWISTER)', PESCO Projects.

Beyond costs, there are multiple technical challenges associated with producing sufficient thermal protection, accurate guidance and navigation, reliable primary and auxiliary propulsion, and stable aerodynamic surfaces that developers need to overcome. Advanced composites need to be designed to provide the missile's airframe with sufficient thermal protection from the intense heat that is generated at Mach 5+ speeds.[109] The missile's seeker also needs to be protected from heat sources, as excessive thermal loading saturates sensors and degrades a missile's ability to identify targets.[110] Developers must also overcome guidance challenges: Exiting ballistic missiles typically utilize a mixture of internal and external inputs, such as on-board accelerometers and GPS to track their position. Many cruise missiles also use these along with terrain contour matching to provide the missile with an internal map to guide it towards the target. For missiles travelling beyond Mach 5, these guidance methods become problematic, as electro-optical and radio frequency seekers may struggle to operate through plasma sheaths depending on the shape of the vehicle's airframe and sensors can become overwhelmed by intense heat and severe airframe vibrations.[111,112] Knowledge of aerodynamics and control of wedge-shaped glider technologies at Mach 5+ speeds is also much less understood than with conical ICBM reentry vehicles and maneuverable reentry vehicles (MaRVs), and numerous related test failures of HGVs have been recorded.[113] Producing efficient, reliable, and cost-effective means of primary and secondary propulsion also presents designers with substantial challenges. Scramjets only work at supersonic speeds, meaning developers will also need to develop or adapt heavy and expensive rocket boosters to provide a HCM with its initial acceleration or use aircraft capable of travelling at supersonic speeds to launch the missile. HGVs also require rocket boosters to initially launch the glider. Within Europe, only France and Russia possess sovereign launch capabilities, although the EU as a bloc has access to booster technology through the European Space Agency. Scramjet propulsion is also a substantial engineering challenge, as air needs to enter the inlet, be injected with fuel, mixed, burned and released in around one-thousandth of a second.[114] Although these challenges can be mitigated, each solution requires prospective producers to secure extra funding, conduct additional research and develop new technologies to overcome them.

Even before and, in some cases, after these components have been developed and integrated into a missile system, there are the additional challenges of ground and flight testing. This includes having access to advanced computer modelling capabilities for numerical aerodynamic evaluation, hypersonic wind tunnels to evaluate aerodynamics, intake design, the performance of propulsion systems and separation dynamics (where applicable), followed by live testing at missile test ranges. Currently, few states have access to the full suite of these testing facilities.[115] France's decision to test its LEA hypersonic cruise missile demonstrator in Russia, for instance, may have been driven by this limitation.

Political mechanisms

As well as technical barriers, there are several supply and demand-side mechanisms which could hinder regional HCM and HGV proliferation, including the Missile Technology Control Regime (MTCR), the Hague Code of Conduct (HCOC) the Wassenaar Arrangement, and EU regulations and policies. While these mechanisms have value and may prevent the proliferation of the most destabilizing types of technology, there are gaps in their adherence, application and utility that diminish their usefulness.

The MTCR is an informal political understanding of 35 states seeking to limit the proliferation of missiles and related technologies. Among its members are 18

[109] Van Wie, D. M., Drewry Jr, D. G., King, D. E. and Hudson, C. M., 'The hypersonic environment: Required operating conditions and design challenges', *Journal of Materials Science*, vol. 39 (Oct. 2004), pp. 5915–24.

[110] Hingst, U. and Koerber, S., 'IR window design for hypersonic missile seekers: Thermal shock and cooling systems', Proceedings vol. 4369, Infrared Technology and Applications XXVII (10 Oct. 2001).

[111] Reim, G., 'Plasma blackout is not a worry for USA's hypersonic missiles: Pentagon', Flight Global, 27 May 2020.

[112] Mackey, L. E., and Boyd, I. D., 'Analysis of hypersonic flow effects on sensor performance', University of Michigan, Ann Arbor, 13 June 2016.

[113] Acton, J., Dill, C. and Lewis, J., 'Crashing glider, hidden hotspring', Arms Control Wonk, 3 Sep. 2014 ; Podvig, P., 'Avangard system is tested, said to be fully ready for deployment', Russian Strategic Nuclear Forces, 26 Dec. 2018; and Majumdar, D., 'Chunks blowing away caused hypersonic vehicle crash', FlightGlobal, 23 Apr. 2012.

[114] Airman Magazine, 'Dr. Mark Lewis: Hypersonics and the need for speed', 7 July 2021.

[115] Antón, P. S. et al., 'Wind tunnel and propulsion test facilities', RAND, 2004; and Speier, R. H., Nacouzi, G. Lee, C. A., and Moore, R. M., 'Hypersonic Missile Proliferation', RAND, 2017.

EU member states and six other European nations.[116] It has no permanent secretariat, uses a voluntary rotating chair, and operates by a consensus principle. The regime encourages members to adhere to a common export policy known as the Guidelines.[117] A detailed equipment, software and technology annex defines the most sensitive technologies, including complete delivery systems and production facilities, as Category I items, the export of which are subject to an 'strong presumption of denial'.[118] This includes ballistic missiles, space launch vehicles, sounding rockets, cruise missiles, target drones, and reconnaissance drones capable of delivering a payload of at least 500 kg to a range of at least 300 km. Less sensitive and dual-use missile-related components, as well as complete missile systems capable of ranges less than 300 km regardless of payload, are considered as Category II items. The control of this equipment is less stringent than Category I items and is subject to licensing requirements and casebycase decisions which consider the non-proliferation factors specified in the MTCR Guidelines, including whether the equipment might be used for the delivery of weapons of mass destruction.[119]

Beneficially, many of the world's most advanced missile-producing nations are MTCR members.[120] The regime's comprehensive annex of defined delivery systems and subsystems is regularly updated and forms the basis for many non-subscribing states' missile export controls as well as other multilateral non-proliferation mechanisms.[121] Through its controls, the regime has notably slowed or stopped several prospective missile programmes and contributed to non-proliferation norms through the presumption of denial standard for the regime's most sensitive technologies.[122]

Despite these strengths, in an informal political understanding, the MTCR lacks the ability to impose any legally binding obligations on its members, and transfers of Category I items—although rare—have happened under a special provision whereby subscribers can transfer Category I systems if end-use assurances are made.[123] Moreover, the MTCR's membership omits several prolific missile producers, including China, Iran, North Korea, Pakistan and Taiwan. The MTCR also has membership blind spots, especially in the Middle East, where nations such as Saudi Arabia and the United Arab Emirates are seeking to develop indigenous missile production capabilities.[124] The lack of a permanent secretariat and rotational chair also means that the regime lacks an established international staff that can implement work strands in a consistent and focused way. The regime's consensus rule has also slowed decisions to expand the scope of the agreement where technological developments, for instance in uninhabited aerial vehicle (UAV) technology, have surpassed the regime's original purview.[125]

The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies provides an additional layer of supply-side restraints. The agreement applies to 42 countries—including all 27 EU member states—which voluntarily subscribe to exchange information on transfers of conventional weapons and dual-use goods and technologies.[126] Although Wassenaar creates transparency and beneficially harmonizes and strengthens export control rules, unlike the MTCR, there is no 'strong presumption of denial' underpinning the export of sensitive equipment, meaning that restraints only work if participating states' objectives align with the arrangement's aim to promote 'greater responsibility' and avoid 'destabilizing accumulations'.[127] Moreover, the requirement to notify fellow members of export denials has been criticized as providing a potential export opportunity that less-scrupulous subscribing states can capitalize on.[128]

The HCOC is a voluntary multilateral confidence-building and transparency measure aiming to curb the proliferation of ballistic missiles capable of delivering weapons of mass destruction (WMD). Its

[116] Missile Technology Control Regime, 'Partners', 2022.
[117] Missile Technology Control Regime, 'Guidelines for sensitive missile-relevant transfers', [n.d.].
[118] Missile Technology Control Regime, 'Equipment, software and technology annex', 8 Oct. 2021.
[119] Missile Technology Control Regime (note 118).
[120] Missile Technology Control Regime (note 116).
[121] United Nations Security Council, 'Ballistic missile-related transfers and activities', Resolution 2231 (2015).
[122] For a detailed list of missile programmes the MTCR has hindered, see Spector, L., 'The Missile Technology Control Regime and shifting proliferation challenges', Arms Control Association, Apr. 2018.
[123] Lewis, J., 'Storm Shadow, Saudi & the MTCR', Arms Control Wonk, 31 May 2011 .
[124] Elbahtimy, H., 'Ballistic and cruise missiles in the Middle East: The current landscape and options for arms control', IISS, 28 Jan. 2022.
[125] Alberque, W., 'Revitalising arms control: The Missile Technology Control Regime (MTCR) and the Hague Code of Conduct against Ballistic Missile Proliferation (HCoC)', IISS, Nov. 2021.
[126] Wassenaar Arrangement, 'List of dual-use goods and technologies and munitions list', Dec. 2021.
[127] Wassenaar Arrangement, 'Founding documents', Dec. 2019.
[128] Jaffer, J., 'Strengthening the Wassenaar export control regime', *Chicago Journal of International Law*, vol. 3, no. 2 (9 Jan. 2002).

membership is much wider than MTCRs, consisting of 143 subscribing states. The code does not ban the possession or trade of missiles and related technologies but sets the expectation that members 'exercise maximum possible restraint in the development, testing and deployment of ballistic missiles' and reduce stockpiles where possible.[129] It also asks states to voluntarily submit pre-launch notifications on ballistic missile and SLV launches. As a norm-setting device, the HCOC is a useful confidence-building and risk-reduction mechanism. However, it has been criticized as being progressively irrelevant given the increasingly tenuous link between WMD and ballistic missiles and failures to amend or update the Code since its inception, as originally intended.[130]

As well as international policy mechanisms and instruments, there are several EU regulations that hinder potential proliferation by member states through export controls on missile technologies, dual-use goods and technical knowledge. Some of these measures are aimed at specific countries to avoid contributing to the technological enhancement of their defence and security sectors. Several Russian aerospace firms which develop military technologies, such as Tactical Missiles Corporation JSC and NPO High Precision Systems, have been sanctioned as part of the EU's packages of sanctions in response to Russia's invasion of Ukraine.[131] Other EU regulations, such as Regulation 2021/821 of the European Parliament and Council, for instance, establish a regime 'for the control of exports, brokering, technical assistance, transit and transfer of dual-use items'.[132] The EU's regulation is unique, as it is the only regional framework for regulating dual-use goods, including 'items which can be used for the design, development, production or use of nuclear, chemical or biological weapons or their means of delivery'.[133] Beneficially, this regulation's list of controlled technologies is harmonized with other multilateral instruments, including the MTCR, Wassenaar Arrangement, the Nuclear Suppliers Group and the Australia Group. This has been helpful in providing a consistent export control list across the bloc, simplified the process of adding sometimes complex and highly technical new technologies to the list, and better aligned EU regulations with existing mechanisms, as updates to the regimes are reflected through mirrored updates to the EU's list.

129 Hague Code of Conduct, 'Text of the HCoC', Nov. 2012.

130 Alberque (note 125).

131 European Commission, 'European Union consolidated financial sanctions list', 11 Apr. 2022.

132 European Council and Parliament, 'Regulation (EU) 2021/821 of The European Parliament and of The Council of 20 May 2021', 7 Jan. 2022.

133 European Council and Parliament (note 132).

VI. CONCLUSIONS AND RECOMMENDATIONS TO MANAGE PROLIFERATION AND LIMIT INSTABILITY

The potential proliferation of HCMs and HGVs presents European policymakers with a plethora of problems with which to grapple. Some of these issues are not new, as existing regional missile proliferation and capabilities are already a concern and a challenge.[134] However, given the heightened risk of confrontation between Russia and EU and NATO states and the interest in many European capitals to acquire enhanced precision-strike capabilities for greater deterrence against Russia, further consideration and management needs to be given to this emerging security issue. Therefore, in light of the gravity and potential repercussions of hypersonic missile technology in Europe, to follow are eight recommendations for the EU, the European Commission, and EU member states and member state policymakers to consider.

First, EU member state policymakers should encourage their Russian and US counterparts to continue their discussions of the capabilities and effects of high-speed technology through the recently discontinued Strategic Stability Dialogue (SSD) at the earliest possible opportunity.[135] Through its two working groups, the SSD provides a valuable mechanism for the US and Russia to discuss the challenges and opportunities of incorporating emerging missile technologies—some of which will very likely be deployed in Europe—in future arms control agreements.[136] The New Strategic Arms Reduction Treaty (New START) expires in 2026. Arms control has never been easy, particularly on the contentious issue of non-strategic weaponry, and any attempt to incorporate new technologies within a new agreement beyond already-limited Russian and US

134 Futter, A., 'Explaining the nuclear challenges posed by emerging and disruptive technology: A primer for European policymakers and professionals', EU Non-Proliferation and Disarmament Consortium, Non-proliferation and disarmament paper, no. 73 (Mar. 2021).

135 Detsch, J. and Gramer, R., 'Biden Halts Russian Arms Control Talks Amid Ukraine Invasion', Foreign Policy, 25 Feb. 2022 .

136 These are the Working Group on Principles and Objectives for Future Arms Control and the Working Group on Capabilities and Actions with Strategic Effects, see Bugos, S., 'US, Russia establish strategic stability groups', Arms Control Today, Nov. 2021.

strategic systems will require repeated and sustained engagement through the SSD between now and 2026 if this is to be successful.

Second, EU member states considering developing or acquiring HCM or HGV capabilities, or both, should conduct thorough national cross-departmental assessments of the need, purpose, and implications of these systems before making acquisition decisions. This assessment should account for what specific missions HCMs or HGVs would be used for, whether there are identifiable capability gaps that can be filled with other possible missiles and the risks and implications of procuring or developing high-speed systems for regional stability and security. Doing so would beneficially harmonize sometimes conflicting national policy positions on acquiring high-speed technologies and hopefully limit acquisition decisions that are made without adequate attention to national requirements and regional consequences.

Third, individual national assessments could also be reinforced by multilateral activities organized through the Commission which would provide opportunities for member states to discuss and raise concerns about the implications of regional missile programmes. A series of technical workshops organized by Germany and the Commission between 2019 and 2020 considered a range of emerging technologies and could act as a jumping-off point for a follow-up workshop series focused on hypersonic weaponry.[137] These workshops could consider current and planned regional capabilities, the implications and risks arising from these and potential policy measures in response. Ideally, a new workshop series would include delegations from EU member states but also experts and stakeholders from industry and research, whose presence was lacking in the 2019–20 series. The presence of these individuals would provide member states with a wide range of views and expertise that would benefit discussions and subsequent actions developed by the Commission.

Fourth, the EU should promote transparency among its members by urging European states to be clearer about the nature and purposes of their military HGV and HCM programmes with competitors in exchange for reciprocal information. This could include providing technical information about the system and its associated doctrine. Missiles in search of a mission or those tied to open-ended counterforce doctrines might provide operators with some deterrence benefits due to ambiguity, but they also create risk and uncertainty for competitors and adversaries through possible misunderstandings and miscalculations. Providing information on the capability and roles of these systems would help to ease some of these concerns. A key consideration would be to ensure the retention of sensitive information, so classified bilateral or multilateral briefings would be the most appropriate setting to conduct this.

Fifth, the European Commission should utilize its legislative powers and develop a unilateral declaration to be adopted by all EU member states that renounces developing dual-capable HCMs and HGVs. Warhead ambiguity on existing ballistic and cruise missiles already creates risks for miscalculated escalation in Europe and elsewhere.[138] However, when this is combined with depressed reaction times (especially in a theatre environment) and target ambiguity, these risks are heightened even further. While all known European systems deployed or under development appear to have either clear nuclear or conventional roles, the issuance of declaratory statements clearly outlining the intended warhead of the system would be a helpful and beneficial risk reduction measure. The USA's Hypersonics Development Strategy is a potential model that could be adapted for EU purposes.[139] Should sufficient European states sign on to such an agreement, it could build momentum and opportunities for the EU to engage and persuade other non-regional states to also commit to this measure. Although a political statement would lack the transparency, efficacy and determinability of a verification regime, it is likely to be more achievable in the current security environment than securing a legally binding agreement.

Sixth, the EU Council should agree by consensus that no member state will develop long-range conventionally armed HCMs and HGVs and subsequently leverage the European External Action Service to promote a global ban on the development, testing, deployment and use of such systems. If conventionally armed HGVs are accurate enough to deliver a payload across strategic ranges with the same

[137] European Commission, 'Emerging technologies: Developments in the context of dual-use export controls', 9 Sep. 2021.

[138] Lewis, J., La Boon, D. J. and Everleth, D., 'China's growing missile arsenal and the risk of a "Taiwan missile crisis"', Nuclear Threat Initiative, 18 Nov. 2020.

[139] US Department of Defense, 'Defense officials outline hypersonics development strategy', 27 Feb. 2021.

level of accuracy as a modern conventional cruise missile, countries would be subjected to a qualitatively new type of threat. Not only would these systems be extremely difficult to defend against, but they would also allow states to conduct strategic strikes their adversaries below the nuclear threshold that could risk escalation in a conventional conflict. Although a global ban on a particular type of missile is undoubtedly ambitious, policymakers should try to restrict this type of technology before it is fielded, as states will likely be much more reluctant to renounce it once it is in service.

Seventh, given the current security environment in Europe, the European Commission should broaden its range of sanctions to include additional Russian entities that are involved in the development and production of dual-use missile technologies. A number of Russian entities involved in the production and development of civilian and military missile and rocket technologies remain outside of EU sanctions that have been adopted since Russia's 2014 and 2022 invasion of Ukraine. Given that many hypersonic (as well as subsonic and supersonic) technologies developed by these entities have both civilian and military applications—and that some missiles produced by these firms have been used against military and civilian targets in Ukraine—the Commission should consider adding these entities to its sanctions list.[140]

The eighth, and final, recommendation advises that EU member states and the EEAS should work in coordination to consider possible means to reform and revitalize existing non-proliferation instruments such as the MTCR and HCOC to better respond to existing and emerging missile threats. Both valuable mechanisms need addressing to stay relevant in an era of rapid technological change, and both EU policymakers and analysts in member states have made valuable suggestions for how this can be achieved.[141]

To conclude, achieving or even contemplating non-proliferation and arms control measures appears to be particularly daunting and potentially even naïve while Russian forces are conducting an unprovoked invasion of Ukraine, especially as other arms control efforts, such as the bilateral Russian–US SSD, have ground to a halt.[142] However, it is precisely for these reasons that arms-control and risk-reduction measures should be sought in order to manage and reduce the possibility of uncontrollable arms cascades in Europe in times of competition and to lower the risk of miscalculation in the event of a conflict.

[140] For an example of how dual-use components originating from EU member states are used in Russian missile systems see Watling, J. and Reynolds, N., Operation Z: The Death Throes of an Imperial Delusion (Royal United Services Institute for Defence and Security Studies (RUSI): London, Apr. 2022), p. 12.

[141] Deutsche VN–Vertretung Wien [German UN Mission Vienna], 'Erklärung von Botschafter Däuble, HCoC–Jahrestreffen 2018', [Statement by Ambassador Däuble, HCoC Annual Conference 2018], 29 May 2018 (in German) ; Alberque (note 125); Brockmann and Stefanovich (note 22); and Delory, S., 'Ballistic missiles and conventional strike weapons: Adapting the HCoC to address the dissemination of conventional ballistic missiles', HCOC Research Papers, no. 6 (Jan. 2020).

[142] Chernenko, E., 'We didn't think Russia was bluffing', Kommersant, 26 Feb. 2022 (in Russian).

ABBREVIATIONS

DIANA	Defence Innovation Accelerator for the North Atlantic
EEAS	European External Action Service
EU	European Union
GPS	Global positioning system
HCM	Hypersonic cruise missile
HCOC	Hague Code of Conduct
HEXAFLY-INT	High-speed experimental fly vehicles - international
HGV	Hypersonic boost-glide vehicle
ICBM	Intercontinental ballistic missile
INF Treaty	Intermediate-Range Nuclear Forces Treaty
LEA	Letno-ispytatel’naya Avtomobil (flight test vehicle)
MaRV	Maneuverable reentry vehicle
MRBM	Medium-range ballistic missile
MTCR	Missile Technology Control Regime
NATO	North Atlantic Treaty Organization
New START	New Strategic Arms Reduction Treaty
PESCO	Permanent Structured Cooperation
SLBM	Submarine-launched ballistic missile
SSD	Strategic Stability Dialogue
WMD	Weapon of mass destruction

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A EUROPEAN NETWORK

In July 2010 the Council of the European Union decided to support the creation of a network bringing together foreign policy institutions and research centers from across the EU to encourage political and security-related dialogue and the long-term discussion of measures to combat the proliferation of weapons of mass destruction (WMD) and their delivery systems. The Council of the European Union entrusted the technical implementation of this Decision to the EU Non-Proliferation Consortium. In 2018, in line with the recommendations formulated by the European Parliament the names and the mandate of the network and the Consortium have been adjusted to include the word 'disarmament'.

STRUCTURE

The EU Non-Proliferation and Disarmament Consortium is managed jointly by six institutes: La Fondation pour la recherche stratégique (FRS), the Peace Research Institute Frankfurt (HSFK/ PRIF), the International Affairs Institute in Rome (IAI), the International Institute for Strategic Studies (IISS), the Stockholm International Peace Research Institute (SIPRI) and the Vienna Center for Disarmament and Non-Proliferation (VCDNP). The Consortium, originally comprised of four institutes, began its work in January 2011 and forms the core of a wider network of European non-proliferation and disarmament think tanks and research centers which are closely associated with the activities of the Consortium.

MISSION

The main aim of the network of independent non-proliferation and disarmament think tanks is to encourage discussion of measures to combat the proliferation of weapons of mass destruction and their delivery systems within civil society, particularly among experts, researchers and academics in the EU and third countries. The scope of activities shall also cover issues related to conventional weapons, including small arms and light weapons (SALW).

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