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FACTORING RUSSIA INTO THE US–CHINESE EQUATION ON HYPERSONIC GLIDE VEHICLES

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SUMMARY

● Hypersonic glide vehicles are a growing factor in strategic stability calculations. Given their speed, precision and manoeuvrability, these systems are well suited to defeating missile defences. Despite the growing number of countries pursuing these capabilities, the focus on how these systems affect strategic stability tends to be at the bilateral level, which misses the inherent complexity of this emerging field of technological competition and escalation.

This SIPRI Insights Paper seeks to take the current dyadic approach to US–Chinese competition in the field and to insert Russia as a factor that is shaping China's views on the subject. Presenting the key takeaways from 872 of 1675 surveyed Chinese-language texts, the author reviews more than a decade of research on hypersonic and boost-glide technologies, revealing a growing Chinese interest in Russia. Combining this trend with both countries' shared concerns over US missile defences suggests that it is time to start factoring in how Russia's calculations on its own prompt global strike programme might shape China's decisions on future nuclear and conventional payloads, and the targets and range of its own hypersonic glide vehicle programme.

I. Introduction

Hypersonic glide vehicles are a growing factor in strategic stability calculations. These systems are characterized by speed, precision and manoeuvrability, which can be applied to defeat missile defences. Traditional calculations of strategic stability rely on the ability to undermine an opponent's nuclear deterrent capability, and hypersonic glide vehicles are seen as providing this assurance.[1] On reaching near space, the systems are ejected from their missile boosters to begin their glide phase, during which they can accelerate to upwards of Mach 5 or 6138 kilometres per hour. The glide phase allows them to manoeuvre aerodynamically to evade interception and extends the range of their booster missiles. Unlike conventional re-entry vehicles, which follow a predictable ballistic trajectory, hypersonic glide vehicles are almost impossible to intercept using conventional missile defence tracking systems.

Given these technical attributes, it is little wonder that a number of countries (including nuclear and non-nuclear powers), such as China, Germany, India, Israel, Japan, Pakistan, Russia and the United States, are thought to be developing hypersonic or glide-oriented capabilities or both.[2] Nonetheless,

[1] For more on the US conventional prompt global strike programme, which is thought to be driving a number of similar advances in China and Russia, see Woolf, A. F., *Conventional Prompt Global Strike and Long-range Ballistic Missiles: Background and Issues,* Congressional Research Service (CRS) Report for Congress R41464 (US Congress, CRS: Washington, DC, 24 Feb. 2016).

[2] European Space Agency, 'Fast20XX (Future high-altitude high-speed transport 20XX)', 2 Oct. 2012, <http://www.esa.int/Our_Activities/Space_Engineering_Technology/FAST20XX_Future_High-Altitude_High-Speed_Transport_20XX>; Gallagher, S., 'German space researchers reboot effort to launch hypersonic space plane', Ars Technica, 15 Aug. 2015, <http://arstechnica.com/science/2015/08/german-space-researchers-reboot-effort-to-launch-hypersonic-space-plane>; and Japan Aerospace Exploration Agency (JAXA), 'JAXA's Hypersonic Turbojet has been successfully operated in Mach 4 propulsion wind tunnel experiments', 20 June 2014, <http://www.aero.jaxa.jp/eng/research/frontier/hst/news140620.html>. Xiao Song, Tan Zhisi, Wang Hong and Li Zhizhun are affiliated with China's Air Force Radar Institute. 肖松, 谭贤四, 王红, 李志淮 [Xiao, S., Tan, Z., Wang, H. and Li, Z.], '国外临近空间高超声速飞行器探测系统研究' [Foreign near-space hypersonic flight vehicle detection systems], 飞航导弹 [*Winged Missile Journal*], no. 6 (June 2012), pp. 28–31. Wang Peiguang, Liu Yongji and Wang Jun are affiliated with China's Aerospace University Science and Engineering Department and the Chengdu Aircraft Planning Institute. 王佩广, 刘永绩, 王浚 [Wang, P., Liu, Y. and Wang, J.], '高超声速飞行器综合热管理系统方案探讨' [Hypersonic flight vehicles' comprehensive heat regulation systems], 中国工程科学 [*China's Engineering Sciences*], [n.d.]. Li Shuguang is affiliated with the Capital Aerospace Machinery Company. 李曙光 [Li, S.], '国外高超音速飞行器现状及有关工艺技术研究' [The state of foreign hypersonic aircraft and related technological research], 航天制造技术 [*Aerospace Manufacturing Technology*], no. 6 (Dec. 2007), pp. 3–5.

current analyses of the intersection between these systems and strategic stability tend to fixate on bilateral dynamics. This dyadic approach to strategic stability tends to overlook how multiple countries are interacting as part of a greater set of interlocking security relations. It also leads to what Dr Pavel Podvig at the United Nations Institute for Disarmament Research and the Programme on Science and Global Security at Princeton University has described as a series of arbitrary calculations and assumptions about what will result in strategic stability.[3]

While an analysis of the strategic stability relations among all these countries is beyond the scope of this paper, it seeks to open the aperture on these dynamics by factoring Russia into the US–Chinese discussion and to pave the way for more nuanced multilateral discussions. To do so, the author presents the key takeaways from 872 Chinese-language texts on hypersonic glide vehicles that mention Russia. These constitute 52 per cent of the total number of Chinese articles and papers on hypersonic glide vehicles available to the author from open sources. Section II uses this analysis to provide an overview of the growing intersection between China's and Russia's strategic postures and threat perceptions. Section III discusses the key technologies related to payloads and targeting. Section IV provides an overview of postural debates within China on rapid response and asymmetry. Section V offers conclusions on how to integrate a more nuanced multilateral framework into analyses of hypersonic glide vehicles and strategic stability.

II. The China–Russia strategic nexus

In addition to technological advances, the timing of China's flight test of its DF-ZF (previously designated as the WU-14) in April 2016 served as a further sign of the importance of integrating Russia into the discourse on US–Chinese strategic stability calculations. This hypersonic glide vehicle test was reportedly a success, and occurred just days after Russia carried out its own test. Its proximate timing to that of Russia recalls China's previous flight tests, which often came on the heels of those conducted by the USA. This is more than mere coincidence. A review of more than a decade of Chinese writing on hypersonic and boost-glide technologies reveals growing interest in and research on Russia's hypersonic glide vehicle programme.[4] Combining this trend with both countries' shared concerns over US missile defences suggests that it is time to start factoring in how Russia's calculations on its own prompt global strike programme might shape China's decisions

[3] Podvig, P., 'The myth of strategic stability', *Bulletin of the Atomic Scientists*, 31 Oct. 2012.

[4] Zhang Shaofang, Wu Kunlin and Zhang Hongna are affiliated with the China Haiying Science and Technology Information Institute. 张绍芳, 武坤琳, 张洪娜 [Zhang, S., Wu, K. and Zhang, H.], '俄罗斯助推滑翔高超声速飞行器发展' [Russia's boost-glide hypersonic flight development], 飞航导弹 [*Winged Missile Journal*], no. 3 (Mar. 2016), pp. 20–22. Zhang Lingjun, Qin Daguo and Yuan Yuqing are affiliated with the Department of Graduate Management and Space Command at the Equipment Academy of China. 张令军, 秦大国, 袁玉卿 [Zhang, L., Qin, D. and Yuan, Y.], '基于精确打击体系的卫星系统及其发展探析' [Analysis of satellite systems based on precision strike systems and their evolution], 装备学院学报 [*Journal of Equipment Academy*], no. 6 (June 2015), pp. 58–62. '俄罗斯多管齐下反制美国PGS计划' [Russia's multi-pronged plan to counter US PGS], *Conmilit*, [n.d.], pp. 71–74. Wang Jinyun and Wei Sujun are affiliated with the 368 Factory of the China Shipbuilding Industry Corporation. 王金云, 魏素军 [Wang, J. and Wei, S.], '美俄未来高超声速飞航导弹技术发展动向' [Future US and Russian hypersonic manoeuvrable missile technology development], 飞航导弹 [*Winged Missile Journal*], no. 9 (Sep. 2012), pp. 25–29.

on future nuclear and conventional payloads, targets and the range of its own hypersonic glide vehicle.

Russia and China are not simply linked by China's increased interest in Russia's hypersonic glide developments. China's renaming of its Second Artillery Corps as the People's Liberation Army Rocket Force (PLARF) and the publication of its 2015 Military Strategy White Paper also hint at a growing convergence.[5] The full implications of this name change and restructuring, which seemingly mirror Russia's own Strategic Rocket Force, are as yet unclear. Yet, there is an emerging similarity between the two forces. The PLARF commands all three legs of China's nuclear triad and is now thought to be on an equal footing with the ground, naval and air forces of the People's Liberation Army (PLA). While China's 2015 Military White Paper may not be as specific as Russia's 2015 Military Doctrine, it emphasizes a similar vision of a global revolution in military affairs tied to long-range, precise, smart, stealthy and unmanned weapons in both outer space and cyberspace.

Despite these intersecting trends, a gap remains between China and Russia on strategic stability (战略稳定). A literature review of Chinese-language analyses of hypersonic glide vehicles reveals that only 4 per cent make reference to strategic stability, while the bulk of the texts continue to focus on US–Russian relations.[6] In part, this is understandable, since Chinese analysts have long seen asymmetry as precluding them from track-one level arms control dialogues between Russia and the USA.[7] China's advances in hypersonic glide, however, may be beginning to alter this dynamic. Chinese analysts have begun to discuss how China's test flights of its DF-ZF have been more successful than Russia's Yu-71 and the USA's X-51A hypersonic missile. As this shift occurs, and as Chinese analyses of prompt global strike begin to factor Russia into the equation, this presents an opportunity to examine Russia's potential impact on China's hypersonic glide system and its stance on payload, targets and even strategic stability.

III. Technology: payload and target

When examining hypersonic boost-glide developments from within China, the key drivers fall into the categories of technology and doctrine. At the technological level, the Chinese organizations working on hypersonic boost-glide are a multiple and interlocking set of academic, industrial and military research institutes. Within academia, the Harbin Institute of Technology, Northwest Polytechnic University, Xi'an University, the National University of Defence Technology, the Air Force Engineering University and China's Aeronautics and Astronautics University have all published in-depth studies

[5] State Council Information Office of the People's Republic of China, '《中国的军事战略》白皮书(全文)' [China's Military Strategy White Paper (full version)], 26 May 2015, <http://www.scio.gov.cn/zfbps/gfbps/Document/1435341/1435341.htm>.

[6] Saalman, L., 'Prompt global strike: China and the spear', Independent Faculty Research Paper, Asia-Pacific Center for Security Studies, Apr. 2014, <http://apcss.org/wp-content/uploads/2014/04/APCSS_Saalman_PGS_China_Apr2014.pdf>.

[7] For more information on Chinese views on asymmetry, deterrence and strategic stability see Saalman (note 6); Saalman, L., 'The China factor', eds A. Arbatov and V. Dworkin, *Missile Defense: Confrontation and Cooperation* (Carnegie Russia Center: Moscow, 2013), pp. 226–52; and Saalman, L., 'China and the Nuclear Posture Review', *Carnegie Papers* (Carnegie Endowment for International Peace/Carnegie-Tsinghua Center for Global Policy: Washington, DC, Feb. 2011).

on topics from trajectory optimization to re-entry. Within industry and the military, the China Aerospace Engineering Consultation Centre, the China Aerospace Science and Industry Corporation, the China Academy of Aerospace Dynamics, PLA Unit 92493 and the China Airborne Missile Academy have all published studies on how to operationalize these concepts using simulations. At the doctrinal level, China's Ministry of Defence and Central Military Commission, in coordination with the PLARF, are interested in determining how the technological advances in hypersonic boost-glide can be integrated into policy and posture.[8]

Within China, as in Russia, the US prompt global strike programme is discussed as an inherently pre-emptive and destabilizing system. Both countries make the worst-case assumption that the USA will deploy a prompt global strike system that places their arsenals and command and control infrastructures at risk, whether on intercontinental ballistic missiles, air- and submarine-launched hypersonic cruise missiles, or kinetic weapons launched from an orbiting space platform. In the light of these concerns, it is not surprising that both China and Russia are exploring similar capabilities to offset or deter decapitation of their arsenals by the USA.

Thus, Chinese experts from such organizations as the China Airborne Academy in Luoyang and the China School of Aerospace Engineering at the China Institute of Technology already place a high priority on near space attack systems as the future of warfare.[9] China has also been increasing the manoeuvrability of its hypersonic glide vehicles, conducting simulations that leverage near space and heat reduction to allow for successful re-entry, and researching more powerful engines and better trajectory optimization to expand their range.[10] While the majority of these papers involve technological mirroring of US advances, a number also highlight the arc of

[8] Saalman (note 6). Dang Aiguo, Li Shaojun and Xu Bao are affiliated with the Third Research Institute at the Department of General Staff Corps of Engineers. 党爱国, 李晓军, 徐宝 [Dang, A., Li, S. and Xu, B.], '外军快速全球打击能力发展动态' [Developments in foreign military prompt global strike capabilities], 飞航导弹 [*Winged Missile Journal*], no. 7 (July 2012), pp. 51–54.

[9] Li Yake, Liang Xiaogeng and Guo Zhengyu are affiliated with the China Airborne Academy in Luoyang. 李亚轲, 梁晓庚, 郭正玉 [Li, Y., Liang, X. and Guo, Z.], '临近空间攻防对抗技术发展研究' [Near space attack-defence confrontation technology], 四川兵工学报 [*Sichuan Ordnance Journal*], no. 5 (May 2013), pp. 24–30. Chang Jianlong, Zhao Liangyu and Li Keyong are affiliated with the China School of Aerospace Engineering at the China Institute of Technology. 常建龙, 赵良玉, 李克勇 [Chang, J., Zhao, L. and Li, K.], '临近空间平台与空天飞机在未来战争中的协同作用' [Synergies of the near space platform and space planes in future wars], 飞航导弹 [*Winged Missile Journal*], no. 9 (Sep. 2012), pp. 81–85.

[10] Zhang Xiangyu, Wang Guohong, Zhang Jing and Liu Yuan are affiliated with the Institute for Information Fusion at the Naval Aeronautical and Astronautical University. 张翔宇, 王国宏, 张静, 刘源 [Zhang, X., Wang, G., Zhang, J. and Liu, Y.], '临近空间高超声速助推 - 滑翔式轨迹目标跟踪' [Tracking hypersonic boost-glide trajectory targets in near space], 宇航学报 [*Journal of Astronautics*], no. 10 (Oct. 2015), pp. 1125–32. 邱翔宇 [Qiu, X.], '再入滑翔式近空间飞行器飞行姿态控制系统研究' [Re-entry-glide near space vehicle flight attitude control systems], Master's Thesis, School of Information and Control, Nanjing University of Information Engineering, May 2013. Li Qiang was pursuing his doctorate in flight vehicle design within the School of Aerospace Engineering at the Beijing Institute of Technology while writing this thesis. 李强 [Li, Q.], '高超声速滑翔飞行器再入制导控制技术研究' [Study on re-entry guidance and control method for hypersonic glide vehicle], Doctoral Thesis, School of Aerospace Engineering, Beijing Institute of Technology, Jan. 2015. 孟令赛 [Meng, L.], '高速临近空间飞行器跳跃飞行轨迹优化研究' [Optimization of leap trajectory for near space vehicles at hypersonic speed], Master's Thesis, Harbin Institute of Technology, June 2009; and 陈法龙 [Chen, F.] '高超声速滑翔飞行器弹道快速规划研究' [Rapid trajectory planning for hypersonic glide vehicles], Master's Thesis, National University of Defence Technology, Jan. 2012.

Russia's own hypersonic and boost-glide pursuits.[11] Chinese research into aerodynamic properties, manoeuvrability and the G-force effects on the fuselage at high speeds often feature overviews of Russia's programmes, including its Project 4202 that spawned the Yu-70 (102E or 15Yu70) and the more evolved Yu-71 and Yu-74.[12]

As both Russia and China seek to deploy their own version of a hypersonic glide system, they are confronted with many of the same considerations faced by the USA in distinguishing between a conventional and a nuclear payload. Nonetheless, in the case of Russia, reported testing of its hypersonic glide vehicle on the UR-100N and the potential mounting of it on the heavy liquid-propelled RS-28 intercontinental ballistic missile (ICBM) in order to defeat US ballistic missile defences suggest that Russia is making its intentions clear.[13] Given the focus on defeating US missile defences, a nuclear payload would be the most likely option. By contrast, China has been hedging on whether its DF-ZF will be conventional or nuclear. Current discussions on mounting hypersonic glide vehicles on the DF-21 medium-range ballistic missile (MRBM) and the DF-26 intermediate-range ballistic missile (IRBM) indicate a regional contingency. This has elicited a profusion of Western analyses of China's use of its systems for anti-access area-denial (A2AD) to complicate US regional intervention in a crisis.[14]

What these studies disregard, however, is that roughly a quarter of the Chinese technical studies on hypersonic glide vehicles remain focused on US missile defences, rather than any A2AD agenda. Some Chinese experts are even beginning to allege that the very existence of A2AD is a fabrication by Western analysts.[15] Roughly half the Chinese studies surveyed on hypersonic glide vehicles and related technologies concentrate on countering or developing longer-range systems, such as space planes. This suggests that the future uses of China's hypersonic glide vehicles will extend well beyond a conventional payload and a regional conflict. The fact that they place a similar focus on Russia's intended use of these systems to defeat US missile

[11] Among the systems mentioned by Chinese analysts are the Soviet Union/Russia's Eagle (Ying), Hammer (Tiechui), GosMKB (Raduga or Caihong-D2) and Kholod or GLL-8 (Igla or GLL-VK) programmes. Wu Xuzhong was a graduate student at the China Institute of Technology while writing this thesis. 吴旭忠 [Wu, X.], '滑翔式飞行器再入制导与控制方法研究' [Entry guidance and control algorithm for glide vehicles], China Institute of Technology, Jan. 2015, p. 9. Cao Zhi was a graduate student at the Nanjing University of Aeronautics and Astronautics while writing this thesis. 曹智 [Cao, Z.], '高超声速无人机基于特征模型的机动飞行控制研究' [Manoeuvring and flight control based on the characteristic model for hypersonic UAVs], Master's Thesis, Nanjing University of Aeronautics and Astronautics, Feb. 2012, p. 4.

[12] Zhang Sihu was a graduate student at the Aerospace Research Institute of the Harbin Institute of Technology while writing this thesis. 张四虎 [Zhang, S.], '高超声速飞行器再入热环境分析及弹道优化设计' [Heat environment analysis and trajectory optimization for hypersonic vehicles], Master's Thesis, Harbin Institute of Technology, June 2013, p. 7. An Hao was a graduate student at the Harbin Institute of Technology while writing this thesis. 安昊 [An, H.], '高超声速飞行器建模及控制方法研究' [Modelling control methods for hypersonic vehicles], Harbin Institute of Technology, July 2013, pp. 5–6.

[13] 张绍芳, 武坤琳, 张洪娜 [Zhang, Wu and Zhang] (note 4), pp. 20–22.

[14] Heath, T. and Erickson, A. S., 'Is China pursuing counter-intervention?', *Washington Quarterly* (Fall 2015), pp. 143–56; Gompert, D. C., 'Responding to China's anti-access strategy', US–China Economic and Security Review Commission, Testimony, 24 Jan. 2014, <http://www.uscc.gov/sites/default/files/Gompert_Testimony1.30.14.pdf>; and Heath, T. R., Gunness, K. and Cortez, C. A., *The PLA and China's Rejuvenation* (Rand Corporation: Santa Monica, CA, 2016), pp. 1–61.

[15] Chinese expert on nuclear affairs, Conversation with author, Conference of the Chinese Community of Political Science and International Studies, Tsinghua University, 2016.

defences in response to US withdrawal from the 1972 Anti-Ballistic Missile (ABM) Treaty also suggests identification with Russia when confronting this threat.

As a result, when it comes to the question of whether the DF-ZF, or the Yu-71 and the Yu-74, would be used to overcome theatre missile defence (TMD) or national missile defence (NMD), Chinese and Russian analyses have similar perspectives. They do not distinguish between regional and national missile defence.[16] Much as in Russian discussions of US deployment of TMD in Eastern Europe, Chinese debates over TMD in East Asia concentrate on how these systems serve larger US NMD reconnaissance and intercept goals, thereby threatening its strategic deterrent. This has recently come to the forefront of Chinese concerns over the anticipated stationing by the USA of terminal high-altitude aerial defence (THAAD) in South Korea. Moreover, US X-band radar deployment in Japan has been a concern for a number of years.

The implications of these trends are much broader than a regional contingency. When it comes to South Korea, Chinese experts such as Dr Wu Riqiang at Renmin University argue that by providing the USA with greater reconnaissance and intercept capabilities in relation to China's strategic arsenal, South Korea's deployment of THAAD could well lead to China increasing its nuclear warhead numbers.[17] This basic necessity is derived from China's planned expansion of delivery systems to multiple independently targetable re-entry vehicles (MIRVs) and hypersonic glide vehicles. In terms of Japan, a retired general at China's National Defence University has gone so far as to suggest that Japan's use of its missile defence systems to regionally intercept a ballistic missile launched by China would be deemed an act of war.[18] This conflation of threat actors demonstrates that despite the tendency for bilateral analyses of strategic stability, the reality is much more complex. The fact that both Chinese and Russian developments in prompt high-precision systems are trending towards the targeting of US missile defences and a nuclear payload makes the postural crossover of these countries all the more relevant.

IV. Posture: response and asymmetry

At the level of posture, when analysing China's and Russia's intersection of interests and concerns, it is illustrative to begin with China's 2015 Military White Paper. This official document details how the Second Artillery, now the PLARF, 'seeks to improve nuclear and conventional forces and long-range precision strike capability' and 'is building systems of reconnaissance, early-warning, command and control, as well as medium- and long-range precision strike capabilities'.[19] It advocates the development of 'independent new weapons and equipment' and fielding 'a lean and effective nuclear and

[16] Saalman, 'The China factor' (note 7).

[17] Based on publications and speeches by Wu Riqiang at such venues as the 8th US–China Conference on Arms Control, Disarmament and Non-proliferation, 12–13 Apr. 2016; and Tsinghua University's 2016 Conference of the Chinese Community of Political Science and International Studies.

[18] Based on a discussion at the 8th US–China Strategic Dialogue, 'Common strategic interests and building strategic stability', 8–10 June 2016, Ko Olina, Hawaii.

[19] State Council Information Office of the People's Republic of China, Military Strategy White Paper (note 5).

conventional missile force'.[20] In addition to positing the dual-use nature of China's hypersonic and boost-glide advances, these statements suggest the potential for greater delegation of command and control of such systems by using such terms as 'flexibility, mobility and self-dependence' and phrases such as 'you fight your way and I fight my way'.[21] Combining these concepts with greater structural autonomy for the PLARF throws into question, as in the Russian case, the extent to which Chinese field commanders might be presented with greater launch authority. Such authority would relate not simply to payload, but also to targeting.

If China's DF-ZF is intended as a conventional weapon to be used against a non-nuclear target, then the chances of use are likely to increase. This stems from the inherent difference between conventional weapons and nuclear weapons posited by Dr Li Bin at Tsinghua University, who argues that countries do not as a general rule intend nuclear weapons for actual use, but rather for coercion or bargaining in the case of the USA.[22] Unlike nuclear weapons, hypersonic glide vehicles are viewed in a much more utilitarian way in Chinese texts. In part, this stems from their current use, which Western analysts assume is to be mounted on medium-range missile systems in order to thwart US regional intervention. When it comes to Chinese technical and official analyses, China appears to be working towards extending hypersonic glide range and utility from the regional conventional systems to be deployed on DF-21D MRBMs and DF-26 IRBMs, to longer-range nuclear systems that put US missile defences at risk. Given the pre-existing utilitarian concept of these systems as conventional weapons, building hypersonic glide vehicles into China's strategic deterrent creates the potential for them to erode the nuclear taboo, increasing the likelihood of their use even if mounted with nuclear payloads.

The utilitarian posture in China towards hypersonic glide vehicles, which may at some point carry over to nuclear payloads, creates worrying challenges in terms of escalation and overall strategic stability. Exacerbating these challenges is the co-mingling argument made by Dr James Acton at the Carnegie Endowment for International Peace, which posits that a conventional strike against co-located nuclear and conventional command and control centres could trigger a nuclear response.[23] In this case, China's own control architecture poses the greatest challenge. China's assumed conventional and nuclear co-location deters an adversary from launching an attack. Yet, the likelihood of such facilities being compromised in a conventional conflict remains and could result in rapid escalation. If China's DF-ZF system is launched in response to what has been deemed a 'first-use' attack on a co-mingled facility, there is a chance of nuclear escalation. That is why

[20] State Council Information Office of the People's Republic of China, Military Strategy White Paper (note 5).

[21] State Council Information Office of the People's Republic of China, Military Strategy White Paper (note 5).

[22] Based on the writing and speeches of Li Bin, Director and Professor at the Arms Control Programme of the Department of International Relations at Tsinghua University and Senior Research Associate at the Carnegie Endowment for International Peace; and Li, B., 'China's potential to contribute to multilateral nuclear disarmament', Arms Control Association, 3 Mar. 2011, <https://www.armscontrol.org/act/2011_03/LiBin#4>.

[23] Acton, J. M., *Silver Bullet? Asking the Right Questions About Conventional Prompt Global Strike* (Carnegie Endowment for International Peace: Washington, DC, 2013).

the impact of Russia's posture on China—as it pertains to its own hypersonic glide vehicles and tactical nuclear weapons—is so critical.

To this end, further exploration of the concept 'rapid response' (快速反应) may be part and parcel of understanding this postural evolution in China. Although Dr Zhao Tong at the Carnegie-Tsinghua Center for Global Policy has noted that this term could be associated with launch-on-warning, there are indicators that it could just as easily be referring to prompt global strike capabilities.[24] The concept of 'rapid response' appeared in roughly a quarter of the Chinese texts surveyed. In the majority of cases, it was paired with near space, space-based weapons and prompt global strike capabilities. In China's 2015 Military White Paper, 'rapid response' appears on a list that contains 'strategic warning' (战略预警), 'command and control' (指挥控制), 'missile penetration' (导弹突防) and 'survivability protection' (生存防护).[25] While its inclusion on a list with 'strategic warning' could point to launch-on-warning, the positioning of 'rapid response' between 'missile penetration' and 'survivability protection'—combined with the importance of early warning in countering prompt global strike—suggest that this reference could also be applied to hypersonic glide vehicles, space planes and the future of strategic stability.

At the military level in China, US space planes such as the X-37B and X-51 are also frequently paired with discussions of 'rapid response' (快速反应) and 'rapid strike' (快速打击).[26] While the latter term correlates with prompt strike systems as a direct translation to Chinese, the postural implication of 'rapid response' is less clear. In Chinese texts, prompt systems, such as near space aircraft, are seen as providing platforms for reconnaissance, missile defence, electromagnetic countermeasures, transportation, communication and space weapons. For example, 'rapid response' appears in Harbin Institute of Technology theses to describe the use of near space aircraft as space weapon platforms and serves as part of a longer list that includes such capabilities as long-range attack, wide-range, high-mobility, precision-strike capabilities or, in other words, the 'fifth dimension' (五位一体) of joint operations.[27]

Chinese technical studies on hypersonic glide vehicles and related technologies emulate what they call US 'rapid response' programmes, such as the Defense Advanced Research Projects Agency (DARPA) Falcon project, with its common aero vehicle, an affordable rapid response missile demonstrator.[28] While the USA and other foreign powers, such as Russia,

[24] Zhao, T., 'Strategic warning and China's nuclear posture', *The Diplomat*, 28 May 2015.

[25] State Council Information Office of the People's Republic of China, Military Strategy White Paper (note 5).

[26] The author Li Li is affiliated with China's National Defence University. 李莉 [Li, L.], 'X-37B: 遮遮掩掩为哪般?' [X-37B: why so exceedingly secretive?], 解放军报 [*People's Liberation Army Daily*], 3 Jan. 2011, p. 8. 李亚轲, 梁晓庚, 郭正玉 [Li, Liang and Guo], (note 9), pp. 24–30.

[27] Li Xuefei was a graduate student at the Harbin Institute of Technology while writing this thesis. 李雪飞 [Li, X.], '高超声速飞行器气热弹多场耦合数值模拟' [Hypersonic vehicle: thermoelastic numerical simulation of multi-field coupling], Master's Thesis, Harbin Institute of Technology, June 2011, pp. 9–11.

[28] Chen Yingshuo, Ye Lei and Su Xinxin are affiliated with the China Aerospace Science and Industry Corporation, Third Institute, Department 310. 陈英硕, 叶蕾, 苏鑫鑫 [Chen, Y., Ye, L. and Su, X.], '国外吸气式高超声速飞行器发展现状' [The status of foreign air-breathing hypersonic vehicle development], 飞航导弹 [*Winged Missile Journal*], [n.d.]. 党爱国, 李晓军, 徐宝 [Dang, Li and Xu], (note 8), pp. 51–54.

dominate these Chinese studies, they also focus on China's own ambitions when it comes to hypersonic glide vehicles and related systems. Beyond papers advocating that China develop more active prompt global systems, a number also detail China's own efforts to obtain 'rapid response' capabilities. These include: (*a*) hypersonic aircraft ground tests and wind tunnel tests by China North Industries Corporation; (*b*) a robust adaptive approach to near space vehicles based on trajectory linearization control at Nanjing University of Aeronautics and Astronautics; and (*c*) designs and simulations using terminal guidance laws, gas thermo-elastic multi-field coupling and thermal protection for reusable hypersonic vehicles at the Harbin Institute of Technology.[29]

If the postural interpretation of the term 'rapid response' is retaliatory and supports 'active defence' (积极防御), a case could be made that it diminishes the chances of pre-emption on the part of China. However, the larger question becomes: to what are these systems responding? If China's hypersonic glide vehicles are to be deployed regionally to serve as A2AD systems mounted on the DF-21D or the DF-26 and with greater delegation of launch authority, this indicates a conventional payload and pre-emptive use. However, if the ultimate goal of China's hypersonic glide systems is more in line with that of Russia and targeted on defeating US missile defences, this suggests a nuclear payload. This latter trend could alter not only how 'rapid response' and 'active defence' are defined, but also China's postural bedrock of no first use. This bedrock is being eroded by the very systems identified in the US Nuclear Posture Review as the USA's deterrent against China and Russia, namely missile defence and prompt global strike.[30]

V. Conclusion

Given that hypersonic glide tests conducted by China, Russia and the USA have not yet led to deployment, there is still an opportunity for greater analysis of how these technologies will affect the postural evolution of these three countries. Not taking the time to assess the potential outcomes of technology-driven posture could lead to greater strategic instability and arms racing. As part of this process, beyond the US–Chinese paradigm, more emphasis needs to be placed on integrating Russia into analyses of China's hypersonic glide vehicle development. In developing a competitive strategy to address the above-mentioned trends and potential directions of hypersonic

[29] Tian Jianming, Jing Jianbin and Han Guangqi are affiliated with the Test and Measuring Academy of China North Industries Corporation. 田建明, 景建斌, 韩广岐 [Tian, J., Jing, J. and Han, G.], '高超声速飞行器地面试验方法综述' [Overview of hypersonic aircraft ground test methods], 探测与控制学报 [*Journal of Detection and Control*], no. 5 (Oct. 2013), pp. 57–60. Xue Yali was a graduate student at the National Defence Science and Technology University while writing this thesis. 薛雅丽 [Xue, Y.], '基于轨迹线性化方法的近空间飞行器鲁棒自适应控制研究' [A robust adaptive approach to near space vehicles based on trajectory linearization control], Doctoral Dissertation, National Defence Science and Technology University Research Institute, June 2010. 李雪飞 [Li] (note 27).

[30] Even the voices reaffirming China's commitment to no first use, such as PLA Major General (Retd) Yao Yunzhu and Tsinghua University's Li Bin, highlight the impact of concerns in China over US missile defence and prompt global strike. Yao, Y., 'China will not change its nuclear policy', China US Focus, 22 Apr. 2013, <http://www.chinausfocus.com/peace-security/china-will-not-change-its-no-first-use-policy>; and Li, B., 'Chinese thinking on nuclear weapons', Arms Control Association, 3 Dec. 2015, <https://www.armscontrol.org/ACT/2015_12/Features/Chinese-Thinking-On-Nuclear-Weapons>.

glide programmes, there are at least four possible options: (*a*) traditional arms control; (*b*) an arms race; (*c*) trilateral talks; and (*d*) multilateral exchanges.

Traditional arms control

The first option would be to pursue the traditional arms control path that posits constraints or even a ban on the testing of these hypersonic systems and the development of IRBMs. However, this path is unlikely to garner much enthusiasm in China, where its DF-21D and rapid advances in hypersonic glide vehicles, such as the DF-ZF, provide a source of leverage against the USA that it is unlikely to relinquish. Furthermore, as Russia makes its own gains and China develops an edge in these spheres, their own conventional weaknesses in relation to the US military will continue to drive a desire to protect these pockets of excellence provided by hypersonic glide vehicles and related technology.

An arms race

The second option would be for the countries to pursue the opposite direction and engage in an arms race on hypersonic glide vehicle development. This path, which is already starting to emerge, is not necessarily in the interest of the USA, which already faces budget deficits and has demonstrated an inability to deliver an articulated vision of its own hypersonic glide vehicle programme. While Russia pushed ahead with its flight tests in April and October 2016, it is also still lagging behind China in terms of pace. China has conducted seven tests of its hypersonic glide vehicle in two years. The speed and frequency of its hypersonic glide vehicle tests suggest that it has the momentum and resources to move ahead of the technical curve, to address the potential for either arms control or an arms race. As the USA and Russia respond in kind, this action–reaction dynamic promises to accelerate and to be increasingly driven by China.

Trilateral talks

The third option would be to hold trilateral strategic stability talks that focus on hypersonic glide vehicles and invite political, economic, technical and military experts to engage in scenario building and tabletop exercises. Chinese and US experts already meet on strategic nuclear issues at academic and semi-official levels, although prompt global strike is generally a smaller and newer portion of the agenda.[31] Expansion to a trilateral discussion that includes China, Russia and the USA at a more official level would require moving beyond the idea that China's asymmetrical disadvantage in nuclear warhead numbers precludes its involvement in US–Russian strategic stability talks.[32] As China's advances in hypersonic glide vehicle technology grow

[31] The China Foundation for International and Strategic Studies and the Pacific Forum of the Center for Strategic and International Studies, as well as the Institute of Applied Physics and Computational Mathematics and the Nuclear Threat Initiative, are active in this sphere.

[32] Some laudable efforts have been made by the Carnegie Endowment for International Peace to stimulate these trilateral exchanges at the Track II level, but these exchanges and studies require greater systematization and frequency. On these dialogues and seminars see Burns, W.

and its arsenal size responds to missile defence expansion in the Asia-Pacific region, the rationale of asymmetric disadvantage diminishes.

Multilateral exchanges

The fourth option would be for multilateral exchanges and analyses of hypersonic glide vehicle technology and its impact on regional strategic stability dynamics. As noted above, Chinese texts and Western reports feature a range of other countries seeking related technologies, such as Germany, India, Israel and Japan, as well as Russia and the USA.[33] The inclusion of all, or some, of the countries on this list would address some of the asymmetry concerns voiced by Chinese analysts and provide insights into the complexity of the dynamics among countries pursuing hypersonic glide vehicles. It would also create a discussion that is not necessarily targeted at any one member of the group. The current conventional nature of hypersonic glide vehicle development would further allow the various parties to begin talks at a non-strategic level, before moving on to the technology's impact on nuclear deterrence.

While these four paths do not necessarily mitigate the chances of hypersonic glide vehicles paving a new avenue for competition, using the third option of trilateral talks as a stepping stone towards or in tandem with the fourth option of multilateral exchanges would begin to provide some nuance to what has been a stilted, dyadic assessment of US–Chinese strategic stability dynamics. This approach would offer a smoother transition and a more resilient framework, drawing the discussion away from a deleterious bilateral arms race. It would allow not only Russia, but also other countries to be factored into the equation as their programmes evolve. In doing so, it would provide a more realistic, complex and ultimately sustainable foundation for understanding the security implications of hypersonic glide vehicle technology for countries in Asia and beyond.

Abbreviations

A2AD	Anti-access area-denial
DARPA	Defense Advanced Research Projects Agency
ICBM	Intercontinental ballistic missile
IRBM	Intermediate-range ballistic missile
MIRV	Multiple independently targetable re-entry vehicle
MRBM	Medium-range ballistic missile
NMD	National missile defence
PLA	People's Liberation Army
PLARF	PLA Rocket Force
THAAD	Terminal high-altitude aerial defence
TMD	Theatre missile defence

et al., 'The future of arms control and strategic stability', Carnegie Endowment for International Peace, 15 Sep. 2016, <http://carnegieendowment.org/2016/09/15/future-of-arms-control-and-strategic-stability-event-5358>; and Saalman, L., 'China–Russia–US strategic stability and missile defence', Carnegie Endowment for International Peace, 31 Jan. 2013, <http://carnegieendowment.org/2013/01/31/china-russia-u.s.-strategic-stability-and-missile-defense-event-3999>.

[33] 肖松, 谭贤四, 王红, 李志淮 [Xiao, Tan, Wang and Li] (note 2), pp. 28–31; 王佩广, 刘永绩, 王浚 [Wang, Liu, Wang] (note 2); 李曙光 [Li] (note 2), pp. 3–5; European Space Agency (note 2); Gallagher (note 2); and Japan Aerospace Exploration Agency (note 2).

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CONTENTS

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