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THE EXPANSION OF THE NEWSPACE INDUSTRY AND MISSILE TECHNOLOGY PROLIFERATION RISKS

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STOCKHOLM INTERNATIONAL PEACE RESEARCH INSTITUTE

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Executive summary

The rise of innovation and commercialization in the global space sector has resulted in transformative changes within the industry, referred to as 'NewSpace'. NewSpace is changing the nature of the space industry and poses challenges for the effective implementation of export controls, thus potentially increasing missile proliferation risks. Most missile technology is inherently dual-use; it can also be used for civilian space applications, in particular space launch vehicles (SLVs). The emergence and expansion of the commercial NewSpace industry has increased the range of actors—including companies, research institutes, universities and other entities—that have access to the dual-use technology and know-how required to produce rockets and SLVs. This has also increased the number of actors that may be targeted by illicit procurement efforts that seek to acquire the dual-use technology and know-how required to produce missiles capable of delivering weapons of mass destruction (WMD)—that is, chemical, biological and nuclear weapons.

Multilateral missile non-proliferation efforts, in particular through the Missile Technology Control Regime (MTCR), have therefore begun to assess the impact of NewSpace on missile proliferation risk. A key topic of inquiry is the size of relevant NewSpace industry subsectors developing, testing, producing or marketing missile-related technology and the extent to which the states in which these companies are established follow the MTCR's export control standards.

Several segments of the NewSpace industry, including the upstream launch sector, primarily or partially develop or use missile technology. SLVs of all sizes use many of the same, or at least similar, technologies and major components as missiles—particularly ballistic missiles. Yet, the level of awareness of the proliferation risks that transfers of dual-use space technologies pose and the implementation of internal compliance programmes to follow applicable regulations and reduce such risks varies significantly among NewSpace stakeholders.

A SIPRI pilot study mapped the missile-related NewSpace industry of 84 selected states, including the 35 MTCR partners, 4 states that have submitted a political declaration to adhere to the MTCR guidelines (MTCR adherents) and 45 states not participating in the MTCR. Over half of the 49 adherents and other selected non-partners have NewSpace companies developing, testing, producing or marketing missile-related technology established in their domestic industry. Of all MTCR non-partners, China has the largest number of such companies. However, just over one-third of adherents and other non-partners have adopted the current or previous version of the MTCR annex—the regime's control list of missile-related equipment, software and technology—as part of their national export control system. Further, a case study on small and micro launchers in all states identified 118 active small- and micro-launcher projects—all of which are located in states mapped as part of the pilot study. These projects are being developed by at least 111 small- and micro-launcher companies established in 28 states around the world. Among these states, 20 (71 per cent) are MTCR partners, while 8 (29 per cent) are neither partners nor adherents. Of the 118 small- and micro-launcher projects identified, 94 (80 per cent) are located in MTCR partners while 24 (20 per cent) are in non-partners.

The pilot study takes a first step towards helping governments make evidence-based decisions on how to manage and address the impact on missile technology proliferation risks of the growth of the NewSpace industry and its spread to additional states. It illustrates how the NewSpace industry with direct relevance to missile proliferation has spread well beyond the MTCR partners. Notably, a considerable share of non-partners with missile-related NewSpace industries have not adopted the MTCR annex.

In this context, it is particularly important for states to agree and promote common approaches to reducing missile proliferation risks created by developments of the NewSpace industry, including through the MTCR. The partners may advance membership and adherence discussions by considering the value of accepting into the MTCR additional states with NewSpace industries that are developing, testing, producing or marketing missile-related technology. The partners should also consider increasing their targeted outreach missions to actively engage the non-partners with NewSpace companies working with missile-related technology. They should invite these states to technical outreach meetings and, if they have not yet done so, encourage them to unilaterally adhere to the MTCR guidelines and adopt the annex. The partners should consider developing, and making public, guidance on areas that particularly affect the NewSpace industry, such as controls on intangible transfers of technology and software. They should also increase the vigilance they exercise in enforcement of export controls in relation to NewSpace stakeholders and conduct targeted national outreach to their own domestic NewSpace industries, while sharing experiences and good practices in doing so through the MTCR.

Abbreviations

FDI	Foreign direct investment
HCOC	Hague Code of Conduct against Ballistic Missile Proliferation
ITT	Intangible transfers of technology
LEEM	Licensing and enforcement expert meeting
MTCR	Missile Technology Control Regime
R&D	Research and development
SLV	Space launch vehicle
SMEs	Small- and medium-sized enterprises
TOM	Technical outreach meeting
UAV	Uncrewed aerial vehicle
WMD	Weapons of mass destruction

1. Introduction

Most missile technology is inherently dual-use; it can also be used for civilian space applications, in particular space launch vehicles (SLVs). The emergence and expansion of the commercial NewSpace industry has increased the range of actors—including companies, research institutes, universities and other entities—that have access to the dual-use technology and know-how required to produce rockets and SLVs. This has also increased the number of actors that may be targeted by illicit procurement efforts that seek to acquire the dual-use technology and know-how required to produce missiles capable of delivering weapons of mass destruction (WMD)—that is, chemical, biological and nuclear weapons.[1] Multilateral missile non-proliferation efforts, in particular through the Missile Technology Control Regime (MTCR), have therefore begun to assess the impact of NewSpace on missile proliferation risks. A key topic of inquiry is the size of the relevant NewSpace industry subsectors that are developing, testing, producing or marketing missile-related technology and the extent to which the states in which these companies are established follow the MTCR's export control standards.

NewSpace refers to a convergence of trends in the global space sector that include commercialization, innovation, new business practices, and diversification and expansion of actors and activities, along with a growing reliance on venture capital and different types of private funding sources.[2] The commercialization of the space industry, changing economic opportunities and incentives, a conducive funding environment, government contracting opening up to start-ups and small- and medium-sized enterprises (SMEs), and increased demand created by advances in space-based services using geospatial data have prepared fertile ground for a boom in the global NewSpace economy. However, opportunities and growth are not equally distributed and there are variations in how and to what extent NewSpace affects the composition and development of national space industries and thus the extent to which these industries may contribute to missile proliferation risks. The overall growth of the global NewSpace industry has been well documented, with private capital and funding pouring into the sector predominantly in the larger developed economies but also in a growing number of developing states.[3] Analyses of specific parts of the NewSpace industry, in particular the small- and micro-launcher sector, indicate that growth of the NewSpace industry raises challenges for regulatory approaches to controlling transfers of dual-use missile technology—chiefly export controls.[4] There is a lack of research into the potential connections between the growth of the NewSpace industry and an increase in the risk of proliferation of sensitive missile-related technology.

The MTCR is an informal instrument through which a group of 35 supplier states (referred to as the 'partners') seek to coordinate their export controls to prevent the proliferation of missiles and uncrewed aerial vehicles (UAVs) capable of delivering WMD (see box 1.1).[5] The MTCR partners agree on common guidelines for assessing licensing applications for exports of complete missiles, UAVs, major components and related dual-use items (the MTCR guidelines) and maintain a control list of such items which should be made subject to national export licensing requirements (the equip-

[1] Brockmann, K. and Raju, N., *NewSpace and the Commercialization of the Space Industry: Challenges for the Missile Technology Control Regime* (SIPRI: Stockholm, Oct. 2022), pp. 7–8.

[2] Peeters, W., 'Towards a definition of new space? The entrepreneurial perspective', *New Space*, vol. 6, no. 3 (Sep. 2018), pp. 187–89.

[3] BryceTech, *Start-Up Space: Update on Investment in Commercial Space Ventures 2023* (BryceTech: Alexandria, VA, 2023).

[4] Brockmann and Raju (note 1); and Brockmann, K. and Schiller, M., 'Small and micro launchers in the NewSpace era: New missile proliferation risks or more of the same?', SIPRI, 1 Dec. 2023.

[5] MTCR, 'Objectives of the MTCR', [n.d.].

Box 1.1. The Missile Technology Control Regime

The Missile Technology Control Regime (MTCR) is an informal political understanding among a group of 35 supplier states that aims to limit the proliferation of missiles and other uncrewed delivery systems capable of delivering chemical, biological or nuclear weapons—referred to by the MTCR as weapons of mass destruction (WMD).[a]

It was established by the Group of Seven (G7) large industrialized states in 1987, originally as an instrument to help prevent the proliferation of nuclear weapons by controlling missiles capable of delivering them. The scope of the MTCR has since expanded to include ballistic and cruise missiles capable of delivering and WMD.

The MTCR partner states harmonize their export controls through the MTCR. They do this by following the MTCR guidelines for sensitive missile-relevant transfers and by jointly maintaining a control list (the MTCR equipment, software and technology annex) that covers missiles and certain uncrewed aerial vehicles (UAVs) and relevant dual-use goods and technologies.

The annex divides the items it covers into two categories.[b] Category I includes any complete missile or UAV 'capable of delivering at least a 500 kg "payload" to a "range" of at least 300 km' (e.g. ballistic missiles, space launch vehicles, cruise missiles and reconnaissance UAVs); complete major subsystems (e.g. rocket stages and engines, guidance systems and re-entry vehicles); related software and technology; and specially designed production facilities. For all Category I items, the partners commit to exercising an unconditional strong presumption of denial.[c] This means that no licences for exports of such items should be issued under all but the most exceptional circumstances. The export of Category I production facilities is prohibited without exception.

Category II includes dual-use missile- and UAV-related components, and complete missile and UAV systems with a range of at least 300 kilometres, regardless of their payload capability. Exports of such systems destined for any end use in the delivery of WMD are also subject to a strong presumption of denial. All other exports of Category II items are subject to licensing procedures and are to be assessed with consideration of the criteria outlined in the guidelines.

The MTCR takes decisions—for example, on admitting new partners or making amendments to the annex—by consensus and these decisions are politically, rather than legally, binding. The main decision-making body of the MTCR is the plenary, which convenes every year, usually in October, and is hosted by the annually rotating chair. The MTCR has several subsidiary bodies that cover different topical areas and operational functions: the technical experts meeting (TEM), the information exchange meeting (IEM), the licensing and enforcement experts meeting (LEEM), point of contact (POC) meetings, and reinforced point of contact (RPOC) meetings.

[a] MTCR, 'Objectives of the MTCR', [n.d.]; and MTCR, 'Frequently asked questions (FAQs)', [n.d.].

[b] MTCR, 'Equipment, software and technology annex', MTCR/TEM/2023/Annex, 14 Mar. 2024.

[c] MTCR, 'Guidelines for sensitive missile-relevant transfers', [1987].

ment, software and technology annex, or MTCR annex).[6] A further four states have officially become adherents to the MTCR by submitting a political declaration to follow the MTCR guidelines (and, thus, the annex), but they do not participate in the regime.[7]

The MTCR collectively refers to goods, equipment, software and technology required for missiles and UAVs as missile technology. In the specific context of export control regulations and in MTCR annex items, technology is defined as information 'required for the "development", "production" or "use" of a product', either in the form of 'technical data' or 'technical assistance'.[8] Unless otherwise noted, this report refers to 'missile-related technology', defined as including complete missiles and SLVs and any dual-use equipment, software and technology covered by the MTCR annex, as

[6] MTCR, 'MTCR guidelines and the equipment, software and technology annex', [n.d.]; and MTCR, 'Equipment, software and technology annex', MTCR/TEM/2023/Annex, 14 Mar. 2024.

[7] MTCR, 'MTCR partners', [n.d.].

[8] MTCR, MTCR/TEM/2023/Annex (note 6), p. 13.

well as emerging production technologies and geospatial data products and services particularly relevant for missile production and operation.

The MTCR is the primary forum for states to agree and promote common approaches to reducing missile proliferation risks created by developments in the NewSpace industry. To support initiatives through the MTCR, as part of SIPRI's 'Quo Vadis MTCR II' research project, a small research team (including the authors of this report) conducted an exploratory study to create a preliminary mapping of NewSpace companies in 84 selected states that have a NewSpace industry or show signs that such an industry is emerging. This pilot study identified over 600 companies developing, testing, producing or marketing missile-related technology. It also developed profiles of the 84 states covered, mapping their missile and SLV possession, MTCR membership status and adoption of the MTCR annex. In a survey of all states, the pilot study also identified 118 small- and micro-launcher projects undertaken by 111 different companies and entities in 28 states, all of which were among the states selected for the pilot study.

The pilot study is necessarily limited in scope and only seeks to provide data on the extent to which NewSpace companies in the MTCR partners cover the different item categories of the MTCR annex and, in the case of adherents and other non-partners, on the number of relevant NewSpace companies and the state in which they are located. The goal is to inform efforts to strengthen the MTCR in terms of its membership and adherence, its outreach programme directed at adherents and other non-partners, and the partner states' own domestic outreach efforts towards industry and other relevant NewSpace stakeholders.

This report continues in chapter 2 by describing the characteristics of the NewSpace industry, the dynamic development of its funding environment, regional differences and competition. The chapter also discusses the extent to which the spread of missile-related technology in the NewSpace industry raises missile proliferation risks. Chapter 3 then describes the pilot study of national NewSpace industries—that is, the relevant companies, both private and state-owned, established on the territory of the state—and presents the methodology employed in the data-collection effort before describing its key findings. It continues with a case study on small- and micro-launcher projects and companies. Chapter 4 goes on to discuss the implications of the pilot study findings for the MTCR in terms of future membership and adherence and outreach to adherents and other non-partners and for the MTCR partners' outreach to their domestic space industry stakeholders. Finally, chapter 5 summarizes the findings of the report and presents recommendations for the MTCR partners on how to address the missile proliferation risks linked to the spread of the NewSpace industry demonstrated by the pilot study.

2. The NewSpace industry

The rise of innovation and commercialization in the global space sector has resulted in transformative changes within the industry, referred to as 'NewSpace'. With NewSpace, new types of private actor—including start-ups, innovation hubs and research centres—have emerged, challenging a previously state-centric industry. But established space actors have also adapted: some have set up subsidiaries branded as NewSpace that develop novel space technologies, while others have acquired NewSpace companies to strengthen their existing operations or set up incubators.[9] NewSpace and more traditionally established space actors are therefore not necessarily mutually exclusive, but NewSpace has certainly permeated the broader space sector. Beyond this, many of the services that NewSpace provides are used in many other industries.

NewSpace companies are also known to adopt lean organizational structures and agile business practices to innovate and to develop, produce and commercialize space technology.[10] The development of novel space technologies has opened new markets and, in some areas, significantly reduced cost and commercial pricing for access to space. Smaller and cheaper satellites have led to the development of a wide range of downstream applications, in particular more and more space-based services. NewSpace has also led to new growth in the upstream segments of the space industry, including the manufacturing, satellite and launch sectors.[11]

Governments remain central in incentivizing NewSpace developments, be it by establishing public–private partnerships, developing national space policies and establishing space agencies, or acting as the source or promoter of investment. However, NewSpace actors have increasingly relied on various forms of private investment. While the NewSpace sector is still growing, this funding model also means that parts of the industry may be more vulnerable to fluctuations in investment priorities, and it renders the NewSpace sector as a whole more volatile.

Funding dynamics and volatility in the development of the NewSpace sector

The viability of the NewSpace boom

The NewSpace sector has experienced steep growth in recent years and is still in the process of expanding to and within many regions. One of the most visible examples of this growth is the huge increase in the number of commercial launches, which reached 116 in 2023, accounting for more than half of all launches, up from 41 in 2020.[12] The growth in the NewSpace sector has largely been driven by access to private funding—especially venture capital, which can be defined as 'funds provided by wealthy individuals, investment banks, or other financial institutions to relatively new and small companies that appear capable of exceptional growth and long-term success, including nascent private companies, or "start-ups."'.[13] It is exemplified in the major 'series' funding rounds, where NewSpace start-ups collect large investments at different stages of their growth.[14]

[9] E.g. Parsonson, A., 'ArianeGroup to increase MaiaSpace investment to €125M', European Spaceflight, 10 Jan. 2024; SatixFy, 'SatixFy announces completion of strategic $60 million transaction with MDA', Press release, 31 Oct. 2023; and 'Qui sommes-nous?' [Who are we?], Comat, [n.d.].

[10] Brockmann and Raju (note 1).

[11] Moranta, S., *The Space Downstream Sector: Challenges for the Emergence of a European Space Economy* (French Institute of International Relations (Ifri): Paris, Mar. 2022).

[12] BryceTech, '2023 orbital launches year in review', [n.d.]; and Bryce Tech, '2020 orbital launches year in review', [n.d.].

[13] Duignan, B., 'Venture capital', *Encyclopaedia Britannica*, 3 May 2024.

[14] Falcão Serra, J. et al., *Space Venture Europe 2023: Investment in the European and Global Space Sector*, European Space Policy Institute (ESPI) Report no. 91 (ESPI: Vienna, May 2024), p. 5.

Yet, behind this NewSpace boom lies a lot of volatility in the financial ecosystem surrounding the sector. After a period of consecutive increases, total investment in NewSpace in 2023 was lower than in 2022 as rising interest rates led to a preference for safer sectors.[15] The long timelines and the uncertainty that characterize many space projects at least partially clashes with the logic of venture capital—which is often aimed at generating returns in the short-to-medium term.[16] For small and micro launchers, although some NewSpace companies have managed to develop a launcher in just a few years, many have needed more than 10 years and have experienced development delays of several years.[17] In this context, signs of consolidation in the sector are visible. In the United States, a number of NewSpace companies have filed for bankruptcy and others that had been publicly listed received delisting notices after the values of their shares plunged.[18] China is also witnessing a concentration of major NewSpace companies.[19]

Despite the current volatility, the NewSpace sector as a whole is still expected to develop.[20] However, there is uncertainty about where funding will come from and to which actors this funding will go. In the private investment realm, venture capital alone does not appear to be able to support the growth of the entire NewSpace sector. That said, it does have a role to play, especially with the emergence of investment funds that exclusively focus on NewSpace. Such specialized funds may be more inclined to provide the long-term investment that NewSpace companies need.[21] There are signs that other forms of private investment may increase, including from financial asset managers and pension funds and from established companies in other sectors that see a value in the development of space-based services.[22]

Many governments are also taking initiatives to increase public funding for the NewSpace sector. This includes using public investment funds, such as the European Investment Fund, to invest in NewSpace-focused venture capital firms.[23] It also includes governments setting up new organizations to attract private investment into sectors that align with their strategic priorities, such as the Office of Strategic Capital set up by the US Department of Defense in 2022.[24] Some governments are also taking steps to increase cooperation with the NewSpace industry from the research and development (R&D) stage already, and to adapt their contracting models so that they can award contracts to more start-ups.[25] There is also ongoing reflection on where public support may be most useful: in both China and India, for example, the downstream sector does not seem to require substantial public support or government contracts to sustain itself, while the upstream sector (e.g. R&D, manufacturing and launch) partly relies on government funding to develop.[26]

[15] Falcão Serra et al. (note 14).

[16] Moeller, H. L., 'Venture capital financing gap: Towards a European space investment fund?', Director's Perspective, European Space Policy Institute (ESPI), Mar. 2024.

[17] Kulu, E., 'Small launchers—Industry survey and market analysis', Paper presented at the 74th International Astronautical Congress (IAC 2023), Baku, 2–6 Oct. 2023, p. 10.

[18] Hearst, E., 'America's SPAC-funded NewSpace industry is crashing', *SpaceNews*, 10 May 2023.

[19] Jones, A., 'China's commercial sector finds funding and direction', *SpaceNews*, 25 Apr. 2021.

[20] World Economic Forum, 'Space economy set to triple to $1.8 trillion by 2035, new research reveals', News release, 8 Apr. 2024.

[21] Falcão Serra et. al. (note 14).

[22] Moeller (note 16); and Rainbow, J., 'Europe's space funding gap threatens industry potential', *SpaceNews*, 1 July 2024.

[23] European Commission, 'InvestEU: EIF commits €60 million to the European NewSpace Fund Alpine Space Ventures', Press release, 25 May 2023.

[24] US Department of Defense, 'DoD announces release of FY24 investment strategy for the Office of Strategic Capital', News release, 8 Mar. 2024.

[25] Murray, R., 'The NewSpace market: Capital, control, and commercialization', Atlantic Council, Apr. 2023.

[26] Murray (note 25).

Regional differences and competition in NewSpace

NewSpace is not at the same stage of development everywhere: while there were signs of NewSpace development in the USA from the 1970s onwards, the sector is still emerging in other regions.[27] The funding landscape also differs, with some governments having taken a leading role in supporting NewSpace sector developments, while others have largely let private investments act as the main funding source for the sector.

The USA alone accounts for half of all global commercial space activity. It also saw much earlier growth of the NewSpace sector and was first to experience signs of consolidation.[28] Most of the global decline in private investment so far can be attributed to the USA, in part because access to venture capital has become more difficult as a result of recent macroeconomic and geopolitical shifts.[29] However, there is also a history of the public sector contracting the commercial space industry for a range of critical missions as well as a diversity of private investors in the NewSpace sector. This means that there might be better conditions in place in the USA for the NewSpace sector to sustain itself.

The European NewSpace sector (outside Russia) is reported to have recorded a high number of investment deals in 2021–23 (96 deals), not much lower than the US sector (114).[30] However, at €1.4 billion (US$1.5 billion), the total value of investment into the sector in Europe remains four to five times lower than that in the USA, at €6.3 billion ($6.9 billion). Venture capital did not penetrate space funding markets in Europe as much as it did in the USA, which may protect Europe from some of the financial shocks. In addition, the continued increase in mixed public–private funding in Europe in recent years could be a factor underpinning greater resilience.[31]

In Asia, China is leading the growth with over €7.5 billion ($8.4 billion) raised by more than 150 companies in 2014–23.[32] Around 10 companies received 34 per cent of all this funding, with heavy support from Chinese institutional investors.[33] A noticeable feature in China is also that around half of the total funding has gone to launch companies.[34] In terms of satellite launches, China has been the most active country in the region, with a total of 64 launches in 2022, placing it behind only the USA.[35] Trailing China is India, which deployed over 50 satellites across four separate launches in 2022.[36]

NewSpace is developing, albeit at a much slower pace, in other regions too. In Africa, space startups have raised at least $184 million since 2015.[37] The vast bulk (84 per cent) of these investments were received from 2021, representing the first major surge of NewSpace investment in Africa. The ongoing volatility, the funding conditions and the different structure of the NewSpace sector in different states raise financial and economic uncertainties regarding long-term funding and sustained demand for companies in the sector. These factors also raise a set of political and security risks, particularly in relation to whether, as a result of consolidation in the sector, NewSpace companies with missile-related technology and production facilities, as well as engineers with

[27] Brockmann and Raju (note 1).

[28] Kreps, S., Melamed, A. and Jayawardhana, R., 'The promise and perils of the new space boom', Brookings Institution, 2 Nov. 2022.

[29] Falcão Serra et. al. (note 14).

[30] Falcão Serra et. al. (note 14).

[31] Falcão Serra et. al. (note 14).

[32] Falcão Serra et. al. (note 14).

[33] Falcão Serra et. al. (note 14).

[34] European Space Agency (ESA), 'China's space sector: Commercialisation with Chinese characteristics', Apr. 2021.

[35] Moeller, H. L., 'From Djibouti and the Northern Territories to the use of space—An outside perspective', Perspectives, European Space Policy Institute (ESPI), Nov. 2023.

[36] Murray (note 25).

[37] Falcão Serra et. al. (note 14).

know-how and experience, could be exploited for illicit procurement activities and thereby increase proliferation risks.[38]

The NewSpace industry and dual-use missile technology

Missile-related technology in the NewSpace industry

Several segments of the NewSpace industry primarily or partially develop or use missile-related technology. The upstream launch sector naturally centres around SLV technology and therefore also dual-use missile technology. SLVs of all sizes use many of the same, or at least similar, technologies and major components as missiles—particularly ballistic missiles.[39] Many small and micro launchers are currently being developed in response to the growing demand for 'responsive space' capabilities—that is, satellite-launch capabilities with minimal preparation time to strengthen the resilience of military, critical infrastructure and commercial space-based assets and services.[40] Many of the small and micro launchers tailored to providing responsive space capabilities include an ability to deploy on short notice from a variety of launch locations as well as a suitability for stockpiling. Thus, they share characteristics with ballistic missiles and use some of the same technology and engineering optimizations as missiles.[41]

However, the propagation of missile-related technologies is not confined to the launch sector and also involves other industry segments. The missile-related technologies developed and produced by NewSpace companies include, for example, re-entry vehicle technology manufactured for orbital cargo-retrieval systems for future space mining and in-orbit manufacturing; propulsion systems for spaceplanes; launch-support and communications equipment for small and micro launchers and a variety of spacecraft; tools for analysing and preparing satellite imagery; and engineering consulting services for launch vehicles, satellites and other spacecraft that could constitute controlled technical assistance.[42] Next to their applications in satellite launch, in-space economy and space-based services, such technologies could also be misused, for example, for developing warhead re-entry vehicles, missile propulsion and launch support, or terrain matching for targeting and guidance.

In addition, the NewSpace industry is pioneering or an early adopter of a range of emerging technologies—such as additive manufacturing—that are currently not explicitly listed in the MTCR annex but can already be used to produce parts and could potentially enable qualitative improvements to existing production techniques and designs.[43] While many start-ups in the NewSpace industry are challenging established concepts, engineering approaches and business practices, this is also increasingly changing the dynamics between the industry and national civilian space programmes and military projects in the space domain. However, in this evolution, the sensitivity

[38] Brockmann and Raju (note 1), p. 5.

[39] Maitre, E. and Moreau-Brillatz, S., 'The Hague Code of Conduct and space', HCoC Research Papers no. 10, Fondation pour la recherche stratégique (FRS), Mar. 2022; and Maire, C., 'The rise of small launchers: What impact on ballistic missile proliferation?', HCoC Research Papers no. 13, Fondation pour la recherche stratégique (FRS), Apr. 2024, pp. 16–22.

[40] Rocket Lab, 'Responsive space', [n.d.].

[41] Brockmann and Schiller (note 4).

[42] Brockmann and Raju (note 1); and Authors' exchanges with participants at 'Mapping states' missile and (new) space industry capabilities: Data sets, new research, lessons learned and synergies', SIPRI workshop, Mar. 2024.

[43] Brockmann, K., *Additive Manufacturing for Missiles and Other Uncrewed Delivery Systems: Challenges for the Missile Technology Control Regime* (SIPRI: Stockholm, Oct. 2021); Brockmann, K. and Kelley, R., *The Challenge of Emerging Technologies to Non-proliferation Efforts: Controlling Additive Manufacturing and Intangible Transfers of Technology* (SIPRI: Stockholm, Apr. 2018); and Brockmann, K. and Bauer, S., '3D printing and missile technology controls', SIPRI Background Paper, Nov. 2017.

of missile-related technology is not always fully appreciated. Similarly, data-driven engineering using specialized software also means that a wide variety of actors across and within different companies are commonly provided with access to sensitive data, without necessarily understanding its significance.[44]

Missile proliferation risks and export control challenges linked to the proliferation of missile-related technology through the NewSpace industry

The prevalence of missile-related technology in the NewSpace industry, together with its significant growth and many of the trends that characterize the NewSpace industry, poses a range of challenges to export control licensing and enforcement for national authorities, as well as compliance challenges for NewSpace stakeholders. In particular, the level of availability and access to the missile-related technology—along with the number and diversity of commercial actors that are developing, testing, producing or marketing (and exporting or otherwise transferring) such technology—is increasing significantly. The rapid global expansion of the NewSpace industry, including in MTCR non-partners, increases the resulting proliferation risks. It also raises the question of how and to what extent this trend varies across states.

There is a variety of different scenarios in which NewSpace companies may inadvertently or intentionally contribute to missile technology proliferation or where NewSpace activities may be used to hide a ballistic missile programme. Transfers of goods, software and technology and the provision of technical assistance can knowingly or unknowingly contribute to missile programmes.[45] Almost all missile programmes have relied on foreign assistance or procurement from foreign suppliers, which indicates that controlling such transfers is particularly important.[46]

The level of awareness of the proliferation risks posed by transfers of missile-related space technologies varies significantly among NewSpace stakeholders. So too does the implementation of internal compliance programmes to follow applicable regulations and reduce such risks.[47] Intangible transfers of technology (ITT) and transfers of software pose a particularly significant licensing, enforcement and compliance challenge in the context of NewSpace. Many start-ups and new entrants to the sector working with missile-related technology have limited knowledge of and experience with export controls and especially with controls on ITT and on transfers of software. The structure of global supply and value chains also means that many stakeholders require a good understanding of the export control regulations of different states.[48] Many of these NewSpace companies are relatively small or have been only recently established and lack a dedicated export control compliance department and the appropriate procedures established by an internal compliance programme.[49] Moreover, the business culture in many NewSpace start-up companies is such that staff are likely to rotate more often either because some start-ups shut down or because the staff seek career development opportunities elsewhere. This increases possible knowledge transfers within a state or, if staff go on to work abroad, to other states. As a result, there is considerable risk of such a company inadvertently sharing controlled technology or software with an entity in its

[44] Héau, L. and Brockmann, K., *Intangible Transfers of Technology and Software: Challenges for the Missile Technology Control Regime* (SIPRI: Stockholm, Apr. 2024).

[45] For an overview and discussion of such scenarios see Brockmann and Raju (note 1), pp. 9–12.

[46] Schmucker, R. H. and Schiller, M., *Raketenbedrohung 2.0: Technische und politische Grundlagen* [Missile threat 2.0: Technical and political basics] (Mittler: Hamburg, 2015), p. xvii.

[47] Brockmann and Raju (note 1), pp. 20–21.

[48] Stewart, I. and Brewer, J., 'Engaging the private sector in nonproliferation: Reflections from practitioners', *Strategic Trade Review*, vol. 2, no. 3 (autumn 2016).

[49] Brockmann, K. and Héau, L., 'Developing good practices in export control outreach to the NewSpace industry', SIPRI Insights on Peace and Security no. 2023/04, Mar. 2023.

supply chain, a subsidiary or a client, which can both contribute to the proliferation of missiles and other uncrewed aerial systems capable of delivering WMD and result in severe legal penalties.[50]

In this context, the process of establishing and, where necessary, adjusting the regulatory environment around the NewSpace sector is key. Although this process may lead in the short term to additional costs for companies, in the longer term export controls and other regulations—including the drafting or updating of national space legislation—also contribute to establishing a level playing field and enabling peaceful transfers of technology.[51] Regular updates to export control regulations are important for ensuring that they do not have a disproportionate impact on trade.[52] Export controls are also one of the main tools that governments can use to mitigate proliferation risks exacerbated by ongoing developments in NewSpace.

[50] Héau and Brockmann (note 44).

[51] Jones, S. and Karreth, J., 'Assessing the economic impact of adopting strategic trade controls', US Department of State, Bureau of International Security, Office of Export Cooperation, Dec. 2010.

[52] Foust, J., 'US government plans review of space technology export controls', *SpaceNews*, 10 Apr. 2024.

3. Mapping study of the missile-related NewSpace industry

Understanding the dynamics of missile technology proliferation involves understanding an increasingly complex picture of missile-related technology, space launch vehicle technology, and the developers, possessors, producers and exporters of emerging technologies. In order to reduce proliferation risks, governments therefore need to monitor developments in space launch technology and the space industry, including small- and micro-launcher projects, and conduct outreach to and raise awareness among relevant stakeholders in the NewSpace sector.

The pilot study reported here takes a first step towards helping governments make evidence-based decisions on how to manage and address the impact on missile technology proliferation risks of the growth of the NewSpace industry and its spread to additional states. This study focuses on states where there are companies and other NewSpace actors that are developing, testing, producing or marketing missile-related technology and examines whether they are already MTCR partners or follow the regime's export control standards. This enables an initial analysis of the extent to which the MTCR's current partners and adherents and the outreach efforts of both the MTCR itself and its partners are fit to address missile proliferation risks linked to the expansion of the NewSpace industry. With a case study later in this chapter, the pilot study also seeks to enable a more granular understanding of the proliferation and impact of small and micro launchers and the companies developing them. The pilot study is intended to create a data set that can also be used to enable additional analyses in the future to assist missile non-proliferation efforts and manage the proliferation risk associated with NewSpace.

Methodology

To ensure that the data-collection effort yields consistent and reproducible data and that the collected data set allows for correlation, comparison and analysis, the research team developed a common methodology, data-collection strategy and template for the pilot study.

Research design

The pilot study was designed to create a unique data set on the spread across MTCR partners, adherents and other non-partners of NewSpace industry actors that are developing, testing, producing or marketing missile-related technology. The data points collected for each state were chosen to enable a better understanding of the nature of the growing NewSpace industry and the national contexts in which that growth was taking place. In terms of national contexts, the study focuses on export control measures that could mitigate the risks created by the proliferation of missile technology holders via expansion of the NewSpace industry. Considering the time and resources available to do the study, the data collection was conducted using a two-tiered mapping approach and a case study.

The first tier covered the 35 MTCR partners, seeking to map the extent to which there are companies within their domestic NewSpace industries that are developing, testing, producing or marketing items from the categories of the MTCR annex. The choice to focus on identifying whether there were any such entities, by item, and not to map every one of them, was made because of the significantly higher number of NewSpace companies in many MTCR partners. In addition, mapping each of these companies

would add limited value for answering the questions central to this study. Instead, the mapping provides qualitative findings about the spread of the NewSpace industry within MTCR partners and generates insights useful for the calibration of appropriate levels and strategies for outreach to NewSpace industry actors.

The second tier covered the four MTCR adherents and a selected group of 45 non-partners from across regions and with different profiles. For these states, a comprehensive mapping of all relevant NewSpace companies was conducted to try to map the extent to which the growth of the NewSpace industry is potentially increasing access to missile-related technology through commercial providers beyond the MTCR partners. This would also help to inform future efforts by the MTCR and its partners for outreach, engagement and capacity-building with non-partners.

The case study on small- and micro-launcher projects, with a focus on NewSpace companies leading such projects, was chosen due to the particular position of commercial SLV manufacturers as the most directly relevant entities that combine most of the know-how, technology, and components, equipment, and materials required for missiles. The case study covered all states, yet all projects identified are located in the 84 states selected for the pilot study.

The pilot study was not designed to generate a data set that shows the missile technology capabilities of states or their industrial base. This would require a much larger data-collection effort and an assessment of the wider arms industry and industrial base of each state, which would have been beyond the capacities of the research project. Instead, the data-collection effort was designed to specifically gather information about NewSpace companies established in the past 20 years to discern the specific impact of the spread of the NewSpace industry on missile technology proliferation risks.

Identification of 'relevant' NewSpace companies in no way implies that they pose a proliferation risk. The intention is to create a better understanding of the size of this group of companies, where they are predominantly located, what technologies they develop, test, produce and market, and the export control regulatory context in which they are operating. In order to avoid any misperceptions about companies' intentions, the study does not name the companies identified.

Data-collection methods

Data-collection framework. For each state mapped, information was collected on whether the state possesses missiles or SLVs.[53] The mapping further includes information on a state's membership of the MTCR or adherence to its guidelines and whether the state had adopted the MTCR annex or another control list that includes the annex or a derivative list as a control list in its national export control system.[54] In addition, the mapping includes information on which states have received MTCR outreach missions and participated in the most recent MTCR technical outreach meeting (TOM), held in Oslo in 2023.[55]

[53] To determine the missile possession status of a state, for the purposes of this pilot study the research team considered all states possessing missiles with a minimum range of 100 kilometres and the ability to target ground targets (including anti-ship systems), drawing information from International Institute for Strategic Studies (IISS), *The Military Balance 2023* (Routledge: Abingdon, Feb. 2023); Missile Threat, Missiles of the World database, Center for Strategic and International Studies (CSIS); and SIPRI Arms Transfers Database, Mar. 2024.

To determine SLV possession, the research team considered all orbital delivery systems, from micro launchers to super heavy SLVs, using data from Gunter's Space, 'Launch vehicles'; and NewSpace Index, 'Small satellite launchers', 15 June 2024.

[54] MTCR, 'MTCR partners' (note 7).

[55] MTCR, 'News', [n.d.]; and United Nations, Security Council, 1540 Committee, 'Missile Technology Control Regime (MTCR) technical outreach meeting (TOM)', Information note, 1 Aug. 2023. Note that the TOM held in Oslo in 2023 is the only one for which public information on state attendance was available.

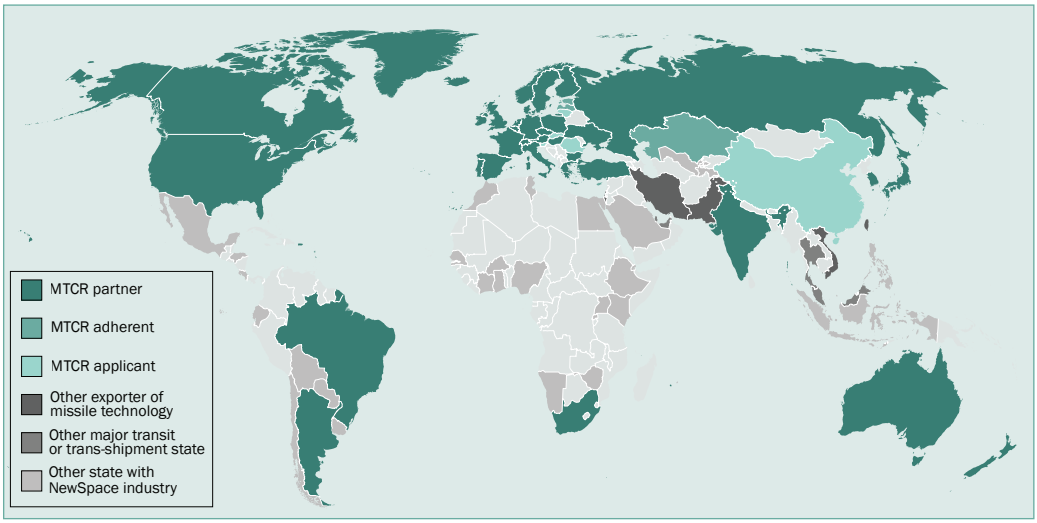

Figure 3.1. States covered by the pilot study

For each state included in the study, a list was created of individual NewSpace companies identified and the technologies they develop, test, produce or market, classified broadly in line with the items listed in the MTCR equipment, software and technology annex. Based on this data, the data set provides an assessed range, rather than a specific number of companies, to provide an estimate of the size of the missile-related NewSpace industry of each of the states. The information on the technologies held by the companies was then used to generate an overview of the extent to which the domestic NewSpace industry in MTCR partners holds technologies from across the relevant item categories.

The study also collected limited information on national space agencies, space industry and innovation hubs, accelerators, and universities from which many new companies may be created. This information supplemented the assessment of the number of companies identified for each state as a range but is otherwise not specifically reflected in the data and the analysis presented in this report.

Sources consulted. To identify relevant NewSpace companies, the research team followed a common data-collection framework and kept a research log for each state mapped to ensure reproducibility. Researchers consulted information provided by national NewSpace and space industry associations, industry databases and analyses, venture capital and funding databases, national space agency projects, reporting in trade journals and—where accessible—company registries. In addition, Janes 'Space systems and industry 2022–23' was used as a reference data set.[56] The research team also conducted literature and web searches using keywords drawn from the MTCR annex to identify NewSpace companies developing, testing, producing or marketing missile-related technology.

For each data point on a NewSpace company, at least one (and ideally two) reputable source was required to warrant inclusion. For the purposes of the pilot study, authoritative sources were considered to include company websites, news articles from professional outlets, and funding and project reports, among others.

Sample selection

Geographical scope. The pilot study covers a total of 84 states (see figure 3.1). These were selected based on several criteria and the desire to both cover the most relevant

[56] Jadhav, A. (ed.), *Janes Space Systems and Industry 2022–23* (Jane's Group UK Limited: Coulsdon, 2022).

states from the perspective of proliferation risk and a range of different profiles among non-partner states.

All 35 MTCR partners and all 4 official MTCR adherents are included in the mapping, as most of them are already possessors and exporters of missile-related technology, including through their national space industries. In addition, several known MTCR applicants are included that are of similar profile and fulfil most of the criteria generally considered to become a partner. The pilot study also covers all major exporters of missile-related technology among MTCR non-partners, based on transfers of relevant missiles recorded in the SIPRI Arms Transfers Database.[57] Several states that have been major transit and trans-shipment hubs in past cases of proliferation (e.g. Malaysia, Singapore and the United Arab Emirates) are included in the mapping. Finally, another set of countries was selected either because of indications of a growing NewSpace industry or in an attempt to ensure that the overall sample included states from all continents and regions and a diversity of small and large and developing and developed economies.

This pilot study does not cover all states, but rather has collected data on a subset of relevant states that represents a diverse set of contexts in which trends associated with NewSpace are visible and may coincide with the creation of missile proliferation risks.

Industry scope. The study set out to collect data on NewSpace companies established in the selected states that develop, test, produce or market missile-related technology. For the purposes of the mapping study, 'NewSpace companies' are considered to include all companies in the aerospace or space sector that have been established since 2004 and demonstrate at least some of the characteristics generally associated with NewSpace. This includes start-ups and other companies relying on venture capital; a wide range of companies that are developing new space-based services, launch solutions and emerging technologies for space applications; and subsidiaries, spin-offs and SMEs that identify with NewSpace.[58] Service providers are only included if the service they provide is likely to involve the transfer of controlled technology.

Not all companies share all characteristics, but their inclusion in the data set was assessed based on these characteristics as criteria and limited to those NewSpace companies developing, testing, producing or marketing missile-related technology.

Limitations

It is in the nature of conducting a pilot study that there are certain limitations to the completeness, accuracy and precision of the resulting data set.

The NewSpace industry is developing rapidly in many states. This means that many new companies are established every month. However, a considerable number of companies also close down, are acquired or are part of mergers, which will not always be immediately evident on company or industry association websites and in reports—and analyses may quickly become outdated. Due to the lack of a common definition of which companies belong to the NewSpace sector, even with the characteristics used by the study to define and distinguish relevant NewSpace companies, a company may not always clearly fit in the sector or there may be a lack of specific information on the company and its products. Where the criteria did not allow for a clear distinction, the researchers made an informed decision about including individual companies based on the available information.

The collection of original data by the research team was also constrained by the available time and prescribed timeline of the project. The collected data set therefore does

[57] SIPRI Arms Transfers Database (note 53).
[58] Murray (note 25), p. 2.

Table 3.1. Estimated number of NewSpace companies developing, testing, producing or using missile technology in Missile Technology Control Regime adherents and selected other non-partners

No. of companies (range)	No. of states	Share of total (%)
0	22	*45*
1–5	19	*39*
6–10	6	*12*
11–15	1	*2*
16–20	–	–
21–30	–	–
31–40	–	–
41–51	–	–
51–75	–	–
76–100	1	*2*
Total	**49**	***100***

Source: Appendix A in this volume.

not have a claim for completeness but presents a best effort to create a reproducible data set using a clear methodology.

A specific difficulty that the research team encountered is linked to the types of public sources available and the ability to classify the technologies that companies claim to develop, test, produce and market. It was not always possible to ascertain whether the open-source information (in particular company websites and secondary sources reporting on their activities) was complete, up-to-date and accurate. It was also beyond the scope of this pilot study to conduct a technical assessment of specific parameters of each of these technologies to determine whether they are subject to export controls based on the MTCR annex. Company websites and secondary reporting often do not show the full suite of technologies developed, used and transferred. Instead, they tend to focus on a small number of marketed products and services offered or on the performance of the launch vehicle, satellite or spacecraft a company is producing or to which it is otherwise contributing.

The research team primarily relied on open-source English-language sources, sources in other languages in which members of the research team are proficient, and automatic translation offered through web applications. However, most NewSpace companies are trying to attract international funding and venture capital for their activities, making an accessible English-language website a staple feature. This limited the selection bias introduced by primarily conducting searches using English sources and translation tools.

Mitigation

To mitigate the acknowledged limitations of the pilot study, the research team adopted a broad definitional approach for the inclusion of companies in the mapping based on their NewSpace characteristics. Considering a broad set of criteria also accounts for the different nature of the domestic NewSpace industries across different states. Further, instead of providing the specific number of relevant companies identified in a mapped state, the data set provides the number of companies as a range (e.g. 1–5 companies, 6–10, 11–15, etc.). The intention was to create a buffer that could account for errors in the inclusion or omission of specific companies, and to account for the volatility of the sector and the likelihood of companies closing down or new companies being created or not having been identified.

Any company that was found to develop, test, produce or market a technology that appears in the MTCR annex for space applications was included. Even if marketed products are below the technical thresholds of the items listed in the annex, the company is likely to hold the required know-how, its portfolio may expand, it is still subject to catch-all controls for unlisted items, and it should have due-diligence and compliance procedures in place—such companies should thus be among those targeted by governments' outreach to industry.

Multinational companies were counted in each state in which they have established facilities contributing to development, engineering, testing, production or launch. Only sales offices were excluded: while generating offers for potential customers also poses certain export control challenges, the inclusion of sales offices would have led to an over-emphasis of particularly strong consumer markets, rather than the NewSpace industry itself.[59]

Overview of pilot study results

The size of missile-related domestic NewSpace industries

The mapping study found that 27 of the 49 mapped MTCR adherents and selected other non-partners (i.e. 55 per cent) have relevant NewSpace companies developing, testing, producing or using missile-related technology established on their territory. Nineteen of these 49 states (39 per cent) have 1–5 relevant companies established on their territory, and six (12 per cent) have 6–10 companies. One non-partner—Israel—was found to have 11–15 relevant NewSpace companies, while another—China—had was found to have 76–100 (see table 3.1). Of the 49 adherents and other non-partners, 17 (35 per cent) have adopted the current or a previous version of the MTCR annex into their national export control legislation. Sixteen of these 17 also have domestic NewSpace companies developing, testing, producing or using missile technology. None of the remaining 11 states with relevant NewSpace companies have adopted any version of the annex (see appendix A).

Among the mapped adherents and other non-partners, China stands out with its high number of 76–100 companies developing, testing, producing or using missile-related technology within its large domestic NewSpace industry (see figure 3.2). This can in part be attributed to the significant focus on the launch sector in the Chinese space industry and the intentional decision to locate such projects within the commercial portion of China's space industry.[60] Notably, many Chinese small- and micro-launcher companies benefit from technology transfers from Chinese state-owned or -controlled entities and central and regional government funding.[61] These conditions differ considerably from those in many other states and reflect the specific characteristics of the Chinese commercial space sector. The other 26 mapped adherents and non-partner states with relevant companies each have between 1 and 15 such companies.

Prevalence of certain MTCR annex technologies in the NewSpace industry

The MTCR annex lists controlled items in 17 item categories (see table 3.2). The results of the mapping study show that of the 35 MTCR partners, only 12 have NewSpace companies that—collectively—develop, test, produce or market missile-related technology across 13–17 items. Sixteen partners have relevant companies that do so across 8–12 of

[59] For a discussion of ITT challenges linked to NewSpace business operations see Héau and Brockmann (note 44), pp. 6–8.

[60] Solem, E., 'The emergence of China's commercial space companies and start-ups', China Aerospace Studies Institute, Sep. 2020.

[61] Solem (note 60), p. 15.

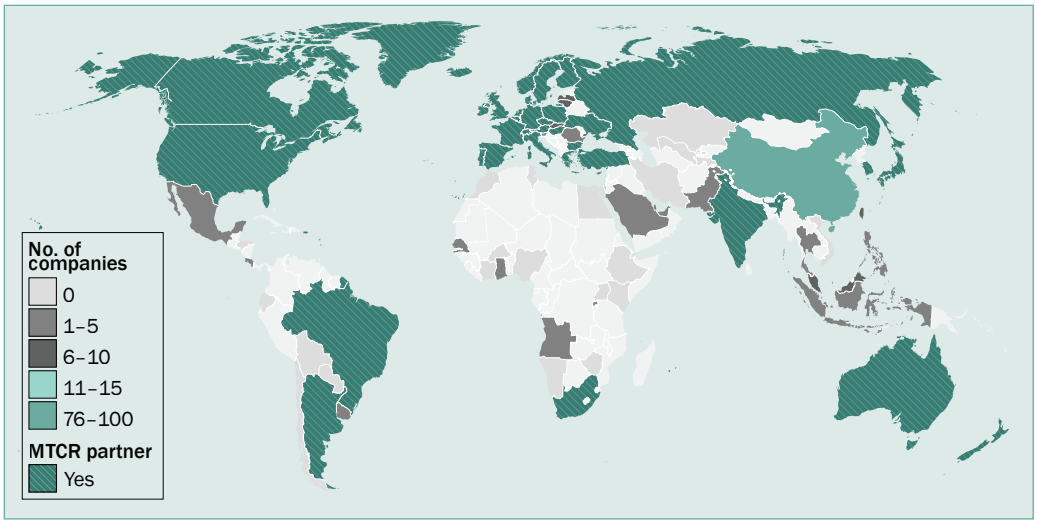

Figure 3.2. Estimated number of NewSpace companies developing, testing, producing or using missile technology in Missile Technology Control Regime adherents and selected other non-partners

Note: The ranges provided here are assessed estimates based on the actual number of companies mapped and taking into account the frequent turnover and founding of companies in the sector.

Source: Appendix A in this volume.

the 17 MTCR item categories, while six have companies that together cover 1–7 items. Only one MTCR partner—Iceland—has no relevant NewSpace company (see appendix B).

The data indicates that NewSpace companies have been established across subsectors of the space industry in many MTCR partners and they develop, test, produce or transfer missile-related technology across many of the MTCR-controlled items. They may, therefore, inadvertently or intentionally contribute to missile proliferation risks, including by being targeted by illicit procurement efforts. Even in cases where companies based in a particular state work on only a smaller number of item categories, this does not indicate a lack of technology capabilities. Rather, it may result from strong domestic or international competition restricting new entrants in certain technologies; lack of scope for innovative approaches to NewSpace technologies in certain item categories (e.g. analogue-to-digital converters); or limited civilian applications (e.g. stealth). In certain cases, technologies in certain item categories may have also been difficult to identify by the research team or are less prominently featured in company sources.

NewSpace industry profiles compared to missile possession, space programme and MTCR membership status

Among the 84 states mapped as part of the pilot study, 55 possess missiles and 28 have operational SLVs or are currently developing small and micro launchers.[62] Of the 55 missile possessors, 44 were also found to have NewSpace companies developing, testing, producing or marketing missile-related technology, while 27 of the 28 states with operational SLVs or developing small- or micro launchers also have such NewSpace companies.

This demonstrates that there is both a high correlation between states' missile possession and having a missile-related NewSpace industry and between SLV possession and development and having such a NewSpace industry. The latter finding is not surprising

[62] Among the 55 missile possessors are 26 MTCR partners, 3 adherents and 26 non-partners. Among the 28 SLV possessors are 20 partners and 8 non-partners.

Table 3.2. Item categories of the Missile Technology Control Regime equipment, software and technology annex

Item no.[a]	Description
Category I[b]	
Item 1	Complete delivery systems
Item 2	Complete subsystems usable for complete delivery systems
Category II	
Item 3	Propulsion components and equipment
Item 4	Propellants, chemicals and propellant production
Item 6	Production of structural composites, pyrolytic deposition and densification and structural materials
Item 9	Instrumentation, navigation and direction finding
Item 10	Flight control
Item 11	Avionics
Item 12	Launch support
Item 13	Computers
Item 14	Analogue-to-digital converters
Item 15	Test facilities and equipment
Item 16	Modelling-simulation and design integration
Item 17	Stealth
Item 18	Nuclear effects protection
Item 19	Other complete delivery systems
Item 20	Other complete subsystems

[a] Items 5, 7 and 8 currently have no list entries, but are retained in the current list structure and may be used if new list entries should be added to the annex.

[b] Category I items are 'items of greatest sensitivity'.

Source: Missile Technology Control Regime (MTCR), 'Equipment, software and technology annex', MTCR/TEM/2023/Annex, 14 Mar. 2024.

but demonstrates that the NewSpace industry is a factor in all spacefaring states and in those with concrete ongoing SLV development projects.

Case study: Small- and micro-launcher companies

The growth of the NewSpace industry, the demand for launch capacity for small satellites, and the desire to reduce launch costs and to increase the availability of variable and rapid launch options are driving the development of small and micro launch vehicles by commercial providers.[63] The expansion of the space-based services sector and smaller, lighter and to some extent cheaper satellites have resulted in significant perceived demand for launch services that can be used at short notice and tailored to the delivery of small satellites. This demand is primarily created by commercial satellite companies, critical infrastructure providers and militaries. There is also a general demand for more launch capacity, as several older heavy launchers have now been retired and limited capacity remains for small satellites to 'rideshare' or 'piggyback' along with other, primary, payloads. This means that such spots often have to be booked several years in advance. Another indicator of the current demand for small-launch capacity is that many companies in the advanced stages of developing a launch vehicle claim to have

[63] Kulu (note 17); and Schiller and Brockmann (note 4).

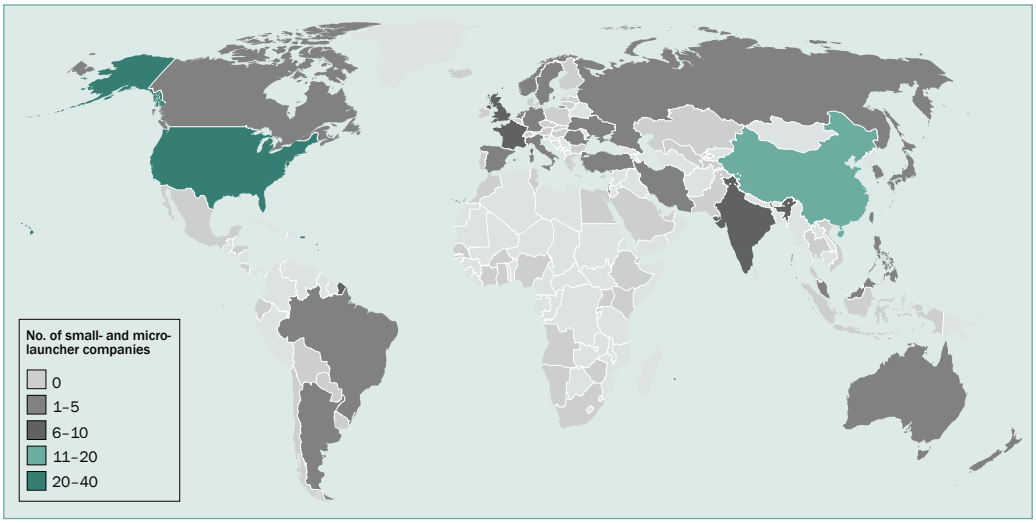

Figure 3.3. Number of small- and micro-launcher projects, by state

Sources: See description of methodology in this volume.

already filled their order books for the first scheduled launches. However, there are also indicators that there may be insufficient demand to justify the large number of small and micro launchers currently in development.[64]

For the purposes of this study, small- and micro-launcher projects are distinguished from small- and micro-launcher companies. A small- or micro-launcher project is any effort to develop an individual small or micro launch vehicle (including rockets and spaceplanes with propulsion systems similar to ballistic or cruise missiles). In contrast, a small- or micro-launcher company is the principal developer or manufacturer of one or more small or micro launchers. Several small- and micro-launcher companies develop or produce multiple small and micro launchers, either to target different markets or as natural development steps towards producing increasingly larger launch vehicles. These companies are often focal points of missile technology development, testing and production.

All space launch vehicles use many of the same, or at least similar, components and technologies as ballistic missiles.[65] There are different requirements for SLVs (including small and micro launchers) and missiles. Among the most significant differences are the requirement for an SLV to reach circular velocity to deliver its payload and the necessary configuration and engineering optimization of the vehicle.[66] The use scenarios of small and micro launchers as satellite-launch vehicles, as opposed to missiles as means of warfare, mean that the stakes are different. There are also different operational demands in terms of timely readiness, hardening and ruggedness, serial production and individual adaptation to specific missions.[67] Despite their differences in optimization, the technologies used in small and micro launchers are still highly relevant for any developing missile programme and would be highly valuable.

Spread of small- and micro-launcher projects and companies

The mapping conducted as part of the case study, which covered all states, found that the number of small- and micro-launcher projects and companies has multiplied and they are spread across a growing number of states. As of October 2024, the study identified 118 active small- and micro-launcher projects, 21 of which work on a small or

[64] Schiller and Brockmann (note 4).
[65] Maitre and Moreau-Brillatz (note 39); and Maire (note 39), pp. 16–22.
[66] Schiller and Brockmann (note 4).
[67] Schiller and Brockmann (note 4).

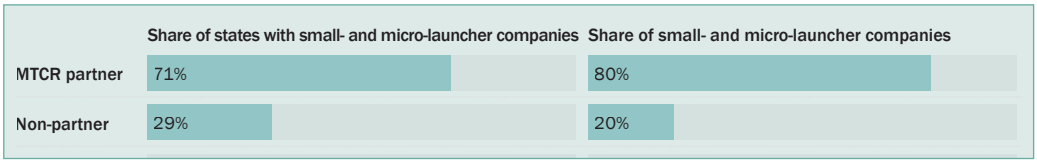

Figure 3.4. Share of small- and micro-launcher companies established in Missile Technology Control Regime partners and non-partners

Sources: See description of methodology in this volume.

micro launcher that is currently operational. These 118 projects are currently being developed by at least 111 small- and micro-launcher companies established in 28 states (see figure 3.3). The states with the largest numbers of small- and micro-launcher projects are the United States (38 projects) and China (16), followed by France (7), India (6), Japan (6), the United Kingdom (6), Germany (5) and Spain (5).

Among the 28 states in which active small- and micro-launcher companies are located, 20 (71 per cent) are MTCR partners, while 8 (29 per cent) are non-partners (see figure 3.4). No small- and micro-launcher project was identified in the four MTCR adherents. Of the 118 small- and micro-launcher projects identified, 94 (80 per cent) are located in MTCR partners while 24 (20 per cent) are in non-partners. Each of the eight non-partners with active small- and micro-launcher projects already possesses at least some short-range missiles. The vast majority (98, or 88 per cent) of the 111 identified small- and micro-launcher companies are NewSpace companies, including spin-off companies emulating some of the characteristics of a NewSpace start-up.

Responsive space and other drivers of the development of small and micro launchers

Many of the small- and micro-launcher projects currently in development specifically seek to fulfil the demand for 'responsive space' capabilities.[68] Responsive space refers to a capability to launch satellites and other space assets on short notice to ensure the functionality of critical space-based services and infrastructure. The desired capabilities therefore often include an ability to launch a satellite payload to a range of different orbits within a comparatively short timeline.[69]

Building this type of resilience and redundancy can be achieved using different approaches. Some companies are developing small and micro launch vehicles that use solid-fuel rocket motors and can be manufactured in serial production and stockpiled until they are needed for a launch. Others have explored launchers that can be launched from a road-mobile transporter-erector-launcher or shipped in a small number of standard shipping containers and assembled and launched using minimal launch-support equipment.

The configuration and technical optimization of these different vehicles means that the engineering solutions deployed in some small and micro launch vehicles make them more similar to ballistic missiles and thus more desirable for missile programmes.[70] As a result, the proliferation risks that are linked to transfers of components and other goods, technologies and software from companies undertaking such small- and micro-launcher projects are higher. Particular vigilance and effective compliance procedures are therefore required.

[68] E.g. Rocket Lab (note 40).

[69] Albon, C., 'Space Force awards rapid satellite launch demonstration contracts', C4ISRnet, 4 Oct. 2022; and Hadley, G., 'Space Force wants operational capability for tactically responsive space in 2025', *Air and Space Forces*, 21 Mar. 2024.

[70] Schiller and Brockmann (note 4).

Sustainability of funding and demand for small and micro launchers

There are significant differences across states in the small- and micro-launcher projects that are currently being undertaken. Some have developed and produced launch vehicles that have successfully completed missions and attracted hundreds of millions of dollars in venture capital and funding. Others are merely projects of hobbyists with the dream of building their own rocket, limited by the personal capital they are able and willing to invest.

There are also significant differences in the extent to which small- and micro-launcher companies rely on innovative solutions and in-house development and production and whether they have access to legacy technologies, components, or even entire missiles or launch vehicle to kick-start the development of their small or micro launcher. In particular, several of the launch vehicles developed in China appear to build strongly on legacy systems and to benefit from close ties with state-owned missile producers, military-related research centres and universities.[71] This is also a reflection of how small- and micro-launcher companies are affected by the differences in the significance and nature of state funding, state support, and access to proven technology and components—and how this may set apart commercial and state-owned or -supported companies in different states.

Developments in the market for small and micro launchers over the past decade also show that—despite the growth of the sector—a considerable share of companies are acquired by competitors, go bankrupt or otherwise close down.[72] The geographically diverse pool of experienced technicians and engineers therefore moves around frequently, and companies may be susceptible to financial pressures that can be exploited by illicit procurement agents.[73]

[71] Solem (note 60), p. 15.
[72] Kulu (note 17), pp. 15–18.
[73] Schiller and Brockmann (note 4).

4. Implications for the Missile Technology Control Regime

The Missile Technology Control Regime was established in 1987 as a result of concerns around the proliferation of missiles and space-launch capabilities.[74] The first partners initially focused on bringing into the regime other possessors and suppliers of missile-related technology, and they largely succeeded in doing so in the 1990s. The MTCR admitted both major missile producers and suppliers, such as Russia, and states which had an exclusive focus on peaceful space programmes, such as Argentina and Brazil, but which had previously attempted to develop missile capabilities.[75] However, the growth in MTCR membership has largely halted in the past two decades: since 2004, only one state has joined the MTCR (India in 2016).[76] Several current and past major possessors of missiles and suppliers of missile-related technology remain outside the MTCR, including China, Iran, Israel, North Korea, Libya and Pakistan, either because these states are not interested in joining or because there is a lack of consensus among the partners about admitting them.[77] Ongoing disagreements on possible new partners and growing geopolitical tensions have made new accessions increasingly unlikely.[78]

Technological developments over the past two decades, combined with the emergence of the NewSpace sector, have led to questions about whether the MTCR still gathers most of the possessors and suppliers of missile-related technology. This consideration is important not least because MTCR partners decide on updates to the MTCR annex and are the first to implement them, and because partners can share among themselves privileged information (e.g. intelligence on proliferation threats and cases) and good practices on enforcement, which can be instrumental in preventing potential (and evolving) proliferation risks.[79]

Membership criteria in the light of the spread of the NewSpace sector

With the growth of the NewSpace sector, the number of possessors of missile-related technology is rising. Seven non-partners are currently developing small- and micro-launcher technology: China, Israel, Malaysia, the Philippines, Romania, Singapore and Taiwan (see figure 3.3). Aside from small- and micro-launcher technology, a larger group of states are on their way to developing a NewSpace industry; at least 27 adherents and other non-partners have at least one NewSpace company based on their territory that is developing, testing, producing or marketing missile-related technology (see table 3.1).

Thus, NewSpace developments are reducing the proportion of missile-technology-possessing states that participate in the MTCR. Given the consensus rule and the ongoing stalemate in membership, it appears likely that most of these states will not join the regime. That said, the partners should hold discussions with at least the states that have or will soon obtain small- and micro-launcher capabilities on their objectives with regards to MTCR membership, and they should discuss among themselves whether the inclusion of these major NewSpace actors as new partners would be beneficial. Some

[74] Beck, M. D. and Jones, S. A., 'The once and future multilateral export control regimes: Innovate or die', *Strategic Trade Review*, vol. 5, no. 8 (winter/spring 2019), p. 62.

[75] Ozga, D. A., 'A chronology of the Missile Technology Control Regime', *Nonproliferation Review*, vol. 1, no. 2 (winter 1994); and Maitre, E. and Héau, L., 'The HCOC and Latin America', HCoC Issue Brief, Fondation pour la recherche stratégique (FRS), Apr. 2021.

[76] Brockmann, K., Bromley, M. and Héau, L., *The Missile Technology Control Regime at a Crossroads: Adapting the Regime for Current and Future Challenges* (SIPRI: Stockholm, Dec. 2022).

[77] Brockmann et al. (note 76).

[78] Brockmann et al. (note 76).

[79] Brockmann et al. (note 76).

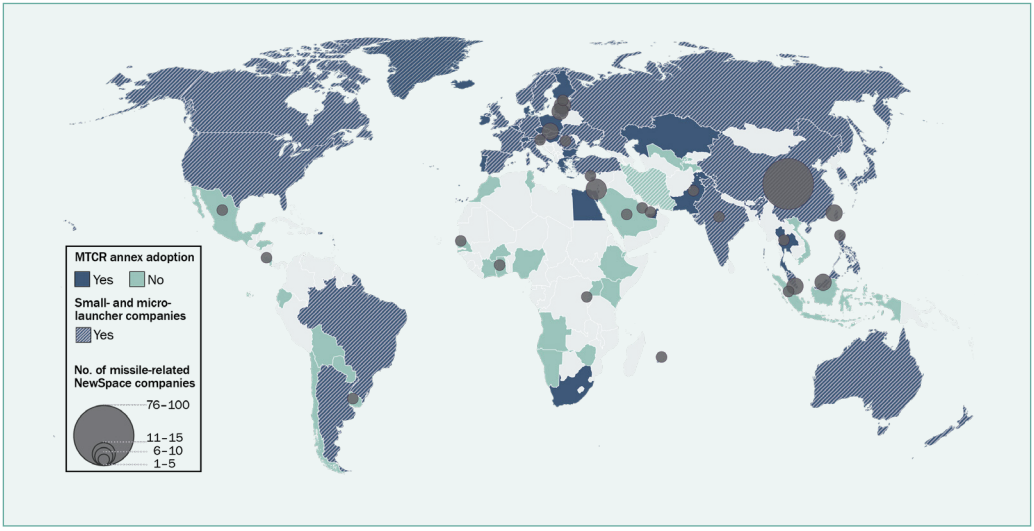

Figure 4.1. Adoption of the Missile Technology Control Regime annex and estimated number of NewSpace companies developing, testing, producing or using missile-related technology, and small- and micro-launcher companies in adherents and selected other non-partners

Note: The ranges provided here are assessed estimates based on the actual number of companies mapped and taking into account the frequent turnover and founding of companies in the sector.

Source: Appendix A in this volume.

of these states are also major transit and trans-shipment hubs, which would make them especially relevant. Some already apply the MTCR annex (e.g. Malaysia and Singapore), which could enable easier consensus on admittance among partners.[80] For those states that do not currently do so, adopting the MTCR annex would be an important commitment (see figure 4.1).

As previous research has demonstrated, many NewSpace companies still lack detailed awareness of missile proliferation risks and do not have effective internal compliance programmes in place.[81] It is therefore key that the exchanges that take place on NewSpace within the MTCR gather a majority of the states that possess and supply relevant technology. This can both ensure the continued relevance of the regime and strengthen implementation of the guidelines. The regime should also hold information exchanges with relevant states, allowing proliferation concerns to be addressed early on.

MTCR adherence of states with NewSpace companies developing, testing, producing or marketing missile-related technology

Aside from MTCR membership, there are alternative ways in which non-partners with an active NewSpace industry can be involved, one of which is to become formal MTCR adherents. To date, four states have become MTCR adherents: Cyprus, Estonia, Kazakhstan and Latvia.[82] While none of them has small- and micro-launcher companies on its territory, Cyprus, Estonia and Latvia do have emerging NewSpace industries, each with at least 1–5 NewSpace companies developing, testing, producing or marketing missile-related technology on their territory (see appendix A). In addition, China, Iraq, Israel, North Macedonia, Romania and Slovakia have at one point announced that they would adhere to the MTCR guidelines, but without using the formal MTCR adherence

[80] Van Diepen, V. H., Remarks for Center for Nonproliferation Studies–Arms Control Association MTCR 30th year event, 15 Feb. 2018.

[81] Brockmann and Raju (note 1).

[82] MTCR, 'MTCR partners' (note 7).

procedure.[83] Among them, China, Israel and Romania have small- and micro-launcher companies on their territories (see appendix A) A fourth, Slovakia, counts 6–10 NewSpace companies developing, testing, producing or marketing missile-related technology with a focus on developing rocket engines and suborbital rocket technology (see appendix A).[84] Continued engagement with these states would thus be beneficial for the regime. It could lead to some of them formally becoming MTCR adherents, which would enable the formation of a relevant group of states that would lead to the further development of the adherence mechanism.

Formal MTCR adherence brings a range of opportunities for dialogue and information exchange. Such exchanges can take place during a bilateral outreach visit or a technical outreach meeting. TOMs provide an opportunity for the MTCR to brief adherents, applicants and those interested in becoming adherents or partners.[85] Presentations made by partners at MTCR licensing and enforcement expert meetings (LEEMs) can also be shared with adherents; if some of these touch on topics related to NewSpace, they could provide a valuable resource for adherents.

NewSpace developments could provide an opportunity for the MTCR to revive its formal adherence procedure, which, despite Cyprus joining recently, has not seen a large uptake since its establishment in 2014. To support this, the partners should develop a strategy that targets states with NewSpace companies developing, testing, producing or marketing missile-related technology.[86] Of the states mapped, eight non-partners have at least one such NewSpace company but do not possess missile or traditional SLV capabilities (see figure 4.1). Adherence could thus be particularly relevant for those states that were not previously directly exposed to missile-related technology developments on their territory but which now host an emerging NewSpace industry.

MTCR and partner outreach to adherents and other non-partners

The MTCR and its individual partners carry out outreach to adherents and other non-partners to promote the MTCR's objectives, further adherence to its guidelines and adoption of the MTCR annex into national control lists, and to contribute to the regime's transparency.[87] They do so through formal bilateral outreach visits, technical outreach meetings and more informal bilateral contacts.

Available data suggests that, through outreach, the MTCR has recently engaged with a majority of the eight non-partners that have small- and micro-launcher companies: since 2020 the MTCR has held at least one bilateral outreach visit to China (informally), Israel, Malaysia and Singapore, and both China and Romania attended the 2023 TOM in Oslo (see figure 4.2).[88] This leaves three of these eight states—Iran, the Philippines and Taiwan—lacking direct engagement with the MTCR. In the case of Taiwan, this may be partly linked to its contested status, which has impeded its association with the MTCR and the other multilateral export control regimes. Iran was subject to United Nations Security Council sanctions over its missile activities for many years and thus lacked the missile non-proliferation credentials to be considered for outreach.

Given the relevance of this group of states, the MTCR should continue to actively engage with them. There would be particular value in intensifying outreach to China. China has declared in the past that it unilaterally implements the MTCR guidelines,

[83] Brockmann et al. (note 76).
[84] E.g. Borospace, 'About Borospace', [n.d.]; and SBS Group, 'Slovak Aerospace Technologies', [n.d.].
[85] MTCR, 'MTCR experts groups', [n.d.].
[86] Brockmann et al. (note 76).
[87] Brockmann et al. (note 76).
[88] MTCR, 'News' (note 55); and United Nations (note 55).

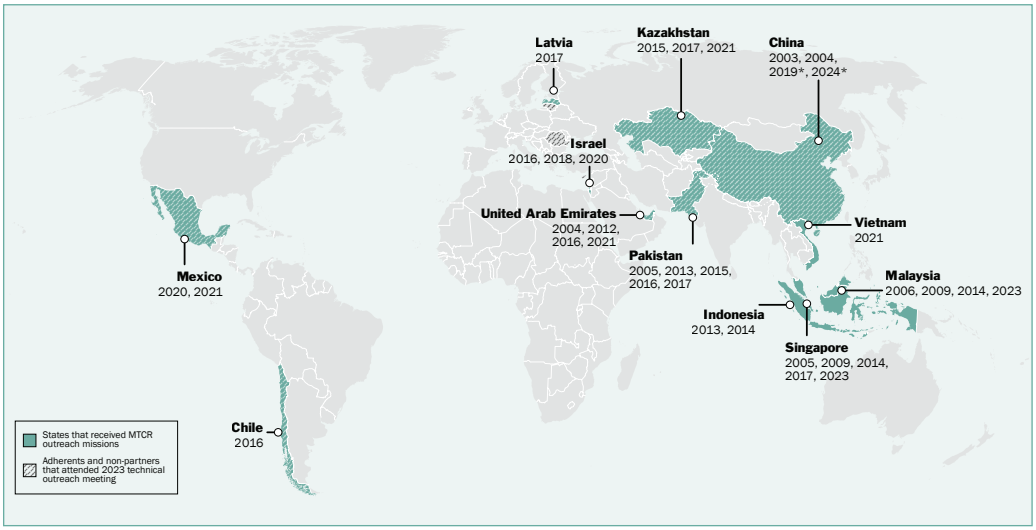

Figure 4.2. States receiving Missile Technology Control Regime outreach missions and participating in the 2023 technical outreach meeting

Sources: Missile Technology Control Regime (MTCR), 'News', [n.d.].

and recently imposed new export controls on missile and UAV-relevant technology.[89] Due to previous proliferation concerns and political divisions, there remains an absence of consensus among the MTCR partners on China's potential membership. Moreover, given its ongoing external criticism of the multilateral export control regimes, China may also not be currently inclined to join the MTCR.[90] There has been no official MTCR outreach to China since 2004, but unofficial visits took place in 2019 and 2023. Given the size of its NewSpace sector, setting up a formal MTCR outreach mission to China and discussing NewSpace as one of the key topics may lead to constructive dialogue.

So far, there appears to be less of a focus on MTCR outreach directed at the broader group of 'emerging' NewSpace industry states. Of the 19 adherents and other non-partners that have 1–5 NewSpace companies developing, testing, producing or marketing missile-related technology, only 6 have been involved in some form of MTCR outreach. Cyprus, Mexico, Pakistan, Romania and the United Arab Emirates (UAE) attended the 2023 TOM and the MTCR held bilateral outreach visits to Indonesia, Mexico, Pakistan and the UAE (see appendix A). The number of bilateral outreach visits is limited by the time and resources available, and these visits therefore target states that are deemed most directly relevant—for example, because they have small- and micro-launcher companies established on their territory or because they have already developed a NewSpace industry.

To more actively target such states with a growing number of relevant NewSpace companies, the MTCR could create an informal category of 'NewSpace industry states' for outreach. Future TOMs could strengthen their focus on NewSpace and consider including more of these emerging NewSpace industry states. This includes states that have started to produce MTCR-relevant items. It also includes states that have a more downstream-focused NewSpace ecosystem. Although downstream NewSpace activities can appear less relevant for the MTCR, because they do not directly involve developing, testing, producing or marketing missile-related technology, downstream companies regularly interact with the upstream portions of the space industry, includ-

[89] 'China imposes new export controls on "dual-use" parts for military and civilian drones', *WorldECR*, 1 Aug. 2024; and 'China imposes export controls on aviation and space technology and components', *WorldECR*, 6 June 2024.

[90] Bromley, M., Mustafić, S. and Yuan, J., 'China takes aim at the export control regimes: Targeted critique or misguided attack?', *WorldECR*, no. 123, Dec 2023/Jan 2024.

ing through ITT. This makes states that have downstream NewSpace companies a relevant group for the MTCR because they could also be vulnerable to (indirect) proliferation risks. Moreover, while those states may not yet be in a position to export MTCR-relevant items, given ongoing developments they are likely to be increasingly relevant for the MTCR in the near future.

In conducting outreach with NewSpace industry states, the MTCR and individual partners may want to include content that is directly relevant to those states. At the 2023 TOM in Oslo, for example, while NewSpace was not mentioned explicitly among the topics raised with participants, an information note indicates that ITT and outreach to industry were among the topics discussed.[91] Both topics are relevant for states with a NewSpace industry, and a sustained focus on those topics is key for awareness raising. Depending on the relationship that individual non-partners have with the MTCR, the state of their NewSpace industry and their specific national priorities, there are a number of ways in which they can be associated with the MTCR and which the regime and partners can raise. Outreach by the MTCR and partners should encourage all non-partners to adhere to the MTCR guidelines and adopt the MTCR annex into their national control lists. This would provide a valuable public good to both structure and enable oversight of the transfer of MTCR-related items. Currently, only 16 of the 27 adherents and other non-partners that were found to have an active NewSpace industry have adopted the MTCR annex (appendix A). Holding more regular TOMs could also enable participation by a wider pool of states, including more states with an emerging NewSpace industry. For those states that wish to be more regularly engaged, the MTCR and the partners should also continue to promote MTCR adherence and related incentives.

Finally, there are several avenues whereby the MTCR and partners can cooperate with other existing instruments and forums to limit the risk of missile proliferation and to raise awareness of the relevance of export controls. For example, the MTCR should continue to be involved in regional export control forums to support regional approaches through complementary forums.[92] A regional focus could be especially useful in Asia, where at least five non-partners have companies developing small- and micro-launcher projects on their territories and where further states (e.g. Indonesia) have plans for the development of similar capabilities.[93] In addition, the Hague Code of Conduct against Ballistic Missile Proliferation (HCOC), as a politically binding transparency and confidence-building measure open for all states to join, provides a valuable, complementary tool to the MTCR.[94] Joint outreach from the HCOC and the MTCR could be encouraged or, perhaps more pragmatically, each instrument could invite the chair of the other to take part in its outreach missions. Encouraging states to subscribe to the HCOC could be a way for states with emerging NewSpace industries to demonstrate their commitment to non-proliferation of ballistic missiles capable of delivering WMD.

Outreach to the domestic NewSpace industry

Conducting outreach activities for domestic industry is a key component of a state's implementation of an effective national export control system. As part of such outreach

[91] United Nations (note 55).

[92] Lewis, J. and Brockmann, K., *Missile Proliferation and Control in the Asia-Pacific Region* (International Institute for Strategic Studies (IISS): London, Apr. 2024).

[93] Lewis and Brockmann (note 92).

[94] Brockmann, K., 'Controlling ballistic missile proliferation: Assessing the complementarity between the HCoC, MTCR and UNSCR 1540', HCoC Research Papers no. 7, Fondation pour la recherche stratégique (FRS), June 2020; and Hague Code of Conduct against Ballistic Missile Proliferation, adopted 25 Nov. 2002.

activities, governments inform companies about national legislation, compliance obligations and the risks created by illicit transfers of items. The NewSpace industry is an increasingly important target for such outreach activities, particularly as it relates to raising awareness of missile proliferation risks that might occur for start-ups, university spin-out companies and other non-traditional industry actors. These stakeholders in particular are often less aware of—and less prepared to fulfil—their due-diligence obligations as they often lack appropriate compliance programmes and resources committed to implement them.[95]

The spread of the NewSpace industry involves the spread of commercial NewSpace companies developing, testing, producing or using missile-related equipment, software and technology in many states. Of the 84 mapped states, 73 per cent have NewSpace companies developing, testing, producing or marketing missile-related technology (see table 3.1 and appendix B). It is therefore important that all states with nascent or growing NewSpace industries engage in targeted outreach to NewSpace companies to raise awareness about missile proliferation risks. Previous research has identified key elements of an effective outreach strategy for the NewSpace sector. These include identifying stakeholders; incentivizing participation in outreach activities; consistently engaging with launch vehicle manufacturers; inter-agency cooperation; and raising awareness of risks related to foreign direct investment (FDI) as a pathway for illicit technology acquisition.[96]

Among the states mapped in this pilot study, in most adherents and other non-partners with a missile-related NewSpace industry, there are 10 or fewer relevant NewSpace companies developing, testing, producing or marketing missile-related technology (see table 3.1 and figure 3.2). Particularly in states with a relatively low number of such companies, individual engagement with the companies by the national licensing and enforcement authorities is more manageable. It also enables the organization of outreach events for relatively small groups of companies that share NewSpace characteristics and face related challenges, while emphasizing the desire to engage in dialogue with industry and maintain a level playing field. Sharing good practices in tailored outreach to this size of domestic NewSpace industry as part of outreach missions to adherents and non-partners and during TOMs would therefore be appropriate. There is also a need to devote a share of the resources allocated for outreach to industry to address the broader NewSpace ecosystem. This includes universities, research centres and companies that form part of the innovation ecosystem, value chains and international business operations. Intangible transfers of technology and software are particularly prevalent among these actors and may often go unnoticed in the absence of a comprehensive internal compliance programme.[97]

[95] Interviews conducted by the authors with compliance officers and other representatives of NewSpace companies, industry associations, licensing and enforcement officers from several different states have provided concurrent anecdotal evidence that a lack of appropriate internal compliance programmes and awareness of missile proliferation risks persists among many stakeholders in the sector.

[96] Brockmann and Héau (note 49), p. 16.

[97] Héau and Brockmann (note 44).

5. Conclusions

The growth of the NewSpace sector is a widespread, but not global, phenomenon and its opportunities and risks are not equally distributed. Moreover, the companies working with missile-related technology make up only a relatively small share of the overall number of companies in national NewSpace industries; instead, downstream applications, in particular space-based services, are much more prevalent.

Two key conclusions can be drawn from the pilot study described in this report. First, the NewSpace industry with direct relevance to missile proliferation and the Missile Technology Control Regime has spread well beyond the MTCR partners. Second, a considerable share of non-partners with missile-related NewSpace industries have not adopted the MTCR annex. In this context, it is particularly important for states to agree and promote common approaches to reducing missile proliferation risks created by developments of the NewSpace industry, including through the MTCR. The following recommendations are offered as steps in this direction.

Advance membership and adherence discussions

The growing proliferation risks that come with the spread of missile-related technology through the NewSpace industry are particularly concentrated around small- and micro-launcher projects. This aspect should thus be considered in discussions of MTCR membership applications and when encouraging adherence. The partners should discuss the objectives they have with regards to MTCR membership and whether extending MTCR membership to some of the states developing small and micro launchers would be beneficial.

Because the prospects of the MTCR accepting new partners, especially China, are slim, it is important to continue official outreach and dialogue efforts and build on recent engagement. The MTCR should also actively promote adherence to its guidelines and adoption of its annex, including among states with a domestic NewSpace industry. Because MTCR adherence includes dialogue and information-exchange opportunities, adherence could be relevant for many states with an emerging NewSpace industry and which are—at least for some of them—newly exposed to missile technology proliferation risks.

Conduct targeted MTCR outreach missions

The MTCR should actively engage with the non-partner states with NewSpace companies working with missile-related technology and encourage those that have not yet done so to adhere to the MTCR guidelines and adopt the annex. In particular, the MTCR should continue to engage through outreach missions with the states that have small- and micro-launcher projects pursued by NewSpace companies established on their territory—that is, China, Israel, Malaysia, the Philippines, Romania, Singapore and Taiwan.

MTCR outreach towards the broader group of adherents and other non-partners with an emerging MTCR-relevant NewSpace industry could also be strengthened. This could be done by inviting more of these states to future technical outreach meetings and by discussing during those meetings the economic opportunities of NewSpace and the value of adhering to the MTCR guidelines and adopting the annex. In doing so, MTCR partners should encourage a dialogue on peaceful uses of space launch vehicle technologies and on enabling international cooperation and development based on the benefits offered by access to space and space-based services.

Provide targeted guidance

Both the MTCR and all states acting individually have a role to play in providing targeted guidance. The MTCR should consider developing, and making public, guidance on areas that particularly affect the NewSpace industry, such as ITT and software controls.[98] The guidance material could include case studies and contact information as well as additional resources that are specifically focused on the challenges faced by NewSpace companies. These types of material would enable companies with often limited awareness of export control regulations and proliferation risks to develop knowledge and expertise on these issues, as well as to strengthen specific areas of export controls that are proving more challenging to implement.

Each state should also provide and regularly update targeted guidance materials for its NewSpace industry to include detailed information on export control policies and the broader regulatory framework, as well as good practices for internal compliance programmes.[99] With the exception of the United States, which published and later updated a guide on export controls for its commercial space industry, there remains a lack of specific guidance produced by national governments.[100]

Exercise vigilance in enforcement

As developments within the NewSpace sector come with increased proliferation risks, dedicating enough resources and expertise to enforcing the controls prescribed by the MTCR is key. The partners should also exchange information about NewSpace-related export control violations and proliferation risks within the LEEM, including where possible on specific cases, as well as how they have been detected, investigated and prosecuted. The MTCR provides a forum for enforcement officers to share good practices. Outreach conducted to adherents and other non-partners should also involve discussions on key export control violation risks related to NewSpace and share lessons learned to sensitize other states.

Conduct outreach to industry

The pilot study has substantiated the assessment that the spread of the NewSpace industry has resulted in a significant spread of commercial providers and users of missile-related technology.[101] The spread in particular of commercial small- and micro-launcher companies that either possess a broad set of relevant missile-related technology and know-how or rely on an ecosystem of suppliers of major components and technologies means that outreach to these industry actors is particularly important. Depending on how industry outreach is structured in each state, it could focus on the NewSpace sector as a whole or it could target a specific group of companies (e.g. defence start-ups) that share common characteristics and challenges in terms of limited risk awareness on export controls and FDI and inadequate compliance departments.

The findings about the extent to which NewSpace companies are developing, testing, producing or marketing missile-related technology listed in the MTCR annex is a clear indication of why investing in such outreach initiatives would be timely and why exchange among the partners is particularly valuable. In addition, developing good practices in outreach to the NewSpace industry would also be an important topic

[98] Héau and Brockmann (note 44).
[99] Brockmann and Héau (note 49).
[100] US Department of Commerce (DOC) and US Federal Aviation Administration (FAA), *Introduction to US Export Controls for the Commercial Space Industry*, 2nd edn (DOC/FAA: Washington, DC, Nov. 2017).
[101] Brockmann and Héau (note 49).

to raise during outreach missions to adherents and other non-partners. Non-partners may be more willing to discuss NewSpace than other missile-related security questions that may be raised during outreach visits. Combined with publicly available guidance, fostering discussions on NewSpace could also help promote the public goods that the MTCR provides.

Appendix A. Pilot study data set on adherents and selected other non-partners

State	Missile possessor	SLV possessor	No. of small- and micro-launcher projects	No. of NewSpace companies (range)	MTCR annex adoption	Attended 2023 TOM	MTCR outreach missions
MTCR adherents							
Cyprus	✓	×	×	1–5	✓	✓	×
Estonia	×	×	×	1–5	✓	×	×
Kazakhstan	✓	×	×	×	✓	✓	2015, 2017, 2021
Latvia	✓	×	×	6–10	✓	✓	2017
Other MTCR non-partners							
Angola	✓	×	×	1–5	×	×	×
Bolivia	×	×	×	×	×	×	×
Burkina Faso	×	×	×	×	×	×	×
Chile	✓	×	×	×	×	✓	2016
China	✓	✓	16	76–100	✓	✓	2003, 2004, 2019*, 2024*
Costa Rica	×	×	×	1–5	×	×	×
Côte d'Ivoire	×	×	×	×	×	×	×
Djibouti	×	×	×	×	×	×	×
Ecuador	✓	×	×	×	×	×	×
Egypt	✓	×	×	×	×	×	×
Ethiopia	✓	×	×	×	×	×	×
Ghana	×	×	×	1–5	×	×	×
Honduras	×	×	×	×	×	×	×
Indonesia	✓	×	×	1–5	×	×	2013, 2014
Iran	✓	✓	2	×	×	×	×
Israel	✓	✓	1	11–15	✓	×	2016, 2018, 2020
Kenya	×	×	×	×	×	×	×
Lithuania	×	×	×	6–10	✓	✓	×
Malaysia	✓	✓	1	6–10	✓	×	2006, 2009, 2014, 2023
Mauritius	×	×	×	1–5	×	×	×
Mexico	✓	×	×	1–5	×	✓	2020, 2021
Morocco	✓	×	×	×	×	×	×
Namibia	×	×	×	×	×	×	×
Nigeria	×	×	×	×	×	×	×
Pakistan	✓	×	×	1–5	✓	✓	2005, 2013, 2015, 2016, 2017
Paraguay	×	×	×	×	×	×	×
Philippines	✓	✓	1	1–5	✓	×	×
Qatar	✓	×	×	1–5	×	×	×
Romania	✓	✓	1	1–5	✓	✓	×
Rwanda	×	×	×	1–5	×	×	×
Saudi Arabia	✓	×	×	1–5	×	×	×
Senegal	×	×	×	1–5	×	×	×
Singapore	✓	✓	1	6–10	✓	×	2005, 2009, 2014, 2017, 2023
Slovakia	✓	×	×	6–10	✓	×	×
Slovenia	×	×	×	1–5	✓	×	×

State	Missile possessor	SLV possessor	No. of small- and micro-launcher projects	No. of NewSpace companies (range)	MTCR annex adoption	Attended 2023 TOM	MTCR outreach missions
Taiwan	✓	✓	1	6–10	✓	×	×
Tajikistan	×	×	×	×	×	×	×
Thailand	✓	×	×	1–5	✓	×	×
Tunisia	✓	×	×	×	×	×	×
UAE	✓	×	×	1–5	✓	✓	2004, 2012, 2016, 2021
Uganda	✓	×	×	×	×	×	×
Uruguay	×	×	×	1–5	×	×	×
Uzbekistan	✓	×	×	×	×	×	×
Viet Nam	✓	×	×	×	×	×	2021
Zimbabwe	×	×	×	×	×	×	×

✓ = yes; × = no; MTCR = Missile Technology Control Regime; SLV = space launch vehicle; TOM = technical outreach meeting; UAE = United Arab Emirates; * = informal outreach meeting conducted by the MTCR chair.

Sources: See description of methodology in chapter 3 in this volume.

Appendix B. Pilot study data set on partners of the Missile Technology Control Regime

For each MTCR partner, the table shows whether any NewSpace company (as defined according to the pilot study methodology) that is developing, testing, producing or marketing missile-related technology under the corresponding item has been identified in that state. It does not convey any assessment of the level of that technology's viability in the state or the state's industrial capabilities. See table 3.2 for descriptions of the item categories.

	Item[a]																	
State	1	2	3	4	6	9	10	11	12	13	14	15	16	17	18	19	20	Total
Argentina	×	✓	✓	✓	✓	×	×	✓	×	✓	×	✓	✓	×	✓	✓	✓	11
Australia	✓	✓	✓	×	✓	✓	×	×	✓	×	×	✓	✓	×	×	✓	✓	10
Austria	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	×	✓	✓	12
Belgium	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	×	×	✓	✓	13
Brazil	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	14
Bulgaria	×	×	×	×	✓	×	×	✓	×	✓	×	×	×	×	×	×	×	3
Canada	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	×	✓	✓	14
Czechia	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	×	×	×	✓	9
Denmark	×	✓	✓	×	✓	✓	✓	✓	✓	×	×	✓	×	×	×	✓	×	9
Finland	×	×	×	×	✓	✓	×	×	✓	×	×	×	✓	×	×	×	✓	5
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	16
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	15
Greece	×	×	×	×	✓	×	×	✓	×	✓	×	×	✓	×	×	×	×	4
Hungary	×	×	✓	×	✓	×	✓	×	×	✓	✓	✓	×	×	✓	×	✓	8
Iceland	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0
India	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	×	✓	✓	14
Ireland	×	×	✓	×	✓	✓	×	✓	✓	×	×	✓	×	×	✓	×	×	7
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	×	14
Japan	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	×	×	✓	✓	13
Korea, South	✓	✓	✓	×	✓	✓	✓	✓	✓	×	×	✓	✓	×	×	✓	×	11
Luxembourg	×	×	×	×	✓	×	×	✓	✓	✓	×	×	✓	×	×	×	×	5

Netherlands	×	✓	✓	×	✓	✓	×	✓	✓	×	×	✓	✓	×	×	×	✓	9
New Zealand	✓	✓	✓	✓	✓	×	×	×	✓	×	×	✓	×	×	×	✓	✓	9
Norway	×	×	✓	✓	✓	×	×	×	✓	×	×	✓	×	×	✓	✓	✓	8
Poland	×	×	✓	✓	✓	✓	×	×	×	✓	×	✓	×	×	×	✓	✓	8
Portugal	×	✓	✓	×	✓	✓	×	✓	×	×	×	✓	×	×	×	×	✓	7
Russia[b]	✓	✓	✓	✓	✓	✓	×	×	✓	×	×	✓	×	×	✓	✓	✓	11
South Africa	×	✓	✓	×	×	✓	×	✓	✓	✓	×	✓	✓	×	×	×	✓	9
Spain	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	✓	✓	14
Sweden	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	×	×	×	×	10
Switzerland	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	12
Türkiye	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	14
Ukraine[c]	✓	✓	✓	✓	✓	×	×	×	×	×	×	✓	×	×	×	✓	✓	8
United Kingdom	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	15
United States	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	16

✓ = yes; × = no.

[a] Items 5, 7 and 8 currently have no list entries, but are retained in the current list structure and may be used if new list entries should be added to the annex.

[b] The Russia–Ukraine War and the extensive sanctions regime placed on Russia by many Western states mean that there is a high degree of uncertainty concerning Russia, particularly in relation to collaborative space projects or imports of products from states that have imposed sanctions on Russia.

[c] There is a lack of reliable data and a high degree of uncertainty about the status of NewSpace companies in Ukraine because of the ongoing fighting during the war there, and the consequent displacement of personnel, possible targeting of facilities producing missile-related technology and reorientation of industry towards a war economy.

Sources: See description of methodology in chapter 3 in this volume.

About the authors

Kolja Brockmann is a Senior Researcher (non-resident) contributing to the work of SIPRI's Dual-Use and Arms Trade Control Programme. He is the project lead of the project 'Quo vadis MTCR II: Mapping and mitigating the potential impact of the NewSpace industry on missile technology proliferation' and its predecessor 'Quo vadis MTCR? The Missile Technology Control Regime at a crossroads'. His recent work has focused on the multilateral export control regimes, the European Union's dual-use export controls, post-shipment controls, and non-proliferation and export control challenges linked to additive manufacturing, artificial intelligence, hypersonic missile technology and the NewSpace industry.

Lauriane Héau is a Researcher with SIPRI's Dual-use and Arms Trade Control Programme. As part of her work, she follows developments within the main instruments and regulations established to regulate the arms and dual-use trade at the national, European and international levels. Her recent work has focused on the Missile Technology Control Regime (MTCR), the impact of NewSpace, and intangible transfers of technology. She also conducts research on mitigating arms diversion risks, and follows developments within the Arms Trade Treaty.

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