Metis

Study

New Space

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Summary

The space age is entering a new phase as a result of commercialisation, privatisation, digitalisation, miniaturisation, and new cooperation formats between private and state actors.

The motivating factors behind this new development termed "New Space" are primarily economic in nature, but the implications extend much further. This study looks at key economic, political and defence aspects.

New Space

Space flight and the aerospace industry are changing. "New Space" as the term used for this new era mainly refers to the emergence of companies and cooperation formats that use innovative approaches and technologies to shift the parameters of space flight as we know it – away from an endeavour that was previously the preserve of government agencies and towards commercialisation and privatisation. This is mainly made possible through more efficient launch systems that reduce the payload costs per kilogramme, thus facilitating more affordable access to space. The objectives are to make broader use of satellites and satellite constellations, to develop new launch systems and spacecraft, and to generally promote a new cross-sectional industry with economic potential for the future.

Economy

Today, new materials and production methods such as automation and friction stir welding allow for faster and less expensive production of lighter and reliable rocket parts, some of which are reusable. The cost of sending a payload mass of one kilogramme into low Earth orbit [1] has steadily decreased since 1957, a trend that has accelerated again since 2005 (see Fig. 1).

Compared with the SpaceX Falcon Heavy used today, the US-American Delta E in the 1960s was 100 times more expensive to launch in terms of payload per kilogramme (USD 177.900 / kg for the Delta E vs. USD 1.500 / kg for the Falcon Heavy). In terms of sheer number of launches, SpaceX is the global leader by some distance, not least because of the deployment of the Starlink satellite network (see Fig. 2). SpaceX is also the frontrunner in terms of mass transported into orbit. Miniaturisation allows for smaller satellites or constellations of several such small satellites, as in the case of Starlink. This has opened up a new business segment for small and micro launchers as well as air-launch systems, i.e. rockets with payloads of only a few hundred kilogrammes.

The first main area of interest for the New Space economy is Earth's orbit and the use of satellites and satellite constellations therein. Business models in the low and geostationary orbit concern numerous branches that profit from space-based services, such as communication and Earth observation services, agriculture and forestry, the energy sector, logistics companies, insurance firms, the financial sector, and the construction sector. Climate monitoring, disaster relief and environmental protection as well as planning and administrative agencies also benefit from more affordable Earth observation options. The cost of high-resolution satellite images, be they optical or radar-based, are steadily decreasing. In combination with AI-supported pattern recognition, for example, such images make it possible to develop powerful new tools for automatic image data analysis. According to the Federation of German Industries (BDI), 76 % of German New Space businesses already have customers outside the space industry whose biggest business segment globally is, by far, satellite data. The total commercial space economy in 2022 was more than USD 350 billion (see Fig. 3).

1 A low Earth orbit is an orbit relatively close to the Earth's surface – usually 160–1.000 kilometres above it.

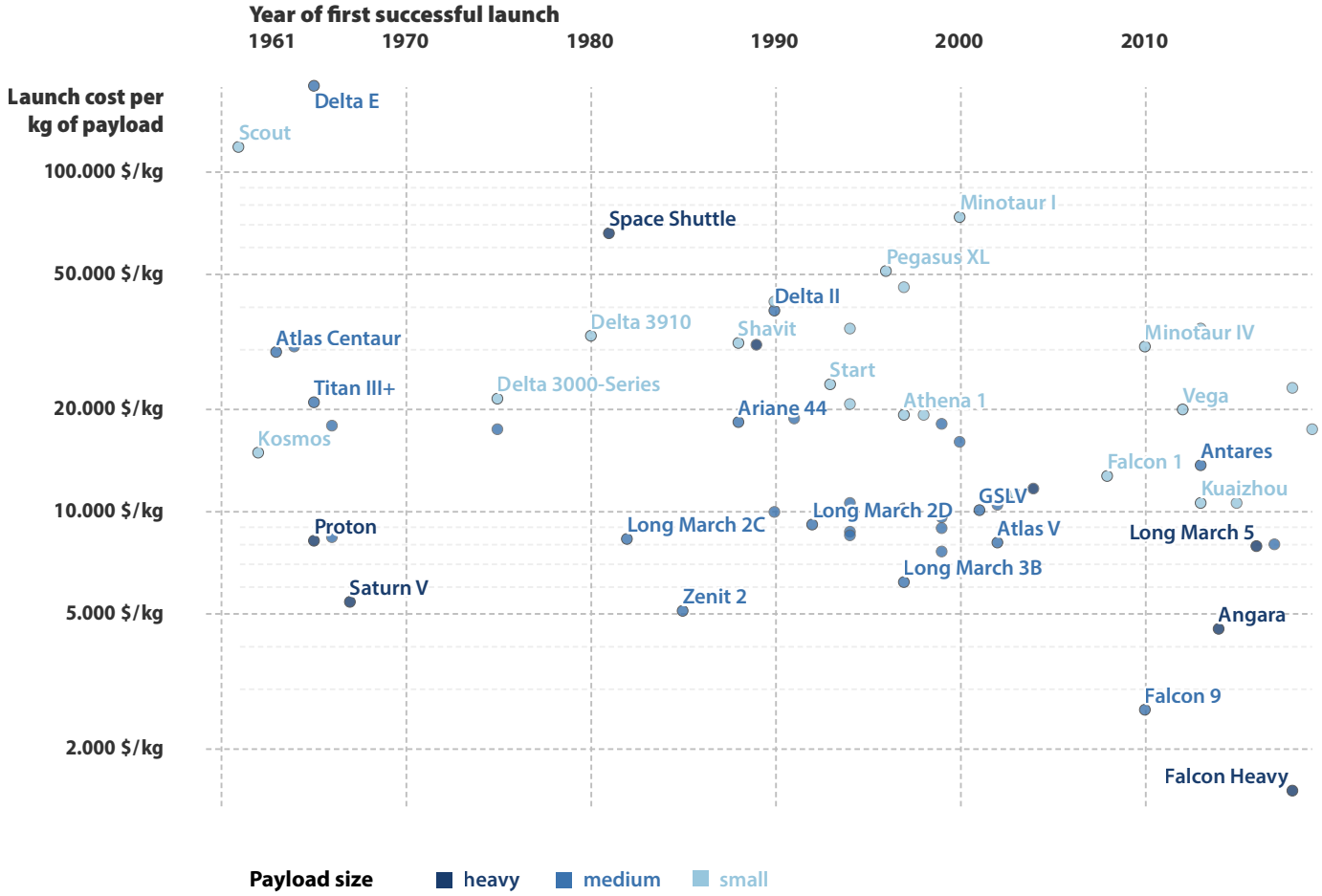


Fig. 1 Cost to launch one kilogramme of payload mass to low Earth orbit. This data is adjusted for inflation. | Source: https://ourworldindata.org/grapher/cost-space-launches-low-earth-orbitOur World in Data. See also Thomas G. Roberts: "Space Launch to Low Earth Orbit: How Much Does It Cost?", Aerospace Security, [1] September 2022.

And so companies are emerging in the field of New Space whose clients are not limited to government, which means that the market mechanisms of supply and demand will increasingly affect business. In addition to decreasing costs, New Space is also distinguished by new opportunities for cooperation and service formats. (These same aspects are, of course, not entirely new in the aerospace sector. They already existed in the heyday of "conventional" government space programmes. Even NASA's Apollo programme was supplied by individual US companies, such as Grumman as the manufacturer of the lunar module.) NASA's Commercial Lunar Payload Program (CLPS), for example, now only invites tenders for specific payload deliveries to the Moon, for which a whole range of companies then compete. In addition to several small companies, these most notably again include SpaceX with its Starship.

New Space attracts venture capital. The fact that not all private space companies succeed is evident in the high-profile example of Virgin Orbit, which was a spin-off of the Virgin Galactic space tourism company and intended to provide launch services for small satellites. It went bankrupt in 2023. SpinLaunch is an example of an ongoing New Space venture with an as yet uncertain outcome. The company plans to use mass accelerator technology as an environmentally friendly means of catapulting a rocket to high altitude, from where it only needs a small rocket stage to reach orbital speed with its payload.

The Moon is another focus of increased government and private space endeavours, also driven by economic interests. With its Artemis programme, NASA intends to cooperate with international partners to take robots and humans to the Moon and its surface. These plans include the Lunar Gateway, a permanent station in the Moon's orbit intended to serve as a communication relay, research laboratory, and short-term habitation module. There are currently plans underway all over the world for hundreds of lunar missions, especially rover landings. Commercial interests include raw materials contained in lunar regolith, such as silicon, aluminium, calcium, iron, magnesium and rare earths, lunar water ice for in-situ production of fuel

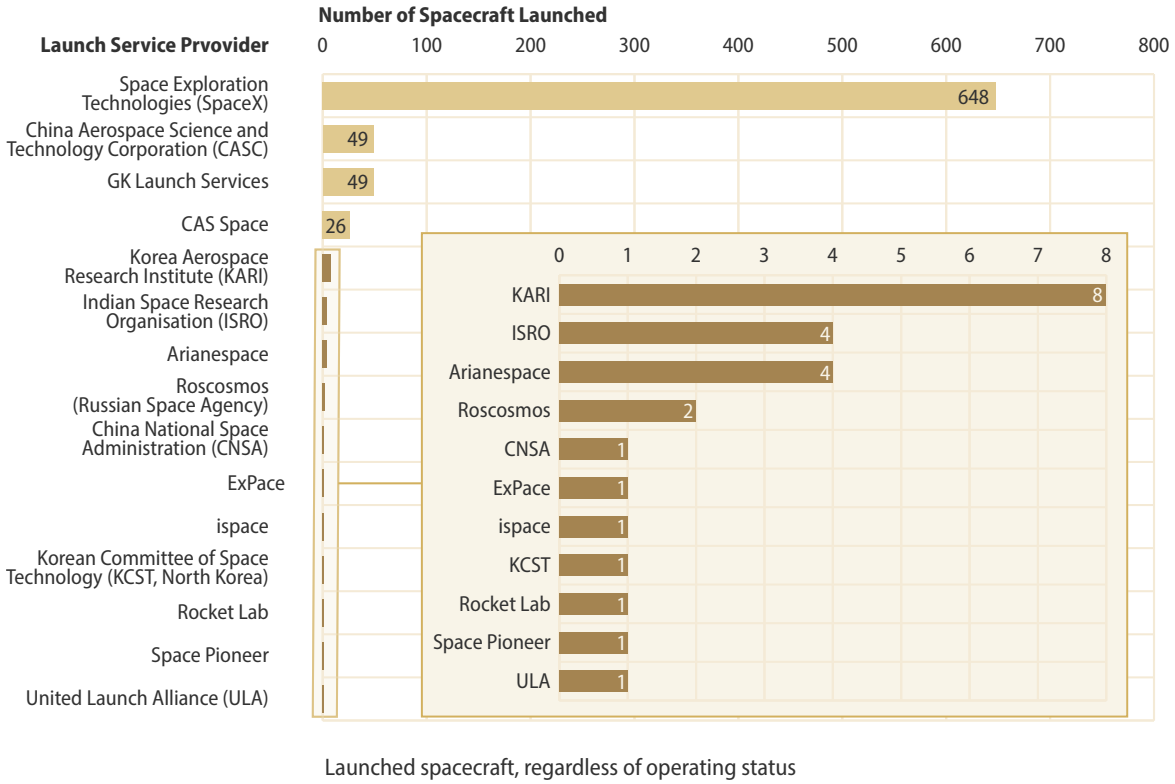
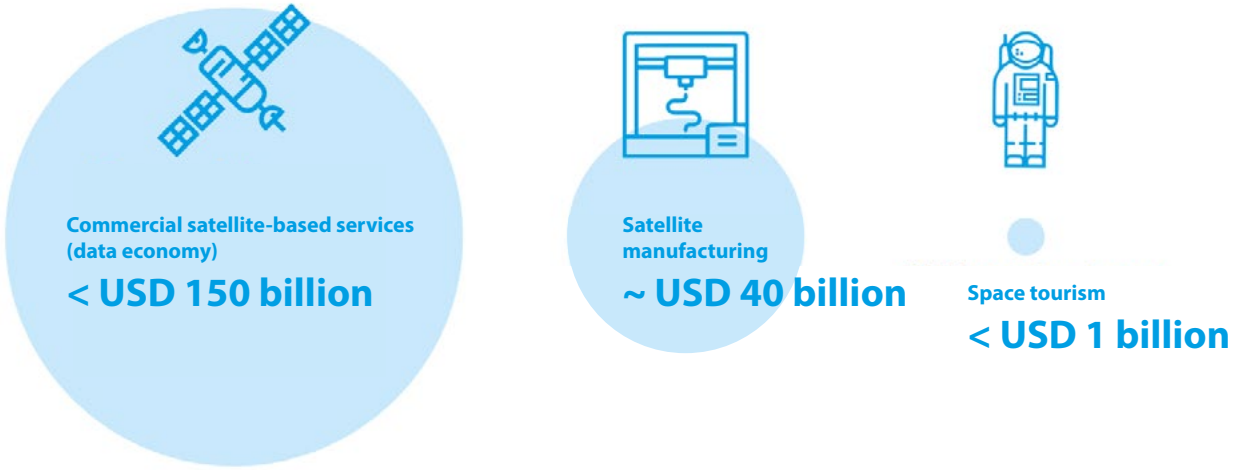


Fig. 2 **Space launches in the 2nd quarter of 2023; Source: BryceTech briefing: Global Orbital Space Launches Q2 2023** | https://brycetech.com/reports/report-documents/Bryce_Briefing_2023_Q2.pdf

(by using electrolysis to split it into hydrogen and oxygen, then liquefying those) as well as helium-3 for use in potential future fusion reactors – in short: the prerequisites for a self-sustaining space economy, a permanent human presence on the Moon, and the onward journey to Mars. A particular focus lies on the region around the lunar south pole. The Russian Luna 25 mission to the region failed in August 2023, while India succeeded (at the second attempt) on 23 August 2023 with Chandrayaan-3, making India the fourth country to achieve a soft Moon landing after the US, Russia and China. Japan launched a lunar probe in September 2023. The first private lunar mission, an attempt by the Japanese company ispace to land a rover, failed in April 2023.

A third area of economically driven New Space activity – albeit one that is still hypothetical – is space mining. Discussions in this context often point to examples of near-Earth asteroids that contain metals to the value of several billion euros. Overall, it is estimated that there may be as many as 17.000 such asteroids within reach of current rocket technology. Nevertheless, the technical challenges are immense and the business model is unstable, as evident in the prominent failure of Planetary Resources Inc., which promised not only to exploit asteroids but also to build fuel filling stations.

Space mining, tourism or debris disposal – not all (commercial) activities that are possible or already happening in space are covered by the 1967 Outer Space Treaty. A lot is not regulated with relevant judicial authorities, at least not bindingly. Where international law applies, a combination of ambiguous wording and lack of precedent permits disputes over articles that are subject to interpretation – of which governments as well as business have long been making full use. Articles II and VI of the Outer Space Treaty, read in combination with the Moon Treaty, prohibit governments from taking possession of celestial bodies and oblige signatory states to authorise and supervise any private space activities conducted from their territory. From the perspective of private companies, however, this can be interpreted to mean that, legally, nothing stands in the way of the private sector engaging in resource extraction in space – similarly to fishing on the high seas. In a nutshell: The specific details of the New Space era are still up in the air and remain the subject of legal and political debate.



Source: Space Foundation; Northern Sky Research; public press; McKinsey analysis

Today, the entire commercial space industry is worth more than USD 350 billion

Fig. 3 Source: BDI 2022: NewSpace Made in Germany – Recommended action for an ambitious agenda. | https://bdi.eu/publikation/news/newspace-made-in-germany-handlungsempfehlungen

Astropolitics

The amorphous term "geopolitics" covers a wide range of areas, including geography, climate, trade routes, power balances, and other earthbound parameters. In a similar vein, the term "astropolitics" is an attempt to provide an analytical framework that encompasses distances, technical capabilities and economic interests in – as well as possible access to – the Earth's orbit and space. Yet astropolitics is still subject to the gravitational force of power balances and conflict lines on Earth.

The US is by far the biggest investor in space, spending approximately five times as much as China. The EU, on the other hand, only spends a fifth of what China invests, which means that it is still behind Russia and Japan in international competition (see Fig. 4). There are also dependencies that the EU has become painfully aware of in the wake of the Russian invasion of Ukraine and which are very much comparable to the reliance on Russia's natural gas. Sanctions against Russia led to the isolation of the Russian space agency Roscosmos from its Western partners, which has put an end to the cooperation and brought Soyuz flights for medium loads to an abrupt halt. Furthermore, the initial launch of the Ariane 6 system for heavy loads has been delayed and the light carrier rocket Vega-C is struggling with reliability issues, leaving Europe caught in a launcher crisis. A lack of capabilities in the field of mini and micro launchers as well as reusable rockets is also a contributing factor.

In 2020, the US initiated the Artemis Accords as part of their Artemis programme with the aim of accelerating the development of space law. This is a non-binding agreement that 29 states have since signed in order to participate in the US Artemis programme (see Fig. 5).[2] Germany acceded to the agreement in mid-September 2023.

On the one hand, the Artemis Accords reify and codify a number of established and undisputed principles of existing space law, such as peaceful, sustainable and responsible use, transparency, interoperability, emergency relief etc. On the other hand, however, they are criticised as an attempt by the US to hegemonically enforce its own interpretation of existing space law, in particular with regard to the Moon. Critics say that the chances of reaching a broad multilateral agreement would be sacrificed in favour of national regulations, e.g. in the above-mentioned area of space mining.[3]

China and Russia are opposed to the agreement, condemning it as a colonisation of outer space characterised by commercial interests (of the US). With its plans to establish an International Lunar Research Station (ILRS), China has presented an alternative concept and has thus far motivated Russia, Pakistan, Venezuela, South Africa and the United Arab Emirates to express interest or to cooperate.

In the meantime, multilateral regulation efforts at UN level, such as in the Committee on the Peaceful Uses of Outer Space (COPUOS), which was actually established to develop regulation for the sustainable and peaceful use of

2 "The Artemis Accords. Principles for Cooperation on the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes", https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf.

3 As specified in its space strategy, the German Federal Government is seeking to establish a national space law.

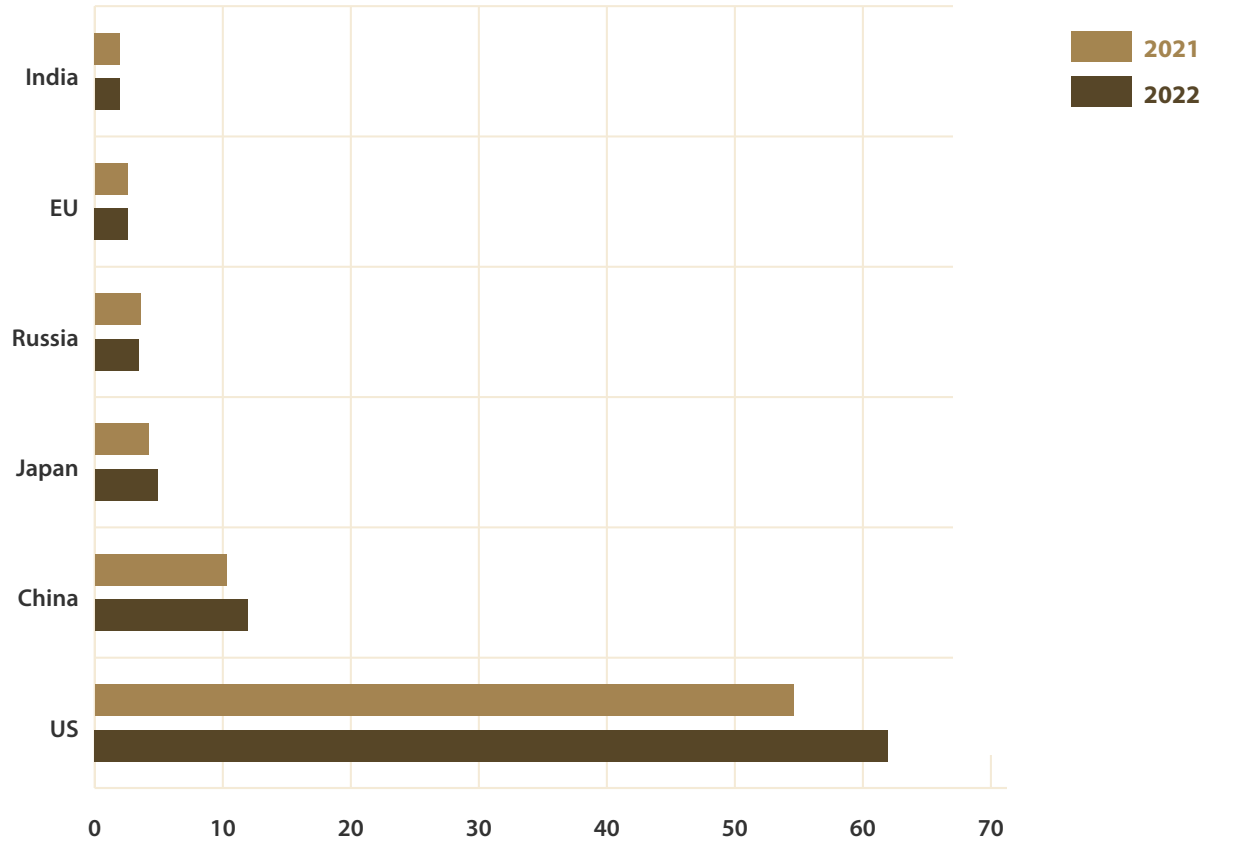


Fig. 4 Comparison investments in space programmes in billions of USD, own work; data accurate as of: December 2022 | Source: Statista

space, are slow to get off the ground. Since Russia's invasion of Ukraine, UN forums have also been increasingly exposed to aggressive blockades by Russia. The open-ended working group (OEWG) on reducing space threats through norms, rules and principles of responsible behaviours at the UN in Geneva failed in September 2023 to adopt a formal closing report or a simple progress report. In its policy of obstruction, Russia was supported by only a small number of countries, including China, Venezuela, and Iran. A government expert group also established at the UN Disarmament Conference in Geneva to discuss regulations for the Prevention of an Arms Race in Outer Space (PAROS) will be chaired by Russia from the end of 2023. In this current "arms control ice age", however, this is not expected to produce substantial results either.[4]

Proposals that could attract large international majorities in Geneva will not likely be reflected in international documents for the time being. These include, for example, the specification of authorisation and supervision requirements that result from Article VI of the Outer Space Treaty as well as a widely agreed and mandatory ban on the testing and use of anti-satellite weapons (ASAT).

Direct-ascent ASAT missile tests have thus far been carried out by the US (2006), China (2007), India (2019) and Russia (2021). The space debris caused by ASAT endangers satellites, the International Space Station, and access to certain orbits – in extreme cases for a long time. Since 2022, a growing number of countries (including the US, Canada, New Zealand, Japan, the UK, and, since August 2023, all EU members) have at least politically committed themselves to not to carrying out destructive direct-ascent ASAT tests with rockets. Even without ASAT activities, however, there is a risk of collisions and danger from debris in low Earth orbit,[5] because further mega-constellations (with magnitudes of up to 100.000 additional satellites, both private and state-owned) are likely to be set up in the future. According to ESA Space Environment Statistics (12 September 2023), there are about 34.000 pieces of space debris that can be regularly

4 See "*Zeitenwende*: The Russian invasion of Ukraine and its implications", Metis Study No. 31 (November 2022).

5 On the Kessler syndrome feared in this connection, see "Space security", Metis Study No. 13 (August 2019), 3–4.

Fig. 5 Signatory states of the Artemis Accords | Source: NASA. Last updated: September 2023

recorded and catalogued by space observation networks. The estimated number of collisions since the beginning of the space age already exceeds 640.

Starlink has demonstrated how important first-mover advantage is when it comes to the competition for flight paths and the frequencies assigned by the ITU. This is likely to lead to unregulated competition and, ultimately, congestion in low Earth orbit, which is the exact opposite of sustainable use of space.

In all, we have two emerging blocs that differ in their focus on private and state-owned space travel and that increasingly compete for the distribution of the orbit and the development of future space law. At the same time, prospects for the international community to specify binding arrangements for the use of space as common property are dwindling.

Defence [6]

Space as a fifth domain alongside land, air, sea and cyber space obviously has its own relevance in terms of security and defence policy. Like other countries, Germany also depends on free access to space and its peaceful and sustainable use. Germany's National Security Strategy consequently ascribes increasing importance to the space domain for Germany's security in the context of national and collective defence and includes plans to expand German space capabilities in order to press ahead with the implementation of the EU Strategic Compass and the EU Space Strategy for Security and Defence (EU SSSD).[7] These plans include efforts to improve the German picture of the space situation in order to be able to make a contribution to deterrence and defence within the EU and NATO, to increase the resilience of German space infrastructure, and to create replacement capacities. The National Security Strategy also includes an announcement of an independent space security strategy for resilience and the capacity to take military action as well as the intention to advocate international order in space.

The example of ASAT illustrates the significance and the specifics of two key concepts of security policy in relation to space: deterrence and dual use.

Over the last two decades, potential adversaries have developed a broad spectrum of kinetic and non-kinetic means to disrupt or even destroy space capabilities. Recently increasing tensions between the major powers have lent new urgency to the question of how to handle these developments.

6 See "Space security", Metis Study No. 13 (August 2019).

7 The Space Security Strategy announced by the German government in its National Security Strategy is still in the development phase.

Resilience – through redundancy, hardening, stealth and defence mechanisms, i.e. deterrence by denial – thus plays a prominent role in key NATO and EU documents,[8] because, much like in cyber space, the approach of deterrence by punishment, i.e. the credible threat of costly reprisal, obviously has its limits in outer space. In addition to the challenge of having sufficient space situational awareness in the first place to identify threats, there is also the problem of attribution, without which the threat of retaliation is rendered ineffective.

The picture of the space situation is further complicated by the fact that all objects that have the capacity to affect systems in Earth's orbit – no matter how, be it through cyber attacks, simple ramming or manipulation with gripper arms, microwaves, lasers or chemical substances – can be used as ASAT weapons. Some, however, can also be useful for peaceful space debris disposal. This dual-use issue thus also complicates the situation for categorial, object-oriented arms control methods. These have to be replaced by behaviour-based approaches,[9] and transparency is the only way to build trust or to at least not allow it to erode even further.[10]

The cyber attack on the Viasat KA-SAT network at the beginning of Russia's invasion of Ukraine highlights the significance of redundancy. The failure prompted Elon Musk and his company SpaceX to answer Ukraine's call for help and to offer Starlink as a replacement, even though military use of this constellation actually violates the company's terms of use. Another unusual point is that SpaceX started communicating with the Ukrainian government directly without going through the US administration in Washington, unlike all other support provided to the invaded country. There is also still speculation as to whether Musk was initially unaware of the dual-use nature of his own product or whether supplying it was more of a targeted PR campaign to prove Starlink's potential for military application. In any case, in 2022 Musk called a decidedly military SpaceX product into play: Star Shield, another constellation, this time for exclusive use by the US government. An initial contract with the US Space Force was concluded at the end of September 2023.

The Starlink example in Ukraine also demonstrates the immense benefit of satellite-based capabilities for communication and reconnaissance in warfare, particularly with regard to operational command and control. In the second half of 2022, Starlink became the essential technical enabler for the Ukrainian side to pass intelligence on to its own artillery with commercial drones and thus to accelerate its own kill chain. Discussions about individual weapon systems provided or refused by the West sometimes obscure the fact that, in reality, Starlink is the only technical artefact that merits being considered a gamechanger for Ukraine.

Space-based capabilities in the fields of surveillance, reconnaissance, command and control, and communication thus act as powerful military multipliers. The fact that, with Starlink, commercial access to low-cost broadband communication all over the world – beyond the capabilities of national militaries – lies in the hands of just one man, who has been known to act erratically at times and now has the power to enable and restrict its use at will, has since 2022 given rise to major concerns not just in Washington. The lesson to learn from the private monopolisation of critical space infrastructures is that from a security policy perspective, there are pitfalls if, in the New Space era, states act merely as clients that purchase services. Sovereign tasks sometimes require the availability of sovereign capabilities.

With IRIS 2 (Infrastructure for Resilience, Interconnection and Security by Satellites), alongside the satellite navigation system Galileo and the Copernicus Earth observation programme, the EU is therefore planning a space infrastructure primarily for government organisations. The aim is for IRIS2 to provide fast internet access by means of a satellite constellation intended for launch in 2024 and scheduled to be fully operational in 2027.

Recommended action

According to the current budget draft, the German space programme will receive a good 15 % less in funding (approx. EUR 314 million) in 2024. This does not tally with the level of ambition specified in relevant key documents.

In the context of the Zeitenwende, the complete rethink of German security and defence policy in the wake of Russia's invasion of Ukraine, more of the same is not an option for the Federal Ministry of Defence, which is why, despite the lack of funds, faster processes and formats need to be identified and tested.[11] Specifically, the following fields of action should be addressed:

- According to the National Security Strategy, research establishments and private players should be more deeply involved in Germany's space security architecture; the new space strategy envisages a space innovation hub. This requires the development and testing of new agile cooperation formats

8 Since the 2021 NATO summit in Brussels, NATO has viewed attacks on Alliance members in, from or into space as potentially relevant under Article 5. NATO's Overarching Space Policy (Paragraph 11) lends increased significance to resilience for the Alliance's deterrence capability. The EU SSSD also places particular emphasis on resilience and the protection of space infrastructure.

9 See "Conventional arms control and emerging technologies", Metis Study No. 20 (September 2020).

10 See "*Zeitenwende*: The Russian invasion of Ukraine and its implications", Metis Study No. 31 (November 2022).

11 See "Zeitenwende: The Russian invasion of Ukraine and its implications", Metis Study No. 31 (November 2022).

between the Bundeswehr and (space) industry to achieve shorter innovation cycles. The European Launcher Challenge, which the German government's new space strategy considers a key project, together with the German Aerospace Center's (DLR) already ongoing micro-launcher competition, could serve as building blocks in these efforts.

- Much like the strategy document announced by the US Space Force, the FMoD should issue guidelines for civil-military commercial cooperation in peacetime in order to be able to use commercial services easily, quickly, and legally. The set of criteria currently being developed for EU Space Surveillance and Tracking (EU SST) could serve as blueprints for the requirements and duties on which to base future contracts with industry partners.

- The next expansion phase of the SATCOMBw communication system must provide the Bundeswehr with its own broadband communication capability so that it does not have to depend on commercial providers and can reliably achieve the NATO goal of multi-domain integration (with the ultimate aim of joint all-domain command and control) and ensure appropriate tactical use of uncrewed systems [12] and standoff precision weapons. Network solutions between SATCOMBw and IRIS2 must also be tested. In the interest of resilience, it is also necessary to practise procedures for emergencies in which these capacities are limited and must be prioritised or have failed entirely. Maintaining operational capability while being aware of one's own dependence on space forms part of space domain awareness.

- Germany must establish its own fast and flexible launch options for payloads in order to maintain and expand independent access to space and to secure its own space-based capabilities, not least with an eye toward military applications. This responsive space capability ensures that payloads can be launched and losses can be compensated within days or hours. Initial steps in this direction have already been taken, for example, with the German Aerospace Center's Responsive Space Cluster Competence Center (RSC). Against this background, it seems appropriate for Germany to establish its own mobile launch platform for small payloads in the North Sea and have it be open to European partners.

- In the medium and long term, the Bundeswehr must develop its space capabilities in such a way that its own critical space infrastructure is monitored and can be protected against (kinetic, electromagnetic and cyber) interference by third parties without creating space debris.

12 See "Uncrewed systems: armaments, control and arms control", Metis Study No. 28 (June 2022).

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