ÉTUDES
DE L'IFRI

EUROPEAN SPACE GOVERNANCE INITIATIVE

JUNE
2021

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Commercial Space in Europe
A Balancing Act between Physics, Politics and Profession

KP LUDWIG

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ISBN: 979-10-373-0355-4

How to quote this publication:
KP Ludwig, "Commercial Space in Europe: A Balancing Act between Physics, Politics and Profession", *Études de l'Ifri*, Ifri, June 2021.

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This initiative is intended to provide analysis pertaining to the international competition in space and its impact on the European space industry as well as its governance. Through a series of publications and public events, the goal of the initiative is to raise awareness among stakeholders in the European Union about the challenges presented by the transformation of the global space industry. It is coordinated by Éric-André Martin, General Secretary of the Study Committee on Franco-German relations (Cerfa) at Ifri.

Acknowledgments

This paper, the result of a research carried out during March-April 2021, provides a summary from personal experience, expert interviews, literature and Internet searches. The author is especially indebted to Mr Jürgen Ackermann, President at JAISPOIR Consulting, and Mr Sonay Sarac M.A. for their valuable contributions, critical comments, and patient assistance in the last phase of the study.

Author

Born in North-Rhine Westphalia, **KP Ludwig** studied Space and Aerospace Engineering at Aachen University RWTH. He began his career as system engineer at ERNO-Raumfahrttechnik GmbH in Bremen. Having spent two years as assistant to the Management Board, he took over responsibility as head of strategy development at DARA/Bonn, the newly founded German Space Agency in 1990. Seconded to BMFT (Germany's National Ministry of Research and Technology), he was in charge of preparing the European Space Agency (ESA) ministerial conference in Munich. Three years later he returned to MBB/ERNO as head of business development, being promoted later to the company headquarters as a member of the DASA managing board. Returning to the operational business in 1996, he became head of institutional relations at Dornier Satellite System in Friedrichshafen. In 2000, he became a representative for EADS space business at the newly formed representation office in Berlin. After some years as managing director of Astrium (in the Czech Republic in Prague), he returned to Berlin. Following his retirement in 2018, he co-founded Craftwerk-Consult, a consultancy company in Berlin/Potsdam, and later supported the foundation of Leadership Empowerment GmbH in Bern, Switzerland. He is a member of DGLR, DGAP and VDI, and a board member of Nathan-Zuntz-Förderkreis, a German non-profit association for fostering developments in space medicine.

Executive Summary

This report tries to address Europe's common interests, linking governmental and private objectives, and drafting initial conclusions:

- Even after Donald Trump's defeat, China and the United States (USA) will be furthering their rivalry in seeking global economic dominance.
- The digitized economy is a key battlefield, with actors such as the Chinese Huawei, and Nokia or Ericsson in Europe, while the USA has lost much of its 5G competence in recent years.
- Core elements of digitized globalization include the satellite networks, providing communication and data services, positioning information and Earth observation data. Based on the indisputable US space competence, the economic struggle between the rivals has therefore reached near-Earth space.
- Commercial space got a "push" at the end of the US space shuttle period. Maturity in technology and innovations in electronics, etc. lowered the risks for private investors, who are also backed by attractive public contracts.
- Compared to governmental or military users, commercial space actors are in a weak position. Rules and regulations are driven by administrations or international organizations; which private operators must follow. Without the regulatory and financial support of governments, it would be unrealistic to expect a sufficient return on investment (RoI) in the purely commercial field, covering non-recurring and recurring costs.
- Germany's space policy is strongly linked to the policies of the ESA and the EU. Its unstated objective is to continue cooperation as an indispensable partner with clearly shaped, and substantial contributions. Small launchers are seen here as an appropriate add-on to the European launcher family.
- Launch service competition at European level may be economically worthwhile only if market size and accessibility allow it. This also requires a commitment by the European nations to prefer European launch services.
- While reliability will continue to be more important than "cheap" prices, most of the current global launcher developments may fail to achieve profitability.

- Innovations (additive manufacturing, green propellants, dual-use applications, etc.) will influence ecological considerations and will become more "responsible", to gain acceptance by society.
- For commercial space actors, the unrestricted access to and usage of the space business zone from Leo to GEO is becoming increasingly important, while rival nations are beginning to protect their interests in arming their space infrastructure.
- A concerted industrial policy at the European level is one of the prerequisites for a strong and competitive space economy in Europe. This may also require balancing governmental demands and commercial capacities in the industrial landscape. The latter is also true for the future European space port infrastructure.
- President Macron's remarks on February 18, 2021 about merging multiple European activities in SSLV developments into a single program could be seen as a first step.

Table of contents

Introduction

At the end of 2020, the European Space Agency (ESA) awarded three German space start-ups competing contracts in order to support its small-launch system developments by, at a later stage, implementing public launch service procurement contracts. Behind these placements one may identify a change in Germany's space policy, which may already have been realized during the ESA Ministerial Council (MC) in Seville in late 2019. At this meeting the German delegation committed to a major share of ESA funding for the coming years; Germany is the member state contributing most to the €14.5 billion budget. Besides supporting programs in its traditional fields of interest, Germany showed a special interest in supporting the Commercial Space Transportation Service (CSTS) acceleration program for the above-mentioned German space start-ups.

The move took place towards the end of the presidency of Donald Trump who – as no US president before – converted the global economy into a battlefield of superpowers struggling to enforce their national interests. China was identified as the most powerful rival, leading the international high-tech sectors in a number of promising fields such as 5G telecommunication, a core technology for global digitalization. Unfortunately, the US had lost its leading competence in recent decades, since Motorola and Lucent were taken over by European companies.

As one of the drivers of globalization, space systems are (besides the terrestrial cable networks) the carriers for digitalization, which motivates the US to use its prominent position in this sector to keep up with China. At the same time, the political and commercial ambition to expand one's own space architectures goes hand in hand with the increasing need to protect one's infrastructure. It is, therefore, not surprising that civil-military fusion takes on greater significance.

Satellites, being objects of innovation through digital technologies, are essential elements for carrying all kinds of sensors to acquire high volumes of data in Earth observation, for positioning purposes, and as the backbone in transmission networks for communication, broadcasting, television, streaming services and the Internet of Things (IoT). They rapidly pass on "Big Data" volumes from one point of the globe to another. Growth and profitability in the space business are currently directly linked to the increasing demands of the digitized society. It is, therefore, not only in the focus of

politicians but also of private investors, looking for new profits and compensation for their heavy losses in the "old-fashioned" asset markets, which have shown poor interest rates for many years.

One main driver of the so-called "New Space" sector is those private stakeholders. In particular, they feel tempted by predictions of a massive growth in the global space market – forecasted at up to US$2.7 trillion by 2040 by the Bank of America. Satellite constellations, which will form a cornerstone in "the global net", will become core elements of the digitized world. Current plans indicate that, over the next decade, several thousand satellites, 85% of them small ones with a maximum mass of approx. 350kg, will be placed at dedicated positions in orbit to fulfil their functions.

For positioning satellites, preferably in Low Earth Orbit (LEO) of between 500 and 2,000km altitude, reliable and affordable launch services are essential. For the establishment of sat networks, the use of heavy launchers is the most effective way to orbit in terms of price per kg. But, for the operational phase or in maintenance cases, small launchers are mandated, which can provide reliable, cheap, accurate and – if possible – environmentally friendly services. That may well best explain Germany's engagement in the development of Small Satellite Launch Vehicles (SSLVs), described above.

Due to the rather attractive market expectations, a number of industrial consortia are being pressed by private investors and supported by governmental R&D funds to offer such services. The latest listing of the New Space Index shows around 150 ongoing SSLV developments or production plans, seeking to catch a share of the AM market. Around 40 of them are planning to become operational within the next 2-3 years, including a few European systems.

This report is focused on a more technical analysis of the market demands and the special commercial market conditions in LEO. It describes the competitive situation and, especially, the limiting conditions, which may hinder private investors from continuing to support a sound technical solution. These are: the size of the accessible market share, the natural risks of operating complex systems in a hostile environment, and the regulatory hurdles in acquiring formal approval by the authorities. A major factor for the expected business success is and will be the governmental support that the consortia can acquire. Here, a focus is on German space policy and its embedding in the European and global space arena.

A digitized world and its space infrastructure

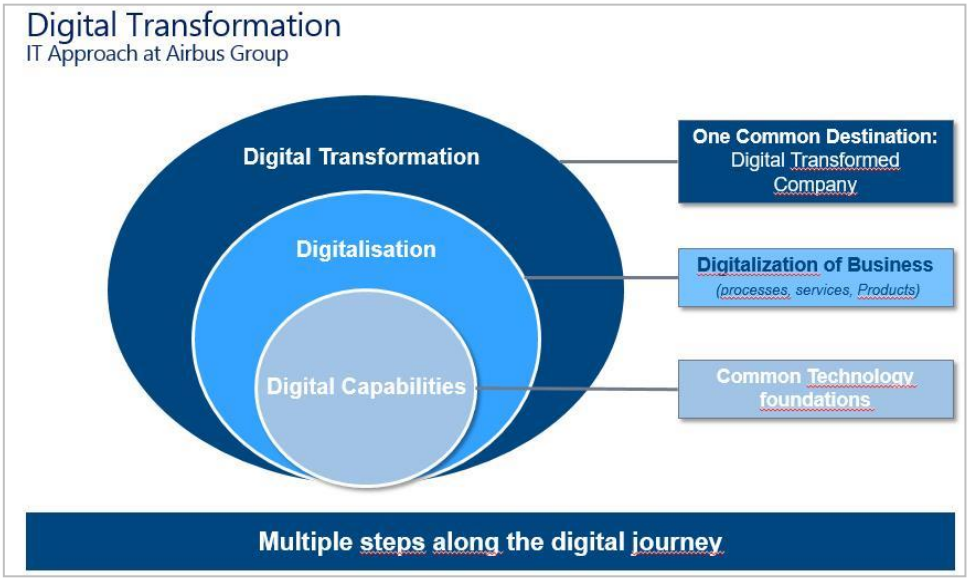
Digitalization – a driver in transformation

In early November 2020, ESA – the European Space Agency – awarded within its Boost! program three support contracts[1] to the German New Space companies Isar Aerospace Technologies, HyImpulse Technologies and Rocket Factory Augsburg. All three companies aim to develop a commercial launcher concept for placing small satellites into LEO. These contracts (worth €500k each) are also a visible sign of a new aspect in Germany's space policy, which had showed up already at ESA's last Ministerial Council (MC) "SPACE19+" in November 2019.[2] At this conference, the ESA member states signed commitments worth €14.3 billion (40% more than in the 2016 MC). Germany contributed a total sum of €3.3 billion, the biggest share, which probably surprised other ESA members such as Italy and France. The strategic objectives for this step cannot be found in Germany's Space Program, of which the last edition was published in May 2001.[3] In fact, the reasons for the unexpected engagement – at least concerning the CSTS engagement – can be explained by government considerations that Germany, as an export nation (with established concentrations in machine construction and car manufacturing), can sustain its position in the markets of a digitized world only if proficient in the key competences of the digital transformation process. In this, the launcher is an indispensable tool. ESA's decision to place the AM contracts is therefore fully backed by the German Ministry of Economic Affairs and Energy (BMWi).

In current discussions, "digitalization" is often understood a little wider than the original definition: "The process of converting analog into digital data, in order to allow their handling by computers".

1. European Space Agency, "ESA Signs First Boost! Commercial Space Transportation Contracts", November 3, 2020, available at: www.esa.int.
2. European Space Agency, "ESA Ministers Commit to Biggest ever Budget", November 28, 2019, available at: www.esa.int.
3. Bundesministerium für Bildung und Forschung, Deutsches Raumfahrtprogramm, May 2001, available at: www.dlr.de.

In line with this explanation, a first wave spread into the manufacturing area in the machine construction business, penetrating in a second step the engineering and finally the service and aftersales sector.



Source: "Industry 4.0" - © Airbus Group.

The advantage of this innovation was quickly recognized and soon adapted by other players along the production line or within the value chain. Detailed knowledge of physical and chemical processes or machine performances is concerned with the monitoring of operation and therefore its optimization. Investment in sensors, data links and clouds is justified due to the enormous savings over, e.g., the lifetime of a system. At its current stage in 2021, the cross-linking is actually leaping the "species barriers" between neighboring branches. Most recently, the German car manufacturing industry[4] announced that it will build a cooperative and open data network over the complete supply chain. Here the future lies in technologies and systems of "Autonomous Driving". This will revolutionize European car production, downgrading the solely mechanical parts of a car to less than 50% of its value. The trend is proven, since Apple has shown an interest in establishing its own car brand – Apple Cars.[5] This trend many transform companies such as VW and BMW into subsystem providers of the big IT giants.

4. Vdi nachrichten, "Autoindustrie baut gemeinsames Datennetzwerk aus", March 5, 2021, available at: https://elibrary.vdi-verlag.de.
5. CNBC, "Apple Targets Car Production by 2024 and Eyes 'Next Level' Battery Technology", December 21, 2020, available at: www.cnbc.com.

"Internet of Things" sensor market

22%	image cameras
14%	bio-sensors
12%	pressure pickup
8%	chemistry probes
7%	torque sensors
7%	positioning sensors
6%	temperature measures
5%	filling level meter
19%	diverse

The IoT sensors market is expected to grow by more than 200% to $29.6 billion by 2026 (from $8.4 billion in 2021).

Source: globenewswire, March 15, 2021.

In general, the mobility sector is a good example to address the wider technical consequences of globalized digitalization. There are not only increasing demands for, e.g., rare earth metals for billions of end devices, already indicating a rise in global trade conflicts between some of the monopolists.[6] The ever-growing demand to acquire, collect, transmit and process all kinds of digitized information from all over the world is purely dependent on another critical resource: *electrical power* – under "reform pressure" in any case due to the climate-change challenge.

It may be interesting to note that, in late 2020, the power consumption of global "streaming services" alone (turnover in 2020 totaled around $60 billion), heavily desired by all consumers in quarantine or working in home offices, is more than 200 billion KWh,[7] requiring the power output of about 50 standard power plants, each with a performance of >500 MW. This dependency, a kind of "Achilles heel", reveals one of the weak points in this transformation: safe "digitalization" requires – at least for critical parts – new designs in safety, system partitioning and redundancies, to name only a few weak spots.

6. Investopedia, "Why Rare Earth Minerals Are Key to the US-China Trade Conflict", June 25, 2019, available at: www.investopedia.com.
7. International Energy Agency, "The Carbon Footprint of Streaming Video: Fact-Checking the Headlines", December 11, 2020, available at: www.iea.org; more details at www.eon.de : "So hoch ist der Stromverbrauch des WWW."

Over the last decade, "digitalization", like a virus, has affected not only the technical but also the social environment, and we recognize today an even wider transfer process that is "infecting" human society globally.

What began with legitimate intentions to improve processes in manufacturing by implementing sensors, data links (e.g. via satellites) and storage devices like "the cloud", has led to unintended impacts in social areas – e.g. in the "re-education" of the Uighurs by the Chinese government[8] (e.g. using Huawei's 5G telecommunication competence) or Cambridge Analytics' significant influence on the Brexit decision.[9] All of these programs have in common to collect, transmit and analyze data.

It would probably be best to use the phrase "digitized society" in order to differentiate between a major part of mankind *enduring* this transformation, and an active part *pushing* it.

Space infrastructures for a digitized world

In the so-called "New Space" business, the most enthusiastic and disruptive actors can be identified as the private investors. After years of scientific or technologically driven developments, space systems, products and services have reached a level of maturity that arouses the interest of private enterprises. Space systems or space-based services – in the past developed and "handcrafted" exclusively for governments – are increasingly being discovered by IT companies, which are looking to extend their ground-based business with satellite services as a safe and cost-effective element. New production processes (like 3D printing) combined with achievements in miniaturization and digitalization are drastically reducing the prices of high-tech products, while increasing their performance and reliability. Attractive yields are luring Google and Amazon – and this trend will be accentuated in the near future.

These enterprises, however, are not converting into space companies – at least not yet, if one recalls the Apple AM example. They are using "space" capabilities to extend their own portfolio on Earth, where increased demand is found in the telecommunication or navigation sector (e.g. in the logistics branch). Even the famous German machine construction industry has identified opportunities to use "space" for cutting costs and widening markets. Key elements

8. Prospect Magazine, "Big Brother vs China's Uighurs", Darran Byler, August 28, 2020, available at: www.prospectmagazine.co.uk.
9. "The Cambridge Analytica Files", *The Guardian*, available at: www.theguardian.com.

are, for example, the maintenance and repair sector, which can be globally managed by a digital upgrading of the export product itself.

Predictive maintenance[10] – a strategic service – is becoming calculable because it will happen "on demand". While saving money for the, e.g., "quarterly service", one can enhance system reliability and customer satisfaction. In this example, satellite-based data transmission is not generating real innovation but improves the "normal" business.

Customers & Investors

In today's space market, three types of stakeholders can be identified. Since the 1950s governments have been investing in R&D, technology development, and organizational applications – e.g., for military purposes and for scientific space exploration missions.

As a second group, globally acting enterprises – e.g. in the IT branch – are acquiring space-based services, starting with a focus on widening their core business on Earth in the telecommunications and broadcasting sector. They are now being followed by companies offering worldwide maintenance and repair services for their own export products, as well as newcomers in the logistics sector, seeking navigation support.

In recent years, entrepreneurs – spending a hot-money inflow into space systems and services from various type of private investors, expecting attractive rates of returns in a risky environment – have been forming the third group.

The latest analysis, The Space Report 2020, shows that the global space economy grew to US$423.8 billion in 2019. It indicates that more than 75% of this budget came from the two investor groups mentioned above.

Source: "Global Space Economy Grew in 2019 to 423.8 Billion", The Space Report 2020, *July 30, 2020.*

New customers' expectations are also changing, sometimes disrupting the business models of already established space manufacturers. High reliability, quick market access and affordable prices have to be balanced with high technology standards and quality assurance measures. For the space business, this means that satellites must become small, light, reliable and high-performing, while launch and insurance costs are reduced – as demanded by both private and governmental clients. Satellite constellations, as sensor carriers or

10. Digital Predictive Maintenance, white paper, available at: www.pega.com.

data transmission enablers, are in both applications indispensable elements to foster the global digitalization process. New Space[11] also means: "I'd like to get more 'space' for my money" – a wish that bitterly challenges the established original equipment manufacturers (OEMs) of the industry. For the purpose of this report, it's worth looking into the latter point.

SPACs in Space

A special purpose acquisition company (SPAC) is the *dernier cri* in the financing of private space activities. It allows private companies – often young, not yet profitable start-ups – to go public and cash in with less supervision. Generally, a SPAC's only purpose is to raise money for the acquisition of the target, usually privately held.

On March 1, 2021, Rocket Labs merged with the SPAC Vector Acquisition, feeding US$750 million cash into the small rocket business Electron, designed to deliver a 300kg payload into LEO. Already in February, Astra Space, a start-up producing small satellite-delivering rockets, announced that it was merging with venture capital corp. Holicity and going public, rating the company at US$2.1 billion. The hype continues.

Source: NASDAQ: 4 Space SPACs With Exciting Futures and Big Risk, by Vincent Martin, March 30, 2021.

Having financed Germany's Space Program since the early 1960s, the OEMs are used to fully carry the loads for scientific missions' interstellar probes, etc. (i.e. one-time developments with manmade fabrication) while they insist more and more on gaining profit also from the achievements of the series production in the commercial sector. In recent years, this tendency has resulted in three separate acquisition policies:

- For science missions, maximizing the knowledge output is still a priority, resulting in the requirement to use off-the-shelf equipment wherever possible, without endangering the primary scientific goals. If a mission does not demand a special purpose satellite design, commercial components may be used – e.g. in a series production line – as far as possible.
- For governmental services such as data transmission, Earth observation, etc. priority is set purely on the output. The specifications of the RfP (request for proposal) or the system requirements is 100% fulfilment of requested services. Also, for

11. P. Lionnet *et al.*, "From 'Newspace' to 'New Space Policy'", ASD Eurospace, January 2021, available at: www.eurospace.org.

military purposes the type of technical solution will be in the hands of the manufacturing company. It is their risk to guarantee the performance.

- The latter is also valid for all kinds of commercial services that governments will buy to achieve their results. This is especially true for launch services. Here, the only demand to be fulfilled by the provider is the safe positioning of the satellite in its selected orbit position. The customer normally does not care about the type of launcher, except in a situation where the provider cannot guarantee launch date and quality. Short-time access is the buzzword.

The latter development fosters German government support for commercial suppliers in the AM CSTS-sector.

The last topic has been a European dilemma for more than a decade. Being limited in size, the European governmental launch market alone in no way ensures sufficient volume and thus profits, which would allow amortization of recurring (RCs) and non-recurring costs (NRCs). Moreover, the open commercial market is the battlefield of launch service providers with various systems and levels of public support (thus with subsidized prices). Therefore, being present on this market is important in terms of volume but does not allow NRC absorption. The only launcher in the past that could amortize fully the RCs and part of the NRCs was the European Ariane 4, benefitting from the policy of NASA in the 1980s, to rely on shuttles alone. This allowed AR4 to grasp a significant share of the “free” commercial market at good price levels. It is a European political goal to secure guaranteed independent access to space for its nations, while being a competitive provider on the international market, relying on a commercial industrial base. And this market is demanding thousands of satellites that could also be launched by SSLVs.

Low-Earth Space Market – an attractive future

© Picture by Craftwerk-consult, Potsdam.

As mentioned, the private sector is greedily looking for New Space business opportunities. Twelve years after the Lehman Brothers fiasco and the resulting regulations in the financial markets (leading to a meltdown of interest rates to nearly zero), it is tempted by the forecasts of massive growth in the satellite constellation business, and the growing demand for providing indispensable services for "the global net" in data acquisition and transmission. The above picture offers a flashlight view of some of the planned systems. It will provide the necessary infrastructures for the space market, which the Bank of America in 2020 projected to reach a total volume of US$2.7 trillion by 2040, and in which hardware is indeed the smallest part. We must assume that approx. 80–85% of the market's revenue comes from "external" terrestrial services, provided via the orbital architecture. At least, the "internal" space market is now attractive to invest in.

The major current satellite constellations under construction

Mega-Constellations under Construction				
	OneWeb	**Starlink**	**Lightspeed**	**Kuiper**
Operator	OneWeb	SpaceX	Telesat	Amazon
Country	UK	USA	Canada	USA
No. of Satellites	1980... 6372	2824... 30.000	298	3236
mass of a satellite	150 kg	400 kg	750 kg	n.d.
Orbit height	1200 k,	550 km	1015 km	600
already operating	146	1147	0	0
data rates	400 Mbits/s	300 Mbits/s... 1Gbit/s	7,5 Gbit/s per terminal	400 Mbits/s
Sat manufacturer	Airbus	SpaceX	Thales Alenia	n.d.

Source: vdi-nachrichten, "Lichtgeschwindigkeit", I Hardbrich, March 19, 2021.

Not only is the total number of major satellite constellations under construction – which total around 40,000 – remarkable; so also are the different masses of the selected sat designs, which will drive the requirements for the relevant launch services and thus the performance characteristics of the available SSLVs. We will come to this later.

Following the known plans of all key players, whether states, commercial organizations or private entrepreneurs like Elon Musk, the "infinity of space" around the globe will be filled up with thousands of satellites for all kind of applications for governmental, military and commercial purposes. Innovations in satellite design (such as the "All-Electric-Satellite"[12]) and production (e.g. 3D-printings) as well as the trend of governments outsourcing the risks of setting up expensive orbital architectures to private enterprises,[13] is considered as an opportunity by private companies. Space, already chosen by NATO as its fifth area of operation,[14] has become a promising business zone, the "eighth continent" to be explored and exploited in a new gold rush. History will prove the resilience of this hype (see OneWeb's bankruptcy in spring 2020).

The increase in the "population" in LEO by more than 16,000 satellites in the coming years does not include projects dealing with so-called pico- or micro satellites of 50kg max. These constructions of smaller and lighter-weighted satellites will even enhance their numbers in orbit and populate the orbits in their respective inclinations.

12. Satsearch, "An Overview of Satellite Electronic Power Systems ...", June 10, 2020.
13. Spacenews, "NASA Looks to Support Development of Commercial Space Stations", Jeff Foust, October 8, 2019, available at: www.spacenews.com.
14. "NATO to Build Space Centre in Germany", *The Defense Post*, October 23, 2020, available at: www.macaubusiness.com.

Economies of the 8th continent (LEO)

- Communication
- Space-based data collection
- In-orbit services
- Human exploration
- Bio/medical research
- Space resources exploration
- Space-based manufacturing
- New applications

Source: SpaceWork 2019

In its 2019 market forecast for satellites of the 50kg class, the US company SpaceWork[15] assumed a growth rate of 15% to 20% already in the coming 3-5 years. They hope to see the number of launches of micro-satellites in that class climbing to 750 in 2030 – which sounds rather an overestimate. For the next five years, there seems to be a total demand for launching approximately 2,000 to 2,500 small satellites (<50kg), 70% of them to be set in orbit for the benefit of commercial companies and most of them in bulk by heavy launchers. But – there is always a "but" – approx. 5% may be placed for military operators, which, given their governmental links, dominated the placement and rules on frequencies and orbit selection (see below). The rest (<30%) will be of public civil character, representing science or institutional organizations. Due to the tasks involved, 40% may be carrying Earth observation sensors or cameras, and 30% communication transmitters – two strong sectors in the digital transformation process. Technology and scientific devices complete the picture. Satellite IoT is expected to be the most powerful driver of this future market growth. In fact, even this forecast of a special market segment seems attractive enough for private investors.

15. Smallsat News, SpaceWorks Releases 2020 Nano/Microsatellite Market Forecast, February 12, 2020, available at: www.smallsatnews.com.

On regulations and physical or technical limitations

As mentioned, there is always a but! We must address a few important facts that must be considered carefully and traded in any special project before taking the risk of investment.

Legal aspect

Space is not a lawless environment. Physical laws are not the only limiting factors in this hostile milieu. We have discussed already the armed forces' interests in this class of satellites. Due to close linkages to their governments, they not only have influence on the national position but also on the international – for example, via the International Telecommunication Union (ITU),[16] which governs globally the allocation of frequencies and the orbit spectrum. The ITU a sub-organization of the United Nations, is mandated by its 162 member states to manage and supervise the international usage of frequencies as well as orbital spots. It also moderates the harmonization process between old players and newcomers. Military interests may thus override parallel commercial requests. At least in some nations, commercial bodies must apply for a national license or governmental support vs. the ITU. A licensing process is included in Germany's current draft space law.[17]

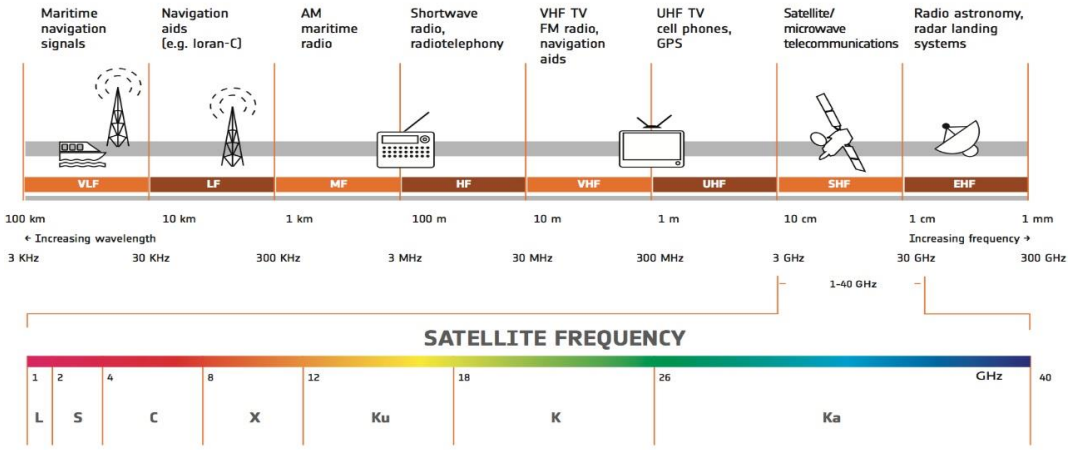
A few years ago, the German Ministry of Economic Affairs and Energy (BMWi) drafted a first version of the national space law[19] with the focus on the national licensing process and the establishment of a supervising organization. It's planned that any private company providing space-based services or operating space systems from ops-centers on German territory must apply for a license and must obey specific regulations. Unfortunately, the draft faced strong headwinds and was shelved.

Back to frequencies and orbital positions: both are considered to be rare resources today, and even more for the future of the space eco-system. On one hand, not all parts of the electromagnetic spectrum can be used for telecommunication applications, etc. on the other, there is a nonstop struggle between terrestrial and orbital suppliers, which always needs more frequencies than are currently technically or physically available. For example, the international community, represented by the ITU, has assigned a few small

16. ITU, Committed to connecting the world, available at: www.itu.int.
17. Jura online, Bundesregierung plant Weltraumgesetz, August 15, 2018, available at: www.jura-online.de.

frequency bands to special purposes in space science alone; e.g., 5.003–5.005 kHz and 10.003–10.005 kHz. Other applications such as radio, mobile telephony and optical data links occupy the rest of the complete available spectrum. Always too little for too many demands!

The space-related frequency allocation over the electromagnetic spectrum[18]



Source: © ESA.

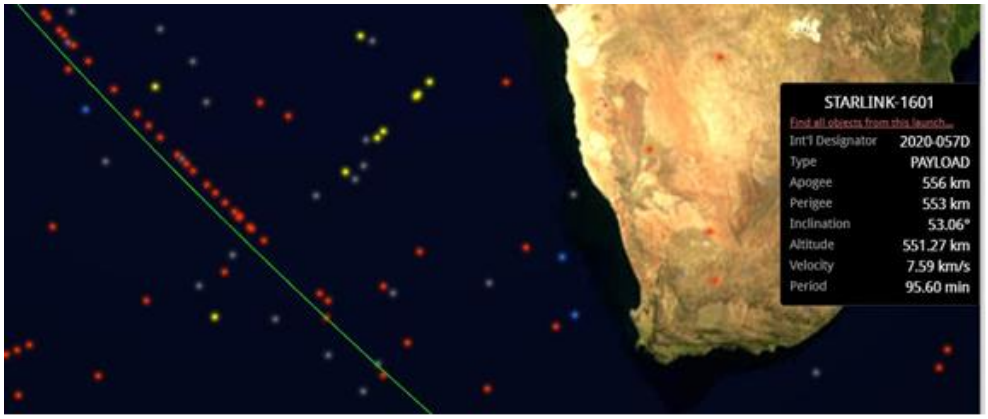
Safety concerns

Satellite spacing has become vital in an increasingly crowded environment. Since the end of the 1960s, any company or nation planning to place a satellite into Geostationary Earth Orbit (GEO) must apply to the ITU for an orbital slot. Since then, commercially attractive positions over North America, Europe and Asia have become congested. Only a few slots are left for new participants. The same will happen in LEO or Medium Earth Orbit (MEO) if only a few of the constellations, currently in planning, become operational. While frequencies are allocated (if available) following the "first come, first serve" principle, orbits and satellite position can be selected by any applicant also when available and – more importantly – if they do not cause interference with other users. It is therefore in the interest of any space system operator to place its satellite or sat constellation safely in free spaces, which provides enough distance between other orbiting objects. Today, a safe distance between two co-orbiting

18. European Space Agency, "Satellite Frequency Bands", available at: www.esa.int.

satellites in GEO (at the same height and inclination) lies in the order of 1.470km (i.e. 2 degree of the circumference – previously defined more carefully as a 3 degree distance).[19] For LEO,[20] 240km would be preferable, but it could be much closer if the distance is continuously monitored and corrected. TanDEM satellites, for example, are co-orbiting at a distance of 250–500m.

A row of Starlink satellites (red) over South Africa



Source: www.stuffin.space.

When discussing limiting factors, which may constrain the plans of private investors, we must address another safety topic. During its application process at ITU, the company OneWeb[21] identified an operational problem concerning its mega-constellation, when trying to harmonize the different orbits with those of another constellation under construction. To avoid an increased risk of collision, it proposed implementing a safety distance between different orbits of at least 150km, which would further reduce the available "space" of the economic business zone in LEO. As a first summary one can say that orbit slots, frequencies and safety distances will have a massive influence on the probability of effective realization of commercial plans.

Still unsolved is another topic of regulatory measures that must be defined soon: "Space Traffic Management".[22] The title summarizes all kind of legally binding agreements, such as terrestrial traffic regulation. This includes, for example, the demand that any new LEO orbiting satellite should have the autonomous capability (e.g. in form of a self-reliant subsystem) to perform a de-orbit maneuver at the end of its lifetime or in the case of a critical malfunction. In the past, those

19. Space.stackexchange.com, "How Closely Spaced Are Satellites in GEO?", available at: https://space.stackexchange.com.
20. D. Arnas *et al.*, "Low Earth Orbit Slotting for Space Traffic Management Using Flower... Theory", MIT, June 5, 2020, available at: www.arc.aiaa.org.
21. More details available at: www.oneweb.world.
22. M. Sorge, W. H. Ailor and T. J. Muelhaupt, "Space Traffic Management: The Challenge", September 2020, available at: https://aerospace.org/.

systems were often transferred out of GEO into the so-called graveyard orbit, which is a minimum of 250km higher than GEO, at approx. 36,000km. For LEO, that is not an option. With the upcoming challenge of planned mega-constellations with several thousand systems – for Starlink alone more than 30,000 units – a parking solution is in no way acceptable as it would occupy the precious "LEO resource" and even represent over time a danger for active satellites. The regulation for self-induced, destructive re-entry will result in more weight and heavier satellites, which has implications for the necessary launch capacities.

Space debris[23] and the operational environment

Furthermore, the ecological aspects of destructive re-entry of "rotten" satellites in our atmosphere will set up restrictive design criteria for "eco-friendly" satellite materials, for example. It may already be difficult to suffer a single burn-up of system hardware in the upper atmosphere of the "blue planet", but an increase in their number of several hundred or even thousands a year would be unsustainable for an ecologically sensitive society. This is especially true for 500–600km orbits. Here, the planet's atmosphere decelerates the satellite's velocity, requiring more propellant for orbit-maintaining maneuvers and thus limiting the lifetime of a single system to approx. three years. For such kinds of single replacements, contracts for SSLVs may be expected.

Finally, we have to discuss the pollution of near-Earth space by debris and wrecked systems. In almost six decades (since 1957) more than 5,000 launches have resulted in about 34,000 objects (>10cm) remaining in space – these being regularly tracked by special organizations such as the US Space Surveillance Network.[24] Objects larger than about 5–10cm in LEO and 30cm to 1m at GEO altitudes are continuously monitored. Only a small fraction – about 3,300 – are operational satellites (updated in 2020 by statista.com). The rest are pure litter, travelling uncontrolled at cyberspeed (in LEO ca. 10km/sec).[25] Their numbers are growing, for example with accidental break-ups or planned interventions (e.g. for military testing).

In 2007 the Chinese FengYun-1C event enhanced the debris "population" in LEO by 25%. The weather satellite was used as a test target for an anti-satellite system and its "success" generated more

23. European Space Agency, Phys.org, "The Current State of Space Debris", October 12, 2020, available at: https://phys.org.
24. NASA, ARES | Orbital Debris Program Office; https://orbitaldebris.jsc.nasa.gov.
25. DGLR, Martin Schuermann, Bezirksgruppe Braunschweig, "Space Debris: First Online Seminar…", held on February 8, 2021.

than new 3,000 fragments, forming over the years a drawn-out cloud around the original orbit, reducing the potential operational environment for newcomers.

It is not clear whether such destructive events will still take place in the future when the orbit is congested with operating commercial satellites. What we currently observe is that similar tests with ballistic missiles are still taking place in a non-destructive way. Additionally, Jamming and Spoofing events have increased dramatically over the last few years; this can also be seen as a new trend where the aim is to achieve military effectiveness without leaving a fingerprint by creating more space debris through military actions.

As a lesson learned, we can conclude that governmental and intergovernmental regulations, the finiteness of "physical" resources, and past human carelessness and misbehavior will reduce the probability of participating profitably in the expected market growth on the 8th continent.

On market accessibility

Besides the market perspectives noted above, everyone should be aware that only a small share will be accessible for internationally acting commercial providers. The Russian and Chinese markets are not open for Western system operators. The US has spent billions of dollars via NASA on building up a competent and capable private capacity, mainly supported by IT tycoons such as Jeff Bezos and Elon Musk, which enables the agency to rely to a large extent on such national "commercial" capacities. These public markets are not only closed for international competitors; in parallel they provide a well-protected greenhouse for native providers, which are allowed to offer their services also on the free global market. Space X – as one example – is offering its Falcon 9 launch service internationally for a price of approx. US$50 million, while NASA is providing a national "cost coverage" for its launch providers of about US$150 million for the same performance.[26]

Furthermore, the home market for the major space-faring nations is quite stable, or even rapidly growing. NASA's Gateway plan and the new defense architecture of the Space Development Agency (SDA) are allowing the US launch providers to invest in innovations, while expecting sound profitability over several years.

26. V. Tangermann, "Elon Musk: SpaceX Launches Will Cost 1% of Current NASA Launches", Futurism, November 6, 2019, available at: https://futurism.com.

Compared to the USA, Russia is more frugal. Dimitri Rogosin, head of the Russian space agency Roskosmos since 2018,[27] announced recently that Russia was no longer interested in offering its rockets on the global market, because the AM prices were not attractive to Russian industry. He considers the segment (totaling only 4% of the global space market) far too small to justify the effort to "elbow Musk and China aside".

In contrast with Moscow's restraint, Beijing is seeking a substantial share of the world's space market, thus following the US approach. Over the last seven years, nearly 160 commercial space companies[28] have been founded. In 2018 approximately RMB3.6 billion (US$550 million) has been invested, mainly to meet China's own growing national demands. CASC – the China Aerospace Science and Technology Corporation – claims a need to launch more than 4,000 commercial satellites over the next decade, boosting China's sat system by nearly 1,000%. "Commercial" in China often means state-owned, and thus cost coverage or pricing is not really a problem.

Luckily for its potential competitors on the market, at least for the moment, there is another important constraint. Due to its conflict with the US, the People's Republic has no access to special US-made electronic equipment – which is not even allowed to be brought into China inside a foreign satellite. China's exports are limited by the International Traffic in Arms Regulations (ITAR). This means that Chinese launchers, now operated from Chinese soil, are prevented to launch international commercial satellites as they almost always use high-tech electronic equipment, subject to ITAR regulations. China fights this limitation in two ways: on the one hand, it offers to emerging countries a turnkey solution for the (Chinese) satellite and its launch service. On the other hand, it also seeks to operate its launchers out of other countries in the hope that this would allow circumventing the ITAR constraints.

Beside these powerful actors, it's not only the German start-ups mentioned earlier that have an interest in the commercial satellite launch service; as also noted above, the latest New-Space-Index lists around 150 ongoing developments or production plans for SSLVs, trying to catch an attractive share of the global market.

27. Roskosmos, "Russia Doesn't Want to Fight for Commercial Launch Market", April 24, 2018, available at: https://realnoevremya.com.
28. B. Waidelich, "China's Commercial Space Sector Shoots for the Stars", EastAsiaForum, March 13, 2021, available at: www.eastasiaforum.org.

On the request of some member states, ESA proposed at its latest Ministerial Conference in Seville a programme to assist these European systems. Apart from the first contracts signed with three German-based consortia, others from Spain, Italy and the UK may follow. The question is: for how many of them will there be market demand?

Summarizing the actual situation in spring 2021, it is obvious that only a few of the AM actors will survive the first test launches. Nevertheless, it is also apparent that, even if there is market demand, there are extremely high hurdles to leap over: any investments by national or international governments, organizations such as ESA or private financiers such as Bezos and Musk face high competition, a missing license, limitations in the access to market, or critical safety operational conditions.

All in all, it is more an opportunity than a risk to "burn money", which may be ok for scalpers and gamblers of the financial sector. For states or multinational organizations, it would be wise to stay aside, limiting their backing to regulatory or legal activities. They may carefully support the first steps of new start-ups financially, as Germany does in relation to ESA's CSTS project. As it is a commercial endeavor "by name" already for the second phase, venture capital must take over both the business and the risk.

Finally, we must repeat the "mantra" that, without support through licensees or funding, it will be very difficult to survive economically in this regulated business environment.

The key players of the German SSLV spectrum

What are the best design parameters for a highly reliable, innovative, environmentally friendly and cost-effective launch system for the expected demands of the future market? Shall we consider using the multi-launch capacity of a heavy carrier? Maybe that is a scaling topic, for handling by ArianeGroup and Avio, which both got a support contract from ESA too. Shall we optimize the performance of a small rocket, able to place one (or more) small satellites into its dedicated orbit position? Maybe that is a cost-driving factor! And which, in early 2021, are the most promising competitors worldwide? The answer can probably be found through comparing the actual competitors in ESA's Booth program.

As already said, the first round was closed with ArianeGroup, Avio and three German start-ups, offering different solutions to the problem.

- HyImpulse[29] introduces its initiative with the following wording: "We are developing an orbital small launcher, powered by our unique, green hybrid propulsion technology, delivering a higher performance at a fraction of the cost, with a higher operational safety and flexibility."
- "ISAR Aerospace[30] offers satellite constellations flexible, sustainable and cost-effective access to space. Based on cutting-edge rocket engineering research, environmentally friendly propellants and advanced manufacturing, Spectrum precisely delivers small and medium payloads to orbit"
- Rocket Factory Augsburg[31] describes its purpose as follows: "It's about transporting and precisely positioning small and light satellites in a near-Earth orbit quicker and more cost-effectively than ever before."

However, that is marketing talk. We need to look at the facts and figures.

29. Website of HyImpulse: www.hyimpulse.de.
30. Website of ISAR Aerospace: www.isaraerospace.com.
31. Website of Rocket Factory Augsburg: www.rfa.space.

Rocket Factory Augsburg (RFA)

Rocket Factory Augsburg (RFA) was founded in 2018 by OHB and Apollo Capital Partners GmbH, Munich. Besides being labelled as a "New Space" start-up, (more or less a subsidiary of OHB System in Bremen. J.J. Dordain, former ESA director general, holds a seat on the supervisory board of RFA.

The company is developing RFA One, a liquid fueled, three-stage carrier with a launch capability for a payload range of 200–400kg in LEO. Recent modifications seem to allow a service ranging from 450 kg to GTO up to 1,6 tons into the ISS orbit.

It plans a "national launch pad", located on a swimming platform on the North Sea between Norway and the British Isles. The first test flight is foreseen in 2022, from a Norwegian space port. For market access support, RFA has contracted Exolaunch, a Berlin-based university spinoff, acting since 2010 as a launch service provider, which up to spring 2021 had managed successfully 140 satellite launches on Falcon 9, Soyus and Electron, the SSLV of US Rocket Lab.

ISAR Aerospace

The company was formed in 2018 as a Munich University spinoff, later backed financially by the German venture capital fund UVC Partners and by the industrial partners Viessmann and Airbus Ventures. Today around 100 employees are preparing the maiden flight.

Parallel to RFA, the first launch of its launcher Spectrum is foreseen in 2022. The system is a two-stage, liquid-fueled (LOX – liquid oxygen-kerosene) carrier, capable of transporting 1,000kg in LEO, or 700kg in a sun-synchronous orbit. Both stages are reignitable, which would allow complex orbit maneuvers – e.g. for placing satellites in different orbits, thus offering the capacity for multi-satellite launches for constellations.

HyImpulse

The start-up, formed by rocket specialists from the German space agency DLR, is targeting the first flight of its launch vehicle in late 2022. Financially it is backed by IABG, a formerly state-owned German tech company, acting for decades as an aerospace test and development center on the international level.

Founded in 2018, the company is developing a sounding rocket, able to carry 350kg of payload to 200km altitude for microgravity and atmospheric research. The rocket is powered with a 75kN propulsion system, using a paraffin-based fuel with liquid oxygen. The same technology will be used for its second product, a small launcher with three stages designed to carry 500kg in LEO.

The table below summarizes the known data, and shows comparisons with a few competitors, already in or close to the market. We have chosen the Italian Vega C, the Indian SSLV/PSLV and the Electron by Rocket Lab.

Small Launch Vehicles						
	RFA	**Hyimpulse**	**ISAR**	**Vega C**	**Electron**	**PSLV**
Investor	OHB et.al.	IABG et.al.	Airbus et.al.	Avio	Rocket Lab	ISRO
1st Launch	2021	2022	2022	2022	2017	2020
Fuel	LOX/Kerosene	Paraffin/LOX	Cryogen/LOX	Solid Prop.	LOX/Kerosene	Solid Fuel
Orbit	LEO	LEO	LEO/SSO	LEO	LEO	LEO
Payload mass	300 kg	500 kg	1000kg/700 kg	2200 kg	300 kg	500 kg
Price/kg	>20.000€/kg	15.000€/kg	----	----	25.000$/kg	----

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Considering the actual status of the developments, it is difficult to get accurate data. In particular, the launch prices seem to be "best guesses" – except for Electron, having already performed successfully around 20 launches. RFA is proposing to achieve at a later stage of production a price of 2,000–3,000 €/kg, which is – compared to Electron – a reduction of around 90%. HyImpulse offers a relatively low price, relying on its hybrid fuel concept (paraffin plus liquid oxygen), which should allow also a safer and eco-friendly operation. Vega C, a consolidated version of the original Vega, stands out among its competitors due to its mass-carrying capacity of two tons, which may allow it to fulfil a wider range of customer demands, perhaps in the build-up phase of a constellation.

It will be interesting to see the parameters, weightings and rankings in ESA's final evaluation, due in 2021.

The German space eco-system and the national space policy

The players

The industry

In the wake of the early space race between the USSR and USA (Sputnik, Explorer 1, etc.), German space activities started early in the 1960s, when a few national aerospace companies (such as Messerschmitt, VFW, and HFB) opened their first departments dedicated to space technology developments. Activities were focused at that time on launcher systems, in accordance with the first European launcher program, Europa, under the lead of the European Launcher Development Organization (ELDO), later followed by various satellite projects (TD-1A, AZUR). Since 1974 (Spacelab contract) the industrial competence spectrum has been expanded to astronautically oriented themes such as pressurized habitats, environmental control, life-support systems, space suits, etc. During that period, only a small number of system-oriented space companies played an industrial role, such as MBB, Kayser-Threde, Dornier and ERNO. Over the next fifty years, the industrial landscape changed drastically. Mergers and acquisitions formed a concentration on the one side, while new space companies were founded, many of them in recent times ("New Space"). Their numbers are still rising. Currently around a dozen system companies or OEMs (e.g., Airbus and OHB) supported by around 50 specialized SMEs[32] (e.g., Astro Feinwerktechnik, vH&S...) complete the picture. BDLI, the national association of aerospace companies, published the following figures for 2019: approx. 10,000 employees generated a revenue of €2.7 billion.

Research centers

The Treaty of Paris in 1955 lifted the restrictions on aerospace research. First, universities opened space institutes, as in Stuttgart, which engaged mainly with rocket technologies. The formation of a special national research center (DFVLR - Deutsche Forschungs- und Versuchsanstalt für Luft-und Raumfahrt) happened rather late, in

32. For German Space SMEs, see Companies – Raumfahrt-KMU – Best of Space; https://best-of-space.de.

April 1969, as a national counterpart and partner to the European Launcher Development Organization (ELDO), established in 1962, and the European Space Research Organization (ESRO). A parallel development took place in the German Democratic Republic (DDR), where in the frame of the Interkosmos agreement with the USSR space activities were handled by the Academy of Science (AdW). In 1989 DVFLR was reorganized after German reunification and renamed DLR,[37] the current national space and aerospace R&D organization (30 national plants, 10,000 employees). Prominent and major space institutes at German universities are located in, e.g., Aachen, Stuttgart, Berlin, Munich, Wurzburg, Darmstadt and Dresden. Special technologies are also under investigation at the major research platforms, such as Fraunhofer and Helmholtz.

Space policy stakeholders

The German government formed its first space research-related commission in 1965. At that time also, the first Space Research Program was published under the auspices of the ministry of scientific research. The responsibility for all space activities, whether on a national, bilateral or European level, lay with this ministry up to 2005, when E. Stoiber, the designated Minister for Economic Affairs and Energy (BMWi), demanded a transfer under his responsibility. Today, space policy is handled in four organizational units in the Department of Industrial Policy. They supervise the national Space Agency, a separate unit of DLR – the German Aerospace Center, being mandated with the execution of the German Space Program. The political leadership of all national space activities is assigned by the Federal Cabinet to the "National Aerospace Coordinator" reporting to the Minister for Economic Affairs and Energy. The coordinator position is currently held by Thomas Jarzombek, MP.

Space-related competencies and responsibilities are distributed among different governmental institutions. Besides the Ministry of Economic Affairs and Energy, the Ministry of Transport and Digital Infrastructure is responsible for activities concerning the Galileo program, the European Geostationary Navigation Overlay Service (EGNOS), Earth Observation, Meteorology, and the Public Regulated Services (PRS) of Galileo – the more security-sensitive area. The latter area overlaps with activities of the Federal Office for Information Security in the field of space. The Federal Foreign Office deals with issues related to arms control and space law[33] whereas the Federal Ministry of Defense oversees activities around space security – operations in and from space, including the operation of

33. Auswärtiges Amt, Organisationsplan des Auswärtigen Amts, April 1, 2021, available at: www.auswaertiges-amt.de.

reconnaissance satellites.[34] Furthermore, the ministry is working closely together with the DLR in terms of Space Situational Awareness. This civil-military cooperation is institutionalized in the form of a Space Situational Awareness Centre, which in turn is, up to a certain point, in interaction with the Space Safety Office of ESA but also with NATO.

National Space Program

There are two official documents that give instructions for the execution of national space policy. The formal German Space Program[35] was published in 2001 and is therefore no more relevant. It was superseded when BMWi issued in November 2010 a second document,[36] labelled in its subtitle as "the Space Strategy of the German Government". Generally, it says that international space activities are largely driven by public-sector space interests, linked to international agreements (such as EU or ESA conventions) and weighted according to the available budget funding – which explains somewhat the fact that both documents for the most part do not describe physical targets or objectives. The identification of concrete goals is avoided because the naming or even description of timetables and budgets would bind the ministry legally to successful execution. The documents therefore concentrate on the description of running (i.e. old) projects on the national level or with international cooperation. The content of German space activities is generally determined, therefore, by external (foreign affairs) interests and limited by budget.

German Space Policy

As mentioned, space activities started in the 1960s in BRD and DDR with R&D activities, one side linked to European space activities, with a focus on ELDO, the other connected to the USSR-led Interkosmos cooperation (with a clear competence profile in Earth observation sensors based on technology competence in optics). The political focus was set on foreign trade and foreign affairs aspects, on both sides, with a main objective of being recognized as a partner in an international R&D alliance.

34. BMVg, Organisationsplan BMVg, April 2021, available at: www.bmvg.de.
35.Bundesministerium für Bildung und Forschung, "Deutsches Raumfahrtprogramm. 2001", available at: www.dlr.de.
36. Bundesministerium für Wirtschaft und Technologie, "German Space Strategy, 2010", available at: www.dlr.de.

This approach has not changed over time; it was maintained through all the difficulties in merging DDR and BRD technology and scientific competence. As a consequence of the collapse of Interkosmos (in the wake of the USSR's downfall), only a few centers remained. Germany space policy stays focused on "targeted" participation in ESA (with an historical link to NASA in astronautic activities, based on the bilateral Spacelab cooperation). We should mention the fact that all knowhow around Spacelab's pressurized module construction was transferred at the end of 1970 to Italy, which explains to an extent the sound bilateral cooperation between NASA and Italian industry in that area.[37]

Germany remains committed to its partnership in ESA; there does not seem to be any intention to steer European space policy in favor of national priorities. As noted, the current point of emphasis lies in space utilization and application matters such as Earth observation, with a newly expressed interest in fostering public safety (also in the military area) and commercialization in the New Space sector – e.g. in the small-launcher business. The political intention in the latter case is concentrated on supporting industrial activities to become commercially competitive. Thomas Jarzombek made this clear in an interview,[38] announcing that the initial phase could be supported by government money while the future growth of small-launcher initiatives would be a clearly a commercial endeavor.

Germany's Future Funds for Start-Ups

Recently, the German government instructed Kreditanstalt für Wiederaufbau (KfW), a governmental bank, to set up an investment fund[46] of €10 billion, dedicated to "young companies". Minister Altmaier expects that this kind of state-owned venture capital will motivate other VC companies to spend an additional €20 billion. The initiative should help start-ups to overcome the hurdles of bringing complex technologies into use. As an example, the small-launcher business was addressed.

37. Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), "History of German Spaceflight", 2010, available at: www.dlr.de.
38. M. Rasch, "Die deutsche Industrie macht Ernst "mit einem Weltraumbahnhof für Miniraketen an der Nordsee- oder Ostseeküste", *Neue Zürcher Zeitung*, December 3, 2021, available at: www.nzz.ch.

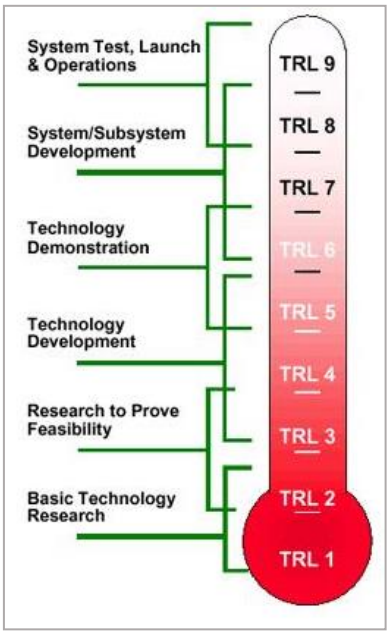
As an actual proof of this policy, we may refer to a publication of Germany's Ministry of Research and Education (BMBF). In January 2021, a discussion paper[39] was distributed on national level that connects national R&D efforts to European partnership networks. "With unilateralism we can't keep pace with the USA and China," a representative of the ministry was quoted as saying. After careful evaluation, the internal paper sums up the technological areas in which Germany should spend a major part of the budget allocated in 2021 (totaling €21 billion). Technological sovereignty should be achieved – for example, in artificial intelligence, IT security, Industry 5.0, quantum computers and communication technologies. Space technologies were not specifically mentioned. We can find the same argument in Minister Altmaier's (BMWi) welcome address to the 10th EU Space Council on November 20, 2020. As key technologies, he mentioned space traffic management, robotics and cyber security (focused around the GovSatCom project of the Union). The German government still follows the directive to participate in European joint activities with a clearly substantial contribution.

On the industrial policy side,[40] some of the above-mentioned government agencies are currently working on various space-related policy fields, thereby slowly raising public awareness of space issues, with a focus on SMEs. The R&D budget is allocated normally on a pro-rata basis and limited to the Technology Readiness Level - TRL 6 (see illustration below). Currently, the German space start-up scene is getting more political support – mainly driven by the Ministry of Economic Affairs and Energy and the Federation of German Industries (BDI). Additionally, with "AeroSpacePark Trauen – Vision 2035", the DLR and other political actors at the civil-military interface recently laid the groundwork for a German "Responsive Space" approach. This initiative aims to develop and expand the strategic capability to replace defunct satellites within a few days or even hours with smaller satellites, with a maximum weight of 500kg. This step highlights that agility in space has become a recognized security need to ensure Germany's national and external security, as expressed in the 2010 strategy document. In the same context, innovative propulsion technologies for small launchers and satellites are gaining more attention, and the BDI is promoting an offshore spaceport in the North Sea, which is currently the subject of controversial discussion. The formation of the German Offshore Spaceport Alliance, which is currently planning the spaceport, is aimed at making the first step towards independent access to space.

39. R. Bönsch and B. Reckter, "Der Souveräne Weg", vdi nachrichten, February 5, 2021, available at: www.vdi-verlag.de.
40. L. Serenelli, "German Government Quick Starts Fund with €10bn for 'Future Tech'", IPE, March 30, 2021, available at: www.ipe.com.

Overall, these developments can be seen as positive because they are fostering public awareness about space-related topics. And, in view of geopolitical developments, it is long overdue to think of civil and military aspects together, with a stronger focus on the latter. Nevertheless, Germany has neither a national space law (which is in preparation) nor a published vision, translated into a space strategy. On the contrary, it seems that Germany's strategy is not to have a space strategy but an adaptable, not to say timeserving, space policy. In this light, it may seem advantageous not to have to commit to a space strategy in order to avoid making cost concessions, but this is not always the wise direction – especially in a highly ambiguous policy field, where the dynamics are constantly changing. It sends a signal of political uncertainty to European partners and the world.

NASA Technology Readiness Levels



Source: NASA, available at: https://web.archive.org.

Instead of acting proactively, the German government seems to react to foreign policy impulses coming from NATO, the United States, France or the UK. Also, an innovative space law framework, which provides investment and legal securities to New Space start-ups, is currently lacking. One of the many reasons for these difficulties, especially in the field of space law, is the heterogeneous landscape of interests. For instance, the Ministry of Economic Affairs and Energy and the Federal Ministry of Finance have not yet been able to reach consensus on the direction and content of such a space

law.[41] Germany is well positioned industrially and is investing high sums in national and European space programs, but these political-bureaucratic mechanisms decelerate the political decision-making process as a whole. This in turn increasingly overshadows the financial contributions.

41. D. Sürig, "Streit um das Weltraumgesetz", *Süddeutsche Zeitung*, March 26, 2021, available at: www-sueddeutsche-de.cdn.ampproject.org.

European cooperation in the SSLV-sector

Considering the background elements developed in the previous chapters concerning the market needs for dedicated small launchers, European institutional demand, the question of public support for such initiatives, and how far European cooperation could enhance the chances of success of such initiatives, the following conclusions are proposed:

- All existing market projections point to limited numbers of small satellites on the open commercial market (200 per year), of which most will be launched with larger launchers, for cost reasons.
- In Europe, up to now no defense-driven "Rapid Access to Space" doctrine has been developed by any country, and there is no obvious boost to be expected by such "wealthy" customers (as in the case of the US and likely also in China).
- When considering today's market actors such as Rocket Lab, one can see that public demand is key for their business success – especially with US public customers (NASA, DOD, DARPA), which tend to pay significantly above the commercial market prices.
- The success of any new European small-launcher actor will depend to a certain degree on public support. The ESA CSTS program decided at C-MIN 2019 is a first step in this direction (confirming the assumption).
- European independent access to space, which is the political justification for financially supporting the development and operations of European launch systems, is fully secured with the existing Ariane and Vega launchers.
- The Ariane and Vega launchers are developed and produced by two independent industrial prime contractors and their consortia but commercialized and operated by the common entity Arianespace.
- Public payload allocation between the two systems has been regulated by member states in order to secure a long-term perspective for both systems.
- The competitive battlefield for launchers is not the very limited European (public and commercial) market but mainly the worldwide commercial market and some foreign public demand.

What, then, might be the benefits of cooperation between European players for the institutional side as well as for the respective industry, and how can it be implemented? Such a cooperative policy was recently addressed by French President Macron during a visit to the French Space Agency.

Future small-launcher business cases will only be successful in a public-private partnership (PPP) setup, meaning they will need at least a regular number of public orders. As independent access to space cannot be the major reason, the small-launch vehicles will generate additional benefits and profits. These could be in their ability to act more quickly and possibly more simply (if other design rules remain acceptable) when selecting and testing lower-cost new technologies and operational concepts. These kinds of benefits could have high added-value for the large-launcher consortia, and thus also for the national space agencies. This would be the first field of cooperation between the incumbent and the newcomer, which should be seen as bidirectional. The newcomer can test on a small vehicle – and thus with minimum cost and risk – disruptive low-cost approaches for the later enhancement of the large launchers. As the newcomer does not master the full spectrum of background experience or main products needed for the business, it could also benefit from specific competences brought in by the incumbent actor. This could be a win-win approach for both sides.

In general, the small-launch vehicle start-ups are built around a team of inspired engineers and experts. Their main focus is to build up a team mastering the development, production and operation of a new launch vehicle with a minimum level of resources. This is already a big challenge. But the launch vehicle alone will not secure the business case. You also need capacities to commercialize, sell, secure export financing, and insure the launches – a totally different set of competences. This could be the second axis of valuable cooperation in Europe. As is already the case between Ariane and Vega, integrating the small launcher offer into the network of Arianespace could make a lot of sense. Establishing and running *one* worldwide acting commercial team to sell launch services is a major investment (in competence and cost). Beyond that, a lot of specific competences are needed to bid for public offers in many countries, as well as to seal contracts in various countries under local legislation, as is often the case. How can you afford this when you have only a very limited level of sales? Sharing existing customer relations, business intelligence, competences, resources and thus fixed costs is an efficient path to success. Another aspect could be launch insurance, especially for a new launcher, where not only experience but one's own insurance capacity could be an additional value of such cooperation.

All in all, considering the high number of worldwide initiatives to develop small satellite launchers, the chances of success of any new European player are limited. They will increase substantially if cooperation at European level is achieved, especially when generating benefits for the institutional actors. This should allow the securing of a certain level of public support for the small-launcher start-ups, without which their chances of surviving in the face of many aggressive international actors, already receiving direct and/or indirect public subsidies, would be very low.

Conclusion: a system analytical attempt

At the end of this report, it is time to bind all information together to close the file.

- We started with noting that the digital penetration of industry and society will continue to change our daily life. Today's technical capability to acquire, transmit and analyze all kinds of data is used to understand, optimize and influence processes on a global level. Satellite constellations for communication, navigation or Earth observation will continue to play an active role in this transformation process, being identified as one of the backbones of worldwide digitalization.
- Near-Earth space, whether LEO, MEO or GEO, has been developed over the last decades into a sphere of different interests – the players in science, information-gathering for governmental affairs, military missions, and private business. It is already a matter of power and assertiveness who will have the *jus primae noctis* (*droit du seigneur*), i.e. priority access. Due to international regulations and national laws, government, armed forces and science are overriding commercial interests in most cases. Policy continues to dominate, with its requirement for sovereignty and autonomy. Business can participate in the wake of policy if its capacity is adequate to fulfil the demands of the institutional customer.
- The operational field in near-Earth space is not unlimited. Its access is limited and regulated. Its environment is hostile for man and manmade machines. And it has become crowded and littered after fifty years of carelessness. Freedom of operation is narrowed by globally spreading plans to construct new infrastructures for civil and military application. For commercial activities, the chances of undisturbed operation are limited, and further developments, such as high insurance costs, may lead to further constraints.
- Current trends on our digitized globe include several plans to construct network-type architectures, called mega-constellations. The Space Development Agency proposal to establish a multilayer satellite infrastructure in LEO for US defense purposes is a good example. In the build-up phase, any producer will use the mass carrying capabilities of heavy launchers like the Falcon 9, while replacement of a single failed satellite within the net will require a smaller and lighter carrier (SSLV) to allow accurate and quick

repair of the network by sending a substitute into the right orbit position. For any customer, reliability in delivering the satellite will always be more important than the price of this service.

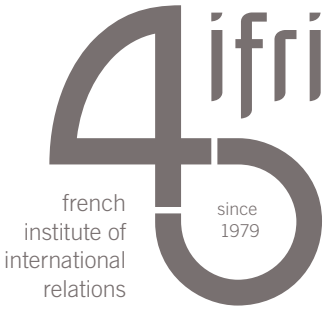
- Hype in the commercial space sector has motivated an increasing number of investors, who are trying to catch a share of the market. There are now around 150 plans to construct and operate a small launcher. We can assume that most of them will not reach their design and development phase, and only a few – competing against each other or the piggyback offers of the heavier vehicles – will start operating. In any case, the market, restricted by regulations in the commercial business, may not be big enough to survive without the support of national governments, insisting on unrestricted access to space at any time (e.g. in military conflicts). Their cross-subsidization will stabilize the market position of the commercial product.
- For Europe, having established its competitive launch capabilities (Ariane, Vega and Soyuz) over the last decades, a small number of SSLVs may be attractive, to complete its vehicle portfolio. There may be the need for redundant capacities, but too many systems are increasing internal costly competition and the demands for further subsidies.
- An independent business of small launchers by one or more commercial operators to take care of, for example, rapid-response requirements by national organizations, should be discussed politically. An industrial alliance between all providers is worth considering; it could offer advantages for start-ups in the form of easy access to customers, a common marketing platform and benefits on the insurance side. Also worth bearing in mind is the IT wisdom that the merging of rivals is a way of surviving in times of digitalization.
- As a consequence, and a kind of conditio sine qua non, the ESA/EU member states should guarantee – as demanded for years – "preferred use" of the domestic launch capacity by all European nations.
- German Space Policy has since its beginning focused on European or bilateral cooperation. Any activity is guided by the objective that a common purpose should be achieved, relying on a substantial and "valuable" German participation. National R&D often prepares such inputs.
- German industrial policy supports SMEs up to a given limit, set by technology readiness level (TRL). R&D funding is permitted on rare occasions up to demonstration level (TRL 6) only. Acting, for example, as a shareholder in a commercial business is not foreseen.

- To enforce any "legitimate" interests, even imperfectly interpreted, requires political power. In the near-Earth space (LEO to GEO), as a field of national or European ambitions, reliable technical capacities should be on hand as formidable tools. Even if globalization develops smoothly, with conflict-free cooperation, Europe has to rely on an independent source in the field of satellites and launch capacity. We should remember the deficits in masks or vaccine production facilities at the beginning of the Covid-19 pandemic.
- The ESA/EU need to achieve the common objective in space exploration and utilization through careful harmonization of national interests. Redundant capacities may be reasonable, provided that they are properly calibrated. "too much for too little".
- A common industrial policy will follow the directive to steer (support and limit) the build-up of industrial space capabilities – e.g. on the launcher side – corresponding to the defined joint ambitions. The USA and China are currently demonstrating this in a nearly absolute way. This may be seen as unfair from the point of view of commercial competitors, but, as long as the global hype continues, the arguments to protect mutual resources may still be valid.
- Last but not least, it's of utmost importance, for the fair and open participation of European actors in future commercial space activities, that unrestricted access to and civil usage of the space eco-sphere remains the basis of all kinds of international legal agreements. UN treaties and resolutions (such as UN resolution 75/36) should be supported, updated and reinforced to achieve this goal. This may include enforcement of the role of the ITU; a "first come, first served" rule in, for example, occupying orbit slots would probably foster further rivalry between space powers and the militarization of space.

Annex

AdW	-	Academy of Science
AM	-	Additive Manufacturing (AM)
AR 4	-	Ariane 4
BDLI	-	German Aerospace Industry Association
BMBF	-	German Ministry of Education and Research
BMWi	-	German Ministry of Economic Affairs and Energy
CSTS	-	Commercial Space Transportation Services
CASC	-	China Aerospace Science and Technology Corporation
DDR	-	German Democratic Republic
DLR	-	Federal-funded Research & Development Corporation
DOD	-	Department of Defense (USA)
DARPA	-	Defense Advanced Research Projects Agency (US)
EGNOS		-European Geostationary Navigation Overlay Service
ELDO	-	European Launcher Development Organization
ESA	-	European Space Agency
ESRO	-	European Space Research Organization
ERNO	-	Entwicklungring Nord
GEO	-	Geostationary Earth Orbit
HFB	-	Hamburger Flugzeugbau
IABG	-	Industrieanlagen-Betriebsgesellschaft mbH
IoT	-	Internet of Things
ISS	-	International Space Station
ITAR	-	International Traffic in Arms Regulations
LEO	-	Low Earth Orbit
MBB	-	Messerschmitt-Bölkow-Blohm GmbH
MEO	-	Medium Earth Orbit
NASA	-	(US) National Aeronautics and Space Administration
NRC	-	Non-recurring costs
OHB	-	German Space System Company in Bremen

OEM	-	Original Equipment Manufacturer
PPP	-	Public Private Partnership
RC	-	Recurring costs
RoI	-	Return on Investment
SDA	-	(US) Space Development Agency
SMEs	-	Small and Medium Enterprises
SPAC	-	Special Purpose Acquisition Company
SSLV	-	Small Satellite Launch Vehicle
TRL	-	Technology Readiness Level
VFW	-	Vereinigte Flugtechnische Werke Bremen



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