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Revolutionary by Design

The US National Security State and Commercialization in the US Space Sector

Torben SCHÜTZ

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This tripartite initiative (Ifri, DGAP, IAI) is intended to provide analysis pertaining to the international space competition 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 on 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 French-German relations (CERFA) at Ifri.

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Executive Summary

The US space sector, comprised of its government organisations and its commercial industry, is leading the revolution in space, often called "new space". This should come as no surprise. This case study will investigate how and why this is the case. While the US has excellent basic conditions with a strong industrial base, extensive talent and continuous government support, the truly impactful innovation is how National Aeronautics and Space Administration (NASA) – as an extension of the US National Security State (NSS) – handles the commercialisation of parts of its traditional space activities. In doing so, it follows an established pattern of US government support for new technologies or industries and their eventual commercialisation. The successful commercialisation of space activities can be attributed to geopolitical drivers, the NSS as a technological enterprise and US antistatism. On its most fundamental level, NASA provides the US space industry with a market, investment, technical challenges, its know-how, and learning experiences. This, in turn, enables US space companies to develop both the necessary product or service and the confidence to take the first commercial steps.

Résumé

Le secteur spatial américain, à travers ses organisations gouvernementales et son industrie commerciale, domine la révolution spatiale, souvent appelée « New Space ». Cela ne devrait pas surprendre. Cette étude a pour objet d'expliquer comment et pourquoi tel est le cas. Au-delà des atouts considérables dont disposent les États-Unis, à travers une base industrielle solide, un réservoir de talents et un soutien gouvernemental continu, l'innovation vraiment déterminante est la façon dont l'Administration nationale de l'aéronautique et de l'espace (NASA) – en tant qu'extension de l'appareil d'État américain pour la sécurité nationale (NSS) – assure la commercialisation de certaines de ses activités traditionnelles. Elle reproduit ainsi un modèle bien établi de soutien du gouvernement américain aux nouvelles technologies ou industries et à leur commercialisation. Le succès de la commercialisation des activités spatiales peut être attribué à des facteurs géopolitiques, au NSS en tant qu'entreprise technologique ainsi qu'à une forme d'antiétatisme. À son niveau le plus fondamental, la NASA offre à l'industrie spatiale américaine un marché, des investissements, des défis techniques, son savoir-faire et l'occasion de réaliser des expérimentations. Ceci permet en retour aux entreprises spatiales américaines de développer à la fois le produit ou le service adapté et de disposer de la confiance nécessaire pour effectuer les premiers pas sur le plan commercial.

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Leading the Space Revolution

The US space industry is currently leading a technological revolution that fundamentally changes essential parts of the space market, especially in the launch segment. US leadership should come as no surprise. While the US has excellent basic conditions with a strong industrial base, extensive talent and continuous government support, the truly impactful innovation is how National Aeronautics and Space Administration (NASA) – as an extension of the US National Security State (NSS)[1] – handles the commercialisation of parts of its space activities. During the Cold War, the NSS could be understood as a technological enterprise that aimed to continuously mobilise the national science base to persist in a tense geopolitical struggle. Together with the traditional antistatism of the US political system,[2] a specific system emerged that strongly supported technological progress, while aiming for the commercialisation of this progress at the same time.

Consistent with US commercialisation of other technologies and entire industrial segments, NASA provides the US launch providers with "a ready market, problem sets, technical know-how, learning experience, and investment[…]".[3] Historically this enabled companies to develop both the necessary product and the confidence to take the first commercial steps.[4] Government funding is crucial in two ways here: First, to take on the high risk of early investments.[5] Second, it routinely funds stages of development for technologies before other actors are willing to do so.[6] Once spurring technological progress, commercialisation helped lower prices and, in turn, help actors in the NSS exploit advanced products for their ends. This cycle is

1. I define the US National Security State in accordance with Weiss (2014) "The NSS is a wholly new postwar creation that is geared to the permanent mobilization of the nations's science and technology resources for military primacy […]. Although centrered on defense preparedness, the NSS is a good deal broader than the military, yet narrower than the state as a whole." Crucial actors involved in space-related activities are included in this definition, first and foremost NASA. See L. Weiss, *America Inc.? – Innovation and Enterprise in the National Security State*, Ithaca/London: Cornell University Press, 2014, p.4.

2. Antistatism in this context means a political opposition to a strong concentration of economic control and planning in the hands of the state. Linda Weiss sees this characteristic of the US political system as the main driver of hybrid private-public organisational forms, which in turn have a unique way of supporting innovation and emerging markets. See L. Weiss, *America Inc.?, op. cit.*, p.7.

3. *Ibid.*, p. 81f.

4. *Ibid.*, p. 81f.

5. M. Mazzucato, *The Entrepreneurial State – Debunking Public vs. Private Sector Myths,* New York: Public Affairs, 2015, p.55.

6. *Ibid.*, p.66f.

now occurring in space services. This approach to commercialisation and innovation pursued by NASA is happening in a specific political and industrial context, which this paper will outline.

The Space Industry Revolution

Recent changes to the space sector are typically bifurcated into "old" and "new" space. Old space represents a largely state-centric sector with a limited commercial share, as well as limited tasks and missions in space. New space, on the other hand, essentially envisions the emergence of a state-independent market around space activities. This change intends to democratise and commercialise space but also supports its transformation into a domain that is congested, competitive and contested.[7] Yet while "New Space" seems to just stem from private and commercial initiative, much of it still depends on the state – the US NSS in particular – and its distinct policies that support the emergence of this new market.

From Old to New Space

The 20th century was the time of old space: State-funded military and scientific activities dominated the sector, with a limited role of private actors – largely defence companies – to provide the hardware to government agencies. Huge entry barriers to the sector due to high launch costs and complexity of satellites made commercial activity costly and limited it to communication for TV or satellite phones.

New space builds upon old space capabilities but incorporates two different streams of innovation: First, technological advances in launch systems and space assets. Second, new business models based on these technologies and lessons from other industries. Technological innovation is most notable in launch systems. Several innovations in production, management and use of launchers (re-usability) progressively reduce the cost of bringing assets into space.[8] The costs of bringing cargo to the ISS while using SpaceX's reusable Falcon 9 are about one-fourth of using NASA space shuttles.[9] US space companies use innovations in materials like printed carbon fibre instead of metals like aluminium[10] or 3D-print metal

7. R. G. Harrison, "Unpacking the Three C's: Congested, Competitive, and Contested Space", *Astropolitics*, Vol. 11, No. 3, 2013, 123-131.
8. H. W. Jones, "The Recent Large Reduction in Space Launch Cost", Conference Paper, 48th International Conference on Environmental Systems, 2018, last retrieved 08.09.2020 from: https://ttu-ir.tdl.org.
9. *Ibid*.
10. "Electron", Rocket Lab, 2018, last retrieved 08.09.2020 from: www.rocketlabusa.com.

parts to simplify designs and lower costs.[11] SpaceX has also shown how vertical integration can improve control over supply chains, and thus cost and reaction time for technical improvements.[12] Cheaper access to space reduces costs through economies of scale – a crucial mechanism for a future self-sustaining space economy.

Another trend that already enables more actors to send assets into space is the miniaturisation of satellites and the digitalisation of information. In the past 5-10 years, cheaper, miniaturised electronic components have made satellites accessible to private, state, commercial and educational actors.[13] Networks of small satellites are already providing daily earth observation at comparatively low cost.[14] In the future, such 'mega-constellations' could provide global internet access at lower prices than current satellite-based services.[15] Geographically limited initial beta service has already begun.[16] This potential designates constellations and the required launch industry and satellite manufacturing as critical actors for future infrastructure.

Business innovations (see Figure 1) in turn, use these technological advances to provide services for earthly economic activities. Less expensive, more capable space assets for earth observation can now serve a growing client base at a profit. Beyond earth observation and beginning with in-orbit re-supply and maintenance missions, future space applications listed in Figure 1 are the first signs of an emerging space-based economy.

11. M. Sheetz, "Space Start-Up Relativity Verified its 3D Printing Process Works to Build a Rocket", CNBC, 2019, last retrieved 08.09.2020 from: www.cnbc.com.

12. L. Grush, "This Was the Decade the Commercial Spaceflight Industry Leapt Forward", The Verge, 2019, last retrieved 08.09.2020 from: www.theverge.com.

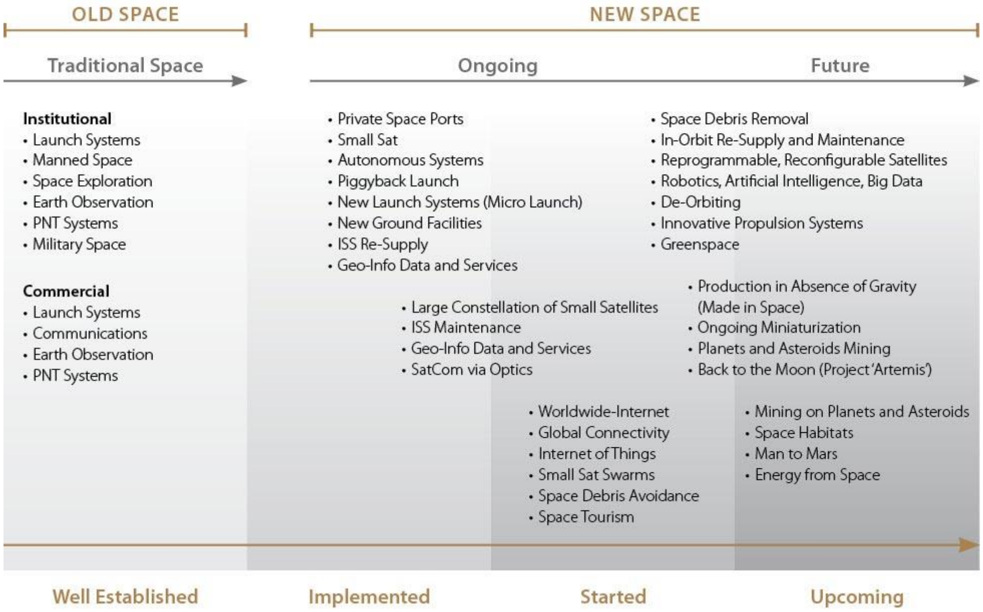
13. P. Lewis and D. Livingstone, "What to Know About Space Security", Chatham House, 2016, last retrieved 08.09.2020 from: www.chathamhouse.org.

14. "Using Space to Help Life on Earth", Planet Lab Inc., 2019, last retrieved 08.07.2020 from: www.planet.com.

15. J. Amos, "Satellite Mega-Constellation Production Begins", BBC, 2017, last retrieved 09.09.2020 from: www.bbc.com; M. Wall, "SpaceX's Prototype Internet Satellites Are Up and Running", Space.com, 2018, last retrieved 09.09.2020 from: www.space.com.

16. M. Sheetz, "SpaceX Prices Starlink Satellite Internet Service at $99 Per Month, According to E-Mail", CNBC, 2020, last retrieved 30.11.2020 from: www.cnbc.com.

Figure 1: Overview of Old and New Space[17]



Up- and down-stream innovations combined mark the revolutionary nature of the ongoing development in the space industry. Together, this vicious circle of private supply and demand for both launch services and space assets is an important element in the further commercialization of space. Nevertheless, this shall not disguise that in the early stage this commercialization is in today, state demand and policy remain the most important elements in the development of space.

Congested, Competitive and Contested

One result of the opening of space is that the domain itself becomes more congested, competitive, and contested. In addition to the fact that "new" space opens the sector to more actors and thus more traffic,[18] space also serves as a stage for earthly rivalries. Space powers – including the US, Russia, China and India – are developing and testing and fielding anti-satellite weapons, which contribute to the perception that space currently is a competitive and contested arena.[19] International space law, primarily in the form of the 1967 Outer Space Treaty (OST),[20] is unprepared to meet the

17. H. Grest, "New Space – Advantage or Threat for the Military?", Joint Air Power Competence Centre, 2019-2020, last retrieved 09.09.2020 from: www.japcc.org.
18. *Ibid.*
19. T. Schütz, "Technology and Strategy: The Changing Security Environment in Space Demands New Diplomatic and Military Answers", German Council on Foreign Relations, DGAP kompakt 14, 2019, p.3, last retrieved 10.09.2020 from: https://dgap.org.
20. "United Nations Treaties and Principles on Outer Space", New York: United Nations, 2002, p.3ff, last retrieved on 10.09.2020 from: www.unoosa.org.

changing circumstances as the international community conceived it for a different framework of actors, technologies and activities. This new environment challenges civilian regulation and military planning, from space traffic management for a surging number of satellites, to strategic strains on deterrence and defence in space.

The USA as a Space Power

Three features explain why the United States is the world's leading space power[21]: Its current space policy and associated goals, state-driven organisations, and the broader space-related industry and ecosystem. These features also constitute the foundations for US space commercialisation.

US Space Policy

The US perception that the geopolitical environment is changing/challenging is reflected in its space policy. This is consistent with the "old-space" precedent: just as geopolitics framed the cultivation of the NSS during the Cold War, great power competition motivates bipartisan support for a competitive commercial space industry today.

The Trump administration has sought to strengthen space as a key domain for US leadership and influence. The National Security Strategy sets the scene to bring military competition to space, including with a specific reference to deterring interference with critical US space infrastructure.[22] US space policy has subsequently been fleshed out in a range of documents, in particular the National Space Strategy and the Department of Defense (DoD) Defense Space Strategy. Other documents, such as NASA's Strategic Plan, and Presidential Space Policy Directives, are subject to the guidelines of the aforementioned strategies.

The National Space Strategy[23] underlines the close relationship between national security, commercial and civilian actors. It stresses the goal to "unshackle American industry" from regulation to enable more commercial and innovative activity.[24] Relatedly, the National Space Council

21. N. R. F. Al-Rodhan, *Meta-Geopolitics of Outer Space*, Basingstoke/New York: Palgrave Macmillan, 2012, p.112.
22. As formulated in the US National Security Strategy (2017): "The strategy affirms that any harmful interference with or attack upon critical components of our space architecture that directly affects this vital interest will be met with a deliberate response at a time, place, manner, and domain of our choosing." See "National Security Strategy of the United States of America", Washington, D.C.: The White House, 2017, p.31, last retrieved 10.09.2020 from: www.whitehouse.gov.
23. "President Donald J. Trump is Unveiling an America First National Space Strategy", Washington, D.C.: The White House, 2018, last retrieved 10.09.2020 from: www.whitehouse.gov.
24. M. Smith, "White House Releases Fact Sheet on New National Space Strategy – Updated", Spacepolicyonline.com, 2018, last retrieved 10.09.2020 from: https://spacepolicyonline.com.

has also underscored the importance of government contracts to create and mature a commercial space economy.[25]

In turn, the Defense Space Strategy guides DoD efforts to achieve "a secure, stable, and accessible space domain whose use by the United States and our allies and partners is underpinned by comprehensive, sustained military strength."[26] This strategy drew criticism for reviving the concept of space superiority, signalling an aggressive US stance that complicates international negotiations and détente with Russia and China.[27] In addition to the well-known Russian space and anti-satellite capabilities, Chinese strides, including crewed flight in 2003 and its ASAT test in 2007, worry Washington.[28]

Civilian agency regulations also show the same tendency towards encouragement of private actors. Two examples stand out here: First, the allocation of orbits via the Federal Aviation Administration and the controversies that followed the deployment of SpaceX's Starlink satellites and their effects on astronomical observations.[29] Second, NASA's Artemis Accords, which aim "to establish a common vision via a practical set of principles, guidelines, and best practices to enhance the governance of the civil exploration and use of outer space […]".[30] In them, NASA enshrined important incentives for private and state actors such as the legality of space mining and its accordance with existing international law, especially the Outer Space Treaty, even though this is still debated internationally.[31]

US Government Space Organisations

Of the vast NSS,[32] three actors are most relevant to US space commercialisation: the National Aeronautics and Space Agency (NASA), the US Space Force (USSF) and the Defense Advanced Research Projects Agency

25. "A New Era for Deep Space Exploration and Development", The White House National Space Council, 2020, p.6, last retrieved 10.09.2020 from: https://spacewatch.global.
26. "Defense Space Strategy Summary", US Department of Defense, 2020, p.1, last retrieved 10.09.2020 from: https://media.defense.gov.
27. See e.g. F. A. Rose, "The U.S. Defense Space Strategy Works on Paper, But Will It Be Implemented?", Brookings, 2020, last retrieved 10.09.2020 from: www.brookings.edu.
28. N. DeGrasse Tyson, "The Case for Space", *Foreign Affairs*, Vol. 91, No. 2, 2012, pp.22-24.
29. L. Grush, "The True Impact of SpaceX's Starlink Constaellation on Astronomy Is Coming into Focus", The Verge, 2020, last retrieved 29.11.2020 from: www.theverge.com.
30. "The Artemis Accords", NASA, 2020, p.2, last retrieved 29.11.2020 from: www.nasa.gov.
31. C. Newman, "Artemis Accords: Why Many Countries Are Refusing to Sign Moon Exploration Agreement", The Conversation, 2020, last retrieved 29.11.2020 from: https://theconversation.com.
32. "Other Space Agencies and Related Organizations", NASA, 2007, last retrieved 11.09.2020 from: www.nasa.gov.

(DARPA). Taken together, the US government is still by far the largest spender on space-related activities in the world.[33]

The NSS, particularly NASA, has three main motivations to encourage the commercialisation of space: First, commercialisation promises cheaper services. Second, commercialisation would provide a hedge against ever-shifting political priorities,[34] which tend to derail major projects with long runtimes. Commercialisation can also increase the agency's political independence, making it more difficult for politicians to tie funding with jobs in their districts.[35] Lastly, shifting "routine" tasks to the private industry might allow NASA to focus on tasks that are impossible to commercialise, like deep-space exploration.

The new USSF is interested in the military potential of ongoing commercial and civilian innovation, which are relevant to its responsibilities over space-related assets and training and equipping space forces. As the branch matures, it is expected to become more dominant in the NSS, especially for mega-constellations and related technologies[36] as well as rapid, reliable, and affordable access to space. In order to further spur commercial technological progress towards that end, DARPA challenges the industry to come up with innovations in the launch segment. One example is the "DARPA Launch Challenge", which aimed to "demonstrate responsive and flexible space launch capabilities",[37] crucial for a timely replacement of space assets losses, e.g. in a conflict. Even though the challenge ultimately failed with no contender reaching the agency's goals,[38] it certainly pushed the technological development within the companies, which are further pursuing their projects.[39]

Additionally, the US government also aims to reform its side of the deal and accelerate and change its own procurement structures and processes with regard to space. The DoD's Space Development Agency is a prime example for this move. Since its inception in 2019, it has worked at a breakneck pace in acquisitions for space assets, including work with new

33. S. Seomari, "Global Government Space Budgets Continues Multiyear Rebound", SpaceNews, 2019, last retrieved 11.09.2020 from: https://spacenews.com.

34. "It's Time to End Washington's Bad Habit of Changing NASA's Goals in Midstream", Scientific American, 2017, last retrieved 12.09.2020 from: www.scientificamerican.com.

35. E. Dourado, "The Space Launch System Is an Irredeemable Mistake", Medium.com, 2020, last retrieved 12.09.2020 from: https://medium.com.

36. Such as a mature mass production of satellites, command and control capabilities for large constellations, satellite buses (delivery hardware) and sensors to track such distributed assets in the future. – Remarks by a USSF official during an Online-Event on the US Space Force.

37. "DARPA Launch Challenge", darpalaunchchallenge.org, last retrieved 13.09.2020 from: www.darpalaunchchallenge.org.

38. "DARPA Launch Challenge Closes With No Winner", DARPA, 2020, www.darpa.mil.

39. K. Lyons, "Astra's First Attempt to Reach Orbit Ends Early After Rocket Fails in Mid-Flight", The Verge, 2020, last retrieved 13.09.2020 from: www.theverge.com.

industrial partners.[40] Here, organisational innovation from a space-related agency might impact other defence domains if they are transferred to other agencies, especially defence procurement agencies, which also operate in a fast-changing technological environment.

US Space Industrial Base

Given the historically strong position of the USA in space, both driven by the NSS and early commercial activities,[41] the leading role of the US space industrial base means it can develop, manufacture and operate launch vehicles and spacecraft across the whole range of performance classes (mini-launchers to heavy-launch), orbits and tasks (satellites for all kinds of missions to crewed spacecraft).

Besides traditional suppliers of the commercial and government market (typically large aerospace companies), the US space industry also features new private companies solely focused on space such as SpaceX and Blue Origin, respectively founded by Elon Musk and Jeff Bezos, and a host of start-ups, heavily funded by venture capital.[42] Beside fostering technological innovation in a competitive market, these relatively new entries also have positive second-order effects like introducing new management methods and talent streams into the space industrial base.[43]

The three largest companies of the US space industrial base and the primary system integrators emerged from the consolidation of the US aerospace and defence industry in the early 1990s: Boeing, Lockheed Martin, and Northrop Grumman.[44] Boeing and Lockheed Martin further own a joint venture, United Launch Alliance,[45] specialised on launches for the US NSS market.[46] Boeing and Northrop Grumman are also prime contractors for NASA's Space Launch System (SLS), the most ambitious ongoing development project of the agency.[47] These contractors very much

40. N. Strout, "Gotta Go Fast: How America's Space Development Agency Is Shaking Up Acquistions", C4ISRNET, 2020, last retrieved 29.11.2020 from: www.c4isrnet.com.
41. S. J.Butow, T. Cooley, E. Felt and Joel B. Mozer, "State of the Space Industrial Base 2020", 2020, p.9, last retrieved 15.09.2020 from: http://aerospace.csis.org.
42. "Start-Up Space – Update on Investment in Commercial Space Ventures", Bryce Space and Technology, 2020, p.VII, last retrieved 16.09.2020 from: https://brycetech.com.
43. "New Space – Geschäftsmodelle an der Schnittstelle von Raumfahrt und digitaler Wirtschaft", Bundesministerium für Wirtschaft und Energie, 2016, p.28, last retreived 15.09.2020 from: www.bmwi.de.
44. "Final Report of the Commission on the Future of the United States Aerospace Industry", US Congress, Commission on the Future of the United States Aerospace Industry, 2002, p.7-4 (p.134), last retrieved 12.09.2020 from: https://history.nasa.gov.
45. M. Smith, M. S. Allen and L. M. Delgado López, "Commercial Space Activities", Spacepolicyonline.com, 2020, last retrieved 13.09.2020 from: https://spacepolicyonline.com.
46. S. Erwin, "Boeing, Lockheed, ULA Corner the Government-funded Space Market. SpaceX Moving Up", SpaceNews.com, 2018, last retrieved 14.09.2020 from: https://spacenews.com.
47. "Space Launch System (SLS) Overview", NASA, 2020, last retrieved 15.09.2020 from: www.nasa.gov.

focus on the US domestic market and have no share in the global commercial launch market.[48] Together with Raytheon, another giant of the US defence sector, and Ball Aerospace these are also the primary provider for satellites for the US NSS.[49]

Beyond these "traditional" actors, new system integrators and launch providers entered the market or are aiming to do so, such as SpaceX, Blue Origin, Virgin Galactic or Rocket Lab. SpaceX certainly is the most notable as a vertically integrated company that develops, builds, and operates launch systems and spacecraft. Its innovative approach is in no small part responsible for the current drop in prices for assets to orbit.[50] In contrast to the traditional suppliers, SpaceX captures about 60% of the global addressable commercial heavy-lift launch market[51] and can boast participation in all of NASA's recent commercialisation initiatives, as well as the launch of several NSS missions onboard its vehicles.

While these successes have cemented SpaceX's status in the US space industry, other contenders worth mentioning have not yet reached this goal. Blue Origin and Virgin Galactic are still struggling to prove their ability to provide regular, repeated and reliable access to space. The NSS has also integrated other smaller players into the US space industry, such as the small-launch provider Rocket Lab. Originally a New Zealander company, Rocket Lab moved its registration to the US after receiving funding from the NSS, including the Central Intelligence Agency's In-Q-Tel venture capital fund.[52]

Beyond the system integrator level, a total number of upwards of 4,500[53] smaller companies comprise the US space industrial supply chain.[54] However, some 30% of the smaller suppliers face immediate risk due to COVID-19, broader problems in the aerospace industry or space industry

48. B. L. Triezenberg, C. Peyton Steiner, G. Johnson *et al.*, "Assessing the Impact of U.S. Air Force National Security Space Launch Acquisition Decisions", RAND, 2020, p.26, last retrieved 15.09.2020 from: www.rand.org.

49. "Top 10 Satellite Manufacturers in the Global Space Industry 2018", TechnavioBlog, 2018, last retrieved 15.09.2020 from: https://blog.technavio.com.

50. H. W. Jones, "The Recent Large Reduction in Space Launch Cost", Conference Paper, 48th International Conference on Environmental Systems, 2018, last retrieved 08.09.2020 from: https://ttu-ir.tdl.org.

51. B. L. Triezenberg, C. Peyton Steiner, G. Johnson *et al.*, "Assessing the Impact of U.S. Air Force National Security Space Launch Acquisition Decisions", *op. cit.*

52. O. Neas, "What Lies Inside Rocket Lab's Secret US Military Contracts?", The Spinoff, 2018, last retrieved 15.09.2020 from: https://thespinoff.co.nz.

53. S. J. Butow, T. Cooley, E. Felt and Joel B. Mozer, "State of the Space Industrial Base 2020", *op. cit.*, p.72.

54. For an overview of the Supply Chain Tiers and respective products see *Annual Report to Congress - Industrial Capabilities*, Department of Defense, 2018, p.60, last retrieved 15.09.2020 from: www.businessdefense.gov.

developments like the bankruptcy of OneWeb.[55] Their loss might lead to delays and a general loss in some industrial capabilities but will impact different sectors of the industry differently.[56]

In 2019, start-up space ventures received a record-breaking 5.7 bn USD in private funding.[57] However, this influx of capital was quite concentrated with SpaceX, Blue Origin, OneWeb, and Virgin Galactic receiving nearly 70% of the invested money.[58] Accordingly, it comes as no surprise that over 80% of the total investments went to US companies.[59] Not only are large companies favoured by venture capital, but it is also very much concentrated in the launch market, which requires massive investment, and is critical to future cheaper and easier access to space.

Beyond money, new companies also bring new management styles and personnel into the industry, to which some observers attribute their success.[60] For personnel, the start-up nature of some of these companies is likely to lead to a high fluctuation and turn-over of talent, which might help to build networks and spread ideas, knowledge and best practices. Other newly introduced business philosophy elements include: a focus on the product and service, visionary goals, attractive location, personnel management and attractiveness for high skilled talent, cost orientation, disruption of the status quo and the symbiosis of information technology and space.[61]

55. S. J. Butow, T. Cooley, E. Felt and Joel B. Mozer, "State of the Space Industrial Base 2020", *op. cit.*, p.72.
56. L. Scatteia and Y. Perrot, "Resilience of the Space Sector to the COVID-19 Crisis", PricewaterhouseCoopers, 2020, p.3, last retrieved 15.09.2020 from: www.pwc.fr.
57. "Start-Up Space – Update on Investment in Commercial Space Ventures", Bryce Space and Technology, 2020, p.11, last retrieved 16.09.2020 from: https://brycetech.com.
58. *Ibid.*, p.11.
59. *Ibid.*, p.13.
60. "New Space – Geschäftsmodelle an der Schnittstelle von Raumfahrt und digitaler Wirtschaft", Bundesministerium für Wirtschaft und Energie, 2016, p.24ff, last retreived 15.09.2020 from www.bmwi.de.
61. *Ibid.*

Commercialization as an Innovation

Since the end of the Second World War, the US has pioneered several transformative advanced and high-tech industries and technologies that since have had revolutionary impacts on economies and lives. While there is a prevalent notion that private capital, especially risk-seeking venture capital (VC), is responsible for supporting risky but potentially valuable endeavours, recent research highlights the role of the state, and the NSS in particular, in enabling these innovations.[62] Today, NASA encourages companies to commercialise their services to support the emergence of a self-sustaining space economy. From such an economy, both NASA and the USSF can expect to reap the benefits in various fields, such as cheaper and more reliable access to space, innovations in mega-constellations, materials science or in-situ resource utilisation. It builds upon two prerequisites: a capable space industrial base, described above, and a specific US approach to commercialisation and innovation, described here.

A Specific US Approach to Technological Innovation and Commercialization

According to Weiss, three distinct drivers continue to shape significant parts of the US innovation ecosystem: the NSS as a technological enterprise, geopolitical drivers, and US political antistatism.[63]

Through its NSS, the US government gears its agencies and institutions toward permanent mobilisation of the scientific base. In US strategic culture, the resulting technological superiority translates to military superiority.[64] Historically, the US has a propensity towards technology as an instrument to solve problems.[65] This was reinforced by the victory in World

62. L. Weiss, *America Inc.?, op. cit.* and M. Mazzucato, *The Entrepreneurial State, op. cit.* are prime examples of this trend. Others include the work of e.g. M. O'Mara, *The Code – Silicon Valley and the Remaking of America,* New York: Penguin Books, 2019.

63. See e.g. L. Weiss, *America Inc.?, op. cit.*, p.4ff or M. Mazzucato, *The Entrepreneurial State, op. cit.,* p.80ff.

64. D. Adamsky, *The Culture of Military Innovation*, Stanford, California: Stanford University Press, 2010, p.75ff.

65. B. F. Harris, *America, Technology and Strategic Culture – A Clausewitzian Assessment*, Abingdon/New York: Routledge, 2009, p.74ff.

War II, which is to a good part attributed to technological feats like the atomic bomb.[66] As space is inherently a domain of technology, it is no surprise that the US strives to retain its superiority there.

The Cold War-creation of the NSS was driven by the geopolitical rivalry with the Soviet Union, especially after the Soviets launched the first satellite, which led the US to create both the respective precursors of DARPA and NASA.[67] The Sputnik shock also led to a massive increase in federal research and development (R&D) funding for security-related projects as well as a centralisation of technology development, at least in the military realm.[68] Today, the US sees itself in another great-power competition,[69] which arrived in space years ago, at the latest with the successful Chinese ASAT test in 2007.[70] With space being a congested, competitive and contested domain, the US sees a need for technological advances in this field, both to gain international prestige, as well as for civilian and military purposes.

Lastly, US antistatism led to the emergence of a complicated web of hybrid organisations that merge private and public resources.[71] Publicly funded venture capital funds (VCF), like the above mentioned In-Q-Tel, are one example for such organisations. NASA, for example, supports the successful[72] the Small Business Innovation Research Programme (SBIR)[73] as well as the mixed VCF Red Planet Capital which invests directly into promising companies.[74]

Historically, the NSS has provided US companies with a "ready market, problem sets, technical know-how, learning experience, and investment".[75] This enabled companies to develop both the product and the confidence to take the first commercial steps.[76] Creating a market for products that did not exist before still has several advantages: First, it stimulates national economic development. Second, it advances technological progress and in turn, military advantage if the technology is utilised effectively in combination with operational concepts and organisational innovation.[77]

66. T. G. Mahnken, *Technology and the American Way of War Since 1945*, New York: Columbia University Press, 2008, p.2-5.
67. L. Weiss, *America Inc.?, op. cit.*, p.32f.
68. *Ibid.*
69. US 2017 National Security Strategy.
70. B. Weeden and V. Samson, "Global Counterspace Capabilities: An Open Source Assessment", Secure World Foundation, 2019, p.1-14 (p.31), last retrieved 11.09.2020 from: https://swfound.org.
71. L. Weiss, *America Inc.?, op. cit.*, p.7.
72. M. Mazzucato, *The Entrepreneurial State, op. cit*, p.86.
73. L. Weiss, *America Inc.?, op. cit.*, p.62.
74. *Ibid.*, p.69.
75. *Ibid.*, p. 81f.
76. *Ibid.*, p.80ff.
77. See e.g. M. C. Horowitz, *The Diffusion of Military Power*, Princeton: Princeton University Press, 2010, p.22f.

Third, economies of scale and learning help improve product performance and reliability over time while decreasing cost.

NASA Commercialization Efforts

From its inception in 1958, NASA used private companies to develop and produce launch vehicles and spacecraft, albeit under strict oversight from NASA.[78] When delivered, these vehicles transferred into NASA's ownership, which then was responsible for the missions.[79] The years between 2003 and 2005 proved decisive in changing this pattern: the loss of Space Shuttle Columbia in February 2003 lead to a new US Exploration Policy which in turn directed NASA to acquire cargo transportation to the ISS. The NASA Authorization Act of 2005 further directed NASA to develop a commercialisation plan.[80] Underscoring principles of this initiative were limited government investment, "buy a ticket, not a vehicle", performance-based fixed-price milestones and a non-contract approach.[81] Limited funding, dysfunctional legacy programmes and looming capability gaps led the agency in this new direction.

In the following years, NASA launched a series of programmes that mimicked the historical NSS approach to commercialisation and provided and provide the US space industry with a ready market (fixed demand through missions), problem sets, technical know-how (knowledge transfer from government agencies or laboratories), learning experience (new tasks for companies/endowed learning environment), and investment (technology procurement). Four programmes[82] make up NASA's commercialisation approach, beginning with the commercial cargo program and ending with the next human lander for NASA's crewed Moon missions.

For the Commercial Cargo programme, the chosen companies provided more than 50% of the development costs to their respective transport systems, with an additional NASA investment of 500 (later 700) Mio. USD.[83] NASA awarded fixed-price contracts for the delivery of cargo to the ISS. These contracts did not feature strict technical requirements, but rather specific services the contractors shall perform, e.g. to deliver a certain amount of cargo to the ISS. The fixed-price nature of the contracts and the

78. "Commercial Orbital Transportation Services", NASA, 2014, p.2, last retrieved 11.09.2020 from: www.nasa.gov.
79. *Ibid.*
80. *Ibid.*, p.8.
81. *Ibid.*, p.11f.
82. Information on the newest fifth programme for the collection of Lunar regolith is too few to assess effectively here.
83. Congress later increased this sum to 700 Mio. USD after the "Human Spaceflight Review of U.S. Plans Committee" put its weight behind commercialization as an effective and efficient way forward.

fact that the companies would retain their Intellectual Property Rights (IPR) were deviations from former NASA practices. Moreover, NASA focused more on certification requirements of spacecraft and cargo instead of on extensive risk management and technical oversight.[84] In the ongoing programme, the commercial companies can transport cargo to the ISS 2-3 times cheaper than the agency could have done with traditional approaches like the Space Shuttles.[85]

Compared to the Commercial Cargo program, the Commercial Crew program was riskier as the technological complexity of crewed spaceflight is considerably higher, and there are fewer alternatives to bring astronauts to the ISS – only the Russian Soyuz. This meant a reduced autonomy in space for the US. Between the shuttle retirement in 2011 and 2019, NASA paid the Russian space agency ROSCOSMOS about 3.9 bn USD for the transport of astronauts to the ISS.[86] NASA aims to use the Commercial Crew program to foster an industry to meet its needs as well as to spur a commercial market for crewed LEO flights, thus eliminating the dependency on Russia.[87] In 2014, NASA awarded firm-fixed-price contracts to Boeing (4.3 bn USD) and SpaceX (2.5 bn USD) for six crewed missions to the ISS each.[88] Some parameters remained the same as for Commercial Cargo, such as companies retaining IPR and certification remaining a core NASA responsibility.

That said, technical oversight is stricter.[89] As the crew program puts astronauts' lives on the line, NASA has an additional budget to request further tests from the companies. Technical hurdles delayed the programme by about three years.[90] In May 2020, SpaceX successfully performed its final crewed demonstration flight (Demo-2) and conducted the first regular flight – Crew 1 – on November 16th.[91] Boeing seeks to conduct a second uncrewed demonstration flight to the ISS later this year, as the first launch did not match its mission objectives and had to be aborted.[92] Despite the delay in the program, it is celebrated as a success and audits put at least the SpaceX

84. "Audit of Commercial Resupply Services to the International Space Station", NASA Office of Inspector General/Office of Audits, 2018, p.5ff, last retrieved 12.09.2020 from: https://oig.nasa.gov.
85. E. Zapata, "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions", AIAA Space 2017 Conference, 2017, p.8, last retrieved 16.09.2020 from: https://ntrs.nasa.gov.
86. *Ibid.*, p.1.
87. *Ibid.*, p.1.
88. *Ibid.*, p.4.
89. "NASA's Management of Crew Transportation to the International Space Station", NASA Office of Inspector General/Office of Audits, 2019, p.14, last retrieved 12.09.2020 from: https://oig.nasa.gov.
90. *Ibid.*, p.4.
91. *Crew-1 Mission*, SpaceX, last retrieved 30.11.2020 from: www.spacex.com.
92. L. Grush, "Boeing Will Refly Its Passenger Spaceraft for NASA Without Crew after Flubbed Debut Launch", The Verge, 2020, last retrieved 13.09.2020 from: www.theverge.com.

service at a lower price than the procurement of additional Soyuz seats.[93] SpaceX successfully managed crewed spaceflight, a feat only achieved by the US, the Soviet Union/Russia and China. Yet this would not have been possible without NASA's support through the Commercial Crew programme.

NASA chose to continue its commercialisation approach as tested with Commercial Cargo and Crew for its next step: the return to the Moon. Consequently, the Commercial Lunar Payload Services (CLPS) initiative aims to enable NASA to acquire lunar delivery services from US space companies.[94] CLPS missions require the 14 selected companies to conduct the whole mission, from payload integration to landing on the Moon. Furthermore, companies are actively encouraged to fly commercial payloads in addition to NASA payloads.[95] In terms of contact volume, CLPS enables infinite fixed-price[96] contracts (deliveries) until the maximum contract value of 2.6 bn USD is used up, starting in 2021.[97]

The latest commercial program from NASA is the Artemis Human Lander programme, under which it invited private companies to design and offer their crewed spacecraft for the return of humans to the Moon. Three companies were selected to develop landers that will land humans starting in 2024. NASA directly links this programme to its predecessors, and their success and NASA explicitly hopes to be only one customer among others.[98] Stimulating such commercial activities then supports the emergence of a market and the related innovation, ready to be utilised by the NSS. The first contracts have a volume of 967 Mio. USD for the first 10-month period and are firm-fixed-price and milestone-based.[99] Until February 2021, the companies will refine their lander concepts while NASA will evaluate them, to select later those who will perform the first demonstration missions.[100]

Table 1 shows how the programmes fit into the NSS' traditional commercialisation pattern: In three of four programmes, NASA provided the industry with a ready market, often planning for multiple mission or a

93. "NASA's Management of Crew Transportation to the International Space Station", NASA Office of Inspector General/Office of Audits, 2019, p.4, last retrieved 12.09.2020 from: https://oig.nasa.gov.

94. *Commercial Lunar Payload Services Overview,* NASA, 2020, last retrieved 14.09.2020 from: www.nasa.gov.

95. *Ibid.*

96. *CLPS On-Ramp Industry Day Pre-Proposal Conference Presentation,* NASA, 2019, p.38, last retrieved 16.09.2020 from: https://beta.sam.gov.

97. *Commercial Lunar Payload Services Overview,* NASA, 2020, last retrieved 14.09.2020 from: www.nasa.gov.

98. *NASA Selects Blue Origin, Dynetics, SpaceX for Artemis Human Landers,* NASA, 2020, last retrieved 14.09.2020 from: www.nasa.gov.

99. *NASA Names Companies to Develop Human Landers for Artemis Moon Missions,* NASA, 2020, last retrieved 15.09.2020 from: www.nasa.gov.

100. *Ibid.*

set market volume, even if no competitor had yet proved to be able to perform the mission. In all programmes, the companies would have to manage progressively complex and new mission types. Hence, problem sets from development to actual execution of the missions were provided. Moreover, NASA allowed for learning experiences as contracts would continue even in the face of difficulties. NASA also supported the industry with technical know-how, if not directly, then with extensive certification processes in which the technical products of the industry held against NASA standards and subsequently improved upon. Lastly, NASA provided direct investment, e.g. into the development and testing of new vehicles for Commercial Cargo, Commercial Crew and the crewed Moon lander.

Table 1: Overview of current NASA Commercial Programs and how they fit the traditional NSS Commercialisation Approach

Commercial Programme	Ready Market	Problem Set	Technical Know-How	Learning Experience	Investment
Commercial Cargo	Yes, 20 missions to ISS	Yes, no rocket, nor capsule, of the contenders had flown at the time	Likely, NASA certification oversight	Yes, increased level of technical complexity (e.g. unpressurised to pressurised goods)	Yes, NASA paid just shy of half the development costs of companies
Commercial Crew	Yes, twelve missions to ISS	Yes, achieved the difficult feat of crewed spaceflight	Likely, NASA certification oversight	Yes, close NASA safety oversight resulted in direct improvement, e.g. capsule parachutes	Yes, at least 6.8 bn USD to Boeing and SpaceX, some millions more to other contenders in early contest phases
Commercial Lunar Payload	Yes, fixed market set at 2.6 bn USD	Yes, execution of complete mission from payload integration to Moon landing	Likely, NASA certification oversight	Unknown – no missions were flown yet	Yes, NASA investing into the companies before any missions have been flown
Artemis Human Lander	No, only lander development. Likely that future landing services will see a ready market	Yes – development of crewedMoon lander	Yes, NASA sending personnel to companies	Unknown – no missions were flown yet	Yes, investment of nearly 1 bn USD into the three selected companies and their designs

Source: Author's assessment.

The US NSS and the Space Industry: From Hardware to Service

It is no surprise that it is the US space industry that is leading the current "new space" revolution. While the US has excellent basic conditions with a strong industrial base, extensive talent and continuous government support, the truly impactful innovation is how NASA – as an extension of the NSS – handles the commercialisation of parts of its traditional space activities. Now, all parts of the US NSS can reap the benefits of this process – so far primarily technological innovation – and hope for further and accelerated progress if a self-sustaining market in the cis-lunar space does emerge over the coming years and decades. Moreover, the first-mover advantages the US enjoys not only touches on technological progress but also extends to increased leverage when it comes to "setting the rules" and claim valuable and scarce resources like orbits (e.g. for mega-constellations) or real resources (e.g. on the Moon through the Artemis Accords).

A tense geopolitical situation is contributing to the US government's ambitions to retain its primacy in space.[101] Great-power competition and the growing importance of space assets for all kinds of military capabilities and operations as well as economic wealth make space an essential domain of this competition. As the world's primary space power, which, at the same time, is most dependent on its space assets, and with the current administration's focus on "America first", it is only logical for the US to seek military supremacy in space. In line with deeply rooted cultural predispositions and the genuine technical nature of space as a domain, technological progress and technological supremacy are the US' preferred path to retain its lead in space. While the space policy of President- elect Joe Biden is not clear as of now, it is likely that his administration will also recognize the importance of space as a domain. However, observers expect it to shift NASA's more towards helping humanity in its fight against climate

101. Vice President Pence called it a new space race in a speech last year: "Now, make no mistake about it: We're in a space race today, just as we were in the 1960s, and the stakes are even higher." See "Remarks by Vice President Pence at the Fifth Meeting of the National Space Council", Huntsville, AL: The White House, 2019, last retrieved 15.09.2020 from: www.whitehouse.gov.

change rather than pushing for extremely ambitious timetable for human exploration of Moon and Mars.[102]

Beside the cultural predisposition towards technology in the USA, a second deeply rooted cultural element of US politics comes into play: antistatism. Not only a preference for small government[103] but a general belief in the private sector and its superior capabilities. Notably, NASA's Commercial Cargo and Commercial Crew programmes survived three administrations (Bush, Obama, Trump) without significant changes and are likely to do so with the next administration.[104] In contrast, other programmes in the agency like SLS and its precursors underwent massive shifts in funding, structure, and goals. For NASA in the early 2000s, limited funding, a dysfunctional procurement in legacy projects, and capability gaps with the end of the Shuttle era also supported its adoption of commercialisation schemes.

Given the success of ongoing commercialisation efforts as well as the likely continuity of the geopolitically challenging environment and the national US context (NSS and antistatism), it is likely that future administrations will uphold these programmes and their approach. In the future, this development will likely provide the US NSS with new and more advanced, more reliable, and cheaper space technologies, products, and services. However, a more problematic part of this success story is, that the US – at least under the current administration – is likely to retain a close national lid on this development. As technonationalism[105] is the talk of the town for vital industries on the technological edge and with military and economic relevance, the US NSS will likely try to retain companies in the US and lure more companies from around the world to the US – as in the case of Rocket Lab and some German start-ups.[106]

The US space commercialization in its current form has economic, technological, political, and strategic consequences for Europe. Economically, the displacement of European launch providers in the addressable launch market by SpaceX will increase costs and change the economics of existing and future Europeans launchers (Ariane 5 & 6, Vega).

102. J. Feldscher, "Biden's Space Policy: One Giant Leap for Climate Change", Politico, 2020, last retrieved 29.11.2020 from: www.politico.com.

103. L. Weiss, *America Inc.?, op. cit.*, p.7.

104. J. Kluger, "As a Candidate, Biden Said Little About Space. Here's What He Might Do as President", TIME, 2020, last retrieved 29.11.2020 from: https://time.com.

105. Defined as: "Technonationalism is a set of mercantilist-like policies that link tech innovation and enterprise directly to the nationale security policies, economic prosperity and social stability of a nation." See A. Capri, "Semiconductors at the Heart of the US-China Tech War", Hinrich Foundation, 2020, last retrieved 15.09.2020 from: https://research.hinrichfoundation.com.

106. T. Stölzel, "Ruf des Geldes – Wie CIA, US-Militär und Nasa deutsche Start-ups in die USA locken", WirtschaftsWoche, 2020, last retrieved 15.09.2020 from: www.wiwo.de.

Technologically and politically, this increases costs to reach unity on future European space policy and projects amongst European governments. In the worst case, diverging views on the acceptable price for a dedicated European launch system and thus independent access to space as well as other issues, e.g. on the exploitation of space resources, risks a renationalization of European space policies. Moreover, both an attractive US market as well as the flexible financing instruments of state-funded VCs could draw innovative companies and talent away from Europe. Strategically, the question for Europe is whether it regards space and adjunct technologies as a critical to its sovereignty/autonomy. If the answer to this question is yes, it would be advisable, in a further step, to identify lessons from the example examined here and adapt them to European space policy and industry.