ESPI

European Space Policy Institute

Full Report

Evolution of the Role of Space Agencies

Report:
Title: "ESPI Report 70 - Evolution of the Role of Space Agencies - Full Report"
Published: October 2019
ISSN: 2218-0931 (print) • 2076-6688 (online)

Editor and publisher:
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Design: copylot.at

Cover page picture credit: NASA

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1 INTRODUCTION

1.1 Background

In the first 60 years of global space activity, national governments played the principal role in driving the majority of space ventures. Supporting the public agenda on space, the private sector under this model acted as contractors for public programmes, thus owing its early and continued existence on the availability of public funding. For the past decade, various trends show a growing involvement, and types of involvement, from the private sector in an expanding range of space-related initiatives and programmes. Taking place at a time when technologies are becoming more affordable and easier to develop, and together with more business-oriented political leadership and a favourable financial landscape, these developments are giving way to an increasingly prominent role for commercial actors in the space sector. It is therefore clear that the increasing involvement of commercial companies in public programmes and a change in the nature of the public/private sector relationship, presents a paradigm shift that is becoming an ever-greater focus of consideration for governments and space agencies.

The growing opportunity for new and emerging space actors to make wider and more significant contributions to the space sector is most referred to as the so-called "New Space" dynamic. While a clear definition of this dynamic is difficult to come by, New Space has been described as "*a disruptive sectorial dynamic featuring various end-to-end efficiency-driven concepts driving the space sector towards a more business- and service-oriented step*".[1] In this emerging ecosystem, it has been noted that the future of this dynamic will also be highly dependent on the implementation and success of new public strategies. Indeed, most agencies have started, or are continuing, to adapt their strategy, approaches and ways of interacting with the private sector to match and foster the emergence of private endeavours, building new types of partnerships and – to a certain extent – readjusting their role. One of the most relevant features, amongst a number of other demarcations, is that this new ecosystem enables the sharing of both costs and risks between the private and public sectors, thus possibly reducing the financial burden for the public actor.

This emerging approach is so far most evident in the U.S. Since NASA's foundation in 1958, the Agency has "*focused on government-owned and -operated space missions. Throughout the Mercury, Gemini, Apollo, and Space Shuttle programmes, the space agency hired private contractors to develop launch vehicles and spacecraft*".[2] In this regard, industry was involved in NASA programmes almost exclusively as contractors through cost-plus contracts "*based upon the actual cost of production and any agreed upon rates of profit or fees*".[3]

However, at the turn of the century, the replacement of the Space Shuttle provided an opportunity for NASA to explore new mechanisms building on various prior initiatives resulting from the agency and industry effort to proactively seek alternatives to traditional public-private relations, including but not limited to new contracting schemes and new procurement approaches. Indeed, in recent years, U.S. public policies and NASA have supported the development of public-private partnership schemes as a strategy to achieve cost-effective means for cargo and crew access to the ISS under cost-sharing contractual arrangements, using the milestone payment-driven Space Act Agreements (SAAa). In 2005, the

1 Vernile, A. "The Rise of Private Actors in the Space Sector". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2018.
2 "Orbital Transportation Services: A New Era in Spaceflight". Lyndon B. Johnson Space Centre Staff.
3 Meehan, Colette L. "Fixed Price vs. Cost Plus". Chron Magazine. Web: http://smallbusiness.chron.com/fixed-price-vs-cost-plus-2220.html.

establishment of the NASA Commercial Crew & Cargo Program Office (C3PO) resulted in two key programmes that would provide a national private sector capability to transport cargo and crew to the ISS.

Such a tangible shift in U.S. space policy is nowadays leading towards a rich and new innovation ecosystem, with increased engagement with private actors, thereby changing "*NASA's role from one of orchestrating/directing, to a more facilitating one driven by commercialization needs*".[4] These new U.S. policies have thus far contributed to the offering of some more affordable and accessible space programmes, but moving away from a traditional public procurement framework and getting access to space related services on much cheaper terms involves more ambitious PPP schemes. For this reason, the risk sharing approach pursued by private actors such as SpaceX, Blue Origin, Orbital ATK, etc. is based on the assumption of long-term government commitments that will enable them to come up with an optimized offer for commercial customers. This is intended to create the conditions to enter into a loop-favouring take up by private markets. With its new procurement approach, NASA has shifted design and delivery onto the private sector, and through this shift from the traditional cost-plus system procurement process, the agency has facilitated the development of commercial space capabilities, benefiting both from cost-sharing and innovative commercial system development practices. For these reasons, the U.S. appears to be at the forefront of New Space, as the vast majority of such new endeavours are being led today by American companies.

With regard to Europe, it must be noted that the continent certainly showcases a string of successes with regard to commercial space. Since the late 70s, a number of private European companies have achieved success in exploring the potential of commercial space. For example, Arianespace, founded in 1980, was the world's first private space launch operator, and SPOT Image, founded in 1982, was the first commercial operator and dealer for space imagery. Likewise, the satellite communication company SES started its activities in 1985, to become today one of the major TLC players on the global scene. On top of these (and other) success stories, European space agencies and relevant institutions have continued to engage in an increasing number of ambitious commercial incentives and PPPs in different fields, for example, the ARTES programme, TerraSAR-X, RapidEye and the Hylas project, among many more.

While a direct comparison between the U.S. and European space sectors and their modus operandi is obviously not applicable, owing to inherent differences between the two models, it can be argued that the European space sector is also experiencing a period of similar transformation. In light of this, new opportunities are being developed to create and stimulate new forms of public and private collaboration. Indeed, the European Space Agency (ESA) and other national space agencies are already making significant steps in this direction to foster entrepreneurship and/or leverage a more prominent role for private actors in space programmes.

In 2016, at the ESA Ministerial Council in Lucerne, ESA Member States allocated €10.3 billion for space programmes based on the vision of a "United Space in Europe in the era of Space 4.0". In this emerging ecosystem, and as an analogue to the concept of Industry 4.0, Space 4.0 represents "*the evolution of the space sector into a new era, characterized by a new playing field*".[5] More specifically, "Space 4.0i", describes the way ESA is aiming to play its role as a space agency for Europe in the future: the concept combines the global situation of space developments with the 'i' standing for an ESA-specific interpretation of such tasks, encompassing four actions: innovation, information, inspiration and interaction.[6] The Agency aims to realise these actions through more disruptive and risk-taking

4 Mazzucato, Mariana and Robinson, Douglas K. R. "Market Creation and the European Space Agency". Web: http://esamultimedia.esa.int/docs/business_with_esa/Mazzucato_Robinson_Market_creation_and_ESA.pdf
5 ESA Press Release: "N° 42–2016: Media Backgrounder: ESA'S Ministerial 2016 in Lucerne". Web: http://www.esa.int/For_Media/Press_Releases/Media_backgrounder_ESA_s_Ministerial_2016_in_Lucerne
6 See: ESA Space 4.0i. Web: http://www.esa.int/About_Us/Ministerial_Council_2016/Space_4.0i

technologies; through the reinforcement of the link with large public and user communities; through the launch of new initiatives and programmes, both current and future, and through enhanced partnerships with member states, European institutions, international players and industrial partners.[7]

Ultimately, it can be argued that the various policies that were introduced in the early 2000s to foster the development of a stronger and self-sustaining commercial space sector have achieved their objective, particularly in the U.S. Subsequently, public space agencies have been facing the programmatic opportunities and strategic challenges in this evolved context, and are acknowledging the need to further adapt their approaches to continue to optimally fulfil their mandates.

1.2 Rationale

Against this background, this research aims to investigate the customer-provider relationship between space agencies and the private sector, in particular by:

- Analysing the historical mandate, role and models of selected space agencies, identifying core tasks and responsibilities, and describing typical mechanisms of interaction with the private sector;
- Outlining the characteristics of the New Space dynamic and Space 4.0 concept for the evolving "spacescape" of the 2010s;
- Highlighting emerging models and approaches between space agencies and private entities; identifying the merits and limits of such models of interaction and their applicability in the spectrum of space activities;
- Elaborating on how space agencies in the European context could benefit from the sectoral evolution by revisiting and possibly expanding their traditional roles.

Regarding methodology, this study has been mainly carried out through desk research of publicly available documents, external and internal databases, conference proceedings and other bibliographic sources, spanning both sectorial and general contributions. The research has been complemented and strengthened by a number of targeted interviews, conducted under Chatham House Rules, with heads of space agencies, high-level officials and stakeholders, experts and other representatives of the European institutional as well as private space sector, in order to gain insights and corroborate research findings.[8]

1.3 Structure

This report is structured as follows.

Subsequent to an introductory chapter detailing background, rationale and structure of the research, Chapter 2 provides a brief overview and history of Space Agencies' roles, mandates and models. The spotlight is put on NASA, as an example of a prominent national space agency, and ESA, representing the successful model of an intergovernmental space agency. Furthermore, a description of three more national space agencies is given: ISRO, DLR and UKSA, each one representing respectively a so-called "end-to-end" space agency model, an R&D + Operations agency, and lastly a "commercially-oriented" model. The chapter identifies and summarises the core, or key tasks pertaining to most worldwide space agencies, namely: the elaboration of a space policy, its implementation, and country- or regional-wide representation in relevant international fora. The third section discusses and details the mechanisms of interaction of space agencies with the private sector, in order to fulfil their missions and objectives. A

7 Ibid.

8 The authors are grateful to representatives of ESA, CNES, ASI, DLR, the French government, Airbus Defence and Space, Arianespace, ArianeGroup, who agreed to be interviewed under Chatham House Rules for this research. The authors are furthermore grateful to the experts from space agencies, institutions and industry who kindly reviewed the final report in their personal capacities providing appreciated feedback.

description of traditional public procurement and public-private partnerships models is provided. Finally, the chapter concludes by highlighting the role of space agencies in market creation. In particular, it provides a case study of ESA and the role it had in the creation and development of separate and dedicate entities (public or private), each dealing with specific segments of the whole spectrum of space activities.

Chapter 3 focuses on the unfolding trends and emerging approaches in the public / private space sector ecosystem. It initially provides a description and discussion of the so-called New Space dynamic – as well as the broader concept of Space 4.0 as presented by ESA. The chapter then analyses the emerging models of interaction between space agencies and the private sector both in the United States and in Europe. In the U.S., the focus is put on the shift of paradigm established by NASA vis-à-vis the space transportation programme, within the overarching long-term goal of enabling a broad, private sector commercialisation of the LEO activities. As for Europe, attention is devoted to the initiatives and approaches put in place by ESA, in particular following the decisions undertaken at the CM/14 and CM/16 with regard to Space 4.0 and the evolving relationship with the industry. Some examples related to innovative partnerships and roles are provided, in particular regarding space transportation, space exploration and telecommunications. The chapter then includes a brief overview of the most recent developments across the European institutional space landscape, in particular the proposals put forward by the European Commission with regard to the European Union Agency Space Programme, as related to the discussion on the next Multiannual Financial Framework (MFF). Lastly, as the third element of the so-called "European space triangle", this section concludes by putting the spotlight on new European national space agencies and their relation to the on-going commercial dynamic.

Chapter 4 presents a qualitative assessment of both traditional procurement and public-private partnerships models in the space sector. The chapter in particular discusses and analyses the merits and limits of both approaches, as well as the conditions of applicability.

Chapter 5 elaborates on how space agencies in the European context could reassess the public-private interaction for the development and conduct of space programmes, and enhance their role. In particular, and concluding the study, it provides recommendations for European agencies to rethink their long-standing customer-provider relationship with industry, in this era of the increasing commercialisation of space.

2 A Brief History of Space Agencies: Roles, Mandates, Models

2.1 Historical Overview

To most, the origins of the space sector lie firmly in the initial technological accomplishments stoked by the political tensions of the Cold War, signposted by the launch of the Soviet satellite Sputnik I in October 1957, and soon followed by America's Explorer I in January 1958. Sputnik's launch marks the beginning of the Space Race and "*starkly accentuated the relationship between national identity and technology*", creating a space-fronted "*symbolism of politics and technology*".[9, 10] Sputnik's success and its subsequent psychological impacts placed the U.S. in a scramble to catch up as "*a crisis of confidence washed over most of American society, an anxiety that was dependent on an intrinsic equation between modern America and science and technology*".[11]

The Space Race had begun, and national, ideological and military competition would initially characterise the space sector for nearly two decades. The grand products of this industry during the Cold War period, culminating in the 1969 Apollo Moon landing, were indeed propagated as national and ideological (not just technical) achievements of their nation states. Space technologies did not only resonate in the culture and the imagination of the populace, but served to symbolise the power of the two world leading ideologies, becoming a "metric of modernity", a "measure of men", a means of domination and deterrence.[12] Scratch below the surface, albeit not very deep, and the dual nature of this technology is revealed: on one side a glimpse of human ingenuity for the benefit of all mankind, while on the other side national security and ideological superiority toils. This dual nature is very much reflected in the political context that gave birth to the space sector, becoming a topic of administrative and legislative dilemma in itself, giving rise to the emergence of national space agencies.

As highlighted, the evolution of the motives and means of the space sector are visible from the very beginning, exemplified in the context of the creation of the world's first national space agencies and international bodies for the governance of space. The task of national governments, and the international entity of the United Nations, was to balance and shape the somewhat conflicting interests in space activity. For a national government of a country like the U.S., this meant integrating space-related efforts for military and national security reasons with space for civilian purposes, leading to the convergence of once separated agencies and departments to form NASA. Evolutions like this, from protectionist, to civilian and international collaboration, serve to set the tone of the space sector and space activities, and are inevitably the result of shifting circumstances and political will, subsequent changes of which are still visible today, most notably in the context of the rise of private actors and the commercialisation of space.

From the onset of the space age, the wide range of space activities was initiated and driven exclusively under public control. In 1957, with Sputnik I orbiting the Earth, the principal interests in outer space were most distinctly for military and early space science purposes. Each of these interests was driven exclusively by the public sector, that became the primary category of players in the space endeavour, with the private sector and the emerging aerospace industry acting as contractors for public programmes.

9 Siddiqi, Asif A. "Competing Technologies, National (Ist) Narratives, and Universal Claims: Toward a Global History of Space Exploration", pg. 428. Technology and Culture Vol. 51, No. 2, April 2010, pp 425-443.
10 McDougall, W. A. "The Heavens and the Earth: A Political History of the Space Age", pg. 164. New Ed edition. Baltimore, Md. Johns Hopkins University Press, 1997.
11 Siddiqi, Asif A. "Competing Technologies, National (Ist) Narratives, and Universal Claims: Toward a Global History of Space Exploration", pg. 428. Technology and Culture Vol. 51, No. 2, April 2010, pp 425-443.
12 Ibid., pg. 436.

Moreover, the large initiation, development and operational expenses of any space activity constituted a burden that only nation states could possibly bear.

From the late 1960´s, the scientific and militaristic character of the space endeavour shifted as opportunities arose for commercial participation and exploitation of space activities. While the public sector continued as the exclusive manager, with its public character remaining fundamentally unchallenged for decades, the rise of commercial actors became a promising opportunity for the public sector to develop increasingly ambitious programmes. Nowadays, this transferal to the private sector has progressively solidified and it is clear that the increasing involvement of commercial companies in public programmes constitutes a paradigm shift, becoming a greater focus of consideration from governments and space agencies.

The following paragraphs will describe the characteristics of selected space agencies in terms of their core mandate and "model" following a brief historic and contextual introduction. This categorisation is intended to be neither strict nor comprehensive, since there are obvious similar responsibilities and objectives (such as conducting basic space science research, among others) that are further discussed in Chapter 2.2, and additional characteristics not taken into consideration for the purpose of this research. Nevertheless, the focus of the various space agencies' exhibits differences from one to another in their drivers and approaches, owing to different legal status, scope of activities, financing stream, as well as national priorities, strategies, histories, and capabilities.

2.1.1 NASA: Inception and Evolution of a Superpower Space Agency

Prior to the launch of Sputnik and the formation of the National Aeronautics and Space Administration (NASA), the American aerospace sector suffered greatly from a lack of institutional unity and subsequent limitations in areas such as funding. The space agency at that time in the U.S. was the National Advisory Committee for Aeronautics (NACA) which was an early version of the modern NASA, whose activities and budgets were to a large extent limited to priorities set by military research. The influence of Sputnik I caused an immediate chain reaction in the political administration of space-related activity in the U.S. By the new year, the NACA director and a few others had formulated an ordered concept of a feasible space program, based on a cooperative model between the Department of Defence (DoD), National Science Foundation, National Academy of Science, universities and industry; all centred around and managed by the NACA.[13] After a protracted debate over military versus civilian control of space, the resultant legislation was the National Aeronautics and Space Act, signed into law by President Eisenhower on 29 July 1958. The act inaugurated a new civilian agency, designated as the National Aeronautics and Space Administration (NASA).

As this ensemble of organisations joined together in the formation of NASA, from public and private sectors, military and civilian, it put the highlight on the administrative paradox: if the space sector served military purposes (therefore subject to closed-off secrecy) how would other aspects of space-research receive sufficient attention (e.g. science and international cooperation); on the other hand, if space-related research was to be *open,* having civilian and international dimensions, how would the U.S. be able to maintain a technological military superiority in space – and thus ideological superiority.[14] The NASA Space Act is thus a reconciliation between the intended military and civilian purposes of such Agency, highlighted by the creation of a 'Civilian-Military Liaison Committee' in sec. 204 (a) while simultaneously making NASA open for 'international cooperation' (sec. 205). NASA's foundation was directly related to the launch of the Sputnik and the ensuing race to demonstrate technological superiority in space.

[13] Ibid.
[14] McDougall, W. A. "The Heavens and the Earth: A Political History of the Space Age", pg. 166. New Ed edition. Baltimore, Md. Johns Hopkins University Press, 1997.

Therefore, since its foundation, the Agency has "*focused on government-owned and-operated space missions*".[15]

The Space Act of 1958 assigned NASA broad powers to plan and coordinate the efforts of the U.S. in matters relating to aeronautical and space activities. The Act established both the basic national policy and the organisation to implement that policy. In declaring the policy and purposes of the Act, the Congress stated that activities in space were based on peaceful purposes for the benefit of all mankind and that general welfare and security of the nation required that adequate provision be made for aeronautical and space activities.[16] President Dwight D. Eisenhower signed the Space Act "*to provide for research into problems of flight within and outside the Earth's atmosphere, and for other purposes*".[17] The Congress declared that it was the policy of the U.S. that activities in space should be dedicated to peaceful purposes for the benefit of all mankind and that the general welfare and security of the U.S. required that adequate provision be made for aeronautical and space activities.[18]

The creation of NASA as an agency controlling, developing, stimulating and undertaking non-military space activities stood out as a prominent feature. While NASA´s authority to "*direct (…) space activities was established, the category of space activities did not go beyond space activities of the United States or sponsored by the United States*".[19] The Space Act did not provide for many relevant provisions from the point of view of domestic legislation vis-à-vis private enterprise. The main role of the Space Act lay in the creation of the space agency with two potential functions: as entity directing and customer of the (nascent) space industry, and as national regulatory body.

NASA began by absorbing the earlier NACA. From this reorganisation, NASA was then in the position to conduct space missions, and in particular to undertake programmes in the nascent human spaceflight activities and aeronautics research for civilian purposes. It is important to note that while one of the motives for establishing NASA was to integrate already existing national bodies with space-oriented aims, NASA certainly has not been and is not, as of today, the *only* entity in the U.S. conducting, and receiving funding for, space activities. For example, in terms of military-oriented space activities, the roles and responsibilities are undertaken by the Department of Defence (DoD). In addition to this, the National Oceanic and Atmospheric Organisation (NOAA) exists as a scientific body conducting research in areas such as meteorology, climate, coasts and oceans, utilising space assists to provide products and services to relevant stakeholders.[20]

While commercial actors have been engaged in NASA programmes as contractors since the Agency's founding – i.e. the Communications Satellite Act of 1962 enabled private companies to own and operate satellites – it was not until the 1980s that a turnover of routine space operations to the private sector was significantly pursued. This effort gained a new dimension under the Reagan administration with the Commercial Space Launch Act of 1984 which "*recognized the United States private sector as having the capability to develop commercial launch vehicles, orbital satellites, and operate private launch sites and services*".[21] Throughout the Mercury, Gemini, Apollo, and Space Shuttle programmes, the space agency

[15] "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617, pg. 2. Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.
[16] Dembling, Paul G. "The National Aeronautics and Space Act of 1958: Revisited ". Journal of Space Law, Volume 34, Winter 2008, Number 2, pg. 203. Web: http://airandspacelaw.olemiss.edu/pdfs/jsl-34-2.pdf.
[17] "National Aeronautics and Space Act of 1958, As Amended". NASA, 2008. Web: https://history.nasa.gov/spaceact-legishistory.pdf.
[18] Ibid.
[19] Von Der Dunk, Frans G. "Private Enterprise and Public Interest in the European Spacescape: Towards Harmonized National Space Legislation for Private Space Activities in Europe". Rijksuniversiteit Leiden, 1998. Web: https://lib.ugent.be/catalog/rug01:000447867.
[20] NOAA Website – About our Agency. Web: http://www.noaa.gov/about-our-agency.
[21] "H.R.3942 - Commercial Space Launch Act". 98th Congress (1983-1984), U.S. Congress Website. Web: https://www.congress.gov/bill/98th-congress/house-bill/3942.

aimed to develop launch vehicles and spacecraft with strict oversight and responsible care and management of the contractor activity. This model of relationships set the shape for NASA-industry relations for decades to come.

Over the years, fostering a commercial space sector became an integral component of U.S. space strategy, thus supported at the highest political level. The Reagan administration's plans to use the Space Shuttle as a commercial launcher indicated a significant step towards developing the U.S. commercial space strategy, with particular regards to the deployment and exploitation of the International Space Station (ISS). The new vehicle was planned as a reliable, low-cost method of launching government and commercial payloads into orbit. This new system underlined "*a sense that a new era was dawning in space, one in which commercialization would play an important part*".[22] Reagan's administration intended to encourage the emergence of commercial space with the concept of a "new frontier" of economic development, and progress a space policy and strategy that integrated and stimulated commercial activity. Ever since, the U.S. space commercialisation strategy has applied to a growing number of space domains – i.e. telecommunications, space transportation, remote sensing, etc. – through various governmental initiatives and the incremental adoption of a legal and regulatory framework to foster commercial endeavour.[23]

Indeed, during the signing ceremony of the 1984 Commercial Space Launch Act, President Reagan stated "*one of the important objectives of my Administration has been, and will continue to be, the encouragement of the private sector in commercial space endeavours*".[24] In other words, the Commercial Space Launch Act was enacted to deal with one of the fields of potential interest to private enterprises - that is, launching activities. This continuous effort was first and foremost motivated by the opportunity to consolidate American leadership in space activities and a reduction of government budgets. Throughout these programmes, the space agency hired private contractors to develop launch vehicles and spacecraft. In this context, industries were involved in NASA programmes almost exclusively as contractors through cost-plus contracts "*based upon the actual cost of production and any agreed upon rates of profit or fees*".[25]

In 1985, the "National Aeronautics and Space Administration Authorization Act" amended NASA's governing statute declaring that that the general welfare of the U.S. required NASA to "*seek and encourage, to the maximum extent possible, the fullest commercial use of space*".[26] This moment was an important step to enable later legislation, providing NASA with further direction, responsibilities and authority to cooperate with private U.S. companies.

Such long-standing and continuous effort in the U.S. to support and foster the private space industry further intensified at the beginning of the 21st century, with a series of acts adopted under the various Administrations. The George W. Bush administration's cornerstone space policy was mainly associated with the Vision for Space Exploration announced in 2004 to "*pursue commercial opportunities for providing transportation and other services supporting the International Space Station and exploration missions beyond Low Earth Orbit*".[27] This strategy, elaborated under a new program named Constellation, planned

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[22] "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617, pg. 11. Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.

[23] "National Aeronautics and Space Act of 1958, As Amended". NASA, 2008. Web: https://history.nasa.gov/spaceact-legishistory.pdf.

[24] Speech of U.S. President Donald Reagan during the signature of the Commercial Space Launch Act.

[25] Meehan, Colette L. "Fixed Price Vs. Cost Plus". Small Business - Chron.com. Web: http://smallbusiness.chron.com/fixed-price-vs-cost-plus-2220.html.

[26] "Title 51—National and Commercial Space Programs". Office of the Law Revision Counsel, United States. Web: http://uscode.house.gov/view.xhtml?path=%2Fprelim%40title51&req=granuleid%3AUSC-prelim-title51&f=&fq=&num=0&hl=false&edition=prelim.

[27] "The Vision for Space Exploration". NASA, 2004, pg. 7. Web: https://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf.

to return humans to the Moon and to continue onward to manned exploration of Mars. Notably, this new U.S. space exploration policy included a key provision fostering private space transportation companies, by directing NASA to "*acquire cargo transportation as soon as practical and affordable to support missions to and from the International Space Station*".[28]

Indeed, the retirement of the Space Shuttle was a turning point for both the U.S. and the global space sector, and one of the decisive factors in shaping and allowing the emergence of the contemporary so-called "New Space" dynamic. As the Space Shuttle was tasked primarily with the assembly and exploitation of the International Space Station, its retirement caused a dramatic lack of independent manned access to space.[29]

The 2004 space policy not only paved the way for an American return to the Moon as part of the Constellation programme, but also for the development of human-rated launcher vehicles, primarily developed by American private companies, to meet the needs for space transportation services by institutional actors. However, the 2004 strategy did not fully pan out, as the focus of U.S. space exploration efforts changed thrice during three different administrations between 2004 and 2018. These more recent evolutions will be addressed in Chapter 3.2.

2.1.2 ESA: The Regional and Intergovernmental Space Agency

In some ways, the creation of ESA shares similarities with the establishment of NASA in that it arose out of the merging of individual but related space entities created at the very outset of the space age. In particular, this happened in the context of newly forming European intergovernmental bodies, specifically oriented for research. This trend began in 1954 with the establishment of a European Organisation for Nuclear Research (CERN), to be followed in the fields of space science and technology with the creation of the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO) in 1964 – both concerned with space and intergovernmental organisations (IGOs), but with differing missions, memberships, and methods for contract management.[30] Moving forward, discussions in the early 1970s to revise the Conventions of ESRO and ELDO took place with the aim of amalgamating the two institutions into one encompassing organisation. The resulting political agreement eventually culminated in the creation of ESA in 1975.[31] Being an intergovernmental issue, the situation presented more complexities, and took a longer amount of time, than seen in the case of the creation of NASA, however the core motive remained the same. Another major difference between these cases is seen in ESA's initiating Convention, which states: in "*considering that the magnitude of human, technical and financial resources required for activities in the space field is such that these resources lie beyond the means of any single European country*",[32] highlighting the new role of this European-wide space sector as compensating for non-superpower status, and pooling resources for space endeavour on the global scene which would have been, otherwise, hardly reachable.

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[28] "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617, pg. 16. Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.

[29] Major reasons that led to the retirement of the Space Shuttle included: age of the vehicles, that were built to last 15 years but instead reached almost 30; safety issues, particularly in light of the two major incidents that caused the loss of two shuttles of the fleet and their entire crew (Challenger in 1986 and Columbia in 2003); and ultimately its economic non-sustainability in the long term.

[30] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.

[31] Ibid.

[32] "ESA Convention and Council Rules of Procedure" ESA, SP-1317/EN, December 2010. Web: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf.

The treaty that founded ESA, the "Convention for the Establishment of a European Space Agency", opened for signature on 20 May 1975 and entered into force on 30 October 1980. It is an international treaty containing 26 articles and five annexes, which has been and remains the legal reference text guiding European space activities. The founding states have been then joined by other European countries through an accession mechanism, and to this day it numbers 22 Member States, plus an Associate and a Cooperating State. In essence, ESA was founded to enable cooperation amongst European states in space, and in doing so, ESA member states "*cooperate through ESA, and ESA cooperates with other partners*".[33] More specifically regarding the first aspect, ESA can be defined as a mechanism of international cooperation among states. In the latter aspect, ESA is considered as an actor of international cooperation.[34] However, the commonality in both cases is that space activities are typically undertaken on a wide multilateral basis.

Furthermore, in enabling cooperation on a regional level through a single institution, ESA was established as a derived subject of public international law with an international legal character, thus capable of having and enforcing rights and duties, and being entitled to actions and responsibilities distinct from those of its member states. The capabilities gained from setting up such a dedicated IGO have allowed European space cooperation to become permanent and institutionalised with a solid legal basis.

In essence ESA is not only defined as a space agency "*in the meaning used by space-faring States*",[35] but also as a facilitator and integrator of national programmes and the creator, coordinator, and manager of European-wide space programmes.[36] It is mandated to be operative in fields such as space policy, space activities and space coordination. Overall, the purpose of ESA is "*to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications*".[37] It does so by:[38]

- elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
- elaborating and implementing activities and programmes in the space field;
- coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
- elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

As a key role, since its foundation ESA has been tasked with supporting the developing of the nascent European space industry and, later on, furthering Europe's competitiveness in global value chains.

Throughout the decades after its foundation, ESA, as an intergovernmental agency for research and development, has contributed to the advance of technical capabilities across the European space sector through inception, development and procurement of a variety of space programmes in areas encompassing space science, Earth observation, telecommunications, navigation, human and robotic

[33] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018, pg. 3. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.
[34] Ibid.
[35] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018, pg. 4. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.
[36] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018, pg. 5. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.
[37] Art. II ESA Convention. See: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf.
[38] Ibid.

exploration, basic technology programmes and, naturally, space transportation. Indeed, by pooling the resources of European Member States, ESA has been able to undertake – successfully – large-scale space programmes and activities "*far beyond the scope of any single European country*".[39]

Going into the specifics of ESA programme management, and in particular from a financial and budgetary standpoint, the programmes developed by the Agency are categorised as either mandatory or optional: Art. V of the ESA Convention introduces a special mechanism of intergovernmental cooperation that is considered as "*key to the functioning of ESA*".[40] Concerning mandatory programmes, they are performed in the framework of the general and scientific program budget. As implied, mandatory programmes are a set of defined activities to which all ESA member states are obliged to contribute. As such, the mandatory programmes of ESA are funded by a financial contribution from all the Agency's member states, calculated in accordance with each country's gross national product (GNP). These programmes embrace the basic activities of ESA such as scientific programmes, the examination of future projects, technological research, common technical investments, information systems and education programmes. Accordingly, the mandatory activities are of utmost relevance because their scientific and technological content is a stable contributor to knowledge, innovation, and competitiveness in Europe in which each member state participates. The core mandatory programmes to which every member state contributes are the: Science Core Technology Programme (CTP); the Basic Technology Research Programme; and the General Study Programme (GSP).

With respect to these types of mandatory activities, as outlined in the ESA Convention, the Agency:[41]

- Ensures the execution of basic activities, such as education, documentation, studies of future projects and technological research work;
- Ensures the elaboration and execution of a scientific programme including satellites and other space systems;
- Collects relevant information and disseminates it to Member States, draws attention to gaps and duplication, and provides advice and assistance for the harmonisation of international and national programmes;
- Maintains regular contact with the users of space techniques and keeps itself informed of their requirements.

In particular, several mandatory key programmes of ESA revolve around basic technology research and development, including: the Technology Research Programme (TRP), the General Support Technology Programme (GSTP), the Future Launchers Preparatory Programme (FLPP) and the Telecom/ARTES programmes – all of which account for about three quarters of the total of technology R&D conducted in ESA.[42]

Alongside the mandatory programmes, ESA also conducts a large number of optional programmes spanning the whole spectrum of space activities. Each Member State independently selects which optional programme they wish to participate in and the amount they wish to contribute. Distinct from the mandatory programmes, the optional activities themselves are decided upon by ESA Member States (not by ESA as an IGO), based on national and cooperative interests.[43] Optional activities allow ESA Member

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[39] Preamble of the ESA Convention. See: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf.
[40] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.
[41] Art. V ESA Convention. See: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf.
[42] A breakdown of ESA's technology programmes is available at: https://www.esa.int/Our_Activities/Space_Engineering_Technology/Shaping_the_Future/Background_of_ESA_s_Technology_Programmes.
[43] "The European Space Agency as a Mechanism and an Actor of International Cooperation". Paper at the 57th Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS), 2018. Web: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.22018crp/aac.105c.22018crp.20_0.html.

States to arrange the type and extent of their involvement, further and beyond their obligations emanating from the ESA Convention, and thus their cooperation in outer space activities is in accordance with respective national political, strategic, industrial and scientific interests.[44] The areas of activity for these optional programmes include Earth Observation, Human Spaceflight, Telecom & Integrated Applications, Navigation, Robotic Exploration & Prodex, Space Transportation, Technology Support and Space Situational Awareness. Notably, the execution of optional programmes, in particular, includes:[45]

- the design, development, construction, launching, placing in orbit, and control of satellites and other space systems;
- the design, development, construction, and operation of launch facilities and space transport systems.

Notably, and in contrast to NASA, for example, which is today fully focused on space science and human/robotic space exploration, ESA is active in all types of space activities, except within the military space domain which in Europe is conducted at national level.

As mentioned above, the mission of building and fostering a competitive European space industry is indeed at the heart of the ESA Convention. The historic, strategic reasons for doing so were initially to ensure European independent access to space, and thus to reap the benefits of a space sector economy that could create a flourishing market in Europe, an opportunity – and necessity – that became more and more clear in the early 1980s as the western space sector was experiencing the first commercial space activities.

In order to reach this overarching goal, the convention not only mandated the Agency to elaborate and apply an industrial policy appropriate to its programmes, but it also set the specific objectives of such policy:[46]

- a cost-effective response to requirements of the European and coordinated national space programmes;
- improve the world-wide competitiveness of European industry by maintaining and developing space technology and by encouraging the rationalization and development of an industrial structure appropriate to market requirements;
- ensure that all Member States participate in an equitable manner, having regard to their financial contribution, in implementing the European space programme and in the associated development of space technology.

As the Agency supported European space industry to be competitive in the global value chain, the whole ESA procurement approach was aimed at developing the capacity of European industry and to enable it to react to market demands in the most efficient and the most economical way. One of the main elements in ESA's Industrial Policy was the set of rules relating to geographical distribution or fair return for member states, allowing ESA to essentially remove many of the risks associated with space ventures by returning the majority of each nation´s budgetary contribution in the form of industrial contracts (geographical returns or "geo-return").[47] Indeed, in a quite unique characteristic of the ESA model as an intergovernmental space agency, both mandatory and optional programmes are developed through the assignment of contracts to the industries of various ESA Member States following the principle of geo-return: [48]

[44] Spagnulo, M., Fleeter, R., Balduccini, M, and Nasini, F. "Space Program Management - Methods and Tools". Springer-Verlag New York, 2013.
[45] Art. V ESA Convention. See: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf.
[46] "ESA, an intergovernmental customer". ESA Website.
Web: https://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/ESA_an_intergovernmental_customer.
[47] Ibid.
[48] Ibid.

- A Member State's overall return coefficient is [defined as] the ratio between its percentage share of the total value of all contracts awarded among all Member States and its total percentage contributions;
- For the purpose of calculating return coefficients, weighting factors are applied to the value of contracts on the basis of their technological interest;
- Ideally, the distribution of contracts placed by the Agency should result in all countries having an overall return coefficient of 1.[49]

Overall, the principle of geo-return was established to ensure the fair return of any individual member state's input into an optional programme through the awarding of contracts to the respective nation's space sector industry. In turn, this policy safeguards a member state's investment, and directly serves to stimulate its respective industry. It is important to note that geo-return has been a crucial tool for creating a situation in which contracts would not by default be awarded to a single, predominant country, and balancing the intergovernmental nature of ESA in an equitable manner. Importantly, this policy can be seen as a tool for encouraging member states to participate in optional programmes.

In relatively recent years, the European Union (EU) has become an increasingly significant stakeholder and director of European-wide space policy and strategy, representing a significant change in the dynamic of the European spacescape. Now contributing one-third of the overall ESA budget, the EU has been utilising a close partnership with ESA for the procurement of several of its critical infrastructure systems and flagship programmes including the Galileo satellite navigation system and the Copernicus Earth observation system. To describe in more detail this rather recent development, it is useful to refer to the case of the Galileo programme as an example. In terms of the structure of the value chain of Galileo, the EU initially defined its needs and requirements and communicated them to ESA; and provided the necessary funding through its research and innovation programmes – in this case Horizon 2020; ESA subsequently developed the system working alongside industry, and once deployed the system was handed over to a third entity – in this case the EU Global Satellite Systems Agency (GNSS) for its operations. Lastly, the services provided by the system are made available to civilian users by the GNSS, with the capacity for wider applications to be developed by business, SMEs in particular.

As an IGO, ESA is rather a unique entity amongst space agencies across the globe. Built to address space needs in the emerging European context in the second half of the nineteen century, ESA's structure serves as an effective platform for the cooperation and collaboration of each of its member states, with a legal personality to facilitate its international structure and strategic objectives. To this end, ESA is a functioning tool to fulfil European ambitions in space. Pooling, multi-national resources for space programmes allows them to be conducted at scales that would not be achievable by any single member state – bringing forth benefits for European development and competitiveness on a whole, as well as back to individual member states.

However, while necessary, this structure is not without its complexities and weighty features. One example is the complex decision-making process of an IGO with multiple member states – inevitably more complicated than in a nationally-administrated space agency. This notwithstanding, there is no doubt that the ESA model has been a successful model, ultimately ensuring Europe's current forefront position in the global space arena.

[49] Ibid.

2.1.3 ASI: Focus on Industrial Policy as "System Architect"

The Italian Space Agency (ASI) was founded in 1988, with the mission of "*promoting, developing and promulgating scientific and technologic aerospace research […], placing a strong focus on supporting the competitiveness of the Italian industrial space compartment*".[50]

Over the years, the agency has established itself as a significant European and global player in a number of space domains, namely space science, satellite technologies (including in particular Earth observation, navigation and telecommunication), robotic and human exploration, as well as launchers and space transportation.[51] Furthermore, as is the case for CNES and DLR, ASI has established strong collaborations with the Italian Ministry of Defence, particularly in the development, deployment, and operation of dual-use satellite systems. And, similar to all other space agencies across Europe, ASI represents Italian national interests in European institutions and organisations, including ESA, the EU, EUMETSAT and more.

The Italian agency is renowned for conducting cutting-edge space science and astrophysics research throughout the past decades, in collaboration with a number of Italian public scientific research institutes and with other countries' agencies.

Furthermore, as clearly stated in its mission, on top of basic scientific research activities, one of the core tenets of ASI is a strong focus on supporting the national space industry. This is achieved by, inter alia, providing national industrial policy guidelines, including through the assignment of industrial and research contracts for the realization of the national space programme and its international collaborations, ultimately contributing to the development and competitiveness of the Italian industrial space compartment.

Along these lines, the agency has recently put forward an updated strategy which particularly focuses on the development of the space economy,[52] aiming at investing a significant amount of capital provided both by the public and the private sector. In this way, ASI is reaffirming its position as a central player in the Italian space investment ecosystem, expanding its role in order to further stimulate the creation of value chains benefitting small and large industrial players within the country, and ensuring their competitiveness abroad.

2.1.4 CNES: Encompassing Civil and Defence

The history of the Centre National d'Etudes Spatiales (CNES) is undoubtedly closely intertwined with the country's development of its own space launch vehicles for defence purposes (including deterrence) in the decades immediately after the second world war.

Indeed, as stated in its mission, guaranteeing France's access to space is one of the main objectives of the agency – on top of conducting a broad range of cutting-edge space technology research as well as space science, partnering with the national scientific community and industry. The Ariane programme, the crown jewel of France's and Europe's launcher vehicles, is explicitly mentioned as one of the five domains of activity of CNES, alongside Sciences, Observation, Telecommunication and, notably, Defence.[53] In this regard, it is significant (but not surprising) that the agency acts under the supervision of both the French Ministries of Education and Research as well as the Ministry of Armed Forces. This close link with the defence/military community places CNES in a unique position among European national

[50] "Documento di Visione Strategica 2016-2025". ASI, 2016.
Web: https://www.asi.it/sites/default/files/attach/dettaglio/dvs-ita_web_0.pdf.
[51] "Introduction to the Italian Space Agency". ASI Website. Web: https://www.asi.it/en/agency/about-asi.
[52] "Documento di Visione Strategica 2016-2025". ASI, 2016.
Web: https://www.asi.it/sites/default/files/attach/dettaglio/dvs-ita_web_0.pdf.
[53] "About CNES". CNES Website. Web: https://cnes.fr/en/web/CNES-en/3773-about-cnes.php.

space agencies, as the agency is highly and actively involved in the development and operation of the country's military satellites.[54]

Furthermore, CNES is mandated by the Ministry of the Armed Forces to act as a contracting authority for most of the space components of defence programmes. Along this line, the employment of dual-use space systems (e.g. Pleiades, Syracuse 4, OTOS among others) is heavily pursued, in order to "*meet common needs of civil and military users*" in a more affordable and effective way for both customers.[55]

Lastly, as with other agencies, CNES is fully embedded and participates in all the broader European institutions' programmes and activities, from ESA to the European Union to other intergovernmental organisations, and is particularly active in conducting "space diplomacy" across the globe, collaborating with a myriad of other countries' agencies and research institutions.

2.1.5 DLR: Research, Administration and Operations

The German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt, "DLR") is the German national research centre for aerospace. Notably, the DLR has wider functions beyond aerospace research activities, including cutting-edge research in aeronautics, energy, transport, digitalisation and security.

Furthermore, in addition to the research activities and acting on behalf of the German Federal Government, DLR performs the function of a space agency (Raumfahrtmanagement/Space Administration), i.e. designing and implementing the German national space programme representing German space interests internationally, i.e. with ESA, as well as facilitating contracts and grants for the national space programme across the board.[56]

As noted, the DLR is both nationally and internationally oriented. Nationally, the DLR implements Germany's space programme, with its main client being the Federal Ministry for Economic Affairs and Energy, as well as a number of other national ministries (including Defence) in areas such as Earth Observation, navigation and satellite communications.[57] Working under the Federal Government, the Space Programme provides "*both business and science with a reliable political framework for independent planning and action, thus ensuring that public funds are used efficiently*".[58]

The German Space Programme itself operates under several general guidelines: orientation to benefits and needs – i.e. state-funded space activity for the benefit of the Earth, contribution towards global societal challenges, and broader involvement of users; orientation towards the principles of sustainability – i.e. the protection and utilisation of space infrastructures to fortify industry - and conducting space activities with future generations in mind; intensifying international cooperation – i.e. collaboration of expertise on technical complexity and with costs -, balancing cooperation and competition, and participation with European institutions as well as multilateral cooperation.[59]

Internationally, on a European plane, the DLR Space Administration manages Germany's relations with ESA, EUMETSAT, and the EU (i.e. partaking in the European Framework Programme for Research and Innovation), promoting the interests of German scientific institutions and industry within the space sector.[60]

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[54] "The Spirit of Space". CNES Website. Web: https://corporate.cnes.fr/l-espace-en-tete/domains-activity-defence.html.
[55] Ibid.
[56] Presentation of DLR. Web: http://a3space.org/wp-content/uploads/2017/09/DLR-uloga.pdf.
[57] Al-Ekabi, C., Ferretti, S. "Yearbook on Space Policy 2016: Space for Sustainable Development", pg. 303. Springer, 2018.
[58] DLR Space Administration. DLR Website. Web: https://www.dlr.de/rd/en/desktopdefault.aspx/tabid-2099/3053_read-4706/.
[59] "European Space Technology Master Plan 2017", pg. 121. ESA and EC, 2017.
[60] DLR Space Administration. DLR Website. Web: https://www.dlr.de/rd/en/desktopdefault.aspx/tabid-2099/3053_read-4706/.

Orientating itself towards benefits and needs, tapping new markets, innovation and sustainability,[61] the German national space programme focuses on:[62]

- solving societal and institutional problems,
- exploring promising applications in which Germany holds a leading position or may hold such a position in the future,
- increasing Germany's share in commercial sales and opening up new markets,
- promoting top-flight German research that is recognized worldwide, and
- using the fascination of space flight to awaken an interest in science and technology in school students and young adults.

The DLR model is peculiar within the European context as it embraces the typical role of a cross-sectorial aerospace research and development (with over 40 institutes in 20 different locations),[63] coupled with a strong component of a national space administration, and a dedicated centre for space operations (GSOC),[64] responsible for operating spacecraft both at national level and within international cooperation frameworks (e.g. with ESA and NASA).

2.1.6 UKSA: Business-Oriented

The UK Space Agency (UKSA), an executive Agency of the Department for Business, Innovation and Skills, is Great Britain's dedicated body for the UK civil space programme with a mandate to lead a strategic approach to the management and funding of UK civil space activity with integrated policy to synergise government departments, scientific institutions, and industry.[65]

As with many other space agencies, UKSA was established to streamline existing national departments of government and scientific institutions, and to support national industry. This had been attempted already in the 1980s with the creation of the British National Space Centre (BNSC) – a voluntary partnership formed to coordinate the 10 main government departments and research councils relevant to UK civil space activity.[66] However it was commonly held that the BNSC had not quite achieved the cohesion it had hoped for,[67] lacking the authority and resources to direct the wide range of activities within the UK space community, or to represent it adequately on the international stage.[68] Thus UKSA was formed on 23 March 2010, remaining in close partnership with BNSC's original partners, but with a more extensive top-down approach, taking over full budgetary responsibilities in April 2011.[69]

Collaboration is central to UKSA activity, and on a national level UKSA works closely with research councils, the Technology Strategy Board (Innovate UK), and its industrial partners, through a number of

[61] Presentation of DLR. Web: http://a3space.org/wp-content/uploads/2017/09/DLR-uloga.pdf.
[62] "DLR Space Administration". DLR Website. Web: https://www.dlr.de/rd/en/desktopdefault.aspx/tabid-2099/3053_read-4706/.
[63] "DLR in 2018". DLR Website. Web: https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10989/1769_read-25907/year-all/#/gallery/14331.
[64] "The German Space Operations Center". DLR Website. Web: https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10368/562_read-479/#/gallery/546.
[65] "UK Space Agency Civil Space Strategy 2012-2016", pg. 4. UKSA Website. Web: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/286219/uk-space-agency-civil-space-strategy.pdf.
[66] "European Space Technology Master Plan 2017", pg. 174. ESA and EC, 2017.
[67] Amos, J. "New UK Space Agency Aiming High". BBC News, 1 April 2011. Web: https://www.bbc.com/news/science-environment-12924060.
[68] "Submission to the British National Space Centre consultation on the UK civil space strategy 2007-2010". The Royal Society, RS policy document 10/07. Web: https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2007/8064.pdf.
[69] "European Space Technology Master Plan 2017", pg. 174. ESA and EC, 2017.

sectorial domains.[70] On a regional level, UKSA primarily works alongside ESA, channelling a large proportion of its investments into this collaboration.[71] Beyond this, UKSA contributes to other European institutions on space-related matters, such as the EU and EUMETSAT, with the UK providing the necessary expertise required for effective representation on the UK's behalf, complementing and synergising national activity with other European-wide space ventures. On a global scale, the UK collaborates with a number of the world's space agencies, is a member of global bodies such as the United Nations Committee for Peaceful Uses of Outer Space, the International Space Exploration Coordination Group, the Group on Earth Observation, and the Committee on Earth Observation. Overall, the roles and responsibilities of UKSA include:[72]

- leading the UK civil space policy and increasing the UK contribution to European initiatives
- building a strong national space capability, including scientific and industrial centres of excellence;
- co-ordinating strategic investment across industry and academia;
- working to inspire and train a growing, skilled UK workforce of space technologists and scientists;
- working on national and international space projects in co-operation with industry and academia;
- regulating UK civil space activities and ensuring they meet international treaty obligations.

2.2 Core Tasks of Space Agencies

The historical context of creation, roles, and mandates of a number of worldwide space agencies were detailed in the preceding section of this chapter as key cases. Naturally, there is a multitude of other space agencies in operation around the globe, working in a variety of national contexts, different national interests, budgets, regulatory, policy and legal frameworks, space sector statuses and objectives for both public and private actors, and of course space programmes.

It is true that the majority of space faring nations have created, and continue to create, dedicated national space agencies to foster their respective space sector both nationally and internationally. The establishment and utilisation of a national space agency is justified from multiple angles: i.e. the costs and risks of a solely private space sector have been, and are still in many respects, unrealistic; government's role as a financer and administrator is a reliable – and still indispensable - means; space R&D and applications fulfil a public good, with socio-economics benefits, and thus ought to be given public direction. This said, there is no strict or universal definition of a "space agency", however, conceptualising space agencies "*is not a matter of definition, but of function*".[73]

It is manifestly clear that already between NASA and ESA alone there are very significant differences, one of the most notable being that ESA is an intergovernmental organisation that joins together a large number of nations – giving ESA a contrasting structure to NASA, having implications for funding and the decision processes in which this funding is allocated and to which programmes. Furthermore, as outlined above, there are several other "models" of space agencies in operation, each one different to a certain

[70] "UK Space Agency Civil Space Strategy 2012-2016", pg. 4. UKSA Website.
Web: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/286219/uk-space-agency-civil-space-strategy.pdf.
[71] "Corporate Plan 2017-2018". UKSA.
Web:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/641447/corporate_plan_2017-18.pdf.
[72] "Corporate Information". UKSA Website.
Web: https://www.gov.uk/government/organisations/uk-space-agency/about#corporate-information.
[73] Piva, A. "Societal and Economic Benefits of a Dedicated National Space Agency for Australia". Università Bocconi and Government of South Australia, 2017.
Web: https://www.defencesa.com/upload/capabilities/space/FINAL%20version%2029.08.2017.pdf.

extent in terms of mission-orientation, approach, connection to the national industrial and research base, and so on.

However, while the contexts of space agencies around the globe may show significant differences, there are several general and common roles and responsibilities that the majority of space agencies serve to fulfil (see Figure 1), detailed in the following paragraphs.[74]

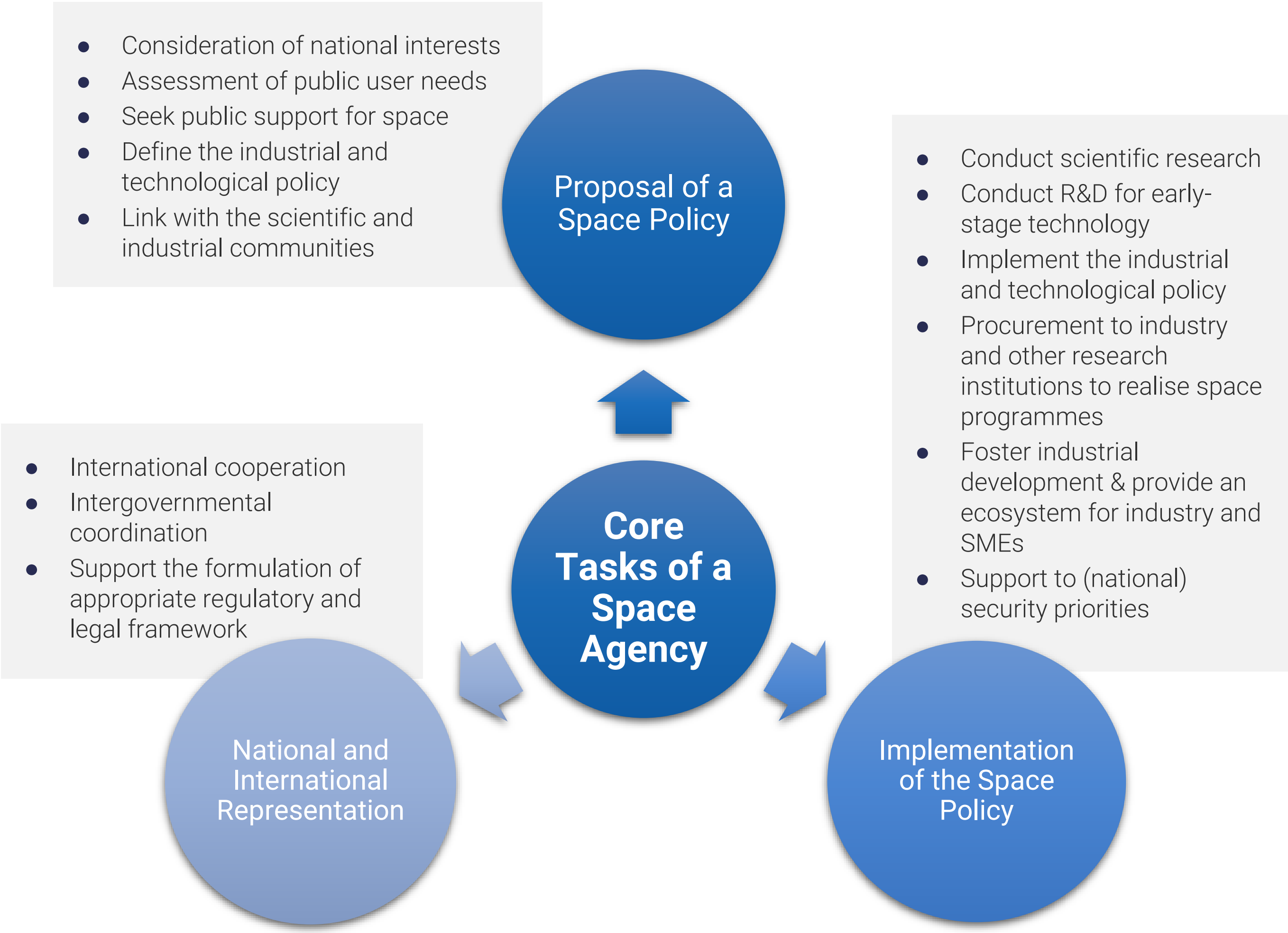

Figure 1: Core tasks of space agencies. Source: ESPI.

2.2.1 Proposal of a Space Policy

One of the primary roles of a space agency is to define and prepare a national/regional space strategy and policy, to be submitted for approval to the relevant government or supervisory authorities. Key to this is the outlining of the national space agenda and direction, and consequentially the delineation of specific space programmes to be conducted within a certain timeframe and budgetary limits. In this sense, the space agency is equipped with the necessary expertise to devise the details of a space strategy and promote the importance of a specific space programme to higher levels of government – for ultimately,

[74] The role of ESA, as a regional and intergovernmental agency, has obviously an additional layer of responsibilities, such as the mandate to "*coordinating the European space programmes and national programmes*" as well as "*integrating the national programmes as completely as possible into the European space programme*", among other purposes outlined in its Convention. At the same time, other responsibilities typical of a national space agency, such as to elaborate and propose a structured space policy for approval by government bodies, or support national security priorities for example, do not apply for ESA.

as public bodies, justification of expenditures and agendas must be aligned and approved by national governments.

The space agency has the fundamental task of assessing and collecting public user needs, on top of considering the national interest, wider economic benefits and industrial priorities. Due to its own expertise and competencies, the space agency is typically the only institutional body with the proper links and mandate to do so.

On a pragmatic and organisational level, space agencies additionally serve to streamline the relevant space-related public institutions/governmental departments and industry through a single entity. As outlined in the former section of this chapter, this joining of related entities is seen in the creation of NASA from the once disconnected compartments of NACA, the Department of Defence, and industry. The context is slightly different for ESA as an IGO, but the structural alignment remains the same, with ESA becoming the entity aligning the efforts of multiple nations and their respective industries on top of their national programmes.

Historically, a principle objective of national/regional space policies for long-established agencies has been to foster the development of a sound industrial space sector at large, and thus support its competitiveness. In the case of ESA, the agency is clearly mandated to do so through mechanisms outlined in its convention; however, the development and support of the space industry certainly remains a staple also in national space agency strategies. In either case, such support – both for the downstream and the upstream segments – is achieved through the creation and implementation of related technology policies and roadmaps, often cross-sectorial, as well as well-defined industrial policies, and ultimately through procurement of technologies and systems from the private sector, as described below.

The process of proposing a space policy typically builds upon previous decades of strategic orientation set by the national executives (in established spacefaring nations), or, in recent times, following broad consultations across the various stakeholders (in emerging spacefaring nations that are establishing a new space agency), taking into account national priorities and the capabilities of a multitude of actors.

2.2.2 Implementation of the Space Policy

Ensuing their role in the development of a space strategy and policy, space agencies act as the implementers to fulfil the objectives and goals in the form of space programmes. In doing so, many space agencies act as the research and development bodies to conduct their own activities in space science, exploration, exploitation and applications. To the same end, space agencies maintain the responsibility for administrative procurement bodies, directing and working alongside industry to realise the technical aspects of space programmes.

In meeting the objectives set by the space strategies and resultant space programmes, there is a level of variance in how individual space agencies might go about it – i.e. a space agency may primarily conduct its own research and development, contracting private industry as an additional resource where it sees fit; conversely in other instances, the administrative and procurement role of a space agency may take precedence over the research and development role, more extensively fostering and directing private ventures towards national objectives.

In terms of R&D, many space agencies often have dedicated and specialised R&D centres focused on specific areas of space science or applications, possessing the necessary expertise and receiving direct funding from their respective governments. This is conducted in line with broader national research and technology policies, of which the space segment constitutes the relevant part of interest for space agencies.

Furthermore, implementation of a space policy is chiefly conducted through procurement from industry for the realization of space programmes. To do so, space agencies have a number of means of acquiring desired technologies and systems from the private sector, chiefly through build & design contracts or public-private partnerships etc., which are detailed in Chapter 2.3. In this line, space agencies additionally maintain the role of defining and implementing an adequate technological and industrial policy, in accordance with national orientations and strategies, to foster and stimulate the private space sector, and to ensure their competitiveness on the open market wherever applicable.

Lastly, in a number of countries the space agency is also actively coordinating and working alongside the relevant Ministry of Defence for the development and operation of dual-use or military-specific space systems, to support relevant national security priorities and objectives.

2.2.3 National and International Representation

Space activity of course has strong international dimensions by its very nature, giving an inherent internationally-focused aspect to any space agency. As such, next to the common roles of space agencies, although somewhat inclusive but distinct from the former two, is the responsibility of representing a country's national/regional interests, including management of international collaborations. This role can be seen from two sides, the first of which is to be a focal point for promoting space activities within an agency's respective country, and second, but significantly, is to represent national interests on the international stage. In the former case, as a focal point for national space ventures (or on a regional scale) as described in previous paragraphs, the space agency plays a role in devising and implementing the national space strategy in accordance with the national agenda, regulations and laws. The space agency provides the necessary expertise to advise government on the scientific, technical, and budgetary aspects of a specific space programme as well as acting on its behalf in respect of delivery including R&D and procurement. Space agencies, in general also act as the relevant experts on space related issues for wider national governmental departments– for example there may be cross-overs between domains/departments such as agriculture or energy in which a national space agency may actively engage to tackle societal issues of national priority.

In this context, acting as the relevant body of expertise in space matters, space agencies additionally play a role in supporting space-related regulatory and legal discussions and their implementation, including wider international treaties and the processes of ratification and implementation at the national level. Indeed, space agencies also have the role of representing national interests on the international stage. This can come in a variety of forms, including; in collaboration on mutual space programmes between two or more nations on a bi- or multilateral basis; cooperation in disaster or risk management, i.e. sharing satellite observation data on natural disasters; representation in intergovernmental entities or international forums, (e.g. ESA for national space agencies, UNCOPUOS, WMO among others); as well as providing a national go-to for expertise on space related issues, being the point of contact for the country's institutional and private entities wishing to discuss or collaborate on space-related matters. One example, among many, of such international representation and collaboration, in the case of disaster management, is the International Charter for Space and Major Disasters that is a worldwide initiative set up to facilitate collaboration on the response to such events, through sharing and making available satellite-derived Earth observation data.[75] Many of the world's leading space agencies contribute under this Charter, working alongside non-governmental organisations to collectively cope with the aftermath of natural or man-made disaster events significantly more effectively than on a separate basis.

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[75] "About the Charter". International Charter Space and Major Disasters Website.
Web: https://disasterscharter.org/web/guest/about-the-charter.

2.3 Mechanisms of Procurement

As outlined above, on top of R&D activities, space agencies – in line with their historic mission of developing a solid industrial base – act as public procurement bodies to acquire from industry the necessary hardware to conduct relevant space programmes and allow their development.

Generally speaking, procurement is a term that essentially refers to the relationship between public entities and private industry to ensure the reliable transfer of goods, i.e. technological objects or systems that form critical technological infrastructures, or services, from industry to the public domain. Programmes and policies for procurement support national and international space programmes and play a significant role in not only "*maintaining or developing a domestic industrial base, but they also stimulate innovation by creating a demand for innovative products or services*".[76] In this sense, methods of procurement also aid in bridging the "pre-commercialisation gap" by stimulating an initial market and demand via public space programmes.[77]

Methods of procurement essentially form the fundamental basis of any wider connected industrial policy. In the sense, the shift in trend from traditional private contracts, to public-private-partnerships (PPPs), to possibly a *provision-of-services* in the very long term, mirror evolving relationship between space agencies and the private sector.

In recent years, the many ways in which procurement methods are established in the space sector are expanding and evolving with the shifting nature of both the public and private domains. Individual models of procurement methods, less and more recent, will be detailed in the following paragraphs, followed by an assessment of the changing private space sector landscape that continuously shapes and directs the relationship between the public and private space domains.

2.3.1 Traditional Public Procurement

In the area of traditional public procurement models, namely those employed by space agencies to fulfil the mandate and objectives of their role, private contracts have been historically the first and regular way of interaction with the industry. Generally speaking, these private contracts are in essence an agreement between a public entity and a private company in which a designated prime contractor, that is, a private actor, provides a good ("built-to-order") or service on a "cost-plus" basis (see below), with the cost and risks being incurred entirely by public resources. Such agreements have historically played a critical role in the initial development of the space sector, constituting the majority form of relationship between the public and private sectors since its emergence.

Under this model it is clear that the public partner has complete control in directing and implementing the programme strategy – outlining its goals and requirements – i.e. "what" and "how"[78] – awarding contracts based on the ability of the prime to meet such requirements. Second to this, the contract-based style of relationship has also served as a means for public actors to encourage and foster a private space industry, which would have historically had limited, or zero, sources of funding beyond the public domain – "business to business" or "business to customer" relationships are relatively novel and still emerging in the space sector, and not necessarily widespread or even viable across all space domains at present.

[76] "Space and Innovation", p. 74. OECD, 2016. Web: https://read.oecd-ilibrary.org/science-and-technology/space-and-innovation_9789264264014-en#page74.
[77] Ibid.
[78] "Commercial Spaceflight Status Briefing". NASA presentation, 2012.
Web: https://www.nasa.gov/sites/default/files/files/CommercialStatus_September_508.pdf.

The traditional and predominant form of private contract used in the space sector has been cost-plus, or cost-reimbursement, contracts. Under this model, the prime contractor is paid in full for the total expenses of a particular procurement as well as an additional "plus" payment that ensures that the contractor makes a profit and is incentivised to do such business.[79] Although this type of contract, in all its variants, has had a sturdy heritage in the space sector and significant role in its development, it has been argued that it provides "*little incentive to control the project costs*",[80] and therefore might breed inefficiencies.[81]

Nonetheless, cost-plus contracts have proved indispensable in many space ventures in which the associated risks are high and profit projections for a business to safely invest in are uncertain, being sustained by government subsidy in order to satisfy greater public interests and priorities, e.g. national security among others.[82]

As such, and alongside accelerating changes within the commercial space sector (detailed in Chapter 3), a shift away from the cost-plus model in the space sector to customer-provider relationships has occurred in recent years. Moreover, it is apparent that this shift is catalysed by the more commercialised a particular space industry domain is. For example the commercial communications satellite industry was one of the first to divert from cost-plus contracts, as well as being one of the first self-sustaining commercial space industries – "*by demanding a fixed price bidding process whereby competing satellite manufacturers assumed the risk of cost overruns, satellite operators moved away from the cost-plus business model*".[83] Novel approaches to replace the cost-plus model are clearly exemplified in new contracts developed for the COTS Programme through NASA's Space Act Agreements (see Chapter 3.2).[84]

2.3.2 Public-Private Partnerships

A strict single definition of a public-private partnership (PPP) is difficult given its many variations. However, a great amount of literature has been produced to describe, discuss and analyse this type of interaction between the public and private sector.

The IMF (2006) refers to PPPs as "*arrangements where the private sector supplies infrastructure assets and infrastructure-based services that traditionally have been provided by the government*".[85] The OECD refers to Standard & Poor's (2005) definition of PPP which specifies the duration and type of the relationship as "*any medium-to-long term relationship between the public and private sector, involving the sharing of risks and rewards of multi-sector skills, expertise and finance to deliver desired policy outcomes*".[86] The EIB's description (2004) summarizes both definitions, together with an indication of the several types of PPPs: "*A Public-Private Partnership is a generic term for the relationships formed between the private sector and public bodies often with the aim of introducing private sector resources and/or expertise in order to help provide and deliver public sector assets and services. The term PPP is, thus, used*

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[79] "Defense Industrial Initiatives Current Issues: Cost-Plus Contracts". Center for Strategic and International Studies. Web: https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/media/csis/pubs/081016_diig_cost_plus.pdf.
[80] Gurtuna, O. "Fundamentals of Space Business and Economics", pg. 12. Springer Science & Business Media, 2013.
[81] Ibid.
[82] Ibid.
[83] Ibid.
[84] "Commercial Crew Program - The Essentials". NASA Website. Web: https://www.nasa.gov/content/commercial-crew-program-the-essentials/.
[85] Cangiano, M. et al. "Public-Private Partnerships, Government Guarantees, and Fiscal Risk", pg. 1. International Monetary Fund, 2006. Web: https://www.imf.org/en/Publications/IMF-Special-Issues/Issues/2016/12/31/Public-Private-Partnerships-Government-Guarantees-and-Fiscal-Risk-18587.
[86] "Public-Private Partnerships: In Pursuit of Risk Sharing and Value for Money". OECD, 2008. Web: http://www.oecd.org/gov/budgeting/public-privatepartnershipsinpursuitofrisksharingandvalueformoney.htm.

to describe a wide variety of working arrangements from loose, informal and strategic partnerships, to design build finance and operate (DBFO) type service contracts and formal joint venture companies".[87]

Therefore, generally speaking, PPP is used as a term to describe schemes that are "*partnerships between the public sector and the private sector (industry), for the purpose of delivering a project or a service traditionally provided by the public sector*".[88] More broadly, PPPs can be viewed from multiple angles: i.e. as institutional arrangements for financial relationships between the public and private sectors; a development strategy; or even rhetoric to deter opposition met from the "privatisation" label.[89] However one wishes to label PPPs, four common characteristics of these arrangements may be drawn from their use in practice:[90]

- A long-term relationship between public and private partners;
- Funding is sourced from both the public and private sector;
- An important decisional role is placed on the private entity;
- Partial transfer of risk from public to private parties.

PPP models have been traditionally employed by public institutions in a number of non-space public infrastructures such as road transportation, water management, and many more. Furthermore, they certainly do not constitute a novelty in the space sector either. However, their increasing rate of adoption by space agencies, and their structure in certain regards, mark a significant change in public-private space sector relations in the 21st century.

Key demarcations of PPP from the traditional space sector private contract have already been delineated – for example, funding is not provided only by public sources; the private partner can have a role at multiple stages, including a greater say in the design, development or operation of a service in accordance with the high-level requirements set by the public partner; and crucially, the distribution of risks, as they fall on both the public and private partners (see Figure 2).

PPPs can come in many forms dependent on a number of variables that are defined in the contract, including the designation of responsibilities, costs, risks, and the degree of involvement of the public and private actors at the different stages of a project.[91] While a PPP does not guarantee a success story when in place of a traditional contract, when executed appropriately some key benefits are expected from sharing risks and resources over a project's duration, including but not limited to improved efficiency, lower costs, and ultimately greater revenues for the private partner.[92]

Under the PPP model the private sector is thus further incentivised to optimise its design and build methods, finance, life-cycle, cost of operations and maintenance, as well as maintaining a high customer/market focus in order to maximise revenue.[93] The longer-term relationship with the public and private partner, the continuous financial intake, as well as private participation at multiple stages, all allow for ongoing updating and optimisation of procedures to improve overall efficiency over time – however

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[87] Killemaes, E. "Study of Public-Private Partnerships in the European Space Industry". Katholieke Universiteit Leuven, and Universiteit Gent, 2012.
[88] Bertràn, X., Vidal, A. "The Implementation of a Public-Private Partnership for Galileo - Comparison of Galileo and Skynet 5 with other Projects". Paper at the ION GNSS 18th International Technical Meeting of the Satellite Division, 13-16 September 2005. Web: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.456.4833&rep=rep1&type=pdf
[89] Khanom, N. A. "Conceptual Issues in Defining Public Private Partnerships (PPPs)". Paper at the Asian Business Research Conference 2009. Web. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.525.7599&rep=rep1&type=pdf.
[90] Adapted from: Nardon, L., Venet, C. "The Development of Public-Private Partnerships in the European Satcom Sector". Actuelles de l'IFRI. Web: https://www.ifri.org/sites/default/files/atoms/files/europeandspaceseries4ppps.pdf.
[91] Ibid.
[92] Ghandeharian, H., Shoamanesh, A. "Public Private Partnership (PPP) for Development of Space Sector". Presentation at National Space Conference, 17 - 19 September 2012, Islamabad, Pakistan. Web: http://suparco.gov.pk/downloadables/nsc7.pdf.
[93] Ibid.

conflicts of interests, meeting user requirements, and the risks placed on the private partner present key challenges to PPP implementation.[94]

PPP models can take a variety of formats and shapes, the main ones being described below:[95, 96]

- Design-Build (DB) or Build-Transfer (BT): Public partner contracts with private partner to design and build a facility in accordance with requirements set by the public partner. The private partner then takes title once completed and assumes the responsibility for operating and maintaining the facility.
- Design-Build-Maintain (DBM): Similar to DB, with the exception that the private partner maintains (but does not operate) the facility.
- Design-Build-Operate (DBO) or Build-Transfer-Operate (BTO): Similar to DB, except that following transfer of title to the public partner on completion, the private partner operates the facility for a certain period.
- Design-Build-Operate-Maintain (DBOM) or Build-Operate-Transfer (BOT): Combines design-build procurements with operation and maintenance of a facility for a certain time by the private partner.
- Build-Own-Operate-Transfer (BOOT): The public partner grants a franchise to the private partner to finance, design, build and operate the facility for a specific period of time. Title is transferred back to the public partner at the end of the period.
- Build-Own-Operate (BOO): The public partner grants the rights to finance, design, build, operate and maintain a project to a private partner, who retains ownership of the project. In this instance, the title is not transferred back to the public partner.
- Design-Build-Finance-Operate/Maintain (DBFO, DBFM or DBFO/M): The private partner designs, builds, finances, operates and/or maintains the facility under a long-term lease. At the expiry of the lease period, the facility is transferred back to the public partner.
- Private Finance Initiative (PFI): An arrangement in which the public sector contracts to purchase quality services on a long-term basis so as to take advantage of private sector management skills, incentivised by having private finances at risk. This includes concessions and franchises, where a private sector partner takes on the responsibility for providing a public service, including maintaining, enhancing or constructing the necessary infrastructure.

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94 Ibid.

95 Extracted from: "Applicability of Public Private Partnerships in the Next Generation of Satcom Systems". ESPI, Euroconsult SA, Milbank, Tweed, Hadley & McCloy LLP. ESTEC Contract Number 21487. ESA, 2010.

96 Additional "hybrid" PPP models can include: Competitive/Incremental Partnerships, Alliancing/Bundling, Joint Ventures.

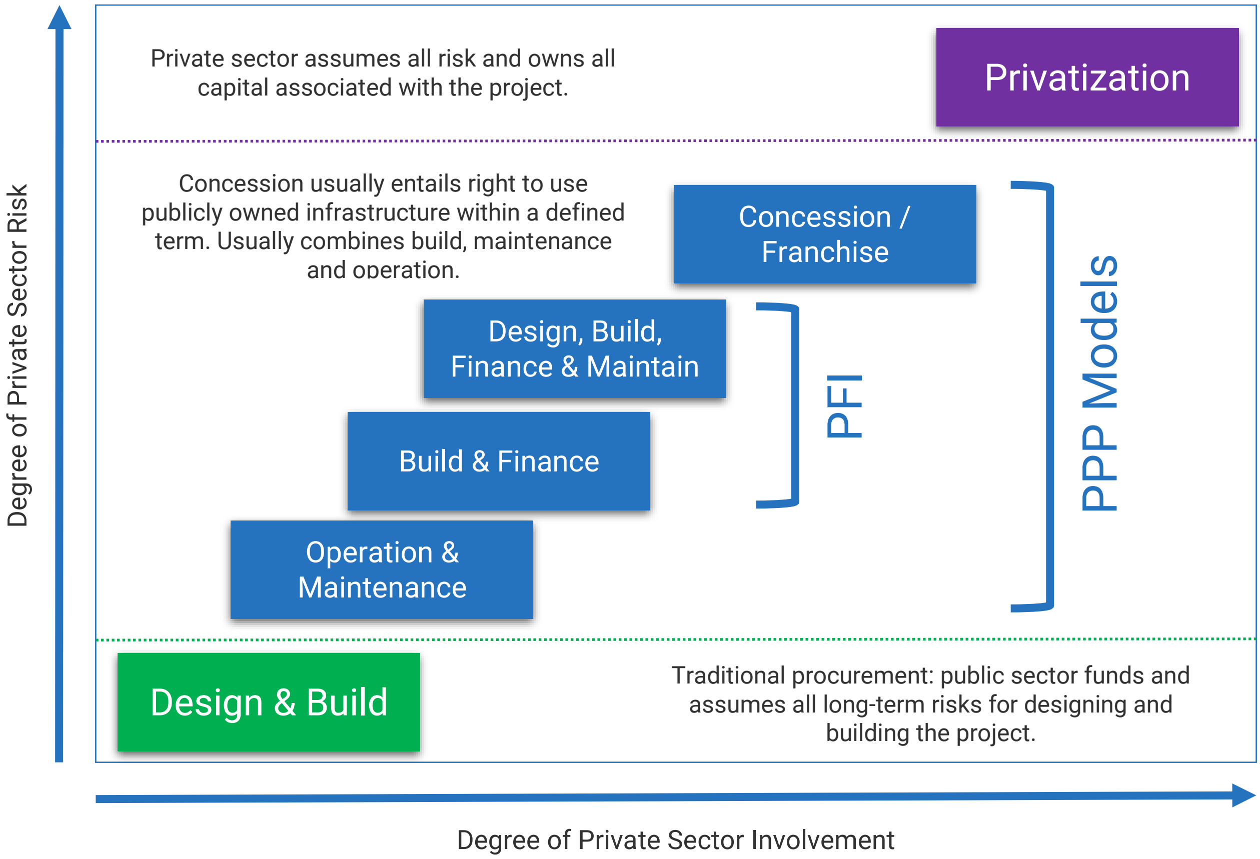

Figure 2: Traditional public infrastructure PPP. Adapted from Jones, K. L. "Public-Private Partnerships Stimulating Innovation in the Space Sector". The Aerospace Corporation, April 2018.

To summarize, public-private partnerships differ from traditional procurement contracts in the following ways:[97]

- Funding: Public funds are not dispensed at outset. Instead, a PPP private partner receives periodic payments, typically based on reaching specific project milestones.
- Duration: PPPs often extend beyond construction or deployment, and often include operations and maintenance.
- Requirement: "Performance versus Design". As PPPs should focus on performance rather than design requirements, performance requirements are based on stakeholder expectations and define what needs to be accomplished to meet the objectives of the project.
- Risk Allocation: In traditional procurement, risk is fully borne by the public sector. PPPs, on the other hand, offer a way for risk to be shared with the private sector.

Private Finance Initiatives (PFI)

It is worth discussing in greater detail an example of a Private Finance Initiative (PFI), as this particular model was successfully employed in the UK Skynet/Paradigm satellite telecommunication programme. Under the PPP umbrella, PFIs are a "*method of financing private investment, which requires the private sector design, build, finance and operate facilities*" (DBFO).[98] As with PPPs in general, PFIs are a flexible approach to private financing, development and operation of public programmes and infrastructures in the long-term, similarly transferring aspects of risk and control. While PFI agreements might vary from deal to deal, i.e. in terms of levels of risk and cost transfer to the private partner etc. – as they originated in the early 1990s under the UK Conservative party, PFIs entailed private contractors financing the development costs (in part) before renting the operational system back to the public sector. Regarding the Skynet programme, the UK has a long history of interest in space-based telecom systems for strategic reasons, and thus has had Europe's longest running national military communications programme.[99] The Skynet family of satellites emerged in the late 1960's, though its most recent generation, Skynet 5, was procured under a PFI valued at £4 billion. The prime contractor for the design and build of the complete Skynet 5 system was Astrium Services, while Paradigm Secure Communications Ltd, a wholly owned subsidiary of Astrium, is to manage and operate the system, delivering the final service to its end users on a 20-year contract. The primary end-user is the UK Ministry of Defence, which is given 80% service priority (thereby acting de-facto as an anchor customer), however the service is also provided to selected other partners as well as NATO.[100] Overall it has been stated that the British Skynet programme under PFI has been an "*unequivocal success; the satellites have exceeded lifetime expectancy and fulfilled completely their mission requirements*".[101]

Turn-key

On the extreme side of the interaction between public and private actors, and completely opposite to the design & build / built-to-order model, stand *turn-key* projects and services. This is a relatively new addition to space sector procurement, brought about by the rise in capabilities and autonomy of industry in recent years. In this type of interaction, the final product, system or service is in essence fully privately developed and ready to buy off the shelf by the public entity. This directly contrasts with the traditional structure of

[97] Adapted from: Jones, K. L. "Public-Private Partnerships Stimulating Innovation in the Space Sector". The Aerospace Corporation, April 2018. Web: https://aerospace.org/sites/default/files/2018-06/Partnerships_Rev_5-4-18.pdf
[98] "Private Finance Initiative and Public Private Partnerships: What future for public services?". European Services Strategy Unit. Web: https://www.european-services-strategy.org.uk/wp-content/uploads/2008/03/What-Future-for-Public-Services-.doc
[99] "UK Space Policy: a 'Hidden Success Story'", pg. 4. Royal Aeronautical Society. Web: https://www.aerosociety.com/Assets/Docs/Publications/DiscussionPapers/UKSpacePolicy.pdf
[100] Killemaes, E. "Study of Public-Private Partnerships in the European Space Industry". Katholieke Universiteit Leuven, and Universiteit Gent, 2012.
[101] "UK Space Policy: a 'Hidden Success Story'", pg. 4. Royal Aeronautical Society. Web: https://www.aerosociety.com/Assets/Docs/Publications/DiscussionPapers/UKSpacePolicy.pdf.

procurement within the space sector conducted through contracts, representing a PPP approach at its extreme.

The traditional "design & build" model in the space sector has remained the prime and possibly only source of procurement over the decades for significant reasons. Namely, in order to have a successful turnkey model, for the producer to avoid risks and ensure revenue, security must be found in an adequate customer base that will purchase their products. The turnkey approach is therefore reserved mostly for the most mature space companies and space domains, those with significant public and private customers, to the point that such systems or services could be considered as a commodity. However, traditionally in the space sector, because of limited and most often publicly-driven markets, the conditions for a private actor to sustain a turnkey model for public and private customers have not yet been favourable.

2.4 Agencies' "Catalyst" Role in Market Creation: The Case of ESA

In line with the objectives of this research, it is highly relevant to discuss another key function that space agencies have accomplished over the first 60 years of the space era, that is the "catalyst" role in spawning entirely new commercial or institutionally-governed operators for specific space applications domains, thereby opening up new markets.[102]

For example, this has been the case for the Centre National d'Etudes Spatiales (CNES), which in the late 1970s initiated the development of the SPOT Earth Observation satellites (in partnership with the Belgian Scientific, Technical and Cultural Services – SSTC, and the Swedish National Space Board - SNSB). The development of these systems was accompanied by the creation of the first commercial operator and dealer for space imagery, the company SPOT Image,[103] which to this day still commercialises remote sensing data (from both the new generation of SPOT satellites as well as the dual-use Pléiades constellation, among others).[104]

At a broader European level, it is worth discussing in detail the role of ESA in this regard, as its R&D and early-development undertakings have ultimately led, across the decades, to the creation of new sector-wide European entities in the fields of space telecommunications, remote sensing, and space transportation to name a few.

ESA is defined as an R&D entity mandated to be active in space science and the development of technology, and in optional space programmes at the discretion of its member states. To this end, ESA receives its budget for its mandatory and optional programmes from its member states, however, it is not standard procedure for ESA to manage the full operation of a system, at least not in the long term. An ESA managed operation is not impossible however, as Article V.2 of the ESA convention of 1975 states: "*In the area of space applications the Agency may, should the occasion arise, carry out operation activities under conditions to be defined by the Council by a majority of all Member States*".[105] However, it may be

[102] For an extensive analysis of the potential role of ESA in market creation, see: Mazzucato, Mariana and Robinson, Douglas K. R. "Market Creation and the European Space Agency".
Web: http://esamultimedia.esa.int/docs/business_with_esa/Mazzucato_Robinson_Market_creation_and_ESA.pdf

[103] SPOT Image was a public limited company created in 1982 by CNES, the French National Geographic Institute (IGN) and other space manufacturers. It is today a subsidiary of Airbus Defence and Space.

[104] Airbus Intelligence Website. Web: http://www.intelligence-airbusds.com/en/8289-imagery-services.

[105] Art. V.2 ESA Convention. See: https://esamultimedia.esa.int/docs/LEX-L/ESA-Convention/SP-1317_EN.pdf. See also Mathieu, C. "Space-Based Services in Europe: Addressing the Transition Between Demonstration and Operation", pg. 31. ESPI Report 17, 2009. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/119-space-based-services-in-europe-addressing-the-transition-between-demonstration-and-operation.

considered common for the Agency to seek an independent operator, transferring responsibilities for operations and user engagement, although providing support and necessary facilities if need be.

In this sense ESA has played a significant role in the early development of space systems and applications, but second to this has had a role in catalysing the creation of entities for the operation of services that it has developed. The agency, here in the case of space services, is crucial in the process of establishing a sustainable service – it initiates, researches, develops a space application from its inception to pre-operation, importantly demonstrating the technology and outlining its financial aspects. From successful demonstration and pre-operational capabilities, the agency is then either in the position to select an operator or establish one.[106] Once a service is in operation, the development agency is likely to maintain a strong relationship with the operator, helping in the integration of a space system with other systems and providing expertise.

The original developing space agency, in many cases, still acts as the development body for the operator, becoming the procurement source for new generations of space systems. On the side of the operator, once selected there is a direct transfer of responsibilities from the development agency to the operator – besides obviously operating the system, the operator has the responsibility of guaranteeing the availability and continuity of its products and services, including but not limited to engagement with its users, identifying requirements for and procuring new systems, and ensuring cash-flow up the value chain.[107] Once this process is complete in its technical, financial and wider operational aspects, and somewhat cyclical in that the developer still plays a role as a procurement source, a service is considered sustainable. This process has occurred in several cases in ESAs history, in meteorology, telecoms, and launchers, however each instance has very significant details of difference. Notably, in the cases of meteorological services and telecommunications, the former were maintained as a public entity for a public good, while the later stimulated a sufficient market to be privatised. Both of these entities, however, were established as public IGOs in the 1970s, only later did they evolve. These cases will be discussed in the following paragraphs.

2.4.1 Meteorology: EUMETSAT

The establishment of a European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) is an interesting example of the role of space agencies in catalysing the creation of new space-related critical infrastructures, institutions, value chains, and the establishment of a dedicated operational entity. EUMETSAT was established in 1986 as a meteorological satellite operator to provide the National Meteorological Services of its member states, and wider users, with continuous weather and climate related satellite data services through exploiting European weather and climate observation systems. EUMETSAT conducts a wide range of weather and climate-related activities, generally including: the development of complete end-to-end systems, relying on ESA for the development of satellites, a long-term commitment to the operation of such satellite systems, the archiving and distribution of data for monitoring weather, climate, oceans, and atmospheric composition, as well as the processing of Essential Climate Variables (ECVs), and the support to international capacity building initiatives related to meteorology and climate.[108]

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[106] Mathieu, C. "Space-Based Services in Europe: Addressing the Transition Between Demonstration and Operation", pg. 28. ESPI Report 17, 2009. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/119-space-based-services-in-europe-addressing-the-transition-between-demonstration-and-operation.

[107] Ibid.

[108] Schulz, J. et al. "CLIMATE@EUMETSAT: EUMETSAT Climate Data Records". EUMETSAT, 2016. Web: http://www.cmsaf.eu/EN/Outreach/Workshops/past_workshops/Workshop2016/pdf/CLIMATE@EUMETSAT:%20EUMETSAT%20Climate%20Data%20Records.pdf?__blob=publicationFile&v=4.

In terms of its role and function, EUMETSAT:[109]

- Provides relevant meteorological data services to national meteorology offices in an operational way;
- Owns, manages and operates meteorology satellites and ground systems and ensures the programmatic overview of the development of new systems and their integration through its relations with ESA, industry and its member states;
- Obtains its operational funding from the budgets of the ministries responsible for meteorology or from national meteorology offices, and re-invests in infrastructure.

It is clear that EUMETSAT is mandated with a wide set of roles within the field of meteorology. In a sense this is one of the key factors leading to the spin-off of EUMETSAT from ESA, since EUMETSAT's role as an operational entity goes beyond the traditional role of ESA as an R&D entity. However, sharing the same European political environment, many characteristics of EUMETSAT are based on the structure of ESA: i.e. both EUMETSAT and ESA are IGOs with member states, have a legal personality, and have mandatory and optional programmes funded by their member states. Furthermore, and notably, ESA acts as the procurement body for EUMETSAT's satellites. While being responsible for the overall system architecture, EUMETSAT procures directly its launch services and the development and operations of its systems. These EUMETSAT direct procurements are made under the Best Value for Money criteria.

EUMETSAT receives its operational funding, ensuring sustainability and cash-flow up the value chain, from its individual member states. One of the key reasons for this is that in the field of meteorological satellites there is no sufficient or sustainable market in which to commercialise its products, as applications are mainly driven by science. Rather, the National Meteorological Services of its member states act in many ways as the customers and a conduit, providing the data products and services to their respective nation's consumers (i.e. public institutions, private companies, and citizens) as a public good. In this line, ESA also acts as the procurement body for EUMETSAT's satellites – EUMETSAT engages with its users in continuous feedback, aiding it in defining evolving user needs and high-level requirements for new generations of satellites and data services. Subsequently, EUMETSAT communicates these needs for satellite observations to ESA, which acts as the research, development and administrative body for new batches of satellites.

Since recently, EUMETSAT also supports the European Commission in the implementation of the EU Copernicus programme – for which a different set-up has been put in place.

2.4.2 Telecoms: EUTELSAT

EUTELSAT shares a very similar history to that of EUMETSAT, in that it was established as an IGO with a legal personality, however developments within their respective domains caused significant differences in how each organisation advanced. EUTELSAT's interim body was created in 1977 as an IGO with the role and responsibility to develop and operate satellite telecommunications infrastructure for Europe, mandated to operate the first generation of communication satellites commissioned by ESA.[110] However, the convention establishing EUTELSAT was later open for signature in 1982, entering into force in 1985.[111] EUTELSAT was created with the purpose to:[112]

[109] Mathieu, C. "Space-Based Services in Europe: Addressing the Transition Between Demonstration and Operation", pg. 25. ESPI Report 17, 2009. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/119-space-based-services-in-europe-addressing-the-transition-between-demonstration-and-operation.

[110] EUTELSAT Website. Web: https://www.eutelsat.com/en/group/our-history/1977-1989.html.

[111] EUTELSAT Convention. Web: https://www.eutelsatigo.int/en/wp-content/uploads/sites/2/2014/12/E-Convention-establishing-EUTELSAT.pdf.

[112] Mathieu, C. "Space-Based Services in Europe: Addressing the Transition Between Demonstration and Operation", pg. 25. ESPI Report 17, 2009. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/119-space-based-services-in-europe-addressing-the-transition-between-demonstration-and-operation.

- Provide relevant telecommunication services to telecommunication operators in an operational way;
- Own, manage and operate telecommunication satellites and ensure the programmatic overview of the development of new systems and their integration through their relations with industry;
- Sell their services to telecommunication operators and re-invest in infrastructure.

As EUTELSAT progressed and effectively demonstrated its operational capabilities in areas such as Direct-to-Home (DHT) television broadcasting, notably with commercial potential, restructuring became a topic of discussion. In 1999, Member States of EUTELSAT successfully passed an amendment to its original establishing convention, and in 2001 "*all the assets, operational activities and related liabilities and commitments of the intergovernmental organisation EUTELSAT were transferred to Eutelsat S.A.*".[113] This was effectively the privatisation of EUTELSAT, allowing the expansion of its commercial activities even beyond Europe. However, according to the amended convention, the original EUTELSAT still maintained a substantial role in protecting the European wide public good aspects of the new company and ensuring its concordance with international law.[114]

The evolution of EUTELSAT into a commercial company from its original public-oriented structure was driven by the substantially mature and large space-based telecommunications market.[115] Crucially, differentiating it from EUMETSAT's trajectory, the existence of a significant market base enabled its sustainability from non-publicly sources of operational funding, securing cash flow up the value chain from wider stakeholders, i.e. telecommunications service providers. A breadth of broader applications and sub-markets could be facilitated in telecommunications with commercial dimensions, which was not the case in meteorology which is still considered a public good with a somewhat limited scope in terms of applications and market potential. While the technologies at the disposal of EUTELSAT will route back to "*involvement of development agencies and research funding*", essentially public sources, unlike EUMETSAT, EUTELSAT procures its new generation of satellites directly from industry.[116]

2.4.3 Launch Services: Arianespace

Another prime example of how ESA's early development activities led to the establishment of a successful commercial company is the Ariane programme. Throughout the 1960s and 1970s there was a growing need for independent launching capabilities in Europe. Access to space, particularly for the launch of telecommunication satellites,[117] was soon deemed of strategic importance for any kind of further development of the European space sector. Europe's first organisation to this end, and a precursor to ESA, was the European Launcher Development Organisation (ELDO), formed in 1962 and coming into force in 1964.[118] The development of European launching capabilities under ELDO however, namely the Europa programmes, was characterised by political disagreements, and, ultimately, failure in developing a viable rocket.

The year 1973 saw some drastic changes in light of the struggling efforts in prior years – to begin with, the Europa rocket programme was abandoned. Nevertheless, the will for European launching capabilities had certainly not dissipated, and among European countries, for France in particular, the need for independent access to space continued to be of paramount strategic significance. Thus, at the European

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[113] EUTELSAT IGO Website. Web: https://www.eutelsatigo.int/en/about/restructuring/.
[114] EUTELSAT Amended Convention. Web: https://www.eutelsatigo.int/en/wp-content/uploads/sites/2/2014/12/E-Amended-Convention-281102.pdf.
[115] Mathieu, C. "Space-Based Services in Europe: Addressing the Transition Between Demonstration and Operation", pg. 25. ESPI Report 17, 2009. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/119-space-based-services-in-europe-addressing-the-transition-between-demonstration-and-operation.
[116] Ibid.
[117] Notably, following the notorious political incident of the Symphonie telecom satellite launch.
[118] "History of Europe in Space. ELDO/ESRO/ESA: Key Dates 1960-2018". ESA Website. Web: https://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/ELDO_ESRO_ESA_br_Key_dates_1960-2018.

Space Conference of 1972 the French Minister of Industrial and Scientific Development proposed a European plan for the launching of telecommunication satellites, while the British Minister proposed the merging of ELDO and ESRO into a single European Space Agency.[119] France, having a strong connection to launching capabilities, presented the "Launceur a Trois Etages de Substitution (L3S)" at this conference, bearing over 60% of the initial costs. This was subsequently optimised and accepted by key European players in 1973.[120] Europa was dead, but a new, more consolidated, European effort had been founded – through ELDO and ESRO and the later finalisation of the establishment of ESA – with France taking the lead. The French L3S programme was worked into the broader European through the 1973 "package deal" [121], and thus the later renamed Ariane Launcher Programme was born, beginning development through the ESA framework in 1974.[122]

Unlike Europa, Ariane was conceived in a framework where European-wide management and responsibilities replaced a clear-cut division of tasks among European nations. Within the new framework, CNES was given full technical and financial delegation from ESA to manage the programme, in exchange for paying the largest share of the project (62.5%), assuming the risks of cost overruns, and ensuring a minimum of 80% industrial return to all participants in the arrangement.[123] Although from a financial perspective the development of Ariane encountered considerable hostility, particularly in France, from a technical point of view no major hurdles were faced. The inaugural launch of Ariane 1 eventually took place in December 1979, opening a new era in the balance of power in the international space arena.[124]

Building on the developments of the Ariane programme, in 1980, the world's first commercial launch service provider was formed, Arianespace. This company was established to promote, market and manage Ariane operations, on a nascent worldwide launch service market. This seemed like a natural progression in the context of the emerging and maturing global satellite market, which coincided with the need for launch systems, therefore the commercial potential for satellites in general became a market driver for launcher systems. Since then, Arianespace has achieved worldwide renown and success (claiming 60% of the worldwide commercial launch market in 2014), ultimately managing a family of European rockets which, as of 2018, on top of the latest iteration of Ariane, include also the medium-lift Soyuz and Vega.

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[119] "The Origins of Ariane". ESA Website.
Web: https://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/The_origins_of_Ariane.

[120] "Thirty-Five Years of Ariane: How Ariane Was Born". ESA Website.
Web: https://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/Thirty-five_years_of_Ariane_how_Ariane_was_born.

[121] For a detailed description of the so-called "1973 package deal" see:
Krige, J., and Russo, A. "A History of the European Space Agency 1958-1987", pp 363-374. Volume 1. ESA Publications Division ESTEC, Noordwijk. 2000.

[122] Aliberti, M. and Tugnoli, M. "The European Launchers Between Commerce and Geopolitics", pg. 14. ESPI Report 56, ESPI, Vienna, 2016. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/10-the-european-launchers-between-commerce-and-geopolitics.

[123] Sillard, Y. "France and Launchers". In: Proceedings of an International Symposium on "The History of the European Space Agency", pp 69-78. ESA SP-346. 11-13 November 1998, London, 1999.

[124] Aliberti, M. and Tugnoli, M. "The European Launchers Between Commerce and Geopolitics", pg. 14. ESPI Report 56, ESPI, Vienna, 2016. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/10-the-european-launchers-between-commerce-and-geopolitics.

3 Unfolding Trends and Approaches in the Space Sector

3.1 A New Approach to Space

In recent years, the so-called New Space dynamic refers to the emergence of novel actors, primarily private, and their ventures, and implications for the global space sector – the framework of which contrasts with the earlier period of space activities and endeavours that were traditionally public-driven and funded.

In the second decade of 2000, the evolving dynamic promises to challenge the traditional model of the space sector with a rise in the role of private enterprise, essentially aiming to facilitate reduced costs for spaceflight and spaceflight technologies,[125] and unlocking commercially viable markets and opportunities to generate revenue. The convergence of industrial verticals, academia, systems of governance and sectorial domains is also a prominent feature of this changing paradigm, integrating new concepts, technologies, and processes both into the space sector and emerging from it. The concept itself is exemplified by (see Figure 3):[126]

- New entrants in the space sector including large information and communications technology (ICT) firms, start-ups and new business ventures;
- Innovative industrial approaches with announcements and initial development of ambitious projects based on new processes;
- Disruptive market solutions offering, for example, integrated services, lower prices, reduced lead times, lower complexity or higher performance among other value proposition features;
- Substantial private investment from different sources and involving different funding mechanisms;
- New industry verticals and space markets targeting the provision of new space applications;
- Innovative public procurement and support schemes involving new R&D funding mechanisms and costs/risks sharing arrangements between public and private partners;
- Involvement of an increasing number of space-faring nations investing in the acquisition of turnkey space capabilities or even in the development of a domestic space industrial base.[127]

Although typically the term "New Space" is primarily used to describe the evolving nature of the private space industry in the U.S. context, it also has implications for broader changes in the relationships between the private and public sectors globally, the increased usage of PPPs in Europe being a key example of this. Overall, "New Space" places more of the direct costs and risks upon private companies as they have matured their processes and technologies in specific space domains, in turn granting them far more autonomy and influence on the direction of the space sector, on top of commercial capabilities and emerging revenue sources.[128]

In accordance with the evolving strategy of ESA, as announced at the Ministerial Council of 2016, the adoption of the resolution entitled "Towards Space 4.0 for a United Space in Europe" signifies

[125] Martin, G. "NewSpace: The "Emerging" Commercial Space Industry", pg. 6. NASA Ames Research Center. Web: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011156.pdf.

[126] From: Vernile, A. "The Rise of Private Actors in the Space Sector". ESPI, 2018. Executive Summary. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/304-executive-summary-the-rise-of-private-actors-in-the-space-sector.

[127] Vernile, A. "The Rise of Private Actors in the Space Sector". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2018. Web: https://www.springer.com/de/book/9783319738017.

[128] Ibid.

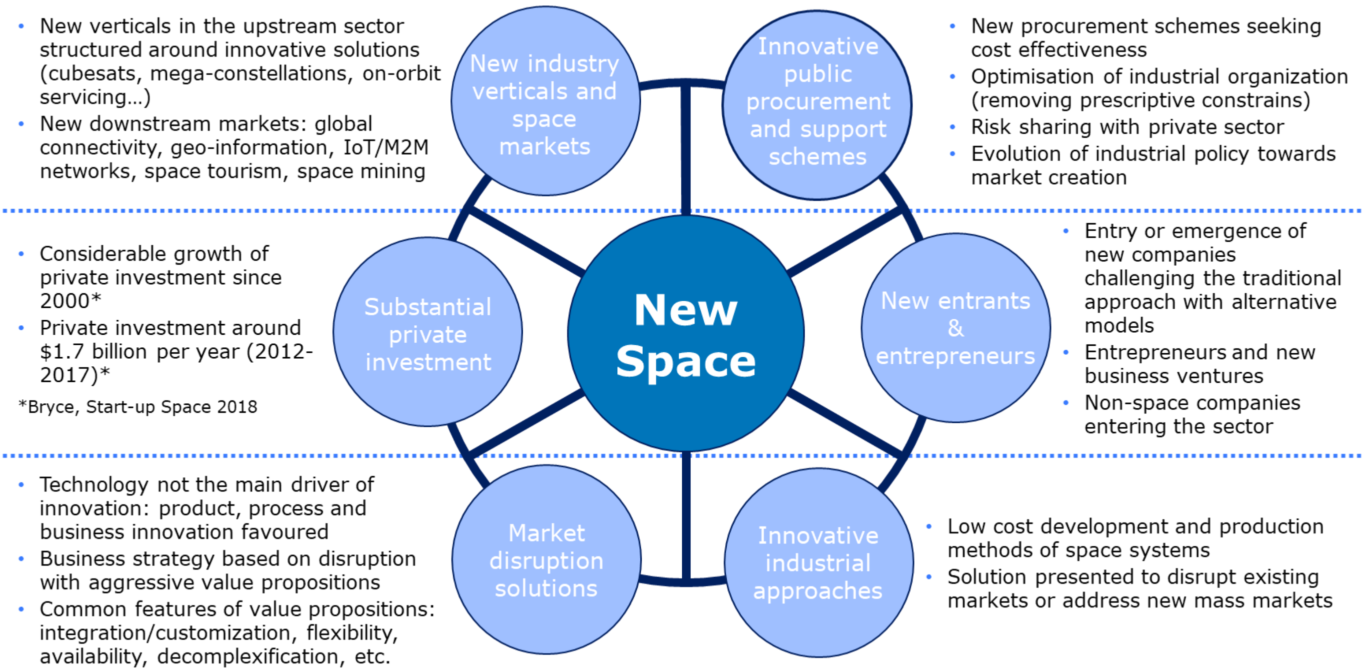

Figure 3: Characteristics of the "New Space" dynamic. Source: ESPI.

acknowledgement and adaptive transition into the new, increasingly interconnected and participatory, space age.[129] The resolution outlines the vision for a "United Space for Europe", with ministers showing confidence in the ability of ESA to "conceptualise, shape and organise the change in the European space sector and ESA itself" – acting to respond to needs of its member states, regional needs of Europe, organising and integrating institutions and industrial stakeholders, as well as representing Europe on the international stage as a broker and mediator for international cooperation.[130]

In parallel to the description of previous industrial ages, ESA's conceptualisation categorises the history of the space sector into distinct chapters, distinguished by their activities, actors and their interactions, and overall ecosystem of development and operation.

Space 4.0, building on the previous three chapters of space age evolution, can be characterised by the multiplication of actors and their means of interaction, and can be entitled the "age of Participation" within the space sector.[131] This emerging environment, with a plethora of novel actors, is coinciding with novel models of interaction between governments, the private sector (small and large companies), and the wider aspects of society and politics.[132] In this sense, the overarching objective of Space 4.0 is to foster and increase the interconnectivity between science, industry, politics and society,[133] broadening the scope of the space sector in terms of active participants, and further integrating it into the wider society.

[129] "Council Meeting Held at Ministerial Level on 1 and 2 December 2016. Resolutions and Main Decisions". ESA, Lucerne, 2016. Web: https://esamultimedia.esa.int/docs/corporate/For_Public_Release_CM-16_Resolutions_and_Decisions.pdf.

[130] "European Ministers Ready ESA for a United Space in Europe in the Era of Space 4.0". ESA Website. Web:https://www.esa.int/About_Us/Ministerial_Council_2016/European_ministers_ready_ESA_for_a_United_Space_in_Europe_in_the_era_of_Space_4.0.

[131] Ibid.

[132] "What is Space 4.0?". ESA Website. Web: https://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0.

[133] Ibid.

As mentioned by ESA officials, Space 4.0 is not occurring within an isolated bubble within the space sector, but rather can be considered embedded in the so-called "Fourth Industrial Revolution",[134] encompassing manufacturing and services. Moreover, in some European countries the term Industry 4.0 has also gained traction to describe this broader trend, referring to the collective advancements within the manufacturing industry, driven by scientific and technological advances in artificial intelligence, digitalization, 3-D printing, robotics and a number of other areas – all promising radical transformations for not just industry, but also the wider society and economy.[135] In this regard, it is expected that a feedback loop between Space 4.0 and Industry 4.0 will develop, since integration and participation of different actors and sectors is at the forefront, but this may also entail spin-off/spin-in of technologies, processes and expertise from terrestrial industry to space, and from space back to traditional industry.

ESA is eager to take on board and expand on the implications of Industry/Space 4.0 and what it can bring to the space sector, integrating the idea into its overarching strategy for the coming decade. In this vein, ESA has devised its own interpretation of Space 4.0, namely Space 4.0i, which outlines the core objectives of Space 4.0's uptake in the agency. The four "i"s of ESAs Space 4.0i entail distinct categories of tasks, or principles, which ESA seeks to integrate into its policies and programmes in the age of Space 4.0, including: Innovation – adopting and progressing increasingly disruptive and risk-taking technologies; Informing – transforming ESA's role of engagements with wider public and user communities; Inspiration – launching newer and bolder initiatives and programmes for both current and future generations; and Interaction – enhancing existing partnerships with its member states, European institutions, international actors, and industry, as well as forging new ones.[136] While evolutions in domains such as space science may be non-revolutionary and gradual, and general objectives such as supporting industrial competitiveness will remain unchanged, their implementation strategy in the wider scheme of things will contain new approaches and new types of partnerships.

Overall, aside from the terminology, it is clear that the global space sector in the late 2010s is undergoing distinctive, impactful and long-lasting changes. The following paragraphs describe in greater detail the main dynamics at play.

3.1.1 New and Increased Number of Actors

One of the first, distinctive trends that characterises the evolution of the space sector in recent years is the clear increase in the number of entities capable of conducting space activities, both public and – even more so – private.

Regarding the public sector, recent years have seen the emergence of a considerable number of new space-faring nations (i.e. countries that have developed access to space capabilities, or more likely, launched their first satellites), as well as the establishment of several new space agencies (Australia, Luxembourg, Portugal, to name a few). There are many drivers contributing to why evermore countries are settings sights on space ventures, but at the core are the benefits that a flourishing national space

[134] See: Schwab, K. "The Fourth Industrial Revolution". World Economic Forum, 2016. Web: https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab.
[135] "46th Annual Meeting of the World Economic Forum to Focus on Fourth Industrial Revolution". World Economic Forum press release, 2016. Web: https://www.weforum.org/press/2016/01/46th-annual-meeting-of-the-world-economic-forum-to-focus-on-fourth-industrial-revolution/.
[136] "Space 4.0i". ESA Website. Web: https://m.esa.int/About_Us/Ministerial_Council_2016/Space_4.0i.

sector can bring for national interests, both domestically and internationally. Access to space, notably in this context the services it can provide, is becoming an increasingly crucial pillar of many critical infrastructures, i.e. telecommunications, remote sensing, and navigation systems; permeating into traditional sectorial domains ranging from national security, agriculture, transport, and energy. Autonomy in such activity is one of the main drivers for access and the emergence of new, independently space-faring nations. There is no doubting of the benefits of space applications for domestic social and economic priorities, as such it is in the national interest of many countries to invest in space-faring activities in both the short- and long-term. In this vein, the space sector is a growing market in the world economy, and as such is stimulating space ventures in otherwise non-space-faring countries as it expands at an accelerating rate. In itself, this provides novel opportunities for international trade and partnerships between countries and regions.

The rising levels of autonomy for individual nations in the space sector is also reflected in the private domain. As discussed, the public sector has always been at the forefront of space activity, dictating its overall strategy, needs and requirements, utilising the private sector as a procurement source in fulfilment of its objectives. In this sense, in space ventures private actors have been secondary and acting mostly in response to public sector needs, supported almost completely by public funding. However, as technologies are becoming more consolidated and affordable, the space industry itself is becoming increasingly mature, and thus increasingly able to conduct space activities themselves.

Furthermore, the accelerated usage of PPPs not only brings about private investment on scales greater than before, but also has implications for the autonomy, role and responsibilities of private actors (as discussed later). Several factors have led to this fairly recent shift: notably, budgetary limitations on public sector space activity have always been a restraint, thus increased outsourcing has been an attractive alternative to public entities and, similarly, as the market and potential for revenue for private companies have grown, so too has commercial viability. Expanding PPP usage is just one signifier of this, although PPPs are conventionally used in circumstances where the private sector is drawn in to fulfil a public good. However, more commercially driven approaches which involve, e.g. private-to-private, models are being utilised, opening up room for new private entrants as it grows.

Key to this is the opening of new markets. This is particularly exemplified by the mass advent of smallsats, in which the reduced costs of development allow private companies to bear the financial burden of participation in space missions, in contrast to the high monetary thresholds in previous decades.

This recent rise of private actors in the space sector is not just limited to large or even solely space-focused companies, but can generally put into two categories:[137] first, non-space companies, primarily in the field of ICT, looking to expand and collaborate in the field of space applications; second, start-ups or new space companies utilising both public and private funding to initiate new business models in the space sector, addressing both traditional space markets with disruptive solutions, or seeking to create novel footholds into emerging space markets. The novel processes, business models or solutions which come alongside these new types of more independent entrants into the space domain bring challenges to the traditional way of doing things in the space sector.[138]

Among various examples of novel entrants in space activities, it is worth mentioning the university and academia environment. While universities are certainly no strangers to space science and research, the emergence of university-developed satellites marks universities as having somewhat space-faring capabilities. This change has primarily been enabled by the emergence of small satellites, reducing costs and time of development, and allowing them to be constructed within university tier facilities, permitting

[137] Vernile, A. "The Rise of Private Actors in the Space Sector". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2018.
[138] Ibid.

smaller-scale actors to participate. Secondarily, while universities do not possess their own launching capabilities, the size factor of small satellites facilitates them being taken aboard on opportunity ride-sharing, otherwise known as "piggyback",[139] often for free in cases where additional space/weight is available on top of the original payload. Besides the obvious benefit of giving universities and students access to and participation in space activities, the advantages include: low-cost orbital platform from hands-on research, training for young space professionals in all levels of design, development and operation, and innovation by capitalising and improving on constraints on size, weight and power – bringing opportunities to test and qualify new concepts in space for new operational approaches, components, and measurement techniques.[140]

As mentioned, these new entrants are supported by both public and private funding, having the potential to bring novel innovations, not just in technical form, into the space sector, and overall to increase the diversity, participatory capacity, and sources of funding of activities in the space sector at large – each of these will be discussed further in the following paragraphs.

3.1.2 New Mechanisms and Availability of Funding

Space activities and endeavours are notoriously expensive. Indeed, throughout the first 60 years of the space age, funding for most if not all global space programmes was sourced publicly, not least because of the continuous strategic importance of the space domain.

In the European context, the vast majority of space sector funding comes from individual national budgets through national programmes, or through intergovernmental organisations such as ESA, or supranational organisations such as the EU. In the EU context, funding comes through Research and Innovation Programmes (i.e. FP7 and Horizon 2020), the European Investment Banks (EIB) Intermediated Loans, the European Fund for Strategic Investment (managed by EIB), and the Programme for the Competitiveness of Enterprises and SMEs (COSME). As detailed previously, ESA has several mandatory programmes to which all of its member states contribute, but also a larger number of optional programmes in which member states decide their own levels of contribution. While private sector investment has been somewhat limited and insignificant compared to public sources, traditional private funding has been received through corporations, investment banks, and public markets (i.e. the stock market).

However, new sources and mechanisms of funding, from both public and private domains, are supporting the emergence of new entrants into the field as discussed in Chapter 3.1.1 above. Indeed, not only are new sources appearing, but the mechanisms through which funding is transferred, and subsequently the nature of the value chain and the relationship between stakeholders, is shifting. As highlighted in Chapter 2, moving away from the traditional method of contracting has implications for the roles, responsibility, and levels of autonomy of private actors, in additional to the extent of financial investment.

The public sector has also broadened and adapted its practices in terms of allocating funding and stimulating new private companies. The establishment of Business Incubation Centres (e.g. ESA BICs) and the increasing usage of prizes and challenge schemes are two of these adaptations of the public space sector, drawing in from a wider pool of talent, serving to foster new players and business opportunities.

[139] For an analysis of small satellites market and launch strategies see: Tugnoli, M., Sarret, M. and Aliberti, M. "Executive Summary: Business and Policy Perspectives on Micro Launchers." Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/174-executive-summary-european-access-to-space.

[140] Cummings, D. W. "Small Satellites: Advancing University Scientific Research and Workforce Development". Universities Space Research Association. Presentation to the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space, 2014. Web: http://www.unoosa.org/pdf/pres/stsc2014/tech-03E.pdf.

While different for individual funding mechanisms, this highlights the wider effects of shifting away from traditional funding sources, which is of most significance for more commercialised approaches in which private risk is heightened. These most notably include angel investors, venture capital firms as well as private equity.

These trends in private funding sources are currently considerably more advanced in the U.S. due to dedicated fostering of the emergence and growth of private industry, with U.S. private investment alone being "*higher than available European funds to support industry competitiveness and innovation*".[141] This typically places pressure on Europe to follow suit to maintain a competitive edge. Replication and European adaption of these trends is a promising prospect for private space sector activities within Europe.

3.1.3 Technological Spin-in and Digitalisation

The term "spin-in" may best be defined in opposition to its widely known sister procedure "spin-off" – i.e. spin-off describers the process in which technological innovations which are developed in – and primarily for – the space sector, are then funnelled downstream for similar or new uses in terrestrial applications, generally finding a market. Conversely, spin-in entails innovations for originally Earth-based uses that are taken aboard by the space sector for uses in space systems. Besides technological transfer, spin-in additionally entails the transfer and integration of human capital and know-how from wider domains. There are several examples technological and industrial processes spin-in from the automotive and ICT sectors, including 3D printing now employed in rocket manufacturing, and machine learning algorithms and cloud computing that are massively employed in space big data processing.

In many ways this is incredibly valuable to the space sector for spin-in can save huge expenditures in associated costs and time for development as the product, while possibly in need of tweaking for space applications, is relatively ready for immediate use. On top of this, insight from expertise in external fields can be an effective means of developing innovative solutions, exploiting novel perspectives and know-how. While advantageous for the space sector in itself, spin-in can have a dual benefit for its original market source: first in that the market gains a new niche in space, and second, that it can help the market "*gain additional market visibility and penetration in terrestrial applications*." Once it is spun into a space venture "*it is likely to benefit from the public's admiration for products that are space proven*"'.[142]

A practical example among many of a successful spin-in comes from the INNOspace Masters competition overall winner of 2016: two computer scientists from the University of Würzburg won the award for developing the "world's first wireless satellite" named Skith.[143] To add some context to why this innovation is of significance, traditionally the components within satellites have been connected using cumbersome wires known as harnesses – so far necessary for satellites, but "*costly, heavy and a major risk factor*". However, the proposed harnessless satellite uses short range, high speed radio communication links to interlink the satellites components, thus avoiding the need for heavy wiring.[144] This new system utilises spin-in from Industry 4.0, notably a combination of modular and fault-tolerant software with ultra-wideband technology, and essentially promises to bring a number of benefits including: "*higher reliability for satellites, cost and development time reduction, reduction of launcher price, higher flexibility to add/substitute devices and computers as well as easier to outsource modules and reuse*

[141] Vernile, A. "The Rise of Private Actors in the Space Sector". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2018. Web: https://www.springer.com/de/book/9783319738017
[142] Simpson, M. "Spin-Out and Spin-In in the Newest Space Age", pg. 76. ISU, 2010. Web: https://iisc.im/wp-content/uploads/2016/07/Spin-Out-and-Spin-In-Simpson.pdf.
[143] "World's first wireless satellite". Julius-Maximilians-Universität Würzburg, JMU, 2016. ScienceDaily. Web: www.sciencedaily.com/releases/2016/05/160512084905.htm.
[144] INNOspace Masters Challenge. Web: https://www.innospace-masters.de/challenges/#DLRChallenge.

modules in different missions/satellites".[145] In practical terms, the implementation of such a system will bring benefits to stakeholders across the spectrum, from manufacturers to space agencies and research institutions. This example additionally highlights the increasingly utilised mechanism of using prizes and competitions (see Chapter 3.1.4) to stimulate innovative solutions within the space sector from external sources – this joint DLR and INNOspace Masters competition being specifically open to and directed at SMEs, universities, and other non-university research institutions.

3.1.4 Wider and Deeper Engagement

As already outlined, new trends in the space sector have opened it up to participation by wider communities – i.e. reduced costs for small satellites have allowed smaller companies and universities to engage in developing and deploying their own spacecraft. However, widening the participatory capacity of the space sector is also being broadened to be inclusive of public expectations and input. Traditionally, the space sector has operated in quite an isolated manner from public input. While considerable efforts for improved educational outreach activities and the promotion of programmes and missions have solidified, active public participation had not been conducted by the space sector in the same way – this is true for space agencies in particular, which serve as public actors. Although this is not necessarily the fault of the agencies as concerns traditional space activities, it is somewhat difficult to perceive how public input could be facilitated or beneficial overall. A shift away from this previous trend – partially driven by a growing culture of public participation, partially by ICT as a communicative tool, and partially by the diversification of space sector activity – places growing value on public feedback and its integration. Means of engagement include surveys, consultation events, as well as user needs and requirements assessments, beyond the traditional linear educational style of communication. Active participation from the public has also been seen in crowdfunding approaches for the development of a few small satellites, including SkyCube, KickSat, Ardusat and Hayabusa 2.

In recent years, a growing trend of using competition challenges for prizes and awards has been employed to incentivise private ventures. These types of schemes are valuable for fostering smaller private space companies and "astropreneurs". In addition, competitions may be used to select a prime contractor for a project, aiding the project's development as well as supporting the budding business. Challenges and prizes are relatively recent tools used in the space sector to stimulate innovation and entrepreneurship but they are multiplying, and have been employed by governmental agencies as well as private organisations, and in some instances jointly.[146] They have been used in a wide variety of space-related domains, and may include "*cash prizes for new concepts, technology development, incremental developments or technology implementation in new products and services*".[147] This non-traditional method of innovation stimulation can bring in innovators from outside the space sector, and has proven utility in gearing technology diffusion towards end-user communities, and additionally in providing novel opportunities for outreach to the public.[148]

In the specific case of the U.S., the use of prizes, competitions and crowdsourcing has played a significant role in encouraging innovation and helping NASA solve tough problems. These mechanisms offer competitive awards and the use of crowdsourcing solicits products, services, ideas, or content contributions from many people, oftentimes (but not necessarily) through the Internet. These prizes are

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[145] "Technology transfer goes both ways – from Earth into space and from space to Earth". AZO Space of Innovation, 2016. Web: https://www.space-of-innovation.com/technology-transfer-goes-ways-earth-space-space-earth/.
[146] "Space and Innovation", pg. 77. OECD, 2016. Web: https://read.oecd-ilibrary.org/science-and-technology/space-and-innovation_9789264264014-en#page74.
[147] "Space and Innovation", p. 77. OECD, 2016. Web: https://read.oecd-ilibrary.org/science-and-technology/space-and-innovation_9789264264014-en#page77.
[148] Ibid.

often financed by non-space actors and are utilised to mobilise resources and interest. The most high-profile prize was represented by the X Prize Foundation which in 2004, funded the Ansari X Prize relating to suborbital spaceflight. The first part of the Ansari X Prize, $10 million, was won by Spaceship One. This award was a major milestone in the development of private spaceflight capabilities.[149] A similar prize was introduced in 2007, the Google Lunar X Prize, intended to inspire a new generation of private investment in space exploration and technology. The prize was however unclaimed at its deadline (mid-2018), and was transformed into a non-cash competition.

While these prizes and incentives have ultimately achieved a fairly limited number of successes, the Israeli company SpaceIL is worth mentioning. Following its participation in the ultimately cancelled Google Lunar XPRIZE, it was able to continue the development of its lunar spacecraft and lander. In early 2019, the spacecraft reached Moon orbit, but the attempt to land on the surface was ultimately unsuccessful.[150] However, a follow-up mission has already been funded.[151]

3.2 The U.S. Push to Commercialise LEO

The American effort to foster commercial space activities and markets is a long-standing one, starting as early as 1962 with the Communications Satellite Act which enabled private companies to own and operate satellites. This determination gained a new dimension under Reagan administration with the Commercial Space Launch Act of 1984 which "*recognized the United States private sector as having the capability to develop commercial launch vehicles, orbital satellites, and operate private launch sites and services*".[152, 153]

With the objective of encouraging more prominent investment and involvement of private actors in space activities, in line with Reagan's vision of the "new frontier" of economic development, multiple legal initiatives in various domains further defined and expanded the perimeter of commercial space. This continuous effort was first and foremost motivated by the opportunity to conciliate American leadership's strategic objectives and the reduction of government budgets. Over the years, fostering commercial space activity has become an integral component of U.S. space strategy, supported at the highest political level. Reagan administration's plan to use the Space Shuttle as a commercial launcher was the first step that indirectly linked U.S. human spaceflight and space exploration programmes, especially the case of ISS, to the U.S. commercial space strategy.

In the field of space exploration, a longstanding and continuous push from the U.S. to support the emergence of a private space industry further intensified at the beginning of the 21st century with a series of acts adopted under the Bush, Obama and Trump administrations. In 2004, President George W. Bush announced a "*Vision for Space Exploration*" directing NASA to "*pursue commercial opportunities for providing transportation and other services supporting the International Space Station and exploration missions beyond Low Earth Orbit*".[154] The U.S. Congress endorsed this vision and adopted the NASA Authorization Act of 2005 which explicitly directed NASA to "*develop a commercialisation plan to support*

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149 "Emerging Space. The Evolving Landscape of 21st Century American Spaceflight." NASA. Web: https://www.nasa.gov/sites/default/files/files/Emerging_Space_Report.pdf.

150 SpaceIL Website. Web: http://www.spaceil.com/mission/.

151 Ibid.

152 This Chapter contains excerpts from Iacomino, C. "Commercial Space Exploration: Potential Contributions of Private Actors to Space Exploration Programmes". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2019.

153 "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617. Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.

154 "The Vision for Space Exploration". NASA, 2004. Web: https://history.nasa.gov/Vision_For_Space_Exploration.pdf.

the human missions to the Moon and Mars, as well as support Low-Earth Orbit activities",[155] and in particular to "*acquire cargo transportation as soon as practical and affordable to support missions to and from the International Space Station*". It is in this context, and in view of replacing the aging and costly Space Shuttle, that the Bush administration laid the foundations of the Commercial Orbital Transportation Services (COTS) program which relied on the commercial space sector for the servicing of the ISS.

The Obama administration marked a turn from the previous Bush administration's direction for various important elements of the U.S. space exploration programme, but still further consolidated U.S. engagement with private companies in the field. Under the Obama administration, the role of private actors to lower space programme costs, restore NASA human spaceflight capabilities and reaffirm U.S. independence in space became central.[156] The NASA Authorization Act of 2010 explicitly approved NASA plans to work with private companies to develop commercial spaceflight capabilities to deliver both cargo and crew to the ISS.[157] Another key initiative under the Obama administration was the adoption of the Spurring Private Aerospace Competitiveness and Entrepreneurship (SPACE) Act (or the U.S. Commercial Space Launch Competitiveness Act) of 2015. This act updated U.S. commercial space legislation in the field of private spaceflight and space resources exploitation, expanding the realm of commercial space activities.

The Trump administration again marked a turn from the Obama's administration's direction and restored to a certain extent the Constellation programme vision, but the willingness to further involve commercial actors in pubic programmes remained a dominant consideration. The NASA Transition Authorization Act of 2017 places much emphasis on the importance of commercial space industry in various domains including human spaceflight and space exploration. The bill acknowledges the achievements of the COTS programme and supports its continuity but also emphasises the importance of using the ISS as a platform to foster the commercialisation and economic development of Low-Earth Orbit. In several sections the Act directs NASA to continue its effort to engage in ambitious partnerships with private industry.

During its first meeting in October 2017, the newly reformed National Space Council took another important step in solidifying U.S. continuous commitment to foster commercial space activities. Mark Albrecht, who was executive secretary of the Council from 1989 to 1992, underlined that "*the agenda [of the National Space Council] will be substantial and urgent, from rationalizing space launch to fully integrating new privatized and commercial space capabilities into all national space activities*".[158]

It is important to highlight the intention to work on a transition plan that could turn the ISS over to the private sector. Despite the cessation of direct U.S Federal funding for ISS in 2025, this decision does not imply that the platform itself will be deorbited at that time, but the intention is to secure the U.S.´s long term-presence in LEO orbit, partnering with industry to develop commercial orbital platforms and capabilities that the private sector and NASA can use.[159] In its budget request, the administration requested $150 million in fiscal year 2019, with more in the next years "*to encourage development of new commercial Low-Earth orbital platforms and capabilities for use by the private sector and NASA*".[160] In this

155 "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617. Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.

156 Mosher, D. "Russia is squeezing NASA for more than $3.3 billion — and there's little anyone can do about it". Business Insider, 2 September 2016. Web: http://www.businessinsider.de/astronaut-cost-per-soyuz-seat-2016-9?r=US&IR=T.

157 "National Aeronautics and Space Administration Authorization Act of 2010". S.3729 — 111th Congress (2009-2010). U.S. Congress Website. Web: https://www.congress.gov/bill/111th-congress/senate-bill/3729.

158 Space News Staff. "BREAKING | President Trump re-establishes National Space Council". Space News, 30 June 2017. Web: http://spacenews.com/breaking-president-trump-reestablishes-national-space-council/.

159 NASA Strategic Plan 2018. NASA, 2018. Web: https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf.

160 Wall, M. "Trump's 2019 NASA Budget Request Puts Moon Ahead of Space Station". Space.com, 12 February 2018. Web: https://www.space.com/39671-trump-nasa-budget-2019-funds-moon-over-iss.html.

regard, the current U.S. administration has a clear intention to push that public-private partnership even further to encourage "*the emergence of an environment in LEO orbit where NASA is one of many customers of a non-governmental human space flight managed and operated enterprise, while providing a smooth and uninterrupted transition*".[161]

The most recent developments in U.S. space policy are the Space Policy Directives (SPD), issued by the newly-established National Space Council, as they entail relevant provisions for the commercial space sector in the U.S. (and, arguably, worldwide). In particular, SPD-2 aims at streamlining regulations on the commercial use of space, further easing the way for an increased role of private actors in commercial spaceflight launch of institutional payloads.[162] SPD-3 is focused on establishing a "National Space Traffic Management Policy",[163] and SPD-4 is centred on the creation of a so-called Space Force as a separate military branch.[164]

In the following paragraph, the origin of the modern U.S. commercial approach to space is further described, as it ultimately originated in the early retirement of the Space Shuttle in the early 2000s, and progressively led to a shift of paradigm in the way the NASA was instructed to conduct its space programmes.

3.2.1 Space Shuttle Retirement and the COTS Programme: Foundations of a New Approach

An essential step that profoundly impacted the relationship between public and private actors in the U.S. – later spread worldwide – came following the Space Shuttle's retirement. The reusable vehicle was initially "*envisioned as a reliable, low-cost method of launching governmental and commercial payloads into orbit*",[165] but these objectives were not entirely achieved for a variety of reasons (including restrictions following the Challenger disaster in 1986 leading to a launch rate significantly lower than expected, and refurbishment operations that were much more expensive than initially anticipated). Between 1971 and 2011, NASA spent around $192 billion on the program for an average cost per launch between $1.2 and $1.5 billion.[166] The programme was terminated during the Bush administration in 2011, thus leaving the U.S. in a critical and costly situation of dependence on Russian capabilities for manned spaceflight, and requiring a quick and cost-effective replacement.

Recalling its foundation while reflecting on the new approach, the agency noted that since 1958 it had "*focused on government-owned and -operated space missions. Throughout the Mercury, Gemini, Apollo, and Space Shuttle programs, the space agency hired contractors to develop launch vehicles and spacecraft*".[167] As a result, private actors had been involved in NASA programmes almost exclusively as contractors through cost-plus contracts "*based upon the actual cost of production and any agreed upon rates of profit or fees*".[168] As mentioned, this traditional public procurement approach is applied also to

[161] Davenport, C. "The Trump administration wants to turn the International Space Station into a commercially run venture, NASA document shows". The Washington Post, 11 February 2018 Web: https://www.washingtonpost.com/news/the-switch/wp/2018/02/11/the-trump-administration-wants-to-turn-the-international-space-station-into-a-commercially-run-venture/?utm_term=.9d8533cba50a.
[162] "Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space". White House website. Web: https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/.
[163] "Space Policy Directive-3, National Space Traffic Management Policy". White House website. Web: https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/
[164] "Space Policy Directive-4: Establishment of the United States Space Force". White House website. Web: https://www.whitehouse.gov/presidential-actions/text-space-policy-directive-4-establishment-united-states-space-force/
[165] The amortization is paying off an amount owed over time by making planned, incremental payments of principal and interest.
[166] Pielke, R. J., Radford B. "Shuttle programme lifetime cost.". Nature volume 472, pg. 38, 07 April 2011. Web: https://www.nature.com/articles/472038d#/author-information
[167] "Orbital Transportation Services: A New Era in Spaceflight". Lyndon B. Johnson Space Centre Staff.
[168] Meehan, Colette L. "Fixed Price vs. Cost Plus". Chron Magazine. Web: http://smallbusiness.chron.com/fixed-price-vs-cost-plus-2220.html.

enable close control over contractor's operations and to ensure that public money is not spent to create outstanding profits. Although this approach rests on robust arguments, it is often pointed to as a source of cost overruns related to administrative burdens and an indirect incentive for selected contractors to maximise the cost of the program as they receive an ensured percentage. The replacement of the space shuttle therefore provided fertile ground for NASA to explore new ways. Building on prior initiatives which resulted from combined NASA-industry collaboration, new mechanisms between public and private were proactively sought, including public-private partnerships and new contracting schemes.

The Commercial Orbital Transportation Services (COTS) model, announced in 2006, aimed at opening up the delivery of cargo to the ISS by private companies, and represented the way forward for a new cooperation between NASA and U.S. industry. With the overarching objective to improve cost-effectiveness, timeliness of development, as well as sharing development and operational risks with the private partners, NASA implemented an innovative procurement scheme based on competitive, performance-based, and fixed-priced milestones. With fixed price milestones, payments would only be guaranteed after the completion of predefined objectives, not on a continual basis as is customary under the system of a cost-plus contract, where companies are awarded a contract for the total cost of the work performed, plus an additional amount for profit. In other words, funding was issued only after the completion of clearly-defined predefined objectives, and any cost overruns would be the financial responsibility of the company, not the government.[169]

These programmes introduced a new way of doing business in the human spaceflight domain that made a mark in U.S. national space history, creating a symbiotic relationship between the public and private sectors. To provide financial and technical resources to commercial companies, the COTS programme relied heavily on funded Space Act Agreements (SAAs), a type of legal agreement that had already been envisaged in the National Aeronautics and Space Act of 1958 (and subsequent congressional authorizations),[170] and on the basis of which NASA can enter into partnerships with private companies, other government agencies and universities, giving access to a wider range of technologies and capabilities that are not part of NASA's core competency. For the COTS programme, terms and conditions of this mechanism were specially crafted to optimise mutual benefits for NASA and commercial partners. The primary aim of these agreements was to improve and stimulate the commercial space industry to develop innovative and cost-effective space transportation capabilities.

The advantage of the COTS SAAs was to "*enable a portfolio investment in multiple and diverse commercial partners*" with "*the ability to fund a range of companies including large, established companies representing lower technical risk balances by small or emerging companies with higher risk*".[171]

An important feature of these innovative partnership models sought by the government was the achievement of a high return on investment from taxpayer funds. For example, SpaceX and Orbital ATK LEO transportation systems were developed with a total NASA COTS investment of just $788 million. NASA had provided less than "*one half of the cost for the commercial transportation systems development and demonstration*".[172]

COTS SAAs have been considered a "*as a new way of fostering interaction between NASA and the private sector*", different from traditional Federal Acquisition Regulations (FAR) cost-plus contracts, and

[169] "Commercial Orbital Transportation Services - A New Era in Spaceflight". NASA/SP-2014-617.
Web: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.
[170] "National Aeronautics and Space Act of 1958, As Amended". NASA, 2008.
Web: https://history.nasa.gov/spaceact-legishistory.pdf.
[171] Ibid.
[172] Ibid.

eventually proved to be a successful tool to engage into partnership with private actors.[173] The application of the SAAs in COTS and CCDev (Commercial Crew Development, see below) has meant the shifting of design and development to the contracted firm. They key milestones and the associated priced are defined by the private contractor and this aspect means that they "*must deliver on time or not get paid*".[174] In this way, the company has more freedom to define and deliver a service or technical capability, and NASA´s involvement in the process is reduced as a broader reduction in cost, shifting some of the risk away from the agency.

The COTS programme successes and lessons learned were ultimately summarised as follows in the final NASA COTS Report:[175]

- Government seed money was highly leveraged
  - Commercial partners funded over 50% of COTS development costs
- Fixed price milestone payments maximized incentive to control cost and minimize schedule delays
- Minimum firm requirements along with commensurate Government oversight were key to fostering innovation and reducing life cycle development costs
  - Goals (vs. requirements) were established to open trade space and optimize design
  - Firm requirements were identified only where necessary to assure the safety of the ISS and crew
  - ISS interface requirements evolved over time and were coordinated in a collaborative manner with the commercial partners
- A portfolio of multiple partners with different capabilities assured a balanced approach to technical and business risks
  - Increased the chances of at least one successful partner
  - Market forces kept development and operational costs in check
- Commercial friendly intellectual property/data rights and limited termination liability encouraged investment of private capital
- NASA commitment to purchase operational services greatly improves the ability for companies to raise funds
- NASA does not have the statutory authority to provide Government Furnished Equipment (GFE) under a SAA
  - Even though originally contemplated in the SAA and in the best interest of the Government, COTS had to revert to loan agreements and cumbersome GSA excess procedures to transfer equipment to facilitate berthing with the ISS
- Augmentation of funding late in the program enabled additional risk reduction testing not initially affordable
  - Directly contributed to the successful first attempt berthing of SpaceX Dragon to ISS
  - Would be difficult to predict how much, if any, to hold in reserve during program formulation and initialization to protect for such milestone adjustments
- COTS model for public-private partnerships worked!

3.2.2 COTS Legacy and NASA Paradigm Shift

The success of this innovative procurement approach paved the way for a partial but profound transformation of NASA's relationship with industry, which goes beyond the space transportation and human spaceflight domain. According to Gary Martins, former director of partnerships at NASA Ames Research Center, this paradigm shift can be summarised as in Table 1.

[173] Mazzucato, M., Douglas, Robison, K.R. (2016). "Lost in Space? NASA and the Changing Public-Private Eco-System in Space". Working Paper Series (SWPS) 2016-2020. University of Sussex: SPRU (Science Policy Research Unit). Web: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2866430.
[174] Ibid.
[175] Extracted from "COTS: Final Report". NASA, 2014. Web: https://www.nasa.gov/content/cots-final-report.

Programme Characteristic	Early Space Age Approach	Commercial – Oriented Approach
Owner	NASA	Industry
Contract Fee Type	Cost Plus	Fixed Price
Contract Management	Prime Contractor	Public-Private Partnership
Customer(s)	NASA	Government and Non-government
Funding for Capability Demonstration	NASA procures capability	NASA provides investment via milestone payments
NASA´s Role in Capability Development	NASA defines "what" and "how"	NASA defines "what", industry defines "how"
Requirements Definition	NASA defines detailed requirements	NASA defines top-level capabilities
Cost Structure	NASA incurs total cost	NASA and industry share cost

Table 1: Change of paradigm in procurement at NASA. Source: NASA.[176]

Following the success of the COTS model and building upon its legacy, in 2010 NASA launched the Commercial Crew Development (CCDev) programme, once more aimed at stimulating the development of privately-operated crewed vehicles to LEO, in line with the U.S. Space Exploration strategy. The multiphase CCDev was a "*NASA investment [initially] funded by $50M of the American Recovery and Reinvestment Act (ARRA) funds, to stimulate efforts within the private sector that aid in the development and demonstration of safe, reliable, and cost-effective space transportation capabilities*".[177] The programme underwent several phases and funding rounds,[178] from development to certification, and is currently expected to deliver the first crewed private transportation services to the ISS by SpaceX and Boeing in late 2019.[179] Throughout the programme, fixed-price, milestone-based contracts (SSAs) were actively deployed based on agreed-upon goals to be achieved by the competing companies.

The model applied for stimulating commercial companies to provide services to the ISS is also intended for missions going well beyond Earth orbit. In early 2014, the Advanced Exploration Systems Division (AES) in NASA's Human Exploration and Operations Mission Directorate launched several initiatives to

[176] Martin, G. "New Space: The Emerging Commercial Space Industry". ISU MSS 2017.
Web: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170001766.pdf.
[177] NASA Commercial Crew and Cargo (C3PO). NASA Website.
Web: https://www.nasa.gov/offices/c3po/partners/ccdev_info.html.
[178] The funding rounds were as follows: 49.8 M$ for CCDev1 (2010-2011), 315.5 M$ for CCDev2 (2011-2012), 1,167.5 M$ for CCiCap (2012-2014), 29.6 M$ for CPC1 (2013-2014), 6,800 M$ for CCtCAP (on-going).
[179] https://www.nasa.gov/exploration/commercial/crew/index.html

foster innovative approaches and public-private partnerships to rapidly develop prototype systems, advance key capabilities, and validate operational concepts for future human missions beyond Earth orbit.[180] The pioneering model is oriented towards ensuring a sustainable and affordable space exploration programme as well as the efficiency of NASA's investments.[181] In addition to developing building blocks for future missions, the AES division is pioneering innovative ways to drive rapid progress by engaging in mutually beneficial public-private partnerships. Some initiatives that were developed under the cost-sharing model include: Lunar Cargo Transportation and Landing (CATALYST), Next Space Technologies for Exploration Partnerships (NextSTEP) as well as prizes and competitions.

The CATALYST programme´s purpose is to encourage and facilitate the development of U.S. commercial robotic lunar cargo delivery capabilities. NASA's CATALYST initiative has created partnerships with three U.S. companies to support the development of lunar lander technologies and capabilities, and one of the economics research proposals selected plans to assess and analyse the potential for commercial lunar efforts. In particular, NASA awarded three no-funds-exchanged SAAs partnerships with Astrobotic Technology, Masten Space Systems and Moon Express.[182] Those companies are developing landers that will be ready for missions within the coming years. Astrobotic is planning its first Peregrine lander mission in 2019, while Moon Express expects to launch its MX-1E lander in 2019. Finally, Masten Space Systems is working on its XL-1 lander that could be ready by the end of the decade as well. However, the purpose of these SAAs is to encourage the development of robotic lunar landers that can be integrated with U.S. commercial launch capabilities to deliver payloads to the lunar surface. In this way, NASA has the possibility to share technical expertise, access to facilities, equipment loans, and software to stimulate the development of commercial lunar cargo transportation service.

Concerning the announcement for NextSTEP, the agency was looking for ways to stimulate the commercial development of technologies that might have future applications for NASA´s exploration plans. This public-private partnership model seeks commercial development of deep space exploration capabilities with the objective of supporting more extensive human spaceflight missions in the Proving Ground around and beyond cis-lunar space. As the years progressed, NASA issued two NextSTEP Broad Agency Announcements (BAA) to U.S. industry: one in late 2014, and the second NextSTEP BAA in April 2016.[183] With regards to the first NextSTEP, the selection included Bigelow Aerospace, Boeing, Lockheed Martin, Orbital ATK and seven other companies. NASA estimated the combined total of all the awards, covering work in 2016 and 2017, would be approximately $65 million, with additional efforts and funding continuing into 2018.[184] As part of NextSTEP-2, NASA released a solicitation to seek proposals from industry for the conduct of studies in specific research areas. Among these areas NASA solicited proposals for the Power and Propulsion Element of the Deep Space Gateway. In November 2017, NASA awarded contracts to five companies (Boeing, Lockheed Martin, Orbital ATK, Sierra Nevada Space Systems and Space Systems Loral) to examine how they could develop a power and propulsion module that could become the initial element of the Deep Space Gateway. The contracts, which run for four months, have a combined value of approximately $2.4 million.[185]

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180 AES Overview. NASA Website. Web: https://www.nasa.gov/content/aes-overview.
181 Ibid.
182 Lunar CATALYST. NASA Website. Web: https://www.nasa.gov/lunarcatalyst.
183 Broad Agency Announcements (BAAs) are a procurement tool used by USAID to collaborate with the private and public sector when facing a development challenge that does not have a clear solution and there appears to be an opportunity for innovation.
184 "NASA Selects Six Companies to Develop Prototypes, Concepts for Deep Space Habitats. Retrieved from NASA". NASA press release. 9 August 2016. Web: https://www.nasa.gov/press-release/nasa-selects-six-companies-to-develop-prototypes-concepts-for-deep-space-habitats.
185 Foust, J. "NASA issues study contracts for Deep Space Gateway element". Space News. 3 November 2017. Web: http://spacenews.com/nasa-issues-study-contracts-for-deep-space-gateway-element/.

3.2.3 Looking Ahead: the NASA 2018 Strategy

The "NASA Strategic Plan 2018", building upon the past decade's progress in the public-private relationship, is clearly oriented towards further exploiting the successful model to further commercialize LEO activities, with an outlook towards the beyond Earth orbit.

Its first strategic goal is to "*expand human knowledge through new scientific discoveries*" by, i.a., opening the pathway for future robotic-human exploration. The ISS, considered as "*an orbital outpost for humanity, [which] has the key functionality for global cooperation and scientific advancement, and is a catalyst for growing new commercial marketplaces in space and as a test bed for demonstrating advanced technologies*",[186] would possibly become a proving ground for innovative private involvement in the utilization of the station.

The second goal, to "*extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization*", ultimately aims at laying the foundations for the U.S. to maintain a constant human presence in LEO enabled by a commercial market; and to conduct exploration in deep space, including to the surface of the Moon. This goal includes pursuing a sustainable cadence of crewed missions with the aim of preparing the first manned missions to deep space.[187] These include the first test flight of the SLS and Orion crew vehicle near Moon orbit, and the first crewed flight of the SLS, designed for missions beyond LEO.

However, beyond the recent commercial crew and cargo transportation capabilities enabled by the ISS, the agency is continually implementing and developing new partnership approaches to further allow commercial activities and markets in LEO orbit,[188] including addressing the policy environment and associated elimination of barriers and introduction of incentives that could enable commercial use of LEO orbit. As mentioned, to support LEO orbit commercialisation, NASA is leveraging the ISS by maximising utilisation and demonstrating the value of ISS and LEO research, and has put forward plans for ISS transition, i.e. a "*a step-wise approach from the current regime that relies heavily on NASA sponsorship [of the ISS] to a regime where NASA could be one of many customers of a low-Earth orbit non-governmental human space flight enterprise*".[189] To do so, the "Commercial LEO Development Program" was created, to directly support efforts to expand commercial activities in LEO, with a focus on enabling, developing, and deploying commercial platforms that can be used by NASA and other customers. The third goal is to "*address national challenges and catalyze economic growth*", and notes that NASA's mandate is broader today than at its inception. The challenges that the agency addresses today include: gathering climate change data; supplying technological solutions for terrestrial problems; advancing the state of Research and Development (R&D) in aeronautics and other fields; developing commercial and human space launch and transportation capabilities; understanding cosmic phenomena as wide-ranging as space weather, asteroids, and exoplanets; and improving the nation's innovation capacity.[190] Within this goal, the agency acknowledges that "*technology drives NASA's future human and robotic exploration missions. As its technology efforts mature, NASA transfers appropriate technologies to industry and commercializes them to benefit a wide range of users. This ensures that the American people realize the full economic value and societal benefit of NASA's work*".

[186] "NASA Strategic Plan 2018". NASA Website.
Web: https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf.
[187] Ibid.
[188] "International Space Station Transition Report pursuant to Section 303(c) (2) of the NASA Transition Authorization Act of 2017 (P.L. 115-10)". NASA Website. Web: https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf.
[189] Messier, D. "NASA's ISS Transition Report." Parabolic Arc. 21 May 2018. Web: http://www.parabolicarc.com/2018/05/21/iss-transition/.
[190] "NASA Strategic Plan 2018". NASA Website.
Web: https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf.

Finally, with the fourth goal NASA has a particular focus on optimising its technical capabilities and operations. As a result, NASA has assumed "*a new operating model that strengthens its management of the engineering and systems capabilities that are fundamental to every mission and strategic goal*".[191] NASA aims to leverage innovation outside the agency. For this purpose, NASA is developing a robust partnership and acquisition strategy focused on cooperating with the private sectors in order to benefit from their innovations. These principles embrace a "*shared understanding of the responsible use of space, free and open data policies, and the broad benefits of fundamental public Research and Development (R&D)*".[192]

What is important in this context is the clear objective for NASA to engage in more ambitious partnership strategies with the private sector. These partnerships will implement mutually beneficial cooperative space working groups, programs, projects, missions and ground-based research activities that support the Strategic Plan.[193]

3.3 The European Spacescape in the 2010s: New Agencies and New Modes of Interaction

Europe, both at national and at ESA level, has been a pioneer in developing commercial space activities and building a prominent role for the private sector, as particularly outlined in Chapter 2.4. In more recent years, European agencies and institutions have been instrumental in kick-starting an increasing number of what would become very successful ventures based on PPPs in different domains (the ESA ARTES programme in telecommunications, TerraSAR-X and RapidEye in remote sensing, among several others).[194] Not all attempts were successful, and, for example, the PPP model envisaged initially by the European Union for its flagship Galileo programme was eventually abandoned for a variety of reasons. Nevertheless, similar to the U.S., promoting and building on a deep and continuous collaboration between private and public sectors to share costs and risks, pool expertise, share knowledge and ultimately foster competitiveness and economic growth is a central component of today's European space strategy.

This section describes some of the most recent policy developments and practical examples with regard to European public-private interaction at ESA, European Union and member state level.

3.3.1 ESA's Evolving Strategy

With regards to ESA, the "Resolution on the Evolution of the Agency",[195] approved at the ESA Council at Ministerial level in 2014, recognising the fast pace of evolution in the sector placed strong emphasis on

[191] Ibid.
[192] Ibid.
[193] Ibid.
[194] For example, HYLAS-1 is a small geostationary communications satellite within a project of ESA ARTES-3 and UK operator Avanti Communications, the latter of which owns and operates the spacecraft.
TerraSAR-X1 is a German SAR satellite mission for scientific and commercial applications, supported by the German Ministry of Education and Science and managed by DLR. In 2002, EADS Astrium GmbH was awarded a contract for TerraSAR-X on the basis of a PPP: EADS Astrium funded part of the implementation cost of the TerraSAR-X system, and in exchange EADS Astrium/Infoterra received the exclusive commercial exploitation rights for the satellite's data. Furthermore, the satellite is owned and operated by DLR, and the scientific data rights remain with DLR.
The RapidEye Earth observation system comprises five satellites, borne out of a PPP between the German Federal Government and DLR with RapidEye AG. The agreement provided for supporting the technological development of the RapidEye camera system as well as for the acquisition of rights of use in a specified data contingent which will be freely accessible to scientists.
[195] "Resolution on Europe's Access to Space". ESA Council meeting held at ministerial level, 2 December 2014.
Web: https://esamultimedia.esa.int/docs/corporate/Final_resolutions_1_2_3_from_CM_2014_Releasable_to_the_public.pdf.

the evolution of ESA's relations with industry. Among other elements, member states invited the agency to make proposals before the 2016 Council on:[196]

- The most promising opportunities to adapt the relationship between ESA and industry in cooperative endeavours which balance the share of responsibility, cost and risk between them with a view to optimising the economic value of their respective investments;
- Innovative ways to procure and support R&D, including models currently being used around the world to stimulate lower-cost R&D such as prize funds, with necessary adjustments being envisaged to fit the objectives of ESA's industrial policy;

The follow-up Resolution "Towards Space 4.0 for a United Space in Europe", adopted at the ESA Council at Ministerial Level in 2016, addressed these demands with a clear intention to open up the Agency to new partnerships with private actors in both space and non-space sectors and to implement complementary new funding schemes relying on commercial activities.[197]

In the 2016 Resolution, more objectives for ESA's long-term industrial policy were outlined:[198]

- Fostering competitiveness, innovation and a balanced development of the European industrial sector among all Member States, while also facilitating the entry of new economic actors and the integration of its latest Member States;
- Supporting private investment and entrepreneurship, in particular through start-ups and SMEs, and carrying out the SME-friendly policy adopted by the Industrial Policy Committee (IPC) so as to favour their contribution to the success of ESA programmes;
- Promoting public-private partnership schemes that include the sharing of risks and rewards, prioritizing pre-operational space activities with a potential for industrialization and commercialization.

The Intermediate Ministerial Meeting (IMM) of October 2018, a milestone on the road to ESA's next Ministerial Council "Space19+" which will be held in November 2019, progressed on the elaboration of ESA's future strategy vis-à-vis the industrial component. While focusing mostly on aspects pertaining to the relationship between ESA and the European Union, on the topic of the evolution of the Agency the Resolution also mandated ESA to further proposals for CM19 for the purpose of:[199]

- Fostering the evolution of the Agency's activities and programmes through the development of remodelled programme-related instruments, and the promotion of new types of partnership and of funding schemes for partners;
- Defining visionary goals and objectives for each activity and programme to anticipate future public, private and institutional needs, in particular where there is not yet a market;
- Making the Agency a more agile and responsive organisation able to foster innovation and new partnership and cooperation models, building on notable achievements such as the network of ESA Business Incubation Centres (BICs), the network of ESA_Labs and the ESA Grand Challenge, and for this purpose developing the use of grants, Public Private Partnership (PPP) and financing possibilities from different sources.

In practical terms, in recent years ESA has diversified its relationship with industry on a variety of programmes, employing innovative partnerships models on top of traditional procurement.

With regard to the latter, a successful example of traditional procurement processes is Aeolus. Launched in August 2018, the Atmospheric Dynamics Mission Aeolus is the fifth satellite in ESA's Explorer missions,

[196] Ibid., pg. 4.
[197] "European Space Agency - Council Meeting Held at Ministerial Level on 1 and 2 December 2016 - Resolutions and main decisions". ESA. Web: http://esamultimedia.esa.int/docs/corporate/For_Public_Release_CM-16_Resolutions_and_Decisions.pdf.
[198] Ibid., pg. 5.
[199] "Resolution giving mandate to the Director General to establish appropriate relations between the European Space Agency and the European Union". ESA Intermediate Council Meeting (IMM18), 25 October 2018.
Web: http://esamultimedia.esa.int/docs/corporate/C(2018)119_Resolutions_adopted_at_the_276th_Concil_meeting_(IMM18).pdf.

aimed at addressing key scientific challenges and demonstrating advancements in observational techniques.[200] Aeolus is the first of its kind equipped to observe and profile the Earth's wind on a global scale, through ground-breaking technology.[201] This three year-long scientific mission is the result of a contract awarded to ASTRIUM (UK), part of the Airbus family, and launched into orbit by Arianespace.[202, 203] In terms of contracts, this mission is a classic procurement contract, in which the public agency sustained costs and all risks for the development of new technology, in order to develop a mission able to deliver cutting-edge and unprecedented scientific research.

On the other side of the procurement spectrum, in September 2018 ESA published a request for information (RFI) entitled "Request for an Outline Concept for the removal of an ESA-owned satellite to demonstrate commercial in-orbit services".[204] The mission statement was to "*perform the removal from orbit of an ESA-owned satellite(s) in execution of service contract(s) placed by ESA and demonstrate capabilities and technologies for in-orbit servicing*". Overall it is ESA's objective to use this RFI for the removal of an ESA satellite as a precursor to further developing in-orbit servicing and debris removal missions, effectively demonstrating the "*necessary technologies, functions and operational know-how*".[205] The most relevant objective here is that ESA is explicitly trying to arrange a service contract in which the agency acts purely as a customer and the industry fully and autonomously develops the hardware, in order "*to provide an opportunity to space industry to enter into this new space market*".[206]

In between traditional procurement and proposals for purchase of "turn-key" services, the agency has been engaging in a number of public-private partnerships in various space domains, as discussed in the following paragraphs.

Telecommunication

Working within the five-year Telecommunications Long-Term Plan (TLTP), the Advanced Research in Telecommunications Systems Programme (ARTES) is the programme through which ESA established successful PPPs with European and Canadian industry. It is the objective of ARTES to consolidate the efforts of ESA and industry in the field of satcom, conducting R&D activities and exploring "*innovative concepts to produce leading-edge satcom products and services*".[207] As a large part of the ARTES programmes, PPPs are enabling industry to reap more of the benefits in advanced satellite technology, taking upon themselves more risk in doing so, resulting in "*greater and more ambitious projects that provide maximum benefit with minimal cost and risk to the European taxpayer*".[208] The programme, and the call for ideas, is open to any sized satcom-related businesses situated within ESA member state. Submissions are accepted for a number of elements within the ARTES programme, including but not limited to: Large Mission Platform (LPM), Small Geostationary Satellite (SGEO), and Integrated Applications Promotion. Participation in each programme is inclusive of a funding framework and

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200 "Introducing Aelous". ESA Website. Web: https://m.esa.int/Our_Activities/Observing_the_Earth/Aeolus/Introducing_Aeolus.
201 Ibid.
202 "ESA Awards Contract to EADS Astrium (UK) to Build Aeolus". ESA Website. 31 October 2003. Web:http://www.esa.int/Our_Activities/Observing_the_Earth/ESA_awards_contract_to_EADS_Astrium_UK_to_build_Aeolus_the_first_satellite_to_measure_the_Earth_s_wind_from_space.
203 "Vega to Launch ESA's Wind Mission". ESA Website. 7 September 2016. Web: http://m.esa.int/Our_Activities/Observing_the_Earth/Aeolus/Vega_to_launch_ESA_s_wind_mission.
204 "Request for an Outline Concept for the removal of an ESA-owned satellite to demonstrate commercial in-orbit services". ESA Website. Web: http://emits.sso.esa.int/emits-doc/ESTEC/News/RFI-InorbitServicing05.09.2018.pdf.
205 Ibid., pg. 3.
206 Ibid., pg. 3.
207 "Understanding Artes". ESA Website. Web: https://artes.esa.int/about-artes.
208 "EDRS – Partnership". ESA Website. Web: https://m.esa.int/Our_Activities/Telecommunications_Integrated_Applications/EDRS/Partnership.

participation criteria. The successes of the ARTES programme were recognised at the ESA Ministerial Council Resolutions 2016, welcoming the novel approach:[209]

- To support the competitiveness of Member States' industry at the level of technology or products, in particular the Core Competitiveness and Future Preparations Elements;
- To stimulate innovation at the level of end-to-end systems through public private partnership with operators or service providers, thus promoting a balanced risk-sharing scheme between public and private partners so as to enable European industry to keep pace with the intensifying global competition in the vital telecommunications sector;
- And in the framework of the Integrated Application Promotions Element, with a view to fostering interaction between the space sector and the rest of society, enabling the delivery of new commercially-sustainable services to citizens and strengthening the economy.

The European Data Relay System (EDRS), formerly known as ARTES 7, is an example of a successful PPP between ESA and Airbus.[210] The system places data relay satellites in geostationary orbit to "*relay information to and from non-geostationary satellites, spacecraft, other vehicles, and fixed Earth stations that otherwise are not able to permanently transmit/receive data*", in use for dependent systems such as the Copernicus Earth Observation Programme.[211] Importantly, EDRS will be an independent European system, boosting European self-reliance, providing the satellite telecom sector with fast, reliable and seamless data transmission.[212] In terms of the Airbus-ESA aspect of the overall system, Airbus, as the prime contractor co-finances, owns, and operates the infrastructure of the system, maintaining overall responsibility for the launch, space and ground segments, and holding some of the associated risk. Airbus also provides the data transmission to ESA and wider global customers.[213] Airbus has committed to operating and providing these services to ESA for 15 years.[214] ESA on the other hand, funds the development of the infrastructure. Beyond this, the German DLR plays a large role in R&D,[215] and in the case of Copernicus, the EC acts as an anchor customer.[216]

Another example of a recent PPP developed under ESA and ARTES is with Inmarsat, the UK-based leading provider in global mobile satcom.[217] The Inmarsat Communications Evolution (ICE) project – previously named ARTES 33 – was signed by ESA and Inmarsat during the UK Space Conference in 2015, and in essence provides a blueprint for European industry to shape the trajectory of mobile satellite services for land, sea and air. This initiative aims to provide opportunities for industry to propose innovative new technologies and approaches for communication capabilities and expand the market reach of Inmarsat's products and services. In doing so, and as the prime contractor, Inmarsat has two distinct objectives: first, to define the system and identify new technologies for both space and ground systems, maximising coverage, reducing costs, and making an open architecture with a standardised interface allowing for the integration of a number of devices. Second, beginning in 2017, the aim is to address user applications to maximise the commercial potential.[218] Beyond these objectives for Inmarsat, it additionally had the responsibility of conducting a nine-month feasibility study, as well as making a substantial financial

[209] "European Space Agency - Council Meeting Held at Ministerial Level on 1 and 2 December 2016 - Resolutions and main decisions", pg. 5. ESA. Web: http://esamultimedia.esa.int/docs/corporate/For_Public_Release_CM-16_Resolutions_and_Decisions.pdf.
[210] Originally conceived with Astrium, which was later absorbed by Airbus.
[211] "European Data Relay Satellite System (EDRS) Overview". ESA Website. Web: https://artes.esa.int/edrs/overview.
[212] Ibid.
[213] Ibid.
[214] Ibid.
[215] "EDRS – Partnership". ESA Website.
Web: https://m.esa.int/Our_Activities/Telecommunications_Integrated_Applications/EDRS/Partnership.
[216] Ibid.
[217] "Inmarsat Communications Evolutions – ICE". ESA Website.
Web: https://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/ICE.
[218] Ibid.

contribution, bordering on 50% of the total input:[219] The budget of €4.2 million, for which Inmarsat is the prime contractor, includes matching funding by Inmarsat of €1.9 million against ESA funding of €2 million. The remaining budget, approximately €0.3 million, is provided through match funding contributions from three sub-contractors; Space Engineering Italy, Airbus Defence & Space UK and RUAG Switzerland.[220]

Finally, another recent PPP was the one that led to the development of NEOsat, again within ESA's ARTES programmes. The programme is aimed at "*developing, qualifying and validating in orbit next-generation satellite platforms for the core satcom market*".[221] The contract for Phase-B of its development was signed in 2014 between the two co-prime contractors Airbus Defence and Space, and Thales Alenia Space. Each prime will hold their own competitions "*between equipment suppliers for platform building blocks, based on an agreed single set of requirements,*" the winners of which are integrated within the development of the platform lines.[222] Phase-C/D for the development and manufacture of the first two prototype platforms commenced in 2015 – as relatively common nowadays in the satcom sector – under a PPP with satellite operators.[223]

Space Transportation

In 2014, ESA established a six-year roadmap for the development of its next generation of European launching capabilities. This was settled within the context of a growing and more competitive global environment for launching services, one example of which was the emergence of SpaceX and its Falcon 9 rocket which realised consistent reductions in costs, and a shifting relationship between government and industry. Europe's answer came from ESA and its industrial partners through the proposals for Ariane 6 and Vega C. The governance aspects of the Ariane 6 proposals are discussed in the following paragraphs.

Ariane 6, Europe's latest launch system in development, is planned to conduct its maiden voyage in 2020 with the aim of completely replacing its predecessor Ariane 5 by 2023.[224] While there are a number of notable technological advancements made in the jump to this next generation, the interesting and relevant points of this development come in changes to its governance, the overall industrial process and, ultimately, the relationship between ESA and the industry. Indeed, "*the industrial organisation put into place for building Ariane 6 aims for maximum efficiency throughout the production cycle*",[225] and the ultimate goal is to gain reduced production costs of up to 40% - 50% of that of Ariane 5, further keeping the competitive edge on European and global launch markets.[226] In comparison, it has been stated by the prime contractor ArianeGroup, that Ariane 6 is "*basically an industrialization of Ariane 5*".[227]

In this sense, Ariane 6 marks the fruition of ongoing changes in governance to support independent European access to space conducted under ESA, its member states, and industry, achieved through *"[streamlining] the relations between industry and governments in developing and operating launch*

[219] "Inmarsat and ESA sign Public Private Partnership to explore the future of mobile satellite communications technologies". Inmarsat Website. 15 July 2015. Web: https://www.inmarsat.com/press-release/inmarsat-and-esa-sign-public-private-partnership-to-explore-the-future-of-mobile-satellite-communications-technologies/.
[220] Ibid.
[221] "Neosat boosting Europe's Telecommunications by Satellite". ESA Website. 20 February 2014. Web: http://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/Neosat_boosting_Europe_s_telecommunications_by_satellite.
[222] Ibid.
[223] Ibid.
[224] Arianespace website. Web: http://www.avio.com/en/ariane/ariane-6/.
[225] "Ariane 6 Commercial Launch Services". ArianeGroup website. Web: https://www.ariane.group/en/commercial-launch-services/ariane-6/.
[226] Ibid.
[227] Caleb, H: "Ariane 6 is nearing completion, but Europe's work is far from over". Space News. 15 August 2018. Web: https://spacenews.com/ariane-6-is-nearing-completion-but-europes-work-is-far-from-over/.

vehicles".[228] Building on the successes of the previous European launch model for 30 years, these changes became necessary to address the future financial viability of this model vis-à-vis a rapidly changing satellite launch service market.

This refinement of governance of the development of European launchers was further built upon during the 2014 Ministerial meeting of ESA, in which a multipronged strategy was adopted to increase the flexibility and reduce costs in the overall process. This was achieved at a number of levels, including the utilisation of heritage hardware, the streamlining of industrial organisation, the maximisation of common expendable elements and the creation of synergies between different market segments. The same 2014 Ministerial Resolution additionally emphasised that Ariane 6 development decisions would coincide with changes in governance of the European launch sector, placing a focus on balancing responsibility, risk- and cost-sharing between ESA and the industrial joint venture. To be more specific, the new industrial joint venture "*will bear all commercial market risks during exploitation without support from Member States under the understanding that the Joint Venture will control the commercial exploitation of the launch service and that a number of launches will be contracted per year by different institutional actors in Europe that consider as a collective priority and an individual benefit to use competitive European-developed launchers*".[229]

In parallel to the Ariane 6 programme, the 2016 ESA Ministerial also approved the further development of the small launcher Vega, which has so far achieved outstanding success in placing small-to-medium sized payloads in orbit with a string of successful consecutive launches. In the roadmap, the Italian-led rocket will be upgraded in its Vega-C iteration, extending its performances and thus better bridging the gap that will be left by the progressive phase-out of the Soyuz launcher from the European rocket family.[230] Expected to be launched for the first time in 2020, the Vega programme already foresees a future evolution beyond 2025, with Vega-E, which will be based on the existing building blocks (e.g. P120C, P80, Z23, Z40, Z9, AVUM, VUS…) and further enhanced by a new cryogenic upper stage as well as new technologies such as additive manufacturing.[231]

Ultimately, whilst certainly an innovative model *per se* in the European space sector, the model adopted for the development of Ariane 6 can be considered a compromise solution of shared costs and management in which it was attempted to introduce new public-private elements of partnership between ESA and the industry; yet at the same time it did not entail a radical re-organisation (and, possibly, optimization) of the European space transportation sector as far as the Ariane 6 vehicle is concerned, since a number of factors (including political considerations within the complex European space triangle) had to be taken as givens, and could not be subject to change.[232]

Aside from the roadmap outlined for the new European launchers family, more recently ESA has also kick-started other initiatives aimed at gathering new inputs and ideas for the space transportation sector. This is represented by a Call for Ideas (CFI) titled "Space Transportation Ideas: Business Opportunities".[233] This effort has the primary objective of encouraging and fostering open innovation from industry, in both space- and non-space sectors, in order to meet Europe's needs in the long-term and take advantage of

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228 "Resolution on Europe's Access to Space". ESA Council Meeting held at Ministerial Level. 2 December 2014. Web: https://esamultimedia.esa.int/docs/corporate/Final_resolutions_1_2_3_from_CM_2014_Releasable_to_the_public.pdf.
229 Ibid.
230 "Vega-C". ESA Website. Web: https://www.esa.int/Our_Activities/Space_Transportation/Launch_vehicles/Vega-C.
231 "Vega-E". ESA Website. Web: https://www.esa.int/Our_Activities/Space_Transportation/Launch_vehicles/Vega-E.
232 For an analysis of the political process that led to the 2014 ESA Resolution on Access to Space see: Aliberti, M. and Tugnoli, M. "The European Launchers Between Commerce and Geopolitics", pp. 22-27. ESPI Report 56, ESPI, Vienna, 2016. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/10-the-european-launchers-between-commerce-and-geopolitics.
233 "Call for Ideas - Space Transportation Ideas: Business Opportunities". ESA Website. Web: http://emits.sso.esa.int/emits-doc/ESTEC/News/Callforideas_SpaceTransportationIdeasFinal.pdf.

new opportunities and explicitly focused on access to space.[234] The CFI is open to "*start-ups, universities and institutions, oriented towards private customer services and commercially viable ventures that would complement existing ESA space*".[235] It is hoped that this multi-pronged and open approach will mark a significant step toward identifying new venues, technologies, and actors in creating sustainable, commercially viable space transportation services which are essentially customer-oriented. As stated by ESA, the agency intends to take a nurturing role in setting these initiatives into motion.

Space Exploration

In 2014 ESA adopted the 'Resolution on Europe's Space Exploration Strategy'. In one of its five overarching strategic objectives it aims to contribute to the "*competitiveness and growth of the European industrial sector by pushing the frontiers of knowledge and developing new technologies able to be applied in all fields of economic value*" as a driver for the economy.[236] This marks an integrative approach that satisfies ESA's own objectives, jointly with fostering industry as well as fulfilling societal and economic needs.

These objectives have been well addressed in the ESA Space Exploration strategy and E3P, for example. In line with the vision of a "United Space in Europe" in the Space 4.0 framework, ESA aims to pursue a consistent and forward-looking space exploration programme designed to "*further stimulate commercial partnerships with industrial entities*".[237] From this perspective, David Parker, ESA Director of Human Spaceflight and Robotic Exploration commented that "*commercial partnership will play a growing role in the exciting ESA vision for space exploration and (…) ESA intends to stimulate private sector engagement in space exploration and foster innovative and inspiring approaches for ISS services and utilisation and future ESA missions*".[238] In addition to its regular space agencies activities, ESA is increasingly willing to act as a business partner. In the field of space exploration, the objectives of commercial partnerships are to facilitate exploration ambitions by better leveraging European private sector capabilities and resources.

As a further example, in 2017 ESA presented a CFI in several key areas of space exploration, titled 'Space Exploration as a Driver for Growth and Competitiveness: Opportunities for the Private Sector'.[239] The document highlights how space agencies have traditionally led the domain of space exploration, but in recent years an accelerating number of private initiatives are emerging. Within this resolution, ESA aims to take advantage of this trend by seeking new ways of partnership with the private sector, both in space and non-space, to exploit novel resources and approaches for the mutual benefit of both ESA's space exploration strategy and private business opportunities.[240] This CFI is intended to set up a Strategic Partnership between ESA and industry, seeking full cooperation of both partners, committing resources, approaches, expertise and skills for mutual benefit. Ultimately the partnerships will benefit both parties, and aim for increased commercial viability, releasing new products and services onto the market within a mid-term timeframe.[241]

ESA has highlighted several areas of space exploration that are of current interest for such partnerships. These include: "Low-Earth Orbit (LEO) Infrastructures", "Exploiting the inspiration potential", as well as

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[234] "Focus on the Future of Space Transportation: ESA's Call for Ideas". ESA Website. 16 July 2018. Web: http://www.esa.int/Our_Activities/Space_Transportation/Focus_on_the_future_of_space_transportation_ESA_s_call_for_ideas.
[235] Ibid.
[236] "Resolution on Europe's Space Exploration Strategy". ESA Council Meeting held at Ministerial Level. 2 December 2014. Web: https://esamultimedia.esa.int/docs/corporate/Final_resolutions_1_2_3_from_CM_2014_Releasable_to_the_public.pdf.
[237] "European Space Agency - Council Meeting Held at Ministerial Level on 1 and 2 December 2016 - Resolutions and main decisions". ESA. Web: http://esamultimedia.esa.int/docs/corporate/For_Public_Release_CM-16_Resolutions_and_Decisions.pdf.
[238] Ibid.
[239] "Call for Ideas - Space Exploration as A Driver for Growth and Competitiveness: Opportunities for the Private sector". ESA Website. Web: https://esamultimedia.esa.int/docs/business_with_esa/ESA_Call_for_Ideas_Space_Exploration_as_a_Driver_for_Growth_and_Competitiveness.pdf
[240] Ibid., pg. 4.
[241] Ibid., pg. 6.

Lunar and Mars exploration. In regards to the first domain, LEO, ESA's Space 4.0 strategy aims to shift LEO activities from being a "*government-run laboratory to being a commercially driven human and robotic spaceflight economy*",[242] in a somewhat similar fashion to what the U.S. is doing. On this front, ESA's Director of Human Spaceflight and Robotic Exploration, David Parker, has signed a partnership agreement with Space Applications Services NV/SA, Belgium, for cooperation on their International Commercial Experiment Cubes (ICE Cubes) services initiative. The ICE Cubes service presents opportunities for commercial stakeholders to have access to the International Space Station and conduct experiments and research within a weightless environment inside ESA's Columbus laboratory on board the ISS. The "ICE Cubes" themselves are compact modular containers which slot into a rack in the Columbus laboratory – they transmit their experimental data back to Earth through the infrastructures provided by the International Space Station. The PPP established enables a service for its customers in a two-fold manner – first, access to committed and recurring launches to the ISS; and second, Space Applications Services acts as a broker between the customer and ESA, in addition to facilitating the payloads operation and communication back to the customer on Earth.[243] This innovative partnership opens up weightless experimentation in space to a wider number of participants than seen in previous years, including applications for: research/university studies, in-orbit testing and validation of technologies, industrial and commercial R&D, accommodation for new on-orbit manufacturing capabilities, and education experiments/demonstrations in STEM areas.[244]

In February of 2018 another PPP in the domain of space exploration was established between ESA and Airbus for the Bartolomeo payload platform becoming active in 2019.[245] Bartolomeo is an "All-in-one Mission Service" that will provide the International Space Station with end-to-end access for external payloads at competitive prices, offering an "*unobstructed view of Earth, direct control of the experiments from the ground via a high-speed data feed, and the possibility of retrieving samples*".[246] Utilising this service, the customer is able to focus its efforts on its own payload – up to 12 slots for payloads are available on the platform situated in the Columbus module – while Airbus facilitates the wider launch and operation aspects, essentially providing a cost- and time-efficient service for its users.[247] In this regard, the agreement establishes the roles and responsibilities of both respective partners. Airbus is responsible for the construction, launch, operation and payload integration of the commercial Bartolomeo platform. Additionally, Airbus will contribute around €40 million to the initial development, construction and launch. ESA, on the other hand, will facilitate access and Bartolomeo's installation on the ISS.[248]

ESA considers that LEO, the Moon and Mars ought to be "*viewed as part of a single exploration process by maximising the technology and system synergies among these destinations, as well as maximising the respective benefits of robotic and human exploration*".[249] As such, and looking further forward from the LEO PPP cases, ESA is beginning the process of establishing itself as a platform, mediator or broker for various nations, institutions, and commercial companies to create a Moon Village. The term 'Moon Village' in this context does not refer to the traditional conception of a village, but rather refers to "*community*

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[242] "Partners for Space Exploration". ESA Website.
Web: http://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/Partners_for_Space_Exploration.
[243] "ICE Cubes - a Fast-Track, Low-Cost Service for Small Experiments to the ISS Operations Concept". Space Applications Services. 2 June 2016. Web: http://www.essc.esf.org/fileadmin/user_upload/essc/00_ESSC_23-Nov_ICE_Cubes.pdf.
[244] Ibid.
[245] "ESA and Airbus Sign Partnership Agreement for new ISS commercial payload platform Bartolomeo". Airbus website. 7 February 2018. Web: https://www.airbus.com/newsroom/press-releases/en/2018/02/bartolomeo.html.
[246] "All-in-one Services for the Space Station". ESA Website. 7 February 2018.
Web: http://m.esa.int/Our_Activities/Human_Spaceflight/Columbus/All-in-one_service_for_the_Space_Station.
[247] "ESA and Airbus Sign Partnership Agreement for new ISS commercial payload platform Bartolomeo". Airbus website. 7 February 2018. Web: https://www.airbus.com/newsroom/press-releases/en/2018/02/bartolomeo.html.
[248] Ibid.
[249] "Resolution on Europe's space exploration strategy". ESA Council meeting held at ministerial level, 2 December 2014.
Web: https://esamultimedia.esa.int/docs/corporate/Final_resolutions_1_2_3_from_CM_2014_Releasable_to_the_public.pdf

created when groups join forces without first sorting out every detail, instead simply coming together with a view to sharing interests and capabilities".[250] It is through establishing this community of actors that ESA could be equipped to act as a broker. A parallel here could be drawn between this concept and the initial stages of development of the ISS: the ISS is a multi-nation space collaboration, and its coming into being was heavily dependent on platforms for conversation, agreement and cooperation between a variety of stakeholders, to achieve the goals and reach financial inputs that could not be sustained by any single nation. This said, the concept of the Moon Village is intended to be comparatively loose, with potentially no complementary international treaty of the sort seen with the ISS, permitting higher degrees of freedom for different nations and public/private entities to participate. Current research in LEO gives a taste of the range of capabilities still needed to inhabit the moon, e.g. in astronaut health, 3D printing etc. It additionally highlights the number of stakeholders that would be needed to meet such a demand, and a modality to begin discussions and facilitate cooperation between such a variety of actors and technologies is the first milestone.

3.3.2 Space Affairs at European Union Level

It must always be kept in mind that the U.S. space sector, while certainly multifaceted and structured across various agencies and institutional bodies, is substantially different from the European one. As is well known, European space endeavours have taken place over the decades through collaboration between the different responsibilities, roles, prerogatives, and activities of three main institutional entities: ESA, the European Union, and their respective member states, governments and national space agencies.[251]

In light of this, to complement this chapter's overview, this section outlines some of the most recent proposals advanced from the European Commission with regard to its future involvement in European space programmes.

In the 2016 "Space Strategy for Europe", the European Commission had already highlighted its key objective to foster a globally competitive and innovative European space sector to maintain and further strengthen a world-class capacity to conceive, develop, launch, operate and exploit space systems and open up new opportunities to develop innovative products, services and processes which could benefit industry in all member states. To achieve this objective, the Union intends to explore two areas:

- Supporting research and innovation and development of skills: based on dialogues with private actors and other innovation actors to address their competitiveness needs and strengthen the use of innovative procurement schemes. The aim is to stimulate and support the demand-side of innovation and explore new approaches to leverage private sector investments and partnerships with industry;
- Fostering entrepreneurship and new business opportunities: the objective is to support European space entrepreneurs in starting and scaling up across the European single market, enhancing its support to SMEs (small and medium-sized enterprises), start-ups and young entrepreneurs through business incubators and the use of prizes and competitions.

More recently, between 2018 and 2019 the EU has been preparing for the coming post-2020 phase under the new Multiannual Financial Framework (MFF). In early 2018, the proposal for MFF Regulation was submitted to the European Council and Parliament, inclusive of the draft budgetary framework for EU space programmes in the coming years. In June 2018, it was announced that the EU would propose to

[250] Woerner, J. "Moon Village. A vision for global cooperation and Space 4.0". ESA Website.
Web: https://www.esa.int/About_Us/Ministerial_Council_2016/Moon_Village.

[251] For a complete analysis of the evolution of European space policy and relations between its main actors, see: Reillon, V. "European space policy: Historical perspective, specific aspects and key challenges". EPRS | European Parliamentary Research Service, Members' Research Service — PE 595.917. January 2017.
Web: https://www.europarl.europa.eu/RegData/etudes/IDAN/2017/595917/EPRS_IDA%282017%29595917_EN.pdf.

significantly increase its budget for its space programme to around €16 billion for the period 2021-2017.[252] Consolidating all EU space-related activities into a unified Regulation, the budget is broken down into three key areas:[253]

- Satellite navigation systems: receiving €9.7 billion, both the Galileo and European Geostationary Navigation Overlay Services (ENGOS) programmes will obtain further ongoing financial input to continue and improve upon their services. This includes all development, deployment of satellites, operation, maintenance, and the provision of services.[254]
- Earth observation: obtaining a budget of €5.8 billion for the next phase, the Copernicus programme – a globally leading provider of Earth observation data, will continue to "*expand these existing services to meet emerging needs, adding new observation capacities for CO2, and other greenhouse gas emissions monitoring, land use monitoring in support of agriculture, observations of the Polar regions, as well as security needs to improve detection of small vessels in support of border and maritime surveillance, the fight against illegal trafficking or the needs for EU external actions*".[255]
- New security components: a budget of €500 million would be set aside for the development of new security related systems. First, this budget is intended for the new Governmental Satellite Communication (GOVSATCOM), providing "*Member States and EU security actors with guaranteed access to secure satellite communications*".[256] Second, the development of the Space Situational Awareness (SSA) initiative falls into this category, aiming to "*support the long-term sustainability and security of space activities by ensuring protection against space hazards*".[257]

Alongside these plans is the additional proposal to establish a European Union Agency for the Space Programme (EUASP), expanding the current Global Navigation Satellites Systems Agency (GSA) body with a larger mandate. Currently, the GSA is responsible for the market uptake aspects of Galileo: designing and improving upon GNSS services and infrastructure; managing the provision of services in a user-oriented and cost-efficient manner; engaging market stakeholders; and ensuring European GNSS services and operations are secure, safe and accessible.[258] Similar to the GSA, the new EUASP body "*will increasingly support the exploitation and market uptake of EU space activities and play an increased role in ensuring the security of all the components of the programme*".[259] However, it is the intended objective of the creation of this new agency to provide a single EU single entity with oversight for the breadth of all EU space programmes, not just Galileo and EGNOS. In this regard, EUASP will have a larger authority than GSA, and a broader mandate of domains and programmes to cover.

As noted, the new EU space programme intends to establish a single streamlined space strategy, consolidating all existing and future EU-owned space ventures and creating a simpler means of cooperation between institutional actors. In line with this, the creation of EUASP is a consolidation. Beyond this, and looking wider on the European platform, streamlining aims to set up a more distinct organisation of actors with clearly defined roles and responsibilities: the European Commission, ESA and the proposed EU Agency for the Space Programme (as a scale-up in mandate, role, budget and responsibilities of the

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252 "EU budget: A €16 billion Space Programme to boost EU space leadership beyond 2020". European Commission Press Release. 6 June 2018. Web: http://europa.eu/rapid/press-release_IP-18-4022_en.htm.
For the full proposal text see: "Regulation of the European Parliament and of the Council establishing the space programme of the Union and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013, (EU) No 377/2014 and Decision 541/2014/EU". European Commission. June 2018.
Web: https://ec.europa.eu/commission/sites/beta-political/files/budget-june2018-space-programme-regulation_en.pdf

253 "Questions and Answers on the new EU Space Programme". European Commission Fact Sheet. 6 June 2018.
Web: http://europa.eu/rapid/press-release_MEMO-18-4023_en.htm.

254 Ibid.

255 Ibid.

256 Ibid.

257 Ibid.

258 "About GSA". GSA Website. Web: https://www.gsa.europa.eu/gsa/about-gsa.

259 "EU budget: A €16 billion Space Programme to boost EU space leadership beyond 2020". European Commission Press Release. 6 June 2018. Web: http://europa.eu/rapid/press-release_IP-18-4022_en.htm.

existing GSA). Within this structure, according to the proposal, each of the named entities will have the following responsibilities:[260]

- The Commission will coordinate and supervise the different components, define the high-level objectives (budget, security and schedule) and long-term evolution of the programme, and will be in charge of the adoption of regulatory activities.
- ESA, given its unmatched expertise, will remain the main partner and will be responsible for:
  - Copernicus: development, design and construction of the Copernicus space infrastructure, including the operations of that infrastructure;
  - Galileo/EGNOS: systems evolution, development of the ground segment and the design and development of satellites;
  - All the components of the Space Programme with research and development activities in its fields of expertise.
- The EU Agency for the Space Programme will be responsible for:
  - Galileo/EGNOS: The management of operations and ground maintenance; communication, promotion and market uptake;
  - Security Accreditation by the Security Accreditation Board (SAB) for all the components of the Space Programme;
  - Possibility to carry out the market development and users' coordination potentially for all the components of the Space programme.

If such a proposal is ultimately approved and realized, an evolution of this magnitude might undoubtedly influence activities and roles of national space agencies within Europe and of ESA itself in the long term. Furthermore, these changes may lead to the adoption of new regulatory and policy frameworks for space activities,[261] organisational reshuffling of existing EU bodies related to the space programme, and ultimately an evolution of the EU's relationship with ESA and therefore of the European space governance as a whole.

3.3.3 National Agencies: Heightened Focus on Fostering Businesses

National space agencies in European countries are similarly adopting new strategies, also following recently-commissioned studies to analyse the impact of "New Space" on the European space sector,[262] to help identifying new approaches in response to the evolving space dynamic.

Among various initiatives, a recent one launched by ASI is a national mission contributing to the upcoming pan-European programme GovSatCom, a European Commission programme conducted with the European Defence Agency and ESA to provide secure telecommunication services. In July 2019, ASI and a consortium of Italian companies kick-started the Ital-GovSatCom project under a new procurement approach which sees the programme financed 50% through government funding and the remaining half by the private sector.[263]

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[260] "Questions and Answers on the new EU Space Programme". European Commission Fact Sheet. 6 June 2018. Web: http://europa.eu/rapid/press-release_MEMO-18-4023_en.htm.

[261] Notably, a key element characterising the European space sector public procurement is the stark difference between ESA and the EU. As explained in Chapter 2.1.2, ESA's industrial policy is founded upon the principle of geo-return (or fair return) among its Member States with respect to their financial contributions to the Agency, whereas the EU operates under open market competition rules. Much analysis has been done on this topic in the past two decades (see for example: https://www.esa.int/About_Us/ECSL_European_Centre_for_Space_Law/Procurement), and harmonisation between the two approaches, whether desirable or not, was not achieved.

[262] See for example: "NewSpace – New business models at the interface of the space industry and digital economy", commissioned by the German Federal Ministry of Economy and Energy (https://www.bmwi.de/Redaktion/DE/Downloads/B/bmwi-new-space-geschaeftsmodelle-an-der-schnittstelle-von-raumfahrt-und-digitaler-wirtschaft-kurzfassung-en.pdf?__blob=publicationFile&v=6), and "Open Space – L'ouverture comme réponse aux défis de la filière spatiale", commissioned by the French Government (https://www.gouvernement.fr/sites/default/files/contenu/piece-jointe/2016/07/contributions_-_remise_du_rapport_de_genevieve_fioraso_sur_lavenir_du_secteur_spatial.pdf).

[263] Caleb, H. "Italy to increase space projects with "mirror programs" of European agencies. SpaceNews, 30 July 2019. Web: https://spacenews.com/italy-to-increase-space-projects-with-mirror-programs-of-european-agencies/.

Moreover, not just new and innovative initiatives such as funding mechanisms, support to start-ups SMEs, for example in the form of grants for R&T support, as well as PPPs-like programmes are being implemented by long-standing space agencies, but some countries are also establishing new, fully-fledged space agencies, serving a variety of purposes, each one distinct according to national strategies and priorities. Indeed, when looking into detail of the missions of the newer national space agencies in Europe, the explicit focus is often put on unlocking and supporting growing business perspectives for the national space industry within their respective countries, and increasing competitiveness abroad.

For example, most likely due to its comparatively recent establishment, UKSA places a strong focus on supporting UK space-related business development. Detailed in the UKSA's Corporate Plan 2017-2018, and continuously iterated through National Space Policy and strategy documents,264 the UK plans to increase the country's attractiveness for private space ventures, aiming to capture 10% (£40 billion) of the global space market by 2030 and maintain a position as a global leader in space.[265] To this end, UKSA has established a Space Growth Partnership with UK space industry, facilitating joint planning and delivery for both the growth of the UK space industry as well as for societal benefits – this relationship will also provide a means of feedback into UKSA's Space Growth Strategy.[266] More specifically, the UK is further developing its already flourishing small satellite market by working towards small satellite launch services, creating the necessary legal and regulatory framework and working with industry to finalise the creation of a UK-based spaceport in the near future.[267]

Regarding its satellite industry, the UK additionally aims to bolster and promote the downstream satellite applications markets with its domestic and international partners, aiming to advance in areas from precision agriculture, aviation, health, disaster and risk management, to automobile navigation. To this end, UKSA seeks to enable the right conditions to allow industry to grow, particularly in the field of GNSS, in which UK industry is at the forefront in terms of manufacturing and development.[268] Along these lines, Innovate UK, formerly known as the Technology Strategy Board, established the Satellite Applications Catapult in 2013. The Satellite Applications Catapult is a private and independent, not-for-profit, technology and innovation company set up to "*drive economic growth through the exploitation of space*".[269] The company aims to propel the UK's satellite industry by working with businesses of all sizes to fully exploit satellite infrastructures and applications.[270] More recently, Satellite Applications Catapult has added to the growing list of space Business Incubation Centres (BICs) in the UK. This came alongside an announcement by UKSA in 2017 which outlined its intent to provide funding for the creation of four new BICs to increase the number of start-ups emerging across the UK.[271] UKSA now supports 15 BICs across 22 locations as part of the UK Space Incubator Network – "*a growing number of incubators dedicated to*

264 "National Space Policy". UKSA and HM Government, 2015.
Web: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/484865/NSP_-_Final.pdf.

265 "Corporate Plan 2017-2018", pg. 3. UKSA. Web:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/641447/corporate_plan_2017-18.pdf.

266 "Corporate Plan 2017-2018", pg. 13. UKSA. Web:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/641447/corporate_plan_2017-18.pdf.

267 Ibid.

268 Ibid.

269 Catapult Satellite Applications Website. Web: https://sa.catapult.org.uk/about-us/who-we-are/.

270 Ibid.

271 "New Business Incubators Will Help Space Industry Grow". UK Government Press Release, 7 December 2017.
Web: https://www.gov.uk/government/news/new-business-incubators-will-help-space-industry-grow.

identifying and accelerating the growth of start-up and scale-ups that are leveraging space technology as a critical asset in their businesses".[272]

Among the several recently-established space agencies worldwide (notably, the Australian Space Agency, ASA, founded in July 2018), the newest European national space agencies are the Luxembourg Space Agency (LSA), founded in September 2018 and Portugal Space, founded in March 2019. What is interesting is that in these (and possibly other) instances, the creation of the institutional body can be considered embedded in – and possibly a consequence of – the commercialisation of space dynamic.

LSA is explicitly a "*business-focused national space agency*", with the overarching goal of furthering the economic development of Luxembourg's space industry by *"attracting businesses, developing human resources, providing innovative financial solutions and supporting educational and research infrastructure*".[273] In contrast to many other national space agencies further afield, LSA "*will not directly conduct research or launch missions",* rather orientating itself around fostering stakeholder collaboration.[274] Luxembourg's most distinctive characteristic in governing its space industry is that it "*provides a unique legal, regulatory and business environment*," as a foundation for commercial space ventures to flourish in the New Space ecosystem.[275] In line with this, and prior to the creation of LSA, the Ministry of the Economy for Luxembourg launched the SpaceResources.lu initiative in 2017 for the identification and utilisation of space resources.[276] The initiative, now directed by LSA, is aimed at stimulating commercial actors within this domain, complemented by a legal and regulatory framework that provides assurances, clarity, and protection for investors and space entrepreneurship to conduct their operations.[277] In 2017, Luxembourg became the only nation in the world besides the U.S. to adopt its own law on space resources, securing "*the right of private operators working in the space sector to resources extracted in space*".[278] Additionally, the law provides regulation for the approval and surveillance of private missions to explore or gather space resources, requiring private actors to obtain prior ministerial agreement.[279, 280]

The new Portuguese space agency, Portugal Space, has a conceptually similar strong focus on supporting two emerging commercial space domains, one being Earth observation small satellites, the second represented by privately-led small and micro launchers and their related launch infrastructure. Reflecting the importance given to the latter, the PSA will be headquartered in the Azores islands, where a microsatellite launching base will be built.[281]

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[272] "What's The UK Space Incubator Network?". SetSquared Website. Web: http://www.setsquared.co.uk/start-support/uk-space-incubator-network
[273] "Luxembourg launches business-focused national space agency". Press release of the Government of the Grand Duchy of Luxembourg. 12 September 2018. Web: https://space-agency.public.lu/dam-assets/press-release/2018/2018-09-12-Press-release-Launch-Lux-Space-Agency.pdf.
[274] Ibid.
[275] Spaceresources.lu website. Web: https://spaceresources.public.lu/en.html.
[276] Ibid.
[277] Ibid.
[278] "A legal framework for space exploration". Grand Duchy of Luxembourg website. 13 July 2017. Web: http://luxembourg.public.lu/en/actualites/2017/07/21-spaceresources/index.html.
[279] Ibid.
[280] Ibid.
[281] Felipe, L. "Government approves the creation of Portuguese space agency Portugal Space". Portugal News. Web: https://portugalinews.eu/government-approves-the-creation-of-portuguese-space-agency-portugal-space/.

4 Assessment of the Public-Private Interaction in the Space Sector

As outlined in the previous chapter, within the evolving and changing spacescape, space agencies are actively seeking new methods to interact with the private sector, with the double objectives of continuing to fulfil their core mission and mandate, and at the same time exploiting the benefits deriving from the "New Space" / Space 4.0 trends and dynamics. This chapter makes an assessment of the two main methods of interaction for major programmes – traditional procurement and public-private partnerships –highlighting the key merits and limits of these approaches and relevant conditions of applicability.[282] However, it must be noted that other mechanisms exist, such as grant schemes envisaged explicitly for research and technology development, which focus primarily on supporting SME activities.

4.1 Traditional Public Procurement

Traditional public procurement, as described in Chapter 2.3, has been a staple of the space sector since its inception, enabling countries to kick-start, develop and sustain their own space industry in such a successful way that ultimately led to the current space era. In light of the analysis conducted in the previous chapters and interviews with experts from public agencies and private companies, some key merits of traditional procurement can be highlighted, while also pointing out a number of inherent constraints (Table 2).

	Traditional Procurement
Merits	• Capabilities development: effective, and even fundamental, for high-risk technological development • Appropriate for the initial (or sustained) development of systems and infrastructures for public good and societal benefit • Straightforward to decide and implement, with a cohesive and unified overview from overall strategy to design • Enabling step for long-term market creation
Limits	• Risks and costs incurred entirely supported by the public side • Not market-focused in the short- and medium-term • Relationship between agency and industry can be inelastic • Might entail inefficiencies inherent to the necessary public scrutiny and oversight of public investments

Table 2: Merits and limits of traditional procurement in the space sector. Source: ESPI

[282] A detailed analysis of PPPs for the broader Science, Technology and Innovation (STI) domain can be found in: "Strategic Public/Private Partnerships in Science, Technology and Innovation – Final Report". OECD, 2014. DSTI/STP/TIP(2014)15. Web: https://era.gv.at/object/document/1991/attach/Beilage_5a_OECD-_PPP_in_science_and_technology.pdf.

4.1.1 Merits

Capabilities development: effective, and even fundamental, for high-risk technological development

It is clear that for a number of space domains (e.g. science and basic technology), the injection of public funding is fundamental to their continued activity. In this sense, the traditional procurement and management of a space science programme is not only effective in achieving its objectives, it is also the only option available. While great innovations and potential for revenue may result from a basis in scientific research, and it is not unknown for private actors to conduct basic research, there is little market incentive for this type of scientific fundamental research to be substantially privately-driven, particularly in programmes with significantly high costs.

For this reason, space science domains are generally considered as a public good in itself with potential for societal benefit – as such the traditional model, placing risk and costs on the public side, is most adequate in domains in which costs, risks, and limited market prospective rule out private actors.

Appropriate for the initial (or sustained) development of systems and infrastructures for public good and societal benefit

This reasoning for space science domains is also applicable to the development and operation of large-scale technological systems and infrastructures that are public goods but have limited (or no) market potential.

It must be noted that many technological systems (i.e. satellite telecommunication networks) may indeed be considered a societal good. However, as soon as they are profitable, they might be suited to a PPP framework. For instance, in the development and operation of large systems in which substantial public funding is available (e.g., national satellite systems like, among others, the Skynet 5 programme - see Chapter 2.3.2), a more publicly weighted PPP might also be suitable.

Actually, a traditional model for the procurement and operation of a large infrastructure is not without its merits, as was the case in the implementation by the EU of its flagship programmes Galileo and Copernicus.

Straightforward to decide and implement, with a cohesive and unified overview from overall strategy to design

The specific merits of maintaining public control under the traditional model is that the dedicated management of the overall programme can be conducted through a cohesive and unified standpoint. It has already been highlighted in Chapter 2.3.2 that miscommunication or mis-alignment of goals and objectives when establishing a PPP scheme could be detrimental to the smooth development of a programme. Public control and oversight within the traditional model can help alleviate such issues. As such contracts have been employed since the inception of the space age, the relationship terms have reached a certain level of maturation.

Moreover, space agencies have a strong and uncompromised approach to quality assurance and reliability, which might be a requirement for the continued delivery of public services. In the specific case of manned space missions, this is obviously a major driver. While these same factors also apply to private space actors, private companies are, by necessity, more prone to trade-off reliability and costs.

Enabling step for long-term market creation

As described in Chapter 2.4, one of the major historical outcomes of space agencies' R&D undertakings has been the spin-off of entirely new entities (private or still partially publicly-backed), that took over operations, or provision of services (or both), after initial agencies' involvement. The entirety of the initial development of the main space sector domains has relied on this type of contract, whose output in terms of patents and technologies ultimately seeded the opening up of new markets over a few decades.

In light of this, in yet-to-be developed domains an initial and substantial assumption of development and financial risk by public agencies is still instrumental in allowing industry to acquire the expertise that will later morph into greater autonomy to compete on the commercial market.

4.1.2 Limits

Risks and costs incurred entirely supported by the public side

One of the defining features of traditional procurement is that all risks and costs of the enterprise are to be borne by the public institution.

Indeed, while qualities of the traditional procurement model might be more suited to certain domains, these features can render the model inapplicable in other areas. As the traditional model relies on public funding and initiative in its entirety, a programme resulting from a traditional scheme will always be subject to a nation's or space agency's agenda and availability of funding.

Moreover, this approach shows its limits when flexible arrangements are sought for the delegation or transfer of some aspects of design and development, risks, and costs. Currently, such flexibility is considered useful to appeal to private investors, as well as to clarify and tailor roles and responsibilities of stakeholders in an efficiency-driven approach. This basic relationship with industry has financial implications since the burden of potential cost overruns *de facto* mostly remains on the public side. Unless justified by strong quality management or non-negotiable reliability requirements, this model presents inherent limitations.

Not market-focused in the short- and medium-term

In a similar vein, a traditional procurement model is usually not tailored to exploit market potentials – generally being a public good. The development logic to which this model abides, as described in this section, are not intended to spawn systems and services that could be competitive in the short term on the open market. On the other hand, early-stage technology maturation programmes can, as described in paragraph 2.4, lead to long-term market creation.

Relationship between agency and industry can be inelastic

In many ways under a traditional procurement model, an agency's relationship with industry is plain and simple, and its implementation is straightforward. Traditional contracts have little variance in terms of the roles and responsibilities of the public and private partners, and standardised contractual conditions usually set the baseline framework.

Might entail inefficiencies inherent to the necessary public scrutiny and oversight of public investments

Moreover, gaining government approval for funding, or additional financial support throughout development, is sometimes a highly arduous political process subject to a complex array of factors and some bureaucratic overheads inherent with public management might be encountered.

Finally, the above-mentioned drawbacks and limitations are out-weighed by the undisputable merits of this model, which thus is highly relevant for one-shot programmes, high technological risk ventures or the deployment of publicly managed infrastructures. For low-cost or faster options, some other models might be more appropriate.

4.2 Public-Private Partnerships

PPP models have recently been preferred to traditional procurement in several space programmes over the last decade, in particular in Europe. They obviously offer distinct advantages, in particular in terms of the commitment of the private sector. However, they also come along with a number of limits (Table 3), and a number of conditions affecting both partners have to be met for these schemes to be successful,[283] and achieve a balanced win-win outcome between both partners.

<table>
<tr><th>PPPs</th><th>Private Partner</th><th>Public Partner</th></tr>
<tr><td>Merits</td><td>• More autonomy and freedom of action for technical management
• Return on investment and market potential
• Gain intellectual property associated with innovation and R&D
• Gain competitive advantage</td><td>• Timeliness, efficiency and flexibility of programme development
• Transfer of risk to the private sector
• Spin-in from non-space domains technologies
• Reduced upfront costs
• Allow a reallocation of public agencies’ focus and resources</td></tr>
<tr><td rowspan="2">Limits</td><td colspan="2">• Require a well-developed industrial base, able to sustain risk and to commit to the long term
• Possibly complex to establish: require careful alignment of goals, agreement on timelines and governance, clarification on ownership, access, decision and control</td></tr>
<tr><td>• Increased risk to be sustained
• Not easy to balance risk and reward</td><td>• Potentially more expensive in the long term
• Require keen know-how of markets and business risks for proper evaluation</td></tr>
</table>

Table 3: Merits and limits of PPPs for the public and private partners in the space sector. Source: ESPI

[283] A highly relevant case study with regard to conditions of applicability of and preconditions for the success of PPP models is represented by the initial phases of the European Galileo programme, in particular the dedicated structure called “Galileo Joint Undertaking (GJU)”. Whilst Galileo represents today a technological success and outstanding example of European cooperation efforts between ESA, the EC and industry, the report of the European Court of Auditors published in 2009 shed light on a number of issues related to the PPP model envisioned during the initial phases of this programme, and provides insightful recommendations. The full Court of Auditors report is available at: https://publications.europa.eu/en/publication-detail/-/publication/063ee2e2-e08b-4c5b-ac69-e50454bb7818/language-en, and a summary is available at: https://insidegnss.com/european-court-of-auditors-lambastes-galileo-satellite-navigation-program/.

4.2.1 Merits

For the private partner

More autonomy and freedom of action for technical management

From the private actor standpoint, PPPs permit a higher degree of autonomy in the design phase as well as in the technical management of activities as compared to traditional procurement schemes. This is appealing for several reasons:

- First, the private actor is less impacted by potentially cumbersome public procurement procedures applicable at all stages of development,

- Second, companies can decide upon the industrial organisation and technological design of the system or project at hand. As long as they meet the needs and quality requirements laid down by the public partner there is a greater deal of independence for the private actor to self-define the 'how' achieving the objective.

In many respects this may make the project more effective, in particular in terms of schedule-keeping. Such a more "cost-driven" approach, also leaves less leeway for interference with political constraints.

Return on investment and market potential

Business and profit perspectives are basically the major drivers that motivate industry, and PPPs can be quite effective for the private partner to get a satisfying Return on Investment (RoI). Therefore, they may not be the most appropriate for programmes requiring technologies that haven't yet reached a sufficient level of maturity or, on a different note, for projects entirely intended as public goods, meant to exclusively serve the needs of institutions or public customers.

However, as of today there is an abundance of ground to be made especially in commercially viable upstream and downstream fields. PPPs may also be of significant value in the development and operation of systems intended to cover both public and private interests. In this sense PPPs probably best fit in areas offering medium-term and not yet proven market perspectives. They can be useful in providing a foothold in the emergence of new services, facilitating access to existing public infrastructures, or contributing to the growth of existing markets.

Lastly, PPPs allow for a measured transfer of risks towards the private partner. Such risk taking shall of course be rewarded and the expected profits need to be commensurate to the level of risk to be borne by the companies involved.

Gain intellectual property associated with innovation and R&D

Another merit of PPP ventures from the perspective of the industrial partner is the prospective acquisition of intellectual property rights (IPRs) stemming from the public-private research and technology development. While the IP related to developed technologies typically resides within the public agency in traditional procurement, PPP models may allow for greater flexibility. Depending on the contractual arrangements to be defined on a case-by-case basis, IPRs could either be shared between the public and the private partner, or entirely assigned to the private partner. This latter case in particular constitutes a significant incentive for companies, as they would be therefore able to leverage and exploit technologies partially developed with public funding on the commercial market, retaining ownership of such products.[284]

[284] The release of IPRs to industry constituted one of the key components for the successful outcome of NASA's COTS, as recognised in NASA's "Lessons Learned" final report. See: "Commercial Orbital Transportation Services (COTS) - Lessons Learned

Notably, it is not just about actual patents and technologies. Data sharing models between public and private partners as an outcome of a PPP arrangement could equally be beneficial and incentivising for the private partner, in particular towards the downstream market and development of new value-added applications.

Gain competitive advantage

The ultimate reward for industry to be obtained through well-implemented PPPs is to gain a strategic competitive advantage over international rivals. This is achieved in the short term by the expected profits of the venture, and in the longer term through the leveraging of new IPRs and technologies to gain market traction and thus expand the customer base, public or private alike (see Figure 4).

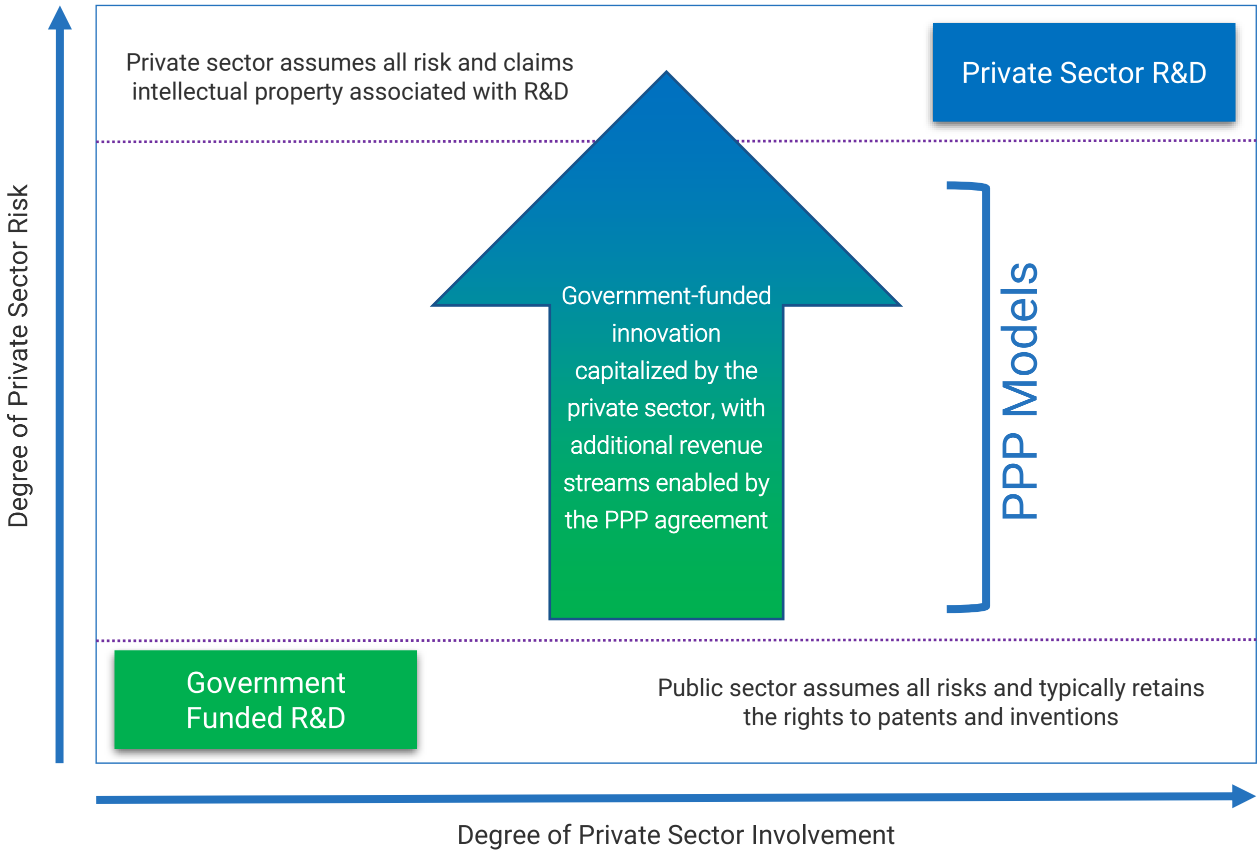

Figure 4: Space Sector PPP Delivery Models in the U.S. Adapted from Jones, K. L. "Public-Private Partnerships Stimulating Innovation in the Space Sector". The Aerospace Corporation, April 2018.

For the public partner

Timeliness, efficiency and flexibility of programme development

Considering a number of space sector PPP examples, it is clear that the partnerships often exhibit as one of their main features a controlled development cycle, probably better than could have possibly been achieved in a traditional fashion. As previously seen, this is mainly due to a more profit- and time-to-market-driven development logic that is bound to be adopted by industry. In this respect, the public sector

for Commercial Capability Development Partnerships". NASA, April 2017.
Web: https://www.nasa.gov/sites/default/files/atoms/files/cots_lessons_learned_report_final_signed.pdf.

thus leverages and incentivises the private sector's efficiency in terms of schedule, costs, and business perspectives.[285]

Such quicker pace of development has been dramatically demonstrated with the NASA COTS programme: arguably, ensuring U.S. independent access to the ISS was an agency priority driven by timing, on top of economic considerations.[286]

Another element of value is the increased flexibility during the overall programme implementation: as seen in the COTS programme and follow-ups, several of the terms and milestones of the SAAs included a degree of flexibility, and could be adjusted or postponed as needed. What is most important here is that even with such adjustments and, possibly, delays, the public partner ultimately does not incur additional costs, which are to be borne by the private industry as part of the increased risks accepted for the venture.

Spin-in from non-space domains technologies

The spin-off of technologies exclusively developed for space to broader, Earth-bound uses has been a successful practice over the past decades, with abundant examples. While this will certainly continue in the future, as highlighted in Chapter 3.1.3, one of the characteristics of the current space age is that non-space technologies, industrial processes, and commercial-off-the-shelf components are being increasingly adopted for the development of space systems.

In the context of space PPPs, this is a particularly beneficial for the public agencies: in typical procurement, systems and technologies are developed for the explicit purpose of the mission, in a rather "vertical" or top-down fashion. PPP models can be structured instead to greatly incentivize innovation, by encouraging space companies to seek and adopt various off-the shelf available technologies, know-hows and methods.

Transfer of risk to the private sector

One of the main benefits of a space PPP for the public institution is the transfer of a substantial amount of development risk (and the entirety of operational risk) to the private side. The objective of the risk transfer is to achieve an optimal risk allocation, as the risks should then be allocated to the party best able to manage them. In other words, the party that is best able to understand the risk, control the likelihood of the risk occurring, and/or minimize the impact of the risk, should also be responsible for managing it.

The effective allocation of risk has a direct impact on the financial structure of the project where the risk allocation is critical for the success of the project. The degree of risk transfer to the private sector will influence the overall cost of the project for the public sector, as risk will be associated with a price premium.

Reduced upfront costs

It is the tendency of PPP schemes to spread the costs of a venture for the public partner over an extended period covering the whole life-time of the project; this can be done at regular intervals or more likely after achieving defined milestones. One of the most prominent benefits of this approach, particularly in the context of public spending, is that the reduced initial expenditure dampens the burden of the project's

[285] On the other hand, stakeholders' interviews conducted for this research pointed out that, from the perspective of the private partner, certain PPPs conducted in the past still lacked the necessary acceleration and speed required for industry to achieve competitive outcomes. This was attributed to a still too-lengthy process inherent in the modus operandi of the public institutions. However, the same stakeholders also noted that the evolving public-private interaction as it pertains to space PPPs is still in a learning curve, with potential for improvement particularly in the matter of timing.

[286] Notably, it was also aligned with the U.S. DoD strategy to foster the emergence of at least a second domestic launch service provider able to launch into orbit national security payloads, thus breaking up the de-facto monopoly of United Launch Alliance (ULA). See: Aliberti, M. and Tugnoli, M. "The European Launchers Between Commerce and Geopolitics". ESPI Report 56, ESPI, Vienna, 2016. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/10-the-european-launchers-between-commerce-and-geopolitics.

cost justifications, facilitating its uptake and acceptance and enabling the project to begin in a timely manner. In this sense, the reduced upfront capital, combined with joint financing between partners, can be an attractive option when the sources of funding are not immediately achievable within a purely publicly funded framework. Beyond this, phased or progressive financing also provides a means of stimulating the private partner to continuously improve upon efficiency. As mentioned previously, traditional contracts could promote less of a will to do so, since there exists a certain level of security in upfront payments. In this sense, PPP models are an attractive option for bringing a wider pool of private actors into public ventures, both reducing costs on the public side and bolstering the industrial base.

Allow a reallocation of public agencies' focus and resources

From an overall perspective, one of the main merits of entering into PPP arrangements with the private sector to conduct space programmes is the possibility for the public agency to free up a considerable amount of resources. This is mostly due to reduced micro-management of the various phases of the programme, as the agency is substantially involved at the outset, when laying out the initial partnership terms and goals in the clearest way possible, and then follows up verifying that the terms and milestones are respected.

Such significant change in management perspective would in principle allow financial, human and technical resources to be dedicated to other priorities, for example conducting ground breaking and cutting-edge R&D programmes, bearing the full risks of development, for which no PPP or private initiatives are possible.

For the sake of proper implementation of PPP arrangements, the world-class technical expertise developed within space agencies would continue to serve as a strong "counter-expertise" with respect to the more autonomous privately-led programmes. Indeed, technical expertise and know-how in such partnerships will primarily reside with industry. However, in order to avoid placing the public partner in a situation of inherent disadvantage, such counter-expertise is indispensable to properly assess industry proposals and give agencies the means to ensure adequate technical oversight of the programmes.

4.2.2 Limits

PPPs require a well-developed industrial base, able to sustain risk and to commit for the long term

As pointed out, one of the key enabling factors for increased adoption of PPPs in the space sector is the greater degree of maturity achieved by industry over the course of the years. Without such maturity, PPPs would hardly be successful. And naturally, in those domains or instances where a mature industrial compartment is not yet primed to sustain the increased risks of PPPs, these models can hardly be implemented from public institutions.

In addition, as for other types of traditional programmes, PPPs are equally structured on a long-term perspective, over the course of which the private partner must continue to fulfil its obligations and respect the agreed milestones (aside from external circumstances such as force majeure). Before entering the partnership, it is key that the industrial partner is in a position to commit on its side until project achievement.

However, in light of the long-term nature of the project and inherent complexities, both parties should still be aware of the possibility and need to renegotiate certain contractual terms during the course of the project, to address and compensate for issues (endogenous or exogenous) that might arise and that were not anticipated at the onset of the PPP agreement.

Possibly complex to establish: require careful alignment of goals, agreement on timelines and governance, clarification on ownership, access, decision and control

While traditional procurement is by now quite straightforward from a contractual and procedural point of view, the variety of PPP models and larger number of factors and actors to be taken into consideration make this kind of arrangement more complex to undertake.

Once established by the public agency that the PPP model is the right approach for the conduct of a certain programme, as demonstrated by the lessons learned from both successful and unsuccessful PPPs in the past, the clear definition of boundary conditions and goals at the onset of the partnership is absolutely essential to help ensure its accomplishment. Public and private partners must agree to the greatest level of detail possible on their objectives, separation of responsibilities, ownership and governance, decision processes, and, ultimately, control over the programme. Moreover, it is imperative for both partners to carefully structure, balance and agree on the milestones, both financial and technical, putting in place mechanisms and strategies to mitigate the risks inherent for potential difficulties encountered during the partnership.

When entering into this kind of agreement, it is advisable for public agencies to acquire and develop adequate and specific skills. While retaining strong technical and engineering know-how, necessary for proper assessment and evaluation ("counter-expertise" to the private partner), an additional understanding of private sector methods, processes and the way to conduct business is required on the agency side.

For the private partner

Increased risk to be sustained

While not a limit per se, but a defining feature of the agreement, the increased amount of risk to be borne by the private partner is still one of the most crucial aspects to be quantified and assessed at the beginning of the partnership. It goes without saying that in order to accept part of the development and operational risks, industry will expect significant control over design decisions and operations.

Moreover, private partners will never accept any major risk beyond their control, and if doing so, their demand for increased price/reward from of the partnership will rise accordingly. A necessary mitigating factor for this second concern is to give industry the means to thoroughly assess potential technological risks before making any commitment.

Not easy to balance risk and reward

As a follow up to the previous paragraph, one of the most difficult challenges of PPP schemes is the balancing of risk and reward – in benefitting from transferring substantial amounts of development and operational risks as well as responsibilities to the private partner, the public actor must in turn offer proportionate reward. This mutually beneficial system, however, can be counterproductive if balance is not achieved.

For example, on the public side, phased/progressive investment in a project is a highly favourable factor in terms of public funding, and institutions should be ready to pay for such convenience. This in turn can act as a stimulus for the private partner and serves as a necessary condition for making industry willing to bear the associated risks. However, assessing technical risks and costs over such a long period is highly challenging and can only be achieved if the public actors have carefully and thoroughly defined their user needs and are determined to stick to them. Actually, one of the key conditions for the success of a PPP is to obtain, from the inception of the project, well-defined and extensive requirements that do not evolve over time.

The balance of risk and reward can also limit the relevance of PPPs to certain domains. Actually, the rewards for the private partner should account for the market potential made accessible through the arrangement. However, profitable business opportunities might not be available in each and every application domain, and the public partner is not likely to bear any of the potential business risks.

For the public partner

Potentially more expensive in the long term

Public agencies often apply different methodologies, such as Value for Money (VfM) with a Public Sector Comparator,[287] to assess the economic benefit of a PPP from their perspective. It is likely that a PPP project, all in all, entails greater costs for the public side over the full course of the venture, mostly due to cumulated provisions and compensations for increased private sector risk.

Therefore, agencies have to carefully assess and decide whether these additional long-term costs are offset by the other strategic merits of the PPP, as they align with their core missions: for example, timeliness of programme development and completion; increased technological innovation and spin-ins for both partners; augmented competitiveness and innovation of the national/regional industrial base, and so on.

Require keen know-how of markets and business risks for proper evaluation

When entering into PPP negotiations with the private sector, public agencies must possess in-house relevant know-how and expertise in a series of areas related to pure business, which they do not traditionally need. As they will be required to initiate, regulate and oversee the development of the partnership, they must have the ability to assess business plans, including market and cost projections, as well as business risks. While this expertise could be outsourced to external specialized entities for the purpose of the evaluation, it is likely that such competencies will be increasingly necessary for them to develop, along with their long-standing technical and engineering expertise.

4.3 The Challenge of Balancing Risk-Sharing, Control and Reward

In the traditional procurement model, the public partner within a contractual agreement bears most of the technological risks associated to the development phase. The private partner in this sense incurs very little of these risks. For the development of major public infrastructure this model is most often used and appropriate for several reasons:

- First, because it is well adapted to the management of high-risk developments in cases in which the technology has not reached a sufficient level of readiness, and in particular for large scale projects. There, the public actor is more likely than the private actor to bear potential delays and cost overruns, sometimes deliberately overlooked to achieve political or strategic imperatives.
- Second, because the amount of risk incurred is not always proportionate to the potential profits and thus is obviously not appealing to private actors if they fail to identify sound market or business perspectives.

While this has been the case for technological systems during their initial development stages, early in the emergence of these technologies, the techniques and processes for many systems, e.g. telecommunications and space transportation, have matured over the decades. This maturation has gradually provided industry with the capacity to technically manage in full autonomy the development of complex space systems, which was the privilege of governmental actors in the early days. As a

[287] That is, the net present value comparison between the lifecycle cost of a programme if it were to be traditionally procured by the public side, or through a hypothetical PPP.

consequence, PPPs have become increasingly relevant, particularly for large-scale infrastructures offering both public interest and commercial viability. In such situations, the private partner can reasonably trade between a higher degree of technological risk during the development phases and stable long-term business perspectives for the delivery of commercial services. This makes the downstream sector a key enabler in such arrangements, shifting the stakes away from design and manufacturing, which used to be the primary focus of agencies and public actors at large.

In the broader economic sense, it should be seen as a positive sign of maturity of the space sector as a whole that private actors are now gaining autonomy, as in other long-established industrial domains. It is actually in the very nature of the private sector to take development and exploitation risks to make profits. One of the outcomes of the recent development of the space economy is to make this rule applicable across the board of the space domain as has long been the case in more traditional areas of the economy. However, the space sector keeps a number of specificities, which still prevent it from a fully standardized market economy.

One of them is the continued strong degree of involvement of major governmental actors worldwide in the sector. As a consequence, it is thus highly regulated and economic considerations have not been a historical driver for the development of regulations, mostly driven by strategic considerations.

A second one is the difficulty of making a clear assessment of the risks, for multiple reasons:

- The highly critical phase of the launch;
- The specific relation to reliability given the impossibility (so far) to perform maintenance and repair operations in orbit;
- The duration of the return on investment cycles, sometimes over 10 years, in high-tech related areas likely to evolve at a fast pace;
- The absence of progressivity in the investment, which requires full deployment before getting a chance to make the reality check of the business case;
- The strategic will of many countries to obtain autonomous capacities of access and operations in space, which prevents a pure "demand and supply" model, inevitably resulting in endemic global over-capacity;

Such a high level of risk or uncertainty should be balanced by very high profit perspectives, which have happened in just a few cases in the short history of space business. However, the trend seems to be today towards a bolder approach to space and a strong belief in promising long-term growth.

However, one condition that will remain applicable is the fact that private actors can only take assessable risks. This issue of "assessing the risk" is particularly critical in the setting up of PPP schemes. In light of this, proper framework conditions should be set up, to give industry the means to assess such risks before they are requested to commit. Clear assessments of this matter before the establishment of a PPP are indispensable to avoid arbitration between the two partners at later stages, possibly leading to increased – and unforeseen – public funding expenditure in order to still complete the programme.

As previously said, from the industrial perspective, higher risks can be sustained provided they are properly rewarded. This should primarily lead to higher payment from the public partner, especially as compared to traditional procurement schemes, although spread over the full duration of the programme. However, if public partners are generally open to transferring more risks to industry, the fact that to achieve so entails increased overall costs is generally not so broadly accepted. Alternatively, the increased risks could be offset by the prospects of profits to be made on the commercial markets (either still partially sustained by public demand or on a purely competitive basis). A third, potentially non-negligible, incentive and reward could lie with the IPR management, provided that companies can reap the benefits of subsequent commercial exploitation of patents and inventions developed during the PPP.

Arguably, one the main issues related to the transfer of risk from public to private partners in space PPPs is the transfer of decisional control that it implies. Transferring risk and control coincide for a number of interlinked reasons. Primarily, a partner expects a greater deal of control once it takes upon itself more responsibility and risk– it is somewhat obvious that should a partner have more of a burden in both risk and responsibility, then they ought to be able to have a larger extent of autonomy in how they uphold their end of the partnership. Whether a company is willing to take on such risk or not will depend on its perception of the sustainability and potential rewards associated with the venture. It is reasonable to grant a mature industry the core endogenous roles over which they can have direct control (i.e. development processes, operations), however factors that are beyond their reach (i.e. broader financial and regulatory fluctuations) should be supported and facilitated by the public side.

Lastly, another concern with such transfers concerns the traditional mission objective of space agencies as developers, equipped with a decades-long strong and unique workforce and culture of engineering expertise. Space agencies are accustomed to retaining the know-how and knowledge to conduct space projects, outlining exactly the "what", and almost entirely the "how" of each programme conducted in traditional procurement of the past decades. From this perspective, giving up – partially or totally – control of the "how", as PPP arrangements suggest, is a major step for the agencies' long-established way of managing activities. Provided it is desirable, it would thus represent a cultural shift of paradigm, highly challenging and most likely irreversible.

5 Reflections on an Expanded Role for European Space Agencies

5.1 Responding to a New Situation

In the first sixty years of the space age, space agencies have undoubtedly been instrumental in shaping and driving the evolution of the sector, fostering and sustaining the development of private industry from its inception (see Chapter 2.1). Acting according to their core tasks and responsibilities, as outlined in Chapter 2.2, these institutional bodies have ultimately achieved outstanding success in unlocking the potential of outer space for the economy and society as can be seen today, through initiatives, collaborations and ever more ambitious programmes across the whole spectrum of what today constitutes modern space activities. Furthermore, in Europe, this has been achieved under very effective economic conditions, as Europe has spent overall a fraction of the space budgets of other major space powers.

Indeed, through a long, cumulative process that took place over the past decades, what began during the cold war as daring space research and technology development programmes – the burden of which was fully borne by the public side – have ultimately spawned entirely new markets and privately-led entities, both in the upstream and in the downstream (as described in Chapter 2.4). From telecommunications and Earth observation, to space transportation and navigation, the value of the global space economy – and the share of private participation in it – is ever increasing. The space sector has moved away from the initial "experimental" framework, to a full operational setup ("commodity"),

In light of this, it can even be argued that in advanced spacefaring nations, one of the "historic" missions that has guided agencies from the outset – that is, fostering the creation and development of a sound space industry – has successfully reached its initial objective.

A new trend for public space agencies' approaches, which will end up characterising the current space age (as described in Chapter 3.1), was initiated in the late 2000s. The origin of this new trend can be traced back to a unique conjunction of factors initially occurring in the U.S., the first of which is the retirement of the Space Shuttle programme and the pressing need to recover independent U.S. manned access to space, and to the ISS in particular (see Chapter 3.2). Notably, this urgent technical and political necessity came at a time when the global financial crisis of 2007-2008 hit the world's economies, leading soon to substantial budgetary constraints for public bodies such as space agencies, and tightened conditions for the timely achievement of the aforementioned objective in the traditional, cost-plus fashion.

The new approach endeavoured first by NASA was thus one of increased reliance on the private/commercial sector to fulfil some of the agency's purposes and goals, substantially changing the main way in which the world's most prominent space agency conducts its space transportation and human spaceflight procurement programme vis-à-vis industry.[288] As shown in Table 1 of Chapter 3.2.2, at the basis of the new approach lie shared costs and risks between the public agency and industry, as well as a transfer of control of key programme characteristics from the former to the latter. From a purely contractual and procedural point of view, the main feature of this new approach lies in the implementation of various public-private partnerships schemes and models, in the perspective of long-term public commitment to the procurement of services offered by private operators (i.e. a growing "anchor customer" role for public bodies).

[288] According to the opinion of some interviewed stakeholders, it can be argued that the so-called "New Space" commercial dynamic can be considered as an outflow of the new acquisition and procurement policy enacted by NASA with the COTS programme, i.e. opening up access and servicing to the ISS to the U.S. commercial market.

Even more fundamental, it can be argued that if such a change in approach was possible (and successful), it is ultimately due to the comprehensive maturity reached by the space industry. This factor eventually enabled companies to have a greater degree of autonomy in developing and conducting space activities, becoming a more independent – and capable – partner to the public side. Naturally, it must always be recognised that such maturity builds upon the cumulative past interaction between private and public actors (namely, public investments), and, in many instances, also on technological developments originally mostly handled by the public sector.[289]

This recent trend, of an increased commercialisation of space activities, progressive shift of risk and responsibility to industry, and procurement of off-the-shelf services,[290] has also spread to Europe, as described in Chapter 3.3. Recognising the potential and opportunities of this approach, European space agencies, particularly ESA as well as national ones, have explored in recent years new ways of partnering with industry, albeit naturally in a different manner than the U.S. model (see Chapter 3.3.1). In particular, the European satcom sector has witnessed the highest number of successful PPPs-like arrangements so far (e.g. the pioneering PFI model of the Skynet 5 programme devised in the UK in the 1990s, and the multiple ESA PPP satcom initiatives in the 2000s previously described). More recently, also in space transportation and space exploration, the blueprints of this approach have been or are in the process of being implemented in a number of European programmes. The Ariane 6 programme (as discussed in Chapter 3.3.1) is a major attempt to achieve an adequate compromise in the relationship between ESA and the European space transportation industry: a higher degree of design autonomy and responsibility for development and industrial setup was given to the private sector, while the programme remains fully backed by public funding.

This on-going commercial dynamic and trend undoubtedly exhibits a number of benefits to be reaped by the public as well as by the private side, as demonstrated by the recent successful examples in the U.S. and, to some extent, in Europe. Yet, as outlined by the CNES President Jean-Yves Le Gall, the so-called New Space dynamic should not be considered as a revolution in the space sector *per se*, but rather as a sectorial evolution responding to a change in the broader industrial and economic paradigm well beyond the space sector, often dubbed as the fourth industrial revolution.[291]

With regard to the various public-private partnership schemes, two major considerations emerge:

- First, it is important to highlight that, as extensively discussed in Chapter 4, PPP models are not intended to nor will replace traditional procurement in a number of areas and domains, for example in early-stage R&D, technology maturation and space science – notably, where there is hardly a possibility for commercial market development, in general or in the short/medium-term (as outlined in Chapter 4.1).

- Second, a number of clear conditions have to be set, and pre-requisites have to be met for PPP models to have a successful outcome. This includes considerations regarding public interest, delimitation of responsibilities, private capability to assess and sustain risk, as well as external factors such as market maturity and uptake, etc. (see Chapter 4.2).

This being said, the above-mentioned approach – which entails a transfer of risk from the public to the private side in exchange for a greater degree of decisional and design autonomy, long-term commitments and investments, as well as avenues for profits on the commercial market, among other key elements – can lead to a number of upturns for the public side:

[289] A prime example is represented by the fact that some technology initially developed by NASA for the Apollo programme, and for VTVL vehicles prototypes in the 1980s is employed in today's privately-developed American space launchers.
[290] In other words, shifting from the status of "almighty customer" to "simple consumer".
[291] Le Gall, J-Y. "Les Enjeux Stratégiques Spatiaux du XXI^{e} Siecle". Réalités Industrielles, pp 17-20. May 2019.

- First and foremost, increased timeliness and cost-efficiency of space developments management as compared to traditional procurement, taking advantage of available industrial skills. In these instances, private companies must obviously follow a different logic (market- and competition-driven, and pressured to generate revenue) than in the traditional cost-plus approach.[292] Naturally, cost-plus approaches still retain their value when addressing high-risk technological development.

- Second, the public-private synergy will continue to efficiently foster and nurture the development of industrial capabilities as well as industry's outward competitiveness and overall sectorial innovation – with the added benefit of technological spin-in from non-space domains.

- Moreover, by placing a lesser burden on the institutional side, focusing on formulation of user needs rather than technical requirements, and reducing micro-management of procurement, space agencies could put increased emphasis and resources in undertaking what no other entity is clearly able to do: dealing with and sustaining the high costs and risks of early-stage technology development and trailblazing space programmes.[293]

As for the private sector, the benefits of a well-structured and arranged public-private partnership scheme are manifold. In particular, these include long-term stability and predictability of business, either as a direct result of the PPP itself, or ideally through access to new revenue streams and markets; increased competitive advantage including acquisition of new intellectual property rights (IPRs) for technologies and capabilities; and ultimately increased technical and business innovation.[294]

It is safe to say that this trend is poised to continue in the future. As its underlying enabling factor is the maturation of the space industry in more and more space domains, and overall forecasts indicate that the space sector will continue growing in the future (in the number of public and private actors, programmes, size of budgets, overall economic value, etc.),[295] likewise the level of capabilities – and, conceivably, appetite for and fitness to sustain risk – of the global space industry will grow accordingly, particularly in the most advanced spacefaring nations.

Moreover, new opportunities and perspectives will foreseeably open up over the next decade. There are several new domains of space activities that could potentially serve as proving grounds for an enhanced and evolved approach of space agencies and governments in procuring programmes. The new areas can be either entirely new and global, such as the emerging in-orbit servicing domain (a broad term that includes satellite life extension and refuelling, tugging, maintenance, inspection, debris removal, even manufacturing);[296] but also regional initiatives within the boundaries of consolidated space domains, such as the upcoming European GovSatCom and Space Situational Awareness (SSA) programmes, and most

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[292] As i.a. shown by the timely and successful outcome of the NASA COTS programme and its follow-ups. Interestingly, the quick development process of commercial space is of particular interest also for military space procurement. As outlined by Mike Griffin, U.S. Undersecretary of Defense for Research and Engineering, it takes the Pentagon an average of 16 years from "stating a need to initial operational capability". Military organisations, particularly in the U.S., are increasingly looking to adopt a similar approach, i.e. heavily relying on and tapping into the commercial sector for their current and future strategic needs. See for example: Erwin, S. "Space Development Agency a huge win for Griffin in his war against the status quo". Space News, 21 April 2019. Web: https://spacenews.com/space-development-agency-a-huge-win-for-griffin-in-his-war-against-the-status-quo/.

[293] Such activity remains, also according to the opinion expressed by some of the stakeholders interviewed for this report, at the core of a space agency's role. This is in line with the view that the governments' role is to be primarily active in those areas of public social, scientific, strategic and economic interest where the private sector is either not willing, able, or even advisable to operate by itself.

[294] For a detailed analysis of the benefits of PPP schemes for the private sector specifically in the field of space exploration, see: Iacomino, C. "Iacomino, C. "Commercial Space Exploration: Potential Contributions of Private Actors to Space Exploration Programmes". SpringerBriefs from the European Space Policy Institute, Springer International Publishing, 2019.

[295] While the fundamentals of the global space sector are certainly solid and there is a huge potential for growth both in developing and established spacefaring nations, such growth would take place provided that limited space resources already strained today (orbits, frequencies, etc.) as well as the overall space environment will be managed in a sustainable way.

[296] A word of caution is due regarding the business case for provision of in-orbit services. As of the time of writing, such business case isn't entirely clear nor proven yet.

likely the development of Space Traffic Management (STM) capabilities and associated regulation in the near future.

In these areas, new procurement approaches and partnerships from the public actor, building on the successful examples of the past (e.g. satcom, remote sensing) and lessons learned, could result in delivering effective space programmes and services.

Looking ahead, as the commercialisation of space will undoubtedly progress in the next few years, more space domains might become a commodity for the delivery of everyday services to citizens. In the longer run, it is not far-fetched to envision space agencies procuring from industry systems and services in the most advanced space domains in a turn-key fashion.

5.2 Rethinking the Customer-Provider Relationship

The on-going dynamic provides many opportunities for institutional bodies such as space agencies, which will require a great deal of behavioural changes to update their institutional toolbox, particularly regarding procurement.[297] Such a step is probably welcome and necessary, since a conceivable risk for established agencies is that not partaking in, or disregarding, this sectorial evolution might result in a reduction of their relevance and role.

This would particularly imply revisiting and rethinking the long-standing customer-provider relationship between agencies and the private sector, as stressed by a number of Heads of Agencies. In a recent interview, the CNES President Jean-Yves Le Gall remarked that *"La quatrième révolution industrielle […] a touché le secteur spatial comme l'ont été tous les autres secteurs technologiques. Face à ce défi, le spatial doit, en France, repenser son partenariat public-privé"*.[298] The ESA Director General, Jan Woerner, observed that "*These [Space 4.0 / New Space] challenges require a new understanding of the role of ESA and the way we carry out and support space activities. Concerning the instruments used to conduct space activities, new methods – including public private partnerships – are to some extent being used already. In addition, turnkey project and multi-partner open concepts may be considered. This diversity of instruments brings with it a diversity of roles which may include traditional agency, partner, broker, enabler or facilitator*".[299]

It is thus clear that the role of space agencies in the new "spacescape" will continue to remain essential, particularly since, as further noted by the CNES President, public investment will remain largely dominant in the space sector in the coming years.[300] Furthermore, the core tasks and missions of space agencies extend across and beyond the increasingly commercial dynamic,[301] so they will not be diminished or outpaced by this trend, but instead augmented by it, opening up new possibilities of partnerships and innovative relationships even beyond PPP models. Finally, as further demonstrated by the recent creation of new agencies in several countries (see Chapter 3.3.3), the space agency as an institutional body will retain a central, conceivably strengthened role in managing the public-private spacescape of the coming decades – also in supporting development of regulations.[302] Notably, the announced European Union

297 It must be stressed once again that space agencies have naturally evolved over the course of the past decades, alongside the evolution of the space sector. The new dynamics of the 2010s represents another turning point – and opportunity – for institutional bodies to reassess and enhance their roles.
298 Le Gall, J-Y. "Les Enjeux Stratégiques Spatiaux du XXIe Siecle". Annales des Mines - Réalités Industrielles, pg. 20. May 2019.
299 Woerner, J. "Looking Ahead". ESA Website. Web: http://blogs.esa.int/janwoerner/2018/07/27/looking-ahead/.
300 Le Gall, J-Y. "Les Enjeux Stratégiques Spatiaux du XXIe Siecle". Annales des Mines - Réalités Industrielles, pg. 20. May 2019.
301 Another example is the responsibility of countries regarding space activities with respect to international treaties. For example, with regard to the Outer Space Treaty and the Liability Convention, as described by ESA: "[…] for each and every object sent into space, there should be at least one State identified which bears international responsibility and liability, regardless of whether the State itself (i.e. the government) is at the origin of the launch or a natural person (citizens of that State for example) or juridical person (economic operators for example) under its jurisdiction."
302 Notably, the new space agencies that are being founded worldwide and within Europe mostly have set as their primary objective to better link and serve their national strategies and interests vis-à-vis the expanding commercial sector. This is achieved

Agency for the Space Programme will not make an exception, as it will be born well within the new trend, and will be mandated to manage deployment and exploitation of space infrastructures – a less challenging and more favourable task than that occupied by long-established agencies.

As discussed in Chapter 2.2, the core tasks of space agencies comprise three top-level areas: proposal of a space policy, its implementation, and national and international representation.[303] In light of the new spacescape, the question arises as to how space agencies can adjust and enhance their modus operandi to fully and comprehensively benefit from the overall sectorial evolution, and continue fulfilling their missions and goals in an optimal fashion. A second question is then how to build up or consolidate the confidence of private investors, and ensure that even a mature industry is motivated and willing to negotiate the increased risk entailed in space PPPs-like arrangements.

Following the research and analysis of the public-private interaction in the space sector as well as interviews with stakeholders, and focusing on the customer-provider relationship between agencies and industry, some considerations for enhancing the role of space agencies are as follows:

1. **Formalise their mission to assess public users' needs, but also aggregating them to facilitate market uptake.** As the space sector has become largely a transverse infrastructure, whose services are now deeply embedded in various economic domains which are in turn becoming increasingly dependent on it, the expanded mission for agencies will be to aggregate user needs including from a broader number of actors from the public and private non-space domains, such as transportation, agriculture, environment, security and so on.

2. **Shift toward a role of "procurement of services" in those domains where feasible,** building on the lessons learned from successful PPPs, and – where suitable – initiate, regulate, evaluate and supervise PPP-like arrangements relying extensively on industrial competition for the delivery of proposals. This expanded role would entail agencies acquiring additional competencies, know-how and business-type expertise, in particular with regard to understanding market assessment and cost projections, business risks, and so on – so to act as efficient evaluators and supervisors of future potential partnerships.

3. **Ensure proper technical oversight** over development, deployment and exploitation of space programmes under PPP models. Strong in their own internal and long-standing technical expertise, agencies would act as a counter-balance (also "counter-expertise") to assess and oversee the proper course of technical development according to the initial objectives and conditions set. This indispensable oversight should obviously not lead agencies to interfere with development decisions that are the responsibility of the private partner. For this, further strengthening of their own technical know-how is fundamental to ensuring the fulfilment of agency missions.

4. **Foster the appropriate industrial and procurement policy** to continue to maintain a healthy degree of domestic industrial competition and thus ensure outward competitiveness of the whole industrial component.

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mostly by providing support to the local companies in terms of access to finance, national and international tenders and the definition of clear space regulations, thus acting more as business-enabling platforms rather than direct public procurement or research-oriented bodies.

[303] With caveats for ESA which, as highlighted in Chapter 2.2, does not have responsibilities in proposing a space policy, nor supporting national security programmes.

5. One major reward and incentive for the private side to undertake PPPs is the profits to be reaped on the commercial market following such partnership. Notably, in the space sector the market is often sustained by a sizable public demand. To close the circle, public entities at large (not just space agencies) should – wherever and if feasible and appropriate – take the role of anchor customers for systems and services, in those domains that include a public good component, ultimately to reap the benefits of available capacities that meet their needs, and to ensure the long-term economic sustainability of the ventures on top of the commercial market.

6. Moreover, in the European context, agreement between all major institutional entities on a broad and clearly stated preference for European industry for institutional programmes, for the procurement of space-based systems or services, could be beneficial and instrumental to further support the strengthening of the whole sector vis-à-vis increasingly competitive international markets. Indeed, the emergence of a strong(er) public demand in the European spacescape is a condition for building up domestic demand, which in turn is a necessary condition for the stability and predictability of the whole sector. In principle, ESA has already been applying such a clause, as stated in its Convention,[304] but in many instances some national space agencies, or the European Commission, have not comprehensively adopted this approach. The preference clause – which has been under discussion among European stakeholders for at least two decades – has both merits and limits,[305] and obviously requires that European stakeholders converge on the principle of its relevance, and also set up the appropriate legal instruments to implement it. This is a major challenge in the EU framework, which doesn't favour such a principle in its overall regulatory and legal corpus, and which might not be able to agree on specific regulations applicable only to the space sector.

7. A key appealing factor for industry is IP ownership. Whereas in most traditional public procurement IPRs typically remain with the public partner, PPP models usually envisage that the ownership of the developed system and its related technologies are shared with the private partner, or assigned to them in an exclusive way. This can act as an additional and potentially strong incentive for companies as they will be able to further leverage and develop these technologies on their own also beyond the completion of the partnership. However, in the European context, there is a stark difference in management of IPRs between ESA programmes (retained by the private partner) and the European Commission (partially retained by the public partner), and therefore reaching a Europe-wide consensus on such a crucial aspect remains challenging. This will need to be fully addressed in the setting up of the implementing rules of the European Defence Fund, which might involve space-related activities.[306]

8. Clear regulatory frameworks and improved access to finance and capitals – an area in which not just space agencies but broader government and financial institutions have a role to play – will be instrumental in setting a level and stimulating playing field for private companies. Moreover, this would increase investor confidence in space ventures.

[304] See Art. II, Annex V of the ESA Convention. Notably, this provision is not legally binding for ESA, and furthermore the Convention enables the ESA Council to decide whether and to what extent ESA can deviate from this preference. See: von der Dunk, F. "European space law" in von der Dunk, F. (Ed) "Handbook of Space Law", pg. 221. Edward Elgar Publishing, 2015.
[305] In the launch service market, see for example: Aliberti, M. and Tugnoli, M. "The European Launchers Between Commerce and Geopolitics", pg. 79. ESPI Report 56, ESPI, Vienna, 2016. Web: https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/10-the-european-launchers-between-commerce-and-geopolitics.
[306] The European Defence Fund is a fund managed by the EU for coordinating and increasing national investment in defence research and improve interoperability between national forces. See: "The European Defence Fund: Questions and Answers" European Commission Fact Sheet. Web: http://europa.eu/rapid/press-release_MEMO-17-1476_en.htm.

5.3 Revisiting Long-Standing Procurement Tenets

The modern, evolved landscape of the European space sector further invites reflection on a number of long-standing industrial policy and procurement principles and policies that were established in Europe at the onset of the space age. In the case of ESA, these principles were enshrined in its 1975 Convention (and further amendments), and undoubtedly have had the merit of fostering and leading the European space sector to the high achievements of today. Yet, decades after their formulation, it could be worth to re-assess and, if necessary, revisit a number of them, with the aim of furthering support and boosting European standing in the global space sector.

Indeed, at the time of the foundation of ESA, significant developments that are occurring today more than half a century later, were hardly foreseeable. These developments include among others:

- The emergence of the European Union as a key space player;
- The development of major public owned and operated space infrastructures;
- A maturation of industry to the point that it is able to conduct major space programmes in an increasingly autonomous way;
- Growing commercialisation and importance of the downstream segment;
- Large increase in the number of ESA's and EU member states.

In this context, revisiting the ESA convention might become a necessity. Actually, very few policy-makers are ready to consider this possibility, given the outstanding challenge entailed in being able to agree altogether on a new set of principles. Indeed, changes to the convention would require unanimity among ESA's member states, which – whilst brilliantly achieved at the time of its original elaboration – is clearly a very unlikely scenario today. Moreover, a decision to re-write the convention (while certainly retaining most of its still valuable content and provisions) is obviously a top-down political decision to be taken at the highest levels.

Specifically, the principle of geographical return (or fair return, see Chapter 2.1.2), essential in motivating the investments of member states as it proved to be instrumental in the building-up of the European space manufacturing industry and is still very much appreciated by member states, might face some restrictions in the implementation of a more services-oriented procurement policy, since it deprives the agency of the control of industrial organisations or consortia.

However, it must be recognised that ESA's procurement policy has been constantly evolving to adapt to the changing situation in an increasingly open market and competitive bidding approach (see for example the Copernicus programme). Yet, while appropriate for building and securing respective national space compartments, this policy is today further challenged by developing trends, leading to bold and aggressive competition from commercial, fast-paced, highly international players focused on providing service-oriented customer value. Even more so, it can be noted that when it was laid down in 1975 and in later updates, growing competition among member states themselves was definitely not as relevant as it is today.

Reflection on the different set of rules of ESA and national/EU procurement comes at a critical time, as the emergence of the future European Union Agency for the Space Programme, with its set of competitive, value-for-money procedures for procurement, is clearly poised to take advantage of the full potential of this new approach to space procurement.

5.4 Conclusion

In conclusion, the consequences of fully embracing the trend of commercialisation of space in the European spacescape would ultimately be to expand the role of agencies at the two opposite sides of the spectrum of their mission.

From one side, increased dynamism and autonomy of industry would enable agencies to enter into more PPP-like models where applicable, so to reallocate precious resources to reaffirm a strong focus on their unique and irreplaceable role – that is, in funding and leading the development of cutting-edge programmes, maturation of early-stage technologies, scientific research (including human and robotic space exploration), and similar non-commodity parts of the space sector.

On the other side, in those mature space domains where industry can afford to sustain more risks, agencies could shift from their traditional support to the offer side to supporting the demand side. In other words, agencies would shift from a *customer* to a *consumer* status. In a sense, the various policy measures put in place in the U.S. over the past decade all point towards repositioning the public sector towards actively supporting the demand for space systems and applications.

From a practical standpoint, such a shift in the role of agencies would particularly entail organising, pooling, and aggregating the demand (and thus user needs) of an increasing number of entities, particularly non-space public actors and institutions. By increasing the integration of the national (or regional) space ecosystem, from start-ups to SMEs to large companies, and extending beyond the traditional, top-down boundaries of the space domain, agencies would then effectively act as the authoritative focal point for space in a transversal fashion across all sectors of economic activities.

Figure 5 summarises the findings of this study with regard to the evolution of the roles of space agencies in the customer-provider relationship, highlighting potential new tasks and areas of responsibilities.

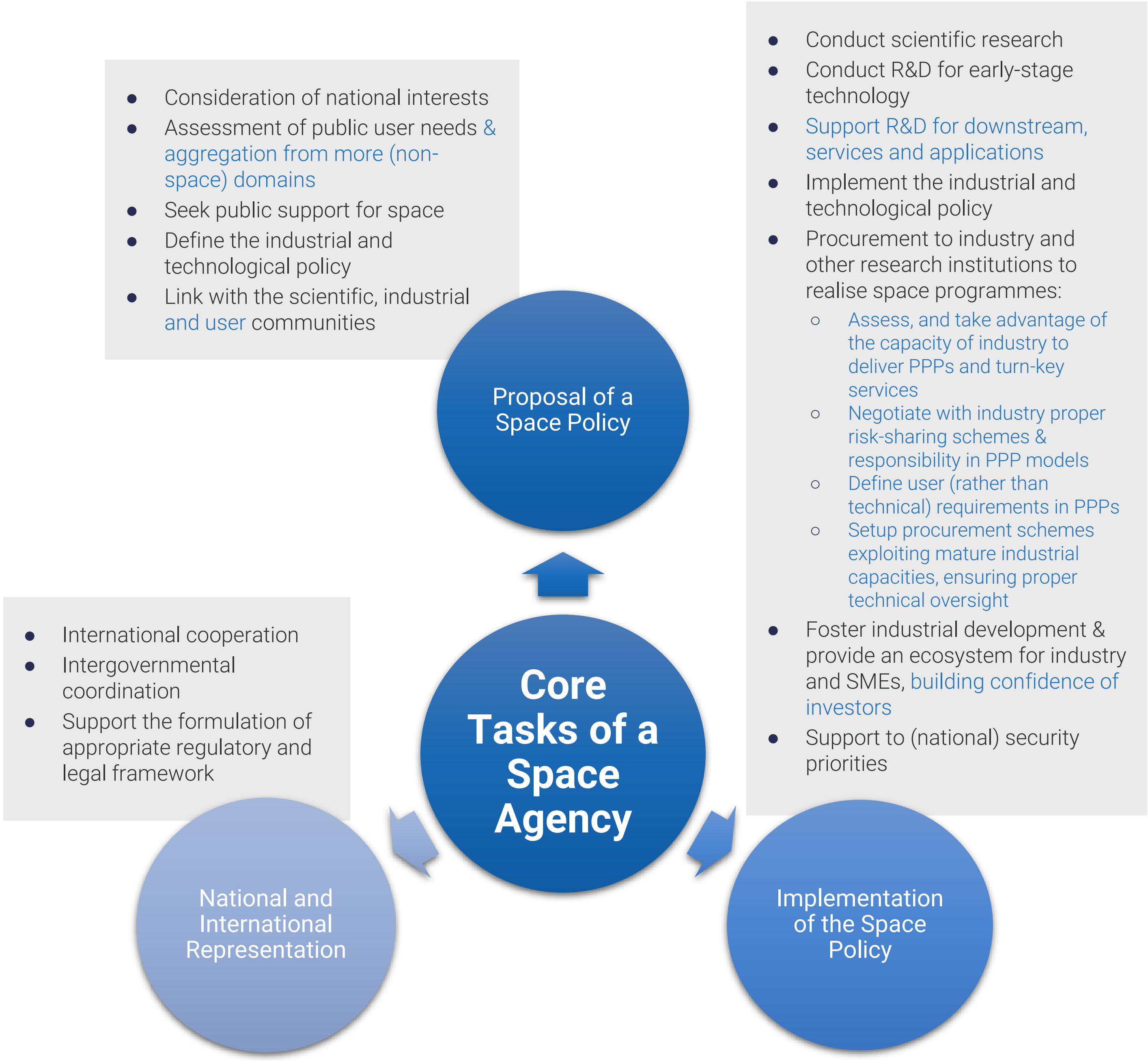

Figure 5: Evolution of the role of space agencies. Source: ESPI.

Acknowledgement

The authors would like to express their gratitude to the experts and officials from ESA, CNES, ASI, DLR, the French government, Airbus Defence and Space, Arianespace and ArianeGroup who agreed to be interviewed for this report under Chatham House Rules and provided their highly appreciated opinions and perspectives. We are furthermore grateful to the experts from space agencies, institutions and industry who reviewed the draft report in their personal capacities, providing invaluable feedback and comments. Lastly, we would like to thank the ESPI Director, Jean-Jacques Tortora, for his guidance and continuous support to this research, as well as the whole ESPI team for constructive and fruitful exchanges.

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