Evolution of Space Programs Governance

Please, quote this book chapter as Paravano, A., Locatelli, G., & Trucco, P. (2023). Evolution of space programs governance. In *Research Handbook on the Governance of Projects* (pp. 411-428). Edward Elgar Publishing.

Evolution of Space Programs Governance

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Abstract

This chapter discusses the evolution of space programs governance from the "Old Space" paradigm to the "New Space" one. For both paradigms, we discuss archetypical governance models, rationale, pros and cons. Ultimately, we explain the driving forces underpinning the evolution of program governance models. We show three governance archetypes. Traditionally program architectures and governance models were quite homogeneous and mostly government-led (archetype 1), while in the "New Space" paradigm, programs may also include partnerships with private actors (archetype 2) or being directly led and owned by private actors (archetype 3).

Keywords

Programs Governance; Governance Evolution; New Space Economy; Commercial Space; Satellite data; Digital technologies, Earth Observation.

1 Introduction

The space sector is based on capital-intensive programs with limited flexibility due to the short life of space infrastructure (e.g., usually 13 years for a satellite). Actors need to understand ex-ante the value generated by a new space infrastructure (e.g., a new satellite constellation) to justify the investment while addressing institutional and open market needs (Sutherland et al., 2012). In the "Old Space" paradigm, organizations teamed up to produce the infrastructure commissioned and paid for by institutional clients (Galluzzi et al., 2006), mostly for military and scientific purposes (e.g., the GPS constellation, the International Space Station). Space Agencies played a central role; in deploying new space infrastructures using a top-down development approach, tasking other organizations to produce new technologies, components, and systems (Landoni & Ogilvie, 2019).

Recently, the space sector is rapidly evolving because of space market liberalization, cost reduction of space infrastructure deployment and management, increasing accessibility to new space technologies (e.g. satellite miniaturization) and their integration with digital technologies (OECD, 2022; Weinzierl, 2018). New end-users from different sectors are looking at the space sector as a source of innovation for services and internal processes (Davidian, 2021; Denis et al., 2020). Space infrastructures are essential to addressing planetary challenges, including climate change and natural resource management (e.g., satellites can monitor the melting of glaciers). These changes in scope and actors are leading to new programs governance models called "Space Economy" or "New Space". Here, we use the term "New Space" to facilitate the comparison between the old and the new boundaries of the space sector and the corresponding models of program governance.

The "New Space" includes "*the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space*" (OECD, 2019). Four main value chains represent the space sector, covering a spectrum of products and services:

- Earth Observation**:** monitors the Earth and its land, water, and atmosphere.

- Satellite Communication: data transmission in telecommunications, TV broadcasting, telephone, radio, and the internet.
- Satellite Navigation: allows users (equipped with compatible devices) to determine their position and velocity.
- Space Access: enables the exploration of outer space (e.g., rockets, telescopes, unmanned and manned space vehicles, such as the International Space Station, Virgin Galactic for space tourism, or Mars rovers).

The supply chain structure of the space sector includes three tiers (Space Economy Observatory, 2020):

- Upstream actors: engaging in research, development, construction, and management enabling space infrastructures and technologies.
- Downstream actors: offering digital innovation solutions and services (e.g., IT provider, system integrator, consulting firm) and specialized research centers that deal with research, development, and implementation of digital technologies leveraging space technologies and data.
- End-users: actors in sectors as energy, insurance, agriculture, transport, and logistics interested in new applications and services deriving from the integration of space and digital technologies.

The "New Space" governance includes actors involved since the early stages of program planning, bringing in technologies and knowledge from other sectors. Military and civilian public institutions are no more the unique or primary clients of space programs (Pelton, 2019) (e.g., NASA partnered with Google to develop "Google Mars", an open-access mapping service of the surface of Mars). Space infrastructure has to generate value more actors than before (Whealan George, 2019), generating revenue streams from the market to grant an economic return on the investment. For example, in 2021, "Earth Observation" generated €2.8 billion in revenues across other sectors such as energy, insurance, and agriculture (EUSPA, 2022). While "Old Space" satellites were often built and used for a single client and with a single purpose, the "New Space" satellites are built for several end-users and purposes, e.g., satellite internet for Telco companies for telemedicine in rural areas. Remarkably space infrastructure produces data for which value and use are largely unknown during the planning and construction phases.

This evolution has relevant implications for program governance as it implies the engagement of new actors, the evolution of the roles of traditional actors (e.g., space agencies), new contractual forms, and new value creation and delivery mechanisms (e.g., value for private consumers). Therefore, the space sector is relevant to studying how and why program governance evolves.

Project studies present limited contributions regarding the evolution of programs governance (Martinsuo et al., 2020). It is a relevant limitation since program governances are often (voluntary or involuntary) configured to respond to contingent factors (Fernandes et al., 2018; Girod & Adamson, 2017; Maylor et al., 2018).

Programs and projects governance evolve (Maylor et al., 2006), a crucial aspect that needs to be further investigated since most of the literature (e.g. Ruuska et al., 2011; Vukomanović et al., 2021) assume a "static perspective".

In this chapter, we consider all these aspects in discussing the evolution of space program governance in the New Space.

We ground our analysis on a wide body of empirical material collected in recent years through the research activities the authors carried out under the Observatory on Space Economy[1]. It comprises 50+ interviews with managers and officers, 10+ workshops and daily involvement with several public and private actors in the space sector.

[1] https://www.osservatori.net/en/research/active-observatories/space-economy.

2 Governance in “Old Space” Programs

2.1 The “Old Space” Sector

The “Old Space” sector is characterized by three key elements shaping its governance:

- Complex and expensive infrastructures.
- Government-driven investment with prevailing military and scientific purposes.
- Investments mostly covered by public funds.

These elements are present in two main sector waves: competitive and cooperative.

The competitive wave started at the end of the Second World War when the military advantage demonstrated by space technologies (e.g., ballistic missiles) was necessary for national security and prestige. This period (also called the “Space Race”) was characterized by the competition between US and USSR for supremacy in outer space.

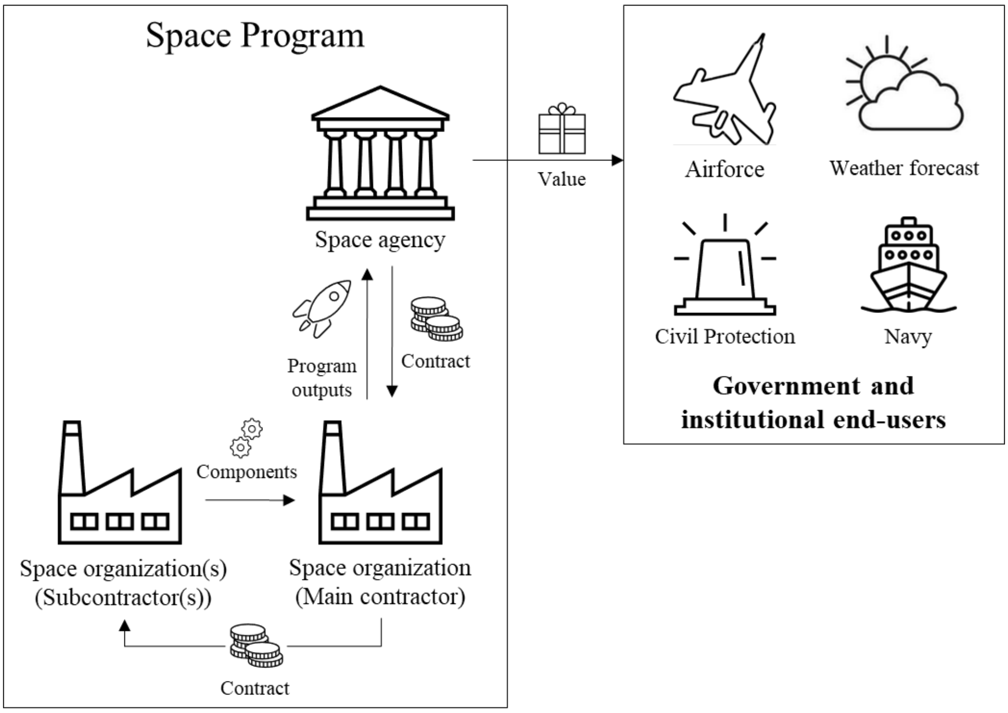
The space technology competition wave gradually became the scientific cooperation wave. In 1972, the US and the USSR signed a cooperative agreement concluding the “Space Race”. In 1975, ten European countries founded the European Space Agency (ESA). In the latest 80s, the end of the Cold War and the necessity of more effective and efficient scientific research resulted in growing cooperative and scientific space programs between nations (e.g., the International Space Station[2]) and in satellite infrastructures development for commercial purposes (e.g., communication satellites for television).

During these two waves, the boundaries of the space sector were limited to space sector organizations (i.e., upstream and downstream) and Space Agencies constituted and funded by governments. The space program was usually funded upfront with public funds. Space Agencies engaged space

[2] https://www.nasa.gov/mission_pages/station/main/index.html

organizations to develop space infrastructure. A representation of the “Old Space” sector during the two waves above is in Figure 1.

Figure 1: The “Old Space” sector



2.2 Space Programs Governance in “Old Space”

During the “Old Space”, space infrastructures were conceived and developed to deliver value to institutional end-users. At the early stage of the program, this value is, for the end-users, at least less tangible than the outputs of every single project. An example is the NASA Apollo program[3], with the key objective of establishing the sovereignty of the US in outer space. Each Apollo mission was a project within the program, but the key objective was achievable only at the program level (Müller, 2009).

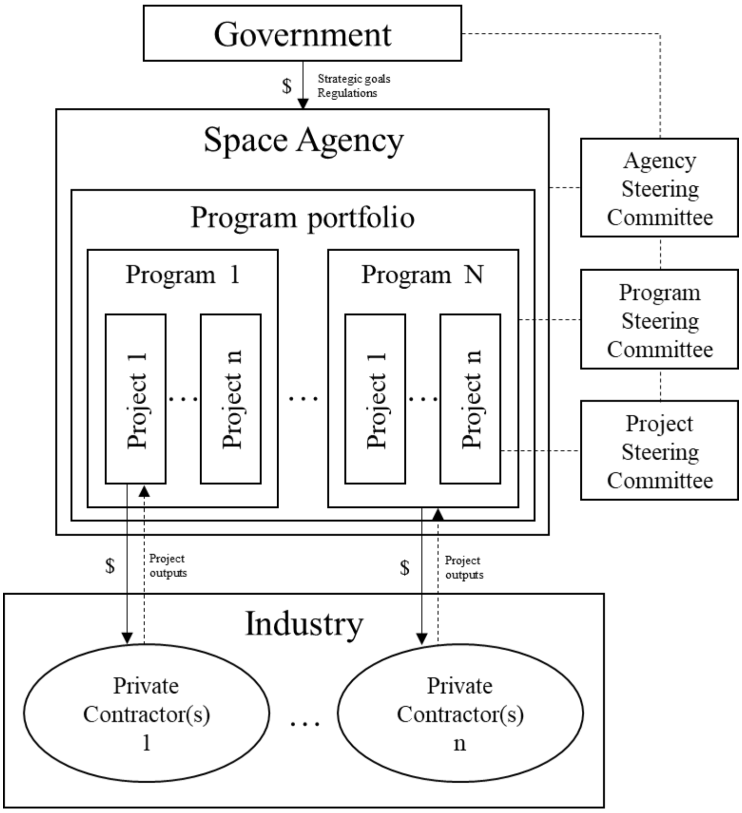
[3] https://www.nasa.gov/mission_pages/apollo/missions/index.html

The space sector is strongly institutionalized and regulated. Traditionally, governments constitute national Space Agencies (e.g., NASA in the US, Roscosmos in the USSR, ESA in Europe) to design and manage the programs. Governments are owners, financers and sponsors[4]. The Space Agencies are operators of the space infrastructures (ESPI, 2019).

Space Agencies are responsible for designing and managing program portfolio strategies and the programs' objective setting, planning, budgeting, and scheduling. Space Agencies act as main clients, which (in the US and Europe) select private contractors through invitations to tender. Space Agencies involve private organizations almost exclusively as contractors through cost-plus contracts. For example, NASA selected private contractors (e.g., Lockheed Martin) to develop rockets and spacecraft throughout the Mercury, Gemini, Apollo, and Space Shuttle programs. Space Agencies mainly cover risks and cost overruns through their annual budget. A strict stage-gate control process was adopted. Figure 2 summarizes the "Old Space" program governance archetype.

[4] We are using the terms "owner", "sponsor", "client" and "partner" following Denicol et al., (2021)

Figure 2: The “Old Space” program governance archetype



Four main rationales explain the “Old Space” program governance archetype. First, space infrastructures and space programs play a strategic role in national (and regional) security and sovereignty. Space agencies operate space infrastructures in a strictly regulated context. Second, the space sector is asset-intensive with high investments, few economies of scale, high risks, and very long development cycles. For example, the total cost of the Apollo program was $25.4 billion (approximately $158 billion in 2020 dollars[5]); unaffordable for private organizations. Third, the space sector is technology-intensive and knowledge-intensive; the program delivery requires many unique competencies that the Space Agency had traditionally coordinated, integrated, and managed. Fourth, the Space Agency mainly promote temporary programs aiming to achieve well-defined objectives

[5] United States. Congress. House. Committee on Science and Astronautics. (1973). 1974 NASA authorization: hearings, Ninety-third Congress, first session, on H.R. 4567. Page 1271. Washington: US Govt. Print. Off.

within a specified time horizon (e.g., the Apollo program); this approach fostered Space Agencies to govern the program primarily via control of milestone achievements (e.g., stage gates reviews) and by use of risk-hedging strategies to manage programs' risks (e.g., additional public funds in case of cost overruns).

2.3 Pros and Cons from a Governance Perspective

The "Old Space" program governance archetype presents several pros. The pivotal role of the Space Agency as a primary client promotes:

- Alignment of programs' goal setting with government priorities and societal needs
- Learning economies: personnel involved in the business acquires specialistic competencies. With tacit and explicit knowledge codified within Agencies for future programs and projects, organisational processes improve.
- Space Agencies have good Control over the program thanks to broader and more integrated information sharing within the organization, along with maintaining strong control over contractors' activities and the overall product development processes.
- Security: all sensitive information is centralized and oversight by Space Agencies.
- Program portfolio balancing: Space Agencies guarantee program portfolio optimization and strategic alignment for accomplishing the value maximization for governments and society.
- Consistency of approach: management and reporting within the program organization, processes, roles, and responsibilities of individuals are internally codified.
- Effective technology exploitation: this governance works well in a technology-push context, where innovation and business are driven by unique technologies (e.g., rocket engines).

The “Old Space” program governance archetype also presents several cons:

- Lack of flexibility and reactivity: strict controls, bureaucracy and rigid structures prevent the organization from quickly responding to external market stimuli, such as adopting new technology for the program development (e.g., a new propulsion propellant for rockets).
- Technical and commercial risks are covered by public funds, a waste of public resources in case of failure.
- Tendency to cost overruns: in a cost-plus contract, contractors may be incentivized to underestimate the program's costs to approve the contract/project.

2.4 Vignette – The Global Positioning System (GPS) Program Governance

“There are too many people, too many bureaucracies, too much politics, and too many agencies involved. Why don’t you just have the Air Force develop it (the GPS) the way we always did?”[6]. This answer of Lee DuBridge, President Richard Nixon’s science advisor, to GPS pioneer Ivan Getting, who suggested developing the satellite navigation system in the early 1970s, synthesizes the governance of the well-established GPS program (formerly NAVSTAR GPS).

By 1972, the US Department of Defense (DoD) had been studying the possibility of improved satellite-based radio navigation (Sturdevant, 1994). In 1973, DoD formed a multi-service Joint Program Office (JPO) between US Air Force and US Navy departments. DoD teamed experts from three earlier space-based navigation programs: the Johns Hopkins University, the Naval Research Laboratory, and US Air Force. In 1974, via competitive tender, the JPO selected the private organization Rockwell International as a contractor to develop the infrastructure of GPS Block I, the

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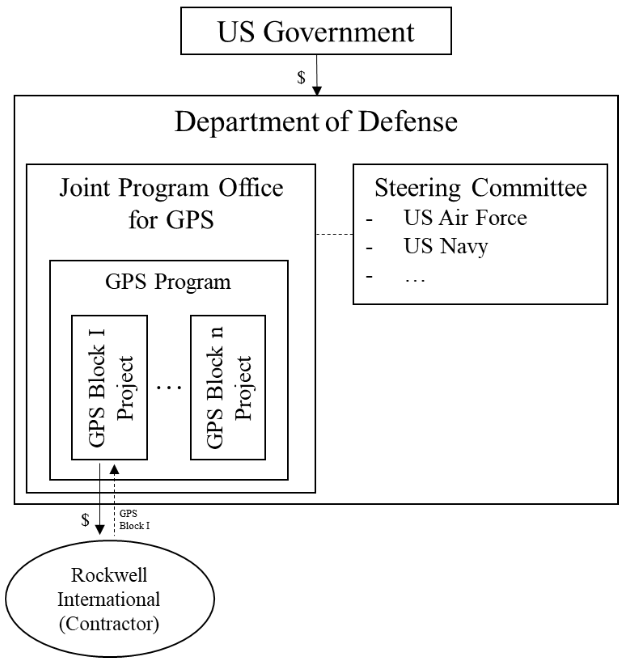
[6] Jacob Neufeld, ed., *Research and Development in the United States Air Force* (Washington,dc:center for Air Force history, 1993), pp. 91–92. https://media.defense.gov/2010/Sep/29/2001329777/-1/-1/0/AFD-100929-006.pdf

first GPS project. JPO defined the technical requirements and managed the project. The DoD owned the risks. In 1978, the first prototype of the satellite infrastructure was launched into orbit and became fully operational in 1995. The infrastructure development cost was $10–$12 billion, and the annual operations costs of sustaining minimal GPS services were $400 million[7].

Turner and Zolin's (2012) framework can describe the success of the GPS program. The program's scope evolved considerably in the short term, resulting in overbudget and delay. Therefore, NASA, i.e., US taxpayers, ultimately paid the extra costs. In the long term, the GPS program had a strong positive impact on fostering useful services (e.g., Google Maps). GPS program governance was functional to develop new capabilities and competencies within NASA and the space sector. NASA's central role mitigates the risks of failures typical of complex and expensive programs such as satellites, favouring the development of novel technologies. Figure 3 presents the GPS program governance.

Figure 3: GPS space program governance



[7] Michael Russell rip and James M. Hasik, *The Precision Revolution: GPS and the Future of Aerial Warfare* (Annapolis, md: naval institute press, 2002), pp. 68–79.

3 Factors underpinning the paradigm shift to the “New Space”

Several factors underpin the space sector's ongoing transformation and the governance of new generation space programs.

3.1 Macro-economics and socio-political changes

Macroeconomics and socio-political changes are radically reshaping the growing space sector (Weinzierl, 2018). The rising space power of China has fostered the US and Europe toward a new space race (e.g., to colonize the Moon and Mars), with a strong impact on national and international space programs and regulations. The value of space technologies and applications for society is increasingly important. Therefore, public institutions are launching and founding new space programs also to foster the achievement of the Sustainable Development Goals. For example, the European Space Agency is launching thematic calls to achieve environmental and social sustainability via satellite technologies across sectors[8].

3.2 New regulations and policies

New regulations aimed at liberalization support the space sector's radical transformation. In the US, a long liberalization process started in the 80s and culminated in 2015 with the U.S. Commercial Space Launch Competitiveness Act[9]. The US law explicitly allows US citizens and industries to "engage in the commercial exploration and exploitation of space resources" (U.S. Space Resource Exploration and Utilization Act of 2015, Title IV, Sec. 402), changing the role of NASA. Second, new policies promote cross-fertilization between the space and non-space sectors (e.g., ICT, energy, healthcare). For example, open satellite imagery data sources are available (e.g., US Landsat[10], EU

[8] https://vision.esa.int/space-for-a-green-future/
[9] https://congress.gov/114/plaws/publ90/PLAW-114publ90.pdf
[10] https://www.usgs.gov/landsat-missions

Copernicus[11]). In 2008 the US government granted free access to its space imagery archives to benefit governments, researchers, and civil society (Zhu et al., 2019). Since 2013 most of the data generated by the European Earth Observation flagship program Copernicus are publically available, based on a Full, Free, and Open (FFO) data policy[12]. Data providers include public (e.g., ESA, European Agency for the Space Programme (EUSPA)) and downstream private actors.

3.3 New funding and financing dynamics

New sources and funding mechanisms support the entrance of new public and private actors (Davidian, 2021). Space agencies are increasingly outsourcing and accelerating new forms of collaboration (e.g., Public-Private-Partnerships). The public sector has broadened and adapted its practices to stimulate the rise of new private actors through specifically allocated funding. For example, ESA increasingly uses prizes and challenge schemes to foster new actors and business opportunities.

The growing market and declining entry barriers (e.g., program development cost) are attracting a growing number of private investors (from less than 50 in 2010 to almost 350 in 2020[13]), fostering private-to-private funding mechanisms and shifting funding from traditional public sources toward angel investors, venture capital firms as well as private equity. In 2020, $5.1 billion[14] have been raised through Special-Purpose Acquisition Companies (SPACs), publicly traded companies established to raise funds to acquire or merge with a private organization seeking "to go public" quicker than traditional IPOs.

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[11] https://www.copernicus.eu/en
[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R1159
[13] BryceTech, Start-Up Space Report, 2021. https://brycetech.com/reports/report-documents/Bryce_Start_Up_Space_2021.pdf
[14] BryceTech, Start-Up Space Report, 2021. https://brycetech.com/reports/report-documents/Bryce_Start_Up_Space_2021.pdf

3.4 New technologies

The space sector and technology innovation are synergic. The space sector generates a plethora of "spin-off" technologies and innovations adopted in non-space businesses and applications. For example, the Apollo program led to many technology-transfer spin-offs (e.g., shocking hearth monitors[15]). Innovations developed in non-space sectors are "spin-in" the space sector, transferring and integrating human capital and know-how. For example, 3D printing, originally developed in the automotive sector, is employed in rocket manufacturing.

The mass advent of small- and nano-satellites is opening the space market to small-medium enterprises, startups, and universities. The technology miniaturization and cost reduction reduce the financial barriers to participation in space missions (Pelton, 2019).

The advent of new digital technologies and their affordable access is transforming the space sector, making it cross-technological. Digital technologies are nowadays massively employed, attracting new actors (e.g., ICT companies) and enabling the creation of new businesses, products, and services for new end users (e.g., satellite images can be used by farmers to monitor their harvests). Digital technologies foster the adoption of agile methodologies, while at a more strategic level, organizations leverage Open Innovation and open-source tools to develop their business (van Burg et al., 2017). Finally, thanks to the digitalization of geospatial marketplaces, satellite data providers are moving to a subscription-based business model, favouring the emergence of platforms (Ansar & Flyvbjerg, 2022).

[15] https://www.nasa.gov/sites/default/files/80660main_ApolloFS.pdf

3.5 New actors

Increasingly new actors are involved in "New Space" programs. The actors in the "New Space" include both organizations belonging to the "Old Space", new non-space organizations (e.g., ICT), and new individual end-users.

There is an increasing number of new space-faring nations (i.e., countries that have developed access to space capabilities), and, in those countries, several new Space Agencies are established. Space access is a crucial pillar of the national critical infrastructure system (e.g., telecommunications), permeating other sectors, including transport, energy, agriculture, and healthcare.

New private actors can be generally divided into three categories: first, space organizations utilizing both public and private funding, addressing both traditional space markets with disruptive solutions, or seeking to create novel footholds into emerging space markets. For example, SpaceX is delivering the Starlink[16] program, a private internet satellite constellation, aiming to bring high-performance internet worldwide. Second, non-space organizations, primarily ICT, integrate space and digital technologies to deliver new products and services to many sectors and end-users. These organizations leverage private and/or public funding to initiate and develop innovative businesses with (often) disruptive solutions (Denis et al., 2020). For example, Google Maps leverages satellite data and other sources, providing services to more than one billion monthly active users[17]. Google Maps primarily charges a price for 1) local ads that businesses post to attract customers and 2) special custom maps that organizations (e.g., UBER) can use for their business.

Furthermore, in 2006, Google and NASA teamed up on a collection of programs to combine large-scale data management and massively distributed computing. These programs positively impact society and enable new products, services, and technologies to emerge. Third, new end-users, public

[16] https://www.starlink.com/
[17] https://sites.google.com/a/pressatgoogle.com/google-maps-for-iphone/google-maps-metrics

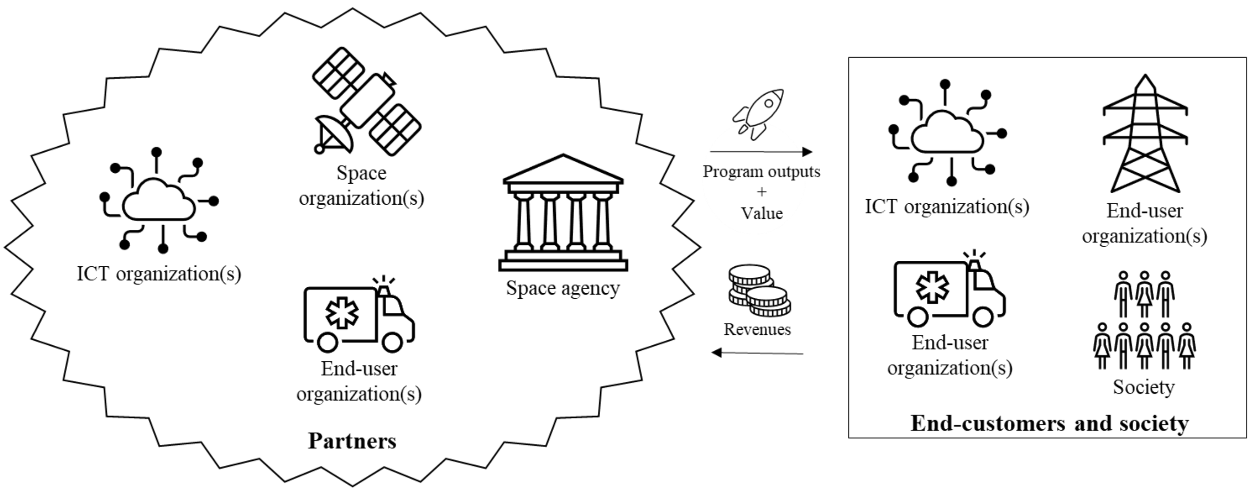
or private organizations, and individuals are using space technologies for their business (e.g., Deliveroo).

4 Governance in “New Space” Programs

4.1 The “New Space” Sector

In the “New space” approach, space infrastructures have to be valuable for new private end-users and generate revenue. Commercial interests attract new funding opportunities and transform the program financing mechanisms. Partnerships between private and public organizations are rising, and in several regions (e.g., US, Europe), the collaboration between the private sector and the Space Agencies is consolidated. The Space Agencies are transforming their role from being almost exclusively clients to being also a program partners. A simplified representation of the “New Space” sector is depicted in Figure 4.

Figure 4: The “New Space” sector



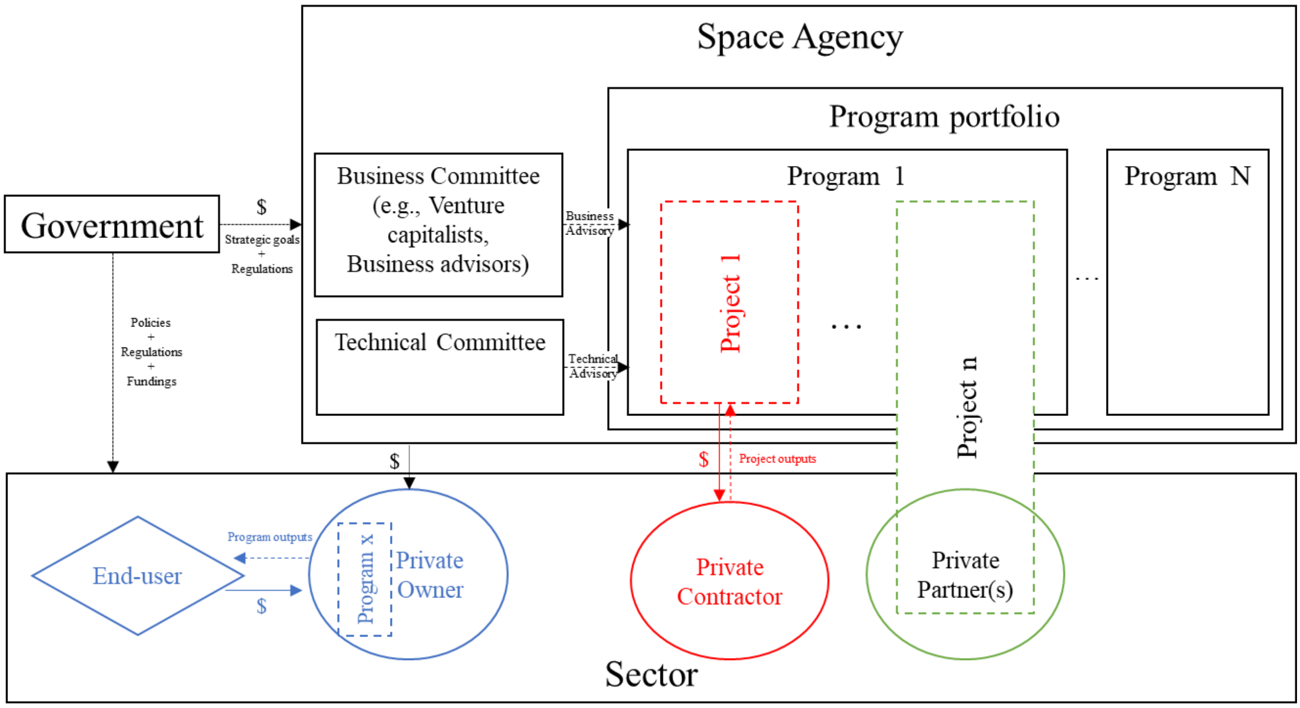
4.2 Space Programs Governance in “New Space”

The governance of space programs in the “New Space” entails new roles and responsibilities. Private actors own and operate new space infrastructures. For example, SpaceX and Amazon are launching their internet satellite programs (Starlink and Kuiper, respectively). Those actors own, build and operate their space infrastructure and sell their data and services to public and private end-users worldwide. Private actors can be sponsors of space programs (Peeters, 2018). For example, the Virgin Galactic space program is mainly funded by the homonymous company listed on the stock exchange. Space Agencies foster the development of commercial space programs by partnering with private actors and funding entrepreneurial initiatives. For example, ESA has launched Business Incubation Centres to support entrepreneurs with space-based business ideas to create a space-based entrepreneurial network in Europe. Despite working in a government/contractor relationship with private organizations, Space Agencies employ new contractual relationships (e.g., Public Private Partnerships), serving as a partner of the space program and technical advisors for the public and private actors. Space Agencies promote the adoption of fixed-price and performance-based contracts to improve cost-effectiveness and reduce development time when contracting private actors. Space Agencies and private actors share the program's benefits, costs and risks. The space sector is slightly moving towards developing semi-permanent programs (Müller, 2009), which requires an entrepreneurial approach to governance and generates value for many actors over time. For example, Copernicus[18], the European Union's Earth Observation program, owned by the European Commission, was originally conceived for institutional purposes (i.e., offering meteorological and security services to public institutions), but in recent years started offering satellite-based information services to private organizations and individual end-users (more than 500,000 in 2022[19]). Copernicus has moved from offering atmospheric data to scientists towards offering commercial services in many non-space sectors (e.g., Healthcare, Insurance, Oil&Gas, Logistics, and Transport). Those services are accessible through Data and Information Access Services (DIAS)[20], data platforms developed by private organizations in partnership with the European Commission and funded by the latter.

[18] https://www.copernicus.eu/eu
[19] https://scihub.copernicus.eu/reportsandstats/ Accessed on: March 28th 2022
[20] https://www.copernicus.eu/en/access-data/dias

Figure 5 shows the “New Space” program governance archetypes. Space Agencies are developing new internal capabilities to cope with the sector's transformation. For example, Space Agencies are forming business committees with venture capitalists and business advisors to be guided in selecting private partners. Meanwhile, they are reorganizing their technical capabilities into technical committees that are involved only when necessary. These new sets of capabilities allow Space Agencies to choose between three different governance archetypes. In the first one, the program or project is managed as in the “Old Space” (e.g., project 1 – in red in Figure 5). The agency provides funding and receives the program’s or project’s outputs. For example, the GPS space program. In the second governance archetype, the program or project is co-developed collaboratively with private partners (e.g., project n – in green in Figure 5), and the ownership and sponsorship are shared among the actors. For example, the COTS (Commercial Orbital Transportation Services) program was developed between NASA and SpaceX (a detailed explanation of this case is presented in section 4.4). In the third governance archetype, private actors build and manage their program and infrastructure (e.g., program x – in blue in Figure 5). Private owners sell their products and services to end-users. Space Agencies may (or may not) act as investors or sponsors for these programs but do not take ownership. Governments provide funding, strategic goals and regulations to space agencies and at the same time regulate the emerging private market and sector by also providing public funding to private companies.

Figure 5: The program governance archetypes in the "New Space"



4.3 Pros and Cons from a Governance Perspective

The governance of space programs in the "New Space" presents several pros:

- Time and-effectiveness development: private organizations have to achieve milestones to get paid, are accountable for program delays and low-quality outputs, and are financially responsible for cost overruns and therefore incentivized to be effective. For example, NASA's Commercial Crew Program[21], aiming to foster the US commercial crew space transportation capability, took just 10 years from its conception to successfully bring the US astronauts to the International Space Station via a private transportation system[22].

[21] https://www.nasa.gov/exploration/commercial/crew/index.html
[22] https://www.nasa.gov/offices/c3po/partners/ccdev_info.html

- Favouring innovation: the application of the Public-Private Partnerships shifts the design and development of the space infrastructure to the contracted private organization. Therefore, private organisations have more freedom to develop the space infrastructure and are interested in developing proprietary knowledge and scalable technological innovations.
- Cost reduction: the fixed price milestone mechanism favours control over the program costs.
- Flexibility: the partnership between Space Agencies and private organizations guarantees autonomy and flexibility to the latter in designing and developing the space infrastructure.
- Broad scope: program goals (vs requirements) are negotiated and established between Space Agencies and private organizations. Space program requirements evolve and are coordinated collaboratively between the Space Agency and private organizations.
- Fostering commercialization:
  - Private organizations co-invest in the space program because they are interested in profit. The space program infrastructure has to be valuable for the market and generate revenues.
  - Space Agencies are promoting commercial-friendly intellectual property/data rights to attract private organizations' investments.
  - Space Agencies' commitments to purchase operational services rather than capital assets favour private space organizations in generating revenue streams during the operational life of the space infrastructure.
- Mitigating Risks: Space Agencies and private organizations share the operational risks and may access the insurance market to transfer a portion. Space Agencies can engage private partners with distinct capabilities to ensure a balanced approach to technology and strategy risks.

However, the governance of space programs in the "New Space" also presents some cons:

- Loss of governmental control: private organizations are the owner of the space infrastructure and, often, the operator. Consequently, governments and Space Agencies do not directly control the (often critical) infrastructure.
- Higher vulnerability to National security threat: private organizations that own the space infrastructure may turn into a threat to national security. For example, sharing sensitive data could occur without Government scrutiny and control.
- Depending on regional regulations and private funds, market regulations are often regional. They may positively (or negatively) prevent the market growth and the capabilities of private organizations from attracting private investments.

4.4 Case study vignette – The Commercial Orbital Transportation Services (COTS) Program Governance

In 2005, with the support of the presidential administration and Congress, NASA allocated $500 million over five years from NASA's budget for investigating commercial transportation capabilities to low-Earth orbit. NASA instituted and charged the new "Commercial Crew & Cargo Program Office" with the task of "stimulating commercial enterprise in space by asking American entrepreneurs to provide innovative, cost-effective commercial cargo and crew transportation services to the International Space Station (ISS)"[23]. From 2006 to 2013, the Commercial Crew & Cargo Program Office advised and invested in three companies in the space transportation industry (i.e., SpaceX, Rocketplane Kistler, Orbital Sciences Corp.) to develop the Commercial Orbital Transportation Services (COTS) program[24], the first program aiming at realizing a private cargo

[23] Michael Griffin, "NASA and the Business of Space" (speech made at the 52nd annual conference of the American Astronautical Society, November 2005), in Leadership in Space: Selected Speeches of NASA Administrator Michael Griffin, May 2005–October 2008 (Washington, DC: NASA SP-2008-564, 2008), 179, accessed March 12, 2022. http://history.nasa.gov/leadership.pdf.
[24] https://www.nasa.gov/content/cots-final-report

transportation service to the ISS. In May 2012, COTS succeeded. SpaceX delivered the first cargo to ISS through its commercial spacecraft, followed by Orbital Sciences Corp. in late 2013.

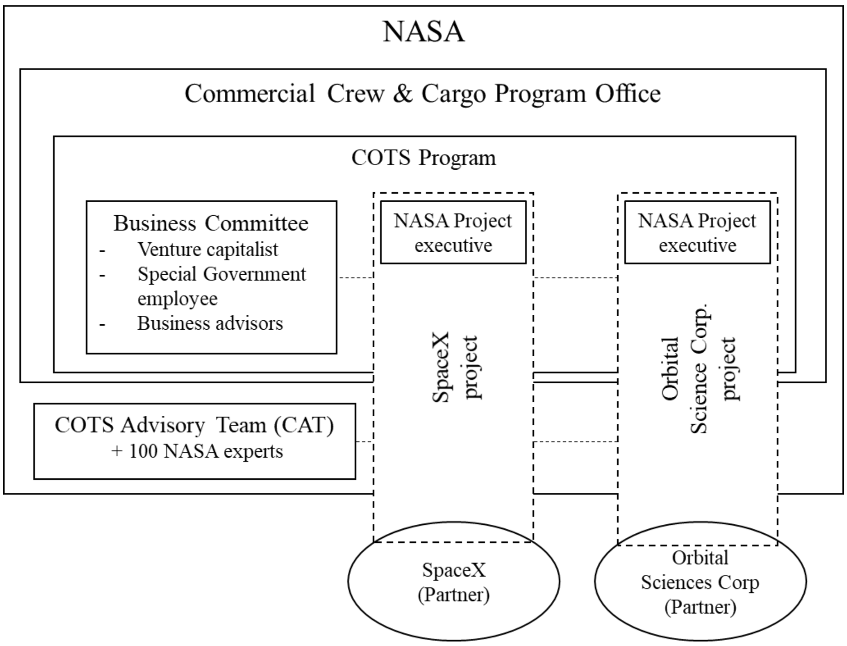
Traditionally, NASA created government-owned and operating systems, working in a government/contractor relationship with private organizations. Under the COTS program, NASA promoted a partnership with commercial organizations to develop private-owned-and-operated transportation services. NASA served as a lead investor and client of transportation services and technical advisor in developing and demonstrating private organizations' services. Each commercial partner had a unique design solution that would remain its intellectual property. NASA established a cost- and risk-sharing collaboration with the sector to incentivize both sides to perform. NASA required commercial partners to share the COTS system development and demonstration cost. The rationale was to incentivise COTS partners to design, build, and demonstrate their systems on time and lower NASA's costs. Instead of using a traditional contract for COTS, NASA developed a procurement scheme based on fixed-priced and performance-based milestones with the private organization responsible for cost overruns.

NASA had limited knowledge of evaluating business plans and making investment decisions when it released the announcement for COTS. Therefore, NASA established a Business Committee, procuring the services of Venture Capitalists as a support contractor and hiring a commercial space advisor as a Special Government Employee and a CEO from a private company as a business advisor. NASA created the COTS Advisory Team (CAT), which consisted of subject matter experts from various NASA centers to offer periodic or on-demand targeted support when specific problems arose. CATs reviewed commercial partners' solutions providing guidance and help but did not dictate design solutions or solve the partners' issues.

NASA operated with a small full-time staff to implement its partnerships with private organizations. Compared to traditional programs that employed hundreds of government employees to monitor technical development, NASA employed just fourteen civil servants. The program maintained lean operations relying on the technical expertise of the CAT and the NASA project executives, who served as facilitators between the private partners and NASA, providing insights rather than oversight to the private organizations and valuing their business models.

Turner and Zolin's (2012) framework can describe the success of the COTS program. In the short term, the COTS program was on time and budget. Shortly after, private organizations developed a transportation system aligned with the program scope. In the long term, the COTS program generates positive impacts. NASA develops capabilities, competencies, and procedures to operate as an investor and partner in space programs. Private organizations developed new technologies, capabilities, and competencies to deliver private space programs. COTS governance model fostered a new era in space programs, including human space flights toward the ISS, Moon, and Mars. SpaceX started this service in 2020 through the Crew Dragon spacecraft, and the Boeing Starliner spacecraft will soon be operational. The governance of these recent programs is similar to the COTS, with spacecraft owned and operated by private organizations and crew transportation provided to NASA as a commercial service. Figure 6 summarizes the COTS program governance.

Figure 6: Commercial Orbital Transportation Services (COTS) program governance



5 Conclusions

The space sector is an exemplar case for studying the factors and rationale underpinning the evolution of program governance. Table 1 summarizes the key governance elements for programs in the "Old Space", typical of the Cold War and Post-Cold War periods, versus the "New Space", a commercial-driven paradigm that emerged in the last two decades.

Table 1: Comparison of programs governance archetypes in the "Old Space" and "New Space"

Governance element	**Old Space Program (almost exclusively Space Agency led)**	**New Space Program**	
		Space Agency led	**Private led**
Archetype	1	2	3
Owner	Space Agency	Private organization(s)	Private organization(s)
Sponsor	Government	Government and Private organization(s)	Private organization(s)
Client	Space Agency	Space Agency	Private or Public End-Users
Contract Fee Type	Cost-Plus	Fixed-price	Various models
Delivery Model	Engineering, Procurement & Construction contracts	Various models, including Engineering Procurement & Construction contracts, Public Private Partnerships, Open Innovation Agreements	Various models, including Engineering Procurement & Construction contracts, Public Private Partnerships, Open Innovation Agreements
Requirements definition	Space Agency defines engineering requirements (how things should be)	Space Agency defines functional requirements (what things should do)	Private organization(s) defines functional requirements (what things should do)
Cost structure	Space Agency incurs total costs	Space Agency and Private organization(s) share costs	Private organization(s) incurs total costs
Risks	Space Agency own all the risks	Space Agency and Private organization(s) share risks	Private organization(s) own all the risks
Revenues	Secondary importance, space infrastructures rarely generate revenues	Primary importance, space infrastructure should generate revenues	Primary importance, space infrastructure should generate revenues

The evolution toward program governance archetypes in the “New Space” is effective in:

- Stimulating the private sector: the private ownership and the commercial purpose of the program output ensure a strong commitment of the private organization to gain a return on investment.
- Fostering private organizations to develop innovative programs: Space Agencies requirements definition assures private organizations’ freedom to design and develop the program output, promoting innovation.
- Guarantee time effectiveness: private organizations have to respect the milestones to get paid, incentivizing the respect of schedule.
- Achieving a wide program scope: private organizations are interested in creating a commercial infrastructure that generates value for a wider set and a larger number of end-users and, more in general, society.

The evolution toward program governance archetypes in the “New Space” is efficient in:

- Reducing public and private expenditures: Space Agencies and private organizations share the program costs, and the latter is responsible for cost overruns. The contract fee type and the delivery model guarantee cost-efficiency. Space Agencies increase their “value for money”. For example, NASA COTS investment in developing the Orbital ATK LEO and SpaceX commercial programs was “just” $788 million.
- Reducing public risks: the risks are shared between Space Agencies and private organizations. The latter is the owner and is responsible for program success and cost overruns.
- Engaging with actors: the delivery model and requirements definitions guarantee a goal-oriented collaboration between the Space Agency and the private organization. The partnership increases the communication efficiency between Space Agencies and private organizations.

In terms of industrial dynamics, the governance of space programs is evolving "following a self-reinforcing cycle". The industrial dynamics of the "New Space" are transforming the governance of space programs, e.g., the rise of commercial interest and new investors is gradually transforming space agencies from primary clients to partners. Also, new governance models are among the factors leading to the transformation of the space sector. Private organizations are now pursuing profit from space programs, widening the space sector's boundaries, including new end-users from different sectors, such as healthcare, transport, and insurance. In parallel, innovation in the "New Space" is increasingly generated by the convergence of heterogeneous, often emerging technologies (e.g., space and digital) and actors. Thus, program governance is progressively shaped by the diffusion of co-innovation and open innovation approaches, shifting from a top-down toward a bottom-up paradigm. The rising of new end-users and the availability of new digital technologies is a bottom-up process promoting space organizations to engage with new actors and to deliver space programs generating value for multiple actors.

Future research on the evolution of programs governance in the "New Space" should investigate how and why space organizations engage non-space organizations, the role of intermediaries in favouring the emergence and the consolidation of new programs governance models; how and why value is created, distributed and captured by the actors involved in space programs according to different governance archetypes.

Finally, studying the evolution of program governance archetypes in the space sector may offer insights for other sectors and project studies. Energy and sustainable transitions, the disruptive role of new digital technologies, or the need to capture the value created by programs and projects in the long term are factors impacting the evolution of programs governance and other industrial sectors, from energy to transport, from telecom to urban renewal. In project studies, governance is mostly studied at the project level with a "static perspective". More research is needed to explore governance mechanisms at the project and program levels. Also, it would be relevant to perform more theoretically reach longitudinal studies to investigate how governance evolves over time and why.

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