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RESEARCH VIEWPOINT

Evolution of the Space Economy: Government Space to Commercial Space and New Space

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ABSTRACT
From an economic point of view, we can distinguish three successive phases in the development of space business. In the first phase, space activities were government driven and based upon national prestige, and were financed with public money. In a second phase, large space companies, as a reaction against reduced government space funding, responded to a market demand and used their own funds or debt financing to perform commercial space business. Since approximately the year 2000, we note a third phase, whereby entrepreneurs acquire equity funding to develop independently space application projects. This phase is referred to as the New Space economy. The three phases will be covered in this paper, with an outlook to the evolution of the space economy the next decades. The outlook for New Space entrepreneurial business activities, with an emphasis on small satellites and micro-launchers, will be developed further herein.

Introduction

In analogy with other major technological steps in human evolution, like ships, trains, and planes, the first interested parties and financers in space activities were governments, as they saw the benefit for military applications. Gradually, there was also in these cases a transition to commercial applications. As an example, the Farman Company started offering regular flights in 1919, using converted Havilland DH116 warplanes,[1] hence only 16 years after the first flights of the Wrights Brothers in Kitty Hawk. Such type of transition also took place in the space sector.

Schematically we can divide this evolution in three phases, as is shown in Figure 1.

The first phase, called Primary Loop in Figure 1, can be labeled as the government business period. Governments decided on strategic objectives and asked dedicated governmental space organizations such as the National Advisory Committee for Aeronautics (NACA) in the United States (the precursor of NASA), to execute these plans. It became clear that an efficient response could only work by joining all forces, which led to the signing of

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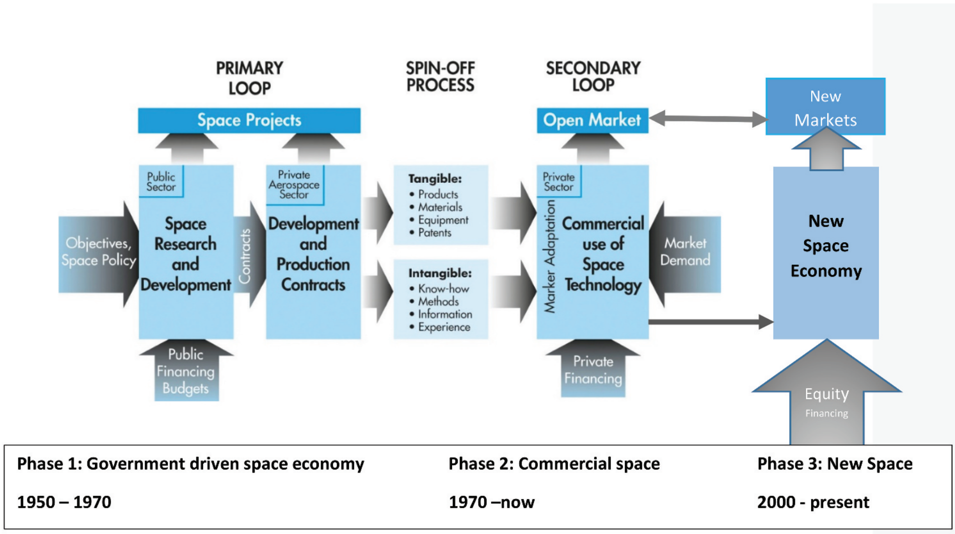

Figure 1. Three phases of space business, 1945–2021.

the Eisenhower Act in 1958, leading to the creation of NASA as central space organization. Whereas there is no doubt that prestige was the main political driver of the Space Race, it deserves to be recalled that in parallel many scientists were convinced already in the 1950s about a more sustainable conquest of the space frontier, over and beyond political motives.[2]

In the Soviet Union as well, the space efforts were government driven and more centralized from the start onwards. The objectives were imbedded in the governmental five-year plans, which were then executed by secured Experimental Design Bureaus, called *Opytnoye Konstruktorskoye Buro* (OKBs). For space activities, OKB-1 was the most important one, led by the Sergey Korolev. Note that this organization was later renamed Central Design Bureau of Experimental Machine Building known by the Russian acronym TsKBEM, then NPO Energia; nowadays it is called RSC Energia.

The lunar project of the Soviet Union was at that time advanced. A lunar landing was planned in a similar way as the Apollo project in the United States, with an orbital module of *Lunniy Orbitalny Korabl* (LOK) and a lander, *Lunniy Korabl* (LK). According to the designated commander of the flight Alexei Leonov, the decision to launch before Apollo was not taken because of the test failure of the N1 launch vehicle, which had to transport both modules in space.[3] Also, an offer of the designated crew to take over the full responsibility in case of failure was not retained. After the successful landing in 1969 on the Moon by the NASA with Apollo 11, the Space Race lessened considerably.

In the absence of the Space Race and Cold War prestige motives, NASA's budget was rapidly reduced. This caused problems for the large industrial complexes, which had supported the U.S. programs, and suddenly were confronted with a considerable drop in turnover. As these industries had acquired a wealth of know-how, both in the field of space hardware as well as in the field of quality assurance and planning, they used their own funding and debt funding to finance space projects, which lead to the boom in telecom operators, which directly ordered their satellites from these industrial providers. Indeed, it must be remarked here that the requirements for crewed flights and for military projects were evidently much more stringent in terms of reliability than in the case of civil satellites. This leads to the second phase in the space business cycle of commercial space business referred to as secondary loop in Figure 1.

At the beginning of the twenty-first century, a new evolution was noted. With a very solid space infrastructure in place, largely financed by public funding as exemplified in satellite navigation that was funded by the U.S. Department of Defense (DOD), many niche applications became evident. This led to creative use of navigation and telecommunication data, enhanced by the availability of increasingly higher resolution images of Earth Observation satellites, which were also publicly financed. In a second step, entrepreneurs started to realize that small satellites (smallsats), when used in constellations, could lead to innovation and cheaper solutions. As a distinction to the second phase, these entrepreneurs did not have access to capital or debt financing. They therefore had to apply for equity financing of business angels and venture capitalists based on a convincing business plan. We consider this here as the third wave in the space business era, often referred to as the New Space economy.

Evolution of space business

We can distinguish three phases in the present space economy evolution: (1) government driven, with national prestige as a main driver; (2) industry driven, with commercial space applications; and (3) a recent phase driven by entrepreneurs using equity funding. Each of these phases is detailed hereafter.

Government-driven phase

In general, we label this phase as the Space Race driven by a political perspective. An important impulse to national prestige in the United States and the Space Race was given after the launch of Sputnik in 1957, when NACA director Hugh Dryden stated in 1958,

> It is of great urgency and importance to our country both from consideration of our prestige as a nation as well as military necessity that this challenge [referring to Sputnik] be met by an energetic program of research and development for the conquest of space

> . . . It is accordingly proposed that the scientific research be the responsibility of a national civilian agency working in close cooperation with the applied research and development groups for weapon systems development by the military . . . NACA is capable, by rapid extension and expansion of its effort, of providing leadership in space technology.[4]

In the context of the Space Race, government budgets in the United States rapidly increased after the Russian launch of Sputnik in 1957, and then by the first launch of a human in space by Russia in 1961. As a reaction to the latter event, for example, U.S. President John Kennedy asked in a letter dated 20 April 1961 to NASA to come up with a proposal, which led to the announcement on 25 May 1961 of the Apollo program. This was considered as national priority with the budget for NASA rapidly growing through an increase of 550% between 1961 and 1965.[4] It is evident that such budgets required considerable contracts to be executed by the U.S. aerospace private sector.

In addition to this, there was a rapid rise of military space interest. Already Sun Tzu, in his famous work The Art of War (5th Century BC), based military strategy upon the principle of the 'High Ground' for observation purposes.[5] Realizing that the highest ground of outer space was within reach, military experts were interested in reconnaissance satellites. Respectively, the U.S. Corona series of satellites and the Russian Zenith satellites, from 1961 onwards, were the first prototypes of this development. An exhibit at the Smithsonian National Air and Space Museum describes the Space Race as follows: "The space race was a series of competitive technology demonstrations between the United States and the Soviet Union aiming to show superiority in spaceflight."[6]

It is worthwhile here to reflect on a different dimension seen by astronauts and cosmonauts. David Scott, a U.S. astronaut who walked on the Moon, and Alexey Leonov, a Russian cosmonaut who did the first extra-vehicular activity (EVA) in history, and was assigned as commander of the first lunar mission for Russia had that taken place, wrote later a book together. Both were military test pilots and decorated fighter plots. In the unique book,[7] they describe their motivations whereby it is clear that, irrespective of the political systems they both strongly believed in, they also both had the same aspirations and dreams, to be envoys of humanity over and beyond political considerations.

Nevertheless, one cannot ignore that the Space Race was a matter of paramount national prestige, which was accepted by all political parties. If we express the NASA budget in function of percentage of the U.S. federal budget, we can note the strong fluctuations as per Table 1 [3] with a peak during the Apollo era. There was no resistance from any political party against these considerable budgets, knowing that the project was supported by the public, irrespective of political convictions. For comparative purposes, NASA's budget today is less than 0.5% of the U.S. federal budget

As far as income for space business is concerned, we shall not ignore the dedicated space budgets of U.S. DOD and several other national defense agencies providing contracts to the space industry. It is interesting to plot the NASA and DOD space expenditures over time[8] whereby both are compensatory; when the budget in one of the two areas decreased, it increased in the other are). As a result, the workload for the space sector in the United States remained stable for many years.

This overview would not be complete without mentioning that several authors believe that a new Space Race could start, be it his time between the United States and China. Already as early as 1991, this possibility was mentioned[9] referring to a first settlement on the Moon or a first human on Mars, in analogy with the previous race to put a first human on the Moon. Of note, as well, were major military space programs that maintained an aerospace industrial based in the United States. This included, among other programs: Milstar, an extensive telecommunication network, which represented government contracts in the order of 25 Billion U.S. dollars in the period 1983 to 2002; Navstar, which to today the Global Positioning Systems (GPS), represented a similar volume of government contracts; and [3] Space Based Infrared Surveillance (SBIRS), an early warning system for launches gave not only an important impulse to Earth Observation technology, but also provided, from an economic perspective, in the order of 20 Billion U.S. dollars in contracts to the space sector.[10]

Commercial space phase

The first space commercial market explored was telecommunications. Although the principle of a repeater was first mentioned in 1945 by Arthur C. Clarke describing a 24-hours orbit, it took until the early 1960s until the first communication satellites were placed in orbit (e.g., Telstar, Syncom, and Relay). In 1965, the first operational satellite, Early Bird, was placed in geosynchronous orbit, opening the area of commercial space telecommunications (telecom).[11] Commercial telecom operators, such as Intelsat, SES Astra, and Inmarsat, proved to be very profitable, and soon afterwards commercialization appeared in other space sectors, like space transportation and remote sensing.

Typical for the commercial space sector is the fact that private companies put their own capital at risk, or use debt funding, to provide services to the private sector. More formal the U.S. National Space Policy of 2010 gives the following definition,

> The term "commercial," for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical

> market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers.[12]

The different definitions of Commercial Space were analyzed recently proposing as an alternative description, "... activity is 'commercial if it is (a) subject to free-market forces (in other words, depends on managerial initiative, efficiency-seeking behavior, and is exposed to multiple risks – investment, development, operation, market and general), (b) operating in a legitimized market place (in other words, legalized through the passage of laws that are enforceable and enforced), and (c) to achieve goals determined by actors independent of the government".[13]

Telecom and then launch vehicles and remote sensing in the following decades created a shift in space budgets from the government to the commercial sector. The shift took place in the late 1970s, at a point where space technology was made public and transferred from governmental monopoly.[14] This point in time can be easily explained by the Moon landing. Indeed, we can consider the Moon landing as the end of the Space Race, which lead to a considerable drop in space government expenditures.

Since military space expenditures in the United States did not compensate NASA's budget reduction post-Apollo, aerospace companies were confronted with a declining market and future orders. A first reaction of the U.S. aerospace sector was to form stronger entities as to resources, infrastructure, and financial capacity by a series of mergers and acquisitions to cope with a more volatile, open market. As examples, Boeing acquired, respectively, De Havilland, Rockwell, McDonnel-Douglas and later Hughes Space; and Lockheed-Martin was formed by Lockheed, GD Aircraft, Martin-Marietta and later Loral. The objective was to form larger consortia with both end-to-end capacity, as well as sufficient financial resources to enter the open markets and respond to market fluctuations.

As shown in Figure 1, aerospace companies gathered a wealth of knowledge executing large-scale space projects like Apollo, and acquired a wealth of know-how. As such, they were capable to evaluate market demand for space-based assets and provide hardware and services that corresponded to this demand. To better illustrate the shift from the first phase of governmental space to commercial space, it is significant that Initially the relation governmental space expenditure versus commercial space turnover was 100 to zero, though by 2019 this relation was 25 to 75 with space commercial markets at more than $360 billion U.S. dollars.[15] This trend will likely result in a Pareto equilibrium of 80 to 20 in the next coming years, especially with the strong presence of the new space economy.

Third phase: new space economy

Initially, the term New Space was used to show a contrast with "Traditional Space" as a new way to execute space activities compared with the traditional agency and large-scale space modus operandi. There is no unique definition on New Space, but a comparative evaluation was made in as follows:

> The traditional space population pursues goals set by governments, with boundaries defined by political and social forces, and executing activities that tend to be risk averse, based primarily on public financing, and generating competence-enhancing, sustaining innovations.
>
> New Space populations pursue common, nongovernmental market goals bounded primarily by market forces (resulting in cost and time pressures, exposure to multiple sources of risk, possibly with the initial support of governmental demand), executing

Table 1. NASA budget as a percentage of the U.S. Federal budget.

Institution	2016	2040	CAGR	Remark
UBS	340 B$	926 B$	4.3%	Pre-Corona
Morgan Stanley	339 B$	1,100 B$	4.9%	Slightly optimistic CAGR
US Chamber of Commerce	383.5 B$	1,500 B$	6%	High starting point
Goldman-Sachs	340 B$	> 3,000 B$	9,5%	Very high CAGR assumption

Table 2. Differences between traditional and new space.

NASA Budget in Fiscal Year	NASA Budget as Portion of the Federal Budget
1962	1.18%
1963	2.29%
1964	3.52%
1965	4.31%
1966	4.41%
1967	3.45%
1968	2.65%
1969	2.31%
1970	1.92%
1975	0.80%
1980	0.84%

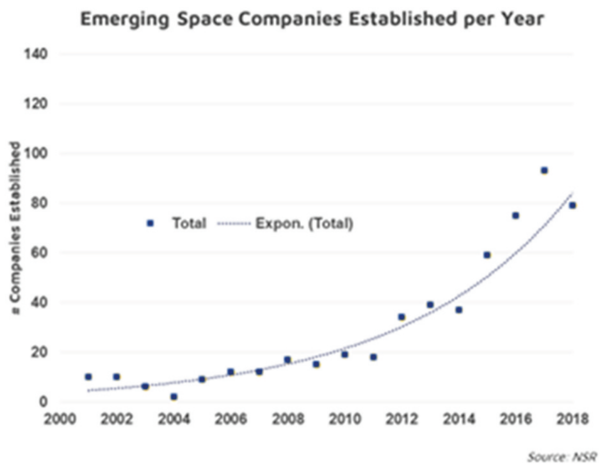

Figure 2. Exponential growth of new space companies.
Source: NSR, Emerging Market Analysis, 2nd edition (NSR, Cambridge MA, 2019).

> activities in an entrepreneurial way (i.e. engaging in risk-taking activities based on private financing, experimenting with competence destroying or disruptive innovations, or commercial-off-the-shelf innovations sourced from other industries).[16]

A few attempts as definitions were driven by different perspectives. Some definitions are given based on the nature of the activities.[17] Other definitions are more focusing on the different way of approaching solutions via different ecosystems.[18] Another approach is to emphasize the financing and entrepreneurial aspect, as "private companies, which act independent of governmental space policies and funding, targeting equity funding and promoting affordable access to space and novel space applications.[19] From a more technical perspective, traditional and new space are compared as per Table 2.

Cost reduction is in the first place obtained using existing space data from satellites available, and combining these data via algorithms for specific niche applications. In case own satellites are needed, they are produced at low cost with limited redundancy, and can be launched relatively cheap as secondary payloads. This explains the rapid, nearly exponential, growth of these type of companies the last two decades as noted from Figure 2.[20]

A transition from large-scale satellites to smallsats constellations is one important factor of this evolution in New Space; smallsats allow for low capital expenditure and lower economies of scale. M. Sweeting, a pioneer in this field, describes several phases, which took place in the Smallsat development as[21]: stage 1, the first smallsats had limited in-orbit lifetime of only a few weeks as they were dependent on on-board, non-rechargeable batteries; stage 2, passive attitude stabilization and rechargeable batteries with solar cells did not only allow the in-orbit lifetimes to be extended, but also to implement simple attitude spin-stabilization; stage 3, active control capacity with advanced logic integrated circuits and, later, microprocessors provided more sophisticated three-axis stabilization and extend the scope of applications; stage 4, implementation of in-orbit reprogrammable computers, as first implemented in 1981 allowed new flexible possibilities; stage 5, extended utility was shown throughout the 1990s over applications in remote sensing and communications, but also military applications; and stage 6, in order to obtain global coverage in low Earth orbit (LEO), it was evident that constellations of smallsats were needed (Orbcom, Globalstar, and Iridium constellations were not a business success and not smallsats, but they demonstrated the future of constellations).

Based upon this evolution, there are several disruptive evolutions involving smallsats.[21] These are highlighted below.

> Mega-constellations such as those announced for internet-from-space by Boeing (1396 satellites) SpaceX (Starlink, 4425 satellites), and Amazon (Kuiper, 3236 satellites). It is expected that mass-production will considerably reduce manufacturing costs at the same time allowing high-performance space applications. Furthermore, the constellations will make use of multiple orbit inclinations to gain global coverage.
>
> Smallsats at geostationary Earth orbit (GEO) with shorter lifetimes, coupled with new advances in Software Defined Radios (SDRs) and support electronics. These new "small GEOs" can respond to shortening technology development cycles, and potentially operate in clusters. The present example are the reconfigurable Quantum satellites, developed for European Telecommunications Satellite Organization (Eutelsat) with flexible in-orbit reprogrammable features.
>
> Space-wide-webs as an extension of the world-wide-web, by merging terrestrial networks with smallsat based space networks, covering terrestrial needs in underserved areas and extending services to satellites and space stations.
>
> Lego-satellites defined as robust smallsats launched in stacks and assembled in space by robotic operations to perform as large objects, but spreading the risk in case of a launch failure and the costs considerably. Large space telescopes are an example of this application which is under study.
>
> Direct to orbit cellular connectivity using the Commercial Off The Shelf (COTS) computer processors on satellites and modern signal processing methodologies, which demonstrate that cellular communications devices can connect to, and communicate with, satellites orbiting in LEO. These technological advances potentially translate all terrestrial cellular towers into orbit ensuring every human on Earth can be connected. Challenges remain to allow more than just data transmissions.

Clearly, equity investors believe in New Space business. Equity investments in space start-ups were in the order of $130 billion U.S. dollars in 2019.[22] As a point of comparison, this figure was only, according to the same source, around $20 billion U.S. dollars in 2014, showing an exponential growth. It must be noted here though that it is hard to put reliable figures on the part of the space economy linked at present to New Space companies. Most yearly statistics published include New Space activities under commercial space turnover; recent economical evaluations are not making a clear distinction between the two categories.[23]

Evolution and outlook

In a recent forecast, Euroconsult makes the following forecasts for the coming decade as per Figure 3 for smallsats with a mass of less than 500 kilograms (kg).

We can note from this that it is expected that in next decade some 1400 satellites will be launched each year, and that the average mass of the smallsats will be increasing from the present 116 kg to 180 kg. An important driver of this growth is the new planned constellations of several hundreds of satellites each, such as One Web, Kuiper (Amazon), Starlink (SpaceX), and Telesat LEO. While the number of satellites may be optimized as was the case with previous constellations and mergers of projects cannot be excluded, the figures will remain important. Many of these smallsats will be launched together as so-called ride-share launches, e.g. the Falcon-9 of SpaceX is presently focusing on this market.

While this is a good solution for constellations, smallsats are often launched as secondary payloads. Here, we note more complications: launch schedule is determined by the readiness of the primary payload, so the secondary payload often needs to wait for these reasons and stored; optimal launch windows cannot be requested by the owner of the secondary payload; orbital trajectory is determined by the prime payload; and the prime payload imposes

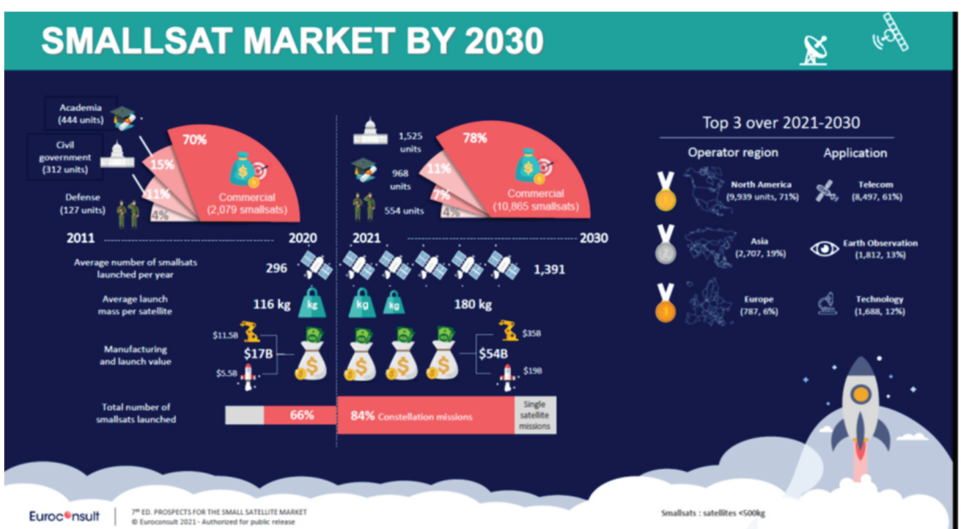

Figure 3. Forecast of smallsats, 2021–2030.
Source: Euroconsult, Prospects of the Small Satellite Market, 7th Edition, (Euroconsult, Paris, 2021).[24].

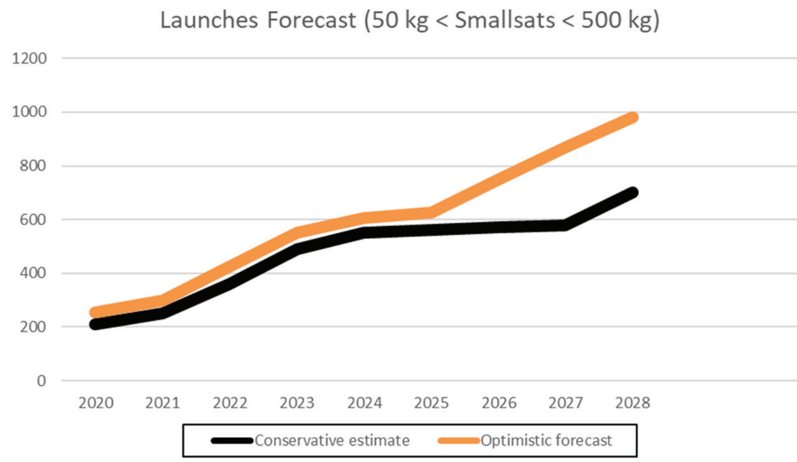

Figure 4. Forecast of number of dedicated launches with smallsat launchers.
Source: Peeters, W., Damp. L. and Williams, P., Launching Smallsats. The Example of Southern Launch. *Newspace* 8(4) (2020)[26].

contamination and power requirements to the owner of the secondary payload. As far as the first point is concerned, for example, a study,[25] covering the period 2015–2019, shows that over the last five years such delays were on average in the order of five months, with even extremes of more than 24 months launch delays. Start-ups, which are working with a limited number of satellites may get into cash-flow problems due to such delays, especially if their expected income depends on the availability of data from their satellites.

If we assume that for smallsats with a mass of more than 50 kg it might be better to have a dedicated launch into an exact orbit, the need for smallsat launchers over the next few years is predictable. An important aspect which will influence considerably the space landscape is the fact that there is a continuous trend towards smallsats in the 50–500 kg category with launches in polar and sun-synchronous orbits. The growth of this market has been recently evaluated[26] with a potential forecast of smallsats targeting a direct and precise injection in these orbits. Taking into consideration parameters such as the satellite mass, orbits, and a possible effect of dual launches, the need for smallsat launchers is shown in Figure 4. Note that the conservative forecast takes into consideration that, especially after the COVID19 period, it is likely that several projects will be canceled.

Several smallsat launcher projects are under development. An interesting record is kept by a website[27] showing that more than 100 of such projects are presently recorded. Although also larger space companies have announced plans for smallsat launchers, most are produced at low cost, often using 3D printing, and operated by New Space companies. While there is little doubt that there is a market demand for dedicated smallsat launchers, it is very

Table 3. Space economy turnover forecasts for 2040.

Characteristic	Traditional Space	New Space
Main Driver	Hardware Production	Software Application
Orientation	Techno-push	Application oriented
Design characteristics	High reliability and redundancy	Simple design, shorter lifetimes
Design philosophy	Customized	Standardization
Engineering	High Quality, High cost	Low-cost, low mass
Launch	Dedicated launcher	Shared launch
Intellectual Property	Patent protection	Technological advantage
Risk aspects	Risk Adverse	Accept business risks
Internal Organization	Hierarchical	Matrix
Financing	Company funds, debt financing	Equity financing

Source: IDA, Measuring the Space Economy[28], IDA document D-10814, (Washington, March 2020).

doubtful that the market will be sustainable in the near-term to support all projects towards a commercial success, especially those carried by start-ups, which may run into funding problems.

Cislunar activities

A recent report[28] analyzed the different predictions made on the growth of the space sector. The different forecasts are compared in Table 3

Besides differences in starting points for 2016, the main differences of the extrapolations are linked mainly to the Compound Annual Growth Rate (CAGR) assumptions, which are in many cases relatively high. Therefore, a figure around a space turnover in the order of one trillion U.S. dollars by 2040 seems more plausible. All these forecasts have one element in common, namely a growth of cislunar activities. Cislunar activities are considered as the next important step in the space economy, as an intermediate step to full-scale space exploration. As expressed in 2017 though, although the step is predictable, it is not clear how it will be taken,"*. . . a general expectation in the space community that the cislunar economy will develop in the next 10–20 years, but there is no clear picture how it will be structured.*[29]

A recent study[30] presented the cislunar activities in several distinct categories as follows below.

- Mining of water from near-Earth asteroids and the lunar pole, as a source for life support systems but also for propellant production.
- Mining of metals from asteroids mainly, like nickel and titanium, to produce structures.

- In-orbit manufacturing to produce structures, components, and spare parts to assemble them in space. Printing 3D spare parts on board of International Space Station (ISS) is an interesting precursor of this possibility.
- In space transportation assistance, which includes In orbit servicing and the use of space tugs to move satellites.
- Cislunar stations dedicated to commercial purposes. In this category, there is the possible use of ISS at the end of the government financed lifetime for commercial aims, including tourism and filming.
- Lunar landers transporting materials in an automated mode and vice-versa transport (scientific) payloads from the Moon.
- Lunar bases, like the Moon Village, providing a permanent working environment for humans on the Moon initially for scientific purposes.
- Advanced orbital services not only supporting in orbit satellites, but also helping to solve the growing space debris problem by removing the debris.
- Moon satellite services, including data relay satellites and a system of navigation satellites around the Moon, which is of paramount importance for future lunar exploration.
- Off-Earth scientific operations in analogy with Antarctic research, leading to spin-off for terrestrial use.
- Solar power, both to supply the lunar settlements with power as well as the Earth with a sustainable source of power.

Many of these applications have been discussed for several years and require considerable obstacles to overcome, requiring government funding to be developed. This idea of a new space economy based on this cislunar model was propagated by United Space Alliance (ULA) as summarized by Paul Spudis, "ULA developed Cislunar 1000 because they foresee a wide variety of potential commercial activities in space built around the manufacture and sale of space resources, specifically water and the propellant derived from it to fuel transfer stages that move payloads around and through cislunar space."[31] Evidently, several regulatory steps will have to be undertaken before commercial exploration in the cislunar environment can take place. Several authors suggested solutions for this, inter alia based upon the analogy of the maritime frameworks a century ago.[32]

Future role of new space

It is impossible to ignore the effects of COVID-19 on the space sector and the development of New Space companies. It is evident that many space projects are delayed due to confinement measures and logistic supply issues. Such a delay is less dramatic than cancelations. An example of the effect of these delays has been studied in a report,[33] which concludes that in the smallsat market the effects will be limited.

Nevertheless, we cannot ignore three major factors. One, space departments in large space companies are linked to aeronautical consortia and benefitted from the increasing sales of planes. The drop-in tourism due to COVID has a serious impact in that sector where drastic reductions are taking place now. A very visual example is the termination of the Airbus A380 production line. Two, governments needed to do strong efforts to support the economy and had to accept debts, which need to be repaid. The figures for the United States and European governments are presently over one trillion U.S. dollars; a similar amount is spent on lending plans by the International Monetary Fund (IMF). Three, New Space start-ups are confronted with delayed or reduced income, and at the same time unexpected expenses. This leads to an increasing number of bankruptcies. In the mid-term, we can predict several effects resulting from this. Government budgets the coming years will come under pressure in view of the loan repayments (although luckily for the economy present interest rates are not high). This will have a direct effect on large-scale projects, which will have at least a delayed start. Several planned constellations will have to revise the business plans and possibly we will see mergers and acquisitions leading to reductions of the number of satellites to be launched. It will be more difficult for start-ups to find funding. Further, existing funds are delaying their exit strategies; less new funds are created as the supporting capital from High Net Worth Individuals and business angel investors is rarer as the uncertainty leads to more risk-aversion.

Nevertheless, this will result in important future possibilities for the private New Space companies.

- Agencies, with reduced budgets, will concentrate on technology development and basic science research, leaving the field open for New Space companies to concentrate on applications (as an example, the New Space company named Spire concentrating now on weather forecasting).
- Also, in exploration activities outsourcing to New Space companies is already taking place (as an example see the transport of cargo and astronauts to the ISS by SpaceX).
- Even the development of smallsat launchers will be left to New Space companies with initial support of government funding (an example is the European Space Agency (ESA) and German Space Agency (DLR) competition supporting private companies to develop smallsat launchers).
- The market will orient to more affordable solutions for space projects, an area where lean New Space companies excel (examples are Internet of Things, IoT, applications and the broadband LEO constellations).

Conclusion

Space entrepreneurs, offering lower cost and more affordable space solutions to customers, will play an important role in the next space economy in the coming years. Because of the COVID-19 economic impact, government budgets will be scrutinized to take into consideration the repayment of the unscheduled expenses and efforts made to sustain the economy. Evidently, these entrepreneurs benefit from the space infrastructure, which is now publicly available, like GPS signals and Google Earth observation data as examples, due to previous government investments. During the Space Race, in the period 1950 to 1970, considerable budgets allowed for such developments. While some authors feel a second space race could take place, now between the United States and China, the considerable economic impact on government budgets due to COVID makes such race next years rather unlikely.

Due to these budgetary restrictions, we can expect a concentration of government on research and development (R&D) and on scientific projects. Large-scale projects will be maintained, but delayed in relation to the duration of the COVID pandemic. Also, large space companies, often linked to aeronautical activities, will have to cope with reducing profitability as new aircraft are in low demand. Also, these companies will become more risk-averse and will be hesitant to launch new projects.

The New Space economy operates outside this pattern. Space entrepreneurs will offer to equity financers investment possibilities requiring relatively low initial capital demand. This will be mainly the case when existing space data are used and combined via smart algorithms to cover new markets, but also for services provided by smallsats in LEO. Due to the lower mass, not only the production costs, but also the launch costs of such smallsats, become more affordable, whereas their capacity is constantly growing. For polar orbits, we can also expect a growth in dedicated launches for such areas as Earth Observation applications for example. This, in turn, will lead to the development of smallsat launchers, another domain where New Space companies will become more competitive.

Notes

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