Definition of New Space—Expert Survey Results and Key Technology Trends

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***Abstract*—This article presents the results of an expert survey aimed at defining the concept of New Space. New Space is a blurry concept which is oftentimes confused with other key ideas, such as the commercialization of space activities, or the use of miniaturized technology (such as CubeSats) in space missions design and implementation. Our expert survey reveals that the three key characteristics defining New Space are instead customer focus, new product development approaches, and new business models (private versus institutional investors). This article provides a semi-quantitative comparison of these characteristics, which we define as traits, which are used to distinguish between New Space and legacy space activities. Based on the results of the comparison and literature search, we provide a brief discussion of key technology trends emerging in New Space, namely, on autonomy, miniaturization, platforms, and crowd. This article will be of relevance to all stakeholders concerned with the creation and growth of New Space ecosystems worldwide, to which we propose ideas for taking different roles in the ecosystem.**

***Index Terms*—Expert survey, New Space definition, space industry, technology trends.**

I. Introduction

SPACE has been traditionally associated with its landmark phase of exploration that unfolded during the 20th century. Well-known achievements of the exploration phase include the first man in space—Yuri Gagarin—Soyuz, the International Space Station and the Moon Race. All these events have marked what space has been over the last fifty years. Since then space endeavors moved from being solely motivated by geopolitical interests to becoming opportunities for private businesses. Space ventures have been historically funded primarily by taxpayer money, through government agencies, such as NASA, ESA, Roscosmos, and Jaxa. Private efforts have been traditionally limited to scattered communication systems, with larger endeavors (such as the Iridium, Teledesic, or Globalstar constellations) failing to achieve commercial success [1], [2]. Public funding allowed the development of space missions with ambitious geopolitical and scientific goals, with none or only indirect consideration of economic returns. For instance, the development of technologies in the U.S. space program with spillover effects in other sectors of the economy [3].

The first two decades of the 2020s saw the appearance of a new business model for space companies, with the emergence of the so-called New Space sector. In addition to traditional government-funded activities, companies started to develop space missions primarily driven by economic profit, with significant funding coming from private capital sources. The definition of "New Space" is, however, highly debated, as it implies the existence of an "Old Space," whereas space companies have been operating commercial projects already since the 1980s. This is indeed an artificial distinction, and more clarity is required to distinguish what is "new" in New Space. Certainly, commercial purpose is not the sole discriminator, as previously indicated. Concurrent with the emergence of New Space, the number of new space companies active in nanosatellites has grown significantly since 1990. We have been observing a growing trend over the last year, with an increasing number of companies founded on private capital.

While nanosatellites (and in particular CubeSats) captured the attention of the New Space community, New Space goes well beyond nanosatellites only though. It is a much broader movement that encompasses miniaturized technology, new product development processes, new ways of working, different risk postures, and so on. The open question in the community is therefore on how to converge toward a definition of New Space, and if this objective is entirely possible at all.

The goal of this article is to shed light on the definition of New Space, by providing a semi-quantitative answer using expert knowledge. We find a definition to point to when addressing New Space is important to avoid *buzzwording* effects. That is, as a term is more frequently used, its original meaning or intent is lost, becoming no longer possible to differentiate New Space from *traditional* space. We believe that this is important for the research community, as they can reach out to our definition to support research that aims at understanding the strengths and weaknesses of New Space, to improve engineering practices of New Space, and perhaps to transfer some New Space practices into *traditional* space. We propose a definition of New Space based on expert interviews, while acknowledging the different interpretations

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that we found. We acknowledge that the endeavor of defining New Space has many blurry edges, and it is still a subject of debate in the community. As such, we provide all assumptions of our proposed New-Space-based definition, so as to provide the required transparency to see how different assumptions would change the classification of different companies.

The remainder of this article is structured as follows. Section II describes the context in which the emergence of New Space took place. Section III describes the proposed definition of New Space, and the approach that has been followed in the review of New Space products, services, technologies, and processes. Section IV provides a qualitative analysis of key technology trends being observed in New Space, as defined in this article. Section V draws the conclusions from the analysis and identifies opportunities for analyzing technology trends of New Space in the future based on the proposed definition.

II. Definition of New Space

The question of what New Sace means and how it could be defined is by itself a subject of debate. In order to provide a comprehensive definition of New Space, we conducted a broad overview of the literature, and we conducted interviews asking $N = 20$ experts the same open-ended question: "what is your definition of New Space?" While this is certainly not a large sample size to draw statistically significant conclusions on the definition, it provides a good first indication of predominant factors that immediately come to mind to experts when thinking about New Space. The experts we interviewed are all space experts coming from academia (4 respondents), a government institution (1 respondent), startups in the space industry (13 respondents), and the space investment community (2 respondents). Experts were polled from the United States, Europe, Asia, and Australia. Experts were recruited to have as much coverage as possible of the space industry value chain as represented by the SpaceTech Map that is issued on a yearly basis by Seraphim Capital [4]. A respondent was considered an expert if they were either startup co-founders, senior engineers, academics, investment managers, or innovation managers. Evaluation of this criterion was performed by the authors based on the respondent's resume or vitae. We recognize that the distribution of the experts' background is skewed toward the start-ups. While this may be a factor in the results we present below, we suggest that higher representation from start-ups better reflect the New Space ecosystem. Furthermore, given that government institutions often offer consolidated, official views in topics such as this one, increasing the relative proportion of experts from governments could skew the results without capturing real diversity of the New Space stakeholders.

The experts were interviewed following a predetermined interview protocol, tailored for an exploratory survey in the context of a pilot study. In order to avoid biases in our responses, we gave interviewees minimal instruction and no preliminary briefing of definitions we were considering for our survey.

The responses were recorded in a time period between January 2020 and August 2020. The responses were parsed into main traits, or defining attributes or aspects, and are reported in Table I. The top 3 traits reflected in the answers of experts are: 1)

TABLE I
"What Is Your Definition of New Space?" Expert Interview Results

Trait	Experts' answers count
Private customers as primary market, as opposed to government customers as	11
primary market	
Unconventional system development approaches	9
New business models / Private funding sources	7
Lower costs and shorter development cycles	6
Democratize space technology	5
Users/customers coming outside of the space sector	3
Build what the end customer (commercial or government) wants as opposed to government telling what the space industry needs to build	2
Quicker access to space	1
Open source technology	1
Exploiting new data	1
Using modern miniaturized technology	1
Generation change (new people)	1
Smaller companies now being able to compete with larger corporate in space sector	1

private customers as primary market, as opposed to government customers as primary market (10 respondents); 2) unconventional system development approaches (8 respondents); and 3) new business models/private funding sources (6 respondents). Data also shows potential relationships between the different traits, which indicate that they collectively form a common theme. For example, the use of unconventional system development approaches may facilitate achieving quicker access to space, lowering costs, and shortening development cycles, ultimately allowing smaller companies to compete with large corporates in the sector. Similarly, the use of *unconventional system development approaches* could have been enabled by the *increase in private funding sources*, the expectations of *users/customers coming from outside of the space sector*, and a *generational change*. Assessing cause/effect relationships is, however, outside the scope of this article. Our interest lies in identifying the common traits that characterize the interpretation of what New Space is.

The conclusion we draw from this pilot survey is the fact that the definition of New Space encompasses both technical and business aspects of a space mission. It indicates a paradigm shift in the reference market, which also reflects private sources of funding for space missions as opposed to traditional institutional (civil and military) funding sources. Surprisingly, among the least cited traits contributing to the definition of New Space is "Using modern miniaturized technology" (only 1 response), challenging the popular misunderstanding that equates New Space to the exploitation of small satellites (and in particular CubeSat) technology. We suggest that, while small satellite technology may be prevalent in New Space, such prevalence may be caused by their convenience as solutions to the problem that New Space addresses, not a defining trait of what New Space is on its own merit.

We conclude from the survey that customer focus, new product development approaches, and new business models (private versus institutional investors) are key distinguishing traits of

New Space. We note that these characteristics are agnostic to the type of system being developed (being it in size, purpose, or quality standards). The New Space approach defined as such, is applied to all types of space engineering systems and is not confined to miniaturized systems (e.g., CubeSats) only. Our survey findings challenge this common belief and bring us to the conclusion that there is no dichotomy between "New" and "Old" Space, but there is rather a range of options between legacy and new approaches to space engineering. "Old" (or "established") space refers to space business traditionally aimed at performance (without necessarily in need to demonstrate market fit with private customers), using well-established product development approaches, and funded by institutional sources.

III. New Space Context and Key Paradigm Shifts

New Space is sometimes confused with the beginning of the commercialization of space activities. Commercial space has been around since the very early days of the space enterprise. The first commercial satellite for TV broadcasting, Telstar, was launched in 1962, built by AT&T—which also paid $3 million to NASA for the launch. Telstar relayed 20-min broadcasts between the U.S. and Europe when the satellite was visible to the ground stations on both sides of the Atlantic [5]. The first commercial satellite placed in geosynchronous orbit for TV broadcasting was Intelsat I, also known as "Early Bird," launched in 1965 and built by the Hughes Aircraft Company for COMSAT (a publicly traded company funded by the U.S. Federal Government, later known as Intelsat) [6]. As Calderoni reported in his analysis: "When we say NewSpace, we are not talking merely of the general commercialization of space, as there has been a commercial element in space activities for decades, but rather the cultural and philosophical shift towards greater private entity participation." [7]. We bring this view even forward, and claim that New Space is not only a cultural and philosophical shift toward greater privatization but also a shift toward discovery and exploitation of new downstream service markets, some outside of the space industry itself, where space assets are not the main actor in service provision, but one of many assets that are collectively used to provide higher order, sophisticated services. New Space has several connotations, and companies exhibit "New Space traits" in different forms, as also identified in our exercise of defining New Space through expert surveys (Section II). We attempt to formalize these traits in the sections that follow, using quantitative threshold criteria. We acknowledge the blurry boundaries around those thresholds and, therefore, mean those as indicative values, rather than as deterministic boundaries. The purpose is ultimately to characterize *alignment* with New Space traits, not to categorically allocate a space endeavor in one or the other category.

Public funding has been key in the nucleation phase of the space industry, due to the high risks and high capital costs involved in launching payloads to orbit. We can identify the first three mainstream commercial applications of space in broadcast television [8], satellite radio [9], and satellite mobile communications [10]. The economic success of those ventures has been mixed, and inevitably with significant public funding to keep many of these ventures alive. The struggle toward commercialization of space is still an issue nowadays, as witnessed, for instance, by the notable cases of Iridium [11] and OneWeb [12] (the latter, being recently acquired in part by the British government, as announced in July 2020). The key difference between New Space and previous space activity is *how* public money is deployed, in conjunction with new funding sources coming from private investors. The public–private partnership (PPP) model used by NASA has allowed for substantial acceleration of the privatization of the space industry, allowing private companies such as SpaceX to flourish since the early 2000s [13]. Furthermore, the last decade (2010–2020) has seen the entrance of private equity (PE) investors, venture capital (VC), and high net worth individuals in the space business. PE and VC require economic profit as a primary driver for space activity, and as such, implied a paradigm shift in the way in which space ventures, and consequently their products and services, are conceived and implemented.

This paradigm shift has technical, business, and policy implications that converge into what is known today as "New Space." "New Space traits" can be decomposed in changes at the *enterprise level* (e.g., company structure and governance), which result into changes at the *business model layer* (e.g., strategy, marketing, and sales), which in turn cascade to changes at the *product layer* (e.g., product development process, engineering, quality assurance, and manufacturing).

The summary of key New Space traits we identified is summarized in Table II. A key trait is the prevalence of different contracting structures between institutional customers and private companies. Traditional space contracts with institutional customers in the United States operate under *cost plus* agreements, where companies are guaranteed a certain profit margin and are reimbursed for all project costs. New Space contracts are typically executed as *fixed price* agreements, where project cost is fixed and payments are made when project milestones are met. Fixed cost agreements are typical contract structures of commercial space projects likewise. In addition, it is important to note that, while some institutional customers also employ fixed price contracts, frequent contractual changes with funding increases, or issue of new fixed price contracts are common. We observe the emergence of new business models. New Space companies focus on delivering turnkey solutions similar to what already emerged in the microsatellite business, in the last 30 years, with the business model proposed by SSTL [14]. They offer data and insights *as a service*, as opposed to just delivering products such as hardware, operated to derive those data and insights. In fixed price agreements, companies have greater incentives to maximize their operational efficiency in order to maximize profits under finite resources.

Efficiency improvements combined with a market pull approach [15] and close alignment to customer needs (both public and private), result in engineering approaches that are different from the risk-averse engineering design practice of traditional space missions. We observe in particular increased acceptance of failure [16], and the adoption of Agile product development approaches [17]. We see a shift from space systems designed for ultimate performance, or design to cost

TABLE II
KEY PARADIGM SHIFTS IN NEW SPACE, AS IDENTIFIED BY OUR LITERATURE REVIEW AND EXPERT SURVEY

	Key Characteristics	**Traditional Space**	**New Space**
Enterprise layer	Shareholding	>30% institutional shareholders	>70% private shareholders
	Revenue sources	institutional tenders, grants, subsidies	commercial contracts
	Shift to privatization	Drive by a need to increase production efficiency	Driven by a desire to maximize profit
	Profitability	Not perceived as a primary driver by individuals, or not ingrained in the company culture	Explicit primary driver, ingrained in company culture
	Customers	>50% institutional	<50% institutional
	Typical operation structure	Towards horizontal integration	Towards vertical integration
Business model layer	**Key Characteristics**	**Traditional Space**	**New Space**
	Primary stakeholder needs	national security; benefits to society; international prestige	economic return
	Total addressable	space sector	all relevant economic sectors

(where cost is another design variable [18]), to engineering tradeoffs where business performance is central. The typical unit cost of New Space space assets is less than 10 MEUR (as opposed to capital-intensive projects where a single satellite would run at > 100–150 MEUR per unit). This goal is achieved through the deliberate use of Commercial Off The Shelf (COTS) hardware [16] for which specific design approaches (e.g., using redundancies and stronger reliance on software) and verification and validation approaches are devised to comply with the demanding requirements for spaceflight.

It is clear that different New Space companies can adopt the New Space traits described in Table II in full, or only in part. There are also specificities to be considered: for instance, whether the company engages in manned or unmanned space projects; where for manned missions, a "design to cost" approach and acceptance of failure are less accepted, or not possible at all.

IV. EMERGING NEW SPACE TRENDS

New Space will likely follow the same technology trends we observe in other industrial sectors [20]. We see future opportunities in New Space emerging by four technology macro-trends in particular: 1) autonomy (such as autonomous spacecraft or autonomous ground station operations); 2) the ongoing miniaturization of technology [21]; 3) the emergence of platforms; and 4) crowd approaches to space product design and lifecycle management. Autonomy is the challenge of evolving spacecraft from passive information collectors, to intelligent machines. Miniaturization is the ongoing trend of utilization of miniaturized instrumentation and miniaturized satellite technology, propelled by the infusion of modern miniaturized digital technology into space systems, and enabling quicker and easier access to space. Platforms are operational federates that build on the idea of the sharing economy, similarly to what we observe for public transportation and bed and breakfasts on Earth. Crowd refers to all those open source approaches where funding, design, creation, and other aspects that are important to the realization of a space project, are distributed over a large number of people through the Internet.

Miniaturization and access to space have been great propellers of innovation, as we know from the emergence of CubeSat technology. An ongoing trend, miniaturization started in the upstream segment with the introduction of miniaturized satellite platforms such as the CubeSat standard originally proposed by Prof. Puig-Suari at CalPoly and Prof. Twiggs at Stanford University [22]. Over the years, miniaturized space technology (and particularly CubeSat

TABLE II
(CONTINUED) KEY PARADIGM SHIFTS IN NEW SPACE, AS IDENTIFIED BY OUR LITERATURE REVIEW AND EXPERT SURVEY

	market		
	Financial model	cost plus (in institutional programs)	fixed price
	Business model	Product delivery and operations	Data and insights as a service
	Key Characteristics	**Traditional Space**	**New Space**
Product layer	Dominant innovation approach	Technology push (due to future market needs)	Market pull (present market needs)
	Product development process	V-model	Agile
	Development time	Several years	12-18 months
	Typical lifetime in orbit	Ranges between 5 and 15 years.	Ranges between months and a few years (less than 5 years).
	Typical unit cost (of the space asset)	> 1,000k USD	10k - 1,000k USD
	Make vs buy decisions	Preference on space qualified, custom components.	Preference on COTS components, qualified for spaceflight.
	Primary system design driver	performance	net present value; performance at cost
	Risk attitude	risk aversion	risk seeking
	Verification and validation approach	Exhaustive V&V approach. Validation typically performed on operational space assets. [19]	V&V "as needed", trading off testing for cost. Allow for failure in orbit as long as lessons learnt are captured in the next iteration of development. Validation performed through In Orbit Demonstration/Validation activities (IOD/IOV), on non-operational or part of the operational space assets.

platforms) transitioned from being academic projects for educational purposes, to advanced platforms used for commercial and defense applications. Miniaturization will certainly infuse to other segments of the value chain of space missions. We already start to observe for instance the emergence of miniaturized ground segments [23] and of miniaturized payload instrumentation [24]. We already see the emergence of novel space mission concepts based on miniaturized systems, such as miniaturized helicopters [25], and novel submarine segment systems for interplanetary exploration [26]. Miniaturization is a key driver for innovation as it allows for reducing the barriers to access to space, while enabling new technical capabilities in terms of greater performance per kg of in-orbit mass, which is a key driver of mission cost as of today.

Autonomy is a growing trend that is expected to take more and more relevance in the coming years. We observe significant research activity in the field of formation flying [27], autonomous navigation [28], and autonomous space traffic management [29]. DARPA has recently launched the Blackjack technology demonstrator program to demonstrate "payload and mission-level autonomy software and demonstrate autonomous orbital operations including on-orbit distributed decision processors" [30] using small satellite platforms.

We observe platform approaches in ground station operations (such as shared ground segment services), but not fully yet into the upstream sector of the space business. Autonomy will play a significant role in future developments; satellites will evolve from being passive information collectors to active, autonomous decision makers. A greater degree of autonomy of spacecraft will be required to enable reliable space operations as we enter the era of satellite mega constellations. The current active population of satellites in orbit is around 2600 units [31]. We expect this number to grow by an order of magnitude over the last 1–2 decades. Think at the Starlink constellation alone, developed by SpaceX, which plans for 12 000 satellites in orbit to deliver broadband Internet all over the globe. In October 2019, according to public domain information, the FCC filed spectrum licenses on behalf of SpaceX for additional 30 000 satellites [32]. An exponential increase in space traffic brings over new challenges in space traffic management and situational awareness. Centralized planning for space operations and in-orbit collision avoidance will become more and more cumbersome. Local awareness at spacecraft level and the autonomous ability for a satellite to forecast and avoid collisions will be paramount. This is a clear example where autonomy will play a significant role in the future space endeavors. Nevertheless, autonomy will span over all lifecycle areas, including design, manufacturing, and all aspects of operations, turning satellites into intelligent machines.

Federated satellite systems have the potential to represent instances of platforms, enabling marketplaces of digital resources in orbit [33]. Platforms allow for sharing of resources which result in an overall efficiency improvement of space assets utilization. The implementation of platform approaches in orbit brings new sets of challenges, such as in orbit coordination and data privacy and security. We already see the emergence of space platforms for in-space cloud computing services, being developed by the New Space community [34].

The space community has observed the emergence of crowd approaches in funding space projects, but less so in other aspects of a typical space project lifecycle. Crowd approaches are yet trends at the very early stages, yet with no significant attention by the space community at the time of writing this article. Crowd approaches span a wide area of activities, including crowdfunding (which was already demonstrated in the case of an New Space project [35]), co-creation, co-design, and co-manufacturing of space system projects. Many of these approaches exist in engineering sectors besides space, but they are yet to be demonstrated in the context of space projects. We see potential for the infusion of crowd approaches in the space industry, as derived from the narrowing gap between space missions and end users, associated with lower barriers of access to space.

V. Conclusion

The purpose of this article is to provide a *measurable* definition of New Space based on expert knowledge, in order to shed light on a rather blurry but quite relevant subject in the space sector. The definition has then been analyzed for semi-quantitative characteristics, and compared to the characteristics of legacy space activities. Our expert survey has identified customer focus, new product development approaches, and new business models (private versus institutional investors) as key distinguishing traits of New Space. It has also challenged the common belief that associates New Space only to CubeSats. We also challenge the notion of "New" versus "Old" Space, rather finding a range of options between legacy and new approaches to space mission design and operations. Furthermore, while we highlight its commercial space, New Space activities are certainly not the first ones focusing on commercialization perspectives.

As discussed in this article, commercialization aspects have always been present since the early years of the space enterprise. Commercialization *per se* is not a distinguishing trait of New Space. Commercial services of TV broadcasting, satellite radio, satellite phones, as well as services based on global navigation satellite systems (GNSSs) are now mature segments of commercial space activities. Since the 2000s, the space industry has observed an increased push toward privatization (for instance with the emergence of PPPs) and the emergence of nontraditional funding actors (PE and VC). Traditional space systems (including for commercial purposes) have been traditionally developed with highly sophisticated spacecraft, capital intensive projects (in the order of hundreds of millions of U.S. dollars per mission), and funded primarily by government institutions. Traditional space missions have societal and national benefits as their primary stakeholder needs. They employ highly sophisticated technology, custom components, respond to the highest quality, and comply to normative standards in terms of design, procurement, manufacturing, and so on. Missions are developed according to rigid systems engineering processes, and tight configuration management control. As launch costs have been historically very high, the capital expenditures involved in a mission, compounded to the public nature of the funding, made it such to favor the emergence of a highly risk-averse environment, and very conservative design approaches. Technical performance historically prevailed over the economic efficiency in mission design.

This landscape has been changing over the last two decades (2000–2020). New Space activities make extensive use of

COTS, leveraging on more commercially efficient solutions for access to space, and focusing on customers (not necessarily coming from the space industry) to execute on projects designed to deliver economic returns. Multimillion dollar satellites that are typically funded by governments and private investors provide financial backing to New Space ventures, in light of interesting prospects of commercial profits, and diversification in their portfolio of activities. Many New Space ventures focusing on the upstream sector make use of CubeSats. Thanks to continuous improvements and miniaturization of technology over the years, CubeSats are no longer relegated to educational purposes, but they can rather serve quite sophisticated missions. In implementing their projects, companies operate with a different, failure tolerant mindset, and new ways of working (such as Agile). As a result of this transformation, space projects are now being designed and launched in shorter timescales (months rather than years), and new markets and applications are being actively explored.

While we proposed a formal definition of New Space in this article, we still believe it is hardly possible to provide a "true or false" definition of New Space. New Space is an ongoing phenomenon that will certainly evolve over time. New Space is not about CubeSats or miniaturization of technology, and it is not about early-stage startup companies. As overviewed in this article, New Space involves all stakeholders in the space sector: from startups to large system integrators (e.g., as investors in New space startups when aligned to corporate strategy), government institutions, and academia. The role of each stakeholder in this new environment is different, depending on their specificity.

Emerging technology trends in the field of autonomy, miniaturization, platforms, and crowd are set to become highly relevant in the development of space mission concepts of the future. New Space is an emerging big phenomenon, which speed has been increasing exponentially over the last few years. The "million-dollar question" of the industry lies on where New Space is going, and whether it will eventually succeed in fulfilling its promises. While we have seen some early success, as in the accomplishments of SpaceX, the role of governments is still essential in maintaining New Space alive. We envision different roles in New Space for existing and new stakeholders. Institutional actors have the opportunity to shape the emergence of the New Space ecosystem by lowering the barriers of access to space, and promoting initiatives to foster the creation and growth of New Space startups. Investors and entrepreneurs have the opportunity of creating New Space solutions to nonspace problems, looking at the intersection of the use of space data with the different verticals of commercial business and nonprofit organization activities. Established industry has an opportunity to infuse technologies coming from the New Space ecosystem in their business lines, and monitor the evolution of the ecosystem for the origination of potential disruptive technologies being demonstrated in New Space activities. As our effort in characterizing New Space with formal definitions show, New Space certainly represents a paradigm shift with respect to the established space industry. We expect the ideas defined in this article to evolve over the next couple decades and shape the way in which space will be exploited as a natural resource, with a combination of existing and new approaches and technical solutions.

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