What makes space activities commercial?

Ken Davidian

Federal Aviation Administration, Office of Commercial Space Transportation, 800 Independence Avenue SW, Washington DC, 20591, USA

Keywords:
Commercial space
New space
Teleologic
Evolution
Variation
Selection
Retention

Abstract
Between the 1950s and 1980s, U.S. space sector activities were government-driven, government-sponsored, government-managed, and assisted by the industry-sector. Awareness of non-governmental space activities originated in the 1980s and gained prominence in the early 2000s with the founding of well-funded private companies. This paper takes an organizational evolution perspective to refine what is meant by “commercial” space markets and activities and compares the results to previous discussions offered by space community authors. From an organization theory perspective, the three primary forces of the evolution change model (variation, selection, and retention) provide a framework for renewed commercial space activity discussions. Together, the strength of these three forces can indicate how “commercial” a market is. Two case examples are presented to illustrate application of this framework: the U.S. space race era activities during the 1960s, and the current space tourism market. Despite competitions for various contracts awarded to industry-sector firms, the Apollo program was clearly government-driven, and was not “commercial” to any significant extent. The current space tourism market is clearly considered “commercial,” but with qualifications. Conclusions from this review include the appropriate levels of analysis to discuss space market characteristics, a comparative analysis of the “commercial” activities of the U.S. space race era and the current space tourism, the inference of proxies for estimating the strength of the three evolution model forces, and a caution about the accuracy of “commercial” market forecasts.

1. Introduction

1.1. Emergence of the “space industry”

During the emerging decades of the “space race era” (SRE), governments directed their industries’ activities in coordinated space programs, driven by ideological forces, and resulting in significant technological achievements. Despite the symbolic express of “soft power” and the social benefits of employment in high technology job sectors and derivative technological “spin-offs,” SRE activities did not enjoy universal support. Significant voices of society admitted the lack of financial return of research and exploratory investments [1], and complained of neglect by the government to address social issues [2]. Throughout the 1960s, approximately half of the United States (U.S.) public, including a vast majority of scientists, consistently thought the space race was clearly government-driven, and not an overwhelming expression of societal demand.

To discuss space activities more accurately, it is recognized that the “space industry” is, in fact, a collection of many disciplines and industries, coordinated into a program by an organizing agent:

“In fact, there is a field in which the complex network has already been very important for some time, namely the space programme. Space technology does not have a unique scientific body of knowledge, as is the case with chemistry or electronics. Space technology is essentially organizational with no ‘production’ of its own. It is merely a kind of agency (e.g., the European Space Agency) which organises an international network of different industries. It is through a process of coordination and imposing of technical and organisational constraints (command delays, charge books, defined standards, etc.) that the space network weaves itself” [4], [p. 253].

“Space” is more accurately described as a “sector” or “field” of the social and economic systems of society, rather than an “industry.” The rich and successful history of nationally coordinated space activities in the 20th century created international and interdisciplinary communities of experienced individuals and organizations, who understood how to solve problems in their various domains and industries. These communities include the International Astronautical Federation (IAF), the European Space Agency (ESA),
the International Academy of Astronautics (IAA), and the International Institute of Space Law (IISL). In this paper, space markets are primarily constrained within a single nation or marketplace, although some discussion of multi-national (multi-regional) space markets are mentioned.

1.2. Heightened awareness of commercial space

Following the SRE activities of the 1960s, the creation and operation of private space launch companies in the mid-1980s raised the international space community’s awareness of commercial space activities that gained greater popularity in the early 2000s. Consolidation of the U.S. aerospace industry, from a large number of SRE contractors to a very few, has been well documented [5–7]. McDougall characterized the space sector at the end of the 1990s as an oligopoly, with Boeing and Lockheed-Martin as suppliers, and a oligopoly, with the National Aeronautics and Space Administration (NASA) and the Air Force as customers [8]. Beginning in the mid-1980s and accelerating in the early 2000s, the creation of firms, such as SpaceX, Virgin Galactic, and Blue Origin, began raising the profile of “commercial” or “new space” companies.

Former employees of SRE organizations (including NASA, the Air Force, and their contractors) took jobs in the new space companies, including Blue Origin and Virgin Galactic, increasing these individuals’ awareness of new space activities. New space capabilities and goals disseminated through to their professional and personal networks. As awareness increased, discussion of the new space activities increased, and so did confusion about what they were and what made them different. Many SRE firms claimed to be similar to the new firms in terms of agility and ability to innovate. Although the two cohorts were thought to be different (terms like “dinosaurs” and “mammals” were not uncommon), articulating their differences made the topic of defining the word “commercial” of common interest.

A proxy for the common level of interest in this topic could be the number of citations of “commercial space” papers, published in journals and presented at conferences. The level of interest in commercial space topics within the space community increased as reflected in the number of google scholar citations returned for the search phrase “definition of commercial space” over the past century (Fig. 1) or the increased number of papers on topics of commercial space presented at the International Astronautical Congress (IAC) since 2010 (Fig. 2). The IAC data also indicates that the increased interest within the space community is global (Fig. 3). Since 2012, Europe, North America, and Asia consistently contributed to the global discussion of commercial space topics, and an increasing contribution to the conversation more recently comes from the Middle East, South America, Africa, and Oceania regions.

The increased level of interest across all regions of the world raises many questions about commercial space among members of the space organizations and companies: What does it mean for a space organization or activity to be “commercial”? Government and company managers work to improve the efficiency and effectiveness of their organizations, and one way of doing this is by better understanding the external environment. As commercial organizations and activities increase, their impact on the space industry also increases. Therefore, improving an organization’s strategic planning requires increased awareness of the commercial influences. A variety of organizations offer data about commercial space organizations or activities, despite the lack of a clear understanding or consistent of what “commercial” space organizations or activities are. How can decision-makers be expected to make insightful decisions to shape future policy or strategy when the information they rely on is not well defined? To solve that problem, this paper attempts to define what “commercial” means in the context of space activities, by applying a competitive (evolution) market model of organizational change, and by reviewing similar efforts of prior authors. Of special note, the focus will be on “commercial” activities instead of organizations, because a single organization often delivers similar services to governmental and non-governmental customers, referred to as “dual use.”

1.3. Paper road map

This paper asserts that certain aspects of SRE and new space organizations and activities (including their goals, membership, and guiding activities) differ significantly. Identifying these differences are fundamental to the definition of the degree to which market activities can be considered “commercial.” This paper first defines market level organizations (commonly referred to as industry segments, industries, and markets, sectors, fields, or ecosystems). Change models that apply to activities at these organizational levels are described, as are those that best fit SRE and new space activities. Next, recent works discussing characteristics of “commercial” space are reviewed and placed within the context of the change models identified. Finally, conclusions are presented regarding the application of the concept of “commercial” to market activities, and limitations of this discussion and ideas for further research, are presented.

2. Theory of organizational change

2.1. Definitions

Foundational concepts for the discussion of commercial market activities include levels of analysis, organizations, and models of organizational change. These are discussed below.

2.2. Levels of analysis

Hierarchical ordering is a natural and common method of framing the analysis of complex organizations [9,10]. Organizations are hierarchically nested with multiple levels of analysis. The lowest level is the individual (referring to people, jobs, technologies), and progresses upward to increasingly higher levels, of sub-unit (referred to by many names, such as “work team”) and then the firm. Work teams are made up of multiple individuals, and firms are made up of multiple work teams, as shown in Fig. 4. The next higher level of analysis, referred to as
industry segments (in economic terminology, or populations, in sociological terminology), consists of multiple similar firms. Multiple similar industry segments (such as producers of liquid rocket engines and solid rocket motors) combine into industries or communities (continuing the example, propulsion systems). Climbing through the hierarchical levels of analysis can continue indefinitely, but this discussion stops with collections of industries or communities within a single country, to form an organization referred to as a market, sector, field, or ecosystem. Levels of analysis from the firm downward are referred to as "nonmarket" levels of analysis, and levels above the firm are referred to as "market" levels of analysis [11]. A comparison of the different terminologies, and examples of organizations at each level, are provided in Table 1, starting at the firm level of analysis. It is important to emphasize this paper treats all the levels of organization above the individual firm level (i.e., the space industry segments, industries, and market (or

---

5 Based on types of business relationship between organizations or individuals [45,46], the difference between economic and sociological terminology is the sociologists' inclusion of affective, and referential relationships, in addition to hierarchical and market ties. For example, "industry" members do not include relationships with regulatory agencies, trade organizations, or social movement groups. In this discussion, either or both terminologies will be used for market-level organizations, although the sociological usage is intended.

---

Fig. 1. Number of google scholar citations for keyword search “definition of commercial space”.

Fig. 2. Increased number and percentage of “commercial space” IAC papers.
sector, field, or ecosystem) as organizations.

2.3. Organizations

Since entire ecosystems are organizations, they can be described using the definition of an organization. Organizations, at any level of analysis, are defined as “goal-directed, boundary-maintaining, and socially constructed systems of human activity” [12]. The first of these three characteristics, deliberate goal setting, differentiates organized activity from other social collectives, such as families. Members, leaders, or owners deliberately and independently set goals for their organizations at all market levels. At the same time, organizations also account for the needs and preferences of other members, especially those providing critical resources. The second defining characteristic, boundary maintenance, is critical for organizational survival because it identifies members and non-members of the organization, with rules for

![Fig. 3. Regional authorship of IAC “commercial space” papers.](image)

![Fig. 4. Nested hierarchy of organization levels of analysis.](image)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Differences of organizational terminology at different levels of analysis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector</td>
<td>Groups of Similar or Related Organizations</td>
</tr>
<tr>
<td>Non-market</td>
<td>Technologies, capabilities</td>
</tr>
<tr>
<td>Market</td>
<td>Firms</td>
</tr>
<tr>
<td>Market</td>
<td>Industry Segments or Populations</td>
</tr>
<tr>
<td>Market</td>
<td>Industries or Communities</td>
</tr>
</tbody>
</table>
enforceable membership (defining the organization) and non-membership (delimiting the organization from the outside environment) [13]. The third defining characteristic of organizations is the presence of socially constructed systems of human activity. These activity systems can operate at the levels of non-markets (such as behavioral or performance expectations of individual workers, or administrative processes within a firm), or markets, reflecting different types of institutional logics that determine rational and accepted activities.

2.3.1. Models of organizational change

In addition to the systems of financial transactions and non-financial relationships that exist between firms within industry segments and industries, market-level organizations are subject to forces that cause them to change over time. Four ideal model types represent how these changes occur, based on different units of analysis (referring to one or multiple organizations) and modes of change (following a prescribed series of steps, or being externally constructed or directed). The four organizational change models are teleology, life cycle, dialectic, and evolution, as shown in Fig. 5 [14].

Two of these models, life cycle and dialectic, do not describe the past or present state of space activities very well.6 The remaining two organizational change models, teleology and evolution, are a better fit for past and present space activities. The teleology model of organizational change describes a process of deliberate and purposeful advancement and performance as directed (constructed) by a single entity (such as a committee or agency). Organizational members in the teleology model do not set their own goals but follow directions from a guiding authority. Decisions to adjudicate any competition of ideas are made by a central entity, and not by distributed marketplace forces. The model is a good fit for SRE activities between the U.S.A. and the Union of Soviet Socialist Republics (U.S.S.R., commonly referred to as Russia), which were directed and controlled by their respective governments. This model is also applicable to governmental space activities of many nations today.

The remaining model of organizational change, the evolution model, involves multiple organizational entities following a prescribed series of stages or forces (variation, selection, and retention, or VSR for short). Organizations progress through the stages serially, although an organization is subject to all three forces simultaneously. The evolution model of organizational change is “not necessarily historically efficient” [15], meaning the VSR forces do not necessarily result in the highest technical performance, the maximum societal benefit, the quickest results, or the most efficient use of scarce resources.

Due to the inherent inefficiencies, there is great uncertainty regarding the outcome of the VSR forces. With respect to organizational changes subject to the evolutionary process, “few people know exactly what they are doing, or why” [16]. Many types of markets fit the evolution model, including those that are established (existing firms competing for new business), evolving (with new firms entering an established industry) and emerging (new firms entering a new industry). Given the lack of unified direction or control of the evolution forces, performance prediction of these “commercial” markets is difficult.

Finally, environments subject to the evolution organizational change model can be competitive and referred to as “hostile.” Environments that are less competitive may exist under many conditions, for example if there is only one provider of a product, or if there are sufficient resources for all active actors (referred to as a “munificent” environment).

2.4. Evolutionary model forces

Since the purpose of this paper is to better define what is meant by “commercial” markets, and because the evolution model of organizational change best fits those markets, a more detailed discussion of the three evolution model forces is given below. This discussion enables the inference of possible antecedent and intermediate variables for each force.

Variations are the intentional or blind departures from routine or tradition, introduced from within or outside an organization, and the “higher the frequency of variations, whatever their source, the greater the opportunities for change” [16]. Because innovations are any “idea, practice, or object that is perceived as new by an individual or other unit of adoption” [17], innovations are variations by virtue of being perceived as new, or different from some norm. The introduction of multiple unique innovations in markets signals the presence of variation forces of the evolution change model. Collections of individual innovations, called technological trajectories, are defined and characterized in many different ways, and include new processes, new organizational forms, etc. [16]. Technology trajectories are typically introduced by individuals, teams of individuals (i.e., company sub-units or divisions), or entire companies. An average single company (innovation source) produces an average number of unique innovations. For a given technology trajectory, multiple innovating companies (innovation sources) likely complement the work of one another, rather than duplicate each other’s efforts [18], thereby generating a greater number of innovations than would a single company. Innovations are typically intentional, but blind (unintentional) innovations may occur through imperfect imitation of competitors’ processes, also known as mimetic isomorphism [19]. Therefore, multiple independent innovation sources produce a greater number of unique innovations than a single innovation source, or multiple sources that are mutually dependent in some way. For example, if two divisions within a single company both innovate at the same time, the number of independent innovations coming from that single company will not be the same as coming from two independent companies. This is because the common coordination and control mechanisms used by a single company, or controlling entity, will make the innovations mutually dependent. Given this, the strength of the variation force is a function of the number of independent innovation sources, working through a mediating variable, the number of independent innovations. This implies that the number of independent innovation sources may be an independent variable, or antecedent proxy, for the strength of the variation force. This also implies that the number of independent innovations is an intermediate variable for the variation force strength.

Selection forces in markets “differentially select or selectively eliminate certain types of variations” [16], and the effect is reflected by the ability of innovations to attract and assimilate the necessary resources for survival. Selection entities include firms and market-level organizations that produce or control the allocation of critical resources, including scientific and technological knowledge, financial resources, and human capital [20]. Regarding financial resources within a single nation, this means the private ownership of capital is required to increase the number of selecting organizations beyond the government itself. In a multi-national context, the requirement for private financing

6 The life cycle model of organizational change is characteristic of highly regulated environments, where organizations proceed through well-defined stages in a prescribed sequence. The life cycle model best fits highly standardized and controlled change processes of organizational development. Developing and bringing a new pharmaceutical or medical device is an example of life cycle organizational change. Drug companies follow specific steps to gain technical, regulatory, and market approvals of a new drug. This model does not duplicate each other’s work, or blind (unintentional) innovations may occur through imperfect imitation of competitors’ processes, also known as mimetic isomorphism [19]. Therefore, multiple independent innovation sources produce a greater number of unique innovations than a single innovation source, or multiple sources that are mutually dependent in some way. For example, if two divisions within a single company both innovate at the same time, the number of independent innovations coming from that single company will not be the same as coming from two independent companies. This is because the common coordination and control mechanisms used by a single company, or controlling entity, will make the innovations mutually dependent. Given this, the strength of the variation force is a function of the number of independent innovation sources, working through a mediating variable, the number of independent innovations. This implies that the number of independent innovation sources may be an independent variable, or antecedent proxy, for the strength of the variation force. This also implies that the number of independent innovations is an intermediate variable for the variation force strength.

Selection forces in markets “differentially select or selectively eliminate certain types of variations” [16], and the effect is reflected by the ability of innovations to attract and assimilate the necessary resources for survival. Selection entities include firms and market-level organizations that produce or control the allocation of critical resources, including scientific and technological knowledge, financial resources, and human capital [20]. Regarding financial resources within a single nation, this means the private ownership of capital is required to increase the number of selecting organizations beyond the government itself. In a multi-national context, the requirement for private financing
is not necessarily valid. Other selection entities could include critical suppliers that support the target industry segment or industry. The ability to attract necessary resources is related to environmental munificence or hostility, described as a function of the market’s carrying capacity and the number of firms [21]. When a market’s carrying capacity is greater than the number of market firms, the environment is considered “munificent,” new firms enter the market, and market growth is driven by increased legitimacy. Once the market carrying capacity is reached or exceeded, the market is considered “hostile” and driven by competition. In summary, the selection force is positively correlated to the number of competing firms and predominates in hostile environments, when the market carrying capacity is met or exceeded.

The level and sources of available resources (scientific knowledge, financial, and human capital) also influence the selection force strength. As was described for the variation force, if most of the available resources come from a small number of independent sources (e.g., there is only a single source of funding or scientific knowledge, such as a central government), then the selection forces decrease because of common coordination and control mechanisms used to control the organizational sub-units. Therefore, the overall level of available resources, and the number of independent resource sources, are also antecedent proxies for the strength of the selection force.

The third evolution model market force, retention, is reflected by the demand generated for a new technology trajectory. The greater the level of demand, the greater the level of the retention force for that innovation. It is possible that a sufficiently high level of demand for an innovation is generated by a single source, referred to as a “monopsony.” For reasons similar to those described for variation and selection forces, the retention force strength in a monopsony is less than to a similar level of demand generated from multiple independent sources. This indicates that the number of independent demand sources is also significant for retention force strength. A combination of multiple independent buyers, retaining one or more innovations through sufficient levels of market demand, can establish a “de facto” standard or “dominant design” for the market. Therefore, both the demand level and number of independent demand sources are antecedent proxies for retention force strength.

3. Results

This section presents the analyses of prior studies, two examples of space ecosystems (the U.S. activities during the SRE representing the teleologic change model, and current suborbital space tourism activities representing the evolution change model), and a “what if” exercise of looking at the U.S. SRE activities through the lens evolutionary change.

3.1. Prior studies

The space community recently published or presented many studies on topics spanning the definition of “commercial,” “commercial space,” and “new space” (Table 2). Some of these studies directly discussed specific characteristics of commercial organizations. All (but two [22, 23]) study made indirect reference to the forces of change in commercial organizations. This section describes how previous studies described the characteristics of market-level organizations, including independent goal setting, organizational membership, and the three evolution forces.

In the context of commercial space, two of the recent space community reports directly addressed the importance of independent goal setting, particularly in relation to governmental influence, stating that actors must have “independence from Government” [24] and “act independent of governmental space policies and funding” [25]. Satellite communications hardware and operations have been free from government control and influence for many decades, but space launch activities have traditionally been government controlled. Although complete independence from governmental policies may be a bold dream for the launch vehicle industry, non-governmental actors at the firm level have recently successfully demonstrated repeated operations. Currently, no market-level space activities (at the population, community, or ecosystem levels of analysis) are entirely independent of...
The general definition of New Space organizations is organizations within the collection of industries based on the use of space rocketry in a competitive, commercial context. NewSpace companies, on the other hand, are small firms and startups with a low-cost focus and the long-term goal of an independent business model that is sustainable without government support. Additional qualities used to help identify NewSpace organizations in this report include (1) their investment in core commercial space flight technologies and infrastructure and (2) their business process and strategy characteristics. NewSpace organizations typically intend to: (1) Substantially reduce investment costs and increase long-term payoffs; (2) Develop innovative operations geared towards small, dedicated teams; (3) Focus on making commercial human space flight commonplace.

These dimensions are generalized characteristics that describe the extent a space activity can be considered ‘commercial,’ including the following: (1) It is free-market driven: This dimension includes components of risk, assumption of managerial responsibilities, the demonstration of efficiency-seeking behavior, subjugation to free-market forces, and the existence (or reasonable expectation) of non-government customers. (2) It has independence from Government: This dimension includes components of design purpose and reliance upon government property. “NewSpace’ describes what is rightly defined as a real paradigm shift of the sector. A partial central of the current evolution—NewSpace—is the revolution in down-stream space applications, which is attracting new governmental and commercial entrants at both ends of the space sector’s value chains, from satellite and rocket manufacturing to satellite applications, services, and products.

NewSpace is … “A global industry of private companies and entrepreneurs who primarily target commercial customers, are backed by risk capital seeking a return, and seek to profit from innovative products or services developed in or for space’ (NewSpace Global, 2019)” “new companies with a high private capital deployment, the use of new technologies and approaches, and the convergence with the information technology (IT) sector that are forming the basis for what has been referred to for some time in the professional world as ‘NewSpace.’

Identification of ‘common classifiers’ characterizing commercial activities: investment risk, performance risk, market risk, private responsibility, private ownership, revenue generation, and existing or potential nongovernmental customers.”

The authors propose a two-by-two framework, based on “risk taker” (government or private/market entities) and “customer base” (government only or government among many). “NewSpace is a worldwide phenomenon of entrepreneurs developing products, and service enterprises focusing on space and are using private funding in their initial developments. While there is no internationally accepted technical definition of ‘NewSpace,’ principally, the ethos of the movement has been to challenge the traditional ways of space exploration that are widely considered as too expensive, time-consuming, and lacking in room for inventive risk-taking.”

“The ethos of NewSpace lay in low-cost commercial off the shelf (COTS) innovation largely; NewSpace business models are mostly financed by private capital without significant anchor customer signings against the promise of mass market sales of EO products and services.”

“Space commercialization with innovative ways is called NewSpace, and seeks for low cost, reusability, small teams, market oriented approach, profitability, human space activities and so on.”

“The entrepreneurial and commercial undertakings of ‘NewSpace’ introduce a new spirit to the ecosystem of space. The New Space ecosystem is more energetic, creative, and dynamic than the Old Space ecosystem.”

... a potential definition of newspace entrepreneurial activities is hereby proposed as follows: ‘Private companies, which act independent of governmental space policies and funding, target equity funding and promote affordable access to space and novel space applications. It is hereby acknowledged that, as each definition, there is a level of simplification imbedded in the aforementioned definition: (1) New space companies evidently have to abide to government regulations, but they have more flexibility, for example, in the choice of a launcher for their (secondary) payloads. (2) New space companies will surely not refuse government contracts, but primarily they try to minimize their dependency in the long run. (3) Affordability is a relative factor, but trying to penetrate in the markets of emerging countries requires providing solutions that are of good quality, at the same time respecting budgetary limitations.”

“NewSpace is the body of [“entrepreneurial efforts by startups and new businesses to exploit new opportunities, technologies and business models to bring about the private use and commercialization of space.”]

“Since the early 1960s, the term NewSpace is primarily growing in the United States, referring to companies that are entering into space commercialization. In Europe, the term Space 2.0 is used in a similar context.

“NewSpace’ is a phrase commonly used to describe the emergence of a different ethos for space where the established aerospace methods and business have been challenged by more entrepreneurial private sector by adopting more agile approaches and exploiting the latest commercial-off-the-shelf technologies. It unfairly infers an ‘old space,’ to the phrase is used in this paper without enthusiasm but provides a convenient shorthand.”
attributed to “commercial” space in this review were also used for definitions of “new space.” The only additional characteristics identified for “newspace” was the attribute of a novel “movement,” “wave,” or “revolution.” The “philosophy” or “ethos” concepts, included in the definitions of “new space,” is not so novel when compared with the definition of “commercial.” Because of this similarity in describing the two term, it may be possible to characterize “newspace” as a subset of “commercial” space activities.

3.2. Case examples

In this section, two specific cases are briefly described and associated with the organizational change model that best describes them. The first case is the U.S. Apollo program during the SRE of the 1960s. The second case is the current human suborbital space transportation, or “space tourism,” industry segment.

3.2.1. Teleology model case: U.S. Apollo program example

U.S. space activity during the Apollo program includes Projects Mercury, Gemini, and Apollo, spanning the time from 1959 to 1969. The goals of these activities were determined by a single entity, NASA, the civilian government space agency, at the direction of the President. Goals were pursued through the activities of U.S. industry actors and selected by NASA through a competitive acquisition process. When problems arose, NASA and the industry partners worked together to identify possible solutions and set new goals. These new goals were then pursued, using the same competitive acquisition processes. This is a good description of the teleology model where organization changes are directed by a single entity, constructing novel solutions to emerging problems, to achieve a defined goal. Innovations of the U.S. space market organization activities were teleologically driven by the Apollo program. Other national examples of teleological direction that directly targeted space market organization activities include the development of the European Aeronautic Defence and Space Company (EADS) in Europe and the United Space and Rocket Corporation (USRC, or Roscosmos) in Russia.

Despite the practice of competitive acquisitions for contracts in space projects, these competitions decided which contractor would execute designs preselected by the government. The U.S. government was the single independent source of design innovation. The government was also the sole funding source of SRE activities, and the sole source of demand (a “customer” in some sense) for these activities. It is well-documented that the U.S. adopted a model of technocracy and a “command economy” for many reasons (including the inherent dis-coordination of the private sector, the market’s corruption by consum-erism, international competition, promotion of political agendas, and proof of the superiority of American institutions) [8,37].

3.2.2. Evolution model case: space tourism example

The current human suborbital space transportation market, sometimes referred to as “space tourism,” provides the industry context for the second case example. The general goal for firms competing in this market is safe, round-trip, human spaceflight, between a single point on Earth and an altitude of approximately 100 km (km). The X PRIZE competition was a major shock event that stimulated the creation of space tourism firms11 [38]. Five space tourism firms reached the stage of manufacture, assembly, or flight testing of full-scale flight hardware: Blue Origin, Rocketplane Global, Scaled Composites, Virgin Galactic, and XCOR Aerospace. Scaled Composites never intended to enter the space tourism market itself, but they competed for, and won, the X PRIZE. By 2020, only two firms, Blue Origin and Virgin Galactic, remained active. Although they are pursuing the same general goals, both firms approach the problem with different innovation set-technology trajectories.12

The evolution model of organizational change best describes the space tourism industry segment emergence based on the following observations. The number of independent firms is a proxy for the variation force strength. Because Scaled Composites and Virgin Galactic were mutually dependent through a licensing agreement, they count as a single source of innovation. Scaled Composites never intended to enter the space tourism market with a viable product to attract paying customers. The innovation they represent was coopted by Virgin Galactic through a licensing agreement, so although they are two separate companies, together they represent only one source of innovative activities. Therefore, there were a maximum of four independent innovation sources in this market, and two currently remain active.

Proxies for the selection force strength include the number of independent sources of important resources (namely scientific knowledge, funding, and human capital), and the available level of these resources. The government (primarily) provided the scientific resources, developing technologies that support the space tourism market, starting in the mid-1950s with rocket-powered suborbital test vehicles (such as the X-15), through the 1990s with vertical take-off and landing vehicles (the Delta Clipper, or DC-X). More recently, individual companies conducted internal research and development activities, providing the required technological knowledge to solve problems particular to their designs. Regarding funding, each of the five firms succeeded in securing funds, to varying degrees. Those that failed to raise sufficient funds, including Rocketplane Global and XCOR Aerospace, were forced to leave the market. Scaled Composites did not raise more funding than other firms, but they had sufficient internal resources to accomplish their goal of winning the X PRIZE. Scaled Composites left the space tourism market by choice. The two active firms, Virgin Galactic and Blue Origin, raised more funding than the other firms, by two or three orders of magnitude.13 Each tapped into different independent funding sources, including personal, angel, venture, and institutional investors, providing equity and non-equity funding. Finally, human capital, with aerospace and other technical degrees for the space tourism market, is considered plentiful, especially in comparison to the same resources of the early 1960s. Since that time, universities have achieved a long history of strong academic and experimental programs in these technical disciplines. Given the strong foundation of governmental research and human capital, combined with a sufficient number of independent funding sources, the selection force proxy levels for this market are high, indicating the presence of a strong selection force.

Proxies for the space tourism retention force include the number of independent sources of demand as well as the level of demand for suborbital flights. Since 2005, Virgin Galactic has sold approximately 600 reservations for seats on future flights of SpaceShipTwo, primarily to

11 The X PRIZE Foundation offered $10 million purse to the first team that could fly a vehicle capable of carrying three human adults, to an altitude of 100 km, return safely to Earth, and repeat the feat within two weeks.

12 Virgin Galactic suspends a rocket-powered, winged spacecraft underneath a carrier aircraft. The carrier aircraft takes off like a normal plane and flies the spacecraft to an altitude of approximately 15 km before releasing it. Once a safe distance from the mothership, the spacecraft then ignites its engine and ascends toward space. Once the engine stops, the spacecraft coasts to its maximum altitude, before returning to Earth and gliding to a horizontal landing at same location from which it took off. Blue Origin uses a more traditional approach, with the human spaceflight participants in a capsule placed on top of a cylindrical propulsion module. The propulsion module takes off vertically (like a “normal” rocket), and when the rocket firing stops, the capsule separates from the first stage, and coasts to its maximum altitude. The propulsion module returns to Earth due to the force of gravity and makes a propulsive “soft” landing on a designated landing pad. The capsule also returns safely to Earth, under parachutes, within a designated landing zone.

13 Whereas the other firms raised funding on the order of tens of millions of dollars, both Virgin Galactic and Blue Origin raised hundreds of millions of dollars to support their space tourism activities.
individual firms or people, each buying some small number of seats. As of this writing, Blue Origin has not set a price, nor sold any reservations, for space flight participants to ride in the New Shepard capsule. Based on Virgin Galactic’s reports, the number of independent sources of demand is high, on the same order of magnitude as the number of reservations. In fact, this is the only space transportation market in which a “mass appeal” has been demonstrated to any extent (whether directly or, as in this case, by proxy). The level of demand for the human suborbital spaceflight has not been realized since no commercial operations have been conducted by either of the two firms. Considering this, the existence of the retention force is evident, although the strength and robustness of this force cannot yet be clearly determined, quantitatively or qualitatively.

From this discussion, the presence of all three evolution change model forces in the current space tourism industry segment is clear.

3.3. Was the “space race” commercial?

To justify a counterargument to the assertions made above, this final section first attempts to describe the SRE as a commercial market. Is it possible that the U.S. space program during the 1960s was driven by evolution forces of organizational change? If an attempt were made to describe the Apollo program as “commercial,” the strength of the variation force would be very weak, because of the single source of innovation. Despite the high level of financial resources provided to the Apollo program,15 the selection force strength would also be very weak, because the government was the only independent source of the critical resources required (including scientific/technological and financial resources). Even including the military space activities conducted during this time, the ultimate goal-setting institution for both NASA and the Air Force was the U.S. Government (including both the executive and legislative branches). The shared hierarchy of control, overseeing both NASA and the military activities, indicates that the legislative branch funding decisions for each program were mutually dependent. The resource of human capital was initially limited, but universities increased their educational offerings in advanced technical disciplines (such as materials, aero-thermodynamics, and orbital mechanics) as the decade progressed. Therefore, if there were a selection force strength acting during the U.S. Apollo program, it would be considered initially very weak, although it grew (slightly) in strength as the time passed. Finally, in a market subject to evolution model change, a proxy for demand can be defined as the number of independent consumers who acquire the product. Since the U.S. Apollo program products were not offered for sale to consumers, there was no “commercial” demand for these innovations. The only user was the sole designer and the single funding source: the U.S. government. Since there was no demand for these innovations, the strength of the retention force was also very weak. In summary, if an argument were to be made that the U.S. SRE activities were to be considered “commercial,” they would represent a very weak instance of this form.

In summary, from a perspective that characterizes the “space race” era activities as a market-level organization, change was centrally driven, in a teleologic manner. Although the U.S. example was given, the situation was the similar to, if not the same as the U.S.S.R., the only other space actor at the time. The U.S.-U.S.S.R. comparison highlights the point that the industry enterprises do not need to be state-owned to be teleologically directed. Undermining any argument that these were commercial markets in some way, are the zero (or negligibly low) strength of variation, selection and retention forces. In the U.S. case, there was competition to become a contractor to the government in the execution of space activities, but that form of competition made no contribution to the existence or strength of evolution forces that characterize commercial activities.

4. Discussion

This paper attempts to define what it means to be “commercial” for activities at the market-level (i.e., at levels of analysis above the individual firm).16 Similar to the word “transportation,” the term “space” may be too broad to describe a single “industry,” but is better described as a sector, market, ecosystem, or field, that includes a coordinated collection of many academic and technological disciplines. As entrepreneurial space firms emerged, they attracted individuals from governmental space organizations, thereby increasing the awareness of non-governmental space activities within their social and professional networks. This raised the general awareness of commercial space activities and heightened the need for a better definition of the word “commercial.” To accurately analyze the impact of commercial activities on any governmental or private organization or activity, there needs to be a better definition of “commercial” within the context of space activities.

“Space race” era activities in the U.S. were executed by a market organization of privately-owned industry firms but directed and guided by governments. Organizational changes (innovations) of this type are referred to as “teleologic” (i.e., “enacted for a purpose”). Although selection of industry actors may have been through competitive acquisition practices, all decisions of vehicle and operational design were made by a single guiding actor. In contrast, truly “commercial” space vehicle designs and operations are subject to evolution forces. For any specific industry segment, multiple independent sources of variation (i.e., innovative designs), selection (i.e., funding and knowledge allocation), and retention (i.e., consumer demand) are required at sufficient levels to be considered “commercial.” Commercially successful results cannot necessarily be predicted a priori, nor are they necessarily optimized (i.e., the most efficient) in terms of technical performance. This is because evolution is a locally adaptive process whose course is not predetermined. This also emphasizes that few people in an emerging commercial market know what they are doing, or why.

15 The question of whether the number of firms exceeds the market carrying capacity is untested, although actions of all space tourism market actors could provide clues of the status. On the one hand, if the carrying capacity has been exceeded by the number of firms, then actions of both firms, and other space tourism market actors, would reflect strong competitive forces. On the other hand, if the environment is still munificent, then space tourism actors would provide clues of the status. On the one hand, if the carrying capacity has been exceeded by the number of firms, then actions of both firms, and other space tourism market actors, would reflect strong competitive forces. On the other hand, if the environment is still munificent, then space tourism actors would provide clues of the status.

16 Definition of the term “commercial” may be related to, but is different than, terms such as “commercialization” and “privatization.” A complete discussion of the meanings of those two latter terms is beyond the scope of this paper.
As an organization, the space sector is defined by membership boundaries, goal-direction, and a coordinate set of socially constructed activities. Past studies took different perspectives, and used different terminology, to identify these three characteristics for “commercial” space or “newspace.” The socially constructed activities of space include the forces of change that drive space industry innovation. Of the 15 studies reviewed for this report, 13 refer to the variation force of the evolution change model, eight to selection forces, and six to retention forces. Only two referred to “goal direction” as a characteristic, and five mentioned “membership” characteristics of being “commercial.” These results indicate that most industry analysts perceive commercial space as being driven by the evolution engine of organizational change. Identifying the model of change for “space race” activities was not within the scope of the studies reviewed.

It remains to be seen which segments of the spaceport, launch vehicle, and in-space vehicle industries will become truly “commercial.” Two example cases were discussed. The U.S. Apollo program exhibited strong characteristics of a teleologic (government-driven, non-commercial) sector, whereas evidence supports the idea that the emerging space tourism industry segment is “commercial.” Industry segments of the overall space sector need to be considered on a segment-by-segment basis to assess how “commercial” their market may be.

5. Conclusions

Conclusions based on the previous discussion include the appropriate level of analysis for drawing conclusions about space sector characteristics, an analysis of how “commercial” the U.S. SRE activities were, proposed proxies for estimating the strength of the three evolution model forces, and a caution about how accurate the commercial market forecasting may be.

The space sector (also referred to as a market, ecosystem, or field) is divisible into multiple industries (communities) and industry segments (populations). Industry segment characteristics are sufficiently distinct from each other, so representations may be overly generalized if made at, or above, the industry level. To be as precise as possible, market conclusions should target the industry segment level of analysis.

U.S. government goals guided the activities SRE actors in a teleologic change process. Although there was competition among private sector organizations for manufacture, assembly, and integration of various components of the space exploration systems, this ecosystem was not “commercial.” The U.S. space ecosystem was not subject to evolution change processes, typically characterized by significant levels of variation, selection, and retention forces.

Based on the discussion presented, it is reasoned that proxies for the strength of variation forces include the number of independent innovation sources. The actual number of independent innovations is dependent on the number of independent innovation sources, so it may be an intermediate proxy for the strength of this force. Proposed proxies for the strength of the selection force include (1) the number of independent innovation sources (as it affects environmental hostility), (2) the number of distinct resource sources, and (3) the level of available resources. Proposed proxies for the strength of the retention force include (1) the level of demand, and (2) the number of independent demand sources.

Finally, although government organizations may support the goal of the “newspace” movement to operate in a truly “commercial” market, the desire to accurately predict trends and events in that market should be tempered by the realities of an evolution-driven marketplace. The more the evolutionary motor of organizational change characterizes “newspace” emerging and evolving markets, the lower should be the expectation of accurately predicting their future states. This is due to the inherent unpredictability and non-linearity of the innovation process. A major reason why governments enact “command economy” policies is to avoid duplication of effort, and efficiently allocate scarce resources to production functions. Although “free markets” strive toward efficient resource allocation, a “commercial” market’s inherent characteristic of competition cannot dictate a technically superior “dominant design,” and encourages duplication of effort.

5.1. Limitations and further research

There are many possibilities for further research based on the limitations of current studies. This section discusses four possible lines of future research, including validation of the baseline assumptions, taking steps toward theory development, investigating the evolution from one institutional logic to another, and finally, continuing the attempt to define the concept of “commercial.”

First, many of the assertions made in this discussion can be further debated. For example, are multiple government agencies within a single nation (e.g., a military branch and a civilian space agency) dependent sources of variation or selection by merit of their mutual connection to a central governmental legislative or executive branch, or are they independent, despite their common overseeing legislative bodies? The assumption of a unitary approach may be valid for the Soviet SRE activities, but does it hold in the U.S. case, too? While recognizing the military and civilian connection of the U.S. space program, historian Neil Maher also describes how segmented the activity was: “In the Soviet Union the space program remained a classified military effort; failures were rarely acknowledged publicly and accomplishments were announced only after assured success. In response to such secrecy, in July of 1958 President Eisenhower created NASA as a distinctly civilian agency, albeit with clandestine ties to the U.S. military. Yet while more transparent, NASA was far from monolithic. During the so-called Apollo era, which, like its long 1960s counterpart, encompassed most of the 1960s through the mid-1970s, numerous factions vied with one another to publicly define both space exploration and NASA’s place within it. These included a handful of administrators, from James Webb and Thomas Paine to George Low and James Fletcher; three dozen or so astronauts, including not only Apollo’s Lovell, Swigert, Armstrong, and Aldrin but also Project Mercury’s John Glenn and Scott Carpenter as well as Gemini’s Frank Borman and Pete Conrad; thousands of engineers and scientists, such as the famed German rocketeer Wernher von Braun and the climate-change expert Jim Hansen; and tens of thousands of private contractors scattered across the nation” [39, pp. 7–8].

Additionally, the discussion could be expanded to include international space market organization activities.

Second, this report takes the first steps toward theory development that could be pursued by developing a set of propositions based on the evolution change model described here. The ultimate goal would be to develop a set of supported propositions that could then be sufficiently quantified into testable hypotheses, and then independent variables could be operationalized to collect qualitative data testing the proposed theory. Through the application of academic frameworks, such as the process models of organizational change employed here, the discussion of defining the word “commercial” is evolving, from a survey of cognitive perceptions or narrative description of policy, toward the long-term goal of a quantifiable and verifiable theory.

Third, commercial space activities are emerging from an existing institutional environment, and not from an institutional vacuum [40]. The emergence of commercial space activities from their SRE origins can be characterized as the emergence of the evolution process of organizational change against the steady-state backdrop of teleologic space activities. Because the set of commercial space actors includes some fraction of SRE actors, the latter bring “command-and-control” institutional logics (the teleologic change model) to a “market logic” environment (the evolution change model). Mixing the two logics can make a positive contribution by contributing legitimacy and access to resources. However, the blending also may decrease the survivability of...
commercial new entrants by influencing them to adopt internal processes that favor the teleologic environment, aligning them better with central controlling agencies, and deterring them from learning to efficiently meet market demands.

Finally, the fundamental question posed in this study is how to define the concept of “commercial” markets and activities. This interest is not unique to the space community. For example, the legal profession has grappled with this question for decades. Despite decades of decisions since the mid-1970s, multiple courts have not been able to define what constitutes “commercial speech.” The legal imperative for defining the term was to “deny foreign states immunity when they engage in conduct that is based on a commercial activity carried on in the United States” as an exception to the Foreign Sovereign Immunities Act of 1976 [41], or to identify the boundaries of First Amendment protection [42]. To the legal profession, defining commercial speech has proven to be problematic:

“Some critics advocate alternative formulas to the Court’s allegedly fumbling efforts to delineate the ambit of commercial speech. Others assert that no principled distinction exists between commercial expression and other types, so that the entire enterprise is inherently futile” [42, pp. 56–57].

“The perception of the Court’s having repeatedly stumbled in attempting to mark the outlines of commercial speech has inspired a wide array of alternatives to supply the deficiencies in these definitional efforts. A few take a highly expansive view-sweeping in, for example, “any speech by a ‘commercial entity’” or even “any expression concerned with buying or selling.” Others, seeking to narrow the reach of commercial speech doctrine, would confine diminished protection to expression related to the contractual aspects of commercial speech. Under some proposals, commercial speech cannot be reduced to a single unifying principle, but rather must yield to a more nuanced approach based on smaller, discrete categories of commercial communication. Most commonly, candidates for a functional definition of commercial speech center around the role of expression in promoting commercial interests. Some remain close to the core notion of advertising, while others suggest somewhat broader notions of promotion” [42, pp. 86–87].

Similarly, archaeologists and historians struggle with defining the terminology of intellectual constructs, such as “civilization,” and attempt to eliminate any value judgements inherent in the choice of words to describe the construct. Furthermore, these constructs are most useful when comparing the degree among multiple examples of similar kind (for example, comparing one societal system to another), rather than using the definition to determine if a given societal system is a “civilization” or not. Adopting this perspective could drive the assertion that all market organizations are situated at one or more points along a spectrum of teleologic and evolution models of change. A related discussion would make a similar assertion regarding a spectrum with poles of capitalism and socialism. With respect to this report, no value judgement is intended to be attached to the concept of “commercial” in this research, but that does not mean different cultures do the same. It is well documented that societies, at different times throughout history, have attributed different levels of status upon the “commercial” or “merchant” classes [43]. These discussions provide new ways to look at the central topic and raise new questions that challenge our general understanding of the issue. Further research could search for similar definitional efforts from other professions, to better understand their motivations and approaches to this research.

5.2. Implications

Implications of this discussion for managers and policymakers is based on the blending of “command-and-control” (teleologic) with “market” (evolution) institutional logics. As “new space” companies formed, they employed SRE members who brought their experiences of successfully implementing and managing space activities to the commercial sector. Being aware that they are working in an environment that is fundamentally different from what they had previously experienced has important implications. For managers, if the forces motivating past governmental space programs are different from those driving current commercial activities, then past strategies and tactics they used to get promoted and guide successful past programs may not be appropriate for the success of current commercial ventures. Understanding these differences helps identify when historic best practices for space activity management and operations are best employed, and when new practices should be introduced. For policymakers, implications of this discussion are also based on blending the two logics. This discussion concluded that forecasting commercial markets is inherently uncertain, especially when compared to teleologic organizations. It is easier to forecast the outcome of an innovation when all activities are guiding it toward a specific goal. Policymakers who have a strong background in teleologic organizations (e.g., the U.S. military or civilian space programs) may be accustomed to more accurate forecasts than are realistically available in commercial markets. Understanding this difference may help policymakers adjust their expectations, based on the institutional logic guiding their sector of interest.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

I would like to acknowledge the work of all the cited space community authors in their attempts to define what the word “commercial” means with respect to space organizations and activities. I would also like to acknowledge all my colleagues who respond to my different and disparate queries on this topic, even though that information has not been included in this report. My hope is that future papers on this topic will include this information at the appropriate time. Finally, I would like to thank the helpful comments from the manuscript reviewers, resulting in significant improvements to the original submission.

References


