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ARE COMMERCIAL SPACE TRANSPORTATION INDUSTRIES EMERGING?

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Industries have been characterized as following a predictable pattern similar to the familiar product life cycle. The four stages (introduction, growth, maturity, and decline) are defined by points of inflection in the industry sales growth rate. Unlike products that follow an "S" curve growth rate based on the rate of innovation diffusion, industries can affect their growth trajectory in many ways such as through innovations and repositioning. All industries start out with certain barriers to entry, position strength of the buyers and suppliers, etc., and these evolve toward a different structure due to processes such as investment by existing firms and the appearance of new entrants. Emerging industries are created through a variety of forces, including technological innovations, changes in cost relationships, identification of new customer requirements, and others that increase the visibility of business opportunities. Regardless of the specific industry, all emerging industries have common characteristics that have been identified through rigorous academic research. This paper begins by identifying the structure of emerging industries as defined in the text "Competitive Strategy" by Dr. Michael Porter of Harvard Business School. Next, the paper proceeds to cite examples and counter-examples from the current commercial space transportation industry for both cargo and crew for each element of this structure. The desired goal of this activity is to support the claim that the commercial cargo and crew space transportation industries are both emerging, uniquely different from the established space transportation industry that currently services national space agencies. This claim could be a positive indicator that, provided appropriate levels of encouragement and support, both the cargo and crew commercial space transportation industries could develop into a lucrative and mature industry unto themselves.

INTRODUCTION

Will the orbital and suborbital commercial space transportation (CST) industries ever become the "booming business" for which many space advocates hope? Will private companies ever take average citizens, safely, reliably, and inexpensively, into space?

Markets, like products, typically follow life cycles that progress in phases that are typically labeled as "emerging", "growth", "mature", and "decline". Before any industry can enter the "growth" phase, it will by necessity have to "emerge" first. This purpose of this paper is to determine the extent to which the orbital and suborbital commercial space transportation (CST) industries can be considered "emerging" based on a set of characteristics that are independent of any specific industry. The framework for these characteristics is provided in a university text commonly used in business school curricula, "Competitive Strategy" by Dr. Michael Porter of Harvard Business School.

After defining the scope and extent of the CST that is the primary subject of this analysis, Section 1 identifies the emerging industry framework that will be employed as an analytical structure although the a detailed description is not provided for the sake of brevity. The interested reader is encouraged to refer to Chapter 10 of this report's principal reference for supporting information that is both comprehensive and authoritative.

Section 2 focuses on common structural characteristics of emerging industries and the correlation with the orbital and suborbital CST industries. Section 3 will focus on the most common barriers for early mobility that individual companies in emerging industries face. Section 4 will take a broader perspective, looking at the problems constraining the development of an emerging industry. Each of these sections are based on the framework identified in Section 1, and describe

evidence of or resemblance between these characteristics and the current orbital and suborbital CST industry using real-world events whenever possible.

Based on the depth of resemblance as detailed in the prior sections, a final conclusion of whether these CST industries could be considered emerging will be drawn in Section 5.

It should be noted at the outset that, although the final conclusion of this paper might be that the orbital and suborbital CST industries could be considered "emerging" because they share many of the common characteristics of most historical emerging industries, there is no guarantee that these industries will necessarily pass from the "emerging" to "growth" phase. Being an emerging industry is a necessary but not sufficient condition for becoming a growth industry. In other words, this analysis may not be able to provide definitively positive answers to the opening questions of this Introduction, but it may conclude that the CST industries have at least a chance of success.

SECTION 1. CHARACTERISTICS OF EMERGING INDUSTRIES

This paper is an analysis of how closely the inherent structure and demonstrated behavior of individual companies within the US orbital and suborbital commercial space transportation (CST) industries resemble those of past emerging industries.

Before identifying common characteristics of a typical emerging industry, it is necessary to bound the scope of this discussion by defining what is meant by "commercial space." For convenience sake, the definition used in this report will be the following, as given in the US National Space Policy dated June 28, 2010:[1]

The term "commercial," for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers.

It should also be noted that the suborbital CST industry being considered in this report includes rocket-powered launch vehicles only. Other vehicles that enable suborbital research, including aircraft that fly parabolic trajectories, drop towers and balloons, are not included. Also, because of the emphasis of this analysis on commercial operators, suborbital rocket-powered vehicles that are operated under government contract are also excluded from this report.

Specifically, Table 1 below lists the US companies that comprise the orbital and suborbital CST industries in this analysis. The mention of these companies is supported by reference citation where possible and should not be construed as an endorsement thereof. Any omission from this analysis of specific companies of any provenance is not meant to reflect in any way on those companies.

Suborbital CST Companies	**Orbital CST Companies**
• Armadillo Aerospace	• Boeing Company
• Blue Origin	• Lockheed-Martin Corporation
• Masten Space Systems	• Orbital Sciences Corporation
• Virgin Galactic	• Space Exploration Technologies (aka SpaceX)
• XCOR Aerospace	• United Launch Alliance

Table 1. Companies in the U.S. Orbital and Suborbital Commercial Space Transportation Industries

The content of Table 2 is based on the work of Michael Porter as presented in Chapter 10 of the 1980 text entitled "Competitive Strategy" where he lists the common structural characteristics, early mobility barriers and problems constraining industry development for emerging industries.[2]

Each of the characteristics and sub-characteristics listed in Table 2 are discussed below and resemblances to the characteristics and current events of the orbital and suborbital CST industries are noted.

The terminology used in this report is based solely on that introduced and used in the Porter text for the sake of clarity and alignment with the framework introduced and developed therein.

SECTION 2. REVIEW OF STRUCTURAL CHARACTERISTICS

This section will focus on common structural characteristics of emerging industries (as identified in Table 1 above) and the resemblance with the current orbital and suborbital CST industries, providing evidence to reinforce or refute this resemblance by real-world events when possible.

Structural Characteristics

- Technological Uncertainty
- Strategic Uncertainty
- High Initial Costs But Steep Cost Reduction
- Embryonic Companies and Spin-Offs
- First-Time Buyers
- Short Time Horizon
- Subsidy

Early Mobility Barriers

- Proprietary Technology
- Access to Distribution Channels
- Access to Raw Materials & Other Inputs of Appropriate Cost and Quality
- Cost Advantages Due to Experience
- Risk (Raises Effective Capital Barriers)

Industry Development Constraints

- Inability to Obtain Raw Materials, Components
- Rapid Rise of Raw Material Prices
- Absence of Infrastructure
- Absence of Product or Technological Standards
- Perceived Likelihood of Obsolescence
- Customers' Confusion
- Erratic Product Quality
- Image and Credibility with Financial Community
- Regulatory Approval
- High Costs
- Response of Threatened Entities

Table 2. Typical Characteristics of Emerging Industries

Section 2.1 Technological Uncertainty

The increase in privately-funded commercial activity in the CST industry was made possible by a large amount of technological development conducted by national governments over the past half-century. This broad and deep base of intellectual property is widely available to the companies of the orbital and suborbital CST industries via manuscripts, text books and still-living individuals. Despite this access to technical information, these companies still face a great deal of technological uncertainty due in part to the tacit nature of teaching.[3]

Beyond the inherent shortcomings of "learning by reading" only, there are some technological uncertainties that are encountered with each new system that can only be overcome through the actual accomplishment of making the systems operate as planned.

Putting aside the technological uncertainty involved with designing, building and testing a new subsystem for their vehicle, even if one assumed a company was using flight-proven subsystems (e.g., propellant tanks, turbopumps, valves, injectors, manifolds, nozzles, etc.) from a fully-operational, flight-proven vehicle to build a new (different) vehicle, the process of disassembly and then reassembly creates technological uncertainties that can only be overcome through successful integration and operation of the completed vehicle.

Therefore, for both the orbital and suborbital CST industries, and despite the use of 50-year-old space systems, subsystems and components that have benefited from well-funded technological research, development, qualification testing and space flight experience, these industries very strongly resemble an emerging industry because there is still a very large amount of technological uncertainty to be overcome before they will be successful.

Section 2.2 Strategic Uncertainty

The organizational theory known as "population ecology" contends that industries often develop through initial stages where a wide variation of design and approach strategies are attempted until some predominant element is determined by the marketplace. After this initial period of strategic uncertainty, the amount of variation in the industry diminishes around this individual characteristic selected by the market.[4]

The decision of what strategic direction is best for a company in the orbital or suborbital CST industries is still uncertain. In the suborbital domain, the approaches of launch operations and promised flight experiences vary widely. For example, XCOR Aerospace's is designing a horizontal take-off approach from a runway and offers a test-pilot-like experience (referred to as "The Right Stuff" experience[5]) in contrast to Virgin Galactic's air-launch operations and elegant flight experience akin to that depicted in the science-fiction movie "2001: A Space Odyssey" experience.

In the orbital CST industry, there is variation of strategic approach in the domain of manufacturing and acquisition. Although the predominant approach of most new entrants initially mimics the "tried and true" expendable launch vehicle (ELV) configuration, reusability is a stated goal of some new entrants to the industry (see section 2.3 below). Also, manufacturing methods, concepts of operation (e.g., horizontal vs. vertical payload integration) and fixed-price contracts with government customers are domains in which new entrants to the industry are

attempting to win market share by trying different approaches where possible.

Based on this discussion, the orbital CST industry resembles an emerging industry in many strategic areas (e.g., manufacturing, acquisition, etc.). The suborbital CST industry also resembles an emerging industry in many strategic areas also (e.g., launch operations and flight experience). Therefore, the structural characteristic of strategic uncertainty is high for both the orbital and suborbital CST industries.

Section 2.3 High Initial Costs But Steep Cost Reduction

The CST industry in general, as reflected by its specific sectors, has extremely high capital requirements due to stringent requirements of development, testing, safety and reliability.[6] In this way, the CST industry closely reflects this specific characteristic of an emerging industry.

The realization of steep cost reduction however has never materialized in the historic orbital CST industry. The historic consensus of lowering costs has been based on necessity of vehicle reusability and this is still the technology path that is being pursued by private orbital CST.[7]

Suborbitally, high capital costs are also a reality as is the promise of cost reduction through reusability. The newest entrants to the suborbital markets for both human transport (XCOR Aerospace, Virgin Galactic) and scientific payloads (Masten Space Systems, Armadillo Aerospace) are all designing toward a fully reusable vehicle with simplified launch and reentry operations to drastically reduce overall costs.

If the technology of making space vehicles truly reusable can be developed, a steep cost reduction is then possible (although not inevitable).

The resemblance of both the orbital and suborbital CST industries to this structural characteristic is high although unproven to date.

Section 2.4 Embryonic Companies and Spin-Offs

The orbital CST industry consists of companies that cannot be called "embryonic" in any sense of the word. SpaceX is the newest entrant to the orbital CST industry and has a vast amount of experience gained through strategic hiring of individuals from within the industry. SpaceX has grown at tremendous rates ever since its inception in 2002.[8]

Because all the companies being reviewed in the orbital CST industry are either very mature or have grown very quickly past an embryonic stage, the orbital CST industry is estimated to have a low resemblance to an emerging industry.

In contrast, reviewing the suborbital CST industry, there is great variation among the different companies under consideration. Some are fairly new but mature organizations (e.g., Blue Origin and Virgin Galactic) with large numbers of employees (i.e., greater than approximately twenty) although others are companies that truly could be referred to as "embryonic" (i.e., Armadillo, XCOR and Masten) in that they are still comprised of very small teams (e.g., less that approximately twenty individuals).

Because some of the companies in the suborbital CST industry are truly embryonic whereas others are not, the suborbital CST industry bears a medium level of resemblance to an emerging industry.

Section 2.5 First-Time Buyers

Emerging industries are characterized by the attraction of customers that have not previously made use of the available supply of goods or services under consideration. In both the case of orbital and suborbital CST industries, the set of potential customers can be divided into two groups: (i) scientific or commercial payloads (e.g. satellites) and (ii) human spaceflight participants.

In the orbital CST industry for scientific or commercial payloads, the established firms are still reliant on their traditional customer base, including governmental space agencies, the defense department and intelligence community. New entrants to this industry, however, have begun to attract customers who are not first-time buyers per se, but who have not purchased from the US market of orbital launch vehicles due to advantageous pricing of non-US competitors and US regulatory barriers.[9] Specifically, recent public announcements from satellite communications operators indicate their commitment to purchase launch services from SpaceX.[10] These announcements are significant because they are the first indications of the price competitiveness of a US launch vehicle company, a position that was ceded many years ago. In this sense, these traditional customers of the orbital launch vehicle market could be considered "new customers" to the US segment.

In the orbital CST market for human spaceflight participants, there have been no contracts signed between new entrant firms and traditional customers. Potential new customers have been identified but none have flown to date.[11] It should be noted that the service of orbital space transportation of private citizens to the International Space Station has been

provided in the past by a Russian entity that is not included within the scope of this report.

Based on the liberal definition of new customers for the orbital commercial payload market and the fact that none of the new customers have yet to receive an orbital CST service in practice, the resemblance of this structural characteristic in the US orbital CST industry is determined to be low.

In the suborbital CST industry, the designation of new customers is not much clearer. The traditional scientific payload customer has been government-funded which is outside the commercial scope of this analysis. The suborbital CST industry companies have been working hard to attract scientific or other payload customers. For example, after issuing a Request for Proposals (RFP), the flight providers have offered a flight opportunity at no cost to the researchers whose proposals are selected. Although some of these initial customers have launch suborbital payloads before under government contract, some of them are indeed new to this market.

Less ambiguous are the categorization of customers for the suborbital human transportation market as being provided by Virgin Galactic and XCOR Aerospace. These are truly "non-market consumers" who are the first of their kind to purchase this type of service.

Based on the attraction of some new customers to the suborbital payload market and all new customers to the suborbital human transport market, the resemblance of the suborbital CST industry to an emerging industry is estimated to be high.

Section 2.6 Short Time Horizon

It is commonly believed that business works at a very fast pace, especially when compared to other private and public sector entities. Typically this pace is driven by the need for ever-increasing efficiencies to minimize costs so as to maximize return on investment. Although this characterization is overly-simplified and a caricature at best, it is not entirely baseless and is consistent with the overall philosophy adopted by most of the firms in the orbital and suborbital CST industries. Tempering this stated desire for speed is the over-riding requirement for safety in manufacturing, operations and flight.

Often to the consternation of their non-commercial space transportation colleagues, new entrants in both CST industries have often advertised the promise of quick operations and high flight rates. In practice, however, these new firms have continually demonstrated resistance to the temptation of impatient behavior, often referred to as "go fever" or "launch fever". The actual progress of these firms has been quite paced. For example, almost eight years has elapsed since SpaceShipOne was awarded the X PRIZE Foundation's "Ansari X PRIZE" purse of $10 million and SpaceShipTwo has yet to undergo its first powered flight test. Three years since winning the purses offered by the NASA Centennial Challenges "Northrop Grumman Lunar Lander Challenge," both winning teams have yet to fly those same (or any other) vehicles on a regular basis to any appreciable altitude. These long lapses in time could be seen as indications of absences of progress, but in reality, all these companies have been working continuously and diligently, resisting the temptation to fly before they can do so safely. Therefore, given the requirement for safe operations and flight, and despite the seemingly long periods of time between significant flight accomplishments of all involved, the degree of resemblance of this structural characteristic with an emerging industry is rated as high.

Section 2.7 Subsidy

Government funding of an industry is common in emerging industries for many reasons and takes many forms. The topic of subsidies tends to be sensitive and even use of the word can be the source of debate. Regardless of these judgment valuations, both the orbital and suborbital CST industries are currently benefiting from this form of governmental support.

Demonstrations of orbital CST capabilities are being subsidized via acquisition authority known as Other Transactional Authority, in the form of Space Act Agreements (SAAs), with SpaceX and Orbital Sciences in a program called Commercial Orbital Transportation Services (COTS).[12] (The Commercial Resupply Services contract issued to these same companies is not considered a subsidy but is a standard contract.) In what is considered by many to be a highly desirable outcome and well worth the expense, it is widely believed that COTS has greatly accelerated the development of these companies' orbital CST capabilities.

In the suborbital CST industry, a project called Commercial Reusable Space Research (CRuSR) is using government funds to pay for the flights of new entrant suborbital vehicles with the hopes of attracting payloads to take advantage of these flights.[13]

Based on the scale and impact of COTS and CRuSR, the existence of government subsidy in both the orbital and suborbital CST industries is clear. Therefore, the strength of resemblance of this structural characteristic with an emerging industry is high in both cases.

Section 2.8 Summary of Section Results

Table 3 provides a summary of results, showing the degree of resemblance as described and determined in the sections above, between a typical emerging industry and the orbital and suborbital CST industries.

The orbital CST industry demonstrates a strong resemblance to the structural characteristics of a typical emerging industry in all but the categories of "embryonic companies and spin-offs" and "first time buyers." In these two categories this industry bears a low resemblance to an emerging industry. The average of these scores indicates that the orbital CST industry has structural characteristics that bear a medium to medium-high resemblance to a typical emerging industry.

On the other hand, evaluation of the suborbital CST industry's resemblance to a typical emerging industry is high in all categories except one ("embryonic companies and spin-offs") in which the resemblance is medium. Overall, the structural characteristics of the suborbital CST industry bear a high resemblance to those of a typical emerging industry.

STRUCTURAL CHARACTERISTICS	**Orbital CST**	**Suborbital CST**
Technological Uncertainty	High	High
Strategic Uncertainty	High	High
High Initial Costs But Steep Cost Reduction	High	High
Embryonic Companies and Spin-Offs	Low	Med
First-Time Buyers	Low	High
Short Time Horizon	High	High
Subsidy	High	High
OVERALL RESEMBLANCE	**MED-HIGH**	**HIGH**

Table 3. Summary Results of Structural Characteristics

SECTION 3. REVIEW OF EARLY MOBILITY BARRIERS

This section will focus on the most common barriers for early mobility that individual companies in emerging industries face (as identified in the Porter text and listed in Table 1 above) and the resemblance with the current orbital and suborbital CST industries, providing any evidence that reinforces this resemblance by real-world events when possible.

Section 3.1 Proprietary Technology

As space activities are an inherently technological endeavor, the ability of new entrant to firms to efficiently develop, utilize and protect necessary technology will be an important factor in their success. However, many of the aerospace components and subsystem technologies being utilized by the new entrant companies were previously matured in the military or civilian space programs and are not proprietary.

Protection of propriety technology is achieved through the national and international patent systems. In the commercial space industry, there is some, but not overwhelming, evidence of intellectual property (IP) protection through patents or other mechanisms. In late 2010 a search of the U.S. Patent and Trademark Office's Patent and Full-Text and Image Database, returned a listing of almost 4,000 granted patents and more than 2,500 pending patent applications which referenced the term 'outer space.'[14] In addition to new technologies and concepts that can be protected through patents, integration of components and subsystems (previously developed under military or civilian space program contracts) into new systems and vehicles can also be covered by intellectual property right instruments. Examples of concepts and technologies for which patents have been requested by new entrant commercial space companies include novel landing techniques (SpaceX, Blue Origin) and vehicle designs (Scaled Composites). However due to the inherently international character of the space industry, and jurisdictional issues posed by the outer space domain, the international patent system is not optimized for the protection of IP in the space industry.[15]

Mechanisms have been established to allow the established space program (represented by NASA) and the emerging commercial space firms to share technical information and support for technology development purposes. NASA has established a number of SAAs with firms in the orbital CST market. While these SAAs are primarily a means for NASA to advance the development of capabilities it requires, they also include provisions to facilitate the exchange of technical information and services between NASA and the individual firm party to each agreement. Such agreements serve to lower the significance of proprietary technology as a market entry barrier.

Due to importance of technology in this domain, balanced by the access to information and mature systems developed in the established aerospace industry, both the orbital and suborbital CST industries bear a medium resemblance to an emerging industry in this characteristic.

Section 3.2 Access to Distribution Channels

Early mobility barriers of emerging industries include a lack of access to needed or desired distribution channels through which the supply or good can be delivered to the customers. In the case of the CST industry established distribution channels used by the established space launch industry and the established commercial travel industry are available. In general, strategy regarding use of distribution channels differs more by whether the service being offered is one of crew transport or one of cargo transport, than by if the service is orbital or sub-orbital.

New entrant orbital cargo CST firms have found success in direct access to U.S. government customers through specialized procurement vehicles specifically designed to stimulate new markets: NASA's Commercial Orbital Transportation Services (COTS), Commercial Resupply Services (CRS), and Commercial Crew Development (CCDEV), activities. New entrant CRS firms have also been added to the NASA Launch Services (NLS) II Contract, NASA's indefinite delivery/indefinite quantity (IDIQ) contract for general purpose launch services.[16] New entrants are also successfully moving to increase distribution access to non U.S. government customers. For example SpaceX entered into an agreement with the established firm EADS Astrium to market the Falcon 1 launch vehicle to institutional customers in Europe.[17] CST firms have also seen success in responding to commercial Requests for Proposals (RFPs) for launch services. In the suborbital market CST firms providing cargo transport are both using specialized procurement methods (represented by NASA's Flight Opportunities Program) and directly marketing to potential customers.

For CST firms providing crewed flight opportunities, initial distribution channels are leveraging distribution models from the commercial travel industry. Both XCOR Aerospace and Armadillo Aerospace have signed agreements with second firms to broker and market seats on their suborbital vehicles. XCOR is working with Rocketship Tours, and Armadillo with Space Adventures. In both cases the broker firms act in a manner similar to travel agencies. A third suborbital CST firm, Virgin Galactic, acts as its own ticket broker. XCOR and Virgin have also broadened their distribution channels by partnering with commercial airlines, XCOR with KLM and Virgin with Virgin Atlantic, to allow the airlines' frequent flyers opportunity to purchase suborbital flights.

Although there is some evidence of the use of some existing distribution channels by some of the new entrant firms in the suborbital domain, the orbital new entrant firms are not targeting customers that typically utilize retail distribution channels, favoring instead to deal directly with the customer in methods more akin to a wholesale relationship than that of retail. This mobility barrier does not seem to be predominant in either of the emerging CST industries, so their resemblance to an emerging industry is rated low.

Section 3.3 Access to Raw Materials & Other Inputs of Appropriate Cost and Quality

Access to raw materials and other required inputs at the appropriate levels of quality, quantity and cost is a typical mobility barrier of emerging industries.

At the current status of technology and market development, access to raw materials and other inputs for both orbit and suborbital CST firms has not posed a significant problem. While access to certain propellants (e.g. high concentration H_2O_2) has proved to be problematic in the past due to handling hazards, this issue is not unique to the new entrant firms. The established orbital firms have their supply chains in place. The current pace of development of new vehicles is not taxing the needed supplies of raw material and other inputs at the appropriate cost and qualities required. Firms have not yet encountered above-the-norm difficulties in establishing and operating necessary supply chains.

New entrant firms in the emerging suborbital and orbital commercial space transportation industries do not yet manufacture at quantities that exceed delivery capabilities for all the inputs, both raw materials and prefabricated items. Established orbital firms have preexisting supply channels for all their input requirements. Accordingly, both the orbital and suborbital CST industries bear a low resemblance to an emerging industry in this characteristic, although this situation may change if production rates ramp up significantly.

Additional discussion of raw material and supply chain related factors can be found in sections 4.1 and 4.2 of this paper.

Section 3.4 Cost Advantages Due to Experience

Experience in an industry can provide cost advantages which are typically missing from the firms in an emerging industry. Currently, the new entrant firms in the suborbital CST industry are still at the small-scale vehicle testing phase and have not begun to make any volume of sales. Once this occurs, and once the flight operations experience can be accumulated, it would be expected that efficiencies will be realized through experience and knowledge-gained, resulting in lower costs. However, this has not yet occurred and until it does, this CST industry demonstrates a low resemblance to an emerging industry.

The orbital CST industry is in a similar situation. For example, the new entrant orbital firm Space X has a cost advantage over the established orbital firms through streamlined manufacturing operations (a majority of which are performed in-house, contrasting sharply with similar operations of established orbital firms who were contractually obligated to subcontract many of these same operations due to clauses pertaining to small and disadvantaged businesses included in their government contracts). These efficiencies have enabled the firm to price its launch services below those of the established firms, however it remains to be seen if the firm can sustain its current efficiencies over the long-run.

Until the volume of sales increases to a point where cost advantages can be demonstrated between competing firms, these industries bear little resemblance to emerging industries with regard to this mobility barrier.

Section 3.5 Risk (Raises Effective Capital Barriers)

Risk is a key early mobility barrier. Uncertainty about emerging industries and the risks involved in pursuing them can make it more difficult for companies to raise capital to fund perceived opportunities. This is true for both existing companies interested in moving into an emerging market as well as for new companies.

In the suborbital CST market, both technical and market risk are major factors of mobility barriers. The need to develop new vehicles, as well as uncertainty about the size and sustainability of the market, has deterred existing aerospace companies from pursuing this market. As a result, the field is populated primarily by new entrants. However, even for these companies, raising development capital has been a challenge, and some ventures have folded or gone into hiatus because of the difficulty in convincing investors that the risks are worth the required capital. As a result, companies in the suborbital CST arena that have made the most progress are those either with access to large internal sources of funding and/or have relatively low capital requirements, lowering those mobility barriers. This strongly suggests that the strength of resemblance of this characteristic to an emerging industry is high.

Risk is also a major issue in the orbital CST market, where the technical and market uncertainties are even greater than for the suborbital field. While there is more interest from some existing companies in the orbital CST market, notably by Boeing and United Launch Alliance, other incumbent firms in the field have shown less interest in emerging cargo and crew transportation opportunities. One factor that reduces some of the risk is the willingness by the government, through NASA, to invest in the development of cargo and crew transportation capabilities, lowering the overall capital barriers and encouraging existing companies to participate. Given the participation by existing firms in this emerging industry and the role of the government to reduce capital costs and thus business risks, the strength of resemblance of this characteristic to an emerging industry is estimated to be medium.

Section 3.6 Summary of Section Results

Table 4 provides a summary of results, showing the degree of resemblance as described and determined in the sections above, between a typical emerging industry and the orbital and suborbital CST industries.

The orbital CST industry demonstrates a low resemblance to the structural characteristics of a typical emerging industry in all but the categories of “proprietary technology” and “risk”. In these two categories this industry bears a medium resemblance to an emerging industry. The average of these scores indicates that the orbital CST industry has structural characteristics that bear a low to medium-low resemblance to a typical emerging industry.

On the other hand, evaluation of the suborbital CST industry’s resemblance to a typical emerging industry is low in three categories, medium in one (“proprietary technology”), and high in one (“risk”). Collectively the early mobility barriers facing the suborbital CST industry are best assessed as medium to medium-low in similarity to those of a typical emerging industry.

EARLY MOBILITY BARRIERS	Orbital CST	Suborbital CST
Proprietary Technology	Med	Med
Access to Distribution Channels	Low	Low
Access to Raw Mat'ls & Other Inputs of Approp. Cost and Quality	Low	Low
Cost Advantages Due to Experience	Low	Low
Risk (Raises Effective Capital Barriers)	Med	High
OVERALL RESEMBLANCE	**LOW-MED**	**MED-LOW**

Table 4. Summary Results of Early Mobility Barriers

SECTION 4. REVIEW OF INDUSTRY DEVELOPMENT CONSTRAINTS

This section will take a broader perspective, looking at the problems constraining the development of an emerging industry (as identified in Table 1 above) and the resemblance with the current orbital and suborbital CST industries. As in previous sections, evidence is provided that reinforces this resemblance using real-world events when possible.

Section 4.1 Inability to Obtain Raw Materials, Components

The ability of the industry's supply chain (the 'suppliers') to provide the necessary material to meet the production needs of the emerging industry is achieved either through expansion of existing output (i.e. that output which served similar established industry) or through the creation of new materials and/or supply lines.

Firms in the CST industry can either be classified as relatively new entrants (e.g. SpaceX, Blue Origin, Armadillo Aerospace) or as established firms entering a new-to-the-firm market segment (e.g. Boeing and Orbital Sciences). In either case, the technology being developed by this group of firms to provide CST services largely represents adaptation and/or improvement upon existing technology rather than radical change representing large-scale use of new components or materials. Thus firms in the CST market are largely able to rely upon the existing supply chains and material sources that serve an established space transportation industry for which raw material distribution channels are well established. For example, suppliers for Blue Origin's developmental commercial crew space transportation vehicle includes established companies such as Aerojet, Lockheed Martin, and United Launch Alliance.[18] These companies will draw upon existing distribution networks to supply the new entrant companies. Even in the sub-orbital reusable launch vehicle market where systems represent a more novel technical approach, materials required and supply chains used draw upon the existing aerospace industry and have not been a barrier.

Given the use of existing supply chains, and similar material requirements to the established industry, the CST industry's resemblance to an emerging market is low for this factor, for both orbital and sub-orbital systems.

Section 4.2 Rapid Rise of Raw Material Prices

Rapid rise of raw material prices refers to the tendency of key raw materials prices to dramatically increase in costs during the early phases of the development of an industry segment. This price increase is dictated by suppliers in response to conditions of supply and demand.

To date, the effect of this factor in the CST industry has been low. As discussed in the prior section from a materials standpoint, many CST systems have similar requirements to the established systems. This means the materials are available in an established market context that is less susceptible to large swings in price. In many cases suppliers have a vested interest in the success of the new entrant firms (see e.g. the example supplier relationship documented in Section 4.1.). Additionally the demand for CST services remains relatively small, meaning that the level of demand CST firms place on raw materials suppliers consequently remains relatively small.

However, vulnerabilities in the existing supply chain related to dependability on the established market may pose material price risk to new entrants. For example U.S. policymakers have expressed concern over the long-term viability of the U.S solid rocket motor (SRM) industry in the wake of the retirement of the Space Shuttle Program. A reduction in the scope and scale of the SRM industry, resulting in a price increase for those components, would affect the price CST firms pay for launch services on vehicles that rely on that technology, such as certain variants of the EELV family of launch vehicles. However, this risk is not unique to new entrant CST firms; it also affects established space transportation industry actors which rely upon SRM systems.[19]

Nonetheless, because of overall similarity to established markets in terms of materials required,

the CST industry's resemblance to an emerging market is low for this factor, for both orbital and sub-orbital systems.

Section 4.3 Absence of Infrastructure

In general, the CST industry requires the same type of infrastructure (e.g. launch pads, fuel storage facilities, vehicle integration facilities, command and control centers, etc.) as the established space transportation industry. In the United States, much of this infrastructure exists as a result of government development and operations, and is becoming available for commercial sector use.

Orbital CST firms are already making use of some of the extant infrastructure (e.g. government-provided launch range services, SpaceX's use of launch facilities at Cape Canaveral Air Force Station, Orbital Sciences' use of NASA's Wallops Flight Facility) and are complementing it with construction of their own facilities (e.g. SpaceX at Vandenberg Air Force Base or Orbital at Wallops). Existing infrastructure is not optimized for use by suborbital CST providers, yet on the other hand this set of vehicles is more flexible (small launch pads, quick refuel cycles, runway operations) than vertically launched orbital systems. A number of spaceports have been developed in recent years focused on suborbital vehicles (e.g. Spaceport America, Mojave Air and Space Port).

Access to infrastructure is likely to expand in coming years. As NASA winds down the operations of the Space Shuttle Program it is actively seeking to expand commercial-sector use of its facilities. In addition to government operated facilities, as of the end of 2010, the FAA has licensed eight commercial spaceports in the United States.[20] In the near-term, supply of spaceports may outstrip the demand.

Even in cases where firms are constructing their own infrastructure to complement the existing facilities, evidence suggests that the absence of infrastructure is only a low or medium impediment to the development of the industry. The long lead times, and built in schedule margin, in the development plans for many CST systems means that infrastructure shortcomings can be overcome without affecting business outcomes. For example, in July 2011 Orbital Sciences Corporation announced a two month delay to the launch schedule for the first flight of its Taurus II launch vehicle due to construction delays in its new rocket propellant facilities. However the company had built in financial reserves for delays of this type into its program planning, so that this schedule is not expected to impact the financial success of the program.[21]

For orbital systems, where surplus infrastructure exists and where long technology development lead times provide some buffer, the CST industry's resemblance to an emerging market is low for this factor. For suborbital systems, where less infrastructure exists, the resemblance is medium.

Section 4.4 Absence of Product or Technological Standards

Standards affect the development of an industry through a relationship to raw materials needs and cost efficiencies. The degree to which standards are present in the CST industry varies based on application.

For orbital CST systems a range of standards or similar norms of practice exists based on a history of best practices resulting from the established space transportation industry. Standards for launch range interfaces and procedures are well-established and documented. Standards exist for interfaces with NASA payloads and facilities, as represented in the agency's policy documents and procedural requirements. The FAA has made available, through its licensing function, a variety of guidelines related to space transportation reliability, safety, and environmental impacts.

However, standards are less defined in crewed space transportation. The only material similar to standards which exist in the U.S for crewed vehicles are NASA's human rating requirements. Industry actors fear that these requirements will be imposed upon prospective crewed CST systems, and suggest that NASA, the FAA and industry should work together to develop appropriate standards for crewed CST systems.[22]

For suborbital vehicles no standards currently exist. However the community of firms is small, and communication between them is relatively simple.

In a related area, no standards exist to facilitate seamless interfaces between commercial spaceport operators, CST providers and government launch ranges. An effort is currently underway within the FAA's Center of Excellence for Commercial Space Transportation to take the initial steps towards the development of a framework for these standards.[23]

Given the varying degree to which standards are in existence, the CST industry's resemblance to an emerging market is medium for this factor, for both orbital and sub-orbital systems.

Section 4.5 Perceived Likelihood of Obsolescence

An emerging industry's growth will be impeded if buyers believe that next generation technologies will significantly make obsolete current generation products and services, according to Porter.

The perceived likelihood of obsolescence will have limited to no constraint on the CST industry. Unlike highly competitive industries with quick technology development cycles such as consumer electronics, slow development cycles are often seen as a virtue in the CST industry. Building an orbital CST system with minimal new technologies helps developers minimize the large risks involved with successfully creating and operating a new CST system. However, in the coming years there may be a possibility for innovation in the orbital CST industry given the U.S. governments approach to fostering multiple new CST systems, therefore helping to generate competition. This competitive dynamic may motivate some providers to push advances in manufacturing, technologies, and processes in order to outperform rivals. The dynamic may also motivate buyers to avoid long-term contracts with the legacy providers in order to have the flexibility to purchase from the next generation of systems. But orbital buyers do not have the flexibility to wait until the next generation given immediate requirements to support space station operations.

In the suborbital marketplace, innovation is more common but a perceived likelihood of obsolescence has not been an issue as currently understood. This likely stems from the fact that first generation systems have not yet been completed and there is limited discussion of second generation systems. It is also speculated that next generation suborbital systems may look to expand the service offering to include capabilities such as point to point travel. At this point in development perceived obsolescence in the suborbital field is not yet a concern.

Resemblance to an emergent market is low for this characteristic in both the orbital and suborbital CST industries

Section 4.6 Customers' Confusion

An emerging industry may suffer reduced growth if customers are confused by the presence of a multiplicity of product approaches, technological variations, and conflicting claims and counterclaims by competitors according to Porter.

Customer confusion is a limited constraint for the orbital CST industry. While it is true that competitors in the industry often make conflicting claims and counterclaims, the near-term markets buyers, who tend to include brokers or national governments, tend to have experts on staff with a sophisticated knowledge of the various CST system capabilities. These experts may still be challenged to analyze the actual versus perceived risks of new CST systems which do not have historical performance data sets to draw upon. And these experts may have differing views of the risks associated with various CST systems. However, these issues can be solved through risk management and should not lead to reduced industry wide sales given the need to satisfy current buyer launch schedules.

For the suborbital CST industry, customer confusion may be more of a concern. Differentiation in flight experiences and safety technologies and processes may be annoying to spaceflight participants. However, it is likely that participants are motivated primarily by the desire to experience space and will not choose to avoid purchasing a suborbital flight into space because of confusion. Furthermore, if confusion exists, than an opportunity for brokers or spaceflight agents will emerge who can explain the differences in experiences.

Customer confusion in the orbital CST industry is determined to be low because the emerging and established launch vehicles have very similar characteristics. This is very dissimilar from, and therefore possesses a low degree of similarity to, an established market. For the suborbital CST industry the products and services are more novel in nature, potential for customer confusion is higher, and the resemblance to an emerging market can be characterized as medium.

Section 4.7 Erratic Product Quality

In emerging industries, with many newly established firms, lack of standards, and technological uncertainty, product quality is often erratic.

For the orbital and suborbital CST industry, erratic product quality is a concern given the relatively large number of new CST systems in development, under relatively tight budget constraints, that will eventually compete for a limited market. However, the anchor buyer in the orbital CST industry is NASA which has 50 years of human spaceflight experience to draw upon to help ensure that is purchases safe transportation systems. Furthermore, aerospace engineering is a relatively mature discipline with understood development best practices that include rigorous testing and quality standards.

Space transportation is a very challenging endeavor that demands high quality systems that are vigilantly monitored and improved, all of which is very

expensive. As providers increasingly compete on cost and schedule rather than just quality, there could be a relaxation in standards. Such relaxation in standards has historical precedence having contributed to the loss of the Space Shuttles *Challenger* and *Columbia* and has likely contributed to other failures. For a commercial industry, a product failure could lead to an organization's bankruptcy. For the orbital and suborbital CST industries, a failure due to a blatant quality problem will likely impact the industry as a whole and may cause customers, such as national governments, to seek to develop and operate their own space transportation systems, or private citizens to avoid travel into space. Therefore, all CST industry participants have an interest in ensuring high safety standards. Erratic product quality is not yet creating a constraint on the CST industry but could be a significant factor if competing providers relax quality standards. Accordingly, the resemblance to an emerging market for both orbital and suborbital CST industries is estimated to be medium.

Section 4.8 Image and Credibility with Financial Community

As a result of newness and the high levels of uncertainty, customer confusion and erratic quality, an emerging industry's image and credibility with the financial community may be poor. This can affect not only a firm's ability to secure competitive financing but also of buyers to obtain credit according to Porter. This factor is having a constraining impact on the orbital and suborbital CST industries. To date, firms competing in the CST industry rely primarily on self-funding or government development and service contracts.

The retirement of NASA's Space Shuttle fleet in July 2011, and NASA's policy decision to purchase commercial space transportation services from private providers to support the ISS, is the primary opportunity for orbital CST providers. The orbital CST market depends primarily on the opportunity to supply services to NASA and secondarily to provide services to other national governments and private buyers. The limited market and large risks associated with developing an orbital CST system have resulted in the industry having to primarily depend on self-funding and government subsidies while depending secondarily on outside investment, resulting effectively as an industry constraint. As the industry matures it will likely be easier for providers to attract investment. Resemblance of the orbital CST to this constraining factor is estimated to be medium.

The suborbital CST industry has attracted outside niche investors through competitions such as the Ansari XPRIZE in 2004. More recently, Virgin Galactic attracted a $280 million investment by private Abu Dhabi-based investor Aabar, representing a roughly 32% stake in 2009. [24] However, the suborbital CST industry still depends primarily on self-funding or government funding and secondarily on the financial community. Due to the continuing reliance on government support, coupled with some success in private funding, resemblance to an emerging industry can be classified as medium.

Section 4.9 Regulatory Approval

The regulatory environment associated with an emerging industry can either greatly impede or accelerate its development. As Porter notes, "Emerging industries often face delays and red tape in gaining recognition and approval by regulatory agencies if they offer new approaches to needs currently served by other means and subject to regulation." This was the case at the beginning of the commercial space transportation industry in the U.S. in the early 1980s, when regulatory uncertainty caused early entrants to seek approvals from multiple agencies in order to carry out launches. This led to the formation of the Office of Commercial Space Transportation, now part of the FAA, in order to streamline this activity.

Regulatory issues remain in the emerging suborbital and orbital CST industries. Prior to the passage of the Commercial Space Launch Amendments Act (CSLAA) of 2004, there was uncertainty in the suborbital industry regarding whether they would be regulated as launch vehicles or as aircraft; the latter would have required a much greater degree of regulation and safety oversight that could have stunted the development of the industry. While the CSLAA did resolve that uncertainty, suborbital CST providers must still comply with an evolving regulatory environment. In late 2012 a provision in the CSLAA that limits the FAA's ability to impose regulations involving the safety of spaceflight participants will lapse. Such additional regulations could impose increased burdens on companies, slowing its growth.

Orbital CST has a relatively mature regulatory structure through the longstanding system of launch licensing, but the development of cargo and crew transportation systems imposes new, and often uncertain, regulatory burdens on companies. Vehicles visiting the International Space Station must comply with guidelines to ensure that such vehicles safety approach and dock with the station. Crewed commercial vehicles carrying NASA astronauts will also have to comply with NASA human-rating

requirements, some of which are still under development. Regulation of on-orbit activities remains a gray area, with no single agency responsible for regulating safety and other elements of crew or cargo spacecraft in Earth orbit.

The emerging, and often, uncertain regulatory environment for both suborbital and orbital CST, as illustrated above, suggests that the strength of resemblance of this characteristic with an emerging industry is high in both cases.

Section 4.10 High Costs

Because of various structural issues, emerging industries can be faced with high initial costs, which go down over time as volume ramps up, as described in Section 2.3. As Porter notes, this can force companies to price their products below cost or slow their development.

Suborbital CST providers do suggest that their costs, while high, will go down over time. Virgin Galactic has indicated that while their initial price for a seat on their suborbital vehicle will be initially $200,000, they intend to bring it down to $50,000 or less over time. Because the cost structures of these companies are proprietary, it is not possible for an outside observer to determine if those prices are below their initial costs. However, their costs are high enough, relative to available capital, to slow their development, as illustrated by the shifting timelines of a number of suborbital vehicle providers.

Orbital CST providers also face high costs as they develop and introduce their services. Because this field is only now emerging, particularly in the areas of cargo and crew transportation to low Earth orbit, the exact costs for these services are still being determined; a lack of transparency in the cost structures of these entrants also makes a detailed analysis difficult. Anecdotal evidence suggests, though, that providers expect their costs to go down over time if they are able to successfully enter the market.

In both the suborbital and orbital CST industries, therefore, the strength of resemblance of this characteristic with an emerging industry is high.

Section 4.11 Response of Threatened Entities

A key constraint in the development of an emerging industry is the response from existing entities who may be threatened by the new industry, including but not necessarily limited to companies offering substitute products. These entities can respond to the perceived threat of the emerging industry in a number of ways, from lowering their own prices in order to remain competitive to taking political or regulatory action to hinder the emerging industry's development.

There has been relatively limited reaction from any threatened entities to the suborbital CST industry. In many cases the service that suborbital CST providers offer is sufficiently different from substitute offerings—parabolic aircraft, drop towers, sounding rockets, orbital spaceflight—in quality and/or cost that these substitutes do not perceive a threat from suborbital CST companies. This may be in part because suborbital CST providers are targeting new markets not served by substitute products, like space tourism, or are not well served by these substitutes, such as some research applications. As the capabilities of suborbital CST providers grow and/or their costs decrease, they may become more of a threat to existing industries. This suggests that the strength of resemblance of this characteristic to an emerging industry is medium, at best.

There has been a stronger reaction to the development of the orbital CST industry, in particular plans by NASA to rely more on such providers for cargo and crew transportation to the ISS. Some of the strongest reaction has come from members of Congress who have NASA facilities or companies in their districts or states that could be adversely affected by a shift from government-owned and -operated orbital crewed spacecraft to commercial crewed systems. They have argued, for example, that orbital CST providers lack the experience to safely carry out such missions compared to existing providers and are behind on their schedules for cargo missions. This and similar evidence indicates that the strength of resemblance of this characteristic to an emerging industry is high.

Section 4.12 Summary of Section Results

Table 5 provides a summary of results, showing the degree of resemblance as described and determined in the sections above, between a typical emerging industry and the orbital and suborbital CST industries.

In both the orbital and suborbital CST industries a range of similarities to an emerging industry is found across the set of characteristics that represent potential industry development constraints. Overall both industry segments are best characterized as showing medium resemblance to an emerging market.

INDUSTRY DEVELOPMENT CONSTRAINTS	Orbital CST	Suborbital CST
Inability to Obtain Raw Materials, Components	Low	Low
Rapid Rise of Raw Material Prices	Low	Low
Absence of Infrastructure	Low	Med
Absence of Product or Technological Standards	Med	Med
Perceived Likelihood of Obsolescence	Low	Low
Customers' Confusion	Low	Med
Erratic Product Quality	Med	Med
Image and Credibility with Financial Community	Med	Med
Regulatory Approval	High	High
High Costs	High	High
Response of Threatened Entities	High	Med
OVERALL RESEMBLANCE	**MED**	**MED**

Table 5. Summary Results of Industry Development Constraints

SECTION 5. CONCLUSIONS AND POTENTIAL FUTURE ANALYSIS

Tables 3 through 5 above show each emerging market characteristic and the level of resemblance this analysis has assigned for the CST industry.

Based on these results, the orbital CST industry demonstrates:

- A medium-high resemblance to the structural characteristics of an emerging industry.
- A low-medium resemblance to the early mobility barriers of an emerging industry.
- A medium resemblance to the industry development constraints of an emerging industry.
- A medium resemblance to an emerging industry overall.

Also, the suborbital CST industry demonstrates:

- A high resemblance to the structural characteristics of an emerging industry.
- A medium-low resemblance to the early mobility barriers of an emerging industry.
- A medium resemblance to the industry development constraints of an emerging industry.
- A medium resemblance to an emerging industry overall.

The initial thesis of this analysis, that the orbital and/or suborbital commercial space transportation industries can be considered to be "emerging," is not fully supported by results of the subsequent analysis. It is estimated that the orbital CST industry bears a medium resemblance to an emerging industry. The suborbital CST industry bears a slightly higher, but not high resemblance to an emerging industry. Although these industries are not considered to be fully "emerging," they are still in a promising position to one day become the growth industries that commercial space proponents hope they will become.

A message this analysis may convey is, while there may still be well-founded optimism regarding these industries' futures, the growth phase for commercial space transportation industries may be farther away than one might hope. Because of the optimistic outlook, governments should continue to encourage and support these industries to become lucrative and mature.

As with similar market analyses conducted on the emergent commercial space transportation industries, this paper is only a starting point for more study and improved research. Areas of potential future work could include an investigation of the orbital and suborbital CST industries in other individual countries, in multi-country economic zones, or on a global scale.

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