

**ACCUMULATION MODEL PROCESSES OF
HUMAN SUBORBITAL SPACE TRANSPORTATION
INDUSTRY EMERGENCE**

**Thesis Presented for the Degree of
DOCTOR OF PHILOSOPHY IN BUSINESS ADMINISTRATION
In the Graduate School of Business
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by

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1 June 2018

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LIST OF ABBREVIATIONS

| Abbreviation | |
|---------------------|---|
| AIAA | American Institute of Aeronautics and Astronautics |
| AST | Office of Commercial Space Transportation |
| ASTM | American Society for Testing and Materials |
| COE CST | Center of Excellence for Commercial Space Transportation |
| CSF | Commercial Spaceflight Federation |
| DARPA | Defense Advanced Research Projects Agency |
| DIA | Disruptive Innovation Analysis |
| DoD | Department of Defense |
| FAA | Federal Aviation Administration |
| FOP | Flight Opportunities Program |
| HEA | Historic Event Analysis |
| HPV | Human Papilloma Virus |
| HSP | Human Spaceflight Participant |
| HSSTI | Human Suborbital Space Transportation Industry |
| IAASS | International Association for the Advancement of Space Safety |
| IAC | International Astronautical Congress |
| IBM | International Business Machines |
| IIE | Industry Infrastructure Elements |
| IPIC | International Petroleum Investment Company |
| ISA | Industry Structural Analysis |
| ISDC | International Space Development Conference |
| ITAR | International Trade in Arms Regulations |
| km | kilometers |
| MIRP | Minnesota Innovation Research Program |
| NASA | National Aeronautics and Space Administration |
| R&D | Research and Development |
| SAA | Space Act Agreement |
| SBIR | Small Business Innovation Research |
| U.S. | United States |
| USD | U.S. Dollar |

DEDICATION

For Mom and Dad.

ACKNOWLEDGEMENTS

My wife is great.

ACCUMULATION MODEL PROCESSES OF HUMAN SUBORBITAL SPACE TRANSPORTATION INDUSTRY EMERGENCE

Kenneth John Davidian

ABSTRACT

To respond to the research question, “by what processes do new industries emerge?”, the author identified different models of innovation development and industry emergence. Relevant streams of literature included economics, innovation, sociology, economic sociology, and institution theory. A functional goal innovation development theory, referred to as the accumulation model, states that many organizations, from both the public- and private-sectors, collect and accumulate resources in three major social functions. Previous research defined the model state-of-the-art at a high level of abstraction, identifying the three main components (industry infrastructure elements), depicted as separate boxes with arrows between them. This research uses grounded theory extension to identify microscopic processes, delving within and between the three macroscopic infrastructure elements.

The industry context of this research was the emerging human suborbital space transportation (“space tourism”) industry. Data came from secondary sources, archival data, and primary sources. This research collected more than 8,400 pieces of secondary and archival data from news aggregator web sites, distilled them into approximately 600 significant events, and categorized them within the accumulation model framework’s three main components: Institutional Arrangements, Resource Endowments, and Proprietary Functions. Industry structure and disruptive innovation studies provided additional analytical perspectives. Primary data, collected via 40 interviews of industry members, filled in and validated data gaps. The combined analyses resulted in a deeper understanding of the industry emergence process. Observations of the sequence of events, and of linkages between events and actors, allowed the author to propose a set of processes, describing how the accumulated industry resources resulted in industry emergence. Description of these processes required modifications to the original framework. Furthermore, this research analyzed a high-profile prize event that initiated the industry emergence, to propose a supplemental set of processes, describing how prizes influence industry emergence.

The current research proposes that institutional activities contribute primarily to the accumulation of sociopolitical legitimacy, and resource endowment activities contribute primarily to cognitive legitimacy. Both forms of legitimacy are a significant moderator of interactions between the three infrastructure elements. Furthermore, prizes positively contribute to sociopolitical legitimacy, positively moderate the creation of cognitive legitimacy, and positively moderate many steps in the business development cycle. The proposed processes identify the steps of legitimacy creation and industry emergence. This research provides new insights into the industry emergence and evolution processes, for entrepreneurs, managers, policy-makers, and for developing countries on the African continent.

1. INTRODUCTION

For many years, some private citizens have dreamt of space tourism, the ability of buying a ride to space for personal reasons. Depictions of space tourism appeared in literature in the early twentieth century (Launius, 2016). In 2001 and 2002, these dreams became reality when an American and a South African (Dennis Tito and Mark Shuttleworth, respectively) each paid an estimated amount of 20 million the United States (U.S.) dollars (USD) to buy a round-trip ticket to and from the International Space Station (Rankin, 2003), despite objections on the part of the U.S. National Aeronautics and Space Administration (NASA). Tito's experience proved that space tourism was possible, and Shuttleworth's proved that demand for personal spaceflight was greater than just one person. These events impacted the legitimization effect on all types of space tourism, beyond the orbital space tourism market:

*“About the same time, tourism as a whole became validated in a different way by Dennis Tito plunking down money and being persistent enough to tough his way through NASA and get a ride to the space-station. The whole perception of tourism as a plausible market completely changed in 2001 with those two events, and the previous conventional wisdom about what the market for new reusable spaceplanes was, had evaporated.” –
Commercial Space Industry Executive*

To date, seven private individuals paid for eight personal trips to the International Space Station in low Earth orbit. For a ticket price that is 100 times less than what these orbital tourists paid, forecasts predict that thousands of individuals would buy a short flight aboard a suborbital vehicle, one that goes into space (greater than 100 kilometers high)

but doesn't go into orbit (Futron Corporation, 2002; Tauri Group, 2012). The industrial capability to fly humans to orbit for governmental purposes has existed in the former Soviet Union since 1961, and in the U.S. since 1963. Vehicles capable of flying humans into space on a suborbital trajectory do not exist today, even for military or civilian governmental purposes. Consequently, there is significant activity in the private-sector to create a suborbital space tourism industry where one never existed before. In addition to suborbital tourism, scientists and their experiments can also benefit from these same vehicles. This research refers to the combination of both tourism and scientific market groups by a broader category name, the human suborbital space transportation industry (HSSTI).

New industries don't emerge frequently. Research shows, however, an increasing rate of new industry creation over time. This is welcome news to governments that pursue wealth and employment for their citizenry. New industries represent opportunity for growth and prosperity at the national, state, local, and individual levels. By understanding the processes by which new industries emerge, it may be possible for government and public leaders to concertedly and constructively accelerate one, some, or all of these processes, with the goal of creating a new industry. This research pursues an understanding of these industry emergence processes.

1.1 PHENOMENON

New industries come into being, seemingly out of nowhere (despite the fact that the underlying knowledge may have been in existence for many decades) before emergence. (Mensch, 1979). This research discusses the sources of industry emergence once it has begun by asking the fundamental question "how do new industries emerge?" Corollary

questions include “why do industries emerge so slowly?”, and “how can industry emergence be accelerated?”.

1.2 THEORY

The academic streams of literature relevant to this research include economics and innovation, innovation meta-theory, sociology and economic sociology, and institution theory. Each of these streams contributes in a distinct way to the research. Economic theorists originally formulated the concept of innovation as an engine of market dynamism (Schumpeter, 1939, 1947, 1983), and they later identified different types of innovation to explain observed changes in the economy, including growth, disruption, and the creation of new markets (Abernathy & Utterback, 1978; Christensen, 1997; Mensch, 1979; Utterback, 1994), also referred to as industry “emergence.” Sociology identifies the major functions of society (Parsons, 2005), and some models of innovation development use these functions as their structural foundation. Economic sociologists and evolutionary economists (Fligstein, 1996; Nelson & Winter, 1982; Parsons & Smelser, 1956) expand this framework, and emphasize the vital role of government in industry emergence (Capron, 1971). Finally, institutional theorists (Aldrich & Fiol, 1994; Deephouse & Suchman, 2008; Tost, 2011) develop and expand important concepts that are vital to industry emergence, legitimation and legitimacy.

There are many definitions of industry emergence. Gustafsson, et al. (2016) used the term to distinguish different industry emergence processes (including industry transitions, renewals, creation of niches, or actual emergence) and approaches (technologies, activity networks, markets, or industry identity). For the context of this research, the technology and identity of the new, unexploited industry were fairly well defined. Furthermore, some

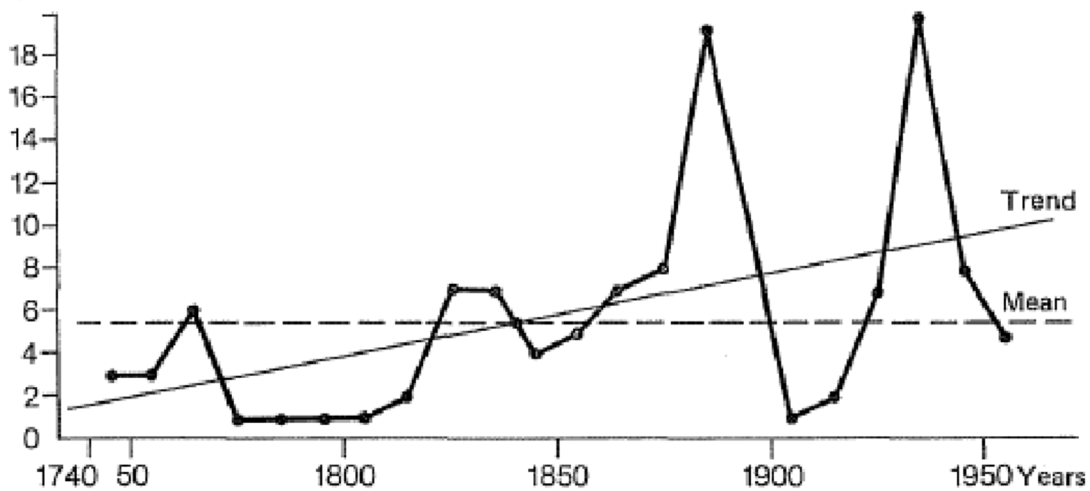
of the actors already existed, but not with a focus on the new industry segment. A lack of incumbent firms already providing commercial services within the industry segment distinguishes the HSSTI as a new industry. This is consistent with the definition of a new industry used by this research. Another perspective on the definition of new markets is one which is not “inherently cannibalistic” (Christensen, 1997), meaning the growth of the new industry does not “eat” into the market share of any existing industry. Industries that experience “sustaining” or “low end” disruptive innovations (Christensen & Raynor, 2003) by incumbents or new entrants are necessarily previously populated with incumbent firms that may or may not launch a competitive attack in response. The existence of incumbent firms prior to the disruption also infers the prior existence of the industry itself, and vice versa. Therefore, as stated above, it seems reasonable to define a new, or emerging, industry as one in which there are no incumbent firms. That is not to say that only de novo firms found new industries. It is possible that non-incumbent, de aleo firms diversify into the new industry, or are parents to the firm entering the new industry. Very generally speaking, however, all new industries are based on a special type or set of innovations. Innovations can be defined in many ways, including “the commercial or industrial application of something new – a new product, process, or method of production; new market or source of supply; a new form of commercial, business, or financial organization” (Schumpeter, 1983, loc. 230), or “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003, loc. 667). Speaking more specifically, however, not all innovations result in industries. Mensch (1979) characterized new industries as being based on “basic innovations” which “open new realms of activity in the cultural sphere, [... and] create a new type of human

activity” (p. 36), and “establish new branches of industry and create new markets” (p. 10). The characterization by Anderson and Tushman (1990) of an industry-creating innovation as “competence-destroying technological discontinuities” may or may not lead to an industry that meets the definition of “new” in this research, depending on whether incumbent firms adopt the innovation. Perhaps the best description of this special type of innovation is Christensen’s (1997) “new market disruptive innovation,” because the new entrants are pursuing an entirely novel performance metric. Given this definition of a new industry, a next logical question to answer might be “how often do new industries emerge?”

When searching historical data for evidence of basic innovations, popular texts list many dozens of innovations throughout history (Johnson, 2010), and academic literature provide long lists of “basic” innovations (Mensch, 1979; National Science Foundation, 1974). Not listed in these reports, however, are those basic innovations that did not lead to successful industry emergence (Milo, 2009). It may be that there are many more basic innovations if we included those industries that never successfully emerged. Therefore, empirical studies that count the number of basic innovations over time, may actually be basing the results only upon the number of successful new industries. Furthermore, the number of reported basic innovations includes both the emergence of new industries and the evolution of existing industries. Mensch (1979) presents the data for the number of basic innovations (which we infer to mean the number of successful industry emergences and evolutions) in Western economies between the years of 1740 and 1960, as shown in Figure 1 below. Anderson and Tushman (1990, p. 610) investigated four industries and tabulated nine “competence-destroying” innovations, emphasizing the point that not all

innovations lead to new industries. Therefore, historic data of successful industry emergence may suffer from left truncation bias, presenting us with the occurrence of successful basic innovations (those that resulted in successful new industries), and not the actual number of basic innovations. Also from 1740 to 1960, industry emergence is shown to be cyclic with approximately six basic innovations per decade, and with an increasing trend line over time (Mensch, 1979, p. 130). In other words, the rate of new industry creation or evolution was increasing over the period of study. A second study found the average number of basic innovations per decade, from 1953 to 1973, to be 3.5, approximately equal to the average number stated above (National Science Foundation, 1974). Variation in the definition of basic innovations from one research organization to another may cause the estimated number of basic innovations of other studies to differ from these results. Therefore, the data shows that new industries emerge or evolve successfully on a fairly frequent basis, averaging one new industry every 18 months to three years.

Figure 1. Frequency of basic innovations in Western economies, 1740 to 1960



Source: (Mensch, 1979, p. 130)

This research does not focus, however, on the reasons for, or frequency of, new industries emergence. This research focuses on the processes that enable successful industry emergence once the basic innovation development process has begun. Furthermore, this research is interested in exploring ways to encourage industry emergence processes. In practice, governments implement macroscopic- and microscopic-level policies to encourage new industry creation. Macroscopic policies are applicable to a broad range of industry segments, and include procurement, regulation, antitrust, patent and other policies affecting property rights on inventions, and general purpose instruments, including tax codes, monetary policy, price supports, and trade agreements (Nelson, 1982). Other macroscopic policies include encouraging increased participation by firms of different sizes, geographic regions, or economic sectors of society, and helping to change public perception, for example. Microscopic policies, targeting specific technologies or industry sectors, include research grants or contracts to specific organizations for significant and novel technology improvements, promoting the commercialization and diffusion of specific technologies and innovations, the creation of new businesses and technological communities, and prize competitions for specific accomplishments.

Reflecting a technology-driven, Schumpeterian perspective (Krafft, Lechevalier, Quatraro, & Storz, 2014), and based on the definition that basic innovations are the foundation of industry emergence (Mensch, 1979), models of new industry development parallel models of innovation development. Innovation development is distinct from the innovation itself, and is defined as “the temporal sequence of events and activities that occur to create and transform basic scientific knowledge into commercially viable

products or services delivered to customers” (Van de Ven, 1993c, p. 214) . Innovation development meta-theory (theory about innovation development theories and models) was the focus of the Minnesota Innovation Research Program (MIRP), initiated in 1983, and was still on-going in 1990 (Poole & Van de Ven, 2000). Results of the MIRP identified three different models of innovation development that vary in their applicability based on the level of development of the institutional context, the degree of innovation novelty, the predetermination of the industry development path, and the “conceptions of control” (Fligstein, 1996) of an industry “end state.” The three classes of innovation meta-theory include theories of historical necessity, functional goal attainment, and emergent processes. For the problems that are the focus of this research, the industry environment contingencies of the evolving HSSTI favor the selection of a functional goal theory of innovation, incorporating Etzioni’s epigenesis model (1963). Functional goal theories are based on an industry’s levels of firm assertiveness, relative strengths of all actors, and the current set of circumstances. The HSSTI currently demonstrates characteristics of both dependent and accumulation roles within the industry, where a center of activity has not been well established, and the relative strength of industry firms in relation to external (typically government) actors is relatively weak. In light of the observation that the HSSTI internal actors have, for the most part, demonstrated responsible (rather than opportunistic) behavior with respect to the external actors, the dependence role is secondary to the resource accumulation role.

One of the basic concepts upon which this research is based is that markets are not merely independent economic systems, but they are a part of larger social systems (Garud & Van de Ven, 1987; Parsons & Smelser, 1956). Literature reviews conducted by

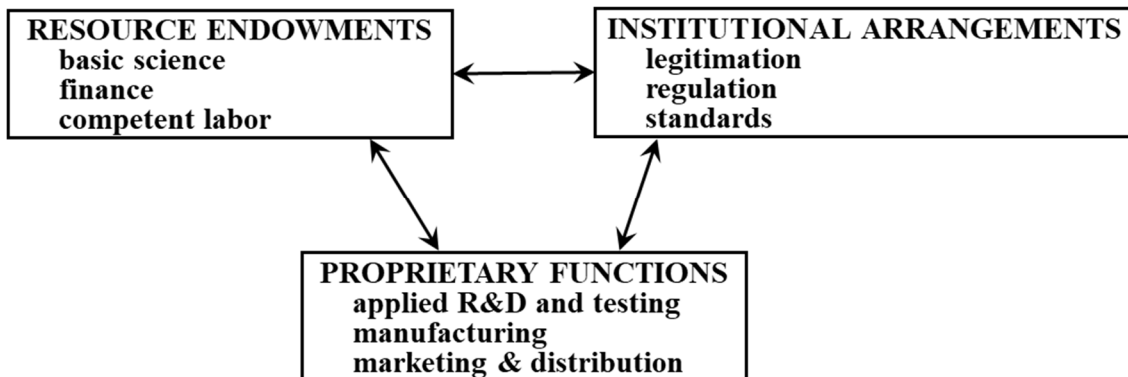
Mowery (1985) and Thirtle and Ruttan (1987) demonstrate that, although a technological innovation focuses on the specific technical (scientific or engineering) details of a new, potential product at the microscopic level, innovations of “social, economic, and political infrastructure” (Garud & Van de Ven, 2000) are also required at the macroscopic level to ensure the product’s commercial success, and long-term viability of the new industry.

The macroscopic foundation of the accumulation model is built upon the societal “system of action” (Parsons, 2005), and the four functional groupings, or “fundamental system problems under which a ... social system operates,” including adaptation, goal-setting, integration, and latent pattern maintenance and tension management (Parsons & Smelser, 1956, p. 18). These concepts are expanded in the field of economic sociology (Fligstein, 1990; Parsons & Smelser, 1956; Swedberg, 2005). The accumulation model adopts three of these system functions, called industry infrastructure elements (IIEs), labelling them Institutional Arrangements, Resource Endowments, and Proprietary Functions (Van de Ven, 1993b), pertaining to the goal-setting, integration, and adaptation sub-functions, respectively. The accumulation model does not include the sub-function of latent pattern maintenance and tension management, corresponding to cultural sub-systems within society, because of its relatively immature state of theoretical modeling. Finally, institution theory literature also fed the development of the proposed process diagrams, adding phenomenological detail to the accumulation model. In these proposed processes, a dominant contributor that positively moderates the interactions between IIEs is the amount and type of legitimacy attributed to the new industry and its firms. Legitimacy research has strong roots in Weber (1978) and others, but multiple typologies were

created and expanded over the past 25 years (Aldrich & Fiol, 1994; Suchman, 1995; Tost, 2011).

The accumulation model suggests that new industry emergence includes the performance of existing functions in new or (perhaps) more specific ways, and the creation of entirely new functions as well. The model attempts to answer questions regarding the order of new function creation, how they are created, and which actors are involved in their creation. The framework used in this study (Garud & Van de Ven, 2000) shows the required functions for industry development in a three-way process diagram (Figure 2).¹

Figure 2. Original accumulation model framework



Source: (Van de Ven & Garud, 1993)

Table 1 gives the complete taxonomy of this framework, listing all the first-, second-, and third-order elements. This is a listing of all the different resources and capabilities

¹ The most recent literature (Van de Ven, 1993a, 1993b, 1993c) adopted the IIE label of “Proprietary Functions.” Early articles (Garud & Van de Ven, 1987, 2000; Van de Ven & Garud, 1989) referred to this function as “Instrumental,” and in later writings (Van de Ven & Garud, 1993), as “Technical Economic Activities.”

required for successful industry emergence according to the accumulation model. This research assesses the status of HSSTI industry emergence by accounting for each of these elements and components.

Table 1. Original accumulation model taxonomy

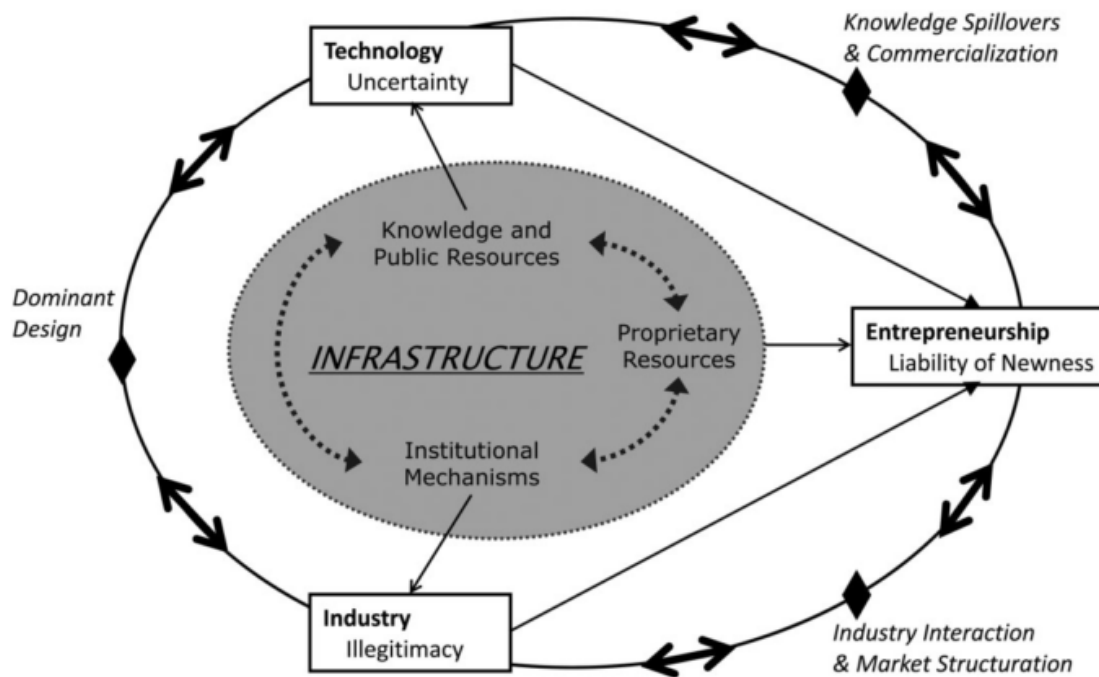
| First-Order IIEs | Second-Order Elements | Third-Order Elements | |
|----------------------------|--|--|--|
| Institutional Arrangements | Legitimation | <ul style="list-style-type: none"> • Guarantees • Licensing Practices | <ul style="list-style-type: none"> • Endorsements • Industry Regulations |
| | Governance | <ul style="list-style-type: none"> • Norms and Rules | <ul style="list-style-type: none"> • Regulations • Laws |
| | Technology Standards | <ul style="list-style-type: none"> • Government Regulatory Mandates • Cooperative/Voluntary Ind. Standards • Market-driven/de facto Standards | |
| Resource Endowments | Scientific and Technological Research | | |
| | Financing and Insurance Arrangements | <ul style="list-style-type: none"> • Public Institutions | <ul style="list-style-type: none"> • Private Org'ns (Venture Capital) |
| | Human Competence Pool | <ul style="list-style-type: none"> • Educational Training Programs | <ul style="list-style-type: none"> • Recruitment and Training • Sharing of Knowledge |
| Proprietary Functions | Technological Development Functions | <ul style="list-style-type: none"> • Applied Research & Development | <ul style="list-style-type: none"> • Manufacturing • Testing |
| | Innovation Network and Resource Channel Activities | <ul style="list-style-type: none"> • Appropriation of Common Goods | <ul style="list-style-type: none"> • Vendor-Supplier-Distributor Channels |
| | Market Creation and Consumer Demand | <ul style="list-style-type: none"> • Marketing • Cultural Norms | <ul style="list-style-type: none"> • Consumer Demand |

Source: (Van de Ven & Garud, 1989)

The IIE framework was initially demonstrated using an historic event analysis (HEA; Miles & Huberman, 1994) of the cochlear implant industry (Garud & Rappa, 1994; Garud & Van de Ven, 2000; Van de Ven & Garud, 1993), and has been applied to contemporary industry contexts seven times since then, prior to this research. Analyses include market studies of over the counter financial derivatives, financial derivative standards, medical test equipment, medical supply storage, floor covering, business

school curricula, and nanotechnology. In the nanotechnology industry study, Woolley (2011b) used the model to extend the firm-level “liabilities of newness” concept (Stinchcombe, 1965) to the (macroscopic) community-level, proposing a “trifecta of burdens” faced by firms trying to build a new industry (Figure 3).

Figure 3. Accumulation model macroscopic extension



Source: (Woolley, 2013, p. 19)

1.3 PROBLEM

New industries emerge and become viable by accumulating resources within all three IIEs. The individual and collective actions of actors from both the public- and private-sectors contribute to resources accumulation. Interactions between IIEs affect the process of resource accumulation to overcome technology uncertainties, industry legitimacy, and the liability of newness (the “trifecta of burdens”). Understanding the processes that constructively mediate or moderate the accumulation of resources within the IIEs, and the

interactions between IIEs, can help promote, assist with, and accelerate, new industry emergence. The current accumulation model requires more detail about the components and processes within and between each IIEs. To date, no prior research of the accumulation model has proposed a better phenomenological understanding of industry emergence processes at the microscopic level.

This research extends our understanding of new industry emergence within the context of the HSSTI by asking the following questions: what are the processes within each IIE based on the emerging HSSTI case?, and what are the implications of common policy options to stimulate and accelerate the emerging HSSTI? This research attempts to answer these questions by proposing microscopic-level process flow diagrams that capture the effects of the accumulation model. By elaborating on the internal workings of the three IIEs, this research enables the understanding of how certain events, whether initiated by industry, government, or natural causes, may affect industry emergence.

1.4 SETTING

The HSSTI, an emerging space industry segment that intends to provide ordinary people with a commercially-available experience of space travel, is the context for this research. The U.S. government conducted supporting research for the HSSTI in the 1950s through the 1970s. More recently, the stimulus for the emergence of this industry was the Ansari X PRIZE competition.

1.4.1 Industry Context

When the X PRIZE Foundation announced the X PRIZE in 1996, many companies around the world signaled their intention to develop commercially-viable vehicles to safely fly ordinary humans to the edge of space and back. New HSSTI firms have

proposed many vehicle designs to date. Some designs look like traditional rockets (with capsules placed atop long cylinders, like the Saturn V or Soyuz launch vehicles) and others look like winged vehicles (similar to airplanes, or the Space Shuttle). Unlike the Saturn V, Soyuz, or Space Shuttle, however, these new vehicles are suborbital. The word “suborbital” describes the vehicle’s path, meaning it does not go fast enough to enter orbit around the Earth. Typically, a suborbital vehicle climbs into the sky under rocket power until the rocket shuts off. The vehicle coasts upward until it slows to a stop (primarily due to gravity), at which time it returns to Earth. This research focuses on vehicles intended to carry ordinary people to a minimum altitude of 100 kilometers (an approximate delineation between “air” and “space”).² These vehicles must return to the surface of the Earth safely, under a parachute (for the capsules), or by flying or gliding back to a runway (for the winged vehicles). From the time the rocket fires until the safe return to Earth, the entire flight typically lasts between 15 and 30 minutes.

Suborbital flights carrying people in rocket-powered vehicles in the U.S. began with the X-2 in 1956 and continued through the mid-1970s with the end of the X-24B

² 100 kilometers (km) altitude is the current definition of space from the Fédération Aéronautique Internationale (Sanz Fernández de Córdoba, 2016). During the X-15 program, the U.S. Air Force used 80 km (or 50 miles) as the delimiting altitude. There is no universally accepted demarcation between air and space.

program.³ Two decades later, in 1996, the idea for a non-governmental industry of human, rocket-powered, suborbital flights was promoted with the announcement of the X PRIZE competition (Uhlenbrock, 1996). The goal of the competition was essentially to develop a prototype HSSTI vehicle that could be commercially viable. The vehicle had to be of sufficient size to carry three people, complete two successful flights within a two week period, and fly to an altitude of at least 100 km (Schwartz, 2004). The ten million USD prize purse was ultimately won by SpaceShipOne and the Scaled Composites team (led by famed experimental aircraft designer, Burt Rutan) in October, 2004 (Schwartz, 2004). As a testament to the magnitude of this accomplishment, the spacecraft was never flown again, and is on display at the Smithsonian National Air and Space Museum in Washington, DC (Hales, 2005). SpaceShipOne is currently hanging in the “Milestones of Flight” gallery, next to another prize-winning vehicle, Charles Lindbergh’s “Spirit of St. Louis.”

As of December 2017, five suborbital vehicles have reached or surpassed the milestone of initial fabrication. Figure 4 shows photographs of four suborbital vehicles, including (clockwise starting from the upper left-hand corner) SpaceShipOne, SpaceShipTwo, New Shepard, and the Lynx Mark I (under assembly). Scaled Composites, Virgin Galactic, Blue Origin, and XCOR Aerospace designed and/or owned

³ Between the X-2 and the X-24B programs were flights of the X-15, HL-10, X-24A, M2-F3, and Project Mercury. NASA conducted Project Mercury, the only civilian program, and the U.S. Air Force conducted the rest.

these vehicles, respectively.⁴ This analysis does not include firms who have designed and operated suborbital vehicles (including sounding rockets) to transport scientific payloads (both inert and animal), but not humans. These firms, including Armadillo Aerospace (which ceased operation in 2013), Masten Space Systems, Garvey Spacecraft, UP Aerospace, and others, may eventually enter the HSSTI, but have not done so to date. One firm that has built initial hardware but is not included in this study, Copenhagen Suborbitals, has been operating since 2008 with the goal of designing a vehicle to fly a single human on a suborbital trajectory in a rocket-powered vehicle. The reason for not including them in this analysis is because the company's long-term public plans do not include commercial operation. Finally, even Elon Musk has included human suborbital flight as one of the possible business operations from his successful orbital space launch business, Space Exploration Technologies, more commonly known as SpaceX (Musk, 2018). The first announcement of initial fabrication of his Big Falcon Rocket, however, only became public in late 2017, too late for inclusion in this study. Of the HSSTI operators included in this study, none has yet begun revenue-generating flights. There is, therefore, currently no direct evidence of HSSTI demand.

⁴ Although XCOR did not design it to fly to 100 km, this study includes the Lynx Mark I because of the important role XCOR played in HSSTI development, and because of its direct connection to the subsequent vehicle designed to achieve that altitude, the Lynx Mark II. Despite its inclusion here, however, XCOR suspended construction of the Lynx Mark I in May 2016 (Foust, 2016). The fifth HSSTI vehicle is the Rocketplane XP, not shown.

Figure 4. HSSTI vehicles as of December 2017



1.4.2 Industry Analogs

A brief discussion of possible analog industries to the HSSTI may demonstrate common or note-worthy characteristics of industry emergence. Transportation or high-tech industries have been studied in the past to find “lessons learned” that may be applicable to different commercial space sectors (Hanson & Rosston, 2017; Launius, 2014). This section is not an in-depth comparison with every possible industry, but is a cursory look, based on a limited number of sources for the selected industries. Comparisons are made below with the industry emergence of steamboats (Geels, 2002), railroads (Launius, 2014), automobiles (Rao, 1994), aviation (Capron, 1971; Launius, 2014; Maryniak, 2001; Phillips, 1971; Stekler, 1967), and computers (Hanson & Rosston, 2017). As a baseline, the HSSTI is a set of privately funded firms, engaged in a prolonged pre-production period of operations and testing, with limited support from the government. Substantial government-funded research, performed 40 to 50 years ago,

preceded the most recent activity. Even before it has begun commercial operation, the public perceives the HSSTI as being potentially unsafe, and only affordable for joy-seeking rich people. There are no dominant HSSTI trade organizations or professional societies. In the U.S., the Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) regulates the HSSTI. The regulatory framework for the HSSTI is well established, and the government policy is generally favorable and supportive of the industry.

The steamboat industry emergence began in approximately 1780 with private construction of the first steamboats (Geels, 2002). Early steamboats were so inefficient regarding fuel (coal) consumption, they had little room for cargo. The result was that they could only survive commercially in areas with heavy traffic of passengers or mail, and by carrying high-value payload. Very early in the emergence process, the government assisted the industry by building canals and deepening rivers to allow for steamboat passage and operation. Military use of steamboats began in the 1820s, approximately four decades after the first experimental vehicles. Industry groups measured better performance as increases in “distance margin” (the distance below which steamships could compete with sailing ships), boiler pressure, and fuel (coal) consumption efficiency. Major improvements in propulsion systems (compound steam engines and screw propulsion) and iron construction occurred in the mid-1800s. Although countries had their own “Navigation Acts” that ensured country-run monopolies could not use privately-owned vessels, the sailing ship industry had previously established private ownership as a norm. This norm carried into the steamboat era, resulting in an industry that was privately funded, although government assisted, from the outset.

In 1829, the South Carolina Canal and Rail Road Company was the first operational railroad in the U.S. (Launius, 2014). The company received local and state government support, improving overland postal connections in the 1830s and 1840s. A philosophy of “build it and they will come” was prevalent within the new industry, as exemplified by the willingness of state governments to invest substantial amounts of money. For example, the state of New York invested \$1.2 million USD (equivalent to approximately \$5 billion 2010 USD) between 1837-1860. The federal government passed the Land Grant Act in 1850, transferring 21 million acres of land to the railroads in the Mississippi River valley by 1857. Railroad companies then raised capital to expand the new transportation system by selling these lands at a profit to willing buyers.

Emergence of the automobile industry (Rao, 1994) occurred between 1879 and 1912. Construction of the first factory to build automobiles began in 1895, more than 15 years after the first hand-built cars appeared. The industry was entirely privately funded, and government support didn't begin until 1908-09, with interest from the War Department, Post Office, and municipal governments. High purchase prices and frequent mechanical failures resulted in a public perception that these early vehicles were unsafe and merely playthings for the rich. The dominant design of a four-cylinder, gas-powered vehicle appeared by 1912. Weak trade associations, governmental organizations, and professional societies characterized the early automotive industry.

Prior to the first flight of the Wright brothers' Flyer in 1903, the U.S. government had invested approximately 100 thousand USD to the Smithsonian's Samuel Pierpont Langley to develop similar technology, which ultimately ended in failure (Launius, 2014). Subsequently, major development of the required technologies, and valuable

operational experience, was accumulated through approximately four dozen aviation contests conducted around the world prior to the First World War (Maryniak, 2017). In the U.S., the Army made their first purchase of a Wright Flyer in 1908, and ended up being a major customer, ordering 21,000 planes per annum by 1918 (Mowery & Rosenberg, 1982). In 1919, the government Army Air Service built 69 air fields for aviation operations, effectively establishing minimal initial infrastructure. The government was practically the entire demand market, however, as evidenced by a reduction of aircraft production in 1922 by over 98%, when the government stopped ordering planes after the war (Mowery & Rosenberg, 1982). Government-funded research, conducted under the auspices of the National Advisory Committee for Aeronautics, had no private-sector influence from the time of its founding in 1915 until the late 1930s (Phillips, 1971). The government was the sole funder of engine development work conducted by private companies between 1919 and 1926. Passage of the Kelly Air Mail Act of 1925 created a government market for mail carried by air. Ultimately, an event that marks major acceptance of aviation as a mode of transport was the successful flight in 1927 by Charles Lindbergh to win the 25 thousand USD Orteig Prize with a non-stop crossing of the Atlantic, between New York and Paris:

“Lindbergh’s flight and widely covered air tours made Americans air minded, setting off a vast aviation boom. Air mail surged, new air routes proliferated, aircraft manufacture increased, and passengers flocked to the airports. Overnight college students turned to careers in aeronautics. Investors, ever alert to the fresh new thing, poured millions of dollars into aviation research, development, and production. And in a very brief span

of time large new aviation companies formed colossal cartels that catapulted America's air industry to world leadership.” (Kessner, 2010, p. xvii)

Despite this heightened level of public acceptance, that could have led to an emergence of a commercial market, the government (military) controlled the aircraft industry after the Second World War, again comprising the vast majority (90%) of the market share, stimulating most of the technical advances within the industry (Capron, 1971), and possessing many of the manufacturing facilities until 1951 (Stekler, 1967).

Finally, the computer industry (Hanson & Rosston, 2017) is presented as an industry analog although it is not associated with transportation. In the late 1930s and early 1940s, the U.S. government funded 100% of the research to build the computer industry in support of military applications (nuclear weapon development, radar systems, and the integration of sensor data for early warning systems). In the 1950s, the government still paid for a majority (60%) of the overall computer research funding. During this same time, however, the government funded 100% of transistor research. International Business Machines (IBM) was a major contractor to the government during these early decades, and was able to benefit by the public investment to accumulate private equipment, intellectual property, and valuable technical expertise. Although there was interest in computing by the private-sector as early as the 1940s (especially by the insurance industry), IBM didn't introduce the first commercial (non-governmental) computer system until the 1960s. The IBM System/360 featured software compatibility (FORTRAN, matured by 1957). IBM introduced the System/370 in 1970. The first personal computers arrived on the market in 1975 (the Altair 880 and the Apple I),

followed by the Apple II, and the TRS-80, in 1977 and 1978, respectively. Apple had its initial public offering in 1980.

This cursory discussion provides a basis of comparison of emergence characteristics between these five analog industries and the HSSTI. The HSSTI is emerging on the basis of private funding, like all the other analog transportation industries. Only the computer emerged primarily based on government funding. It is interesting to note that none of the analog industries were based on prior government research until the aviation industry emerged in the early 1900s. This coincides with the emergence of research “labs” for the purpose of systematizing the production of technological innovations:

“the impact of these and other educational institutions on actual practices of research and the shape of American science was slim to negligible prior to the 1890s” (Mirowski, 2011, loc. 1340).

Since the end of the 19th century, all the industries included here have benefited from prior government research, but that may be a result of the industries chosen in our analog study:

“most of the successful [business-government] cooperative ventures in the past have been either for the government’s military or space exploration needs” (Chakravarthy, 1985, p. 259)

Here, this cursory study notes that emerging industrialists used prior government research when it existed. All of the analog transportation industries were able to benefit from the private market of passenger carriage, and most had access to government contracts to carry mail. Only the automobile and aviation industries did not immediately receive mail contracts. The immediate demand of private markets in the 1960s facilitated the

emergence of the computer industry, in addition to the captive government customer. On the one hand, one can only speculate at this early stage of HSSTI emergence that it will have access to the private market, carrying private individuals on flights similar to the early aviation “barnstorming” activities. On the other hand, there does not appear to be any immediate military or civil government demand for the HSSTI. Finally, the repeated use of contests and prizes is shared by the early days of the automobile (Rao, 1994) and aviation industries (Maryniak, 2001).

Table 2 gives a summary table of this discussion. At first glance, the HSSTI is clearly similar to the emergence of the aviation industry. Future comparative studies could better identify and clarify the emerging industry characteristics, and add more detail for each industry investigated. Also, this section only includes examples of successful industry emergence for this discussion. Future comparative studies could include other transportation innovations that have not yet achieved, or never will achieve, a broad level of adoption, including dirigibles and airships, submarine tourism, flying cars, moving sidewalks, hovercraft, and supersonic passenger aircraft (Milo, 2009).

Table 2. Comparison of emerging industry characteristics

| Emerging Industry Characteristic | Approx. Industry Start Year | Built with Private Funding | Based on Gov’t Research | Access to Public Markets | Access to Private Markets | Use of Prizes |
|---|------------------------------------|-----------------------------------|--------------------------------|---------------------------------|----------------------------------|----------------------|
| Steamboats | 1780s | Yes | No | Yes | Yes | No |
| Railroad | 1829 | Yes | No | Yes | Yes | No |
| Automobile | 1875 | Yes | No | No | Yes | Yes |
| Aviation | 1904 | Yes | Yes | Yes | Yes | Yes |
| Computer | 1940 | No | Yes | Yes | Yes | No |
| HSSTI | 2004 | Yes | Yes | ? | Yes | Yes |

1.5 THESIS ROAD MAP

The rest of this thesis provides detail and description of the research introduced in this Introduction. Chapter 2 covers the literature review, providing more detail about the contributions of the different literature streams, introduced earlier in section 1.2. Chapter 3 describes the research methodology and data collected in support of this research, justifies the methods employed, and addresses data transformations, robustness, and limitations. Chapter 4 presents research results, providing a comprehensive accounting for results in all three IIEs, including their second- and third-order elements. A discussion of the results is the topic of Chapter 5, divided into two parts. The first four subsections cover the results of the three IIEs and the linkages between them. The fifth subsection of Chapter 5 discusses the processes proposed in this research. The first six propositions pertain to processes within and between the three IIEs. The next four proposed processes are related to the effect of prizes on the initial set of industry emergence processes. The last section of Chapter 5 discusses the generalizability of these results to other industries. Finally, Chapter 6 presents the research conclusions, limitations and ideas for future research. A final section on general conclusions compares the results of this research with the basic tenets of the original accumulation model, provides responses to the “corollary” research questions asked here, and gives an explanation of practical implications of this research for new industry entrepreneurs, managers, policy-makers, and, finally, the African continent.

2. LITERATURE REVIEW

This chapter introduces the main streams of academic literature that apply to this research, each contributing in a distinct way, as described below. An explanation of how this research fits into the integrated context of those themes follows. Finally, this research identifies and discusses eight past studies that relate to this research.

2.1 MAIN ACADEMIC THEMES

The main academic themes upon which this research draws include economics and innovation, innovation development meta-theory, sociology, economic sociology, and institution/neo-institution theory. The economic perspective provides the foundation for industry creation and renewal cycles, based on different types of innovations. The link between innovation and industry development provides the setting for the theoretical investigation of different types of innovation development, and how industry development models derive from them. The applicability of the functional goal category of innovation models to the chosen industry context leads us to the accumulation model of industry emergence and evolution, built upon the system of major social functions developed by Parsons (2005) and the epigenesis model of development (Etzioni, 1963). The result is an expanded notion of markets beyond purely economic systems, a perspective developed in the fields of evolutionary economics and economic sociology (Fligstein, 1990; Nelson & Winter, 1982; Parsons & Smelser, 1956). Finally, the discussion concludes with the field of neo-institution theory (with its roots traced back, again, to sociology), emphasizing legitimacy and its role in market emergence.

2.1.1 Economics and Innovation

The word “innovation” is used both as a noun and a verb. As a noun, innovation pertains to items of novelty. There are different types of innovation, and special types of innovations can become the foundation upon which new industries are based. As a verb, the innovation process describes the path, or technological trajectory, by which the innovation evolves and the new industry emerges. This research focuses on the innovation process, rather than the specific innovation, but it is worthwhile to understand the types of innovations that may facilitate new industry emergence.

Early definitions of innovation as a noun include “new products, processes, markets, resource sources or forms of organization” (Schumpeter, 1939, as cited in Wollin, 1996). Other definitions highlight the broad nature of innovation, including “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003), or:

“[a]nything that creates new resources, processes, or values or improves a company’s existing resources, processes, or values. Obvious innovations include new or improved products, processes, and services. New delivery mechanisms, customer service strategies, and business models are all other forms of innovation” (Christensen, Anthony, Roth, & Kaufman, 2004, loc. 3672).

Not all innovations, however, are capable of, or responsible for, the creation of new industries. Recognizing that such a broad spectrum of innovations do not all result in new industries, Mensch differentiated between “basic” innovations (those technological or non-technological activities “which establish new branches of industry” [Mensch, 1979,

p. 3]), and other types (radical improvement and pseudo-innovations). Disruption innovation theory (Christensen, 1997; Christensen & Raynor, 2003) includes an entire category of “new market disruptive innovations” to precisely define those innovations which may result in new markets.

The innovation development process is defined as “the temporal sequence of events and activities that occur to create and transform basic scientific knowledge into commercially viable products or services delivered to customers” (Van de Ven, 1993a, p. 26). Schumpeter (1947) introduced the concept of “creative destruction” to describe the cyclic nature of new opportunities and more efficient operations overcoming established means of production. From an innovation management perspective:

“The process of innovation consists of motivating and coordinating people to develop and implement new ideas by engaging in transactions (or relationships) with others and making the adaptations needed to achieve desired outcomes within changing institutional and organizational contexts.” (Van de Ven, 1992, p. 223).

At the industry level, this process is manifest by the replacement of established industries with emerging and evolving industries. Economic theorists originally formulated the concept of the innovation process as an exogenous engine of market dynamism (Schumpeter, 1939, 1947, 1983), defining it as:

“the whole range of activities that are needed to translate a new idea into commercial practice for the first time. The innovation stage also includes identifying the market for a new product, investing in the capital goods needed for production and distribution, and raising the funds for that

investment” (Schumpeter, 1947, as cited in George, Joll, & Lynk, 2005, p. 231).

This definition was later extended through the identification of different types of innovations (Abernathy & Utterback, 1978; Christensen, 1997; Mensch, 1979; Tushman & Romanelli, 1985; Utterback, 1994). These models explain observed changes in the economy, including the creation, growth, renewal, and disruption of markets.

Changes in technologies translate into changes in industries. Industry emergence is, therefore, a reflection of the innovation development process, since innovation is one of the bases for the creation and development of new industries. Utterback (1994) emphasized the connection between the development of innovation and industry:

“Innovation is at once the creator and destroyer of industries and corporations. Over the years, new technologies have made industrial giants out of many upstart firms, invigorated older ones that were receptive to change, and swept away those that were not. Today, when competitiveness hinges on the ability to develop or adapt new technologies in products, services, and processes, understanding the dynamics of industrial innovation and change is essential for survival and success” (p. xiv).

The connection, however, may not be well-understood or obvious, because Utterback (1994) starts the entire discussion by stating “the importance of technological innovation [to industry] has not been adequately addressed” (p. xiv). Finally, it’s important to realize that as an industry emerges and evolves, a progression of different types of innovations will develop. In support of the innovation process, technological innovations are the

foundations of new technological paths, or “trajectories” (Nelson & Winter, 1982). A new technological trajectory

“diverges from and is often rejected by an existing industry because of its discontinuous rupturing effects on the established technological paradigm. Thus, to explain how this new technological trajectory develops, one has to start almost from the beginning to explain how a new industry is born”
(Van de Ven & Garud, 1989, p. 202).

Opportunities for national economic growth accompany technological change, including the growth of existing industries, or the creation of new industries (Adner & Levinthal, 2002). The opportunities for increased economic growth and, therefore, an understanding of the overall industry emergence process, are of great interest to entrepreneurs, managers, and policy-makers.

Based on this chain of logic, the emergence, evolution, and development of new industries, therefore, mirrors the emergence, evolution, and development of the innovation. Innovation development is a foundation of understanding industry development, so understanding different types of innovation is important as well. Although this study of industry emergence only focuses on the earliest stages of innovation development, understanding the development of multiple types of industry and innovation requires the development of theory about different innovation theories, referred to as innovation development meta-theory.

2.1.2 Innovation Development Meta-Theory

Innovation development meta-theory identifies three major categories of innovation development models, one of which (the functional goal category) includes the epigenesis

model (Etzioni, 1963). When applied at the industry or community levels for the industry context of this research, the epigenesis model is adapted to become the model of resource accumulation, as researched and described in the MIRP in 1989 (Poole & Van de Ven, 2000). This model was initially demonstrated for industry emergence using an HEA of the cochlear implant industry (Garud & Rappa, 1994; Garud & Van de Ven, 2000; Van de Ven & Garud, 1993). Since that time, various researchers have used the accumulation model to contemporary industry contexts seven more times, as detailed below.

Individual theories of innovation development as it impacts industry development, social change, or technological developments are plentiful and varied, including typologies of entrepreneurship (Baumol, 1990; Baumol & Strom, 2010; Spencer, 2004), the impact of technology consortia (Baumol, 2002), disruption innovation theory (Christensen, 1997; Christensen et al., 2004; Christensen & Raynor, 2003), the stimulus of innovation by economic recession (Mensch, 1979), the description of business cycles of different time scales (Schumpeter, 1939), the “creative destruction” phenomenon (Schumpeter, 1947), “punctuated equilibrium” (Tushman & Romanelli, 1985), the cyclic and sequential innovation of product and process (Abernathy & Utterback, 1978; Utterback, 1994), and the “democratization” of innovation by end users (von Hippel, 2006). Innovation processes that have been the subject of study have led researchers to conclude that no one theory can capture the high degree of “complexity and diversity” observed (Poole & Van de Ven, 2000, p. 660). Types of technological and innovation development are encompassed by Poole and Van de Ven (2000) within three “motors:” historic event, functional goal attainment, and emergent processes. Research that concentrates on industry development has a perspective that is quite broad and a long

time-frame. The level of analysis is global, with a focus on the larger “economic trends, social needs, the legal system, cultural norms, and long-term institutional arrangements,” and not on “micro ideas, decisions, actions, or events of particular developmental episodes” (Poole & Van de Ven, 2000, p. 643). The following paragraphs give a brief discussion of these three motors.

Natural sciences of the nineteenth-century influenced social development theory, and developmentalism was the basis for the historical motor logic of innovation development (Nisbet, 1970, as cited in Poole & Van de Ven, 2000). Developmentalism proposed that the evolution of a social system must pass through a certain set of stages that are irreversibly time sequenced. As applied to social systems, creation from a defined starting point leads to a known set of phases, stepping through time, until achieving a predetermined end state. Although it may not be applicable in all industry development contexts, historical models of industry development are applicable in well-defined or highly-prescriptive (regulatory) environments. Furthermore, these types of models are best applied to industries experiencing incremental, or pseudo (Mensch, 1979) innovations. Research of the historic motor of innovation development, however, has shown little consistency of development phase sequence for most industries. Furthermore, boundaries between development phases are indistinct and do not follow regular sequences, resulting in the possibility of phases occurring multiple times (Poole & Van de Ven, 2000).

In stark contrast to historical motor logic, emergent process models are highly relativistic, specifying neither development path nor desired end state. These models characterize innovations of extreme creativity or departure from industry norms, and

typically in undeveloped, or underdeveloped, institutional environments. The emergent process model can manifest itself in different ways, including the Marxian dialectic, Darwinian evolution, self-reinforcing cycles, and garbage can models (Poole & Van de Ven, 2000). The dialectic mode characterizes the creation of an innovation (a stabilized synthesis) as resulting from the interaction between an antithetical position that arises in response to the originally stable thesis (status quo). The evolutionary mechanism of variation-selection-retention (Aldrich & Ruef, 2002; Campbell, 1965, as cited in Greve, 2005) is another emergent process mode of innovation creation. Self-reinforcing cycle modes are “interlocking action loops among interdependent people and organizational units” (Masuch, 1985, as cited in Poole & Van de Ven, 2000). Finally, the garbage can mode (M. D. Cohen, March, & Olsen, 1972) consists of serendipitous encounters to achieve innovative solutions to complex and dynamic problems, similar to what is described as an “adhocracy” (Mintzberg, Ahlstrand, & Lampel, 2005).

The intermediate category of innovation development meta-theory, the functional motor models, typically encompasses innovations of moderate degree, and although it does not make an assumption of historical necessity (as do the historical models), it does assume equifinality. Therefore, a specific development path of the industry is not given, but a desired end state of industry development is presumed (Poole & Van de Ven, 2000). A functional logic drives the innovation toward a stable end state through the accumulation of new resources and power over time, as in the epigenesis model of development (Etzioni, 1963). In an attempt to establish a unique identity, organizations within the innovating industry (i.e., internal organizations) must create and manage relationships with the organizations in the external environment. These functional goal

relationships depend on contingencies of innovation activity centrality, power balance (between the internal and external organizations), and degree of proactivity (or reactivity) on the part of internal organizations. The remainder of this section provides more detail in support of the accumulation model applied to this research regarding the contingencies mentioned above. The possible types of the functional motor model relationships will be described below, and include fortification, problem-solving, peer, accumulation, and dependence (Poole & Van de Ven, 2000), in the order of greatest to least level of dominance of the organizations within the industry with respect to the external organizations.

When the internal organizations (typically the industry firms) are in a dominant position over the external organizations (typically the government organizations), the type of interaction characterizes the specific type of relationship. If the internal organizations are sufficiently independent so they can ignore the external organizations, functional motor theory refers to this relationship as the “fortification model.” If, however, internal organizations react to actions of the external organizations while still maintaining their independence and superior position of power, functional motor theory refers to this relationship as the “problem-solving model.” If the internal and external organizations possess similar levels of power, and the two groups treat each other as equals, then a “peer model” relationship develops, making decisions jointly in a collegial atmosphere, without a loss of independence for either group. In cases where the external organizations have decidedly more power in their relationship with the industry organizations, the internal organizations can choose one of two paths. Either the internal organizations may cede all power to the external organizations, demonstrating “reactive”

or “opportunistic” behavior, in what the functional motor theory refers to as a “dependence model” relationship. They may, however, demonstrate “responsible” or “productive” behavior, accepting their dependencies as a temporary condition, and striving to build the necessary relationships and capabilities, over time and sometimes in cooperation with other organizations within and outside the industry. The functional motor theory refers to this as an “accumulation model” relationship. The goal of accumulating these different resources is to increase the power of the internal organizations relative to the external organizations, striving for independence from the external organizations, toward the other relationships described above (Poole & Van de Ven, 2000).

The industry context of this research is the U.S. HSSTI. Of the three broad sets of innovation theories, the functional motor category provides the most compelling lens through which to explore the development of the HSSTI, given the industry’s level of institutional support, the establishment of a desired industry end state, and the intermediate level of innovation. Furthermore, the accumulation model relationship best describes the collective actions and demonstrable level of positional power of the internal industry actors relative to the external environment of the HSSTI. Within the U.S., the legal structures that define the operation and interactions of HSSTI firms are well defined and mature. Although the norms and accepted practices for space activities were developed by an international treaty (US Department of State, 1967), specific regulatory regimes were left to each country. In many space-faring countries where space activities are only conducted by state owned enterprises, or hybrid firms (i.e., firms with partial state ownership) (Bruton, Peng, Ahlstrom, Stan, & Xu, 2015), the governmental

“authorization and continuing supervision” as required by treaty is conducted implicitly, through direct control and oversight of the firm’s activities (Wang, Hong, Kafouros, & Wright, 2012). In the U.S., it is permissible for privately-owned firms (i.e., firms with no state ownership) to conduct specific space activities, including the launch and re-entry of space vehicles. In order to satisfy international obligations in response to the new private space activity that began in the early 1980s, the U.S. Congress created a regulatory office and framework (Commercial Space Launch Act, 1984) that has been periodically updated and modified (Commercial Space Launch Amendments Act, 2004; Commercial Space Launch Competitiveness Act, 2016). Although the HSSTI is still in a pre-production stage, having only taken “preorders” for future flights, and not yet having flown (and safely returned) a single customer, the existence of a regulatory framework also helps clarify the desired “end state” of a HSSTI that ensures the safety of the uninvolved public and property, and thereby maximizes the probability of safe flights for the paying customers (referred to in the regulations as human spaceflight participants, [HSPs]).⁵ The level of innovation of the HSSTI is “intermediate” because it is neither new nor high performing. U.S. military and civil (government) research organizations were flying a “suborbital trajectory” in a “suborbital vehicle” since the 1950s, as per definitions written

⁵ In the HSSTI, the FAA refers to people who pay to ride in the vehicle as HSPs, not as “passengers.” The latter term implies the guarantee of safe passage. Currently, all “reasonable” people assume that suborbital space flight is a risky endeavor, and none assume the guarantee of safe passage for HSPs.

into U.S. statute (Commercial Space Launch Amendments Act, 2004).⁶ For these reasons, the HSSTI is well-suited to be modeled by a functional goal motor of innovation development. Because they have not yet begun revenue-generating operations, the collective level of power of the HSSTI firms is lower than that of organizations in the external environment (i.e., regulatory agencies, military and civilian space organizations, etc.), despite having substantial financial resources. The HSSTI internal organizations are quite determined, however, to develop into an industry that can operate independently of the government (although servicing government customers is part of every HSSTI firm's market strategy). This posture of the internal organizations clearly defines the internal-external relationship as "accumulation," and not "dependent."

The accumulation model is based on a theory developed to describe the emergence of supra-national organizations. The theory originated from two mutually exclusive perspectives applied to the development of social groupings (including elites, families, and underdeveloped countries), the socialization process, and industrialization (Etzioni, 1963). The first model, preformism (or differentiation), contends that an embryonic form of the group or process of interest possesses primitive versions of all the capabilities,

⁶ Quoting directly from the Commercial Space Launch Amendments Act (2004):

"'suborbital rocket' means a vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which is greater than its lift for the majority of the rocket-powered portion of its ascent," and "'suborbital trajectory' means the intentional flight path of a launch vehicle, reentry vehicle, or any portion thereof, whose vacuum instantaneous impact point does not leave the surface of the Earth."

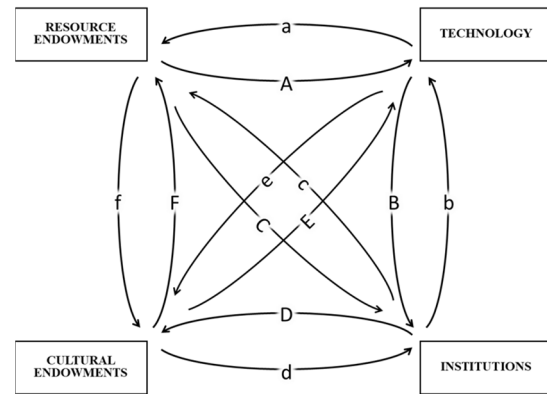
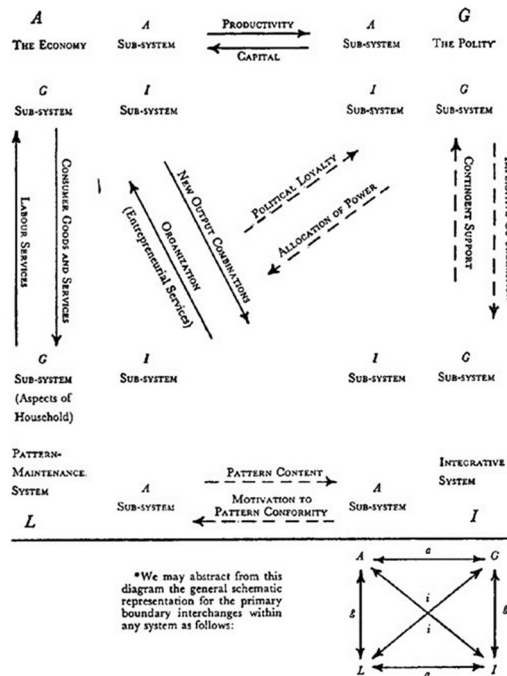
resources, and processes it will ultimately require in its fully mature form. The development of these capabilities and resources grow and mature as does the social grouping or process. The second model, accumulation (or epigenesis), rejects the assumption of preformism, and assumes the lack of critical capabilities and resources in the embryonic form of social groups. These capabilities and resources, however, accumulate over time, in various ways, as the social grouping grows and matures. Furthermore, an emerging industry, the social system of interest to this research, does not exist as an independent entity, but is hierarchically embedded within larger social systems (Granovetter, 1985). Within the emerging industry, a structure of subordinate subsystems will emerge which possess capabilities to perform functions required as the industry matures. The early work in economic sociology by Parsons and Smelser (1956) identify a model that includes “latent pattern-maintenance and tension-management, goal-attainment, adaptation, and integration” as the four general categories of required functions of a social system. Ruttan and Hayami (1984), adopted this general model, and relabeled the four categories as cultural endowments, institutions, technology, and research endowments (respectively) to describe institutional innovation. Figure 5 shows the two models side by side. Omission of the first function category listed above, latent pattern-maintenance and tension-management, is a recognized limitation of the accumulation model, as noted by Ruttan and Hayami:

“We also insist on the potential significance of cultural endowments, including the factors that economists typically conceal under the rubric of tastes and that political scientists include under ideology. ... Until our colleagues in the other social sciences provide us with more helpful

analytical tools, we are forced to adhere to a strategy that focuses primarily on the interactions between resource endowments, technical change, and institutional change” (1984, p. 218).

The latter three of these functions were characterized by subsequent researchers as proprietary functions, allocation of resources, and institutional arrangements, respectively (Van de Ven, 1993a, 1993b, 1993c; Van de Ven & Garud, 1989). This trio of subsystems, “has been a common theme underlying structural descriptions of complex organizations (Pfeffer & Salancik, 1978; Thompson, 1967), corporations (Porter, 1985), and interorganizational networks (Van de Ven, Emmett and Koenig, 1974; Aldrich & Whetten, 1981)” (Van de Ven & Garud, 1989, p. 222). Figure 2 on page 11 shows the resulting model used in this research.

Figure 5. Two social system functional models



Source: (Ruttan & Hayami, 1984, p. 216)

Source: (Parsons & Smelser, 1956, p. 68)

These three functional categories are also referred to as IIEs (Garud & Van de Ven, 2000; Van de Ven, 1993a, 1993b, 1993c, 2005, Van de Ven & Garud, 1989, 1993). The first IIE, Institutional Arrangements, includes second-order elements of Legitimation, Governance, and Technology Standards (Van de Ven, 1993a, 1993b, 1993c). The second IIE, Resource Endowments, includes second-order elements of Scientific and Technological Research, Financing and Insurance Arrangements, and the Human Competence Pool. The third IIE, Proprietary Functions, includes second-order elements of Technological Development Functions, Innovation Network and Resource Channel Activities, and Market Creation and Consumer Demand. Each of these nine IIE second-order elements has its own set of third-order elements, as shown in Table 1 on page 12. For long-term industry viability, these first-, second-, and third-order elements all need to develop through the cooperative or unilateral contributions by the internal and external organizations of the emerging industry. This is a basic description of the innovation development functional model's accumulation relationship.

Each IIE is built by the firms within the industry acting as innovation units, and by other industry actors that are commonly perceived as being outside the industry (Van de Ven & Garud, 1989). In extreme cases of relatively large financial endowments upon entry, individual firms may be able to build some components of the Proprietary Functions IIE by themselves, but in many cases, an industry collective will encourage cooperative efforts between multiple firms to help construct other parts of the Resource Endowments and Institutional Arrangements IIEs. Similarly, external actors may execute unilateral actions that affect the industry (e.g., government mandated standards). In other cases, however, these same external actors will cooperate with the industry firms or

industry groups, as in the case of regulation development that requires some period of time to encourage feedback from industry members on the economic impact and operational constraints the proposed regulations may cause and incur. The process is referred to as “boundary obfuscation,” or blurring of the boundaries (Woolley, 2013), whereby one actor helps build many elements of the industry infrastructure, or where many actors help build a single element.

Within the structure of these IIEs, there are many linkages between all the industry’s elements and firms. First, between the first-order elements of Resource Endowments and Proprietary Functions, there is a linkage that drives the development of new technology (“technology push”). This process of adapting research to create a product is described as “a long, complex, and uncertain journey that amounts to being an interactive search process involving large amounts of ‘backing and forthing’ between technology and market conditions in efforts to reduce uncertainty” (Stobaugh, 1985, as cited in Garud & Van de Ven, 2000, p. 494). Although research commonly precedes most of the IIE subsystems, the commercial application of research is not a well understood phenomenon, setting the stage for the second linkage. Between the Institutional Arrangements and Proprietary Functions IIEs, the linkage drives certain technological developments (“technology pull”). Industry standards force firms to decide whether to cooperate or compete in what is commonly an exercise charged with political tension. Government regulations and/or industry trade groups can mandate standards if industry consensus is not possible. Industry consensus requires collaborative efforts between new entrant firms, and these “exploratory” alliances (Rice & Galvin, 2006) typically occur during the early stages of industry emergence. Between firms, a large number of market

and relational ties are formed, including “exchanging multiple resources, communicating with other firm representatives on industry and trade committees, sharing common pools of knowledge, acquiring personnel trained and socialized in a common pool of competence, friendship and kinship ties, and overlapping board memberships” (Van de Ven, 1993b, p. 224).

2.1.3 Economic Sociology

In this thesis, the role of economic sociology, and its foundational science, sociology, permits the treatment of emerging industries within a wholistic environment of economy, society, and polity (Parsons & Smelser, 1956). There are many differences between economic sociology and “pure” economics, but many of these trends are changing in both fields. Even within the confines of economic theory, attempts by theorists to describe dynamic phenomenon (including business cycles and new firm creation) has forced the reconsideration of many simplifying assumptions. Economic sociology also appreciates the role of government to provide an environment of stability and resource munificence, despite strict interpretations of classical and neo-classical economics. However, through the lens of economic sociology (instead of economics alone), the contextual description of industry emergence is vastly more complex. The economic sociology perspective can better reflect the realities of industry emergence, because of its broader scope of influencing factors, and the greater variation of possible actors’ reactions and behaviors.

There are many important differences between economics and economic sociology. The concept of the economic actor in economics is a disconnected individual. The individual focus, originating in early utilitarianism and political economy, was later referred to as “methodological individualism” (Smelser & Swedberg, 2005a). Economists

assume rational action, defined as the efficient use of scarce resources, based on an actor's stable preferences and the maximization of utility. To economists, economic choices are determined by utility and price, made during an interaction between equals. Market power to economists is vital in the study of imperfect markets, labor economics, and industrial economics. Economists do not consider the influence of social groups or institutional actors on the individual actor's decisions, and focus primarily on markets. Society is a peripheral region to this central focus, assumed to be stable and, therefore, neglected. Economists assume norms and institutions do not exist. Economists emphasize predictive capabilities, and, therefore, the creation of formal, abstract, analytical models. Economists perceive descriptive analysis as being too atheoretical, and ignoring real data. The data upon which the economists rely, however, is created by and for themselves to a large degree.

The analytical starting point for economic sociology, on the other hand, is with groups, institutions, and society. Sociologists (such as Weber) describe many types of actions, such as rational, traditional, or affectual. Rationality to sociologists is a variable. To sociologists, objects have historically developed meaning. Hence, economic decision-making cannot be made without empirical investigation. The economic concept of power in sociology is very broad, and the power relationship between trading parties is also a variable to consider. Social groups and institutional actors, the position of an individual in society, and cultural meanings, all influence the individual actor's decisions. Sociologists embrace description as interesting and essential in theory building, and they tend to state facts and events after they have happened. Sociologists also tend to embrace many types of experimental methods and data.

As early as the first half of the twentieth century, it was recognized that economics was thought to be “a science sufficient unto itself,” but at the same time, “economics must lean on the other social sciences, both on the theoretical and empirical levels, as they also must lean on it” (Parsons & Smelser, 1956, p. 1). There are important reasons why the study of markets should be seen as more than uniquely economic systems. When investigating a phenomenon that is dynamic in nature, the need to examine alternative influencing factors from non-economic sectors of society is particularly vital, due to the assumptions of equilibrium made in the classical and neo-classical formulation of economics.

In the case of emerging industries, economic sociology asserts that there is an important role for government to play. “The protection of infant industries - one of the few effective arguments against the classical case for free trade - involves a similar input of encouragement balanced by an output of productivity” (Parsons & Smelser, 1956, p. 93). Governments provide the necessary environments for markets to exist (Fligstein, 2001). “Stable markets are like sand castles” (Fligstein, 2001, p. 90), and to think that markets could thrive and endure without governmental involvement, “is simply wrong” (Fligstein, 2001, p. 6). Intuitively, building a sand castle through public-private-sector cooperation must be more efficient and take less time than if either did it alone, or worse yet, in conflict between the two.

The government is not the only non-economic actor in the construction of a new industry. The accumulation model used in this research builds upon a foundation of the societal “system of action” (Parsons, 2005), and the four “fundamental system problems under which a ... social system operates,” adaptation, goal-setting, integration, and latent

pattern maintenance (Parsons & Smelser, 1956, p. 18). Goal-setting is the function of “polity” (performed by a group of actors not limited only to government), adaptation is the role of the “economy” (performed by a group not limited solely to private-sector actors), and integration is a function of matching resources to the economy to achieve goals set by the polity. The accumulation model adopts these three system functions, labelling them Institutional Arrangements, Proprietary Functions, and Resource Endowments, respectively. The fourth social function, latency (pattern maintenance and tension management), corresponds to cultural sub-systems within society. The accumulation model does not include the latency function, because of the latter’s immature state of theoretical understanding.

2.1.4 Institution Theory - Legitimacy

All these literature streams fed into this research project in the development of proposed processes that add microscopic-level phenomenological detail to the accumulation model. In these processes, a dominant contributor that positively moderates the IIE interactions is the amount and type of legitimacy attributed to the new industry and its firms. Legitimacy research has strong roots in Weber (1978) and others, but multiple typologies were created and expanded over the past 25 years (Aldrich & Fiol, 1994; Suchman, 1995; Tost, 2011).

Building on Weber’s (1946) initial discussion of authority (rational, traditional, and charismatic) and legitimacy based on conformity with norms and laws, and subsequent discussion in 1956 by Parsons (2005) based on alignment with values, norms, and social laws, the new institutional theory of the late 1970s initiated a resurgence of theoretical investigations, beginning to differentiating different types of legitimacy (Meyer &

Rowan, 1977; Zucker, 1977). By the mid-1990s, scholars discussed descriptive types of legitimacy in different ways. One typology proposed by Aldrich and Fiol (1994) differentiates between cognitive and sociopolitical legitimacy. Cognitive legitimacy refers to society's subconscious acceptance of an activity or its "taken-for-grantedness" (Aldrich & Fiol, 1994; Suchman, 1995; Tost, 2011). Sociopolitical legitimacy refers to "the extent to which a new form conforms to recognized principles or accepted rules and standards" (Aldrich & Fiol, 1994, p. 646), or a "formal legal standing, as coded in laws, charters, regulations, and so forth" (Ranger-Moore, Banaszak-Holl, & Hannan, 1991, p. 37). Scott's categories included normative, cognitive, and normative legitimacy.⁷ A fine-grained categorization scheme exists, such as Suchman's 12-part typology of legitimacy (1995), including three types (pragmatic, cognitive, and moral), two time-frame elements (episodic and continual) and two focus areas (organizational actions and organizational essences). A later study by Tost (2011) combined institutional and social psychology theory to identify four non-exclusive dimensions of legitimacy: instrumental ("rooted in the self-interest calculations of individuals or groups"), cognitive ("taken-for-

⁷ Scott (1995) defines normative legitimacy as "grounded in a social context and to be oriented by a moral dimension" (p. 51), cognitive legitimacy is defined as "widely held beliefs and taken-for-granted assumptions that provide a framework for everyday routines, as well as the more specialized, explicit and codified knowledge and belief systems promulgated by various professional and scientific bodies" (p. 53), and regulatory legitimacy is defined as complying with the governance systems' "codes, norms, and rules" (p. 54).

grantedness”), regulative (“the validity of an entity”), and moral (“the extent to which the entity conforms to moral values and ethical principles”) (p. 692). Although no one typology is necessarily superior to any of the others, researchers need to make a selection for the purposes of their study. A translation table (see Appendix A on page 220) between the different typologies of legitimacy, based on similarities and parallels between them, allows researchers to convert from their selected typology to any of the others. This study utilizes the two-part typology by Aldrich and Fiol (1994), distinguishing cognitive from sociopolitical legitimacy.

2.2 RESEARCH FIT WITHIN THE LITERATURE

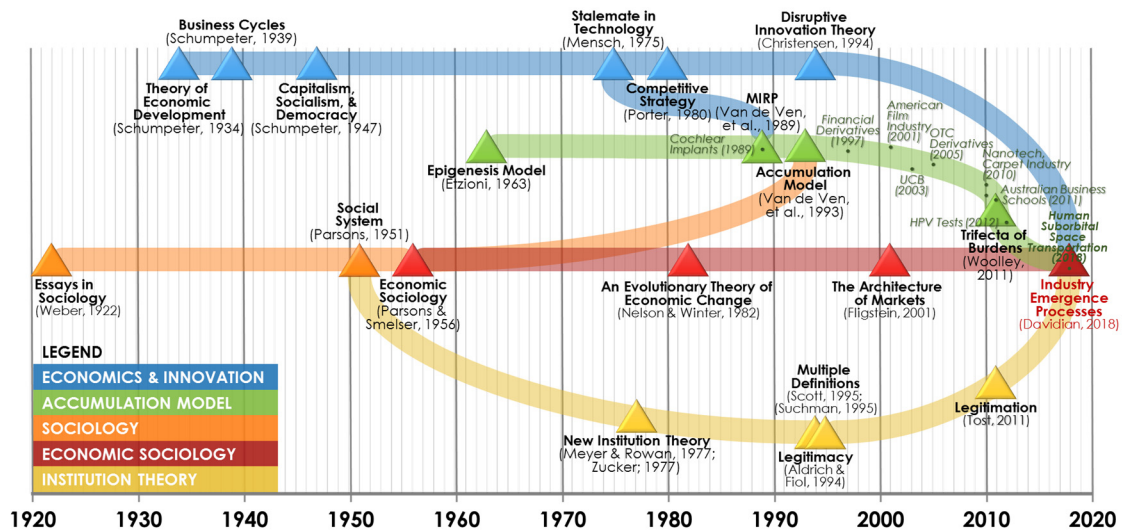
The research performed in this thesis identified the contributions by actors in the HSSTI to each of the IIEs discussed above. Specific events, defined as “an incident when change occurred” in each of the IIEs (Van de Ven & Garud, 1993), were tabulated and chronologically sequenced to construct an industry emergence chart for the HSSTI to date. The expanded IIE framework, shown in Table 1 on page 12, proved to be robust and comprehensive, requiring only minor modification to include the identified HSSTI events. This research made changes to the framework only when needed, primarily at the second- and third-orders of the outline structure. The most substantial modification made was at and beneath the original second-order element of Financial and Insurance Arrangements, in the Resource Endowments IIE. This research found the original second-order emphasis on insurance arrangements overly specialized to the industry context that supported its creation (i.e., the cochlear implant industry), thereby limiting the generalizability of the framework. At the third-order level, this research modified the

original framework elements of public- and private-sector investments to allow for nuanced differences of investment types observed in this study.

In summary, the relevant literatures that contribute to this study include economics with an emphasis on the innovation process (Christensen, 1997; Christensen et al., 2004; Christensen & Raynor, 2003; Mensch, 1979; Schumpeter, 1939, 1947, 1983), the literature stream that became the accumulation model of innovation development (e.g., Etzioni, 1963; Poole & Van de Ven, 2000; Van de Ven & Garud, 1989; Woolley, 2013), sociology, and particularly the theory of action systems (Parsons, 2005), the subsequent outgrowth to economic sociology and evolutionary economics (Fligstein, 2005; Nelson & Winter, 1982; Parsons & Smelser, 1956; Smelser & Swedberg, 2005b), and another subsequent domain of legitimation theory (Aldrich & Fiol, 1994; Meyer & Rowan, 1977; Parsons, 1963; Scott, 1995; Suchman, 1995; Tost, 2011; Weber, 1946; Zucker, 1977), based on institution and neo-institution theory. Figure 6 shows the confluence of these literature streams. In brief, the economic and innovation literature identifies the “creative destruction” process, whereby new industries are created through the process of innovation (Schumpeter, 1947), although only a certain type of innovation results in industry emergence (Christensen, 1997; Mensch, 1979). Mensch (1979) also describes an observed lag in time between an industry’s first scientific inventions and its first commercial implementation, the “seniority principle,” that can last as long as 100 years. The length of time required for an industry to emerge is a function of its development path, which is dependent upon many factors. There are three main types of innovation/industry development models (Poole & Van de Ven, 2000), and the one that best fits the industry context of this research, within the functional goal model category,

is called the accumulation model (Garud & Van de Ven, 2000), based on the epigenesis model proposed by Etzioni (1963). A basic tenet of economic sociology, and the accumulation model, is that the market is not a purely economic system, but an integrated social system (Fligstein, 2005; Parsons & Smelser, 1956). All industry actors (public- and private-sector) helped construct all three IIEs of the integrated social system. The construction and establishment of legitimacy ultimately facilitates the interactions between the three IIEs, and this helps accelerate industry emergence.

Figure 6. Relevant literature streams



2.3 CONTEXT OF OTHER STUDIES

This research study portrays the emerging market as a social system, using the functional goal motor and accumulation model to characterize the predominant industry (and innovation) development. To find other studies that employed this same model, a search was conducted within publications and articles that cite the originating and related works of the innovation meta-theory (Van de Ven, Angle, & Poole, 2000) and the accumulation model framework as applied to the cochlear implant industry (Garud &

Van de Ven, 2000). Based on literature searches using multiple keywords,⁸ eight additional research studies employed this framework. Listed chronologically as they appeared in print, these analyses include case studies of financial derivatives (Rusinko & Matthews, 1997), the American film industry (Mezias & Kuperman, 2001), umbilical cord blood banking (Rusinko & Sesok-Pizzini, 2003), standard setting for over the counter derivatives (Matthews & Rusinko, 2005), nanotechnology (Woolley, 2007, 2011b; Woolley & Rottner, 2008), the incorporation of environmental practices in the U.S. carpet industry (Rusinko, 2010), the introduction of sustainability into Australian business schools (Benn & Rusinko, 2011), and human papilloma virus (HPV) molecular diagnostic tests (Rotolo, Hopkins, & Rafols, 2012). The remainder of this section briefly describes the original study that defined the accumulation model framework, and the additional studies that employed it. As a side note, different authors refer to the framework of three IIEs by different names. Rusinko and her collaborators (2005; Rusinko, 2010; 1997; 2003) call it the “technological community framework,” Woolley (2007, 2011b) called it a “framework for industry emergence,” and both Mezias and Kuperman (2001) and Rotolo, Hopkins, and Rafols (2012) refer to it as the “social system framework.” This research refers to this framework as the “accumulation model.”

The original accumulation model study was conducted as part of the MIRP (Van de Ven & Poole, 2000), for which, researchers performed longitudinal case studies of

⁸ The keywords used were the names of the three IIEs that are key to the framework, “institutional arrangement” AND “resource endowment” AND “proprietary function.”

Any study employing this framework would include all three of these terms.

multiple industries, at multiple levels of analysis, each undergoing different stages and kinds of innovation. These studies were based on a common framework that allowed cross-case comparisons with the goal of developing innovation meta-theory. Research of the cochlear implant industry emergence (Garud & Van de Ven, 1987, 2000; Van de Ven & Garud, 1993) was the case that most closely resembled this research's focus, the HSSTI emergence. The cochlear implant study included an HEA (as was performed in this research), developed the original accumulation model framework (presented in Table 1 on page 12), and described three phenomena observed between IIEs.

Ten years before the Great Recession, Rusinko and Matthews (1997) employed the accumulation model framework to characterize the evolution of the financial derivatives market. The financial derivative community consists of the product providers (financial institutions), consumers (corporate and individual investors), trade organizations, and regulators. This study traces the evolution of derivative markets from its theoretical beginnings at universities, through its operationalization by the efforts of highly educated "financial engineers." Insufficiently educated and informed managers oversaw the sale of products by their employees. Some (but not all) of the derivatives benefitted from regulatory oversight and standardization through the efforts of industry groups. The consumers who bought these products had a wide range of investing experience and savvy. "Breakdowns" of the industry (as indicated by losses to consumers of financial derivatives in the 1991-1995 timeframe) were due to gaps or significantly different levels of IIE development across the community of actors. Such gaps include large securities and commodities firms that traded customized, over the counter derivatives, unregistered

with the appropriate regulatory agencies.⁹ Other gaps included the lack of appropriate education for managers and insufficient management controls, reducing their ability to properly understand the levels of risk represented by the products their sales force was selling. The design of incentive structures for sales people at the financial product companies encouraged increased levels of risk taking. In each identified case of institutional, resource, or proprietary gaps, the authors described the impact upon the rest of the framework system. These gaps were faults in the community-level performance that accumulated and combined until industry performance failed (as measured in losses to consumers). In essence, this study highlights the opposite of resource accumulation being a central element in successful industry performance, in the sense that “gap accumulation” can result in industry performance failures. Although this study focuses on framework gaps of an established industry, and not on industry emergence during the predominant phase, the observation of similar IIE resource development levels is pertinent to the present study.

Mezias and Kuperman (2001) employed one of the IIEs of the accumulation model framework (Proprietary Functions) to develop a community dynamics model of development, expanding the definition of entrepreneurship, and exploring the collective nature of industry emergence, at the industry population and community levels. Furthermore, the authors identified an expanded scope of constructive organizational behaviors that benefit the innovation (and industry emergence) processes, including the

⁹ The U.S. Securities and Exchange Commission and the U.S. Commodities Future Trading Commission.

creation of innovating firms, the creation of imitating firms, firms that innovate internally, and firms that imitate successful behaviors through internal change. The authors also noted that innovations at the community or population levels could affect other members of related communities or populations. This expands the opportunities for industry emergence for the firm, because they may be able to focus their efforts outside the population or community to which they belong.

In the next study, the accumulation model framework was used to analyze the emergence of a market for umbilical cord blood banking (Rusinko & Sesok-Pizzini, 2003). As with the previous case, this study did not extend the accumulation model, and findings included confirmation that gaps, or underdeveloped portions of the framework, could cause undesirable conditions for industry emergence. Identified issues included “product quality problems, product failure, loss of funding, negative press, litigation, financial losses, and ultimately, failure of the innovation or new technology” (Rusinko & Sesok-Pizzini, 2003, p. 417). Additionally, gaps in one IIE could create additional challenges and problems in the others via the IIE interactions.

A second study of financial derivatives was undertaken by Matthews and Rusinko (2005). In 2004, the demand for over the counter financial derivatives was strong, but the regulatory constraints were not. Again presaging the Great Recession, the authors used the accumulation model framework to analyze this new market. Their conclusions described the need for industry members (risk managers, specifically) to become active in the community of traders to ensure the use of the best technologies in support of, and to set risk standards on these financial instruments. As with the other publications by

Rusinko, this study employed the accumulation model framework as an analytical tool, and the objective of the work did not include a theoretical extension of the model.

Of all the studies that incorporated the accumulation model framework, the most comprehensive and thoroughly presented among them was conducted by Woolley in her analysis of the nanotechnology industry (2007, 2008, 2009, 2010, 2011a, 2011b, 2013, 2014; Woolley & Rottner, 2008). Through the analyses of the nanotechnology industry emergence, accumulation of the IIE resources was shown to be accomplished through the activities of individual actors who contributed to multiple elements of the framework, and by the coordinated efforts of multiple actors to individual framework elements, a phenomenon Woolley calls “blurring of the boundaries” (Woolley, 2013). Furthermore, as shown in Figure 3 on page 13, the “liability of newness” faced by individual firms is only one of a “trifecta of burdens” facing the industry or population (Woolley, 2011b). In contrast to the microscopic perspective taken by the present research, Woolley’s studies focus on the influence of the macroscopic entrepreneurial environment on high-technology industry emergence.

Next, Rusinko (2010) examined the adoption of environmentally sustainable practices in the U.S. carpet industry, and used the accumulation model framework to assess possible methods for increasing the adoption and dissemination of those innovative practices. Rusinko assessed the level of development of the three IIEs and their second-order elements, identifying strengths and weaknesses within the industry context. She found gaps in certain parts of the framework, including in the research and development (R&D) functions, education, and training. She also identified those gaps as potential barriers to wide-spread adoption of the environmentally sustainable practices. She also

noted that the gaps “coproduce” each other, with negative reinforcement being an undesirable effect of the linkages between IIEs.

In a study by Benn and Rusinko (2011), an analysis was performed on the introduction of an environmental sustainability curriculum to seven Australian business schools and their industry partners. Barriers to successful implementation, and identification of potential roles for the various actors, were the primary results of the study. As with the other publications authored or co-authored by Rusinko, this study employed the accumulation model framework as an analytical tool, and the objective of the work did not include a theoretical model extension.

Finally, Rotolo, Hopkins, and Rafols (2012) used the same accumulation model framework to analyze the evolution of the HPV molecular diagnostic test industry over the course of two decades, starting in the mid-1980s. Full industry evolution was documented through four stages of a technology “career” (Blume, 1992), starting with exploration, and continuing through the phases of development, adoption, and ending in growth. A new entrant came to disrupt and dominate the new industry, but instead of causing the exit of incumbent firms in the established industry, the authors found that the new technology was able to peacefully co-exist with the old, primarily through its ability to innovate, and the centrality of its position within the broader domain of the communities and field encompassing HPV and medical diagnostic testing. Resource partitioning and mutual forbearance theory (Markman & Waldron, 2014) may well describe the phenomena of coexistence observed in this study. The authors hint at possible policy options to encourage collaboration in research and product development among market actors. Similar to the financial derivatives study, this analysis pays no

special attention to the early emergence phase of industry development. These studies are, however, good examples of how the accumulation model is well-suited for study of the evolution of existing industries.

These eight studies used the resource accumulation framework developed under the MIRP (Van de Ven et al., 2000; Van de Ven & Poole, 1990), with the original study of the cochlear implant industry. The settings for five of the eight studies were previously established industries, with very mature institutional structures and actors, and a well-defined base of existing customers. Although this diminishes the resemblance between those studies and the current research (with a focus on emerging industries), it also emphasizes the applicability of this model to the study of industry evolution. The resemblance of the American film industry study to this research is diminished because the former only focuses on one of the three accumulation model IIEs. The similarity of the nanotechnology and UCB studies to this research is much greater, with its focus on the industry as it emerged from conceptual beginnings. Differences in levels of government involvement between the HSSTI and the nanotechnology study (for example), however, are substantially different. In the space industry, government has participated heavily since the end of the Second World War, and the beginning of the Cold War. This involvement included setting the vehicle performance and design requirements, fulfilled with hardware constructed by the private-sector under contracts funded by the government. In the nanotechnology industry, the private-sector led the way with foundational inventions, such as the scanning tunneling microscope and the atomic force microscope (Woolley, 2010). Similar to the space industry, incumbent nanotechnology firms were not the primary actors in creating consumer markets for the

products they had developed (Woolley, 2013). Suborbital space transportation companies have yet to deliver their service for paying customers, and the U.S. government is continuing to be involved through multiple agencies, programs, and procurement activities. In this way, because of differing kinds of government involvement, evolution of the space industry is different from that of nanotechnology.

Studies are rare that investigate the emergence of a high-technology industry, combining the functional goal of accumulating necessary capabilities, resources, and power, and enacted by industry actors interconnected as a social system. This may be because the innovation development meta-theory, and the resource accumulation framework used in this study, are relatively new (originally published in the late 1980s). Also, this type of industry analysis requires in-depth and detailed understanding of the industry, using data collected from multiple sources and in multiple ways, to ensure high levels of reliability and validity. The task of data collection may be less difficult for industries that have experienced emergence and evolution since the internet became popularized in the late part of the twentieth century, because web logs (also known as “blogs”), focusing on that industry specific sector, may now exist. These blogs, often staffed by enthusiasts, amateurs, or professionals, aggregate many types, and large quantities, of secondary data sources about the subject industry. Aggregated documentation of emerging industries by enthusiastic bloggers may permit an increased number of studies of this type in the future. The analysis methodology and data collected for the current research are the topics of the next chapter.

3. METHODOLOGY & DATA

This chapter is comprised of two major sections, first describing the methodology used to answer the research question, and then providing a detailed justification for the methods selected. This research executed an HEA and created an industry emergence chart through data collection from multiple secondary sources, and augmented with the results of different industry analyses and primary data collection. The resulting chart of HSSTI emergence permitted the induction of the proposed processes within each first-order IIE, thereby extending the current accumulation model.

3.1 METHODOLOGY DESCRIPTION

The paradigm of this research is scientific realism (Azevedo, 2005; Baum & Rowley, 2005; Suppe, 1989), embracing the strength of applying multiple models and frameworks to a problem. This research employed qualitative methods to conduct an HEA, where the unit of analysis was the “event,” and the level of analysis was the “industry” (or population). The researcher collected secondary and archival data to identify significant industry incidents. Analysis perspectives of industry-level structure (Porter, 1980) and evolution (Christensen, 1997) were also incorporated. Aggregating these inputs helped identify significant events that defined the industry’s path of emergence (Van de Ven & Garud, 1989). Primary data, collected via personal interviews, validated and answered questions raised in the secondary data, as well as provided additional insights into the HSSTI emergence. These inputs permitted a longitudinal case study of inductive reasoning (Eisenhardt, 1989) for the purposes of understanding HSSTI emergence, and extending the existing theory. The proposed industry-level processes of industry

emergence resulting from this study are new and testable. This section provides more details of the research methodology.

Grounded theory is defined as “the discovery of theory from data” (Glaser & Strauss, 1967, p. 1). Perceptions of industry study deficiencies are partly because

“much normative literature on organizing for environmental analysis is not based on a grounded theory of organizations; thus, many of the prescriptions applied by corporations are overly rational. Basic phenomena such as intra-organizational power relationships, the inherent structure of decision processes, and effects of environmental contingencies on business- and corporate-level administrative structures and decision processes are often ignored” (Lenz & Engledow, 1986, p. 342).

This study uses grounded theory building to extend an existing theory that describes a specific type of industry emergence. This research extends the accumulation model within the functional goal category of innovation development theories, describing the relationship between internal (typically referenced as “industry”) and external (typically referenced as “governmental”) actors. The current accumulation model (Garud & Van de Ven, 2000) is strong in structure, but lacking in process detail. The grounded theory model extension methodology is well suited to the proposition of industry-level processes, because “grounded theories themselves have meaning only if they can be related to what we already know (existing ideas or theories)” (Gioia, Corley, & Hamilton, 2012, p. 24), and “grounded theory research presumes a level of semi-ignorance or some suspension of belief in the received wisdom of prior work” (Gioia et al., 2012, p. 23). The data collected may not fully support the proposed processes developed in this research,

but this is not unusual. As Gioia, et al. (2012) explain, sometimes “the data structure does not account very well for chains of events and interactions among concepts. That accounting, however, is the purpose of the subsequent grounded theory development, for which the data structure serves as a content substrate for the coming process model” (p. 28). Furthermore, Poole and Van de Ven (2000) assert that “any grounded theory that emerges out of the foregoing interaction between field observations of innovations and theories of development requires testing to evaluate its validity” (p. 659). This approach is ultimately productive, because “inductive theory development efforts grounded in concrete and rich field observations are more likely to lead to significant new insights than deductive armchair theorizing approaches” (Van de Ven, 1992, p. 220).

To conduct the HEA, this research identified individual firm-level incidents (the units of analysis), and combined them, sometimes many of them, into relevant HSSTI-level events. For example, the announcement of an upcoming flight test may occur many weeks or days before the flight, followed by another announcement in the days prior. Those, along with the different accounts of the flight test, and even reports that might occur days or weeks afterwards, are all individual incidents that combine into a single event: the flight test. Multiple events typically followed predictable sequences, describing the evolution of firms, certain legislative or regulatory actions, or industry-wide events (e.g., conferences). For example, firm creation might follow a funding investment event, and precede a sequence of manufacture and assembly events of its flight vehicle. Another example could be the passage of a law, followed by the funding of a firm via a tax credit, that leads to subsequent private investment, etc. Successful completion of this analysis resulted in an industry emergence chart, and provided a visual depiction of the

longitudinal evolution of HSSTI firm life-cycle events (e.g., foundings, exits), a deep industry context, basic metrics of industry emergence (e.g., number of conference and journal articles about the industry, etc.), and details of many types of funding.

Identifying important contributing events of the HSSTI required data collection and analysis of individual incidents. The fundamental datum of these analyses is the individual event, defined as “an incident when change occurred” (Van de Ven, 1993a, p. 33) in each of the accumulation model framework elements. This research initially collected data from industry blogs, primarily including NewSpaceWatch (spanning the time period of August 2012 through today). NewSpaceWatch was the most recent incarnation of a series of blogs, curated by the same individual, including RLV Transport News and HobbySpace, spanning the time period between April 1999 and July 2012 (NewSpaceGlobal, 2015). Of the approximately 28,000 entries available in the website archives, over 8,400 records of incident data were relevant to the HSSTI for the blog coverage dates of 26 April 1999 and 31 December 2016. Individual records relevant to the industry (i.e., HSSTI incidents) were identified by searching the records for text strings that were general descriptors of the industry (e.g., “suborbital,” “spaceport,” “spaceship,” or “prize”), roots of the HSSTI firm names (e.g., “XCOR,” “Virgin,” or “Blue”), and roots of the spaceport names or acronyms (“Mojave,” “OSIDA,” or “NMSA”).¹⁰ Additionally, other valuable sources of information included company web

¹⁰ The complete list of search terms related to spaceports alone includes: “spaceport,” “brownsville,” “oklahoma spaceport,” “osida,” “texas spaceport,” “mojave,” “nm spaceport,” “nmsa,” “wallops,” “spaceport america,” “california spaceport,” “cape

page archives, other web logs, and the traditional media research databases (LexisNexis was employed particularly for incidents and events prior to April 1999 and after December 2016). These sites provided data from various types of secondary archive documents, including press releases, publicly available government documents, conference presentations, news media reports, editorials and commentaries, etc. Secondary data collected after December 2016 did not originate from NewSpaceWatch.

Each incident record underwent a two-stage process of categorization and association of events to framework elements. The event categories and their definitions included: (a) meetings, expositions, and conferences (announcements, milestones, conclusion, and retrospectives of ~); (b) launches (announcements of, milestones for, and results/conclusions of ~); (c) hardware testing (announcements, milestones, and results/conclusions of ~), (d) raffles, or other types of games of skill or chance (the announcements, milestones, or conclusions of ~); (e) individual speaking engagements or interviews (the announcement, profile of, plans for, milestones, or conclusion of ~); (f) organizations or government agencies (the creation/entry, profiles, plans, activities, partnerships, milestones, marketing announcement, milestone forecasts, conclusion, retrospective, or exit of ~); (g) government programs (the announcement of, reactions to, milestones of, conclusion of, or retrospective of ~); and (h) bills, legislation, or laws (the introduction, passage, signature, enactment, or enforcement of ~). The HEA categorized

canaveral spaceport,” “cecil field,” “colorado spaceport,” “florida spaceport,” “front range,” “kodiak,” “mid-atlantic regional spaceport,” “poker flat,” “sheboygan spaceport,” “spaceport florida,” and “west texas spaceport.”

each record by the type of event (or sub-event) and its life-cycle stage. Event life-cycle stages included: (a) start, entry, or introduction, (b) a retrospective, profiles, plans, information, activities, partnerships, reactions, or forecasts; (c) milestones; (d) conclusion, exit, or passage; and (e) retrospective, or future plans. Finally, not every combination of event category and stage was an actual event. From the 8,400 HSSTI incidents, the categorization process identified approximately 600 events.

Analyzing the data involved chronologically ordering each event within the framework elements, and identifying temporal interdependencies between them (Van de Ven, 1993a). The resulting industry emergence chart (Garud & Van de Ven, 2000) was a complex web of lines and arrows that easily overwhelms most casual observers, but which provided ample opportunity for in-depth description and analysis (Appendix B on page 222). The vast majority of historic events easily fit into the accumulation model framework. The industry emergence chart traced a storyline that describes how individual firms entered the industry, sought and acquired financing, interacted with regulatory agencies, conducted vehicle design, assembly, testing, and operations, and, in some cases, exited the industry. The chart also showed relationships between supporting facilities (such as spaceports) and firm activities, and activities that support the creation of knowledge and market resources.

In addition to the secondary data and archival data used, this research also collected primary data through 40 semi-structured personal interviews with members of the HSSTI. Interviewees represented HSSTI private firms, trade organization, the regulator (FAA AST), government executive branch agencies (including NASA, the Office of Management and Budget, the Office of Science and Technology Policy), the U.S.

legislative branch, industry consultants, conference organizers, and supply chain members. The University of Cape Town (South Africa) conducted and granted the initial ethics review for this research. Research ethics required additional reviews and written concurrence by each interviewee's current employing organization in the U.S., due to differences between South African and U.S. policies on research involving humans. Each interview was approximately one hour in duration (for a total of approximately 40 hours of interviews). The researcher digitally recorded, and employed a commercial service to transcribe, each interview. The researcher also coded each transcript using the contextual analysis software, NVivo. The collected primary data validated and supported both the identified HEA events and the proposed accumulation model processes.

In addition to the collection, categorization, and analysis of secondary incident data, the researcher conducted an industry structural analysis (ISA) to provide the industrial organization economic perspective to this study. The ISA is based on industrial organization economics, and the Bain-Mason paradigm of "structure-conduct-performance" (Bain, 1968; Mason, 1939; Porter, 1980). Results of the ISA were based on responses to a list of questions (provided in Appendix C on page 223) derived from Porter (1980, pp. 3–29). These questions cover details for the five forces: the threat of entry by potential entrants, the intensity of rivalry among existing competitors, pressure from substitute products, the bargaining power of buyers, and the bargaining power of suppliers. The data collected for the ISA came primarily from secondary sources and previous studies (Davidian & Conrad, 2012). The researcher also identified the interaction effects between the seven entry barriers, using a method similar to the way mutual goal achievability is assessed in the "classic approach" to strategy formulation

(Andrews, 1980; Porter, 1980, pp. xvi–xx). Successful execution of the ISA provided the HEA with insights into the manufacturing and testing activities of the industry members, the industry vendor-supplier-distributor channels, and the industry consumer demand and firm competition.

Finally, the researcher conducted a disruptive innovation analysis (DIA) to provide an industry evolutionary perspective (Christensen, 1997, 2006; Christensen et al., 2004; Christensen & Raynor, 2003). As with the ISA, the DIA utilized secondary and archival data in response to a list of questions (given in Appendix D on page 234) derived from the disruption innovation citations listed. These responses provide details of the industry context, a definition of the analyzed innovations, and the target industry offerings. The DIA highlighted details of the history of the HSSTI precursor industry, sounding rockets, which, in turn, originated in, and evolved from, the military missile industry. The scientific community uses sounding rockets primarily for lofting experiments to high altitudes on suborbital trajectories. The DIA generated insights into the identities of potential and near-substitute markets. Finally, the DIA collected and used detailed descriptions of HSSTI product attributes. All of these results supported a deep industry understanding of the HSSTI, its “close ancestor” industry, and a possible glimpse into what its products’ characteristics might be, assuming the HSSTI ever evolves past the stage of pre-production operation. Although much of the ISA and DIA results were not suitable for inclusion in the HSSTI emergence chart, the exercise of these analyses increased the understanding of the subject industry, providing depth of insight that complements the grounded theory extension methodology.

After completion of the HEA, ISA, DIA, and the industry emergence chart, the researcher analyzed interactions between events (depicted in the chart by arrows) for patterns or repeating sequences, and recognized the process of general business development and evolution in the Proprietary Functions IIE. Analysis of the interactions between the IIEs provided indications of the content of the IIE linkages. The researcher then introduced elements of legitimacy to both the Institutional Arrangements and Resource Endowments IIEs, and proposed processes to link IIE second-order elements to their respective components of legitimacy. Identification of these processes make this research accessible to others by making the phenomena of industry emergence more explicit. These processes can also provide ideas for different metrics and indices for future testing. By combining the results of secondary data, the archival documents, the personal interviews, and the two independent analyses of the same industry, this research created a rich description of the history that was subsequently diagrammed, fitting within a slightly modified version of the accumulation model framework (described in the Discussion chapter). This deepened understanding led to, and supported, the proposition of legitimacy creation processes.

3.2 METHODOLOGY JUSTIFICATION

This section provides a justification of the selected methodology for the theoretical contribution made by this research, describes the underlying philosophy of the research paradigm, and how the selected method is consistent with the literature. The discussion also describes how the researcher ensured accuracy and validity of the research findings, and avoided and controlled errors (to the greatest extent possible).

The scientific realism research paradigm, emphasizing that “multiple perspectives and research methods are essential” (Baum & Rowley, 2005, loc. 751), downplays the positivist philosophy, and recognizes that the perception of any industry context can be different, based on the observational “lens.” Each perspective is analogous to one of many blind men surrounding an elephant (Mintzberg et al., 2005). The philosophy of this research, therefore, also rejects a purely relativistic philosophy with the assertion that there are a finite number of relevant perspectives. The realist philosophy realizes the need for a select few perspectives, relevant to the particular stage of industry emergence and evolution being studied, and based on situational contingencies. This phenomenological case study of single-industry emergence uses qualitative methods and applies inductive reasoning for the purpose of grounded theory extension. The result is an HEA, where the unit of analysis is the “event” and the level of analysis is the population (industry). The researcher chose the method of merging the results of different data sources and analyses over other possible methods, or any individual method. This resulted in a rich and detailed history of the industry emergence, and it allowed for the incorporation of data from multiple organization theory perspectives. Also, the accumulation model provides a comprehensive perspective of the emerging market as a social system, beyond an isolated economic system, where efficiency, personal interest, and financial rationality are the underlying assumptions (Fligstein, 2001; Parsons & Smelser, 1956; Poole & Van de Ven, 2000).

This method is consistent with the literature because each component analysis (i.e., HEA, ISA, DIA) is methodologically consistent with the literature. These analyses also meet the criteria for data results that are logical, generalizable, dependable, and

confirmable. The data is logical because it has been validated through triangulation (Jick, 1979) of secondary and primary sources, thereby ensuring internal validity to the maximum possible degree. A common question about this study's data generalizability is based on the observation that the number of firms included in the HSSTI is so small (there is a total of five firms altogether, but only two are active as of the time of this writing). In fact, because this is a process study and not a variance study, the relevant metric is not the number of firms under investigation, but the number of events used to describe the phenomenon under investigation. The generalizability of the results may be relatively high, therefore, because of the large number of incidents and events used to describe the HSSTI emergence. Section 5.6, later in this thesis, discusses of the generalizability of these research results to other industries. The data is dependable because of triangulation (with both secondary and primary sources), and there is a well-documented audit trail by which the researcher can identify, examine, and correct any data discrepancies (if need be). The data is confirmable because it is based on public events covered in the popular and trade presses, and validated by eye witnesses or individuals who personally contributed to individual incidents.

Although the purpose of this research is to identify and illuminate accurate representations of reality, it is possible that the findings do not accomplish that goal, in whole or in part. To minimize these types of errors, the researcher made a continuous effort to avoid known and knowable traps and biases, both of data and reasoning. Much of the datum, used to describe individual incidents, include information that has very high accuracy and precision simply due to the nature of the information. The precision of dates was to the level of the day, and the precision of locations was to the level of the city.

Incident and event descriptions were qualitative (narrative) in nature, and the level of detail provided in archived data and personal accounts were reasonably, and sufficiently, accurate and precise. For all these reasons, there is no reason to believe that the data contains levels of error that would alter the results in a significant way.

This research benefited from active and continuous practice of validation of data integrity and logical reasoning. Where possible, the researcher addressed internal validity (an indication of logical reasoning, consideration of alternative concepts, and overall credibility) through triangulation of individual HSSTI incidents events using multiple secondary sources of data. Additionally, personal interviews (as described above) provided validation of specific events. The interviews conducted for this research were effective data member checks of data validity. Time sampling of data was not applicable in this research project. Multiple analyses (i.e., the HEA, ISA, and DIA) used to analyze the emergence of the single industry enhanced the external validity (related to transferability or generalizability of the results). Triangulation (as mentioned previously) enhanced the objectivity (confirmability) of the data and results, as did the notation of all major decisions, processes, and routines. This allowed for consistent application, repeated scrutiny, and error detection/correction (if any), during the entire research activity. The thorough note-taking also created an audit trail of the research methods employed, allowing for a strategy of examining (and adjusting or correcting, if necessary) the data and processes on multiple occasions. In combination with the “code-recode” capability and data triangulation, the existence of this type of “audit trail” helped ensure data reliability (dependability).

The researcher took many precautions not to introduce or create errors within the project. Careful and continual evaluation of the data ensured its accuracy and validity. The researcher repeatedly questioned, evaluated, and tested the logic and reasoning through interactions with experienced primary data sources. Data collection from trusted and established sources helped minimize errors, and avoided relatively new, dubious, or unverifiable sources of information.

Errors of historic incidents and events may occur due to sloppiness of reading, transcription, or other human perception error. Triangulation validation, and the use of other primary and secondary sources of data, helped minimize these types of errors. The researcher made every reasonable effort to ensure validation through triangulation. For concepts more complex than simple incidents and events (such as identification of institutional and cultural norms), errors of interpretation are also possible. Methods employed to minimize interpretation errors included validation through direct questioning of multiple primary data sources. Often, interviewees expressed multiple interpretations of a seemingly obvious concept, and the researcher incorporated these alternative ideas into the findings of this study.

3.3 DATA

Extension of the accumulation model framework required an understanding and depiction of the HSSTI emergence to a sufficient level of detail, richness, and nuance. The researcher accomplished the collection of required data through the execution of three analyses: the HEA, ISA, and DIA. These analyses required many different primary and secondary data types to collect sufficient amounts and quality of information. The fundamental data requirements include many incidents, events, and metrics, gathered

from secondary sources, but validated and supplemented by primary data collection. The three analyses also required supporting data to create a comprehensive story of industry emergence. The following sections provide details of these contributing data components.

Identifying important contributing events of the HSSTI for the HEA, ISA, and DIA required data collection and analysis of individual incidents. The fundamental datum of these analyses is the individual event in each of the accumulation model framework elements. The researcher primarily collected data from a comprehensive news aggregator site, collecting many different types of data sources. The researcher also consulted a secondary aggregator site that commonly identified the same industry incidents, and provided links to the same sources as the principle site. The benefit gained from the secondary site was marginal at best (i.e., very little new information was found). The researcher also queried other valuable sources of information, including company web page archives, other web logs, and the traditional media publishing sources and databases (especially for incidents and events prior to April 1999 and after December 2016).

The ISA and DIA utilized the same set of information sources as those listed for the HEA. The DIA, however, also relied upon on-line databases of rocket flights (planet4589.org and space.skyrocket.de), an astronomical encyclopedia (astronautix.com), and the user guide documents provided by the two major vehicle operators to collect additional data. Both the ISA and DIA relied, to a certain extent, upon subjective assessments by the researcher. For example, the ISA required estimates of the strength of the five forces due to the lack of available quantitative measures. Earlier sections of this thesis described the sources of all the data employed.

The compilation of information about individual incidents into the distinction of events “when change occurred” was the goal of the data collection work. Events were the primary units included in the HSSTI emergence chart. The chart spans seven decades, starting with the earliest events (dating back to the early 1950s) until the present day.

The researcher filtered the required data for the HEA to extract the information from multiple incidents that comprised an individual event. For example, a vehicle flight test event could appear as many public relations press release incidents prior to, during, and after the event. Articles in periodicals included individual incidents that appeared both before and after the single event. Biographical information about the vehicle pilots would appear as an announcement before an upcoming appearance event, and newspaper accounts described the event afterwards. This filtering process reduced the 8,400 incidents down to approximately 600 events.

The identification and use of multiple data sources maximized HEA data robustness. Data triangulation, maintaining records that permit a coherent audit trail, and a thorough description of industry emergence incidents and events maximized the reliability and validity of the data. The use of primary source interviews to validate or correct industry emergence incidents and events further enhanced data reliability and internal validity. The use of multiple sources for individual events (triangulation), and the conduct of interviews with individuals employed by the HSSTI firms enhanced external data validity.

A recognized limitation of the data collection and transformation process for the HSSTI HEA was the heavy reliance upon secondary data, diminishing the data confirmability (objectivity) and credibility (internal validity). Data triangulation and the

use of multiple sources were attempts to counter these limitations. Multiple secondary data sources in conjunction with triangulation addressed possible limitations of data reliability and dependability. The thorough documentation of the research design, detailed data reports, and description of the methodology used, and a cursory study of historical industry emergence analogs addressed limitations of generalizability from this study to other emerging industries.

Given the strengths and limitations of the research methodology described here, the data results are presented next, providing a detailed description of HSSTI emergence dating back to the 1950s, but more recently due to the initiating “shock” (Schroeder, Van de Ven, Scudder, & Polley, 2000) of the 1996 X PRIZE announcement.

4. RESULTS

The first part of this chapter describes the results of the three analyses conducted to understand the development of the emerging HSSTI through the lens of the accumulation model framework. The HEA identified specific HSSTI events for the three IIEs of Institutional Arrangements, Resource Endowments, and Proprietary Functions. The ISA and DIA further enhanced the evidence, and extent, of IIE construction. The results describe and discuss the interactions between the three IIEs. The HEA provided the foundation for the industry emergence chart, depicting the interrelationships of individual firms, their market activities, sources of required resources (e.g., knowledge, personnel, and funding), and their various encounters with institutional entities. The HSSTI emergence chart clearly shows industry as an interrelated social system (instead of an isolated economic system) as defined by the accumulation model. The industry emergence chart identifies and maps specific events into each of the accumulation model's first-, second-, and third-order elements (listed in Table 1 on page 12).

4.1 INSTITUTIONAL ARRANGEMENTS

The Institutional Arrangements IIE is the initial first-order element described below. The original framework consists of three second-order elements: Legitimation, Governance, and Technology Standards. This section details the HSSTI events for each of these second- and third-order elements.

4.1.1 Legitimation

The initial second-order element of the Institutional Arrangements IIE is Legitimation. Van de Ven and Garud define “legitimation” as “the creation of trust” (Van de Ven, 1993a, 1993b, 1993c), but, according to other definitions, legitimation also

results in reputation (Rao, 1994), “market category’s meaning, the formation of categorical and organizational identities, and perceptions about the viability of the business model” (Navis & Glynn, 2010, p. 439), for example. Legitimation of a new venture or industry involves an “approving social consensus” (Blau, 1964), “acceptance by key stakeholders, the public, key opinion leaders, and government officials of a new venture as appropriate and right” (Aldrich, 2005), and the acceptance by new firms and industries that “certain practices or forms are appropriate” (Palmer & Biggart, 2005), with the intention of increasing their chances of survival. To encompass the many definitions of the word, this research defines “legitimation” as “processes that create legitimacy.” Legitimacy leads to trust from society by demonstrating that the “actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions” (Suchman, 1995, p. 574). Within the accumulation framework, the original second-order element Legitimacy includes third-order elements of Guarantees, Licensing Practices, Industry Regulations, and Endorsements. This research sought and found evidence of these elements within the HSSTI, as described below.

Of course, there is no such thing as a “100% guarantee” in practice, but the closest comparable thing in the aviation community, included in the third-order element of Guarantees, is the certification of a vehicle type or design. Certification “guarantees” the safe carriage of passengers that board the aircraft. An equivalent guarantee for HSSTI vehicles does not yet exist. Currently, FAA AST can issue safety approvals, which affirm that a given product (good or service) offered by a firm performs as advertised against some set of criteria, as determined by the firm itself. The company makes the criteria

public so that others could replicate that level of performance (if they so desire), and to encourage the adoption of voluntary consensus standards within the industry. The intention of the safety approval is to allow the company to obtain a “pre-approval” of their product in order to streamline the launch licensing process. It can also be beneficial to the company in its business development efforts, offered as evidence that the product meets its advertised capabilities (hence, the moniker of “guarantee”).

“The company has an opportunity to have a government entity take a look at what they’re doing, and basically give what I sometimes refer to as a “Good Housekeeping Seal of Approval” if you will, that the government has looked at this process, and has agreed that it does what the company says it does, which they could find very helpful in their future business development and engagement with the rest of the industry. They can sell their wares, basically, with this review having been completed by the government already.” – HSSTI Regulator

The FAA AST issues safety approvals for a period of 5 years, and renewals result in a revision to the existing safety approval (not the issuance of a new safety approval). Specific to the HSSTI, AST issued safety approvals to companies and organizations for a suborbital human spaceflight and microgravity environment simulators, an altitude chamber training facility, and a variety of crew and spaceflight participant training programs (including scenario altitude training, crew and spaceflight participant training, and a certified aerospace technician credentialing program). Appendix E lists all FAA AST safety approvals issued in support of the HSSTI as of the time of this writing.

The third-order element of Licensing Practices for the HSSTI include the issuance, renewal, suspension, or revocation of licenses, experimental permits, waivers, or any other regulatory instrument. The types of HSSTI licenses issued (and renewed) by the FAA include experimental permits, launch operator’s licenses, and launch site (i.e., spaceport) operator’s licenses. The process of obtaining a launch license starts with a pre-application consultation. After submitted and deemed to be “complete enough,” then AST conducts a policy review, a safety review, a payload review, a financial responsibility determination, and an environmental review. After issuance of the license, AST conducts compliance monitoring. By law, the FAA cannot take more than 180 days to make a license determination decision. Operation of HSSTI vehicles require licenses when the operator wishes to receive compensation for hire (i.e., getting paid for providing suborbital flights). The experimental permit, available for HSSTI vehicles since 2004 (Commercial Space Launch Amendments Act, 2004), is an abbreviated version of the launch license permit, limiting the time of determination to 120 days. Between September 2006 and February 2016, AST issued ten experimental permits, split between two HSSTI firms (listed in Appendix F). During approximately the same time period (April 2004 to July 2016), AST issued eight launch licenses to four HSSTI firms, including one to a vehicle that only existed “on paper” (listed in Appendix G). From June 2004 to June 2015, FAA AST issued or renewed operator’s licenses for six separate HSSTI spaceports (listed in Appendix H). Of the six HSSTI launch site operator’s licenses issued, two spaceports are currently active, or under contract to be active in the future, both to the same HSSTI firm. The other active HSSTI firm flies from its own launch site that does not require a license to operate, because it is a “private use spaceport.” The small number

of issued launch and spaceport licenses is an indication of the HSSTI pre-production status.

The third-order element of Industry Regulations includes certifications or industry licenses for manufacturing, design, engineering, etc., guidelines (whether adopted or not), proposed by industry or government entities. Examples include guideline documents issued from the safety organizations (IAASS, 2013) and the FAA AST (2017b). At the current phase of HSSTI emergence, there are no industry regulations adopted by all the HSSTI firms. FAA AST (2014) released a document of recommended practices with the hopes that the content would be a good starting point for the development of industry-developed regulations, but that has not yet happened.

Both public- and private-sector actors contribute to the third-order Endorsements element of the emerging industry. When initiated by the HSSTI public-sector, these activities include public acknowledgement of HSSTI milestones (Hales, 2005) and the establishment of public-private partnership agreements (“NASA Space Act Agreements,” 2017). The simple association of the HSSTI firm with a well-established federal agency provides high levels of legitimacy, whether through a funded relationship (as with a reimbursable or funded agreement) or an unfunded relationship (referred to as a “non-reimbursable” agreement). Between NASA and HSSTI firms, there were a total of 14 agreements and amendments between 2012 and 2015 (see Appendix I). Self-endorsements by the private-sector include many forms of corporate political activity, including interactions with the general public, their constituency (fellow industry members), policy-makers (primarily in the legislative and executive branches of government), and other forms of action (both internal and external to the firm). Although

corporate political action is commonly performed discretely, some data is available in the U.S. due to the passage and amendment of the Lobbying Disclosure Act in 1995 (2007). The expenses of HSSTI firms for activities of lobbying and campaign contributions (through political action committees), are indicators of the HSSTI private-sector actors endorsing their programs, capabilities, and perspectives to public-sector actors in the legislative branch of government. Private-sector endorsement activities to public-sector actors in multiple executive branch agencies also took place, although there is no quantitative data available. The following quotes from actors in both sectors emphasize common themes repeated by multiple executive branch individuals (including from the Office of Management and Budget, NASA, and the FAA AST), and participants from the HSSTI firms:

“you’re going to folks in the White House and other places, and every four years sometimes there’s turnover, so it’s an educational process there.” – HSSTI Firm Employee

“At [the Office of Management and Budget] we had numerous people come in for visits to share their ideas for things they wanted to do, through informational and capabilities briefings. Same thing at NASA... a lot of people coming in and sharing ideas and capabilities.” – Government Executive

“...we would be the friendly front door, so to speak, where people who were working the programs would want to keep us informed. We wanted to be up to date on who had what money, who had been raising, who was

trying to raise, and also the issues that people would have, challenges they've had with the program.” – Government Economist

“This has been [a] pretty cordial interaction with them and of course, they always tell us what their interest is, and then we tell them what we can do legally and within the scope of our program. I know that sometimes they may ask us more than what we could do, and we say, “Hey, this is the limits we have.” – Government Executive

4.1.2 Governance

Governance is broadly defined as “the general rules in a society that define relations of competition and cooperation and define how firms should be organized” (Fligstein, 2001, p. 34). Following Legitimation, Governance is the next second-order element of the Institutional Arrangements IIE. Discussed below are the third-order elements of Norms and Rules, Regulations, and Laws (Van de Ven, 1993b) within the Governance framework element.

From a governmental perspective, norms include non-binding resolutions, but from a broader sociological perspective, norms can be defined as “informal rules that facilitate, motivate, and govern joint action of members of close-knit groups” (Nee, 2005, loc. 2432), “commonly or widely shared sets of behavioral expectations” (Pfeffer & Salancik, 1978, p. 147), or “how things should be done; they define legitimate means to pursue valued ends” (Scott, 1995, p. 37). Within the Norms third-order element, this research recognized accepted American business practices, cultural worldviews, and assumptions as influencing interactions of the HSSTI (because of the U.S. provenance of the active firms), but norms which were more specific to the space industry in general were also of

primary interest. During the interviewing process of different individuals from the public- and private-sector HSSTI organizations, a number of space industry norms emerged. The space industry norms were not necessarily particular to HSSTI actors, but deeply engrained within the group. Norms identified and discussed with interviewees include the following: (1) government is the only “reasonable-risk” customer for human spaceflight, (2) safety (in human spaceflight) is the most important consideration in trade-off decision-making (especially involving cost considerations), (3) space industry individuals are highly enthusiastic about space, (4) commercial success in human spaceflight ventures requires large amounts of capital, (5) international cooperation is important, and (6) government has an important role in the commercial space industry.

In addition to norms, this research also identified rules of the HSSTI for inclusion of the third-order element of Norms and Rules. Rules include “contract law; billing practices; banking and credit rules; insurance, health, and safety standards” (Fligstein & Sweet, 2002, p. 1207). They establish “weights, common standards, shipping, billing, insurance, the exchange of money (i.e., banks), and the enforcement of contracts” (Fligstein, 2005, loc. 7753), and they “define who can transact with whom and the conditions under which transactions are carried out” (Fligstein, 1996, p. 658). All these forms of rules are generally well-established and enforced in the U.S., but rules also include treaties. The international treaty on the peaceful uses of outer space (US Department of State, 1967), provides the legal basis for the regulatory framework adopted in the U.S. and executed by FAA AST. In a similar vein, a set of recommended practices for HSPs, and a guidance document for informing HSPs of risk, were released by FAA AST (2014, 2017a).

Regarding the third-order element of Regulations, different countries perceive HSSTI activity differently, and therefore want to regulate it differently. The European approach is to regulate HSSTI vehicles as airplanes that go to space, since the outer space treaty does not consider suborbital vehicles as “space objects.” However, the U.S. is regulating these vehicles as spacecraft that spend a fraction of their flight time in the national air space. In 2006, the FAA AST issued a final rule for crew and HSP requirements (2006) “to protect the safety of the uninvolved public. They also call for measures that enable passengers ... to make informed decisions about their personal safety” (David, 2006). Currently, FAA AST regulates to ensure the safe operation of the vehicle, and the extent to which the crew is involved with operational safety, the regulations apply to them as well. By law, however, the FAA AST does not currently regulate the safety of HSPs. This is because HSSTI members have expressed the desire to minimize regulations, by having a temporary period of time, referred to as the “learning period,” during which the FAA withholds this category of regulations, while the industry matures.

Other forms of regulation exist that either support or supplement the licensing and permitting activities mentioned above. The supporting regulation activities include evaluations of safety, expected casualties, and possible financial liabilities of a launch or reentry operation, the environmental assessments, and the evaluation of policy conformity across the different agencies of the U.S. government. A prominent additional regulation is the International Trade in Arms Regulation (ITAR). The barrier of entry represented by ITAR is estimated by private-sector entities as being very high because it restricts many aspects of doing business in the HSSTI, including employment (firms cannot hire non-U.S. citizens), companies with whom you can partner and do business

(limited to U.S. companies almost exclusively), companies with whom you can share information (again, U.S. companies only, with some exceptions), whether you can export your product, and who your customers can be or what they are allowed to see (C. Nelson, Bolton, & Maynard, 2014). ITAR has a real impact on HSSTI firms, highlighting the difference between governmental (national) and commercial activities, and driving some details of their business plans:

“from a human training and safety perspective, we use a device that is on the [U.S. Munitions List] and ITAR controlled, so we did submit a commodity jurisdiction request which was successful so that we could train participants for space. Typically, for our military clients, we get issued a ITAR license for that country, but in commercial space we train individual participants from a lot of different countries...and this process just doesn't make sense.” – HSSTI Firm Employee

“I developed a wet lease model, which kept all of the control and ownership of the vehicle within [our firm], or [we] designated city areas or entities underneath the control of a U.S. entity. And, of course, [we] put a U.S. person in those positions overseas and worked pretty extensively with State Department on that.” – Former HSSTI Executive

The environmental regulation barrier is restrictive because it requires a lengthy period of time and large amount of money to ensure compliance, typically performed by a third-party, costing hundreds of thousands of USD, and requiring 12-24 months' time. Less burdensome are the safety, expected casualty, policy, and financial responsibility evaluations. Overall, the regulatory burden on HSSTI actors favors larger firms with

surplus resources (e.g., time, money, personnel, and information) to accommodate the regulatory requirements. In response, firms may hire personnel, or consultants with relevant experience, to provide the necessary information, or may take advantage of parent company experience in another industry for application to the HSSTI context.

The U.S. Congress passed three laws to establish the regulations discussed above. The Commercial Space Launch Act (1984) established the commercial space sector within the U.S., identified the Department of Transportation as the regulatory authority, established the “learning period” during which regulations on HSPs were not permitted, and also became the enabling statute for the licensing of launch, reentry, and launch and reentry site operations.¹¹ Later, the Commercial Space Launch Amendments Act (2004) established experimental permits relevant to the HSSTI, and extended the end date for the “learning period.”¹² Next, passage of the Commercial Space Launch Competitiveness Act (2016) again extended the end date for the “learning period.” On the state level, the legislatures of California, Florida, Georgia, New Mexico, Oklahoma, and Texas passed many laws related to the HSSTI. In general, these laws pertained to topics of limited liability, informed consent for HSPs of known spaceflight risks, tax exemptions for HSSTI firms, and the establishment and funding of spaceports.

¹¹ An executive order transferred this authority to the FAA in 1995.

¹² These were the provisions relevant to the HSSTI. Other provisions in this bill, not listed here, are not relevant to the HSSTI.

4.1.3 Technology Standards

The final second-order element of the Institutional Arrangements IIE is Technology Standards. This section discusses the three categories of technical standards as related to the HSSTI, including Government Regulatory Mandates, Cooperative/Voluntary Industry Standards, and Market-Driven/de facto Standards.

Government Regulatory Mandates include standards mandated by government regulatory agencies. To date, the FAA AST has been hesitant to impose standards on the emerging HSSTI. Cooperative/Voluntary Industry Standards include collaborative initiatives on the part of government and industry participants. HSSTI industry participants include federal advisory groups (e.g., the Commercial Space Transportation Advisory Committee - Standards Working Group), national and international organizations (such as the Commercial Spaceflight Federation [CSF], and the International Civil Aviation Organization), and standards-setting organizations (such as the American Society for Testing and Materials [ASTM] International). Most of these groups recognize the need for industry standards, and some have actively attempted to generate standards through cooperative action, with limited success, and despite the inherent difficulties the process entails.

“Developing standards is an activity that takes time. Startups, especially the small companies, don’t have the time to participate. They’re fighting for survival. It’s difficult to get people to support a time-consuming effort with no immediate financial return. It’s becoming easier, though, in the current investment environment. Today, the space investment climate is comparable to “dot com” investment climate of the 1990s. Startups are

well-capitalized and can afford to put in the effort today to save a lot of regulatory grief in the future. I think one of the reasons that the consensus standards didn't arrive earlier is that none of the small guys could participate, and they were afraid that the big guys, who had the wherewithal, would write the standards and use them as a weapon. After having dealt with AST for an interminable length of time, space companies large and small are discovering they'd rather have standards, and that it's worth the investment." - Former HSSTI Entrepreneur

Market-driven/de facto standards are those “imposed by a dominant producer” (Van de Ven, 1993b, p. 217), which does not yet exist in the HSSTI. Because there are no HSSTI firms delivering a service for compensation or hire, there are no de facto standards, created or adopted. Standards that have carried over from the space industry at large do exist, however. For example, standards accepted by the HSSTI include the handling of liquid propellants (such as oxygen and hydrogen), and the siting of propellant tanks. To avoid imposing standards upon the HSSTI firms, FAA AST released more than two dozen non-binding documents, including advisory circulars, guidelines, and other guidance documents, as foundations upon which industry standards could be based.

4.2 RESOURCE ENDOWMENTS

The second first-order element of the accumulation model framework is Resource Endowments, consisting of three original second-order elements: Scientific and Technological Research, Financing and Insurance Arrangements, and the Human Competence Pool. This section describes the construction of each, by public- and private-sector HSSTI actors, down to the third-order elements.

4.2.1 Scientific and Technological Research

The Scientific and Technological Research second-order element includes knowledge and technical inventions primarily from government sources external to the firm, typically in the form of government contracts, research grants, or a category of acquisition instrument referred to as “other transaction authority.” Recipients are typically private-sector firms, non-profit research organizations, or universities.

The first series of government contracts for technologies and vehicle research directly related to the HSSTI dates back to the mid-1950s, and finished in the early 1970s. The U.S. military conducted seven major experimental (abbreviated as “X”) vehicle programs during that time, the most famous of which was the X-15. Large generalist aerospace firms were the recipients of those contracts, and the capabilities gained during these programs contributed to the U.S. space program. In more recent activity that started in the 1990s, the government researched more HSSTI component technologies with the “Delta Clipper” (also known as the “DC-X”) program under government contract (begun by the Strategic Defense Initiative Office, then passed to the Defense Advanced Research Projects Agency, DARPA, and finally handed-off to NASA). Although ultimately cancelled in 1996, the DC-X was the initial foray into reusable, vertical take-off and vertical landing, launch vehicles. DARPA’s “Responsive Access, Small Cargo, Affordable Launch” program next identified three technologies that would be essential to the success of the HSSTI. Although it only lasted four years before cancellation, preliminary design studies of airplane-like operations and flight profiles were studied, and became the basis for some HSSTI entrants. From 2008 until the present, other government contracts were competed and funded, both large and small in award amount.

Some of these contracts benefited firms that assisted in the HSSTI emergence. For HSSTI firms, there were a number of small business innovative research (SBIR) grants awarded by NASA and two U.S. Department of Defense (DoD) units (DARPA and the Air Force), ranging from just under one hundred thousand USD to one million USD (for a total of almost two million USD). All these grants went to only one of the five HSSTI firms operating between the years of 2003 and 2011. The larger contract awards, competed and awarded to HSSTI firms, were for capabilities or technologies that did not help the HSSTI emerge. For example, one of the HSSTI firms received a major NASA award for orbital launch technology and vehicle development. Similarly, DARPA initiated the XS-1 program in 2012 that was partially related to the HSSTI, and made multiple, small awards to teams that included, but were not led by, the HSSTI firms. Finally, the government awards scientific and technological research grants to principal investigators at universities. For many years, NASA and the DoD awarded many grants for the development of technologies that are, or could be, related to the HSSTI. The FAA AST funded research grants specifically for non-governmental space activities (which can be very different from research on governmental space activities) through a consortium of universities, known as the Center of Excellence for Commercial Space Transportation (COE CST). Between 2010 to 2016 inclusive, AST funded the COE CST with approximately 6.3 million USD in non-proprietary research, some of which is partially related to HSSTI technologies, and some of which is directly related.¹³

¹³ In the interest of full disclosure, the author of this research thesis has been the program manager of the FAA COE CST since its inception in 2010.

Space Act Agreements (SAAs), mentioned in a prior paragraph on Endorsements, and the Flight Opportunities Program (FOP), mentioned later in the discussion of the Market Creation and Consumer Demand second-order element, both had an alternative benefit to the industry by providing a mechanism for the transfer of technical expertise and know-how, from NASA to the HSSTI firm. The SAAs provided a way for HSSTI firms to access NASA engineers and their technical expertise directly:

“those broader Space Act Agreement activities are useful from a technology exchange basis. ... we have technology interchange meetings with NASA on a variety of topics. They are able to use that mechanism to say, okay, you don’t have to pay us for five people to sit on the phone for an hour. We’ve got an agreement, they have resources, they have a charge code they can charge. ... they’ve got great expertise and you can say, hey we’re running into this issue, how did you do it? If you want to talk about radiation hardening or whatever it is, seats or windows or however all those things are done. So we’ve had lots of [technology interchange meetings], and those are very useful.” – HSSTI Firm Executive

The FOP contract mechanism allowed a channel of communication between the experienced government agency and the inexperienced private firms. At first the small companies didn’t feel they had anything to learn from the government:

“initially they said, ‘Give us the money and go away,’ ‘We don’t need any government help,’ and ‘Well, we don’t really need your help other than maybe if you create a market for us, that’ll be great.’ That’s how they were standoffish.” – Government Executive

The initial rejection of help from the government had the potential, however, of being very dangerous:

“Out in Mojave ... they are trying to push the envelope and trying to really get beyond just being dependent on government. They rejected the government way of doing things on safety, on how to do all this stuff. And I think it’s led to some tragedies, frankly.” – Industry Analyst

Ultimately, however, the relationship between the HSSTI firms and NASA normalized, and the companies began benefitting from NASA’s experience and willingness to help:

“I think then their approach to NASA and approach to the program, they changed from that perspective, because then they say, ‘Hey, maybe we can get some help from government.’” – Government Executive

A potentially negative aspect of the government financing actions is that they provide an immediate opportunity for revenue generation (previously referred to as “opportunistic behavior”). This immediate opportunity had the potential to divert the firm’s activities from directly pursuing their concept of commercial demand (i.e., previously called “responsible behavior”). Driven by mere survival, firms felt the necessity to pursue immediate contracting opportunities that could result in revenue, but which could divert them, to some extent, from their market goals:

“We were actually opposed to government programs to develop new launch vehicles. But the prospect of the government putting investment into a competitor meant that we had to at least try to get that contract. Otherwise, investors would look at us and our competition and say ‘Well,

NASA is financing them. We can't compete with that.'” - Former HSSTI Entrepreneur

The effects, however, were potentially catastrophic:

“We were moving along, we would have been in flight test and probably in operation by 2008 or 2009 if it hadn't been for [a different government program], and we hadn't been distracted and ultimately bled out.” – HSSTI Executive

By pursuing alternative, revenue-generating goals, in lieu of the company's initial (primary) market goals, this introduced new risks for the company, as was the case when a vehicle developer began selling tickets:

“I never wanted to be in the consumer sales business, and ultimately, getting in the consumer sales business probably is what ultimately killed the company. I didn't want to get into that business because I thought, ‘That's an incredibly different business.’” - Former HSSTI Executive

4.2.2 Financing and Insurance Arrangements

As described by Van de Ven (1993a, 1993b, 1993c) and his colleagues (Van de Ven & Garud, 1989), the Financing and Insurance Arrangements second-order element includes multiple third-order elements, such as Private Organizations (Venture Capital within a corporation or in the market), or Public Institutions (unique industry-wide financing arrangements). In the HSSTI case, this is a fairly coarse delineation of the types of financial (not simply insurance-related) arrangements available during the time of industry emergence. As one of the theoretical contributions, and to better describe the diversity of investment arrangements that can influence the participation of actors (both

public- and private-sector) involved with industry construction, this research proposes alternative third-order elements within, and a slight renaming of, this second-order element. This research proposes to rename this entire portion of the framework from “Financial and Insurance Arrangements” to “Financial Arrangements,” to remove the emphasis on insurance arrangements that are not uniquely generalizable to other industries.¹⁴ These new third-order elements include SBIR Funding, Government Contract Funding, Government Grant Funding, Non-Equity Investments, Equity Investments, and Industry-Wide Stimuli. The government grants and contracts provided funding for research activities described in the previous section on scientific and technological research. The paragraph below picks up the discussion with non-equity investment, equity investment, and industry wide financial stimuli. The paragraphs below discuss each of these new third-order elements.

Included in the Non-Equity Investments third-order element are grants or loans that achieve economic development goals (Pages, Freedman, & Von Bargen, 2003). Although it is not possible to list all possible reasons for non-equity investments, they may include the appropriation of naming rights of programs or vehicles, for example. State and local governments provided investments in this category. One example was for 15 million USD in the form of transferrable tax credits to Rocketplane. Banks purchased these

¹⁴ The original research, conducted within the cochlear implant industry emergence, emphasized industry-wide insurance arrangements of the health care system. Retaining that emphasis in this research would seemingly limit the generalizability of the framework.

credits from the company at a discounted rate for 12 million USD. XCOR was another HSSTI firm to receive non-equity investment, including a three million USD loan from a state-level government organization, Space Florida, and ten million USD from a municipal-level government organization, the Midland Development Corporation (Copelin, 2013, 2014). The latter financial arrangement was a loan that would not have to be repaid, dependent upon the accomplishment of certain milestones. A non-equity investment, totaling 500 thousand USD by FAA AST, was made in 2010 to multiple spaceports that support HSSTI firms (Messier, 2011).

Van de Ven (1989) originally labelled equity investment in a single firm by private organizations as Venture Capital, but for this research has been renamed Equity Investment for two reasons: (1) to draw a consistent but clear distinction between investment for equity and non-equity purposes, and (2) to also include other types of investing organizations and individuals, not just venture capitalists. For example, some fraction of equity investment in the HSSTI has been on the part of individuals and small groups (e.g., angel investors). As one example of individual HSSTI investing, founders of Rocketplane put ten million USD of their own funds to help convince the Oklahoma state legislature to pass the creation of transferrable tax credits for that company:

“...our CEO and biggest investor ended up putting 10 million of cash into the Oklahoma company in order to meet the capital requirements, and that was enough to satisfy the tax commission. We got the certificate signed literally at 4:55pm local time on December 31st, just as they were closing the office when the bill was going to sunset.” – HSSTI Executive

Another individual investor, Paul Allen, invested a reported 30 million USD in the creation of Mojave Aerospace Ventures, a partnership with Burt Rutan (of Scaled Composites) in which Mr. Allen was majority owner. At the high end of individual investing, Jeff Bezos invested 500 million USD in Blue Origin in the year 2000, and another 200 million USD in 2015. In terms of equity investments by organizations in HSSTI firms, a collection of angel investors combined for approximately 25 million USD investment in XCOR in a deal that took multiple years to close, from 2012 to 2015. Additionally, the Virgin Group started Virgin Galactic with 100 million USD in 2004. This was followed in 2009, by a 380 million USD investment from Sheikh Mansour bin Zayed al-Nahyan of the United Arab Emirates, through aabar Investments PJS (280 million USD for the suborbital venture and 100 million USD for a future orbital launcher) in exchange for 31.8% equity share (de Selding, 2012; Ruddick, 2009). The parent company of aabar Investments is the International Petroleum Investment Company (IPIC; Cornwell, 2014), wholly owned by the government of Abu Dhabi (IPIC, 2017). aabar supplemented their initial investment with 110 million USD in 2011, raising their equity share to 37.8% (Tauri Group, 2016).

Regarding the Industry-Wide Stimuli third-order element, the intention of certain HSSTI emergence events was to support not just one firm, but to stimulate investment of many firms simultaneously. In most cases, the events did not target a specific set of existing firms, but desired to provide the catalyst for technological innovation and increases in performance. For the HSSTI, the most influential of these types of events was the X PRIZE, later renamed the Ansari X PRIZE. This competition was announced in 1996 (Uhlenbrock, 1996) and attracted the participation of almost two dozen teams.

The most prominent team among the roster was Scaled Composites, led by Burt Rutan. His vehicle design, SpaceShipOne, ultimately won the competition in October 2004 (Doughton, 2004), claiming the ten million USD purse. A government program that subsequently stimulated activity on reusable rocket and “airplane-like operation” technologies, both important to the HSSTI, was the Lunar Lander Challenge. The NASA Centennial Challenges program¹⁵ funded the two million USD purse, and the X PRIZE Foundation administered the competition. Northrop Grumman (the company that made the Lunar Excursion Module for NASA during the Apollo program) provided funding to cover operating costs in exchange for title sponsorship recognition. Although no HSSTI firms participated in the competition, participating companies expressed future ambitions of flying humans to space. Finally, formation of the private Rocket Racing League in 2005, intended to stimulate the development of the same technologies as the Lunar Lander Challenge, and also attempted to increase public engagement through the excitement of head-to-head, rocket-powered racing. XCOR was the only HSSTI firm to actively engage in the Rocket Racing League by integrating their liquid rocket engines into the air frames of experimental vehicles, resulting in the creation of the X-Racer Mark I. XCOR’s involvement ended, however, when the Rocket Racing League chose another company (Armadillo Aerospace) to continue engine development instead of XCOR.

¹⁵ In the interest of full disclosure, the author of this research was a program manager of the NASA Centennial Challenges program from 2004-2009.

4.2.3 Human Competence Pool (Training and Accreditation)

The Human Competence Pool second-order element of the Resource Endowments IIE includes third-order elements of Educational Training Programs, Recruitment and Training, and Sharing of Knowledge. The category of Educational Training Programs, as originally identified by Van de Ven (Van de Ven, 1993a, 1993b, 1993c), seems to commingle education and training, but for the sake of clarity in this study, training programs that are relevant to HSSTI activities are included in the subsequent Recruitment and Training element. To keep the two types of knowledge separate, this research shall use the separate labels of Educational Programs, and Recruitment and Training. The Educational Programs resources identified below are generally relevant to the HSSTI, focusing on more than just the scientific, engineering, or operations aspects of the space industry. The HEA includes programs that are multidisciplinary in nature, because any industry segment is comprised of a broader community beyond its technical boundaries. Industry actors founded Recruitment and Training activities to support the HSSTI. Finally, within the third-order element of Sharing of Knowledge (or Knowledge Sharing), there have been a wide variety of conferences and a growing number of papers discussing the evolving HSSTI.

To differentiate Educational Programs from the subsequent Recruitment and Training Programs, this third-order element includes university programs that relate to the HSSTI. Starting in the late 1980s, the International Space University and the University of North Dakota both started multi-disciplinary space studies programs. Started in 1987, the International Space University program initially consisted of a ten-week summer program that eventually spun-off a year-long Master's level program in 1995, and a five-week

program for southern hemisphere participants in 2011. The University of North Dakota program also began in 1987 and was part of their College of Aerospace Sciences. Each of these programs included lectures and studies in the technical and non-technical aspects of space, including science, engineering, policy, history, law, remote sensing, medicine, and others. HSSTI firms all have employed graduates from these programs. In 2013, the Embry-Riddle Aeronautical University began a program in Commercial Space Operations/Space Flight Operations to address the educational needs of emerging and evolving space industry segments, such as the HSSTI.

The Recruitment and Training third-order element of the Resource Endowments IIE includes the movement of employees between companies, and companies that possess training equipment and/or provide operational training that is relevant to the HSSTI. For the HSSTI firms, finding employees with the right skill mix was important, but not always easy. Specialization of skills, and a high degree of tacit knowledge, existed in the established space industry. There was a mismatch between this type of employee, and the HSSTI need for highly skilled, but broadly trained, engineers.

“I needed somebody who could design and build a rocket engine, and I was getting people who could design or build, but not both, extremely small parts of the system, and nobody who saw the whole thing soup to nuts.” - Former HSSTI Executive

Despite these issues, finding employees to work in remote areas, such as Mojave, was not a problem.

“The number of people that were willing to take a two-thirds cut in pay to go work in Mojave to go work on this kind of stuff, they’d leave their job

making \$200,000, to go make \$70,000 working in Mojave. There was a stack of resumes always ... I used to always sit there and think, you know, for every one of me, there's 50 people that are working in IT or some other business that would quit their job tomorrow to do what I'm doing."

– Former HSSTI Employee

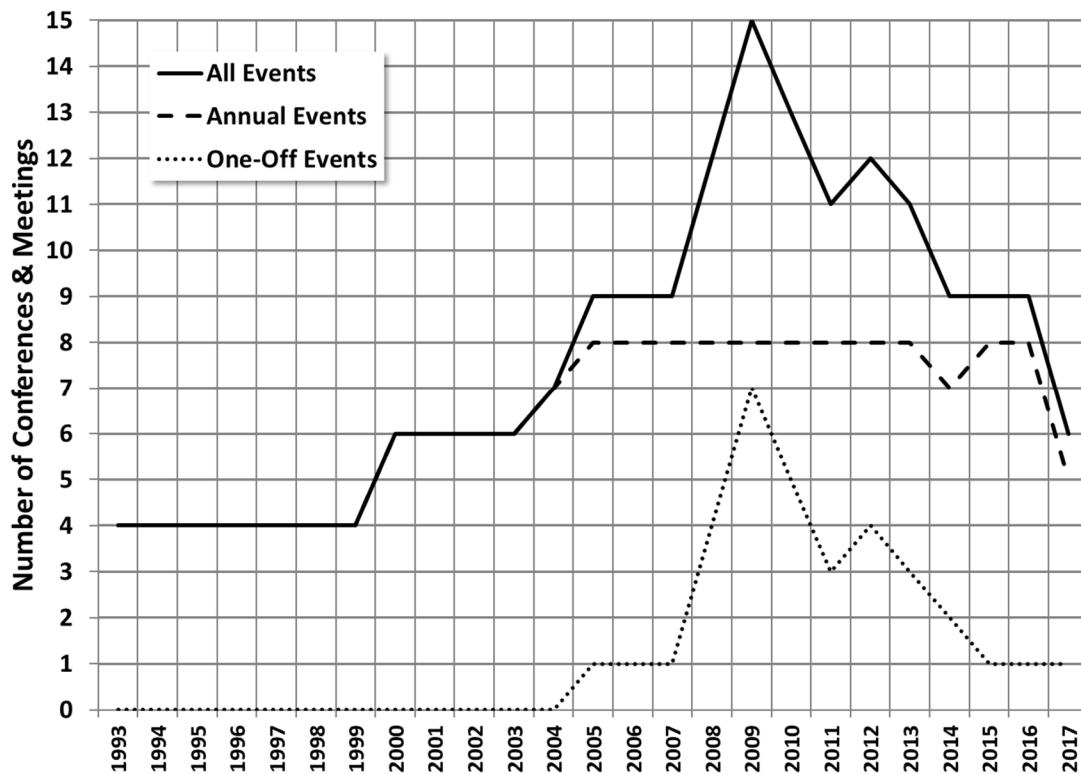
New or diversifying firms began providing preliminary and preparatory training for future suborbital astronauts. Example training firms include NASTAR (Werner, 2011), Astronauts4Hire (Messier, 2010), and Black Sky. To facilitate awareness of this emerging training industry segment, that could support the also-emerging HSSTI, a survey of existing training organizations was funded by FAA AST (Futron Corporation, 2008), including organizations that provide physiological training. Many of the identified organizations are government agencies (e.g., the FAA Civil Aerospace Medical Institute), hospitals (e.g., the Presbyterian Hospital of Dallas), or universities (including Arizona State University, University of North Dakota, and Oklahoma State University). The only for-profit organization among them, NASTAR, has conducted the suborbital spaceflight training for the initial set of Virgin Galactic ticket holders (Futron Corporation, 2008). Some of the educational organizations saw the need for training and began programs, such as the ERAU “Polar Suborbital Science in the Upper Mesosphere” training program (Jarmusz, 2016) that started in 2016 (Roddey, 2016). This category also includes Astronauts4Hire, who train their employees to conduct experiments in weightless conditions for compensation. Another aspect of this category includes personnel activity among HSSTI firms. An important component of development of the human competence required for an industry to emerge comes from the past experiences of firms in related

industry segments, or from those in direct competition. Both of the predominant HSSTI firms have been very selective in their hiring, and have taken advantage of the lessons learned from incumbent firms that comprise other segments of the space industry. As much as the new entrant firms want to develop their own corporate culture, and tap into the enthusiasm and fresh training of younger employees, both HSSTI firms hire many industry veterans, from the public-sector (including NASA, branches of the DoD, and policy offices of both the executive and legislative branches), and the private-sector (including the large space industry generalist firms, Boeing, Northrop Grumman, and Lockheed-Martin). Interestingly, both HSSTI companies have also hired former employees of the other HSSTI firm, but only to a very limited extent.

The Knowledge Sharing third-order element includes widespread attendance at conferences and meetings, the presentation of papers, and the conduct of promotional activities. The number of annual conferences and semi-regular and episodic meetings that are directly related to the HSSTI is very small. Since the early 1980s, there have been many annual conferences and episodic meetings that pertain to “commercial space,” and are therefore related to the HSSTI to some degree. The number fluctuates from year to year. Conferences for space enthusiasts, such as the National Space Society’s International Space Development Conference (ISDC), and for students of the sciences related to space (the SpaceVision Conference by the Students for the Exploration and Development of Space) both began in 1982. The precursors to a conference that had commercial space as a primary focus began in 1991 (the Space Frontier Foundation’s NewSpace Conference). A group that grew out of the amateur rocketry community started the Space Access Society (SAS) meetings in 1993. They met annually in Phoenix

until its last event, held in 2016. The FAA AST began holding an annual conference on commercial space starting in 1998. A “C Suite” conference, initially focused entirely on commercial spaceflight, became the more general “International Symposium on Personal and Commercial Spaceflight,” started in 2005 in Las Cruces, NM. There were many other episodic and non-annual meetings and events held throughout the years, some hosted by the same groups, and others held by newly interested organizations. Figure 7 shows the number of HSSTI events each year, starting in 1993. Appendix J provides the data for this figure. The occurrence of annual conferences and episodic meetings specifically organized on suborbital human spaceflight (including human-tended science) is fairly small.

Figure 7. Knowledge sharing: HSSTI conferences and meetings

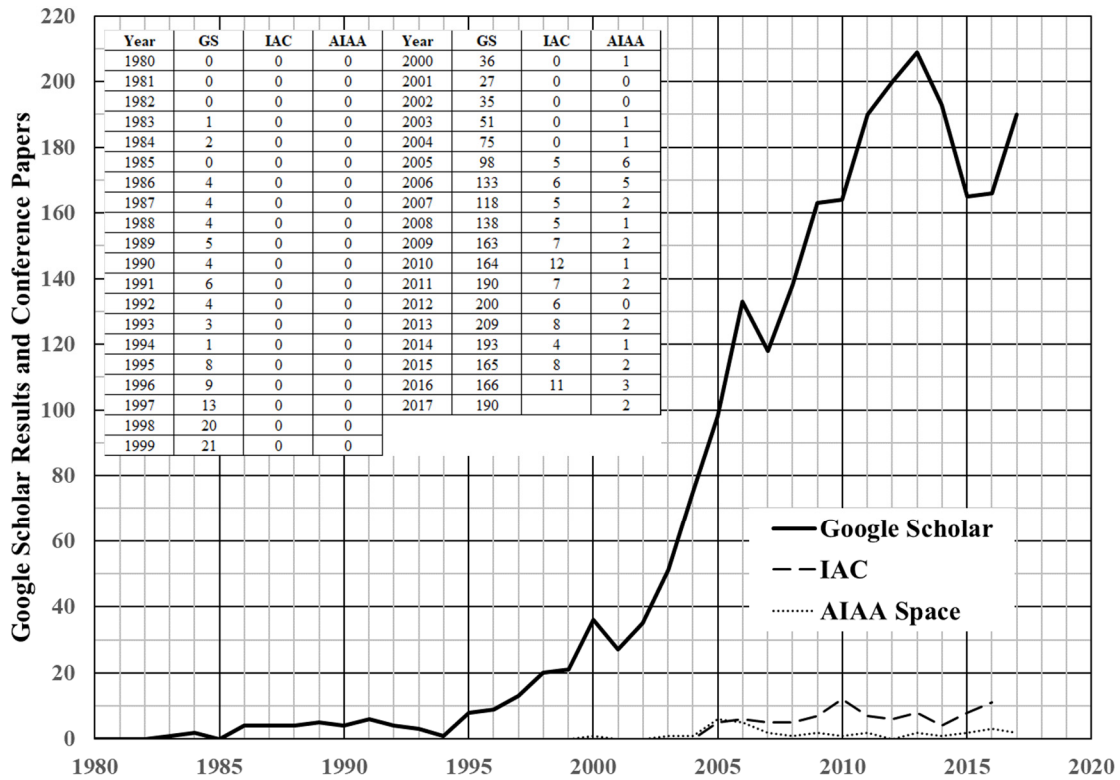


The aforementioned SAS meetings, that began in 1993, were the meeting place of many of the suborbital vehicle pioneers prior to the announcement of the X PRIZE. The

number of special (one-off, or episodic) events increased in the 2008-2009 period at the same time the Lunar Lander Challenge prize purses were won, and the HSSTI community was forming around the industry trade organization's Suborbital Applications Research Group. There was a decline in HSSTI events in 2014, the same year as, but likely not related to, the SpaceShipTwo accident that occurred on 31 October. This accounting does not include firm-specific gatherings of potential customers, although those could be serving a double purpose of knowledge sharing and marketing/customer development.

Another way to demonstrate the increase in Knowledge Sharing resources in the HSSTI is through a basic bibliometric analysis of technical papers submitted and accepted at the major space industry conferences. These conferences include the American Institute of Aeronautics and Astronautics (AIAA) "Space," and the International Astronautical Federation's "International Astronautical Congress" (IAC). The researcher queried the content of papers (including titles, abstracts, and all text) using the composite "suborbital AND tourism" search term. Despite the very low paper counts at both the IAC and AIAA conferences, the total number of both conferences increases after the winning of the X PRIZE in 2004. The number of AIAA papers shows a decrease afterwards, however, and the number of IAC papers stays approximately constant. The total number of google scholar citations (that presumably includes all the papers presented at both these conferences in addition to others) showed a fairly consistent increase in the number of HSSTI papers, with only a recent two-year downward trend. Figure 8 shows these trends.

Figure 8. Knowledge sharing: HSSTI bibliometric analysis



4.3 PROPRIETARY FUNCTIONS

The last first-order element of the accumulation model framework is Proprietary Functions, consisting of three second-order elements, Technological Development Functions, Innovation Network and Resource Channels, and Market Creation and Consumer Demand. This section provides descriptions of how each of these second-order elements have developed for the HSSTI.

4.3.1 Technological Development Functions

The Technological Development Functions second-order element includes third-order elements of Applied (i.e., proprietary) R&D, Manufacturing, and Testing, conducted by HSSTI firms.

Proprietary research results within the third-order element of Applied R&D, conducted by firms for their own purposes, is different from the publicly-available R&D conducted in the Resource Endowments element. The in-house R&D activities of each firm contribute to their intellectual property, protected through the patenting process, or by the keeping of trade secrets. These protections are necessary to ensure that the firm benefits from their research, and “free riders” do not. Patent data exists for HSSTI firms, but the numbers of patents for some firms are small or zero, and the quality and applicability to the suborbital tourism industry of the patents that have been granted are open to question. For these reasons, patent data is not included in this analysis. Primarily for these reasons, firms are reluctant to discuss the specifics of their internal research activities, although an observer can deduce general areas of research by monitoring press releases and media coverage of each firm.¹⁶ For example, Virgin Galactic has conducted research in solid rocket motor and liquid rocket engine development. Blue Origin has also been working on liquid rocket engine technology, as well as the capability to conduct vertical landings of their propulsion module. Without a doubt, both these companies have more extensive in-house R&D programs underway with the goal of bringing their vehicles and services to market, but the details are not available to the general public. A principal goal of proprietary R&D is to create technologies that provide a means of product differentiation between competing firms (Comanor, 1967). Some of the more

¹⁶ For these same reasons, firms normally prefer to conduct their pre-production operations out of the public view. Later sections of this thesis discuss how prizes encourage firms to contradict this tendency.

prominent proprietary technologies belonging to HSSTI firms include the wing “feathering” mechanism and operation (for Virgin Galactic) and the ability to perform a vertical soft landing of the propulsion module (for Blue Origin). Many of the dimensions of product differentiation for the HSSTI, such as customer conveniences, or lower cost, are not necessarily life threatening or mission critical. The functionality differentiator of experiencing a condition of microgravity for more or less time, with bigger or smaller windows to look through, may be an important differentiator for some segment of customers. Vehicle safety and reliability, however, will be the ultimate differentiator for all HSSTI operators, especially once they start carrying paying customers. Attaining the goal of safe and reliable vehicle operation, especially at the earliest stages of production operation, will be a very high barrier to entry of the HSSTI. Overcoming this barrier will favor new entrant firms that have a greater amount of slack resources, because it will allow operators to take necessary precautions, and conduct a reasonable amount of quality assurance and testing activities to ensure adequate safety and reliability.

The Manufacturing third-order element of the Technological Development Functions includes design and assembly functions of HSSTI vehicles. As a condition of inclusion in this research, all five HSSTI firms conducted these activities to some extent, although only three successfully completed and flew their vehicles. Rocketplane was in the initial phase of the manufacturing process with their XP vehicle when major redesign considerations and a strained financial situation forced their permanent cessation. XCOR had completed the Lynx Mark I design, and had begun assembly of the vehicle, but the firm’s financial situation ultimately resulted in the project’s indefinite cancellation (Foust, 2016), 14 months before the firm finally ceased all operation (Messier, 2017).

Scaled Composites was the first HSSTI firm to successfully complete the design and assembly of the suborbital transportation system, including the WhiteKnightOne carrier aircraft, and the SpaceShipOne vehicle. Virgin Galactic, through the creation of a joint venture with Scale Composites, called The SpaceShip Company, also successfully completed the design and assembly of the follow-on system, consisting of WhiteKnightTwo, and SpaceShipTwo. Finally, Blue Origin also completed the design and assembly of the New Shepard vehicle, comprised of the propulsion module and the crew capsule.

The Testing element resources, accumulated by or for HSSTI firms, includes component, subsystem, and system tests conducted on their vehicles. It also includes operational testing, such as vehicle ground tests, captive carry tests, unpowered flight tests, and powered flight tests. Prior to the Lynx vehicle, XCOR conducted several flight tests of their EZ-Rocket vehicle (an experimental aircraft air frame fitted with an XCOR rocket engine) and the X-Racer Mark I vehicles. XCOR also conducted a number of tests once assembly of the Lynx Mark I vehicle began:

“We did pressure tests on the cockpit after it was integrated into the fuselage and tank assembly. The [liquid oxygen] tank took up most of the fuselage on the Lynx, so it was quite a large structural element. Then we did bending tests on them, both with and without internal pressure on the fuselage, [liquid oxygen] tank, cockpit assembly. Most of the complexity was in all the subsystems: the various kinds of engines. Valves, actuators and whatnot, and those were all tested at the component level. We had the avionics suite running on a bench with the sensors driving the displays.

We had the reaction control system running with all of its valves, and we had the propulsion systems still under development.” – Former HSSTI

Executive

Scaled Composite’s HSSTI vehicle, SpaceShipOne, underwent a complete suite of flight testing along with its carrier aircraft, WhiteKnightOne. The WhiteKnightOne conducted a total of 45 flight tests over a period of three years and SpaceShipOne experienced three captive-carry tests, eight glide flight tests, and ultimately had six powered flights. The last two powered flight tests won the X PRIZE competition. Virgin Galactic is conducting a similar set of flight tests with SpaceShipTwo. WhiteKnightTwo conducted 100 test flights between 2011 and 2014, and SpaceShipTwo experienced 32 glide and cold-flow flight tests during the same period. SpaceShipTwo had four powered flight tests in 2013 and 2014, but was lost on the final test flight on 31 October 2014, when co-pilot Michael Alsbury prematurely unlocked the “feathering” mechanism, causing the vehicle to break-up in flight, killing him and seriously injuring the pilot, Peter Siebold (Burn-Callander, 2015; Malik, 2014). Virgin Galactic built a second SpaceShipTwo that, as of November 2017, experienced four captive carry and seven glide or cold flow flight tests. All SpaceShipTwo flights were conducted at an altitude between 15 and 25 km (15 km is the approximate altitude at which SpaceShipTwo is released by the WhiteKnightTwo carrier vehicle). Blue Origin has also conducted an extensive set of tests on different configurations of its HSSTI vehicle. The first test vehicle, named “Goddard,” had a single flight test in 2006. Blue Origin tested an early version of its propulsion module twice in 2011. The actual HSSTI vehicle, named New Shepard, has undergone seven powered flight tests to high altitudes (greater than, or equal to, 91 km)

as of December 2017. Blue Origin also tested a crew capsule abort engine as part of their orbital space transportation system work. Although the crew capsule test did not originate from their HSSTI program, the operational experience gained from this test was valuable for their suborbital vehicle.

4.3.2 Innovation Network and Resource Channel Activities

The Innovation Network and Resource Channel Activities second-order element include third-order elements of the Appropriation of Common Goods, and Vendor-Supplier-Distributor Channels. This section describes both as they apply to the HSSTI.

Common goods include government activities, such as regulatory decision-making and enforcement, the resource endowments of knowledge, financing, and labor (Van de Ven & Garud, 1989), and access to multi-user infrastructure facilities (such as spaceports). Often times, “it appears that the burden of creating other common goods rests with the first mover in the industry” (Garud & Van de Ven, 2000, p. 513). The Appropriation of Common Goods third-order element includes events associated with the acquisition of these common goods. Without access to such goods, disruption of the resource channel is possible. One of the predominant methods by which HSSTI industry members gain access to common goods is through the SAAs with NASA, as described above in the Institutional Arrangements IIE. These SAAs have provided more than legitimacy through association with the government agency. They have also given the participating firms access to important information, facilities, equipment, and tacit knowledge of the NASA personnel. Common goods not created by government are rare in the HSSTI, primarily because none of the firms have yet entered the market, so there

are no “first movers.” Presumably, both Virgin Galactic and Blue Origin are in the process of creating these resources that will benefit future HSSTI firms.

The last third-order element, Vendor-Supplier-Distributor Channels, includes “upstream” and “downstream” channels of HSSTI firms. Results of the ISA identified an HSSTI network of supporting industries, as shown in Figure 9. Typically referred to as an industry “chain,” with industry groupings called “tiers,” this research tries to avoid terminology or imagery that may lead to the implication of linear and sequential external relationships by depicting the network as a set of closely clustered tiles.

Figure 9. HSSTI network of supporting industries



The different categories of industry capabilities and functions include raw materials, infrastructure, supporting communities, subsystems, systems, vehicles and equipment,

retails services, and end-use markets. An important characteristic of the entire network of firms that comprise and support the HSSTI is the extent to which the current HSSTI firms have incorporated different capabilities and functions “in-house” (within the boundaries of the firm). All three HSSTI firms (including XCOR, before it exited from the field) share a common “core” of capabilities, including some sub-systems, all major systems, all vehicle and support equipment capabilities, and vehicle operations. Beyond this set of “core capabilities,” some firms also included the “retail services” function of ticket sales within the firm’s boundary. In addition to ticket sales, Virgin Galactic also internalizes other major retail service functions, upon which the overall Virgin brand rests, including training, hospitality, and customer service. Besides the “non-core” sub-system functions (which includes plumbing and electronics), the only “raw material” function that Virgin Galactic performs in-house is partial provision of financial resources. As mentioned above, Virgin Galactic has entered into a joint-venture with aabar Investments to meet their financial resource needs. More recently, Virgin Galactic has received a substantial investment in their suborbital venture from the royal government of Saudi Arabia (Masunaga, 2017). Like Virgin Galactic, Blue Origin also partially relies on external sources for some sub-system capabilities. However, Blue Origin receives 100% of their financial resources from the company owner, Jeff Bezos, thereby incorporating this important resource within the firm’s boundaries. Additionally, Blue Origin stands alone among the HSSTI firms because it operates its own private-use spaceport, from which it performs all its flight testing.

Another aspect of the Vendor-Supplier-Distributor Channels third-order element are the shared or joint functions that may be available from, or provided by, parent

companies to the HSSTI firms. Lacking specific information or data, it is hard to resist the temptation of seeing connections between Jeff Bezos' Amazon.com enterprise, or any of the transportation and aviation-related companies that are part of the Virgin Group. However, some firm insiders discount those perceptions:

“I think it’s probably less relevant to ask how does Virgin Atlantic or Virgin hotels or Virgin cruise ships relate to Virgin Galactic. I think that the primary connection is probably Richard’s tremendous enthusiasm for the project and his passion for excellence and customer service. I think those things, which are common to all the Virgin companies, are the connective tissue between all things Virgin.” – HSSTI Firm Executive

A special aspect of the supplier channel is the spaceport. Spaceports, established by state, county, and municipal-level governments, can be a “common good” if they are available for use by any HSSTI firm, such as the Mojave Air and Space Port from which Virgin Galactic operates, and XCOR operated (before it exited the industry). Spaceports are essential facilities to the HSSTI because no firm can operate without one. All firms are associated with at least one spaceport, but not all spaceports are associated with HSSTI firms. There are currently seven HSSTI spaceports, six of which had a valid “launch site operator’s” license at one time. At the time of this writing, one spaceport (the Oklahoma Space Industry Development Authority) has allowed its license to lapse for lack of sufficient company activity. An earlier section (covering the Governance second-order element of the Institutional Arrangements IIE) discussed the initial granting of these licenses, and their subsequent extensions. In most cases, licensed spaceports were pre-existing facilities (military, in most cases) that had the necessary buildings, runways,

taxi ways, support services (e.g., emergency response), and propellant storage sites, that could support spaceport operations. In some cases, the infrastructure was usable without modification, and in other cases, spaceport licensing requirements imposed additions or modifications to the facilities. Mojave is a favorable location for a spaceport because of its history as the home of the National Test Pilot School, attracting highly-skilled pilots who are accustomed to operating experimental aircraft. Mojave is also located in a relatively remote location (the Antelope Valley desert), which is good for safety considerations, yet it is only an hour drive from a high concentration of aerospace workers (engineers, technicians, etc.) in the Los Angeles area. Mojave's remote location is not necessarily good for secretive operations, since many competing companies also reside there. Competitors can observe the flight operations conducted in publicly accessible areas (e.g., tarmacs, runways, skies overhead, etc.). Blue Origin operates its own "private use" spaceport in Van Horn, Texas, for use only by Blue Origin vehicles, therefore, it requires no license for its operation. This location is remote, which is good for safety considerations as well as secretive operations.

4.3.3 Market Creation and Consumer Demand

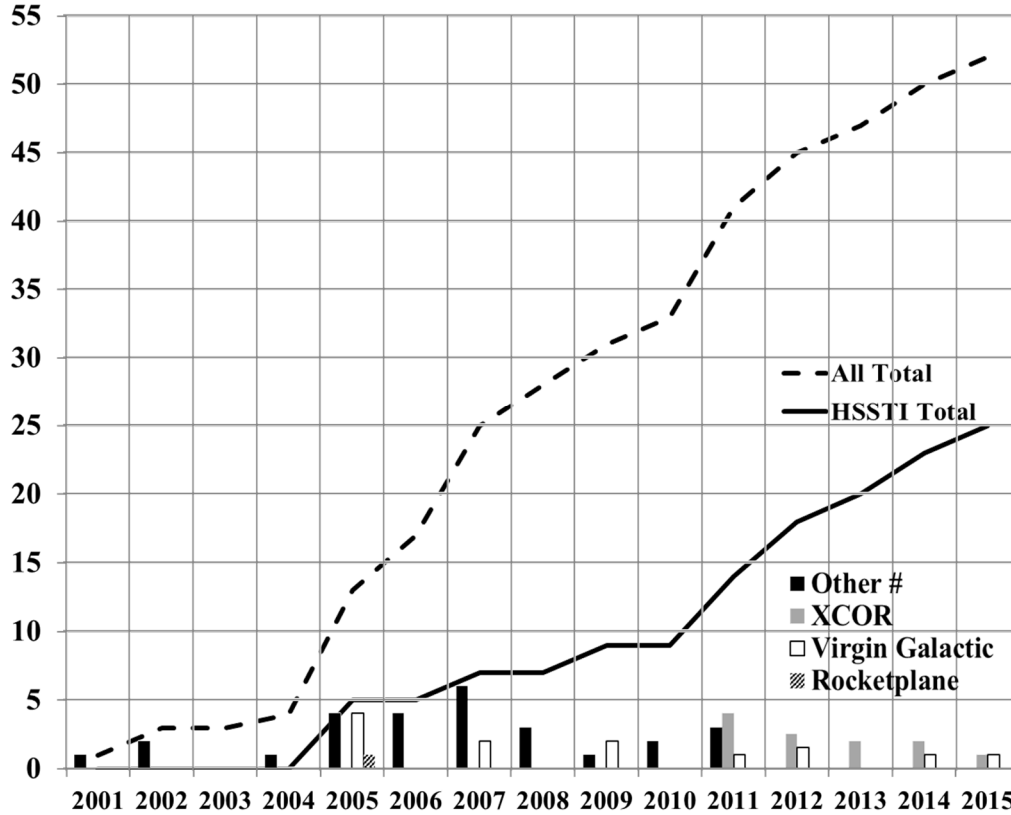
The Market Creation and Consumer Demand second-order element of the Proprietary Functions IIE includes the third-order elements of Marketing, Cultural Norms, and Consumer Demand. This research added a third-order element of Competition, denoted by the HSSTI population ecology, as an indication of the supply side market creation events. This section describes each of these elements below.

Marketing activities take on many forms in the HSSTI, including special events (e.g., the unveiling of a vehicle), the announcement and creation of new programs, the

announcement of contests and raffles for winning prizes of suborbital flights, and predictions of first test flights, first commercial flights, etc. First flights of pre-production vehicles are marketing events because they publicize an HSSTI firms progress toward flight operations. To balance the need for corporate secrecy and the desire for heightened public interest, companies have typically only released a small number of photographs of their vehicle while it is under construction. When the vehicle is ready to undergo preliminary ground testing, keeping it behind closed doors of a spaceport hangar is no longer possible, and the operator conducts an “unveiling” ceremony or celebration. Virgin Galactic held elaborate events, inviting a large number of industry actors to attend, and unveiling the vehicle in dramatic fashion. One of the most-used forms of marketing in the HSSTI has been the announcement and execution of contests open to the general public, for which the grand prize is a ride aboard the particular vehicle. In total, different organizations announced 52 contests of this sort world-wide. Many prize competitions were based on vehicles that never materialized. Figure 10 below shows the number of competitions announced each year from 2005 to 2015, and it differentiates between the HSSTI firms (those companies included in this research) and other, less realistic, suborbital firms.

Publicity was not the only benefit of these contests for the firms. Participating in these contests also provided the firm with economic, market creation, and legitimization returns:

Figure 10. Suborbital flight prize competitions



“almost all of those, or every single one of them produced revenue, which was important. Some of them produced a lot more revenue than others... so first was revenue, second was marketing, these companies put a lot of effort behind the activities. One that was particularly good, ... they paid for the ticket and we did a thing at Comic Con and they followed it up with a lot of push in the news like Entertainment Tonight and TMZ covered it. ... So yeah, second point was obviously free media. And the free media begets ticket inquiries... Which hopefully turn into sales ... And the fourth one, which people don't realize is when you're at a company that is funded the way we were funded, those sorts of activities can really help

with moral of the employees. And they see validation in what they're doing. So, it was always helpful just to have those things going on and people coming through and ... them giving a summary of their work. It's amazing when you have an intern or a first-year engineer who's asked to well, show this person what you're working on. And then they find out later that that's the number 2 producer at The Big Bang Theory, their favorite TV show." – Former HSSTI Executive

A third form of marketing came in the publicity surrounding the predicted dates of first flight tests and first customer (revenue generating) flights, used most prominently by Virgin Galactic. This was a common question that industry observers or reporters often asked of Virgin Galactic officials. Whenever Virgin officials responded to these questions, media outlets publicized this information, raising expectations of industry observers and potential customers, thereby bringing attention to the firm. Between 2006 and 2015, there were at least seven publicized predictions for the start date of powered flight tests of SpaceShipTwo. Between 2005 and 2017, there have been more than twenty publicized start date predictions of Virgin's revenue-generating flights. Just prior to the accident in October 2014, start dates estimates had fallen to within the 6 months following the date of prediction. Since the accident, Virgin Galactic officials have been hesitant to begin making predictions again, but most recently, Sir Richard Branson has set 2018 as the earliest possible date for first customer flights (Quinn, 2017).

Resources within the Cultural Norms third-order element are difficult to define, although from a very limited perspective, it is "best exemplified in the reasonable person standard of care in common tort law" (Van de Ven & Lifschitz, 2013, p. 159). An earlier

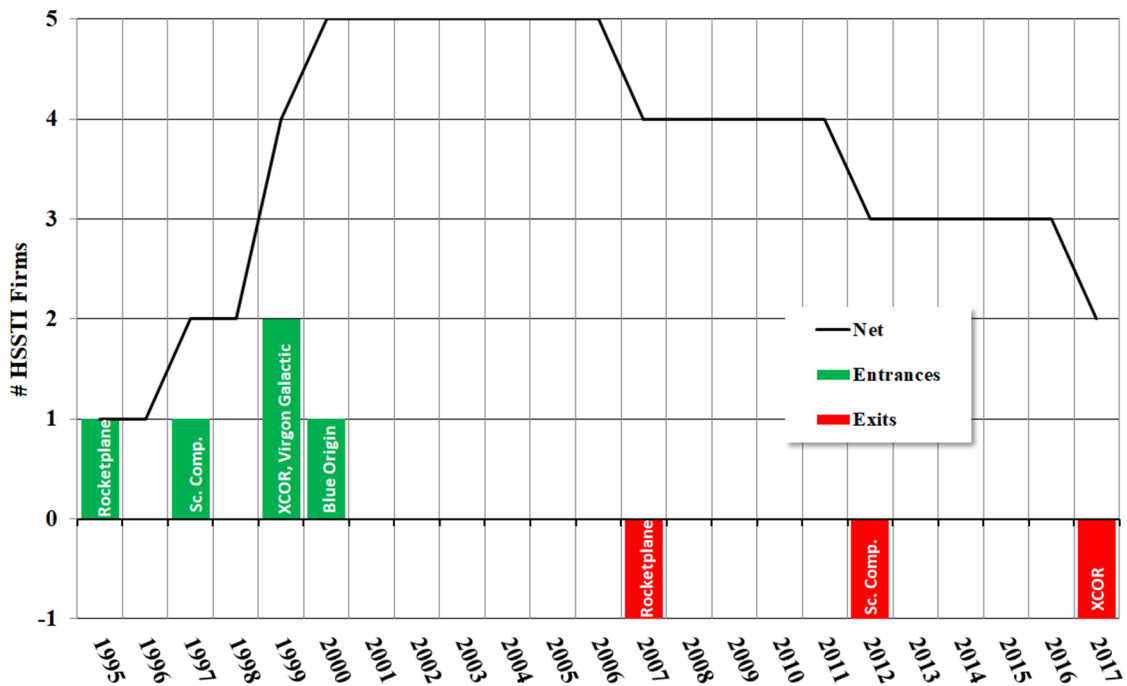
section of this thesis discussed the institutional norms, and these typify the space industry as a whole. Cultural norms in this analysis mean the norms of behavior that are specific to the HSSTI, a subset of, or deviation from, the overall space industry norms. There is an inherent difficulty, in this specific case, of trying to draw generalizations from a very small set of HSSTI firms. It is possible that the establishment of the Personal Spaceflight Federation, later renamed to the CSF, was an attempt to establish norms of all commercial space industry segments, not just that of the HSSTI. To date, the CSF member firms have adopted some common industry standards, but that is the extent of the norms they've helped to create across their membership. It is possible that there is an attempt by HSSTI entrants to create a new “paradigm” for human spaceflight companies. Whereas the traditional space industry norm would allocate a budget in the range of hundreds of millions of USD for the development of a new suborbital vehicle to carry humans as a business venture, a differentiating characterization of HSSTI firms is the attempt to develop these capabilities on a budget, starting in the tens of millions of USD. To date, however, every attempt to create a “low budget” HSSTI company has been unsuccessful.

The last third-order element of the original accumulation model framework is Consumer Demand. At the time of the writing of this report, there has been no operation for compensation or hire by any HSSTI firm. Therefore, no data of sales to customers in return for HSSTI services yet exists. Well-respected industry analysis firms have made market forecasts (Futron Corporation, 2002; Tauri Group, 2012), but the results' credibility is questionable because, for entirely new industries like the HSSTI, “experts' forecasts will always be wrong” (Christensen, 1997, loc. 1882). However, it is possible to

track proxies for actual consumer demand, including government funding of HSSTI firms for industry development purposes (not for purposes of a governmental mission), and announcements by HSSTI firms of ticket “pre-sales” (economic transactions completed prior to initiation of commercial operation). The NASA FOP, and its precursor, the Commercial Reusable Suborbital Research program, have demonstrated government demand for HSSTI services. Both these programs executed contractual relationships with the HSSTI firms for the purpose of flying scientists with their experiments on suborbital flights, but so far, no flights with people aboard have occurred. NASA has paid a fraction of the total contract awards to reserve these flights (up to 40% of the agreed-upon price), but still unpaid is the remaining fraction of the contract amount, reserved for after the successful completion of human suborbital flight. Specifically, between 2011 and 2014, the NASA FOP awarded contracts in the amount of 3.24 million USD to HSSTI firms, with an estimated maximum of 1.3 million USD paid to the companies, but only upon actual flight reservation. There has also been a demonstration of non-government demand for HSSTI flights. XCOR officials have often reported the number of paid reservations for flights on their Lynx vehicle on the order of 200 to 250 tickets. Virgin Galactic has reported a number between 700 and 800 pre-flight reservations made, with different percentages of down-payment, from as low as 10%, to as high as 100% pre-paid by customers who want to fly to space. Although the number of pre-sold tickets may not be a perfect proxy for actual market demand, it is considered to be a benchmark for the survey data that has been collected to date (Futron Corporation, 2002; U.S. Congress, 2012).

This research added a third third-order element, Competition, comprised of the HSSTI population ecology, to document the number and dynamic nature of the HSSTI service suppliers. The pool of HSSTI firms used in this research includes only those companies that have designed their vehicle for commercial operations and have actually started building a flight vehicle. This study excluded some groups, like Copenhagen Suborbitals, who have designed vehicles to carry a human occupant, and have built and tested vehicle hardware, but never planned to be commercially viable. This research excluded other firms, such as Sierra Nevada, who has built and is testing flight hardware that is capable of carrying humans, because its primary purpose is for orbital flight, although they briefly discussed the idea of using their vehicle for suborbital flight. As Figure 11 shows, only two of the five HSSTI firms included in this research is in operation as of December 2017.

Figure 11. HSSTI population ecology



4.4 IIE INTERACTIONS

Information and actions move between the three IIEs, as well as within them. In the discussion of the original accumulation model framework, three primary linkages between IIEs were identified: the balancing act between the forces of “technology pull” and “technology push,” the process of transforming knowledge into a commercial product, and the creation of industry standards (Van de Ven & Garud, 1989). This section will identify and discuss the types of interactions observed in the HSSTI emergence study, and compare them with the findings in the original study.

4.4.1 Institutional Arrangements-Resource Endowments Interactions

Interactions are bidirectional between the Institutional Arrangements and Resource Endowments IIEs. The majority of the interactions from the Institutional Arrangements IIE to the Resource Endowments IIE were policies established, laws passed, and regulations enacted. For example, federal agencies made an effort to work with the HSSTI firms to provide contracting opportunities as a matter of policy, enacted new federal policies, and created new federal laws specifically to give the regulatory agency special tools to encourage HSSTI emergence activities. State and local government organizations passed legislation that provided financial incentives to attract industry actors (and jobs) to a specific location. These policies and laws were positive signals to the private finance providers (both individuals and organizations) regarding the stability and future of laws and regulations affecting the HSSTI. The HSSTI “common goods” (public domain research results, financing opportunities, knowledge sharing events, and spaceport facilities) are all positively impacted by these policies and laws, as well. An increased level of institutional acceptance for the HSSTI resulted in more Institutional

Arrangements-Resource Endowments interaction, thereby leading to increased activity toward overall industry success. This activity encourages students to enter fields of study needed to get a job in the industry, thereby enriching the Human Competence Pool second-order element. Favorable policies and laws encourage the start of new infrastructure projects, and additional funding promotes conferences, education, training, or research on industry-related subjects.

Activities conducted in the Resource Endowments IIE encourage a general public awareness of the new industry. When observed by Institutional Arrangements actors, private investment in new entrant firms assure government leaders at all levels that the new industry is worthy of supportive laws and policies. For example, the state of Oklahoma passed a transferrable tax credit bill for Rocketplane after the firm received a private investment of ten million USD. Other activities also provide positive signals of the new industry's worth, including conferences and other events that feature respected guest speakers from government and industry. The establishment of education and training programs, enrollment and graduation of students from these programs, employment of these students in the industry, and preproduction, publicly visible flight operation events, can also increase awareness of the industry by the Institutional Arrangements actors.

4.4.2 Institutional Arrangements-Proprietary Functions Interactions

Not surprisingly, many forms of interactions also exist between the Institutional Arrangements and Proprietary Functions IIEs. Regulatory actors provide permissions to new entrant firms to conduct flights of their vehicles every time the FAA AST issues an experimental permit or launch license to a vehicle operator. Regulators also provide

licenses to spaceport operators, permitting them to conduct launches, landings, and recoveries as per the terms of their licenses. FAA AST grants safety approvals to various HSSTI firms who want to “pre-qualify” their product for use on a licensed vehicle. In support of the Proprietary Functions actors, the HSSTI regulators also perform “pre-application consultations,” to prepare future operators for the regulatory process, and to make sure the government has all the information it needs to proceed with its different reviews (i.e., environmental, policy, safety, financial liability, and payload). Other government agencies, most notably NASA in the HSSTI case, enter into formal collaborations with individual firms to facilitate the transfer of technical experience, access to unique testing facilities, and sometimes funding from the government to the private-sector. The nature of the collaborations varied, and some SAAs were reimbursable (where the firms paid for access to the expertise), and others were non-reimbursable.

There are also numerous examples of Proprietary Functions actors initiating activities that impact the Institutional Arrangements IIE. With respect to obtaining regulatory permission to operate, whether it is for a permit to make experimental flights or a license to advance toward flights for hire, firms receive regulatory approval by taking the necessary steps of application and evaluation. Policies and laws, adopted and passed in support of the HSSTI, increase the amount of interaction between private firms and government organizations. This increased interaction helps familiarize government employees about how to work with the new industry firms. Private-sector firms also initiate interactions with institutional actors in the form of political activity. Firms do not necessarily intend to apply direct pressure on law makers for the passage of favorable

laws through their actions. Firms, or contractors representing them, often provide information to policy-makers (in both the executive and legislative branches) to educate and inform the government officials of their activities (current and planned) and preferences (with respect to policy issues).

Government activities established the identify of suborbital flight in the 1960s. More recently, however, actions on the part of HSSTI Proprietary Functions actors signal an attempt to create a new identity for non-governmental suborbital flight. An industry conference, hosted by the regulatory agency (FAA AST), promoted the HSSTI concept in 1997:

“At the first AST conference in 1997, I was one of the speakers, and I rattled a whole lot of cages by having this slide deck that showed - this is before anybody thought tourism was a market - and I was showing tourism vehicles, I was showing FedEx global fast package delivery, I was showing military applications of suborbital spaceplanes, I had all kinds of things that were future theoretical applications of what you could do with a high-Mach, suborbital spaceplane.” – HSSTI Executive

More recently, Proprietary Functions actors actively promote the new identity of a “suborbital space scientist:”

“it’s hopefully going to be our time, finally, as space scientists. We’ve watched the marine geologists go down to the bottom of the ocean in submersibles, we’ve seen the field biologists go off to remote valleys in distant places on the planet to do their research, and this is the chance for us, as space scientists, to finally get to our environment to do our job

ourselves. And that's what this capability [the HSSTI vehicles] finally offers us.” – HSSTI Scientist

An unexpected development between the Proprietary Functions and Institutional Arrangements IIEs occurred when individual firms began developing the concepts of identity for their future customers. The regulatory authorities refrained from using the term “passenger,” and instead refer to customers as HSPs. HSSTI firms use alternatives to both these terms, however, perhaps for marketing reasons. One firm refers to future customers as “astronauts,” and although this might increase the level of public awareness (by equating the customers of this new activity with a pre-existing, well-known, and highly respected occupational category), this has had a potential negative effect on the new industry’s reputation within the established space community:

“there were indications that they [NASA astronauts] were pissed off that these people [HSPs] were calling themselves astronauts... [the HSSTI firm was] taking some of the glamour off of being an astronaut, since they [NASA astronauts] had earned it the ‘right way’ by demonstrating ‘the right stuff,’ and almost anybody could just buy a ticket to space. They [NASA astronauts] were very unhappy that “astronauts” weren’t as special or elite as they used to be.” – Industry Analyst

4.4.3 Resource Endowments-Proprietary Functions Interactions

Finally, this section presents the results of Resource Endowments and Proprietary Functions IIE interactions, as identified through the HSSTI case study. Individual and organizational investors provide funding to HSSTI firms to execute Proprietary Functions activities, such as building specialized capabilities, developing the supply network, or

performing initial design, manufacture, and assembly of the HSSTI vehicle. Examples of organizational financing by Resource Endowments actors to HSSTI firms include equity funding by the Virgin Group or aabar Investments to Virgin Galactic. Funding by individuals includes the self-funding of Blue Origin by Jeff Bezos, or Paul Allen's support of Scaled Composites participation in the X PRIZE competition. Public (government) funders provided resources to HSSTI firms through contracts (both fixed-price and cost-plus) and grants (including SBIR and research grants that required matching funds) to conduct research in HSSTI technologies, including human suborbital flight, vehicle reusability, and vertical take-off and landing. Government grantors also provided funding for the development and improvement of spaceport facilities. State and municipal governments also supported the industry financially, often with preconditions, to attract HSSTI firms to specific regions with the hope of generating jobs and economic development. A final interaction from the Resource Endowments IIE to the Proprietary Functions IIE includes the transfer of the pool of human capital as employees for the benefit of Proprietary Functions actors.

Proprietary Functions actors also initiated interactions with the Resource Endowments IIE. HSSTI firms demonstrate technical accomplishments to their investors with the hopes of securing additional funding, and investors witness these events as possible evidence of future economic returns. Commonly, HSSTI firms communicate test results to the investors privately. However, if the test results are openly visible to the public at large, the Proprietary Functions-Resource Endowments linkage has more impact on society at large. These demonstrations of technological capabilities increase the level of interest by the general public, thereby attracting more students to fields that can lead to

a career in the new industry. This, in turn, increases the amount of human capital that chooses to participate in the industry. An interesting reversal of expected interactions occurred with respect to pre-production marketing. Investment funding provides the opportunity to market the product prior to revenue generating activities, but in the case of Virgin Galactic, the pre-production sale of tickets started as a condition of receiving funding from the Virgin Group, to prove a market really existed.

To maximize the generalizability of results, this discussion presented the study results so far without significant inclusion of the events stimulated by the X PRIZE competition. The following section, however, focuses exclusively on the impact of the prize upon HSSTI events, within and between each of the IIEs.

4.5 THE INFLUENCE OF PRIZES

The effect of the X PRIZE on events in the Institutional Arrangements IIE was significant. When first announced in 1996, the X PRIZE featured prominent government and industry members whose very presence was a tacit endorsement of the activity. In response to activities performed to win the X PRIZE, regulators conducted workshops to ensure that competitors were aware of their regulatory obligations prior to being able to conduct flight testing. Spaceport facilities, from which competing vehicles would fly, were subject to FAA AST regulations, so the application for, and receipt of, a spaceport license was an important event stimulated by the X PRIZE. The impact of the prize event on the Resource Endowments IIE was also significant. The announcement of the X PRIZE competition stimulated private investment in HSSTI firms, as was the case with Paul Allen's investment of 30 million USD to Scale Composites, for the design, assembly, and operation of WhiteKnightOne and SpaceShipOne. The prize organization

also organized and executed multiple meetings for all the teams to train the teams, and to provide consistent messaging and information about the competition. Finally, the prize event manifest itself on the Proprietary Functions IIE in many ways. First, the X PRIZE announcement stimulated the creation of many entrants to the competition. Although many of these never became viable firms, the founders of these firms felt sufficiently emboldened to announce their intention to compete, even if nothing more ever emerged. The initiation of the X PRIZE competition also stimulated the entry of pre-existing firms into the HSSTI, as was the case with Scaled Composites. Prior to the X PRIZE competition, Scaled Composites did not design, manufacture, assembly, or operate spacecraft of any kind. It was only due to the competition that the company's founder, Burt Rutan, pursued spaceflight as part of his company's activities. Furthermore, the X PRIZE required firms to perform test flights in a very public setting in pursuit of winning the purse. Normally, firms will avoid widely publicized test flights, when possible, to avoid the possibility of negative publicity, should something go wrong.

Prizes also had an effect on the interactions between IIEs. Between the Institutional Arrangements and Resource Endowments IIE, the U.S. Congress passed laws that authorized the establishment of government-sponsored prize competitions. A contest that directly promoted innovation and achievement for HSSTI technologies was part of the NASA Centennial Challenges program, called the Northrop Grumman Lunar Lander Challenge. Also, the establishment of the X PRIZE competition stimulated industry to pursue commercial spaceflight activities despite legal and regulatory gaps. Progress made by X PRIZE teams increased pressure on policy-makers to fill these gaps, providing the necessary regulations and laws that would permit qualifying flights to take place.

This section has discussed the results of the HSSTI case study. The next section discusses these results and proposes specific processes of HSSTI emergence within each IIE. This research used the accumulation model as an analytical lens with which to interpret the results of the HEA. This led to a deep understanding of industry actors and major emergence events. Some of the interactions between IIEs described above involved, or were the result of, prize competitions. Although prizes played a very important role in the increased and recent HSSTI emergence activity, they are not a common contributor to the emergence of most new industries. Therefore, this research treats prizes as a special policy, implemented to stimulate industry. First, the processes proposed will describe industry emergence events and relationships without prize effects. Subsequent to that, this report will propose industry emergence processes resulting from prizes, distinct from the other proposed processes.

5. DISCUSSION

This chapter discusses the results presented in the preceding chapter with the goal of understanding HSSTI emergence processes through the lens of the accumulation model. This discussion follows the same order of IIEs as before: Institutional Arrangements, Resource Endowments, and Proprietary Functions, followed by the interactions between all three IIEs. Processes without prize effects will be described first, and prize-related processes will be proposed second.

5.1 INSTITUTIONAL ARRANGEMENTS DISCUSSION

Within the Institutional Arrangements IIE, the first second-order element to be discussed is Legitimation. The policy of the U.S. government is to allow the HSSTI industry to emerge without the burden of certification. So far, it appears that the industry reaction to AST's mandate to "regulate only to the extent necessary" is positive, although the relationship could benefit from better communication:

"I do think that the light touch regulatory side is a net benefit... since 2006, when the first set of regs came out, and everything that's come along since then has helped legitimize the market." – HSSTI Executive

"[The relationship between industry and regulators has] seldom been adversarial, but it's often been very frustrating. It's not been the story of the industry and its enemies. It's been the story of the industry and its well-intentioned, but not always very informed, friends." – Former HSSTI Executive

There is discussion within the European community about requiring the certification process for HSSTI firms before they can operate there. Many U.S. HSSTI firms oppose this decision, saying it will keep them out of the European market, since they do not plan on going through the certification process with their vehicles in the U.S. in the foreseeable future. Many HSSTI actors see such guarantees as being an unnecessary entry barrier. Potential HSSTI firms in the European Union favor certification because they feel it is a “*conditio sine qua non* to reach the market” (Booz & Company, 2013, p. 27), with the potential to damage their reputation of safety if they operated with anything less. The U.S. regulatory framework does have limited guarantees in the form of safety approvals, but they do not encompass the entirety of a vehicle design. All safety approvals issued by the FAA AST through 2017 were for HSSTI equipment, facilities, services, or training. The number of safety approvals issued may be a proxy for private-sector level of activity within supporting industries of the HSSTI. Between the years of 2009 and 2017, FAA AST issued safety approvals at a nearly-constant rate of approximately 1.4 per year, but since the sample set of data is small, drawing conclusions is not possible. An increasing rate of experimental permits, launch licenses, or launch site operator’s licenses could indicate an increase in the emergence of the HSSTI. The issuance of only ten experimental permits and eight launch licenses to HSSTI firms since 2004, however, reinforces the inconclusive nature of the evolutionary state or path of the industry. The private-sector has not yet adopted widespread industry regulations, despite some initial attempts, and the prompting by FAA AST. The actions of several government agencies have signaled their support of the HSSTI through the execution of multiple agreements, effectively permitting the use of the agencies’ symbols (e.g., name,

logos) to increase the legitimacy of the private-sector partner (Rao, 1994). Direct association of a firm with major government agencies, such as NASA or the FAA, provided the industry members with a high level of legitimacy:

“having the kind of endorsement, if you will, and the backing of the federal government, does help a lot of these companies, and it helps advance them.” – HSSTI Trade Association Executive

“The association with NASA, the association with FAA, does seem to carry a lot of weight.” – HSSTI Firm Employee

On the one hand, these agreements impact a wide audience, including public-sector organizations, private-sector firms, and the general public, thereby helping to build both sociopolitical and cognitive legitimacy (Aldrich & Fiol, 1994). On the other hand, private-sector (self-)endorsement activities takes the form of political action, signaling their capabilities and activities, intended to develop sociopolitical legitimacy primarily with public-sector organizations that influence the business environment in which they operate.

Within the second-order element of Governance, a detailed discussion of each of the space industry norms explored is beyond the scope of this dissertation, but some common findings about them are worth noting. Although the perception of government as the only reasonable-risk customer may hold true for orbital human spaceflight, the presale of approximately 700 tickets on the Virgin Galactic SpaceShipTwo vehicle is evidence that a non-governmental demand for suborbital human spaceflight exists. The importance of safety considerations in human spaceflight is an international norm in the space industry (Howard, 2014), and although enthusiasm for a new industry technology is common, as

with the automobile industry in the late 19th century (Rao, 1994), many in the space industry are themselves, or perceive many in the industry to be, exceptionally enthusiastic. Interviewees generally agreed with the remaining norms identified, including the requirement of large amounts of capital, the desirability for international cooperation, and governmental involvement in support of the industry. The HSSTI regulatory regime in the U.S. is not unique in the world, nor can it claim to be “the first.” Although HSSTI firms are first appearing in earnest in the U.S., countries in which their space industries are entirely or partially state-owned, controlled, and operated, have their regulatory agencies “built-in” to the industry member. In these cases, the government is “overseeing industry operations” because they own the industry, and this is the definition of the regulatory function required by the outer space treaty. Rules issued by FAA AST have also provided guidance (but not direction) to HSSTI firms. Regulations implemented in the U.S. limit the burden imposed on the industry. At the federal level, there were only three major regulatory acts passed over a period of 30 years, with two of these bills passed in the last decade (reflecting the increased level of non-governmental space activity). Many laws, on the other hand, have passed at the state level, primarily in six states (California, Florida, New Mexico, Oklahoma, Texas, and Virginia).

The last second-order element of the Institutional Arrangements IIE is Technology Standards. The lack of progress in the development of technology standards may be due to the small number of HSSTI firms that are in full operation. The small number of active firms, each pursuing a very different vehicle design and mission profile, limits the areas of potential standardization to technical domains that do not involve, or interface with, each firm’s unique design or operations. This explains the limited adoption of standards

to date (regarding propellant tank siting and propellant handling), whose impact is not unique to the design or operation of either firm. In fact, there has been strong sentiment in the industry against the establishment of standards. HSSTI firms have employed many veterans from the established space industry actors, including both the private and public (civil and military) sectors, however. These individuals have brought with them the best practices, and industry standards, as it pertains to their areas of operation. In this way, HSSTI firms have collectively, albeit inadvertently, incorporated best and standard practices of the space industry at large. With such a limited field of firms, and with no actual market operations at present, the technology standards as applied to each operator seems highly customized to each firm (thereby defeating the concept of standardization). Once these firms are able to demonstrate continued and repeated operations with paying customers, mimetic isomorphism (DiMaggio & Powell, 1983) would be expected to occur on the part of new entrants, thereby aiding with the creation of de facto industry standards. Until the time when more firms are operating within the same industry, industry-wide standards may be more of a distraction than a useful component of the accumulation framework.

5.2 RESOURCE ENDOWMENTS DISCUSSION

Scientific and Technological Research is the first second-order element presented here within the Resource Endowments IIE. Since 1996, government-funded research received by HSSTI firms totaled approximately 12 million USD in SBIR grants, and one million USD in contracts. All the SBIR grants went to the HSSTI firm that had the least financial resources. Perhaps that firm more actively pursued, and received, external funding that aligned with their internal research efforts. It is unknown how much of the

DARPA XS-1 contract funding the HSSTI firms actually received, but it is clear that the level of effort spent on this and some NASA programs was not contributing to the HSSTI emergence. For HSSTI firms with large workforces, this non-HSSTI activity may not have impeded their progress on their suborbital projects, because the orbital and suborbital activities may be separately staffed and supported. For the “smaller” HSSTI firms, however, the only way to work on activities that were not related to the HSSTI was to reduce the resources dedicated to the HSSTI emergence activities. This is an example of “opportunistic” versus “responsible” behavior that differentiates the dependence relationship from the accumulation relationship. The potential diversion created by government contracts, manifest by the pursuit of government goals (in exchange for financial resources) that are different from company goals, should be greater than the diversion created through the execution of research grants. This is because contracts and grants are two different acquisition instruments, and the level of control that government imposes for a grant is less than the level expected for contracts. However, the desire of a recipient to satisfy the funding agency creates the possibility for a significant level of influence and control by government over the firms, even when using a grant. There are cases when other actors (not the government) fund the HSSTI firms. This leads to a discussion of the next second-order element of the modified accumulation model framework, Financial Arrangements.

In addition to the government contract and grant sources of funding already mentioned, Financial Arrangements also includes non-equity investments, equity investments, and industry-wide stimuli. The extent of non-equity investment in the HSSTI totaled approximately 23 million USD, split fairly evenly between the two

smallest HSSTI firm, Rocketplane and XCOR. These investments originated from three different governmental (non-federal) entities, each of which was pursuing a modern version of the strategy known as “smokestack chasing” (Pages et al., 2003). The total investment in exchange for equity, on the other hand, was almost 50 times greater, with just over 1.25 billion USD, distributed primarily to Virgin Galactic and Blue Origin, although XCOR and Rocketplane also benefited to a much lesser degree. The X PRIZE was the industry-wide stimulus that sparked the increase of investment and technological innovation observed in the HSSTI. Although the winning of the X PRIZE competition by Scaled Composites led directly to the public announcement by Sir Richard Branson of the creation of Virgin Galactic in 2004 (although the first mention of “Virgin Galactic Airways” was in 1999 [F. Nelson, 1999]), Blue Origin had already been operating since 2000. Although the government contributed in some ways to the industry emergence, in the form of non-equity investment and by sponsoring subsequent prize competitions, the private-sector was seen as the predominant contributor to the current HSSTI emergence.

The last second-order element of the Resource Endowments IIE is Human Competence Pool. Not including the typical university aerospace, aeronautical, or mechanical engineering programs, educational programs specifically designed for the space industry have existed since the late 1980s, but those specifically targeting the HSSTI only began emerging in the 2010 timeframe. HSSTI training opportunities evolved to meet emerging demand in the mid-2000s, first with the extension of existing military and civil aviation training facilities, to include suborbital spacecraft. The number of conferences and meetings organized to discuss HSSTI topics as a primary (or only) focus are still relatively rare, although the level of activity has increased in the past,

especially when industry events (such as flight testing) occurred. The number of citations found in a search of google scholar shows an increase in publication activity, although conference proceedings from the two major space conference events, not highly attended by employees from HSSTI firms, do not reflect an active discourse about suborbital tourism in the more established industry communities. The low attendance by HSSTI firm employees aligns with the firms' desires to protect trade secrets, and only to expose information in a very controlled way.

5.3 PROPRIETARY FUNCTIONS DISCUSSION

Within the Proprietary Functions IIE, the Technological Development Functions second-order element is the first for discussion. Although most details about the HSSTI proprietary research are based on conjecture, each firm has conducted, or is conducting extensive research, since the industry is still in its early stages of emergence, and the innovations upon which the industry is based, are still under development. Each HSSTI firm included in this research had at least preliminary manufacturing achievements, although some HSSTI firms were not able to survive past this phase, due primarily to a lack of sufficient funding. The remaining firms have completed the manufacturing and assembly of their vehicles, and have progressed to the flight testing phase of business development. Scaled Composites chose to exit the industry after this phase (after winning the ten million USD X PRIZE purse), licensing the intellectual property for SpaceShipOne to Virgin Galactic. Blue Origin and Virgin Galactic are still conducting flight testing of their vehicles. If these companies can successfully complete these tests, they would then progress to the production phase, selling tickets to customers, and providing suborbital flight services.

Innovation Network and Resource Channel Activities are the next second-order element presented here. NASA has been the primary government agency providing access to knowledge, facilities, and equipment through the SAAs, which are a special acquisition instrument, authorized under the category of “other transactions.” As described earlier, categories of these agreements include “funded” (where NASA funds the firm to demonstrate a capability or achieve predetermined milestones according to an agreed-upon schedule), “unfunded” (where there is no exchange of funds between the parties), or “reimbursable” (in which the firm pays NASA, for example, for access to facilities, the use of equipment, or the time of government employees). Some of the NASA facilities are one-of-a-kind, or unique in their performance capabilities, so the access and operational expertise made available to HSSTI firms is an extraordinary opportunity. A common vendor-supplier-distributor network characterizes the HSSTI (Figure 9 on page 108). Each firm, however, includes portions of each network node within its boundaries. The spaceports included in this research are only those that have the potential to service U.S. HSSTI vehicle operations. This research excludes other existing spaceports in the U.S., licensed for vertical take-off (and vertical landing, in some cases) rockets that transport payloads to Earth orbit. For over a decade, there have been many plans for the design and construction of spaceports in China, the Middle East, Southeast Asia (Boyle, 2006; Ruddick, 2009). More recently, there have been discussions about possibly putting spaceports in such regions as the United Kingdom, Europe, Scandinavia, and Japan (Clark, 2009; Lauer, Harillo, & Onuki, 2013; Moro-Aguilar, 2015; Onuki, Ito, Watanabe, & Lauer, 2009).

Market Creation and Consumer Demand is the last of the second-order elements of the Proprietary Functions IIE. Of the 52 raffles, drawings, and other competitions created that featured HSSTI-related prizes, only a small number ever announced a winner, and just under 50% were associated with the HSSTI firms included in this research. In other words, over half of the contests offered rides on vehicles that never reached the manufacture stage. The marketing value of these activities came at a very small cost to the companies, and sometimes even generated income. It is interesting to note that Blue Origin participated in no prize competitions because, prior to March 2016, the firm was very secretive about its progress and operations. Therefore, Virgin Galactic and XCOR, starting in 2005 and 2011, respectively, were the HSSTI firms capitalizing on this form of marketing. The timing of Virgin's participation in contests may have been to retain some level of public visibility during the interim period between the end of SpaceShipOne operations and the beginning of SpaceShipTwo tests in 2010. XCOR also needed increased visibility in the public eye to boost ticket sales, and to successfully close on funding rounds that were undoubtedly in negotiation prior to the public disclosure date of 2012. The type of marketing created by prediction of start dates for revenue-generating operations carries certain risks, because there can be negative effects if the predictions are incorrect. Repeatedly missing the predicted start of operations erodes credibility and legitimacy. As mentioned above, Virgin Galactic is the only remaining HSSTI firm that has accepted these risks, potentially due to pressure from the investment partners. Blue Origin has only recently begun making predictions of operations start dates.

5.4 IIE INTERACTIONS DISCUSSION

In the development of the original accumulation model framework by Van de Ven and Garud (1989), the following processes were described as linkages between IIEs: the allocation of resources for research (the balance between technology push and pull), the conversion of scientific knowledge into a commercial product (the process of innovation), and the creation of standards for the new industry. Observations from the HSSTI case study provided evidence of these processes between IIEs.

Firms decide whether to invest their resources in solving questions that are directly applicable to their operational goals, or to promote more generic, “basic” research, that has the potential to benefit other firms in the industry as well. Prior studies (Illinois Institute of Technology, 1968; Mirowski, 2011; Mowery & Rosenberg, 1979; Sherwin & Isenson, 1969) asked if technological advancement is fastest when promoting advancement in general fields, driven by scientific advances (technology push), or by concentrating on specific problems that may be economically driven (technology, or demand, pull). These studies yielded inconclusive results. The results of this study do not identify any firm-funded basic research in support of the industry, hinting at a predominant tendency for “technology pull” over “technology push.” There were, however, instances of HSSTI firms participating in research activities when funded by the government, either through research grants, SBIRs, or contracts.

The process of converting scientific knowledge into a commercial product is not very well understood, and has been described as “long, complex, and highly uncertain journey” (Van de Ven & Garud, 1989, p. 214). Financial investment in HSSTI firms by individuals and organizations from the Resource Endowments IIE is the primary impetus

behind the innovation process conducted within the Proprietary Functions IIE. To date, there is no evidence of a successful innovation process, because no HSSTI firm to date has yet begun commercial operations. The strongest evidence of commercial demand in the HSSTI are the 700 reservations taken by Virgin Galactic for future flights on their SpaceShipTwo vehicle.

The Institutional Arrangements second-order element of Technology Standards is one of the least developed in the entire HSSTI framework. The small number of firms directly involved does not promote a great desire for standards because of the very different vehicle designs and mission profiles between them. The industry trade association initially coordinated standards development regarding upstream activities of vehicle operations, such as for propellant handling. More recently, ASTM International, an official standards creation organization, has assumed the lead role in this activity. Industry veterans, previously employed in the established space industry, have brought best practices to HSSTI firms, and this may lead to adoption of de facto standards.

Finally, the linkages between IIEs may transcend the market of one country and extend into another. For example, the FAA AST openly discusses the intent and structure of the U.S. regulatory framework at international events, and other countries may construct similar, or related, governance structures for the HSSTI in their country.

“Other people are picking up the message and using what the last ten years with AST has developed as a playbook, to move ahead with their own development and domestic regulations. I think that is a very positive government role.” – HSSTI Executive

Given these results and observations, this research next proposes processes within each of the three IIEs.

5.5 INDUSTRY EMERGENCE PROCESS DIAGRAMS

5.5.1 Industry Emergence Chart

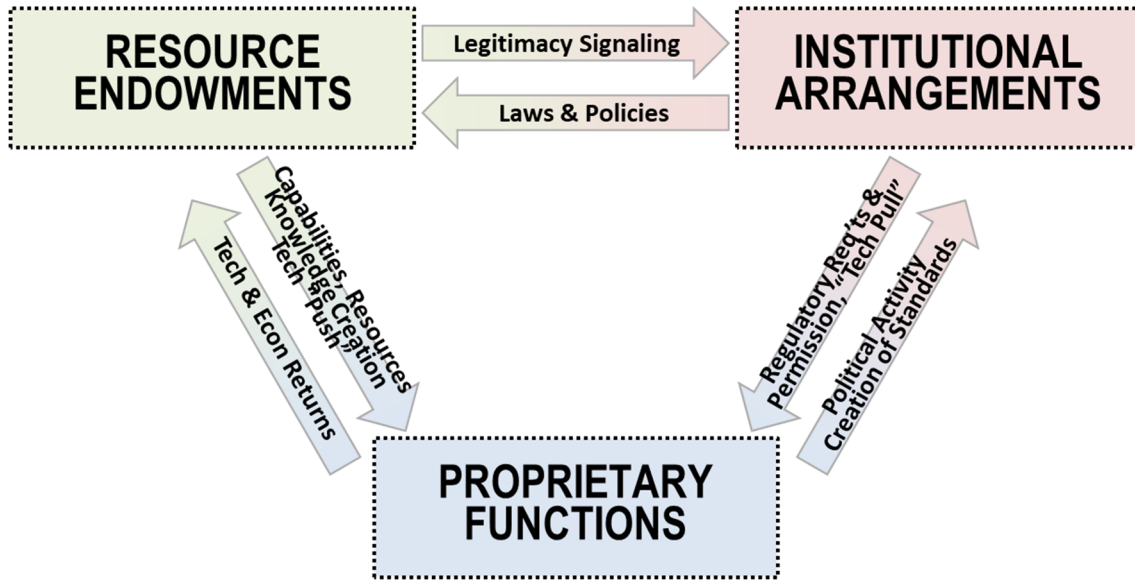
This research chronologically arranged all the events and industry information collected and detailed above in tabular form to graphically depict the HSSTI emergence, starting with the year 1955 through 2017. Appendix B shows a miniaturized (page-sized) version of the detailed chart. For the sake of clarity, color-coding differentiated the three major IIEs and their components from one another. The Institutional Arrangements are red, Resource Endowments are green, and the Proprietary Functions are blue. The detailed HSSTI industry emergence chart includes approximately 600 events identified in the HEA, and is supplemented with ISA and DIA results. The observation of common progressions of events (such as requesting, then receiving, regulatory permissions, or financial investment followed by experimental testing) helped generate a simplified process diagram that describes the detailed industry emergence events. The detailed chart shows that after the initial government research activity (depicted by an inset box that spans the years between 1955 and 1975), there was a low level of activity until 1996, after which time the number of significant events clearly increased with the announcement of the X PRIZE competition. This renewed activity began with the entry and creation of a number of private-sector firms, quickly followed by substantial amounts of private individual and organizational investment (within 3-5 years). Institutional activities at the state-level also began at approximately the same time as the announcement of the X PRIZE. National-level actors also began contributing to the

industry emergence within 3-5 years after the private-sector investment events. As further evidence of a vibrant industry emergence, the popular press frequently reported on HSSTI events, across the private- and public-sectors, by the time the X PRIZE was won in late 2004.

The development of process diagrams based on the HSSTI emergence chart began with the original depiction of the accumulation model, first created to show the three IIEs with the inter-element linkages (Figure 12). The industry emergence chart identifies interactions between IIEs as boundary-spanning arrows, and their content is based on the results of the HEA. The bridge between Institutional Arrangements and Resource Endowments primarily includes legitimacy signaling activities by actors building the Resource Endowments infrastructure, and the passage of enabling laws and policies by actors contributing to institutional arrangement resources. Resource Endowments actors are involved with creating new scientific knowledge (“technology push”) and providing different types of resources, in exchange with Proprietary Functions actors providing capabilities and (potentially) economic returns to the resource providers. In return, Proprietary function actors conform their product to regulatory requirements (“technology pull” behavior) of Institutional Arrangements actors, and also engage in technology standard development (also “technology pull”), political activity, and relationship-building with Institutional Arrangements actors. In exchange, industry actors receive regulatory permission to operate. The perspective in Figure 12 is quite macroscopic, and the objective of the next section is to propose the details of processes that take place within each of the major IIEs. Since prize competitions are not common to the emergence of most industries, the following discussion defers the impact of prizes

upon the HSSTI emergence until after the proposition of more generalizable, microscopic, industry emergence processes.

Figure 12. Original accumulation model process diagram



5.5.2 Process Flow Diagrams

This section proposes and describes a process flow diagram of the industry emergence. The bases of these processes are the inductive research of the HSSTI case study described to this point. This section first describes the accumulation model process diagram within each of the three IIEs, and afterwards, discusses the relationships between each IIE.

In the processes that follow, different forms of legitimacy are proposed to be a major result of the resource accumulation efforts. Multiple observations, made during the HSSTI emergence research, triggered the explicit inclusion of legitimacy to the accumulation model process diagram. First, a subtle inconsistency noted was in the IIE framework at the second-order level. Based on the data collected in the HSSTI emergence chart, most second-order elements denoted or inferred the construction of

objects or events. For example, in the Proprietary Functions IIE, the Technological Development Functions second-order element inferred the development of technologies, the Innovation Network and Resources Channels second-order element consisted of network elements, and the Market Creation and Consumer Demand second-order element resulted in market emergence indicators (firm entrances, exits, and ticket reservations taken). In the Resource Endowments IIE, the Scientific and Technological Research second-order element consisted of research programs and values, the Financial Arrangements second-order element tracked investments, and the Human Competence Pool second-order element contained education and training programs, meetings, and the number of published articles. Finally, the Institutional Arrangements IIE Technology Standards second-order element consisted of adopted technology standards, and the Governance second-order element counted permits, licenses, and safety approvals. The Legitimation second-order element in the original accumulation model framework, however, broke this pattern. Legitimation is the action of creating legitimacy, but the framework does not explicitly include legitimacy. It seems clear the industry emergence processes should contain it, even if the framework did not. In addition to this, and to foreshadow an upcoming discussion at the end of this chapter, fundamental characteristics the HSSTI (specifically, high cost, high technical complexity, and high risk of personal harm) indicate that this is an industry highly sensitive to legitimacy. To highlight legitimacy, and its creation, this research proposes that the resources accumulated within the Institutional Arrangements and Resource Endowments IIEs all contribute to the development of industry legitimacy. Using the two-part legitimacy typology by Aldrich and Fiol (1994), this research proposes that the Institutional

Arrangements resources contribute to the development of sociopolitical legitimacy, and the Resource Endowments resources support the creation of the industry’s cognitive legitimacy. The following discussion provides details for the processes that comprise the accumulation model’s three IIEs.

As mentioned above, this section presents conclusions for the IIE element groupings identified in this research in lieu of using the original framework typology. To emphasize the contribution by all Institutional Arrangements IIE second-order elements to legitimacy, the Legitimation second-order element in the original framework was renamed Endorsements. The purpose of the relabeling was to align this discussion with the process diagrams described above. Gray cells in Table 3 show the differences between the original and new categorizations.

Table 3. Modified Institutional Arrangements IIE second-order elements

| Original 2nd-order Institutional Arrangements elements (Van de Ven & Garud, 1989) | Original 3rd-order Institutional Arrangements elements | Modified 2nd-order Institutional Arrangements elements |
|---|--|--|
| Legitimation | Guarantees | Endorsements |
| | Endorsements | |
| | Licensing Practices | |
| | Industry Regulations | |
| Governance | Norms, Rules | Governance |
| | Regulations | |
| | Laws | |
| Technology Standards | Gov’t Regulatory Mandates | Technology Standards |
| | Cooperative, Voluntary Industry Standards | |
| | Market-driven, de facto Standards | |

Predominant events within the Institutional Arrangements IIE that contribute to the Governance resources of the HSSTI include the adoption of, and adherence to, industry norms and rules, the creation of new regulations, the augmentation of existing

regulations, and the enactment of policies and laws through the legislative process at all levels. Municipal and state legislatures passed laws to permit the creation of spaceports (major supporting infrastructure facilities), to better define liability responsibilities of companies, their subcontractors, of HSPs, and also to provide subsidy incentives for the newly-created HSSTI firms. The passage of multiple federal laws, and subsequent amendments, created a regulatory framework that was able to evolve along with the industry. These regulations resulted in Endorsement decisions that impacted the HSSTI, including the issuance of experimental permits and launch licenses. Experimental permits allow firms to conduct important flight tests with the goal of building operational experience and collecting real-world performance data for their vehicles. Launch licenses give the vehicle operators the final permission to conduct operations that result in “compensation for hire.” Regulatory activities also included licenses for the operation of spaceports. The creation and implementation of supporting policies underpinned these laws and regulations. The issuance of these laws and regulatory instruments over time, plus the execution of partnership agreements between HSSTI firms and NASA, created an increased sense of sociopolitical legitimacy (Aldrich, 2005; Aldrich & Fiol, 1994), or pragmatic-exchange legitimacy (Suchman, 1995). Sociopolitical legitimacy is the establishment of institutional processes and identities that can include the new industry actors and characteristics. Activities such as the creation, application, and award of safety approvals, partnerships between public- and private-sector actors, the political activity (i.e., lobbying and contributions to political action committees) undertaken by the HSSTI firms themselves, all contribute to Endorsement resources, and enhance sociopolitical legitimacy. Although the IIE second-order element of Technology Standards is currently

less developed in the HSSTI case, these would also increase the level of legitimacy for the industry. There are three propositions that summarize the effects of Institutional Arrangements IIE components upon sociopolitical legitimacy, one for each of the second-order elements. The first Institutional Arrangements proposition describes the creation of Endorsements objects and events, including guarantees offered by legitimizing organizations (such as government agencies), endorsements (e.g., government partnerships and political activity conducted by firms), licensing practices, and industry regulations:

Proposition 1a: Endorsement objects/events of the Institutional Arrangements IIE are positively correlated to the establishment and accumulation of sociopolitical legitimacy for the new industry.

The next second-order element of the Institutional Arrangements IIE is Governance. Governance objects and events include all laws (municipal, state, and federal), regulations (such as space port licenses, operating permits and licenses, etc.), norms, and rules.

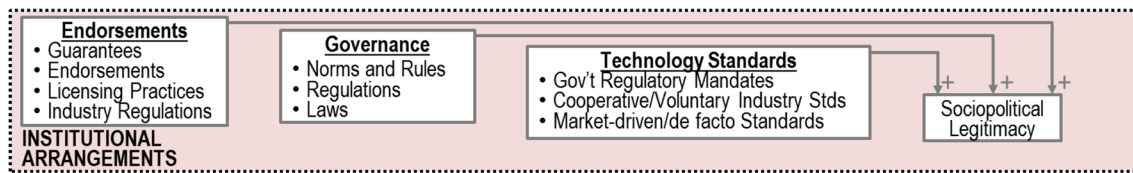
Proposition 1b: Governance objects/events of the Institutional Arrangements IIE are positively correlated to the creation and accumulation of sociopolitical legitimacy for the new industry.

Finally, sociopolitical legitimacy is accumulated through the second-order element of Technology Standards. Objects and events in this element include voluntary industry consensus standards, government mandated standards, and de facto standards of the new industry.

Proposition 1c: Technology Standards objects/events of the Institutional Arrangements IIE are positively correlated to the creation and accumulation of sociopolitical legitimacy for the new industry.

As shown in Figure 13, these propositions describe positive correlations between the three Institutional Arrangements second-order elements and sociopolitical legitimacy. If laws increase the burden on HSSTI firms, if regulations make it harder for firms to operate, if government partnerships decrease, or if the effectiveness of political activity diminishes, the establishment or accumulation of sociopolitical legitimacy can also diminish.

Figure 13. Institutional Arrangements IIE processes



As with the Institutional Arrangements IIE above, there were some modifications made to the Resource Endowments IIE framework to better represent the HSSTI case study results within the discussion of the processes proposed. Whereas the original model included no explicit third-order elements for the second-order element of Scientific and Technological Research, this research included third-order elements of research results from government contracts and grants. Also for this research, the second-order element title, Financing and Insurance Arrangements, was changed to Financial Arrangements. This research also expanded the third-order elements of Financial Arrangements to include government grants, contracts, private non-equity, and equity investments, and

industry-wide investment stimuli. Table 4 shows the new categorization for the process diagrams, with changes shown as gray cells.¹⁷

Table 4. Modified Resource Endowments third-order elements

| Original 2nd-order Resource Endowments elements | Original 3rd-order Resource Endowments elements (Van de Ven & Garud, 1989) | Modified 3rd-order Resource Endowments elements |
|---|--|---|
| Scientific & Technological Research | No further delineation | Gov't Contract R&D Results* |
| | | Gov't Grant R&D Results* |
| Financing and Insurance Arrangements Financial Arrangements | Public Institutions | SBIR Funding |
| | | Gov't Contract Funding |
| | | Gov't Grant Funding |
| | | Non-Equity Investment |
| Human Competence Pool | Private Organizations (Venture Capital) | Equity Investment |
| | | Industry-Wide Stimuli |
| Human Competence Pool | Educational Training Programs | Educational Programs* |
| | Recruitment & Training | Recruitment & Training* |
| | Sharing of Knowledge | Knowledge Sharing* |

* denotes inclusion in Common Goods categorization

Since a grouping of resources, called Common Goods, is referenced in the upcoming Proprietary Functions discussion, it is necessary to identify the different resources included in this “category of convenience.” Common Goods includes all forms of government-funded research results and other resources, such as access to non-exclusive facilities (e.g., spaceports in the HSSTI case, not a part of the Resource Endowments IIE). For the sake of convenience, Common Goods is shown in the proposed process diagram in lieu of the Scientific and Technological Research second-order element. The modified second-order element of Financial Arrangements is the second grouping within this process diagram. A single HSSTI firm may receive many rounds of financing, in

¹⁷ The rephrasing of Sharing of Knowledge, to Knowledge Sharing, was deemed to be too inconsequential of a change to merit a graying of the cell.

many forms, and over a long period of time, from both private- and public-sector actors. Financing from the public-sector includes research grants and development contracts, primarily to take advantage of the firm's capabilities in support of a government programs or projects. Financial subsidies, typically provided by state governments to attract firms with the desire for employment and growth for their region, is a well-established strategy of economic development (Pages et al., 2003). Private capital markets, including individual, angel, and venture capital investors, are some of the major actors in this element. The second-order element of Human Competence Pool includes the third-order elements of Educational Programs, Recruitment and Training, and Knowledge Sharing events (i.e., all conferences, meetings, and publications) that pertain to, and support, the HSSTI. Although categorized here under Human Competence Pool, human capital is also possibly included as a Common Good since it is "under limited organizational control" (Agarwal, Echambadi, Franco, & Sarkar, 2004, p. 503) and freely available to all industry actors. These three second-order elements provide a basis for the establishment and accumulation of cognitive legitimacy (Aldrich & Fiol, 1994). Cognitive legitimacy differs from sociopolitical legitimacy in that the latter distinctively acts upon the institutional segment of society, whereas the former permeates society in general, with the ultimate goal of achieving an unquestionable "taken-for-grantedness" (Tost, 2011).

The second set of propositions of this research pertains to the Resource Endowments IIE process diagram. The first proposition associates the development of, access to, and utilization of Common Goods to the creation of cognitive legitimacy. Common Goods help build the store of cognitive legitimacy when it is positively utilized.

Proposition 2a: Common Goods objects/events of the Resource

Endowments IIE are positively correlated to the creation and

accumulation of cognitive legitimacy for the new industry.

In a similar fashion, the next proposition relates the construction of new industry cognitive legitimacy to the Financial Arrangements third-order elements grouping. This group includes funding from the government for the conduct of research activities (e.g., through grants, or contracts), and other funding from private and public sources, whether in exchange for firm equity or not:

Proposition 2b: Financial Arrangements objects/events of the Resource

Endowments IIE are positively correlated to the creation and

accumulation of cognitive legitimacy for the new industry.

The last proposition addresses a grouping referred to as Human Competence Pool, including Educational Programs, Recruitment and Training Events, and Knowledge Sharing events, and describes their relationship with HSSTI cognitive legitimacy:

Proposition 2c: Human Competence Pool objects/events of the Resource

Endowments IIE are positively correlated to the creation and

accumulation of cognitive legitimacy for the new industry.

These proposed processes are shown in Figure 14. Constructive events in these three categories help build cognitive legitimacy for the HSSTI. Negative events, on the other hand, have a destructive effect on cognitive legitimacy. For example, organizers of conferences associated with space activities (including those of the HSSTI) were aware of the impact their actions had on their cognitive legitimacy, and they changed their customs and behaviors with the expressed intent of increasing their cognitive legitimacy.

Figure 14. Resource Endowments IIE processes



The ISDC, run by a grassroots space advocacy community, practiced a whimsical tradition of “hall costumes,” whereby attendees would dress up as fictional or real characters from space movies, literature, lore, or history. Conference organizers, however, discouraged this practice early in the conference’s history as a means to increase the effectiveness of the organization’s political advocacy activities:

“there was a big controversy because they said ‘no hall costumes,’ because you used to have [Ms. X] used to wear a stewardess outfit for like Pan Am Space or whatever else like that, and a lot of this came from science fiction events where you go and ...[that] used to be called hall costumes. So I remember one of the first ISDCs, one of the rules was no hall costumes, and that did not go over well with people.” – Former HSSTI Employee

A strong motivation to increase the event’s legitimacy was to attract potential investors:

“we had to create events for investors to come to. ... If you want people to invest in an industry, you have to act like an industry, so we were always the ‘other’ category when you’d go to these pitch events, so what we wanted to do was to create things that were our own.” – Former HSSTI Employee

The third element of the accumulation model framework, Proprietary Functions, describes the business development cycle of a firm, starting with an idea in the minds of one or more entrepreneurs, before the firms form. A new firm in this process enters the HSSTI, but it is possible that an already-existing firm expands into the industry, as was the case for Scaled Composites. As firms enter the industry, they begin to assemble the necessary capabilities to execute the many advanced and specialized capabilities (colloquially considered “rocket science”). A long process ensues, including performing the initial HSSTI vehicle designs, conducting all the reviews, having the components and subsystems manufactured in-house or through subcontract, and finally assembling the vehicle and all its supporting systems (test stands, tow vehicles, etc.). If the “trifecta of burdens” faced by firms trying to construct a new industry (Woolley, 2011b) is too great, the company may face “start-up failure” and be forced to exit the market. If the firm can succeed in its initial activities, attract sufficient funding, and experience the necessary growth, they can progress to pre-production activities. At this stage, the firm must acquire the necessary regulatory permits for the operation of their vehicle, that allow for the conduct of initial ground tests, and subsequently more advanced flight testing. The firm may begin marketing activities at this stage, as Virgin Galactic has, selling reservations for tickets aboard the vehicle, once commercial operations begin at some future date. The firm may also begin accepting government contracts for future flights. If the testing conducted at this stage leads to undesirable results, it may be necessary for the firm to perform initial HSSTI activities a second time, redesigning, manufacturing, and reassembling some, many, or all of the vehicle systems. If the funding and capabilities required for these additional activities are not available, the firm may exit the market due

to failure during this major testing phase (referred to here as “testing failure”). However, if results of the testing activities meet expectations, then the firm may progress to the production activity, and enter commercial operations. At this phase, the firm requires a full operating license to operate their vehicle to generate revenue (starting with the backlog of pre-sold tickets, if the firm engaged in pre-production marketing). In this final phase, the firm begins market creation activities in earnest, and they deliver on government contracts they may have won previously. If, during commercial operations, there are anomalies or other flight operation experiences that are undesirable or deadly, the firm returns to the pre-production phase of operations. During the production phase, the firm may not be able to attract enough customers to generate sufficient revenue for profitable operations. If this condition persists over time, the firm exits the market due to market failure. Finally, if the firm successfully builds a sufficient market of customers during the production phase to make the operation profitable, this should attract additional new entrants to the industry field, thereby restarting the cycle for the new company, and helping the industry emerge as a whole. In fact, this begins the cycle of “creative destruction” (Schumpeter, 1947):

“exemplified by entrepreneurs, financed by capitalists, who strike out, often in competition with other, like-minded entrepreneurs, to introduce new innovations which, if successful, provide opportunities to reap extraordinary profits for a temporary period of time. Imitators follow, and an avalanche of consumer goods pours onto the market which dampen prices, profit margins, and innovation investments. This, in turn forces reorganizations of production, greater efficiency, lower costs, the

elimination of inefficient, non-innovating firms, and the replacement of old products and processes with the new ones.” (Van de Ven, 1992, p. 218)

Table 5 below shows how the third-order elements of the Proprietary Functions IIE correlate to the phases of industry development as depicted within the proposed process diagram.

Table 5. Relationship of Proprietary Function 2nd- and 3rd-order elements to industry phases

| 2nd-order Proprietary Function elements | 3rd- order Proprietary Function elements | Industry Phase Relationships |
|---|--|--|
| Technological Development Functions | Applied R&D | Initial Firm Activity |
| | Manufacturing | |
| | Testing | Pre-Production Activity |
| Innovation Network-Resource Channel Activities | Appropriation of Common Goods | Initial Firm Activity |
| | Vendor-Supplier-Distributor Channels | Initial Firm Activity |
| Market Creation and Consumer Demand | Marketing | Pre-Production Activity, Production Activity |
| | Cultural Norms | Initial Firm Activity |
| | Consumer Demand | Production Activity |
| | Competition | Production Activity |

This research proposes two ways that Proprietary Functions IIE resources contribute to cognitive legitimacy. Both involve the public demonstration of their capabilities. The first is during the pre-production phase of firm operations. Normally, operations conducted during this phase are not public, but sometimes the public demonstration of a capability is unavoidable. In those cases, positive public demonstrations of a firm’s capabilities help build cognitive legitimacy, and a negative outcome of these demonstrations can diminish it. Therefore, this research proposes that:

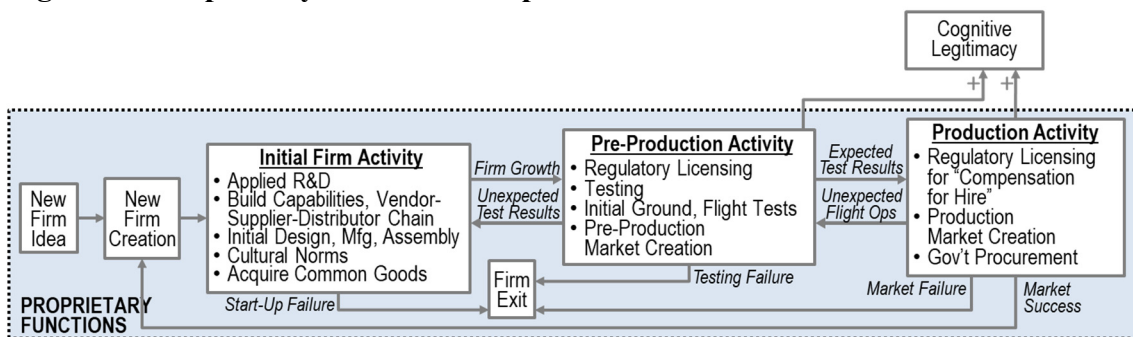
Proposition 3a: Publicly visible, pre-production operations are positively correlated to the creation and accumulation of cognitive legitimacy.

Similarly, any operations conducted during the production phase of firm operations also contributes to cognitive legitimacy. Because all operations during this phase are nominally visible by the general public, these activities also contribute directly to building cognitive legitimacy of the industry:

Proposition 3b: Publicly visible, production operations are positively correlated to the creation and accumulation of cognitive legitimacy.

The majority of these Proprietary Functions processes, shown in Figure 15, are not an extension of theory, but a general description of the HSSTI business cycle.

Figure 15. Proprietary Functions IIE processes



Next, this discussion addresses the impact of both legitimacy types on the interactions between all three IIEs. The sociopolitical legitimacy created through accumulation of component resources of the Institutional Arrangements IIE can amplify the effects of interactions with the other two IIEs. An increase of sociopolitical legitimacy provides policy-makers, regulators, and other government officials with a better understanding of the characteristics and processes of the new industry actors. Regarding the bi-directional interactions between the Institutional Arrangements and Resource Endowments IIEs, increased sociopolitical legitimacy better positions government officials to enact new laws, implement new regulations, or execute acquisition instruments (i.e., contracts or

grants) that are more effective, supportive, or efficiently processed. Additionally, institutional actors more easily understand signals of new industry legitimacy, based on university research, investment histories, employment trends, and conference events. If these signals support the new industry, they reinforce and bolster the levels of sociopolitical legitimacy perceived by the institutional actors, and vice versa. Regarding the interactions between the Institutional Arrangements and the Proprietary Functions IIEs, the discussion above regarding the passage of new laws, regulations and administrative functions also applies, easing the legal and regulatory burden on new firms. Furthermore, through better understanding of the issues and actors of the new industry, increased sociopolitical legitimacy also promotes the efficacy of corporate political activity upon institutional actors. Therefore, the sociopolitical legitimacy built within the Institutional Arrangements IIE impacts the interactions with the other two IIEs.

Proposition 4a: Increased sociopolitical legitimacy is a positive moderator of interactions between the Institutional Arrangements and Resource Endowments IIEs.

Proposition 4b: Increased sociopolitical legitimacy is a positive moderator of interactions between the Institutional Arrangements and Proprietary Functions IIEs.

The interactions between the Resource Endowments and Proprietary Functions IIEs are very important to the success of the industry emergence. Actors in the Proprietary Functions IIE can receive different types of vital resources, including advanced or specialized capabilities, partnerships that provide access to equipment, facilities, or talent

(both technical and managerial), and different forms of funding. Resource Endowments actors receive technical goods or services (in response to grants or contracts), and private capitalists in the HSSTI are still hoping for financial returns. The public demonstration of technical capabilities is an important interaction between the Proprietary Functions and Resource Endowments IIEs, because a broad range of resource actors (financiers, educators and trainers, students and researchers, supporting organizations), as well as the general public, witness these demonstrations. The Proprietary Functions actors also interact with the Institutional Arrangements actors. Firm representatives may conduct various forms of political activity, including informing and educating relevant executive and legislative branch actors regarding their vehicle and firm, or testifying at a Congressional hearing, etc. The interaction by the institutional actors with the proprietary actors includes granting of regulatory permissions, endorsements, or guarantees, in the form of licenses, permits, safety approvals, or SAAs. As mentioned previously, many of the interactions between the Proprietary Functions and the other two IIEs are critical to increasing the cognitive legitimacy of the fledgling industry. Public demonstrations of new technological capabilities (especially when successfully and dramatically performed) increase the cognitive legitimacy of the industry to anyone who witnesses them. These demonstrations of technological capabilities also increase the level of interest of the general public, thereby attracting more students to fields that can lead to a career in the new industry. This, in turn, increases the amount of human capital who choose to participate in the industry. The increased cognitive legitimacy also promotes a heightened level of confidence by the financing individuals and organizations, thereby leading to an increase of their investments in the industry.

Proposition 5a: Increased cognitive legitimacy is a positive moderator of interactions between the Institutional Arrangements and Resource Endowments IIEs.

Proposition 5b: Increased cognitive legitimacy is a positive moderator of interactions between the Institutional Arrangements and Proprietary Functions IIEs.

Proposition 5c: Increased cognitive legitimacy is a positive moderator of interactions between the Resource Endowments and Proprietary Functions IIEs.

Finally, when firms conduct successful test operations in the public view, an increase of cognitive legitimacy is the result. This also positively affects the perceptions by policy-makers, directly affecting the level of sociopolitical legitimacy. This, then, increases the effectiveness of political activity by the private-sector firms. This also leads to a subsequent passage of enabling laws and supporting regulations. This links the two forms of legitimacy in a one-way, moderated relationship (i.e., cognitive legitimacy moderates the level of sociopolitical legitimacy, but not vice versa).

Proposition 6a: Cognitive legitimacy is a positive moderator between Endorsements objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

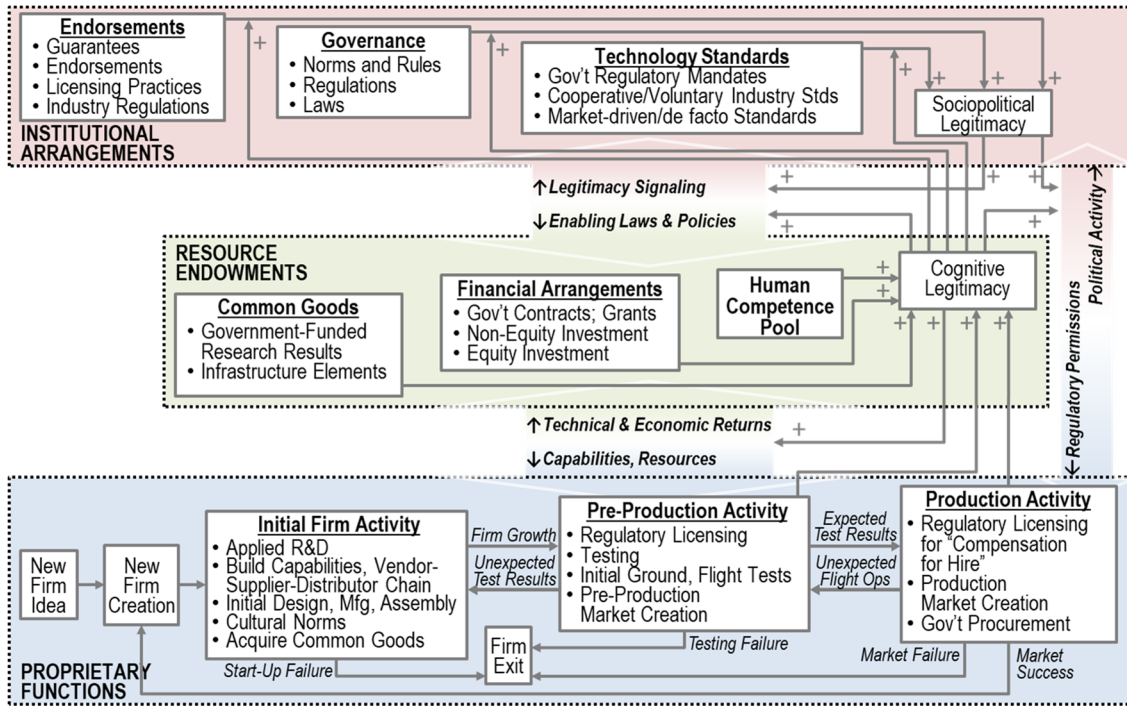
Proposition 6b: Cognitive legitimacy is a positive moderator between Governance objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

Proposition 6c: Cognitive legitimacy is a positive moderator between Technology Standards objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

When combined, the process diagrams of each individual IIE provide an integrated image of industry emergence. As described, the institutional resources accumulate with a positive correlation to sociopolitical legitimacy. The sufficient/insufficient development of institutional resources can lead to a positive/negative impact on sociopolitical legitimacy. In a complementary fashion, cognitive legitimacy is positively correlated to the resources accumulated in the Resource Endowments IIE. The interactions between the Institutional Arrangements IIE and the other two IIEs are positively correlated with the sociopolitical legitimacy, which assists in the passage of laws and regulations to support the emerging industry. Furthermore, this interaction increases the efficiency of legitimacy signaling from the Resource Endowments IIE and political activities from the Proprietary Functions IIE. The cognitive legitimacy, primarily constructed within the Resource Endowments IIE, and assisted by publicly-visible operations within the Proprietary Functions IIE, supports interactions between all three IIEs, by adding foundational credibility to legitimacy signaling and political activities, increasing the level of interest of Resource Endowments actors, whether it be to encourage venture capitalists to invest in the industry, students to enter academic fields that can help them get jobs in the industry, or coordinators of conference and other knowledge sharing events to promote gatherings and meetings within the industry membership. Lastly, the cognitive legitimacy has a positively moderating effect on the creation of sociopolitical

legitimacy by the second-order elements of the Institutional Arrangements IIE. Figure 16 below shows the integrated process diagram that graphically present these relationships. This is the complete set of generalized processes for industry emergence. Next, the special processes related to an industry-wide prize event on industry emergence are proposed.

Figure 16. Accumulation model processes



5.5.3 Process Flow Diagram with Prizes

The process flow described above was based on the HSSTI data and analyses, but intentionally omitted prize events that may have accelerated the overall industry emergence process. In 1996, the X PRIZE Foundation announced the Ansari X PRIZE, and Scaled Composites won the competition in 2004 with SpaceShipOne. Shortly thereafter, the NASA Centennial Challenges program sponsored another prize competition, the Northrop Grumman Lunar Lander Challenge. Both of these competitions

promoted the development of technologies important to the HSSTI, and both were successful. A competitive Rocket Racing League formed subsequent to the X PRIZE, but it only conducted demonstration flights, and never held a racing event. The prior process discussion attempted to identify the industry emergence processes in the absence of these competitions. This section adds the effect of industry-wide incentives (prize competitions in this case) to the overall set of processes. The prize competition was an event that influenced all HSSTI actors, from both the public- and private-sectors, in all three IIEs. The discussion below continues the theory-building process and results in four additional propositions depicted in an amended process diagram, presented near the conclusion of this section. In all propositions, the phrase “prize competitions” assumes that these events are highly credible, and are “industry-wide,” meaning it is open to a wide range of competitors.

To begin the discussion of the effect of prize competitions on the industry emergence process, the HSSTI case study demonstrated that prizes can contribute directly to the emerging industry’s sociopolitical legitimacy in a number of ways. For example, the level of visibility of the initial event announcement, and by the amount of public support given by well-known and respected individuals within the industry, directly impact sociopolitical legitimacy. For example, at the announcement of the X PRIZE in 1996, the press covered a public ceremony, and speaking at the event were many dignitaries from the institutional realm, including the NASA Administrator, the FAA AST Associate Administrator, and former astronauts:

“in spring of ‘96, we announced the X PRIZE at a big public event under the Gateway Arch of St. Louis, which included NASA Administrator Dan

Goldin, and more than 20 astronauts, including Gemini, Apollo and Shuttle astronauts.” – X PRIZE Executive

Leaders tend to use external signals and the opinions of their peers (emulation) when they themselves are unable to make a judgement themselves (Hitt & Tyler, 1991; Scott & Davis, 2007), so the association of respected industry individuals with an unknown prize competition and organization provides a symbolic endorsement of legitimacy. The following proposition describes the direct impact on the HSSTI sociopolitical legitimacy resulting from a gathering of such prominent public figures for the prize announcement:

Proposition 7: Prize competitions are positively correlated to the creation of sociopolitical legitimacy.

Industry-wide stimulus events, such as prize competitions, encourage technological innovation, financial investment, and the accumulation of other Resource Endowments components. For example, these events encouraged young students to pursue higher education in academic fields related to the prize competition. These events also encouraged the research of prize-related technologies, the construction of necessary infrastructure elements (such as HSSTI spaceports), the filling of legal and regulatory gaps by institutional actors, and the execution of conferences and meetings related to the prize subject (either among the contest competitors, the industry actors, or the general public). In the case of prize competitions, the encouragement of these resource creation events is not necessarily direct. For example, prizes don't directly finance the activities of the contestants, but prizes do encourage financial investments in competing teams. Similarly, prize competitions don't affect an increase in the human competence pool by directly educating new students, but the competition encourages more students to enter

the relevant fields of study, thereby increasing the pool indirectly. Keeping in mind that “organizational research have overlooked how certification contests legitimate organizations” (Rao, 1994, p. 30), this research proposes that prizes (and similar industry-wide stimuli events) act as a moderator on the existing (and encouraged) resources as they help build cognitive legitimacy for the new industry. This is consistent with the observation that “certification contests are credentialing mechanisms that invest organizations with cognitive validity” (Rao, 1994, p. 30). The moderating effect is positively correlated with the prize event, so any positive/negative development toward claiming the prize will increase/decrease the amount of cognitive legitimacy earned. Additionally, for the stimulus event to have a discernable impact upon the Resource Endowments IIE components, it has to be credible. There are many ways to achieve prize credibility, such as by having a significant purse, support from recognizable and relevant personalities, or a goal that is both believable, but difficult to achieve at the same time. The results are three separate propositions, using the same groupings of Common Goods, Financial Arrangements, and Human Competence Pool, as described above:

Proposition 8a: Prize competitions are a positive moderator between Common Goods objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

Proposition 8b: Prize competitions are a positive moderator between Financial Arrangements objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

Proposition 8c: Prize competitions are a positive moderator between Human Competence Pool objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

In a less direct way, prizes also impact the general business cycle processes that comprise the Proprietary Functions IIE. Before a firm enters a new industry, the idea for the new company forms within the mind of the future entrepreneur. Over some period of time, a certain fraction of these ideas become a reality, and the “dreamers,” or “would-be” entrepreneurs actually start a new firm within the new industry. In addition to the “regular” or “baseline” process of new firm creation that the new industry may instill within would-be entrants, the announcement of a prize competition may provide additional encouragement for these individuals to create a firm in the new industry. The additional element of encouragement provided by the prize event is, therefore, a moderator to the existing rate of new firm creation. In the case of the HSSTI, after the announcement of the X PRIZE, many new firms became part of the cadre of 23 teams participating in the competition. Only a small fraction of these firms was able to evolve to the pre-production activity phase described in the generalized business development process diagram. Nonetheless, the prize announcement had a positive effect on many people to act on the idea of new firm creation they had been considering.

Proposition 9a: Prize competitions are a positive moderator between consideration of creating a firm and new firm creation.

Subsequent to the creation of a new firm, the effect of a prize event can similarly encourage existing firms, who were working in some other industry prior to the event

announcement, to begin working in the new industry. For example, Scaled Composites specifically entered the HSSTI due to the X PRIZE competition:

“even though Paul Allen put more money into the vehicle design and production than the prize awarded, I think that that base amount of money and the public spectacle that was created around the X PRIZE made all the difference. It clearly sparked Rutan’s inspiration to do it. He kind of acted like he thought about building a spaceship before, but I don’t think he would’ve seriously done it without the X PRIZE.” – HSSTI Analyst

As described in the Proprietary Functions IIE section, “initial firm activities” include the development of internal firm capabilities, and performing initial design, manufacture, and assembly work. This highlights the idea that not all firms entering the new industry are necessarily “new entrants.” Variations of parent-company and diversifying new entrants (Helfat & Lieberman, 2002) are as likely to comprise the initial set of firms in the new industry. For example, the firm that ultimately won the X PRIZE competition, Scaled Composites, had dozens of successful experimental aircraft designs to its credit, but had never designed or built a space vehicle prior to the competition. The 1996 announcement caused a change in the mind of the owner, Burt Rutan, and the firm began to pursue the prize competition goals as a result. Therefore, announcement of a credible prize competition resulted in some pre-existing firms to change their organizational focus, with the intent of initiating HSSTI activities.

Proposition 9b: Prize competitions are a positive moderator to motivate an existing firm from another industry to begin initial activities in the new industry.

In general, the pre-production activities of new firms are not publicized for fear of divulging trade secrets (W. M. Cohen, Nelson, & Walsh, 2000; Levin et al., 1987), or of the negative publicity that could result, should the activity not go as planned. An unsuccessful test could cause potential investors to withdraw support, and could cause relevant law-makers and regulators to increase their skepticism or scrutiny of the activity. During a prize competition, however, the activity performed to win the purse is, by definition, pre-production. Prizes specifically provide an incentive to elicit the earliest possible demonstration of untested technologies. Therefore, prizes are a positive moderator to pre-production activity.

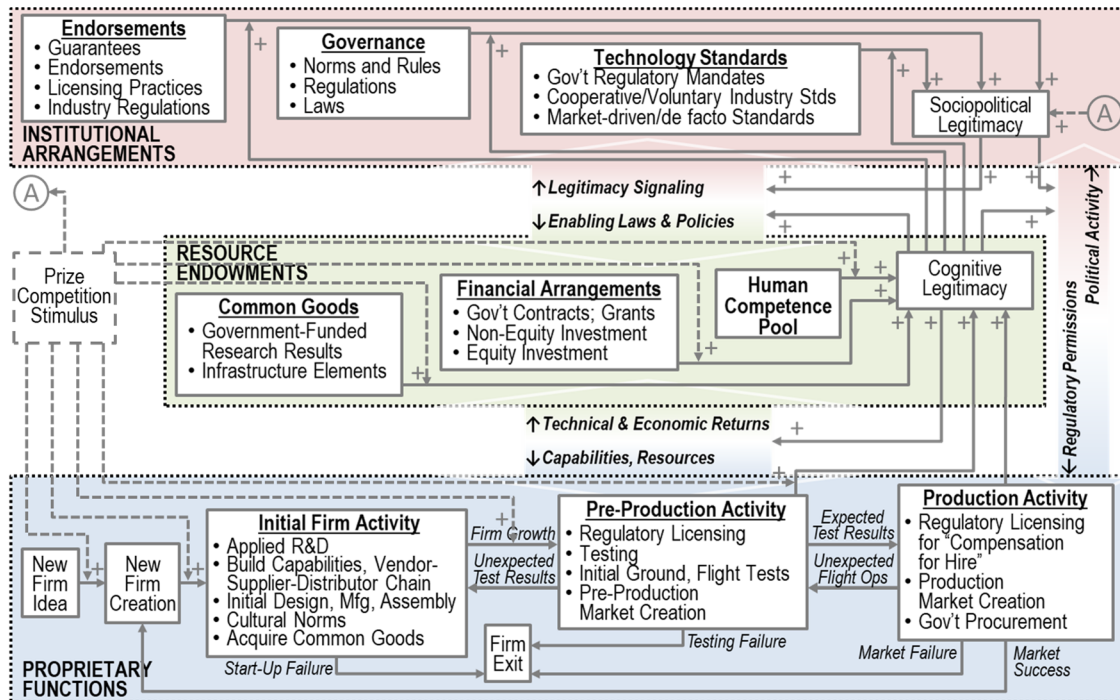
Proposition 9c: Prize competitions are a positive moderator between the processes of initial firm activity and pre-production activity.

Pre-production operations are typically testing experimental designs beyond known operational limits, therefore, they possess an increased risk of failure. Because of the proposed relationship between pre-production operations and cognitive legitimacy, a failure at this stage can damage the firm and the industry. This is one of the reasons that firms will often conduct these operations out of public view. Prizes, however, encourage firms to conduct pre-production operations, increasing the likelihood that a firm will conduct them. Therefore, via the encouragement of the prize competition, pre-production activity conducted in public is part of the set of prize processes, instead of as part of the general business development processes. The resulting proposition is:

Proposition 10: Prize competitions are a positive moderator between pre-production operations and the establishment and accumulation of cognitive legitimacy.

Figure 17 shows the graphic depiction of the complete set of propositions related to credible, industry-wide prize competitions. Solid arrows and boxes depict the original set of processes that do not include prize effects. Dashed arrows and boxes depict the prize-related processes.

Figure 17. Accumulation model processes with prizes



This chapter discussed the results of the HSSTI data collection and analyses, resulting in a deepened understanding of the HSSTI emergence. Additionally, this research extended the original accumulation model framework by taking a microscopic perspective into the three first-order IIEs, and defining the processes within each. This research also slightly modified the original taxonomy of the accumulation model framework, as described in this chapter. The modified framework retained all the original second- and third-order elements, and added some new ones. Appendix K shows a side-by-side comparison of the original accumulation model framework and the modifications

resulting from this research. In the case of the Institutional Arrangements IIE, the modification consisted of renaming one of the second-order elements. For the Resource Endowments IIE, the adapted framework included new third-order elements, and a slight renaming of a second-order element. Within the Proprietary Functions IIE, this research identified a general business cycle process, but only slightly changed the original taxonomy, with the addition of a single third-order element. This research extended the theory further by the proposition of processes, positively correlating Institutional Arrangements second-order elements to sociopolitical legitimacy, and Resource Endowments components to cognitive legitimacy. Processes proposed a correlation between the legitimacy components and the inter-IIE linkages. This research proposes that sociopolitical legitimacy is positively correlated to Institutional Arrangements-Resource Endowments and Institutional Arrangements-Proprietary Functions linkages, whereas the cognitive legitimacy is positively correlated to all three linkage relationships (Resource Endowments-Institutional Arrangements, Resource Endowments-Proprietary Functions, and Proprietary Functions-Institutional Arrangements). This research also proposes that cognitive legitimacy positively moderates the establishment of sociopolitical legitimacy. The processes proposed up to this point describe the “generalized” industry emergence process. This research also proposed the effect of prize competitions on the overall set of processes, including that prizes are a positively correlated antecedent to sociopolitical legitimacy, but is a positively correlated moderator to cognitive legitimacy. This research also proposed that prizes also positively moderate the general business cycle processes of new firm creation, initial firm activity, and pre-production activity. Finally, this research proposed the public execution of pre-production

testing, as a result of competing for a prize competition, positively correlates with the accumulation of cognitive legitimacy. The complete set of proposed processes, given in Appendix L, build upon the original accumulation model framework, and extend the theory in a way that identifies possible ways to verify and validate the proposed processes for future researchers in other industry contexts. But just how generalizable are these results to those other industry contexts?

5.6 GENERALIZABILITY OF HSSTI RESULTS

How generalizable are these results, based on a space industry, to other types of industries? It may be that the HSSTI does not exist within a “conventional market environment” (Mowery & Rosenberg, 1979, p. 150), and is different from other consumer markets, being less suited for commercial environments, and better suited for government partnerships, because it is an off-shoot of the military and aerospace industries (Chakravarthy, 1985; Nelson, 1982). Healthy skepticism may consider these research results not generalizable because of the HSSTI uniqueness. Whether true or not, a constructive outcome of this industry’s unique characteristics is the emphasis on an aspect of the accumulation model that was underemphasized in previous studies to date.

Researchers immediately encounter characteristics of the space industry that distinguish it as unique when compared to other “non-space” industries. An obvious characteristic of the HSSTI is the high capital requirement to make significant strides toward realistic (and profitable) operations:

“operating a space business often requires substantial capital commitments with large minimum investments, long development periods and high fixed costs. Consequently, scale in the form of high market share

provides significant advantages. That 'Space is Hard' and cannot sustain high degrees of competition is not controversial among industry participants or investors. Three competitors is frequently unsustainable even a duopoly does not guarantee profitability. In space 'Two is a Big Number'' (NASA, 2010, p. 50)

High capital requirements, however, are common for many industries, including most of the transportation industries that carry the burden of ensuring passenger safety (e.g., railroads, aviation, maritime, etc.). It is interesting to note that the non-diversifying firms attempting to participate in the HSSTI with “small” investments (totaling less than 100 million USD) have not been successful. Scaled Composites won the X PRIZE competition with an investment of “only” 30 million USD, but they were an established firm that diversified into the HSSTI, so most of the required know-how, facilities, and equipment already existed within the firm. The HSSTI firms with the smallest budgets engaged in a form of “frugal innovation” (Zeschky, Widenmayer, & Gassmann, 2011):

“You’ve got regulated individualism, from an anti-establishmentary view of the world, combined with highly intelligent people, highly innovative people, people who didn’t have a lot of money so they had to be very innovative. And so, the [firms] who were always cash strapped, came up with the best innovations.” – Former HSSTI Executive

Unfortunately, the two firms included in this research that were working with lower levels of investment funding, Rocketplane and XCOR Aerospace, both exited due to start-up failure. Second, it is also possible that the HSSTI emergence activity is sufficiently complex, in terms of integrating many advanced technologies, and

establishing the necessary channels of distribution and supply, and these complexities lead to very long periods of pre-production activities. To date, no HSSTI firms have yet begun commercial operations. Virgin Galactic has been in pre-production operations for at least 13 years, and Blue Origin for 17 years. This is a long time horizon with respect to return on investment for most investors. It may be that the audacity of the goal (the promise of space travel for ordinary people) tempers the impatience of this industry's investors. A "side-effect" of the space industry norm of hyper-enthusiasm for space in general (mentioned previously), may be the perception that this activity is the realization of a dream for humanity, not simply a new product for near-term profit. Some industry observers, therefore, perceive the HSSTI entrepreneurs are not be market-driven, but philanthropy-driven.

"As it turns out, we may not know whether this is a really viable market until we see a new entrant that doesn't have a wealthy, patient backer, but someone that is more of a conventionally venture funded be able to enter the market, develop a vehicle, and then provide a return on their investments, and demonstrate that there really is a viable market, versus simply projects that are willing to be subsidized by people, like a Bezos or Branson, for other ends. They're not looking at this from a strict return on investment question." – HSSTI Analyst

It may be misleading to use the phrase "philanthropy-driven," however, because that could imply that there is no economic motivation to the activity. The established space industry emerged from a series of "cost-plus" contracts awarded to generalist contractors since World War II. This "opportunistic" behavior is consistent with the dependent

relationship, described in the functional goal motor of innovation development, between traditional internal and external space industry actors. In contrast, Richard Branson's stated goal for Virgin Galactic is to pursue point-to-point suborbital flight (Masunaga, 2017), and Jeff Bezos wants to create a system of space transportation infrastructure that could help save humanity if the earth becomes uninhabitable (Chuang, 2016). These are clearly demonstrations of "responsible" behavior on the part of space industry new entrants, characterizing the accumulation relationship. Therefore, analysts might better describe the HSSTI as currently motivated by visions requiring the relaxation of short-term economic goals, in pursuit of activities that may be profitable in the future, while at the same time providing significant future benefits to society.

Another unique aspect of the space industry in general, including the HSSTI, is that small problems can easily result in very significant failures (including the complete loss of a vehicle). Past studies have highlighted the elevated level of operating risks:

"Operating a space business carries with it all of the normal risks of running a business plus many unique risks associated with operating in space (e.g. launch risk, catastrophic failure). This inherently higher level of operating risk generally means the space sector cannot sustain a large number of competitors over the long haul if it is to achieve investor returns commensurate with the assumed risk" (NASA, 2010, p. 50).

Although mistakes that end in failure are common in high-technology industries, a minor mistake of a spacecraft's design, manufacturing, assembly, or operation, of any system, subsystem, component, or subcomponent, can result in a catastrophic loss of the entire vehicle. HSSTI operators and customers pay for the cost of failures, and if they are on

board at the time of the mishap, they possibly pay with their lives. Disproportionately minor problems often cause these major failures, including very simple operational mistakes or design flaws. Therefore, the HSSTI is inescapably a very dangerous activity, with human safety, vehicle survivability, and long-term commercial viability relying on the near-perfect operation of many highly-complex systems. It turns out that these three characteristics, high expense, technological complexity, and personal danger, describe a special type of industry:

“The creation of trust represents a particularly significant entry barrier for product innovations that are costly, technologically sophisticated, and whose purchase entails irreversible health or welfare situations for customers” (Van de Ven & Garud, 1989, p. 211).

As stated previously, Van de Ven (Van de Ven, 1993a, 1993b, 1993c) equates “the creation of trust” with “legitimation,” and this research defines “legitimation” as “processes that create legitimacy.” Therefore, industries with these three characteristics are highly sensitive to the creation of legitimacy, and this provided validation for the addition of legitimacy into the original accumulation model framework. While these industry characteristics may highlight the unique nature of the HSSTI, and seemingly limit the generalizability of these research results, it also emphasizes the importance of legitimacy in a way that previous studies using this model did not. What implications does this have on the generalizability of the results of previous studies, and on the results of this study?

The Introduction of this thesis discussed HSSTI analog industries, including the steamboat, railroad, automobile, aviation, and computer industries. Researchers can

debate whether the relative levels of expense or technical complexity for each of these industries are greater than, or less than, that for the HSSTI. This research, however, estimates the risk of personal danger¹⁸ is high for the HSSTI and civil aviation industry. This research also estimates the risk of personal danger to be moderate or low for all other analog industries presented in this research. In other words, among all these analog industries, the civil aviation and the HSSTI are most sensitive to levels of legitimacy for successful industry emergence. Similarly, regardless of the level of expense or complexity for the industries examined in past accumulation model studies (including cochlear implants, financial derivatives, umbilical cord blood banking, derivatives standards, nanotechnology, business school curricula, the U.S. carpet industry, and HPV tests, discussed earlier), this research estimates the level of personal danger in all of them to be lower than for the HSSTI. Therefore, when compared to the HSSTI, the industry contexts of all prior accumulation model research studies were relatively less sensitive to the legitimacy required for industry emergence. With the exception of civil aviation industry emergence, the same is true for the analog industries included in this research. The HSSTI is unique from most other industries discussed because of the level of personal danger it entails. As a result of this heightened sensitivity, this research proposes a central role for the creation of legitimacy in the accumulation model, as elucidated by the emergence of the HSSTI.

¹⁸ The phrase “personal danger” is shorthand notation for the phrase “irreversible health or welfare situations for customers.” Personal danger is present in vehicles that travel fast and/or high.

In the discussion above, a high level of personal danger distinguishes the HSSTI from past studies and other analog industries. This distinction has both a positive and negative impact on the generalizability of this research. On the negative side, skeptics may hypothesize that these research results have low generalizability based on the HSSTI distinctions described above. To test this hypothesis, researchers can compare the proposed processes against other industries that do not have the same combination of high expense, complexity, and personal danger characteristics. On the positive side, however, previous studies potentially underplayed the role of legitimacy creation, simply as a result of their less sensitive industry contexts. The unique nature of the HSSTI uncovered a central actor in the processes of industry emergence that was mentioned, but unfeatured, in previous studies. The HSSTI represents a limiting case of industry contexts, thereby highlighting the importance of legitimacy. In the proposed industry emergence processes, this research includes the creation of legitimacy because of the central role it plays. In previous studies, legitimacy's role was, at best, on a par with other resources and, at worst, overlooked entirely. The industry contexts of previous studies simply did not feature legitimacy, because their industry contexts were not sensitive to it.

6. CONCLUSIONS, LIMITATIONS, AND FURTHER RESEARCH

This final chapter of this research will first list all the conclusions, followed by the respective limitations, and then discuss possible future research in each area. This chapter also provides a discussion of the original model, and its relationship to the findings of this research, describing how the original and modified accumulation models agree and disagree, and explaining the extensions to the original model. Lastly, implications of this research are presented for entrepreneurs, managers, policy-makers, and more generally for the continent of Africa.

6.1 IIE CONCLUSIONS

This research proposes that all the second-order elements of the Institutional Arrangements IIE, including Endorsements, Governance, and Technology Standards, positively correlate to the creation of sociopolitical legitimacy. For the HSSTI, public- and private-sector actors construct and accumulate Endorsement resources, as evidenced by the number of regulatory safety approvals issued by the FAA AST to HSSTI supporting industries, the number of SAA partnerships between NASA and the HSSTI firms, and the amount of political activity conducted by HSSTI firms with government officials. There has been a deliberate evolution of regulatory authority during this time, and a much more aggressive pace of legal activity, especially at the state level. Specific supporting actions include the passage of enabling laws at the municipal, state, and federal levels, the enactment and issuing of regulatory permits and licenses, and the continuing activity by firms in pursuit of industry emergence. Similarly, there are also many examples of HSSTI actors constructing and accumulating Governance resources since 1967, although a majority of the activity has occurred since the mid-1990s.

Governance's third-order elements, including Norms and Rules, change more slowly than do Laws and Regulations. The least active second-order element of this IIE is Technology Standards. Actors of HSSTI supporting industries discussed and adopted some technology standards, as in the case of propellant handling and tank siting. Despite best efforts of industry or regulatory actors, however, the level of industry emergence may be too immature, and the competing entries too small in number, for the discussion of technology standards to be fruitful or meaningful at this time. Overall, this research estimates the level of Institutional Arrangements resources, and the resulting level of sociopolitical legitimacy, to be moderate, as evidenced by the constructive and supportive actions by institutional actors. The estimated resource level could increase with additional Endorsement and Governance resources, but the adoption of more technology standards is critical to elevating the Institutional Arrangements to a higher level.

This research also proposes that within the Resource Endowments IIE, the second-order elements positively correlate to cognitive legitimacy. The level of Common Goods resources that have been built-up and accumulated within the HSSTI is substantial, including scientific knowledge, human capital, and widely available infrastructure facilities. Scientific and technological knowledge results from government sponsored research, whether conducted by government entities or private firms under contract or grant. The government conducted a substantial amount of research pertaining to the HSSTI in the past, but current levels of government funding are far below former levels. Highly qualified human capital is readily available from public- and private-sector organizations for many reasons. HSSTI firms may hire young employees directly from school, or lure them from established private space companies with the excitement of a

new experience. More experienced employees of the private- and public-sector organizations are also among those joining the new firms, sometimes due to retirement, involuntary separation, or simply changing jobs. Finally, Common Goods includes facilities that are available for hire to HSSTI firms, including spaceports and training centers. The number of available spaceports within the U.S. is sufficiently large (there are currently six active licensed HSSTI spaceports), and these are available to any company desiring the use of their services. Similarly, Financial Arrangements resources are plentiful for the HSSTI. There have been government sponsored research contracts and grants awarded to HSSTI firms. Other sources of public funding are also available, mostly from state and local governments, that seek to lure HSSTI firms to their geographic location, with the hopes of establishing future, high-paying jobs. Ultimately, however, the private-sector has overwhelmed the industry with a high level of funding. Initially, the Ansari X PRIZE served as an industry-wide stimulus of financial and technical activity. Subsequently, Virgin Galactic received approximately 1.5 billion USD of funding from non-government sources, and Jeff Bezos single-handedly financed Blue Origin to the same level of funding. Finally, the Human Competence Pool element also includes many space-related, educational programs, training opportunities, conferences and meetings, all highlighting HSSTI activities. There are not, however, many events that discuss the HSSTI exclusively. These results provide evidence that could lead to the impression that the levels of accumulated Resource Endowments resources, and hence, the amount of cognitive legitimacy, is moderate to strong. Further evidence supporting this claim is Scaled Composite's SpaceShipOne induction into the "Milestones of Flight" gallery in the Smithsonian's National Air and Space Museum after winning the Ansari X

PRIZE. This honor puts the defining event of the emerging HSSTI on par with other aircraft hanging there, including the Bell X-1 (the first vehicle to break the sound barrier), and Charles Lindbergh's "Spirit of St. Louis" (the first plane to fly non-stop across the Atlantic Ocean). However, since the HSSTI is the type of industry (expensive, complex, and dangerous) that is highly sensitive to legitimacy, the current level of cognitive legitimacy may not be sufficient for successful industry emergence. This research estimates that until HSSTI firms have a respectable record of safe, revenue-generating flights, the level of cognitive legitimacy, though strong, remains insufficient to assure successful industry emergence.

Given the progression from the design, manufacture, and assembly of HSSTI vehicles, to the conduct of flight testing, and finally to the provision of flights for compensation, the second- and third-order elements of the Proprietary Functions IIE describe the business development cycle. This research proposes that pre-production and production operations, conducted in the public view, directly contribute to the establishment and accumulation of cognitive legitimacy. One reason the level of cognitive legitimacy is not as high as it could be may be due to a low number of publicly-visible flight tests. Of the five HSSTI firms that initiated the manufacturing process of their vehicles, only two have survived to the flight testing phase. Of the three firms that have exited the industry, two failed during the start-up phase, and one sold off its stake of the market to a currently active firm. It is difficult for external HSSTI observers to accurately identify the proprietary research, functional boundaries, and innovation network and resource channel developments of the internal firms. Sometimes, firms publicize partnerships with other firms, but these aspects also tend to be "trade secrets" of

industry. Regarding Market Creation and Consumer Demand, market forecasts provide minimal reliable evidence of industry emergence, but a number of market interest proxy indicators do exist. All HSSTI firms took advantage of dramatic events, such as public unveiling of their vehicles, to arouse public interest. Virgin Galactic and XCOR capitalized on multiple contests for which the grand prize was a ride in their vehicles. Predictive statements raised anticipation for the Virgin Galactic SpaceShipTwo start of commercial operations. Blue Origin chose not to participate in these marketing opportunities, and was very secretive for the first 15 years of their existence, perhaps because they are in the unique situation of not having to worry about financing. This provides them the luxury of waiting as long as necessary before they begin to widely publicize their activities. Although this research cannot directly observe the Applied Research and Vendor-Supplier-Distributor Channels elements for the two HSSTI firms, they are estimated to be at high levels, based on their continued survival and relatively strong, yet slow, demonstrations of technical performance. This research also estimates insufficient development of the Market Creation and Consumer Demand second-order element, since neither firm has begun commercial operations. Overall, therefore, this research estimates the levels of accumulated resources for the Proprietary Functions IIE to be moderate.

There are a number of observed outcomes of interactions between IIEs. Interactions between the Institutional Arrangements and the Proprietary Functions IIE include the issuance of regulatory guidance, requirements, and permissions (e.g., permits and licenses) that allow the firms to test and fly their vehicles. Institutional actors also enter into partnerships with proprietary function actors, helping increase their sociopolitical

legitimacy. As companies become more experienced and develop plans for their future, they often visit the relevant legislative and executive branch actors in government to communicate their plans and needs, thereby increasing sociopolitical legitimacy. This increased sociopolitical legitimacy also enhances the communication by private-sector actors with institutional representatives, and that, in turn, results in the passage and implementation of favorable policies and laws for the industry (including both the Resource Endowment and Proprietary Function actors). Resources of finances, knowledge, and human capital flow to private-sector firms from the Resource Endowments to the Proprietary Functions IIE, with the beneficial returns of commercial products. Happening in parallel with these interactions, the industry actors also work with institutional actors to develop different sets of technical standards, by which all actors can optimize their interactions. Finally, increased interactions between the Resource Endowments and Proprietary Functions actors sends signals of cognitive legitimacy to the Institutional Arrangements actors, thereby indirectly strengthening the accumulation of sociopolitical legitimacy.

This research proposes that prizes influenced the industry emergence processes of all three IIEs. First, this research proposes that prizes are positively and directly correlated to sociopolitical legitimacy in the Institutional Arrangements IIE. Second, prizes positively moderate the creation of cognitive legitimacy by all three second-order elements of the Resource Endowments IIE. Third, in the Proprietary Functions IIE, prizes positively moderate the creation of new firms, the accumulation of required capabilities to function in the new industry, and the growth from initial capabilities to pre-production operations.

Finally, prizes positively moderate the creation of cognitive legitimacy by encouraging firms to publicly conduct pre-production operations, instead of keeping them secret.

6.2 IIE LIMITATIONS AND FURTHER RESEARCH

This section identifies limitations and possible further research for each of the individual IIEs before including a similar discussion for the linkages between them. A final paragraph will discuss general limitations or further research for the accumulation model as a whole.

Research limitations in the Institutional Arrangements IIE include a lack of quantitative data to analyze legitimacy activities, and the qualitative assessment of partnership quality. The sample size of industry activity, related to the Guarantees second-order element, is insufficient to report any statistically significant findings for a variance study. Therefore, it is difficult to estimate the issuance rate of permits or licenses as an indication of legitimization activity levels. Furthermore, questions arise regarding the impact of partnerships between firms and government agencies on sociopolitical legitimacy creation. A simplifying assumption could be that all partnerships are of equal value, but that is probably not the case.

Further research in the Institutional Arrangements IIE could encompass work on the space industry norms, technology standards, and the measurement of legitimacy.

Regarding space industry norms, multiple observations provided some validity for the industry norm results found in this research, but more focused research could explore each norm in more depth, and possibly include a longitudinal component. Researchers could also conduct studies in the domains of accepted standards, and the way the hiring and movement of personnel affects the diffusion and adoption of standards, from the

established industry to the emerging industry segment, and between firms of the emerging segment. Research that could benefit policy and industry leaders includes the appropriate timing for technical standard development, and the negative repercussions of premature standardization. Currently, HSSTI actors are pursuing technology standard development based on their past experiences in the established industry. It is possible that the approach employed in the past may not be well-suited to an emerging industry. Future measurement of legitimacy could also be researched. Qualitatively, research could employ survey and interviewing methodologies to collect perceptions of public- and private-sector industry actors to assess the sociopolitical and cognitive components of HSSTI legitimacy. Quantitatively, further research could include variance studies of legitimation events once the degree of activity increases to a level that provides statistical significance.

The data collected for elements of the Resource Endowments IIE were qualitatively complete, but quantitatively lacking for many reasons. It was possible, through public-facing web sites, to access most of the information regarding the existence of some government contracts and grants, the number of infrastructure facilities, and the types of available educational and training programs. Getting reliable values for any specific item, however, was not straight-forward. Even when total contract values were available for government procurement events, it was often not possible to know how much money government had actually paid to the firm, and when. This research assumed that the firm used that money exclusively for HSSTI-related activities, although that may not be the case. For example, if NASA signed a ten million USD contract with a company, there was not necessarily any funding actually transferred from the government to the firm. It

is possible there was a small percentage provided to the firm at the time of signing (or shortly thereafter), but the remainder of the funding would be withheld until successful completion of pre-determined (and sometimes proprietary) performance milestones. Similar limitations existed regarding public and private financing deals for HSSTI firms. Although there was consistency in reporting of funding amounts, the validation of report accuracy was not possible. This calls into question whether the data set collected is complete. The uncertainties introduced span from knowing some information is missing but not realizing what the values of that information are, to having no information at all. In either case, and particular to this type of financial investment data, the results are approximations at best, and are probably under-estimated. When identifying the timing of specific partnership or funding events, it is normal to rely upon secondary source reporting. These sources can be incorrect, or they may sacrifice accuracy for understandability, thereby giving approximations of timing or monetary values to make their writing more accessible and understandable to the lay-reader. This research sought validation through corroboration with primary source data whenever possible. Finally, regarding the Human Competence Pool resource, due to the wide applicability of generic education and training programs in general, identification of the complete set of these opportunities that are specific to the HSSTI is prone to under-estimation. This research has included all of the major activities that are engaged in the larger space community events, but included smaller “boutique” education and training organizations only when publicized or recognized at the better-known space industry conferences or meetings.

Since some contract awards were made to teams of firms (comprised of firms both within and outside the HSSTI), it was not always possible to tell what fraction of the

funding went to the HSSTI firm alone. Through primary data collection, further research could try to quantify the amount of funding awarded to individual HSSTI team members. Further research into the Financial Arrangements element of the HSSTI emergence could include gathering more detailed information about all public and private investments received by the HSSTI firms, through interviews with the firm members and/or the investors themselves. If the researcher can guarantee anonymity to the interviewee, and if interviewees share relevant information, better information may result. Finally, further research regarding the development of the HSSTI Knowledge Sharing could include in-depth analyses of this portion of the event chronology, including bibliometrics of the HSSTI. As mentioned in this research, conferences and meetings were very broad in their scope, and covered many segments of the space industry within the same program. Future studies, tracking how the content of these events changes over time, may fix this limitation, thereby identifying HSSTI-specific themes within the more general conferences and meetings, and tracing, with more accuracy, the evolution of industry-building events for the HSSTI. It is also possible for future researchers to pursue quantitative estimations of the cognitive legitimacy created in the Resource Endowments IIE. Data collection via survey or interview, or from the general public (for example, visitors to the National Air and Space Museum), can assess cognitive legitimacy of the HSSTI. Finally, the conduct of bibliometric analyses, in the trade and popular press, can also assess occurrences of symbols, signals, or levels of awareness, as indicators of industry legitimacy and reputation.

Regarding the Proprietary Functions IIE, there were difficulties encountered in identifying the Applied R&D by HSSTI firms in support of technology development and

intellectual property. This limits the insights by industry observers and policy-makers regarding how to help solve those problems. Also, although some of the Market Creation and Consumer Demand third-order elements lent themselves to quantification (e.g., the population ecology of competition, the number of pre-production ticket sales, etc.), there is a large amount of uncertainty surrounding these data, resulting from the levels of secrecy that each firm maintains, the accuracy of the data that is available, and the assumptions made (e.g., that pre-production ticket reservations are a good proxy for consumer demand). To maximize the internal and external validity of the data, this research took care not to over-reach in drawing conclusions from the information collected.

Topics of further research in the Technological Development Functions third-order element could investigate how much Applied R&D firms conducted based on publicly available information about the research results. Regarding the HSSTI Innovation Network and Resource Channel Activities, additional studies could attempt to draw accurate firm boundaries over the complete set of support industry functions. This research of firm boundaries could also investigate how these boundaries change over time, and the impact upon the level of cooperation and competition between firms within a common industry. This might be able to highlight solutions to the paradox of engaging in one strategy over the other. Finally, further research into the Market Creation and Consumer Demand second-order element of the HSSTI could include comparative studies to check the assumption of pre-production ticket reservations as an indicator of the actual demand that may emerge once flights start.

Future research regarding the accumulation model interactions may be able to propose processes for the linkages between the IIEs. For example, how do specific corporate political activities vary as a function of new entrant type (e.g., entrepreneurial start-up, parent company spin-off, de alio diversification, etc.)? Or, what are the specific mechanisms, engaged by the passage of enabling laws and policies, that encourage the accumulation of Resource Endowments elements? Similarly, is there a way to reasonably track economic and non-economic returns, provided by Proprietary Functions actors, in exchange for the capabilities and resources they receive?

Lastly, limitations of the overall accumulation model also provide ideas for further research. One general limitation, as noted repeatedly above, and not limited to this specific research, was the qualitative nature of the data collected and analyzed. Credible results in the social sciences require objectivity, reliability validity, generalizability, reproducibility, and ethicality (O’Leary, 2007). This research made every attempt to achieve these criteria in this research. There still exists, however, a bias toward quantitative data in the social sciences, however misguided that perspective may be:

“Personally, I fear more the faith that lay persons, policy makers, and even scholars, often show in quantitative conclusions drawn from shaky models and data than I do conclusions that are explicitly qualitative and judgmental” (Nelson, 1982, p. 482).

The model employed in this research is robust, stable, and well-founded, and while not perfect, the results based on the qualitative data collected are as reliable as practicable. Although the model generally provides the framework to identify the creation of necessary resources, because the data is qualitative, there is no way to quantitatively

assess whether the amount of any given resource (individually) or resources (in some combination) are sufficient for industry emergence. In other words, when would industry members know when to stop creating a given resource (or combination of resources) because there is a sufficient amount? Identifying the determinants, antecedents, and any possible moderators or mediators for these limits could be an important indicator for practical application of the accumulation model by entrepreneurs, managers, and policy-makers. It is unlikely that “sufficient” resource levels are knowable, however, especially when considered in isolation from others within or among any or all of the three IIEs. In other words, the identification of “sufficient levels” of any given resource is probably dependent upon the other resources. Such research will likely result in a variance study to hypothesize and test some combination of nonlinear, multi-covariate set of equations, including some, many, or all of the different third-order elements as the independent variables. Furthermore, no indication exists whether the process is controllable in any way. Etzioni posed exactly this same questions over fifty years ago:

“Where does the power lie that controls the process - is it evenly distributed among the participant units or is it concentrated in the hands of elites? Are the power-holders members of the new emerging communities or outsiders?” (1963, p. 421).

It may be that the interdependencies are so complex (i.e., covariate, multivariate, nonlinear, etc.) between the different first-, second-, and third-order resource elements, that qualitatively estimating their status is still the best we can do. This limitation could be the basis of valuable future research. Finally, as mentioned above, the HSSTI may be sufficiently unique, such that the results of this research are not generalizable to other

industries. It is possible for future researchers to test process generalizability, comparing these results with those of other accumulation model studies identified in the literature review when possible. Although some of the IIE interactions for the HSSTI may be unique, the interactions observed may be able to broaden the possible linkage outcomes that future researchers may observe, thereby expanding the number of commonalities between this and other industries.

6.3 COMPARISON WITH ORIGINAL ACCUMULATION MODEL

In a description of the original model, Van de Ven and Garud (1989) explained that the linkages between IIEs were evidence of three phenomena: the balance between technology push and pull, the innovation process (the creation of commercial products from scientific knowledge), and the creation of industry standards. The first of these, the balance of technology push and pull, manifests itself between the Resource Endowments and Proprietary Functions IIEs, and between the Institutional Arrangements and Proprietary Functions IIEs, respectively. The innovation process also involves the transference of knowledge from the Resource Endowments IIE to the Proprietary Functions IIE, but involves substantial support from, and interaction with, Institutional Arrangements IIE actors. Finally, the development of technology standards requires collaborative efforts between the Proprietary Functions and Institutional Arrangements IIEs, assuming the government does not mandate these standards unilaterally.

This research identifies evidence of technology push (primarily in the form of the creation of new knowledge from the Resource Endowments IIE, to the Proprietary Functions IIE), and technology pull (in the form of regulatory and legal requirements generated within the Institutional Arrangements IIE, and fulfilled by the compliance of

Proprietary Functions IIE actors). There was a substantial amount of technology push activity in the 1955-1975 timeframe, funded exclusively by the government, before it ceased. There were a few new programs that began in the 1990s, but the funding level they received never matched those of the mid-20th century. With the relative withdrawal of the “technology push” impetus for innovation, this left the “technology pull” forces to stimulate progress. At the request of the HSSTI industry members, and as directed by the U.S. Congress, the authorization language for the regulatory agency minimizes the effects of regulatory requirements, however, by explicitly stating that industry members should be regulated “only to the extent necessary” (Commercial Space Launch Act, 1984). The interactions described in the original model are well-suited to the HSSTI context. It may be, however, that HSSTI emergence would benefit from additional “technology push” programs, including federally-funded, non-proprietary research, to be successful. In addition, and counter-intuitively, increased regulatory requirements, that strengthen the “technology pull” forces, may also benefit overall industry emergence.

The innovation development process is defined as “the temporal sequence of events and activities that occur to create and transform basic scientific knowledge into commercially viable products or services delivered to customers” (Van de Ven, 1993a, p. 26). For the innovation process to be successful, scientific knowledge resources must migrate from the Resource Endowments IIE to firms in the Proprietary Functions IIE. As firms develop their products, they demonstrate and publicize their goods at Knowledge Sharing events in the Resource Endowments IIE. As customers decide to purchase, they provide funding to the firms. There is a substantial role for Institutional Arrangements actors in the innovation development process, too. At the very least, governments pass

laws to ensure the stability of the economic environment, guaranteeing intellectual property rights and protecting against the formation of cartels, etc. Similarly, industry regulators collect information they need to evaluate the impact of the product or service on society. Providing these assurances and oversight is an important aspect of the innovation process. Marketing is also an important part of bringing a product to market. Consequently, the number of publicity events, at which HSSTI firms presented, explained, and demonstrated their products, has evolved over time. Although Blue Origin has refrained from pre-production offerings, the success of Virgin Galactic in selling reservations for future flight opportunities demonstrates partial success of the innovation process to date.

Finally, there has been some activity within the HSSTI for the creation of standards, but the industry has not yet accumulated enough resources to be able to claim any significant accomplishments in this area yet. During the initial rounds of standards creation activity, there were interactions between the HSSTI firms in the Proprietary Functions IIE and the industry trade organization in the Institutional Arrangements IIE. More recently, the HSSTI enlisted an international standards-setting organization, another Institutional Arrangements IIE private-sector actor, to assist with the standards creation process. Initial efforts are currently underway to identify a taxonomy of working groups to help focus the work, and this is an indication that the collection of interests may be too diverse, when considered as a whole. The network of supporting industries identified in this research (Figure 9 on page 108) may provide a starting point to identify the capabilities and functionalities, both upstream and downstream of the specific vehicle operations, that may be receptive to technology standards development at this time.

6.4 GENERAL CONCLUSIONS

The paragraphs above, describing possible further research, presented implications of this work for the academic community. To conclude this work, we continue the discussion by focusing on possible ways additional communities can benefit from this research. First, however, we identify how the HSSTI case study reflects the basic tenets of the original accumulation model, and the status of the HSSTI based on the analysis supporting this research. The next section discusses the questions posed in conjunction with our primary research question: Why do industries take so long to emerge?, and what can be done to accelerate this process?

6.4.1 Basic Tenets of Accumulation Model

The accumulation model includes basic elements, such as the contribution to IIEs through the individual and collaborative efforts of multiple players, across both the public- and private-sectors. It is not only the public-sector actors that help develop the resources of Institutional Arrangements, and it is not uniquely private-sector actors contributing to the Proprietary Functions resources. Second, the accumulation of resources does not seem to follow a scheduled order or pattern, and the accumulation rates are not equal between the IIEs. Third, the results of an HEA identify deficiencies of IIE resources impeding successful industry emergence. This research observed all three of these basic elements in the HSSTI case.

The first basic element of the accumulation model is that actors from both the private- and public-sectors contribute to the development of all IIE resources, individually and collectively. The public-private collaborative nature of accumulating resources in all three IIEs reflects the Institutional Arrangements IIE as a “polity,” consisting of both

public- and private-sector actors. Similarly, the “economy” is not solely the purview of the private-sector, but relies on vital contributions from public-sector actors as well:

“The polity is related to government in approximately the same way that the economy is to ‘business’” (Parsons & Smelser, 1956, p. 48).

For example, the actions of public-sector actors of the Institutional Arrangements IIE (including legislative and executive branch actors) primarily develop laws and regulations that affect HSSTI emergence. Private-sector actors in the Resource Endowments and Proprietary Functions IIEs, however, influence the content of those laws and regulations, through political action and legitimacy signaling. Of course, collaborations between the public- and private-sectors requires participation from both sectors. It is possible that private-sector actors develop technology standards solely in a voluntary, consensus manner. It is equally as possible that institutional actors unilaterally mandate the technology standards. The ideal situation, however, is for a collaborative effort between them, resulting in a set of standards that considers all parties’ concerns. Similarly, the creation of scientific knowledge often requires the collaboration of public-sector funding and private-sector capabilities. Knowledge sharing events, conducted by both the public- and private-sectors, often feature speakers and information from the both sectors. Also, financial investments come from both the public- and private-sectors. When the investments, however, reach substantial levels (on the order of hundreds of millions of USD), the private-sector tends to take the lead in their participation. Finally, even in the Proprietary Functions IIE, although the private-sector conducts most of the activity, there is substantial HSSTI activity funded by state governments, to establish (and sometimes, build) spaceport infrastructure. Embellishment of these spaceports with

supporting services (such as fire and emergency response equipment and personnel) often relies on public-sector (federal government) grants.

As described in the original accumulation model description, there is no set order of resources in each IIE. Garud and Van de Ven state, however, that non-proprietary research “provides the foundation of knowledge that makes possible the commercial birth of a technology” (2000, p. 494), and thereby often precedes the innovation process activities. Other temporal observations, adapted for industry emergence from work by Deutsch (1957) on the development of international organizations, include the creation of rewards or benefits during the industry development process preceding the acceptance of associated burdens or responsibilities, and the provision of consent to meeting industry development obligations preceding compliance with imposed standards. Parsons and Smelser (1956) address the “chicken and egg” question of which comes first, investment or innovation, proposing that innovation ideally precedes investment during the early stages of industry emergence:

“... which of the two categories—the primary input of capital funds for investment through credit creation or the “encouragement of enterprise”—is more crucial for institutional change? We suggest that in the earlier stages of a “growth cycle” input of capital funds is not of primary importance; without any prospect for use, this might cause a glut on the capital market. The prospect that such funds will be available under the proper conditions is, however, very important” (1956, p. 252).

Still, the “role of finance in the knowledge economy and in innovation processes is a feature that is under-developed in the literature” (Dabic, Cvijanović, & González

Loureiro, 2011, p. 201). Aside from these four generalizations, however, the order of resource construction seems to be unspecified. The case of HSSTI emergence seems to demonstrate the first and last of these sequence rules-of-thumb. It may be that the ultimate order of resource development is opportunistic in nature, depending on individual, political, economic, and other contingencies. If this is the case, then predicting the order of resource creation is a futile effort, but the ability to identify the gaps in vital resources is not.

Based on the preceding discussions, and the results of the HSSTI HEA, this research makes an assessment regarding which resources are accumulated and to what (estimated, qualitative) levels, and which require further development. For this study, five firms began conducting pre-production activities, at least to the extent of assembling flight hardware, and two have progressed to flight testing their vehicles. Of these five firms, three have exited the field, one by choice (Scaled Composites), and two after depleting their funding, prior to pre-production operations. The two remaining firms, Blue Origin and Virgin Galactic, both seem to have ample funding sources for the foreseeable future.¹⁹ In the Institutional Arrangements IIE, where the Governance and Endorsement resources appear adequately developed, it is clear that the Technology Standards resources are not. Low levels of regulation and technology standards may be applying an insufficient amount of "technology pull" forces upon the Proprietary Functions firms.

¹⁹ At the time of this writing, Jeff Bezos was (temporarily) named the richest man in the world (Abeyta, 2017), and Virgin Galactic just received a new commitment of funding, from the government of Saudi Arabia, for one billion USD (Masunaga, 2017).

Therefore, with moderate levels of Endorsement and Governance resources, and a low level of Technology Standards resources, the estimated overall Institutional Arrangements IIEs level are moderate, at best. Within the Resource Endowments IIE, there seems to be an ample supply of resources in the Scientific and Technological Research element, and overall, Financial Arrangements seems strong. It is possible that the levels of Human Competence Pool resources are lower than required for successful industry emergence, but there is currently no quantitative way to verify or dispute this. Despite an initial burst of scientific knowledge creation in the mid-20th century, the level of basic research results created over the past 30 years is quite low, thereby asserting an insufficient level of "technology push" force upon the industry emergence process. Therefore, the estimated Resource Endowments resources are at moderate levels, given the strong availability of HSSTI financial and human capital resources, but with the recognition that there is a lack of supporting public knowledge creation at present. Finally, addressing the Proprietary Functions IIE, the general business cycle seems to be progressing as expected, although no HSSTI firm has yet begun commercial (revenue-generating) operation. Furthermore, the level of Market Creation and Consumer Demand activities aimed at the general public seem to have ebbed after an initial flurry of contests and pre-production ticket sales. The industry trade group has conducted knowledge-sharing events to increase demand for suborbital flights within the scientific and institutional communities since 2009. These efforts help increase cognitive and sociopolitical legitimacy of the HSSTI, but because of the narrow focus of the activities, and the low number of publicly-visible, pre-production operations, cognitive legitimacy is being insufficiently developed with these events. Regarding raising awareness among

the general public, the two firms currently conducting flight tests are not executing concerted marketing efforts of their particular services. Articles highlighting “space tourism” as an emerging industry have appeared occasionally in the popular press, but to date, there has been no high-profile, industry-wide effort at increasing the cognitive legitimacy within the general public about the HSSTI market overall. Therefore, because of the strong performance of the surviving HSSTI firms, but due to the long pre-production periods they are experiencing, the level of Proprietary Function resources is estimated to be at moderate levels. In summary, the major resource deficiencies impeding HSSTI emergence seem to be the inability to establish technology standards, the low level of non-proprietary research presently conducted in support of the industry, and the lack of HSSTI market creation activities. It is not clear if these low resource levels are a sufficient impediment to industry emergence. The differences between the HSSTI and other industries, discussed above, include relatively high requirements of capital, high levels of technical complexity, and high potential of personal harm to customers. It may be that 14 years (the time since winning the X PRIZE) is not an unusually long pre-production period for such an industry, but it is typically considered long for non-space industries. The long innovation development process may be the result of the high cost of operational failure, and require an ability to forego profits in the near-term to be successful.

As described above, this review of the basic tenets of the accumulation model, as observed in the case study of the HSSTI, has identified many events and relationships that comfortably conform to the model’s descriptions. Contradictions between the model’s tenets and the HSSTI case study observations were absent. This research

extended the model by proposing intra- and inter-IIE processes, describing how individual second- and third-order resource elements directly correlated to the creation of legitimacy, and moderated both second-order element creation, and the inter-IIE linkages. The original motivating question of this research was “how do new industries emerge?” for which there were two “corollary” questions. The results presented so far have responded to the first of the three questions, “what are the processes that characterize industry emergence?” Based on the process diagrams resulting from this research, it may be possible to identify potential answers to the remaining two questions: “why do industries emerge so slowly?” and “how can industry emergence be accelerated?”

6.4.2 Responses to Corollary Questions

Regarding the question of the time required for an industry to emerge, the sheer complexity of an industry when viewed as a social system is overwhelming. It is understandable to think that the accumulation of necessary resources in all three IIEs takes an extremely long time if left entirely to chance and random events. Even within the guiding context of a capitalist society, where individual actors are incentivized to perceive a set of needs and requirements to make their industry viable, the amount of effort and time required to build a new industry from scratch is still substantial. In a free economy (i.e., an economy that is not subject to central planning), public- and private-sector actors cooperate and dialogue with each other to build these elemental resources. When left to the concerted efforts of all the actors involved, it is only when they are all, or mostly, like-minded (with respect to constructing and accumulating the necessary IIE resources) that an industry can hope to successfully emerge. Mensch explains the long delay between scientific discover and commercial development as being due to the

“normative power of factual knowledge about them” (1979, p. 163). To develop a new foundation of the emerging industry requires at least a generation or two, since the vast majority of actors will reinforce the status quo, resisting the creation of a dialectic sociopolitical and cognitive legitimacy. In addition to changes in technology and business, there must also be changes to government and education institutions.

Furthermore, the investment communities also need to be convinced to accept all the new ideas. In new, high-technology industries, there also needs to be an appetite for initial failure, since utilization of the new technology will be expanding many operational and experiential limits. Given this perspective, it is little wonder that the time required for industry emergence is commonly on the order of many decades. Finally, the

accumulation model is admittedly incomplete due to the omission of Parson’s fourth social sub-function of pattern maintenance and tension management, labelled “latency.”

Social scientists have yet to sufficiently model this sub-function, encompassing the cultural dimension of a social system, so as to include it in the accumulation model.

Without including factors of culture to explain industry emergence, the overall accumulation model remains probabilistic in nature. It may be possible that the inclusion of legitimacy, proposed by this research, is an initial glimpse of cultural influences within the accumulation model framework.

The last corollary question asks how to accelerate the industry emergence. Given the previous discussion of why it takes so long, an initial response might be that central planning and direction of an industrial policy may accelerate the emergence process.

Although successfully applied in the past, it is not necessarily compatible with the norms and rules of all societies, and therefore might be unacceptable in some countries. This is

the case for the U.S. An alternate approach would be to examine the process model resulting from this research to identify ways to constructively moderate the accumulation of different required resources. For example, public or private actors may decide to counteract a perceived lack of technology standardization in a specific function or capability area for which the HSSTI is in desperate need. These actions could help accumulate those resources and assist in industry emergence. It is possible that a privately-funded research consortium (Baumol, 2002) funds the needed basic research, with the goal of identifying, studying, and providing solutions to specific questions within a focused HSSTI function or capability area. Another potential solution may be the creation of a marketing campaign to address the creation of cognitive legitimacy, employing the “normative power of factual knowledge,” and targeting current and future HSSTI clientele. More conferences, meetings, educational programs, or training activities to increase general awareness (cognitive legitimacy) and develop the pool of human capital required by the HSSTI is also a possibility. Additionally, the process steps of the generalized business development cycle could guide the development of private or public programs, encouraging individuals to start a business that could support the HSSTI, or to diversify from an existing successful business, expanding in capability or functionality in support of the HSSTI. As specifically highlighted in this research, it may be feasible to run prizes and competitions, to encourage the pre-production demonstration of HSSTI technology, thereby accelerating technology development and helping develop cognitive legitimacy at the same time. The government is presently attempting to stimulate industry emergence by being a customer of the services, whether those services currently exist or

not. These programs and policies, as well as others, can help construct and accumulate the necessary IIE resources as described in the accumulation model.

6.4.3 Practical Implications

What are the practical implications of this research to communities of entrepreneurs, managers, and policy-makers? This final section addresses these important questions that link the theoretical knowledge creation to the practical, technological and political, communities. This thesis ends with a brief discussion of how this research may be applied to countries on the African continent.

When identifying economic imbalances in potential marketplaces, an important indicator for entrepreneurs is the presence of some type of demand for which there is no supply. To that end, “[e]valuating the level of infrastructure in an area may prove a fruitful strategy for those entrepreneurs seeking to exploit or create an opportunity” (Woolley, 2013, p. 21). The areas of HSSTI industry infrastructure that are under-developed, as described in detail above, include the Technology Standards within the Institutional Arrangements IIE, Scientific and Technological Research in the Resource Endowments IIE, and Market Creation and Consumer Demand activities in the Proprietary Functions IIE. It is possible that regulations for the emerging industry are also lacking. Whether performed with a “for profit” or “non-profit” organization, HSSTI actors are already addressing some of these IIE deficiencies. For example, industry actors solicited the activities of ASTM International to fulfill the deficit of Technology Standards. This current activity is broadly focused, covering many commercial space industry segments and sub-segments, above and beyond the HSSTI. Consequently, many participants, from many different industry segments, bring multiple and diverse

viewpoints and interest perspectives to the discussion. This enriches the overall content and depth of discussion for any given issue. This situation can also lead to additional complexities of arriving at consensus agreements, resulting in unclear or highly-qualified statements, making any resulting documents very symbolic, but significantly less meaningful. There may be entrepreneurial opportunities in developing standards of technological, organizational, informational, or relational (inter-organizational) subjects, with a focus on specific supporting industry segments, upstream or downstream segments of the HSSTI. Opportunities may exist in the domain of conducting non-proprietary research, especially with the low level of government support demonstrated since 1996 (when the level of HSSTI activity demonstrated a noticeable increase after the announcement of the X PRIZE). Although it may not be evident where a third-party organization could find sources of funding to conduct public research, whether non-profit or for-profit, it is worthwhile that HSSTI actors encourage possible opportunities to bolster this important resource element. Finally, beyond the presale of 700 tickets, and a number of competitions and raffles to win free tickets, the activities of HSSTI market creation are glaringly absent. This, however, is an incredibly critical component of the business development cycle. The founders of both existing HSSTI firms are each very successful businessmen, and their ability to execute market creation functions is difficult to question. Presumably, HSSTI firms will create market demand, through more advertising, demonstrations, and educational activities, at the appropriate time, when the customer experience and final products reach sufficient levels of maturity.

This research can provide important information to HSSTI firm managers through use of both the HSSTI HEA results, and the industry-level processes proposed. First, the

HSSTI HEA results can be useful to managers when deciding whether to collaborate with others in resource accumulation activities. If the status of the different resources, required to ensure industry emergence, is known by the managers, then they can trade-off the availability of relevant capabilities within their firm against the need for some resource accumulation activity that may ensure successful industry viability. In other words, it is feasible to use the results of this accumulation model study to decide when to cooperate or compete with the other HSSTI firms. Secondly, the proposed processes of this research can inform managers about the different forms of legitimacy, and help them understand the primary importance of both types of legitimacy. It is very common within the space industry to promote engineers and scientists, individuals with many years of technical experience, and who have demonstrated a high degree of technical proficiency, into managerial positions. These space industry managers have a strong history with, and dependence upon, quantitative methods and positivist perspectives, combined with a general lack of exposure to the social sciences. This results in an under-appreciation for the concept of legitimacy in general. This research emphasizes the importance of legitimacy in the processes of industry emergence, and it employs the two-part typology of sociopolitical and cognitive legitimacy. The more exposure the HSSTI firm managers have to these ideas, and if they can witness the power of legitimacy acting upon their industry, the more they will be better prepared to make decisions informed by the quantitative metrics of the physical sciences, and complemented by the qualitative concepts of the social sciences. Another way in which a deeper understanding of the industry emergence processes may assist the managers of HSSTI firms is in the area of environmental scanning and strategic planning. By providing a view of the overall

industry as a comprehensive social system, spanning multiple social sub-functions, managers may become aware of, and be able to better see, linkages between their firms and external parts of the environment (Astley & Fombrun, 1983). This improved awareness and understanding will allow managers to better plan for, and cope with, changes to the environment that may have negative effects on the firm.

Policy-makers can also implement this research in a number of ways. As in the case of implications of this research for HSSTI firm managers, policy-makers can use the results of the HSSTI HEA. Additionally, they, too, can interpret the proposed industry-level processes. Officials in the legislative and executive branches of government are supportive of HSSTI emergence for the economic benefits the new industry may provide. The accumulation model itself provides a framework with which policy-makers can begin to understand the phenomenon of industry emergence. With the framework, it is possible for policy-makers to identify relevant phenomenological indicators, leading to ideas for the collection of data that can be executed through research or analysis projects, resulting in the computation of evaluative metrics, which can ultimately be used to assess the status of industry emergence. Some research has already been conducted on the effectiveness of specific policies to stimulate innovation and industry emergence, concluding that most macroeconomic policies are overly general to stimulate the “right kind of innovation” (Nelson, 1982, p. 480), and pointing to investments in knowledge creation as the “most potent instrument for nurturing the emergence of high-technology industries” (Chakravarthy, 1985, p. 263). Furthermore, looking at the interactions between the IIEs will help policy-makers identify ways to support overall industry development (Woolley, 2013). Analysts can also measure different indicators inferred or

identified by the propositions in this research. It is important to note, however, that data collected, based on the propositions, can be used to simultaneously validate the propositions and evaluate the status of industry emergence. Currently, evaluation of the sufficient accumulation for any given resource is highly subjective, and it is not possible to definitively state that a measured amount (as indicated by some metric) of a given resource is “enough.” If developed, this type of guidance would be invaluable for policy-makers. The proposed processes from this research can be important to better understand how policy tools of different acquisition instruments (e.g., contracts, grants, prizes, other transaction authorities, etc.) may stimulate economic growth and influence the different components of industry emergence. By being able to understand the impact of these instruments upon the entire industry emergence process, policy-makers can begin to influence emerging industries as a part of the larger social system, where survival and power are the principle driving mechanisms. It is only through over-use of simplifying economic assumptions that industries are seen as atomistic, independent activities, separated from the rest of society, and motivated only by efficiency, profits, personal interest, financial rationality, or technological superiority.

Finally, this research has implications for the development of industries in countries on the African continent. Assuming the generalizability of the processes proposed from the analysis of the HSSTI, these processes can estimate the impact of public- and private-sector policies on the creation of new industries. The term “new industries,” in these cases, do not only mean “new to the world” activities, but can use the definition introduced at the beginning of this thesis: a new industry is one in which there are no incumbent firms. There is evidence from the previous studies, described in this research,

that the accumulation model is applicable to evolving, as well as emerging, industries. Traditional industry sectors that are not new to the developing economies, such as sectors of textiles, agriculture, steel, manufacturing, etc., can benefit from this research. Policy-makers can assess the status of industry needs and development stage by tracking the different first-, second-, and third-order industry infrastructure elements for every industry segment undergoing development. The processes proposed in this research can guide the development and implementation of policies. Managers and entrepreneurs can use this information to guide their decisions regarding collaborative and competitive actions. Researchers would benefit by using these activities as natural experiments, to validate and further extend the accumulation model processes and, possibly, to include the other functional motor innovation development meta-theory relationships (i.e., dependence, peer, problem-solving, and fortification). In these ways, the results of this research can be used to accelerate the emergence of new and existing industries within African economies where appropriate.

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APPENDIX A. LEGITIMACY TYPOLOGY TRANSLATION TABLE

The table below directly compares five different legitimacy typologies as proposed in the literature.

Table A 1. Legitimacy typologies by different authors, listed chronologically.

| (Weber, 1946) | (Aldrich and Fiol, 1994) | (Scott, 1995) | (Suchman, 1995) | (Tost, 2011) |
|---------------|---|--|--|---------------------------------------|
| No equivalent | Cognitive: how taken for granted a new form is | Cognitive: widely held beliefs and taken-for-granted assumptions that provide a framework for everyday routines, as well as the more specialized, explicit and codified knowledge and belief systems promulgated by various professional and scientific bodies | Cognitive-Taken-for-Grantedness: mere acceptance of the organization as necessary or inevitable based on some taken-for-granted cultural account. | Cognitive: taken-for-grantedness |
| | | | Cognitive-Comprehensibility: affirmative backing for an organization. | |
| No equivalent | Sociopolitical: the extent to which a new form conforms to recognized principles or accepted rules and standards. | Regulatory: complying with the governance systems' "codes, norms, and rules" | Pragmatic-Influence: constituents support the organization because they see it as being responsive to their larger interests. | Regulative: the validity of an entity |
| | | | Pragmatic-Dispositional: organizations that "have our best interests at heart," that "share our values," or that are "honest," "trustworthy," "decent," and "wise" | |

| (Weber, 1946) | (Aldrich and Fiol, 1994) | (Scott, 1995) | (Suchman, 1995) | (Tost, 2011) |
|---|---------------------------------|---|--|--|
| | No equivalent | | Pragmatic-Exchange: legitimacy dynamics based on interest, support for an organizational policy based on that policy's expected value to a particular set of constituents. | Instrumental: rooted in the self-interest calculations of individuals or groups |
| Legitimate/ Legal (instrumental): -rational authority | No equivalent | Normative: grounded in a social context and to be oriented by a moral dimension | Moral- Consequential: evaluations of outputs and consequence | Moral: the extent to which the entity conforms to moral values and ethical principles |
| Legitimate/ Legal (value): rational authority | | | Moral-Procedural: evaluations of techniques and procedures | |
| Traditional authority | | | Moral-Structural: evaluations of categories and structures | |
| Charismatic authority | | | Moral-Personal: evaluations of leaders and representatives | |

APPENDIX C. INDUSTRY STRUCTURAL ANALYSIS QUESTIONS

The following set of guiding questions to conduct an industry structural analysis.

Mention throughout these questions of “the text” refers to Porter (1980, pp. 3–29). Also, the acronym “BOE(s)” is used, and stands for barrier(s) of entry.

FORCE 1. THREAT OF ENTRY BY POTENTIAL ENTRANTS

- Identify all business functions (e.g., manufacturing) and sub-functions (e.g., manufacturing of component A, manufacturing of component B) and estimate the economy of scale barrier strength of each. Provide examples.
- Are shared function operations possible for any of the industry players being considered? Provide examples. Is the benefit illusory? (see footnote 2 in the textbook)
- Do joint costs benefits exist? Provide examples.
- Do the industry members have intangible assets to exploit? Provide examples.
- Do vertical integration economies exist? Provide examples.
- In general, what are the economies of scale BoEs in this market, if they even exist? Provide examples.
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?

- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?
- The presence of economies of scale always leads to a cost advantage for the large-scale firm (or firm that can share activities) over small-scale firms. However, even the economies of scale BOEs have strategic limits when used by incumbent firms. Are any of these limits applicable to this specific market?
- What are the BoEs of product differentiation in this market, if they even exist? Provide examples.
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?
- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?

- What are the BoEs of capital requirement in this market, if they even exist? Provide examples.
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?
- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?
- What are the BoEs of switching cost in this market, if they even exist? Provide examples.
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?

- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?
- What are the BoEs of distribution channels for this industry, if they even exist? Provide examples.
- Are the wholesale or retail distribution channels unable to accommodate new clients, or do they have excess capacity?
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?
- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?

- What are the BoEs of cost disadvantages, independent of scale, if they even exist? (i.e., Do members of this market have scale-independent, critical advantages that represent cost disadvantages to their competitors?)
- Are there specific examples of proprietary technology among members of this market?
- Are there specific examples of favorable access to raw materials among members of this market?
- Are there specific examples of favorable locations among members of this market?
- Are there specific examples of government subsidies among members of this market?
- Is this a market where cost declines with experience seem to be significant? Are firms in this market at the proper product development phase where this is a significant factor?
- Are there any examples among members of this market of shared operations or related activities within the same company that can expedite the benefits of increased experience?
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?

- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?
- Experience is a more ethereal entry barrier than scale, and even though it can be just as effective keeping new firms from entering the market, it too, just as in the case of economies of scale, has limitations. Are any of these limits applicable to this specific market?
- What are the BOEs of government policy for this market, if they even exist?
- How strong is each BOE in this influencing factor category?
- How strong is this overall influencing factor category for this market?
- Does the strength of this BOE influencing factor category favor smaller or larger companies? Provide examples.
- Are the specific examples in this BOE influencing factor category independent of, or vary as a function of, the other BOE influencing factor categories?
- What can the firm do to control the specific examples in this BOE influencing factor category?
- Do the firms in this market possess resources or skills that would allow them to overcome the specific examples in this BOE influencing factor category more cheaply than their competitors?

- Provide an estimation of competitor reaction strength supported by specific examples for each industry.
- Overall, how would you prioritize the factors influencing the BoEs to this market? Which is the strongest, and which is the weakest?
- What implications might this ranking of BoEs have on strategic decisions of new entrants and incumbent firms in this market?

FORCE 2. INTENSITY OF RIVALRY AMONG EXISTING COMPETITORS

- Can you cite specific examples of mutual dependency between firms in this market?
- If mutual dependency exists in this market, what are its advantageous and disadvantageous effects on the market?
- What is the status of the different interacting structural factors listed above and what does that indicate about the intensity of rivalry in this market?
- What can you say about the number of firms in this market? How do they match up against each other? Do a small number of firms dominate the market? Are there any non-U.S. entities in this market, and how do they stack up? Does this tend toward market stability or instability? Why?
- What is the growth rate of this market? What implications does that have on the nature of the competition among firms in this market?
- In this market, is a high fixed/storage cost with respect to value added (e.g., is this product hard or costly to store?), pressuring a trend to fill capacity by cutting price in times of excess capacity?

- Is the product of this market seen as a commodity? What is the resulting level of volatility of this market's rivalry as a result?
- What is the size of the increment that capacity can be added in this market, and what does that mean for competition?
- In terms of strategies, origins, personalities, and relationships with their parent companies, what is the level of diversity of the firms in this market?
- Are the strategic stakes in this market high or low? What implications does that have on the nature of the competition among firms in this market?
- What is the state of each of the major sources of exit barriers in this market? What implications does that have on the nature of the competition among firms in this market?
- What is the relationship between, and the joint level of, entry barriers and exit barriers? Often, they are related. Refer to Fig 1-2 in the text.
- What are the time-dependent characteristics of the rivalry in this market due to market maturity, acquisitions, and technological innovation?

FORCE 3. PRESSURE FROM SUBSTITUTE PRODUCTS

- Are there substitutes (products that can perform the same function) in this market?
- If substitutes exist, do they require the attention of the market firms?

FORCE 4. BARGAINING POWER OF BUYERS

- Who are the buyer groups in this market?

- Using the list above, what are the detailed characteristics of each buyer group?
What are the implications of each characteristic? Provide specific examples where possible.
- Are the buyer groups powerful?
- How has/does the buyer groups' power changed/change with time?
- Who are the most and least powerful buyers? Rank the buyers by their level of influence.

FORCE 5. BARGAINING POWER OF SUPPLIERS

- Who are the supplier groups in this market?
- Using the list above, what are the detailed characteristics of each supplier group?
What are the implications of each characteristic? Provide specific examples where possible.
- What is the impact of labor as a supplier on this market? What is the ability of labor to unionize or expand?
- Are the supplier groups powerful?
- How has/does the supplier groups' power changed/change with time?
- Who are the most and least powerful suppliers? Rank the supplier by their level of influence.

GOVERNMENT AS AN INDUSTRY COMPETITION FORCE

- How does government affect competition through each of the five competitive forces?

- What is the rank of the five forces by relative strength? Why? How does this ranking affect strategy formulation?
- How can firms decrease the level of power of their buyers?
- How can firms decrease the level of power of their suppliers?
- Based on the preceding five sections, how would you characterize this emerging commercial space sector as a description of the strength of the five forces?

Remember that the stronger any or all of these forces are, the more competitive the industry will be, and thus the lower the prospects for excess profits.
- Looking at the strength five forces from a different perspective, what are the positions of competitive *disadvantage* that companies should avoid? For example, if the entry barrier of Economies of Scale is high, entering this market without large scale operations that can overcome that barrier would be a mistake. Therefore, to be competitive, companies intending to be successful in this market must avoid small scale operations.

SUMMARIZING QUESTIONS

- What is the rank of the five forces by relative strength? Why? How does this ranking affect strategy formulation?
- How can firms decrease the level of power of their buyers?
- How can firms decrease the level of power of their suppliers?
- Based on the preceding five sections, how would you characterize this emerging commercial space sector as a description of the strength of the five forces?

Remember that the stronger any or all of these forces are, the more competitive the industry will be, and thus the lower the prospects for excess profits.

- Looking at the strength five forces from a different perspective, what are the positions of competitive *disadvantage* that companies should avoid? For example, if the entry barrier of Economies of Scale is high, entering this market without large scale operations that can overcome that barrier would be a mistake. Therefore, to be competitive, companies intending to be successful in this market must avoid small scale operations.

APPENDIX D. DISRUPTIVE INNOVATION ANALYSIS QUESTIONS

The following is a set of questions to conduct a disruptive innovation analysis (DIA).

These questions are primarily derived from Christensen's popularized works (Christensen, 1997; Christensen et al., 2004; Christensen & Raynor, 2003).

INDUSTRY ANALYSIS CONTEXT

- What is the industry context (i.e., the “target industry”) of this analysis?
- What are the facilities, vehicles, and equipment that characterize the target industry?
- What is/are the job(s) being performed by the firms of the target industry?

INNOVATION DEFINITION

- What are the performance measures of the related industry?
- Do we see the characteristic performance increase over time as described by disruption innovation theory?
- How does the target industry fit within the performance measures of the related industry?
- Is the target industry a sustaining, or disruptive (either low end, or new market) innovation?
- How does the target industry fit the characteristics of the innovation type identified?
- If the target industry represents a new market disruptive innovation, what is the new performance metric of the new market?
- Define whether the target industry performance is within the “performance deficit” or “performance surplus” region of the market.

TARGET INDUSTRY DESCRIPTION

- Who are the incumbent firms in the industry related to the target industry?
- What is/are the job(s) being performed by the incumbent firms in the related industry?
- For the different job(s) being performed by incumbent firms in the related industry, who are the high-end, low-end, and non-consuming customers?
- For the different job(s) being performed by firms in the target industry, who are the high-end, low-end, and non-consuming customers?
- What is the attribute-based characterization of the incumbent (related) and target industries?

APPENDIX E. HSSTI SAFETY APPROVALS

The following table lists the HSSTI-related safety approvals issued by FAA AST, their issue date, and the recipient name, as of December 2017. All dates in yyyy-mm-dd format.

| Safety Approval # | Recipient Name | Issue Date | Subject |
|--------------------------|-----------------------|-------------------|-------------------------------|
| 10-001 | NASTAR | 2010-04-07 | Suborbital flight simulator |
| 11-002 | Zero G Corp | 2011-04-20 | Reduced gravity environment |
| 11-003 | SpaceTec | 2011-06-10 | Technician credentials |
| 12-004 | NASTAR | 2012-09-11 | Altitude chamber |
| 13-005 | Black Sky Training | 2013-03-28 | Hypobaric chamber training |
| 14-006 | Black Sky Training | 2014-01-22 | General space flight training |
| 14-007 | Waypoint2Space | 2014-01-23 | General space flight training |
| 10-001 rev 1 | NASTAR | 2015-04-03 | Same as 10-001 |
| 11-002 rev 1 | Zero G Corp | 2016-04-19 | Same as 11-002 |
| 11-003 rev 1 | SpaceTec | 2016-06-03 | Same as 11-003 |
| 12-004 rev 1 | NASTAR | 2017-07-11 | Same as 12-004 |

APPENDIX F. HSSTI EXPERIMENTAL PERMITS

The following table lists the HSSTI-related experimental permits issued by FAA AST as of December 2017. All dates in yyyy-mm-dd format.

| Permit # | Issue Date | Recipient | Vehicle |
|-----------------|-------------------|-------------------|---------------------|
| 06-001 | 2006-09-15 | Blue Origin | Propulsion Module 1 |
| 11-006 | 2011-04-29 | Blue Origin | Propulsion Module 2 |
| 11-006 rev 1 | 2011-05-20 | Blue Origin | Propulsion Module 2 |
| 12-007 | 2012-05-23 | Scaled Composites | SpaceShipTwo |
| 12-007 rev 1 | 2013-05-22 | Scaled Composites | SpaceShipTwo |
| 12-007 rev 2 | 2014-05-21 | Scaled Composites | SpaceShipTwo |
| 14-009 | 2014-02-14 | Blue Origin | New Shepard |
| 14-009 rev 1 | 2014-12-19 | Blue Origin | New Shepard |
| 14-009 rev 2 | 2015-02-05 | Blue Origin | New Shepard |
| 14-009 rev 3 | 2016-02-05 | Blue Origin | New Shepard |

APPENDIX G. HSSTI LAUNCH OPERATORS' LICENSES

- The following table lists the HSSTI-related launch licenses issued by FAA AST as of December 2017. All dates in yyyy-mm-dd format.

| License # | Vehicle | Company | Issue Date | Term |
|-------------------|--------------------|-------------------|-------------------|-------------|
| LRLS 04-067 a,b | SpaceShipOne | Scaled Composites | 2004-04-01 | 1 year |
| LRLS 04-068 | Xerus | XCOR | | |
| LRLS 04-067c | SpaceShipOne | Scaled Composites | 2004-09-28 | 1 year |
| LRLO 16-092 a,b,c | SS2 Unity | Virgin Galactic | 2016-07-29 | 2 years |
| LRLO 17-105 | New Shepard System | Blue Origin | 2017-08-17 | 2 years |

APPENDIX H. HSSTI SPACEPORT OPERATORS' LICENSES

The following table lists the HSSTI-related spaceport operators' licenses issued by FAA AST as of December 2017. All dates in yyyy-mm-dd format.

| ACTION | Applicant | Issue Date | Term |
|---------------------------|---------------|------------|-----------|
| New License 04-009 | EKAD | 2004-06-17 | 5 years |
| New License 06-010 | OSIDA | 2006-06-12 | 5 years |
| Rev1 Mod 04-009 | EKAD | 2007-12-20 | No change |
| New License 08-011 | NMSA | 2008-12-15 | 5 years |
| Rev2 Mod 04-009 | EKAD | 2008-09-25 | No change |
| Rev3 Renewal 04-009 | EKAD | 2009-05-05 | 5 years |
| New License 09-012 | JAA | 2010-01-11 | 5 years |
| Rev1 Renewal 06-010 | OSIDA | 2011-05-06 | 5 years |
| Rev1 Mod 08-011 | NMSA | 2012-07-31 | No change |
| Rev2 Renewal 08-011 | NMSA | 2013-12-09 | 5 years |
| Rev4 Renewal & Mod 04-009 | EKAD/ MASP | 2014-06-13 | 5 years |
| New License 14-015 | MAF | 2014-09-15 | 5 years |
| Rev1 Renewal & Mod 09-012 | JAA | 2015-01-06 | 5 years |
| New License 15-016 | EFD | 2015-06-26 | 5 years |

ACRONYMS

EFD – Ellington Field District

EKAD – East Kerns Airport District

JAA – Jacksonville Area Airport

MAF – Midland International Air & Space Port

MASP – Mojave Air and Space Port

NMSA – New Mexico Spaceport America

OSIDA – Oklahoma Space Industry Development Authority

APPENDIX I. HSSTI ENDORSEMENT AGREEMENTS

The following table lists the endorsement agreement between HSSTI firms and NASA as of 30 June 2017. All dates in yyyy-mm-dd format.

| FIRM | EXECUTE | EXPIRE | TYPE | CTR | SAA # |
|-----------------|----------------|---------------|--------------|------------|---------------------|
| Blue Origin | 2016-Apr-15 | 2021-Apr-15 | Non-Reimb | KSC | KCA-4502 Rev. Basic |
| Blue Origin | 2014-Apr-30 | 2019-Apr-30 | Reimbursable | WSTF | RA-14-16704-1 |
| Blue Origin | 2014-Apr-30 | 2019-Apr-30 | Reimbursable | WSTF | RA-14-16704 |
| Blue Origin | 2013-Dec-23 | 2017-Dec-31 | Reimbursable | ARC | 2-402809 |
| Blue Origin | 2017-Jan-13 | 2017-Oct-13 | Reimbursable | MSFC | 8-1724581 |
| Blue Origin | 2017-Mar-27 | 2022-Mar-27 | Reimbursable | KSC | KCA-4514 |
| Blue Origin | 2017-Apr-18 | 2022-Apr-18 | Reimbursable | WSTF | RA-17-25434-01 |
| Blue Origin | 2017-Apr-18 | 2022-Apr-18 | Reimbursable | WSTF | RA-17-25434 |
| Blue Origin | 2017-Aug-05 | 2022-Aug-05 | Non- Reimb | WSTF | RA-17-20648 |
| Virgin Galactic | 2012-Jul-13 | 2018-Jul-13 | Reimbursable | AFRC | 2-402686 |
| Virgin Galactic | 2012-Jul-13 | 2018-Jul-13 | Reimbursable | ARC | 2-402686 |
| Virgin Galactic | 2015-Jun-29 | 2018-Jun-29 | Reimbursable | ARC | 2-402686-2 |
| Virgin Galactic | 2014-Jun-17 | 2019-Jun-16 | Reimbursable | LaRC | 1-17595 |
| Virgin Galactic | 2016-Apr-20 | 2019-Apr-20 | Non- Reimb | ARC | 2-403106 |
| XCOR | 2015-Jan-14 | 2018-Dec-31 | Non- Reimb | LaRC | 1-18877 |

APPENDIX J. HSSTI-RELATED KNOWLEDGE-SHARING EVENTS

Below is a list of the knowledge sharing events related to the HSSTI.

| YEAR | TOTAL All Events | SAS | NSS ISDC | SF New Space | FAA AST Conf | COMSTAC | SEDS | ISPCS | NSRC | SIS | One-Off Events | One-Off Event Notes |
|-------------|-------------------------|------------|-----------------|---------------------|---------------------|----------------|-------------|--------------|-------------|------------|-----------------------|--|
| 1993 | 4 | 1 | 1 | 1 | | | 1 | | | | | |
| 1994 | 4 | 1 | 1 | 1 | | | 1 | | | | | |
| 1995 | 4 | 1 | 1 | 1 | | | 1 | | | | | |
| 1996 | 4 | 1 | 1 | 1 | | | 1 | | | | | |
| 1997 | 4 | 1 | 1 | 1 | | | 1 | | | | | |
| 1998 | 4 | 1 | 1 | 1 | 1 | | | | | | | |
| 1999 | 4 | 1 | 1 | 1 | 1 | | | | | | | |
| 2000 | 6 | 1 | 1 | 1 | 1 | 2 | | | | | | |
| 2001 | 6 | 1 | 1 | 1 | 1 | 2 | | | | | | |
| 2002 | 6 | 1 | 1 | 1 | 1 | 2 | | | | | | |
| 2003 | 6 | 1 | 1 | 1 | 1 | 2 | | | | | | |
| 2004 | 7 | 1 | 1 | 1 | 1 | 2 | 1 | | | | | |
| 2005 | 9 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | | 1 | X PRIZE Cup |
| 2006 | 9 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | | 1 | X PRIZE Cup |
| 2007 | 9 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | | 1 | X PRIZE Cup |
| 2008 | 12 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | DC-X/XA 15-Year Reunion, IAA Conf on Private Human Access to Space |
| 2009 | 15 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | 2 | 5 | Public roll-out of SS2, NRC Suborbital Research Mtg, CSF SARG Mtg; PSF Emerging Comm'l Suborbital Science Wkshp; FAA Expt Permit Wkshp |

| YEAR | TOTAL All Evens | SAS | NSS ISDC | SF New Space | FAA AST Conf | COMSTAC | SEDS | ISPCS | NSRC | SIS | One-Off Events | One-Off Event Notes |
|--------------|------------------------|------------|-----------------|---------------------|---------------------|----------------|-------------|--------------|-------------|------------|-----------------------|---|
| 2010 | 13 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | CSF SARG Mtg, IISL Suborbital Regulation Mtg; SpaceUp DC |
| 2011 | 11 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 2 | IAA Conf on Private Human Access to Space; COE CST ESIL Wkshp |
| 2012 | 12 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 3 | Human Spaceflight Tech Forum; 2xCOE CST ESIL Wkshp |
| 2013 | 11 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 2 | 2xCOE CST ESIL Wkshp |
| 2014 | 9 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | | | 2 | 2xCOE CST ESIL Wkshp |
| 2015 | 9 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | | 1 | NewSpace Researchers Wkshp |
| 2016 | 9 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | | |
| 2017 | 6 | | 1 | 1 | 1 | 0 | 1 | 1 | 1 | | | |
| TOTAL | 193 | 23 | 25 | 25 | 20 | 34 | 19 | 13 | 7 | 4 | 23 | |

COLUMN HEADINGS

- SAS: Space Access Society’s annual conference started in 1993 on the “technology, economics, and politics of radically cheaper space access”.
- NSS ISDC: National Space Society International Space Development Conference
- Space Foundation (SF) New Space Conference
- FAA AST Annual Commercial Space Transportation Conference
- COMSTAC: FAA AST Commercial Space Transportation Advisory Committee
- SEDS: Students for the Exploration and Development of Space
- ISPCS: International Symposium for Personal and Commercial Spaceflight
- NSRC: In 2008, the Next Generation Suborbital Researchers Conference was the Human-Tended Suborbital Science Workshop, and was held San Francisco, CA.
- SIS: Space Investment Summits

APPENDIX K. ACCUMULATION MODEL FRAMEWORK COMPARISON

This table presents a side-by-side comparison of the original and the modified accumulation model frameworks, with differences shown as gray cells of the table.

| Original Framework | | Modified Framework | |
|--|--|--|---|
| 2 nd -order | 3 rd -order | 2 nd -order | 3 rd -order |
| INSTITUTIONAL ARRANGEMENTS – 1st-ORDER | | | |
| Legitimation | Guarantees | Endorsements | Guarantees |
| | Endorsements | | Endorsements |
| | Licensing Practices | | Licensing Practices |
| | Industry Regulations | | Industry Regulations |
| Governance | Norms and Rules | Governance | Norms and Rules |
| | Regulations | | Regulations |
| | Laws | | Laws |
| Technology Standards | Gov't Regulatory Mandates | Technology Standards | Gov't Regulatory Mandates |
| | Cooperative/Voluntary Industry Standards | | Cooperative/Voluntary Industry Standards |
| | Market-driven/de facto Standards | | Market-driven/de facto Standards |
| RESOURCE ENDOWMENTS – 1st-ORDER | | | |
| Scientific and Technological Research | No further delineation | Scientific and Technological Research | Gov't Contract R&D Results* |
| | | | Gov't Grant R&D Results* |
| Financing and Insurance Arrangements | Public Institutions | Financial Arrangements | SBIR Funding |
| | | | Gov't Contract Funding |
| | | | Gov't Grant Funding |
| | | | Non-Equity Investment |
| | | | Equity Investment |
| | Private Organizations (Venture Capital) | | Industry-Wide Stimuli |
| Human Competence Pool | Educational Training Programs | Human Competence Pool | Educational Programs* |
| | Recruitment and Training | | Recruitment and Training* |
| | Sharing of Knowledge | | Knowledge Sharing* |
| PROPRIETARY FUNCTIONS – 1st-ORDER | | | |
| Technological Development Functions | Applied R&D | Technological Development Functions | Applied R&D |
| | Manufacturing | | Manufacturing |
| | Testing | | Testing |
| Innovation Network and Resource Channel Activities | Appropriation of Common Goods | Innovation Network and Resource Channel Activities | Appropriation of Common Goods |
| | Vendor-Supplier-Distributor Channels | | Vendor-Supplier-Distributor Channels* (spaceports only) |
| Market Creation and Consumer Demand | Marketing | Market Creation and Consumer Demand | Marketing |
| | Cultural Norms | | Cultural Norms |
| | Consumer Demand | | Consumer Demand |
| | | | Competition |

* denotes inclusion in Common Goods categorization

APPENDIX L. COMPLETE SET OF PROCESS PROPOSITIONS

PROPOSED GENERALIZED INDUSTRY EMERGENCE PROCESSES

Proposition 1a: Endorsement objects/events of the Institutional Arrangements IIE are positively correlated to the establishment and accumulation of sociopolitical legitimacy for the new industry.

Proposition 1b: Governance objects/events of the Institutional Arrangements IIE are positively correlated to the creation and accumulation of sociopolitical legitimacy for the new industry.

Proposition 1c: Technology Standards objects/events of the Institutional Arrangements IIE are positively correlated to the creation and accumulation of sociopolitical legitimacy for the new industry.

Proposition 2a: Common Goods objects/events of the Resource Endowments IIE are positively correlated to the creation and accumulation of cognitive legitimacy for the new industry.

Proposition 2b: Financial Arrangements objects/events of the Resource Endowments IIE are positively correlated to the creation and accumulation of cognitive legitimacy for the new industry.

Proposition 2c: Human Competence Pool objects/events of the Resource Endowments IIE are positively correlated to the creation and accumulation of cognitive legitimacy for the new industry.

Proposition 3a: Publicly visible, pre-production operations are positively correlated to the creation and accumulation of cognitive legitimacy.

Proposition 3b: Publicly visible, production operations are positively correlated to the creation and accumulation of cognitive legitimacy.

Proposition 4a: Increased sociopolitical legitimacy is a positive moderator of interactions between the Institutional Arrangements and Resource Endowments IIEs.

Proposition 4b: Increased sociopolitical legitimacy is a positive moderator of interactions between the Institutional Arrangements and Proprietary Functions IIEs.

Proposition 5a: Increased cognitive legitimacy is a positive moderator of interactions between the Institutional Arrangements and Resource Endowments IIEs.

Proposition 5b: Increased cognitive legitimacy is a positive moderator of interactions between the Institutional Arrangements and Proprietary Functions IIEs.

Proposition 5c: Increased cognitive legitimacy is a positive moderator of interactions between the Resource Endowments and Proprietary Functions IIEs.

Proposition 6a: Cognitive legitimacy is a positive moderator between Endorsements objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

Proposition 6b: Cognitive legitimacy is a positive moderator between Governance objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

Proposition 6c: Cognitive legitimacy is a positive moderator between Technology Standards objects/events within the Institutional Arrangements IIE and the creation and accumulation of sociopolitical legitimacy.

PROPOSED PRIZE EVENT INDUSTRY EMERGENCE PROCESSES

Proposition 7: Prize competitions are positively correlated to the creation of sociopolitical legitimacy.

Proposition 8a: Prize competitions are a positive moderator between Common Goods objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

Proposition 8b: Prize competitions are a positive moderator between Financial Arrangements objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

Proposition 8c: Prize competitions are a positive moderator between Human Competence Pool objects/events within the Resource Endowments IIE and the creation of cognitive legitimacy.

Proposition 9a: Prize competitions are a positive moderator between consideration of creating a firm and new firm creation.

Proposition 9b: Prize competitions are a positive moderator to motivate an existing firm from another industry to begin initial activities in the new industry.

Proposition 9c: Prize competitions are a positive moderator between the processes of initial firm activity and pre-production activity.

Proposition 10: Prize competitions are a positive moderator between pre-production operations and the establishment and accumulation of cognitive legitimacy.