TAXONOMY OF MARKET-LEVEL SPACE ORGANIZATIONS

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ABSTRACT

Academic and industry experts build their careers on accurate and precise definitions and meanings of domain-specific terminology, whereas novice practitioners and lay-persons often conflate similar or similar-sounding terms to describe concepts in the same domain of interest. This is common in the space sector when individuals of different academic or practitioner backgrounds discuss “commercial” topics. In English, as in other languages, the word “space” is often followed by words such as “industry,” “industry segment,” “industrial base,” “market,” “ecosystem” and others. The practice of casually using words with ambiguous meanings may often be appropriate for informal discussion if it facilitates the communication and exchange of ideas and all parties generally understand the implications of the casual usage. This practice, however, is problematic for detailed and analytical applications requiring precision and order of thought. Grounded in contemporary organization theory and economic practice, this paper provides background discussions of different levels of analysis that characterize embedded hierarchical social systems of organizations as they pertain to space. This paper then recommends a hierarchical taxonomy for defining specific terms that describe organizations and activities within the space domain for use by practitioners, analysts and academics requiring more precise language to communicate their market analysis ideas. This taxonomy places specific terms within each level of analysis discussed and provides definitions of each, with the intention of stimulating critical discussion and potential modifications or improvements.

1. INTRODUCTION

“The purpose of defining terms, of course, is to classify the subject matter into clearly distinct and important categories. Just as classification of phenomena is critical to problem formulation, it is central to theory construction.” (Van de Ven, 2007, p. 116)

1.1 THE NEED FOR DEFINITIONS

A goal of this paper is to stimulate discussions of commercial space markets. Discussions within the space profession often characterize “space” as a single entity, be it an industry or a sector, treating terms such as “commercial space” as a single atomistic concept. In doing so, discussants are aggregating multiple market-level organizations (such as industry segments or industries, each with potentially significant differences) into one homogenous and expansive entity. This (mis)characterization often weakens the foundation for any ensuing conversation.

However, definitions are important in all meaningful discussions. Obvious problems include possible miscommunication based on individual perspectives and assumptions underlying any given word or phrase. For example, the term “space” and “commercial space” are ambiguous. For the public or management scholars outside of the aerospace domain, these terms are easily misinterpreted as referring to real estate. Definitions also take on a more critical role for purposes of problem formulation, analysis, and theory creation as the opening quote states.

The lack of common definitions related to business terms and concepts also have important strategic and policy implications for private and government organizations involved, respectively (Smith, 2002). Lowi (1972) states, “Finding different manifestations or types of a given phenomenon is the beginning of orderly control and prediction” and “to find the basis of classification offers to reveal the hidden meanings and significance of the phenomenon suggesting what the important hypotheses ought to be concerned with.” Autry (2013) suggests that, “the process of generating such a tool promises to produce theoretical insight as well.” Taxonomical approaches are necessary because typologies are often incomplete, arbitrary and lack explanatory and predictive power (Smith, 2002). Typologies are merely lists of ungrounded concepts and often biased by the perceptions of the researcher, whereas taxonomies provide the context required for meaning (McCool, 1995, p. 213; Smith, 2002).
Leaders base strategic plans and policy decisions on their understanding of activities and information in their industry ecosystem (Freeman, 2010). Understanding any phenomenon (i.e., situational awareness) is based on gathering data, recognizing that not all available indicators (i.e., independent variables, or IV) or presented results (i.e., dependent variables, or DV) are relevant. Recognizing the relevance of IV and DV requires clear definitions of the words and phrases used to describe the concepts and situations of interest. Therefore, making informed strategic decisions about space sector organizations and activities requires clear definitions of terminology and concepts.

This paper develops constitutive definitions for space industry structures and activities.

**Table 1. Three different characterizations of aerospace industry “supply chains”**

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<tr>
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<tr>
<td>Tier 5</td>
<td>Hardware and materials</td>
<td>Hardware and raw material</td>
<td></td>
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<tr>
<td>Tier 4</td>
<td>Components and parts</td>
<td>Components</td>
<td>Raw materials, processing, forging, casting</td>
</tr>
<tr>
<td>Tier 3</td>
<td>Assemblies</td>
<td>Assemblies</td>
<td>Build-to-print, parts</td>
</tr>
<tr>
<td>Tier 2</td>
<td>Subsystems</td>
<td>Subsystems</td>
<td>Components, subassemblies</td>
</tr>
<tr>
<td>Tier 1</td>
<td>Design and integration of final system or service</td>
<td>Final Product</td>
<td>Systems, assemblies</td>
</tr>
<tr>
<td>OEM</td>
<td>NA</td>
<td>NA</td>
<td>Aircraft, aeroengines</td>
</tr>
<tr>
<td>Example</td>
<td>Figure 1</td>
<td>Figure 2</td>
<td>Figure 3</td>
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This paper develops constitutive definitions for space industry structures and activities.

**Figure 1. Supply Chain Visualization from The Tauri Group**

![Space Chain Visualization from The Tauri Group](image-url)
(describing terms with respect to their constituent parts) as opposed to semantic definitions (comparing how the terms are similar or dissimilar to other terms) and concludes with a summary of the major definitions and areas of further research.

**Figure 2. Supply Chain Visualization from Autry & Huang (2014)**

**Figure 3. Supply Chain Visualization from Aviation Week & Space Technology**

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1 Open system organizations are “systems of interdependent activities linking shifting coalitions of participants; the systems are

1.2 PRIOR WORK

Industry analysts commonly depict an economic sector (also referred to as an “ecosystem,” “market cluster,” or “industrial base”) as linear chains or clusters (aka “tiers”). For example, different authors describe these tiers in various ways.

These supply chains from the three sources referenced in Table 1 are visualized in different ways. Although slightly different, these depictions have the common characteristic of linearly aligned groupings to map a collection of concrete objects or systems that collectively comprise a final product or service. Each implicitly assumes a common sector or ecosystem structure. Business ecosystems (Clarysse et al., 2014; Teece, 2007) may be accurately depicted in a linear fashion while other ecosystem types, such as innovation or platform ecosystems (Adner & Kapoor, 2010, 2016; Kapoor, 2018; West & Wood, 2013) have different structures not accurately depicted linearly.

2. TAXONOMY OF MARKET-LEVEL ORGANIZATIONS

This paper defines the space sector organizational system from the social science approach known as organization theory (OT). Contemporary OT takes an open system view embedded in - dependent on continuing exchanges with and constituted by - the
with organizational system orientations described as rational, natural, or a combination of the two. Most OT organizational system perspectives are either purely natural (i.e., theoretical perspectives of institutions, networks, ecology, and evolution) or a mix of natural and rational (cognition and interpretation, power and dependence, technology, learning, complexity, and computation). Economics is the only OT perspective considered to be purely rational (Baum & Rowley, 2005) and is also the most prevalent in space sector discussions. Definitions based on pluralistic viewpoints provide additional clarity and new insights to the discussion and this paper adds natural and hybrid system OT perspectives to the purely rational perspective of economics.

2.1 LEVELS OF ANALYSIS

Social systems are embedded genealogical and ecological hierarchies of organizations (Baum & Singh, 1994; Granovetter, 1985). This paper defines the space sector and its components based on the ecological hierarchical structure comprised of multiple levels of analysis (LOA). The firm is a good starting point because it divides the overall hierarchy into three distinct sections: (1) the central “organizational” LOA (focusing on the individual firm), (2) the “intra-organizational” LOA “below” the organizational level, focusing on a cascading set of firm sub-units within the firm, including business divisions, branches, sections, etc., continuing down to the individual), and (3) the “inter-organizational” LOA, encompassing multiple organizations at the next-lowest level, ascending “above” the individual firm level, are also referred to as market-level systems (Mowery, Rowley, 2005). The entire hierarchy of organizations is shown in Figure 4. Although discreet levels are shown graphically, reality may insert many more levels between those shown as discussions warrant. Intra-organizational levels do not contribute to the discussion of defining the terminology of inter-organizational LOA so will not be discussed further.

The remainder of this section discusses the three levels of analyses of interest in a general sense. The next major section gives detailed descriptions of the space sector communities, including the three core industry communities followed by 25 additional communities that surround and support the core space industry.

2.1.1 Populations

Collections of firms engaged in transactions or relationships for similar goods or services comprise the first market-level organization above the firm referred to as “populations.” Aldrich and Fiol (1994) state that these new populations emerge “when entrepreneurs succeed in mobilizing resources in response to perceived opportunities.” Utilizing an economic lens focused on financial transactions between organizations this level of organizations is commonly referred to as “industry segments.” In contrast to an economic set of networked organizations whose linkages primarily identify financial transactions, the OT set of organizations also includes linkages of non-financial relationships. Examples of non-financial relationships include participation in chambers of commerce, discussions with regulatory or other government agencies, engaging in corporate political activity at any environment in which they operate” (Baum & Rowley, 2005).

2 Rational orientations are “the pursuit of relatively specific goals and exhibiting relatively highly formalized social structures” (Baum & Rowley, 2005). Natural orientations are those that “share a common interest in the survival of the system and who engage in collective activities, informally structured, to secure this end” (Baum & Rowley, 2005).
level of government, contributing to national and international trade organizations, etc.

Examples of a space sector populations or industry segments include “chemical liquid rocket engines” or “solid rocket motors.” Another example industry segment includes “CubeSats.” As mentioned above, realistic models of industry segments may add another level of distinction above the organizational level. For example, CubeSats are designed for astronomical observation, Earth observation, communications, or other purposes, so an intermediate inter-organizational level of analysis between “firms” and “industry segment” may be required, perhaps called “industry sub-segment.”

2.1.2 Communities

The next LOA above populations is called “communities,” comprised of multiple populations. Hunt and Aldrich (1998, p. 272) define the community as, “a set of coevolving organizational populations joined by ties of commensalisms and symbiosis through their orientation to a common technology.” With a sole focus on the financial transactions between these organizations, economists refer to this level as “industries.” Continuing the example from the previous paragraph, the collection of “liquid rocket engine” and “solid rocket motor” (“populations” in OT terminology) industry segments combine within the “propulsion” industry (“community” in OT terminology). Of course, other industry segments of the “propulsion” industry include “hybrid rocket motors” and “ion engines” and “nuclear thermal rockets.” “CubeSats” are only one industry segment within the “in-space vehicles” industry, along with other industry segments of “Capsules,” “Habitats,” etc.

2.1.3 Field

The next LOA above communities can take different names such as “sector” or “field.” In American English, a definition for the word “field” as a noun is “an area or division of an activity, subject, or profession” (https://www.merriam-webster.com/dictionary/field). A definition of the word “sector” is “a sociological, economic, or political subdivision of society” (https://www.merriam-webster.com/dictionary/sector). To include all organizations interacting at the population and community levels conducting space activities, we propose using the descriptor of “sector” in part because its definition clearly aligns with the framework of economic and social hierarchical segmentation. We also prefer “sector” because the phrase “space sector” is already commonly used. Alternatively, we could continue the OT/economic distinction and propose the use of different term for supersets of space organizations. In that case, we make the following recommendations:

Recommendation 1. The term “space sector” is proposed to describe the space market-level organizations connected solely through financial transactions. The next two analysis levels of market organizations, contained within the level immediately above it, are called “industries” and “industry segments,” respectively.

Alternatively, for discussions including both financial transactions and non-financial relationships, we make the following recommendation:

Recommendation 2. The term “space field” is proposed for the space market-level organization including both financial transactions and non-financial relationships. The next two analysis levels of market organizations, contained within the level immediately above it, are called “communities” and “populations,” respectively.

2.2 SUMMARY

Given this, the following table shows the hierarchy of terminology from the two perspectives.

Practically, it doesn’t matter which set of terms are used in a discussion, analysis, or academic activity. What really matters is the consistent use of terms at each tier of the LOA hierarchy up and down the hierarchy of market-level tiers.

Next, we define and discuss space market-level organizations at the community/industry LOA. Together, these comprise the overall space sector (or space field). The discussion references the population LOA at times, but a thorough treatment at that level is beyond the scope of this paper. In all, we identify 28 individual communities/industries within the space sector. Each community can include many populations/industry segments, resulting in
hundreds of individual populations, obviously too many to include in this report. In fact, of the 28 communities identified, only three are treated individually. The remaining 25 are parsed into six groups between the community and field LOA.

3. TAXONOMY OF SPACE MARKET-LEVEL ORGANIZATIONS

Our description of the space sector begins at the community/industry LOA. Space sector discussions at the population/industry segment LOA is outside the scope of this paper because of the large number of populations within each of the communities below. Proper treatment at the population LOA would require limiting the overall report to a small number of communities. For example, discussion of three communities could encompass approximately two dozen populations.

3.1 CORE SPACE COMMUNITIES

Below we first describe the three space sector communities that fall within two groupings comprising a core “space industry.” The first community group, Core Subsystems, includes only a single community called In-Space Vehicles. Two complementary communities are combined into a second community grouping called Critical Infrastructure and includes Spaceports and Launch Vehicles. The latter two communities are on the “critical path” for In-Space Vehicles to function and are therefore complements to In-Space Vehicles because as more vehicles operate, additional spaceport facilities and launch vehicle operations are required (i.e., as the demand for the Core Subsystem increases, demand for the Critical Infrastructure also increases). After describing these three space sector communities in detail, the remaining 25 communities are described as part of their superset groupings, including Raw Materials, Sub-Systems, Systems, Mutually Dependent Communities, Retail Services, and End-User Demand.

3.1.1 In-Space Vehicles Community

In-space vehicles include orbital or suborbital capsules and space planes capable of carrying humans achieve a minimum altitude of approximately 80-100km (50-60 miles), orbital capsules capable of carrying humans, satellites of any kind (e.g., satellite servicing, communications, or observation – either of the Earth or astronomical, and in any wavelength or wave band), or habitats (e.g., international space station modules). Potential future in-space vehicles include orbital transfer vehicles, solar power satellites, space-based computer server farms and fuel depots.

3.1.2 Spaceports Community

Facilities that provide the location, equipment, and capabilities required by vehicle systems to launch, take-off, or return from flight missions are commonly referred to as spaceports. Core spaceport technologies distinguish vertical launch (traditional pad-based rockets) from horizontal take-off/launch facilities (rockets that are launched mid-air from aircraft). Authority relations and market strategies of spaceports vary primarily based on customer bases of government, single, or multiple users. Many multi-user facilities currently exist that conduct activities other than launches (e.g., training, component testing, etc.). As of early 2022, there are many active, inactive, and planned spaceports around the world.

To date, most active spaceports tend to be located on federal ranges serving both governmental and non-governmental customers. Many inactive or less-active spaceports are supported by governments at the local or state levels although significant space launch activity occurred at California’s Mojave Air and

Table 2. Level of Analysis Terminology Hierarchy for Market-Level Organizations

<table>
<thead>
<tr>
<th>(Market) Level of Analysis</th>
<th>Economic Terminology</th>
<th>Organization Theory Terminology</th>
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<tbody>
<tr>
<td>Highest</td>
<td>Sector</td>
<td>Field</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>Industry</td>
<td>Community</td>
</tr>
<tr>
<td>Lowest</td>
<td>Industry Segment</td>
<td>Population</td>
</tr>
<tr>
<td>Network Interactions</td>
<td>Financial Only</td>
<td>Financial and Non-Financial</td>
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place, unless, of course, they are constructed in space, but that case is not part of the present discussion.
Spaceport and New Mexico’s Spaceport America. Purely commercial firms are also entering the spaceport arena with exclusive use sites. Examples include Blue Origin’s private launch site outside of Van Horn in West Texas and SpaceX’s facility in Boca Chica, Texas.

### 3.1.3 Launch Vehicles Community

The traditional definition of a launch vehicle is based on the conversion of potential energy stored in chemical propellants (fuels and oxidizers, either liquid and/or solid, sometimes combined into a single molecule referred to as hypergolic) into kinetic energy through the mechanism of controlled combustion and expansion via a convergent-divergent nozzle. This description fits almost every launch vehicle in operation to date (although some launch systems include an air-breathing aircraft as a “first stage”). There are some other designs that do not depend on chemical reactions, including nuclear rockets and electromagnetic accelerators. Other prominent design architectures include multi-stage cylindrical configurations, launch at altitude by being dropped from underneath a carrier aircraft, and the return of a capsule (with or without humans) via parachute or via a glide or powered landing on a runway. Some launch vehicles are designed to reach Earth orbit (attaining a minimum speed of approximately 29.8 km/sec, or Mach 24) while others do not (suborbital vehicles only typically reach a speed of Mach 3). Some orbital launch vehicles are designed to carry massive payloads (large volumes and mass from 6-10 tons), some to carry humans (requiring higher levels of redundancy and safety), and others to carry smaller payloads (with smaller volumes and less than 500 kg in mass). Planetary missions, beyond Earth orbit, typically require multi-stage launch vehicles capable of delivering “escape velocity” from Earth of 11.2 km/sec.

### 3.2 NON-CORE SPACE COMMUNITY GROUPS

In addition to the “core space industry” communities described above, other communities comprise the space sector and fit into major categories of “upstream” communities (including Raw Materials, Sub-Systems, Systems, and Mutually Dependent Communities) and “downstream” communities (including Retail Services and End-User Demand). The next sections begin with brief descriptions of the “upstream” community groupings followed by descriptions of “downstream” community groups.

#### 3.2.1 Raw Materials Group

The raw materials community includes the traditional three “factors of production” (land, labor and capital) supplemented by a more modern addition (data) reflecting the maturity and adoption of artificial intelligence system architectures: (1) In the contemporary space sector context, the land factor includes Metals, Minerals, Chemicals and Fluids used in the manufacture of all types of hardware, manufacturing processes, as propellants and other working fluids in the operation of the different systems and sub-systems used by spaceports, launch vehicles and in-space vehicles; (2) The labor factor of production is represented in the space sector by the Human Resources and Education community; (3) The traditional factor of production of capital is represented here as the Finance & Capital community; (4) The additional factor of production included in the contemporary Space Sector context is Data, used for decisions at all levels of the design, manufacture, assembly, testing and operations aspects of a space industry organization.

#### 3.2.2 Sub-Systems Group

The Sub-Systems community group includes two fundamental communities common to traditional manufacturing sectors: Plumbing and Structures. The products produced in these communities, pipes and plates of all sorts, are required for almost any constructed item in any sector: (1) Pipes are required to transport fluids and gasses from storage tanks to destination devices (such as heat exchangers) or locations (e.g., pumping oxygen into the cabin for crew consumption); (2) Plates are produced and rolled to make walls of cabins or tanks, or shelves to hold equipment, or used to make structural bars or beams.

#### 3.2.3 Systems Group

The Systems community group includes five distinct communities: Communications, Guidance, Navigation & Control, Power Systems, Propulsion Systems, Space Specialties, and Systems Integration: (1) Communications, Guidance, Navigation & Control (GNC) elements are typically called “avionics” and include a wide variety of electronic devices for the precise purposes given in the community
name: radio transceivers, antennae, navigation computers, etc.; (2) The Power Systems community includes not only the power generation systems required for the space or launch vehicles, but also the radiator systems to eliminate the waste heat generated by all electronics systems (power, communication, GNC, and others); (3) Propulsion Systems include everything from the propellant tanks to the injectors, combustion chambers, and nozzles of the primary, secondary, reaction control, and abort systems. The number of intermediary devices in the propulsion system depends on the specific propulsion system and can range from very simple (pressure-fed) to very complex (staged-combustion cycle) systems; (4) Space Specialties identified in previous literature include satellite busses, docking systems, reentry and landing systems, spacesuits, environmental and life support systems, emergency crew escape and abort systems, etc. (Autry & Huang, 2014), and can also include specialty brokers between any two nodes of the industry sector network; (5) The Systems Integration community solves the non-trivial problem of putting all the systems and sub-systems together and ensuring they work as designed. Although this community does not generate hardware of its own, the service it provides is critical to the safe and reliable operation of all Core Subsystem and Critical Infrastructure operations.

3.2.4 Mutually Dependent Communities Group

The Mutually Dependent Communities group ties the space sector together through financial transactions and non-financial relationships. Both sub-groups are represented by four separate communities.

The four communities linked through financial transactions include Ground Support Vehicles, Flight Support Vehicles, Business Support Specialties, and Other Industries: (1) The Ground Support Vehicles community includes trucks, dollies, cars, trailers, crawlers, transporters, and any other ground vehicle used to support the operation of spaceports, launch vehicles or in-space vehicles; (2) The community of Flight Support Vehicles includes chaser planes, drones, or any other aerial systems used to support the operations of the spaceports, launch vehicles or in-space vehicles; (3) Business Support Specialties includes any of the wide variety of services required to operate a business, such as marketing, human resources, accounting, legal representation, etc.; (4) The Other Industries communities provides ties to other major sectors that effect the emergence of the core communities (Spaceport, Launch Vehicle, or In-Space Vehicles). Industry sectors can be assistive (e.g., automotive, electronics), resistive (as from a complementary product), or potentially both (e.g., sources of free publicity or exposure via media organizations can result in positive publicity or negative exposure to an organization’s activities).

The four communities linked to the space sector through non-financial relationships include Domestic & Foreign Governments, International Organizations, Trade Organizations, and Public Interest Groups: (5) Space sector firms interact with Domestic & Foreign Government Organizations at multiple levels (e.g., local, municipal, state-provincial, departmental, etc.), engaging in political activities and providing education and information in response to general curiosity about on-going programs or regulatory compliance. Some interactions with domestic governmental organizations, including corporate political activities, might not be conducted with foreign government actants for legal or policy reasons; (6) Space sector firms demonstrate positive “corporate citizenship” by forming relationships with International Organizations such as the Organization for Economic Cooperation and Development or the International Astronautical Federation; (7) Trade Organizations include space sector firms as dues-paying members to support educational, networking or political corporate action activities; (8) Public Interest Groups, representing the goals of the involved and uninvolved general public, can be supportive or resistive to space sector actants’ activities.

This concludes the descriptions of the “upstream” community groups, and the following sections discuss the “downstream” community groupings of Retail Services and End-User Demand.

3.2.5 Retail Services Group

The communities linked to spaceports, launch vehicles and in-space vehicles with market customers are referred to as “downstream” communities. The following list is intended to be comprehensive although the creation of new services may result in the creation of new retail communities. The current list includes Business Development, Spaceflight Training, Customer Service, and Hospitality: (1)
Business Development is the point of entry of any commercial space sector customer and includes functions such as the reservation for a future human flight or launch of a payload or satellite; (2) Spaceflight Training represents information exchange between core space industry providers and payload or satellite customers regarding technical specifications to comply with company and regulatory safety requirements; (3) Customer Service refers to the assistance that core space industry companies provide their customers to maximize the benefit from the exchange of services for compensation; (4) Hospitality is equally applicable to space tourism and payload/satellite customers alike, providing accommodations to the customers prior to, during, and after the overall experience.

3.2.6 End-User Demand Group

The final community group discussed here is End-User Demand, including the Demonstrated Demand and Potential Demand communities: (1) The Demonstrated Demand community includes sets of sellers and buyers with a history of financial transactions, providing and purchasing a similar goods or service. Example populations—industry segments in this Demand community include small satellite launch to orbital trajectories or orbital space tourism flights; (2) The Potential Demand community also includes sets of sellers and buyers, providing and purchasing similar goods or services, but with no history (yet) of financial transactions. The transactions between buyer and seller may be envisioned but are not yet realized. Examples of potential Demand populations—industry segments include on-orbit fuel depots, in space resource extraction, in-space manufacturing, etc.

3.3 VISUALIZATION OF SPACE COMMUNITY GROUPS

The complete collection of Space Sector communities is shown in Figure 5. As shown above, prior space sector value chain or network

Figure 5. Honeycomb Depiction of Space Sector Communities and Groups
depictions ordinally label different space sector resources as “tiers.” Although not stated explicitly, the linear numbering of levels implies a linear process whose strength lies in enabling an understanding of concepts such as “upstream” and “downstream” markets. The shortcoming of the linear depiction is its unrealistic implication of transactional relationships modeled as dyadic network connections, as compared to the multi-nodal and complex network configurations of any real-world sector. This paper acknowledges all visual depictions of the collection of space sector (or any sector) communities to be simplified cognitive constructs imperfectly modeling the real phenomenon.

The space sector communities network depiction proposed here avoids any implication of relationship linearity by using a “strategy gameboard” layout of closely fitting hexagons, resembling a beehive configuration, in lieu of a linear “chain” alignment. We accompany our proposed definitions and visualization of the space sector with the explicit statement that all ties, both financial transactions and non-financial relations in nature, are not limited to those between communities shown as adjacent hexagons in the figure.

Design considerations determined the relative positions of each community so no assumption should be inferred by the proximity of any two hexagons. The eight separate community groups are semi-arbitrarily assigned different colors to easily differentiate them. Application of color highlights an important nuance of this depiction. Most community groups are depicted as a solid bright shade of their primary or secondary color, but the “blue” group includes multiple shades. This is a relevant reminder that the boundaries between and within hexagons in real life (IRL) are never unidimensional and contain multiple dimensions of nuance.

4. CONCLUSION

4.1 TAXONOMY RECOMMENDATIONS

This paper uses the ecological hierarchy of embedded organizations to develop definitions and descriptions for three tiers of space industry market-level organizations. The chart changes constantly as time passes and new ideas are included, forming a more comprehensive and realistic framework of the space sector. The evolution of this idea can be seen in earlier versions published by both authors of this report (Autry & Huang, 2014; Davidian, 2019; Townsend & Davidian, 2022).

This paper offers two recommendations intend to stimulate discussion and potential modifications to this taxonomy of communities and community groupings. These are:

**Recommendation 1.** The term “space sector” is proposed to describe the space market-level organizations connected solely through financial transactions. The next two analysis levels of market organizations, contained within the level immediately above it, are called “industries” and “industry segments,” respectively.

**Recommendation 2.** The term “space field” is proposed for the space market-level organization including both financial transactions and non-financial relationships. The next two analysis levels of market organizations, contained within the level immediately above it, are called “communities” and “populations,” respectively.

Ultimately, what matters most is the consistent use of terms up and down the hierarchy of market-level tiers rather than which set of terms are used.

Based on the ecological hierarchy of organizations, this paper aligns popular economic terminology based primarily on financial transactions (industry segments, industries, sectors) with the organizational theory perspectives adding non-financial relationships to the discussion (populations, communities, fields). Based on the hierarchical nature of social systems, multiple firms comprise industry segments or populations, multiple industry segments or populations comprise industries or communities, and multiple industries or communities comprise sectors or fields. We propose this hierarchy to facilitate discussions and calibrate analyses of the space sector (field).

4.2 SPACE SECTOR COMMUNITIES

Based on this hierarchy of levels, the 28 individual communities of the space sector (field) are discussed. The critical infrastructure and core subsystems of the space sector (field) include spaceports, launch vehicles, and in-space vehicles. The remaining 25 space sector communities are combined into six superset
groupings, including Raw Materials, Sub-Systems, Systems, Supporting Communities, Retail Services, and End-User Demand.

The 28 communities are graphically depicted as a set of interlocked honeycombs reminiscent of a strategy game board. This design choice emphasizes the idea that supply or value chains of any sector are non-linear constructs including both financial transactions and non-financial relationships among sector actors.

4.3 LIMITATIONS AND FURTHER RESEARCH

As is common with research activities, identified limitations of the study present opportunities for further research. Three examples of possible new research directions are described below.

First, a common observation about the honeycomb depiction of the space sector is that it heavily emphasizes “up-stream” communities and underplays the “down-stream” activities of specific demonstrated and potential markets. This critique is valid and can be addressed by identifying specific market communities, but for the moment, these are all included in the Demonstrated Demand and Potential Demand communities.

A second limitation of the honeycomb chart is the low level of detail it conveys due to the high LOA it communicates. Within each community shown is two additional layers of analysis, including multiple populations that each encompass multiple individual firms. Moving downward in the levels of analysis requires an exponential increase in the level of detail, thereby increasing the complexity level. The increased complexity decreases the overall understandability of the message being communicated, thereby diminishing the effectiveness of the chart. This is a reason why the current depiction was selected for this study, but future research could isolate one or two communities and identify the many populations and individual firms included within them.

A third opportunity for further research presents itself with the graphic depiction of the space sector communities to describe the “boundaries of the firm.” Recognizing that an individual firm can possess capabilities included within multiple hexagons of this chart, a boundary of irregular shape can be drawn that encloses those capabilities. Financial and non-financial network ties can then be drawn from the firm’s interior to other external capabilities, showing that firm’s “ecosystem.” The use of this graphic to define and visualize terms such as “ecosystem” is an additional option for further research.

These limitations and opportunities demonstrate the opening quote’s point: clear definition of a taxonomy of the space sector communities helps identify multiple opportunities for problem formulation and theory construction in space sector analyses.

A goal of this report, stated at the beginning, is to stimulate space markets discussions. Potential topics include whether the grouping of communities makes sense as described here, or could they be changed in any way to improve analytic distinctiveness and improve communication? All are welcome to join in this discussion, including scholars and practitioners from the many organization theory perspectives, management, the systems engineering approaches of social systems, and any of the economics areas of study (e.g., neoclassical economics, economic history, evolutionary economics, and economic sociology).

REFERENCES


