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SUBORBITAL MARKET OVERVIEW AND APPLICATION OF DISRUPTION THEORY

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ABSTRACT

This report identifies the incumbent and new entrant companies of the suborbital payload market, their industry roles, and how the Christensen Disruption Theory characterizes their possible future interactions.The existing suborbital payload market consists of service providers giving access to either (a) time in a microgravity environment, or (b) access to various launch and/or space environments (e.g., time at altitude, radiation levels, launch conditions, etc.). The suborbital market is currently served primarily by sounding rocket launch vehicles or substitute capabilities in the form of drop towers and parabolic-trajectory aircraft. Traditional customers for this market include universities and government organizations in the following areas of research: physical and biological processes in microgravity, observation and data collection of Earth and its atmosphere, and astronomical observation. The types of facilities and vehicles that characterize the suborbital cargo market and which are included in this report consist of drop towers, parabolic-trajectory aircraft, sounding rockets, and reusable launch vehicles. The types of payloads that make use of these facilities and vehicles can be classified by volume/form factor and intended purpose. Two types of suborbital research vehicles that focus primarily on atmospheric science, the airborne and balloon-based research sectors, are not covered in this report. This report identifies the current suborbital payload market sectors using the classifications mentioned above. A listing of market competitors and customers are given. Using this information, possible new entrant strategies to the suborbital market are discussed using the terminology and constructs of Clayton Christensen's Disruption Theory.

PROLOGUE

The purpose of this report is to demonstrate how business theories, like Clayton Christensen's Disruption Theory[1], can be applied to the emerging commercial space markets and to stimulate discussion about these markets within a well-defined framework and vocabulary. This particular theory, when used in conjunction with other market theories, can provide a useful perspective to government leaders when confronted with making policy or acquisition strategy decisions that rely upon, or affect the development of, an emerging commercial sector, for example.

It is not the purpose of this report to endorse the validity or superiority of any business theory. Disruption Theory is not necessarily more accurate than any other applicable business theory when describing the emerging commercial space sector of suborbital markets. As with any business model, arguments can be made both for and against the underlying assumptions and overall applicability of this particular theory. Finally, the purpose of this report is not to endorse or promote any of the new entrant business scenarios as described. These scenarios are simply provided as demonstrations of the Disruption Theory as applied to these emerging suborbital markets.

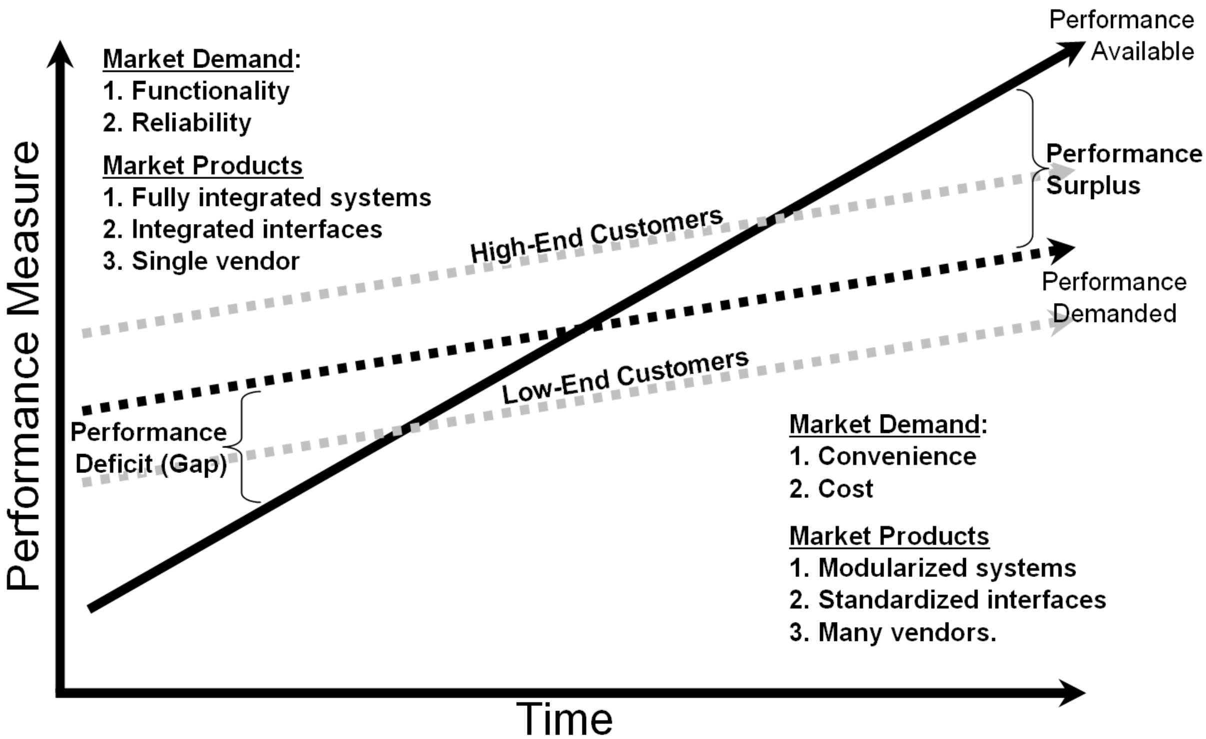
INTRODUCTION

The existing suborbital payload market consists of service providers giving access to either (a) time in a microgravity environment, or (b) access to various launch and/or space environments (e.g., time at altitude, radiation levels, launch conditions, etc.).

The suborbital market is currently served primarily by sounding rocket launch vehicles or substitute capabilities in the form of drop towers and parabolic-trajectory aircraft. Traditional customers for this market include universities and government organizations in the following areas of research: physical and biological processes

1. What this paper refers to as Christensen's "Disruption Theory" has different monikers. In his popular literature and journal articles, Christensen also referred to it as "Theory of Disruption," "Disruptive Innovation Theory," "Innovation Theory" and the "Disruptive Technologies Model." Further, these are different than, but closely associated with the five "Principles of Disruptive Innovation."

Figure 1. Christensen's Disruption Theory Performance Chart.



in microgravity, observation and data collection of Earth and its atmosphere, and astronomical observation.

The facilities and vehicles that characterize the suborbital market and which are included in this report consist of drop towers, parabolic-trajectory aircraft, sounding rockets, and reusable launch vehicles. The payloads that make use of these facilities and vehicles can be classified by volume/form factor and intended purpose. Two types of suborbital research vehicles that focus primarily on atmospheric science, the airborne and balloon-based research sectors, are not covered in this report.

This report identifies the current suborbital payload market sectors using the classifications mentioned above. A listing of market competitors and customers is given. Using this information, possible new entrant strategies to the suborbital market are discussed using the terminology and constructs of Clayton Christensen's Disruption Theory.

Finally, a list of outstanding comments, questions, and future research focus areas that will be addressed in future versions of this document, are provided to complete this report.

BASIC DESCRIPTION OF DISRUPTION THEORY

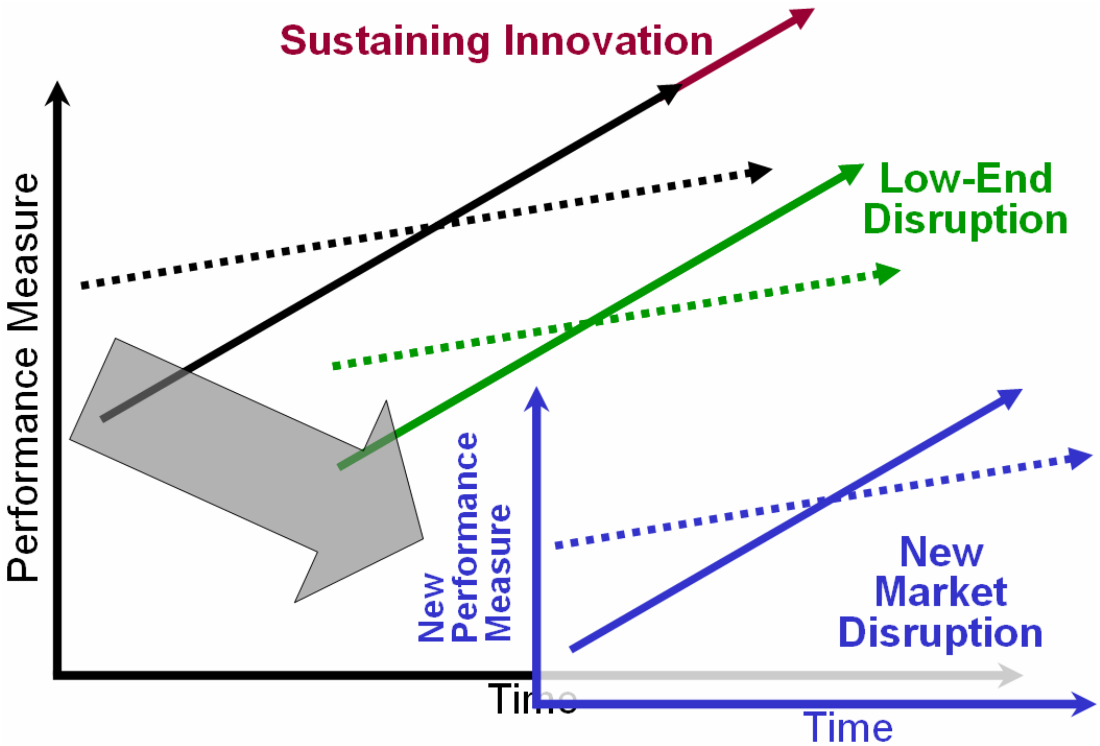
Disruption Theory is a conceptual model of cause and effect that provides a basis on which to predict the outcomes of market competition under different entry circumstances. The term "product" is used to denote a marketable product, service, or process offered by a company in a marketplace.

Background[2]

Clayton Christensen's Disruption Theory puts markets into a context of some measurement of a product's performance as a function of time, as shown in Figure 1 on page 2 by the line labeled "performance available." In an established market, there are one or more established

2. This section is only a brief overview of Disruption Theory. To appreciate the full detail, nuance, and subtleties of this construct, it is highly recommended to read the literature on the subject, including (1) Christensen, Clayton M. *The Innovator's Dilemma*. Harper Business Essentials (1998, 2000). ISBN: 0060521996. http://worldcatlibraries.org/wcpa/isbn/0060521996; and (2) Christensen, Clayton M. and Michael E. Raynor. *The Innovator's Solution: Creating and Sustaining Successful Growth*. Harvard Business School Press (September 2003). ISBN: 1578518520. http://worldcatlibraries.org/wcpa/isbn/1578518520

Figure 2. Examples of Sustaining and Disruptive Innovations



firms that compete in a given market by developing the performance metric to meet the needs of both high-end and low-end market customers. An aggregation of this demand distribution can be represented by the line labeled "performance demanded."

Figure 1 can be divided into two regions, as described below.

Early in the development of a given market, there is a high demand for the product performance that exceeds the available performance level, leading to a "performance deficit" for both high-end and low-end market customers. In the left region of the chart, all customers are under-served by the product suppliers, and the factors by which potential customers make their purchasing decisions (referred to as "the basis of demand") are driven primarily by functionality and reliability. In this region of the chart, available products are highly integrated systems and available only from a limited number of vendors.

Over time, the performance supply increases faster than the performance demand until both the high-end and low-end market customers find themselves in the "performance surplus" (far right) region of the chart. Performance surplus is characterized by low-end market customers that are over-served by vendors offering high performance products that are highly commoditized (e.g. modular by utilizing standardized interfaces). The best competitors provide speed, responsiveness, and convenience since the predominant bases of demand are customer convenience and cost.

Three different types of innovation, one sustaining and two disruptive, can occur in the marketplace. All are discussed below and shown in Figure 2.

Sustaining Innovation

The first type of innovation, entitled "sustaining innovation," is depicted on the market performance graph as a continuation in the performance increase along the established performance available curve. The tendency of sustaining innovations is to drive toward the upper-right corner of the chart, by meeting the increasing demands of current high-end market customers. Sustaining innovations can be evolutionary improvements of established technologies, or technological breakthroughs (also known as "revolutions") that raise the level of product performance, thereby meeting demands of the most demanding customers and allowing premium pricing and profit margins.

Characteristics of sustaining innovations include the following:

- Sustaining innovations provide a product improvement by increasing the level of an existing performance measure that characterizes the established marketplace. This improvement can be an incremental improvement of existing technologies, or discontinuous and revolutionary in character, but it moves along the current performance dimensions as valued by the existing customer base in major markets.

- Sustaining innovations target high-end market customers with increased performance as compared to previously-available products. It thereby allows established companies to increase profit margins with their established organizational processes.
- Sustaining innovations can be introduced by established firms in the market or by new entrants.
- Sustaining innovations do not typically represent a critical threat to established firms since the incumbent firms will be highly motivated and well funded to retaliate quickly.
- Sustaining innovations provide advantage to the followers of sustaining technologies, not to the technology leaders.

Developing successful strategies for sustaining innovations includes talking with existing customers to determine what performance needs are currently unmet or could be improved, identifying improvements or enhancements to existing technologies, and striving for the high-performance, high-margin sector of the market (represented by the upper-right quadrant of Figure 1).

An example of a sustaining innovation in the established suborbital market would be a new multi-staged sounding rocket that could attain higher apogee altitudes (and corresponding longer microgravity times) by the development of a new or improved rocket stage, whether that improvement was a result of a better propellant composition, better aerodynamics, or some other technological advancement.

Disruptive Innovation

The second type of innovation, called “disruptive innovation,” comes in two distinct varieties. The first is the “low end” disruption, and the second is the “new market” disruption. Each of these is discussed following a brief description of the general characteristics of disruptive innovations.

General characteristics of disruptive innovations include the following:

- Products that comprise a disruptive innovation tend to be simpler and less expensive than products offered by the incumbent firms. Part of the allure of the disruptive innovation is lower costs that result from lower profit margins and lower profits.
- Disruptive products tend to be simpler, less expensive, and more convenient than established products.
- Disruptive innovations tend to signal a change in the basis of demand (from customer convenience and cost, to function and reliability) due to performance oversupply.
- Disruptive products are typically first commercialized in emerging or insignificant markets. The attributes that make disruptive products worthless in mainstream markets typically become their strongest selling points in emerging markets.
- The established market’s leading firms' most profitable customers generally don't want, and, in many cases, initially can't use the disruptive product because it is lower in traditional performance metrics.
- For the most part, disruptive products are initially adopted by the low-end market customers that are the least profitable to the established market incumbent suppliers.
- Technology is not the major barrier facing new firms promoting disruptive products. In fact, historic data shows that disruptive products typically involve no new technologies, but are built of existing components and technologies integrated in a new way that offers new or different capabilities to the customer.
- There is a big “first to market” advantage with disruptive innovations. Statistical analysis of historic disruptions indicated that “first to market” entrants in established markets are successful 6% of the time, whereas “first to market” firms in disruptive innovations were successful 37% of the time.[3]

Descriptions and characteristics of low-end and new-market disruptions are provided below.

Low-End Disruption. Low-end disruptions appear on the market performance graph as a new performance supply line that appears below that of the established market. This is an indication that the disruptive product is generally lower performing than similar products currently being offered in the established market by incumbent firms. Corresponding to their lower performance,

3. “…only three of the fifty-one firms (6 percent) that entered established markets ever reached the $100 million revenue benchmark. In contrast, 37 percent of the firms that led in disruptive technological innovation-those entering markets that were less than two years old-surpassed the $100 million level…”, from “*The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*”, Chapter 6, “Match the Size of the Organization to the Size of the Market”.

low-end disruption products tend to be less expensive also.

Other general characteristics of low-end disruptions are:

- Products of a low-end disruption tend to establish a lower profit-margin market, since the product is introduced at lower cost which corresponds to the lower level of product performance.
- The reaction of the incumbent firms of the established market is typically dismissive since the disruptive product cannot meet the established product performance levels.
- Because of the lower profit-margins, established firms choose not to compete against the innovator, and they do not expend resources to keep their low-end market customers from migrating to the disruptive firm.
- Low-end disruption products attract customers that are being overserved by the established market products and who use cost as their basis of product demand. The innovative product steals low-end market customers from the established market.
- Low-end disruption products often need to establish a new value network for supply and distribution of the product to customers.
- As the low-end disruptor iteratively improves the performance of the innovative product, they gain operational experience and steal an increasing number of customers from the established market, gradually attracting customers from higher and higher profit-margins. At this point, the incumbent firms from the established market begin to take the competitive threat seriously. By that time, however, it is not uncommon that the established market firms are too late to successfully compete against the innovator and are driven out of business.

An example of a low-end disruptive innovation in the orbital transportation market was the introduction of the Pegasus launch vehicle in the early 1990s. Although it delivered an order of magnitude less payload mass to orbit, its lower cost allowed it to attract low-end market customers who were being over-served by the established market that was delivering, at the time, thousands of kilograms to orbit.

New-Market Disruption. Unlike low-cost disruptions, new-market disruptions do not appear on the same market performance graph with the established market. New-market disruptions appear on a totally new performance graph by identifying a brand new performance metric that attracts customers that are new to the market. These customers are referred to as “non-consumers” because they were not part of the original marketplace.

Other general characteristics of new-market disruptions include:

- The new-market innovation is a product that identifies a brand new performance metric.
- New-market disruptive products are selected by consumers using functionality as their basis of demand.
- The new-market product attracts the non-consumption customer and requires the creation of a new value network for its distribution.
- There is no reaction to the new-market product by the established market companies since the new product is not stealing customers from the established market incumbent firms.
- As the new-market disruptor iteratively improves the performance of the innovative product, they gain operational experience and increase their market size, benefiting from the significant “first to market” advantage. As the product performance improves, the new-market innovator evolves into a low-end disruption by penetrating the low-end segment of the established market.

In Figure 2, the different innovations are shown with respect to the established market on the Disruption Theory performance chart discussed in Figure 1 above.

- The established market is depicted in black by lines of performance supply (solid) and performance demand (dashed) plotted against the performance metric (y-axis) as a function of time (x-axis).
- The sustaining innovation is depicted in red by a solid line showing how the established performance supply is extended by this type of innovation.
- The low-end disruptive innovation is depicted in green by lines of performance supply (solid) and performance demand (dashed) plotted against the same performance metric used by the established market.
- The new-market disruptive innovation is depicted by an entirely new graph, shown in blue, with new performance metrics and new performance supply and demand lines.

Examples of new-market disruptive innovations include the first battery-powered transistor radio by Sony and the personal computer.[4]

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4. Christensen, Clayton M. *The Innovator's Dilemma*. Harper Business Essentials (1998, 2000). ISBN: 0060521996. http://worldcatlibraries.org/wcpa/isbn/0060521996;

SUBORBITAL PAYLOAD MARKET OVERVIEW

The suborbital market is filled with incumbent, new, and potential suppliers of facilities, aircraft, and/or launch vehicles. The primary provider for access to suborbital space and microgravity research has been sounding rocket launch vehicles. Substitute capabilities in the form of drop towers and parabolic-trajectory aircraft are also a major part of the microgravity research market. Potential entrants in this area include reusable launch vehicles (RLVs). Providers for each of these facility or vehicle types are described below.

Suborbital Payload Market Suppliers

Sounding Rockets

Sounding rockets can provide long (i.e., 4-5 minutes) to very long (i.e., 10-20 minutes) periods of microgravity conditions (as compared to other providers in the suborbital market) depending on a number of factors, including thrust profile, acceleration profile, altitude of trajectory apogee, etc., for payloads that must conform to the geometry, mass, and acceleration limits of the launch vehicle.

General observations and characteristics of sounding rockets servicing the suborbital science market include:

- Sounding rockets can vary in size, but are typically no more than 50cm in diameter.
- Sounding rockets generally use solid propellants that deliver very high acceleration profiles at liftoff.

Incumbent sounding rocket launch vehicles serving the international suborbital marketplace[5] are shown in Table 1.

Table 1. Active Sounding Rockets Since 2005.

• Black Brant V, IX, X, XI, XII	• RX-250-LPN, 320
• Castor 4B	• S-310
• Coyote	• Skylark 7
• HATF II	• SM-2
• Loki Dart	• Super Loki
• M-100B	• Talos Castor
• Maxus	• Terrier-ASAS, -Orion, -Improved Orion, -Lynx, -Malemute, -Oriole
• Nike-Orion, -Improved Orion	
• Orion, Improved Orion	• Viper, 3A
• RH-200, 200SV	• VS-30, -30/Orion
• RH-300 MkII	• VSB-30

5. This list was compiled by querying the JSR Launch Vehicle Database (www.planet4589.org/space/lvdb) for vehicles that have launched at least once since the year 2005.

A relatively new entrant sounding rocket launch vehicles company serving the suborbital marketplace includes:

- UP Aerospace Spaceloft XL

Drop Towers

Drop towers can provide very brief periods of microgravity for experiments with dimensions that conform to the geometry of a protective box (a structural frame enclosed by a drag-reducing fairing). For an experiment being dropped, the box is shaped like a bullet. For experiments being shot from the bottom of the tower (to attain twice the time in microgravity conditions) the fairing is shaped like a sphere.

Drop towers are substitute capabilities in the suborbital payload market because they provide access to microgravity environments, albeit for only brief periods of time. For customers who only need seconds of microgravity, the sounding rocket marketplace is providing more performance than what those customers actually require.

General observations and characteristics of drop towers include:

- Typical microgravity times for dropped experiments are on the order of 2-5 seconds.
- Microgravity times can be doubled if the capability exists in a given tower to shoot the experiment up from the bottom of the shaft instead of simply dropping it from the top.
- Experiments shot from the bottom of a drop tower experience very high initial acceleration impulses.
- All drop tower experiments experience very high final deceleration impulses.

Incumbent drop tower facilities serving the suborbital marketplace include:

- NASA Glenn Research Center (GRC) 2.2 Second Drop Tower
- NASA GRC Zero Gravity Research Facility
- Microgravity Laboratory of Japan (MGLAB) Drop Experiment Facility
- Center of Applied Space Technology and Microgravity (ZARM) Bremen Drop Tower

At the time of the publication of this report, there are no new or potential entrant drop tower facilities envisioned to serve the suborbital market.

Parabolic-Trajectory Aircraft

Aircraft fly parabolic trajectories to provide brief periods of microgravity and can accommodate a wide variety of payload geometries and masses, including traditional experiment racks.

Parabolic-trajectory aircraft are substitutes for sounding rocket launch vehicles in the suborbital payload market because they provide alternative access to the microgravity environment for customers whose requirements are satisfied with 20-40 seconds of microgravity. These customers were being over-served by the sounding rocket capabilities that provided from four to 20 minutes of microgravity time.

General observations and characteristics of parabolic-trajectory aircraft include:

- Typical microgravity times are approximately 20 seconds per parabola flown.
- Typical number of parabolas flown can vary between 20 to 60 per flight.
- The levels of gravity experienced during a parabolic trajectory can be varied to simulate different planets or planetary bodies.
- The quality of the microgravity environment is a function of the quality of the parabola flown and can be measured by on-board accelerometers.

Incumbent parabolic-trajectory aircraft serving the suborbital marketplace include:

- NASA Johnson Spaceflight Center (JSC) C-9B Aircraft
- European Space Agency A300 Zero G
- Ilyushin Il-76 MDK, Russia

A relatively new entrant parabolic-trajectory aircraft serving the suborbital marketplace includes:

- ZERO-G Corporation’s G-Force 1

The preceding section has identified all the vehicles, facilities, and aircraft currently in use to meet the demands of the suborbital payload market. The next section discusses a new class of vehicles that are potential entrants to this market.

Reusable Launch Vehicles

In addition to the incumbent competitors in the established suborbital payload market, there are also potential entrants to this market as well. These are private individuals and companies at various stages of developing and flight testing reusable launch vehicles (RLVs) that may enter the suborbital payload market in the near future in response to different market forces. RLVs may be more than substitutes in the suborbital marketplace by offering new and different capabilities with a different set of performance parameters.

General observations and characteristics of RLVs include:

- The RLVs tend to use liquid or hybrid propellants that have performance benefits and some operational disadvantages as compared to sounding rockets.
- RLV propulsion systems that can be “throttled” allow for better control of the thrust profile compared to sounding rockets, thereby controlling peak acceleration loads on the payload.
- RLVs are designed to terminate their mission by making a soft landing at a designated location and this permits the on-board payload to be recovered and possibly reused.
- RLV operations may allow them to fly multiple times in a single day.

Below is a list of the RLVs and companies[6] that are potential entrants to the suborbital payload market:

- Armadillo Aerospace SuperMod
- Blue Origin New Shepherd
- Masten Space Systems XA 1.0
- SPACEACCESS Skyhopper
- SpaceDev Dream Chaser
- TGV Rockets M.I.C.H.EL.L.E
- Virgin Galactic SpaceShipTwo
- XCOR Aerospace Lynx Mark I

The next section of this report will define the customer base for the suborbital market.

Suborbital Payload Market Customers

The suborbital cargo market customers can be characterized in a number of ways, but a convenient starting point is to distinguish them by categories of volume and form factor, namely:

Small Volume/Form Factor. These payloads fit into sounding rockets and are therefore necessarily small and cylindrical (fitting within the rocket’s outer shell and

6. From the Federal Aviation Administration’s Office of Commercial Space Transportation “2009 U.S. Commercial Space Transportation Developments & Concepts” report, pages 29-39. Companies and vehicles that were developed solely to compete in the Northrop Grumman Lunar Lander Challenge were not included in this list.

fairing, approximately 0.5 meters in diameter and with a taper ratio of approximately 3:1). The mass of these payloads can be up to hundreds of kilograms.

Medium Volume/Form Factor. These payloads can be the size of one or more rack-based experiment (rectangular solids with a volume of approximately 4-5 cubic feet each).

Large Volume/Form Factor. These payloads can be at least the size of a person or larger.

The suborbital payload market customers can also be characterized by the intended function of the payload instead of by more traditional definitions, such as who is paying the bills (which in most cases for the current suborbital market, is a government organization) or who is the subject-matter expert for the subject cargo (the payload's principal investigator, for example, who in most cases is employed by a university or national research organization).

For the purposes of discussion later in this report, marketplaces are classified as "high-end," "low-end," and "non-consumers" based on the level of market performance they require. Additional descriptions of these terms and lists of suborbital payload goods and services in each market category are given below.

High-End Markets

Customer demands in high-end markets are characterized by highly-customized payloads with performance requirements that begin at the high-end of available market capabilities and can grow to exceed what is available in the market. These are typically, but not exclusively, government-funded payloads.

For the purposes of this report, the "high-end" suborbital payload markets are associated with payloads that have the following attributes:

- Microgravity research of long duration (e.g., greater than 5 minutes).
- Earth remote sensing requiring high trajectory apogee altitudes (e.g., in excess of 300 km) to get long linger times.
- Astronomical observations, such as high energy astrophysics, plasma physics, solar and heliospheric physics, solar system exploration, ultraviolet and optical astrophysics, requiring high altitudes (e.g., in excess of 1,000 km).
- Technology demonstrators that require testing in long duration microgravity environments or high altitude trajectory apogees.
- Technology demonstrators that require exposure to extreme launch conditions (e.g., accelerations, vibrations, noise levels, etc.).
- Technology demonstrators that require long-duration testing in space environments (e.g. radiation, vacuum, thermal, etc.).
- Atmospheric observation requiring long linger times at certain altitudes.
- University student outreach, including research and educational missions (REM), that require high-end capabilities of the vehicles, facilities, or aircraft available.

Low-End Markets[7]

Low-end markets are characterized by having performance requirements that are at the low-end of the mainstream market performance supply. Customers in these markets are thus over-served (i.e., the performance available from the suppliers exceeds the customers' needs in the low-end markets), and they would be willing to receive a lower performance capability if it were available at a lower cost.

The following are goods and services required by customers in the "low-end" suborbital payload market:

- Microgravity research of short duration (e.g., less than 1 minute).
- Earth remote sensing that can be accomplished with short linger times, thereby satisfied with low trajectory apogee altitudes (e.g., no greater than 100 km).
- Astronomical observations that can be performed at low trajectory apogee altitudes (e.g., at approximately 300 km).
- Technology demonstrators that don't require long duration microgravity exposure or high altitude trajectory apogees.
- Technology demonstrators that don't require exposure to extreme launch conditions.
- Technology demonstrators that don't require long-duration testing in space environments (e.g. radiation, vacuum, thermal, etc.).
- Atmospheric observation satisfied with brief linger times at certain altitudes.

7. The phrase "Low End," although sometimes commonly construed as being derogatory, is not intended to convey that meaning as it is used here. The use of this term comes from its use in both of Christensen's Disruption Theory texts and is used exclusively in regards to markets.

- University student outreach, including research and educational missions (REM), that can be sufficiently conducted with the low-end capabilities of the vehicles, facilities, or aircraft available.
- K-12 educational payloads that are typically payloads of low cost, mass, size, and performance, due to stringent budget constraints and large class sizes.
- Novelty payloads composed of customers flying their personal effects for the ability to claim their effects were in a space or microgravity environment. Typically, these payloads are small and light due to stringent budget constraints.
- People who want to personally experience microgravity conditions are considered "low-end" simply because they are currently satisfied with the low-end performance of existing parabolic-trajectory aircraft, having no alternative on the current suborbital market.

Non-Consumer Markets

Non-consumers represent demand in a marketplace for which there is no current supply to meet their demands[8]. These customers typically will be satisfied with a new capability in the market that is very low performing at a low or reasonable cost.

- People who want to experience spaceflight, and/or the spectacular view from space, for themselves and/or with others. The size and mass of the payload varies from person to person, but it is safe to categorize this payload, on the average, as between medium and large in both the size and mass categories.[9]

The designations of "high-end," "low-end," and "non-consumer" markets will be set aside until later in the report at which time they will be referenced to describe Disruption Theory interactions in the suborbital payload markets.

8. "We say that new-market disruptions compete with 'non-consumption' because new-market disruptive products are so much more affordable to own and simpler to use that they enable a whole new population of people to begin owning and using a product, and to do so in a more convenient setting." from *The Innovator's Solution*, Chapter 2, "How Can We Beat Our Most Powerful Competition?"
9. Although there have been some customers in the "personal experience in space" category whose needs have been met by the current capabilities of an established *orbital* payload marketplace, this is not the case in the *suborbital* payload market.

SUBORBITAL PAYLOAD MARKET DISCUSSION

This section of the report will begin by looking at the aggregation of performance supply and demand in the suborbital payload market. Next, the historical suborbital payload market will be shown and characterized based on the Disruption Theory as described in the previous section. Finally, interactions between established market firms and new entrants under the conditions of sustaining and disruptive (both low-end and new market) innovations will be discussed.

Suborbital Payload Market Domains

The needs of a given payload category cannot necessarily be met by all the available facilities, aircraft, or vehicles identified in this report. To identify functional groupings of the services provided by suppliers in the suborbital payload market, it is useful to look at the functional attributes for each market provider in addition to the customer being served.[10]

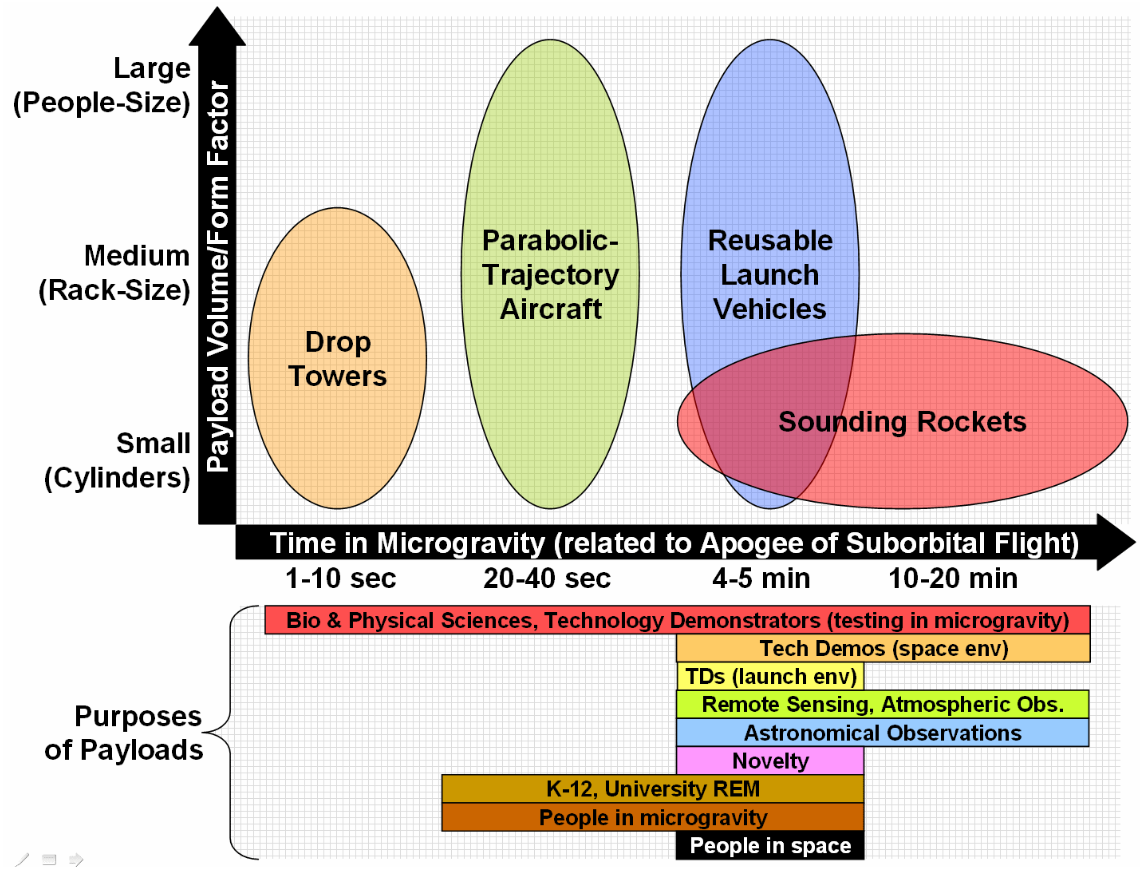
Using this approach, the suborbital payload market domain can be depicted by a two-dimensional space defined by (a) the relative volume and form factor categories of payloads flown (small, medium, and large) on the ordinate axis and (b) the apogee altitude of the sounding rocket (or similarly, the time in microgravity, in order to include the drop towers and parabolic-flying aircraft in the discussion) on the abscissa axis. In this domain, both the relative positions for the different suborbital capabilities (drop towers, parabolic-trajectory aircraft, sounding rockets, and RLVs), and the apogee/time in microgravity positions for each of the suborbital payload purposes can also be shown, as in Figure 3.

From the performance supply perspective, Figure 3 shows the following:

- There is currently very little overlap in microgravity domains of the market, so the drop towers, parabolic-trajectory aircraft, and sounding rockets coexist without the threat of intruding on each others' market domains.
- It can be expected, however, that the new entrant RLVs will be perceived as a competitive threat by providing direct competition to the established firms in the smallest category of sounding rocket payloads.
- New entrant RLVs, however, will not be competitors to sounding rockets for the market domain of small payloads requiring high trajectory apogees.

10. "The critical unit of analysis is the circumstance and not the customer." from *The Innovator's Solution*, Chapter 3, "What Products Will Customers Want To Buy?"

Figure 3. Attribute-based Characterization of the Suborbital Payload Market.



- Similarly, sounding rockets will not be competitors to RLVs for the new markets of medium- and large-category payloads needing only a few minutes in the microgravity environment.

From the performance demand perspective, Figure 3 shows the following:

- A subset of almost all customers could benefit from the introduction of new entrant RLVs to the marketplace if they need between 4-5 minutes of microgravity access.
- Introduction of the RLV capabilities to the market will most certainly increase access to space and microgravity conditions for customers in the following categories: novelty, K-12 education, and personal experience in space. Note that these are all low-end or non-consumers markets.
- Introduction of the RLV capabilities to the market has the potential to open a new market of the "personal experience in space" payload category.

Is Disruption Theory Applicable to the Suborbital Market?

Figure 4 is a simple plot of many (not all) suborbital rocket launches (estimated flight apogee versus launch date) from 16 August 1942 through 20 March 2009.[11]

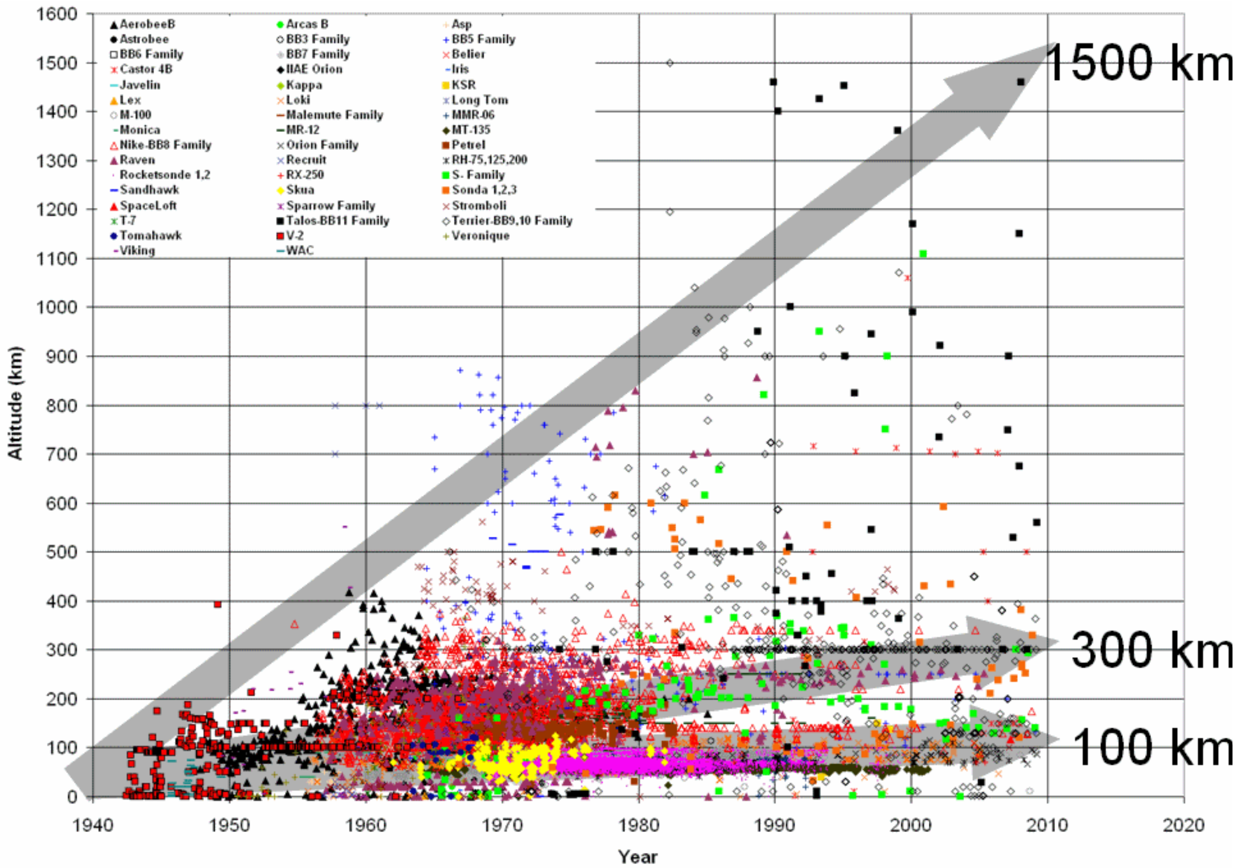
The objective of Figure 4 is simply to show how sounding rocket performance matches the market performance description assumed by Christensen's Disruption Theory. In the case of suborbital rocket launches, there is a similarity between the generic line of performance available shown in Figure 1 and the suborbital performance available as a function of time.

The sounding rocket trajectory apogee altitude was used as a proxy for the capability performance metric for two reasons:

1. Altitude can be used as being directly proportional to performance for microgravity experiments (higher altitude of trajectory apogee roughly correlates to increased time in microgravity), astronomi-

11. This chart comes from the JSR Launch Vehicle Database (www.planet4589.org/space/lvdb).

Figure 4. Plot of Suborbital Sounding Rocket Launches From 1942 to the Present.



cal observations (higher altitudes situate the scientific instruments farther above the Earth's atmosphere), and Earth observation (where higher altitude provides a better field of view).

2. Altitude data is readily available from public sources.

Arrows have been superimposed on this chart to show three clusters of performance at three different launches apogee altitudes: 1,500 kilometers (indicative of the astronomical observation payload category), 300 kilometers (indicative of microgravity conditions of approximately 10 minutes), and 100 kilometers (indicative of microgravity conditions of approximately 4 minutes).

Despite the linear vectors superimposed on the data points, there really is not a continual increase of performance from the first suborbital launches until the present day for the 100 kilometers and 300 kilometers altitude clusters (as shown by the arrows in Figure 4), but rather, there was an increase to that altitude by a certain point in time, and then the performance leveled off and remained constant since then.

The next three sections discuss different ways the new RLV entrant companies can introduce near-term innovations to the established suborbital payload markets. Farther-term disruptions (e.g., large payloads or high apogee trajectories approaching 1,500 kilometers) are not considered in this report because of the high level of uncertainty inherent in any far-term prediction.

The three near-term scenarios include:

- Scenario #1. Sustaining Innovation: New entrants to the suborbital payload market deliver performance meeting or exceeding the best performance of the incumbent suppliers in the established market.
- Scenario #2. Low-End Disruptive Innovation: New entrants to the suborbital payload market deliver performance that is lower than that provided by the incumbent suppliers in the established market and at a lower price.
- Scenario #3. New-Market Disruptive Innovation: New entrants deliver a product with a new and unique performance metric that is very, if not totally, different than that provided by the incumbent suppliers in the established market.

Using the scenario numbers above, Figure 5 below shows how these scenarios fit into the context of the

Disruption Theory Performance chart and the attribute-based market characterization chart.

Scenario #1. Sustaining Innovation

This section discusses how a new RLV entrant to the suborbital payload market could position itself so that it would be considered by the Disruption Theory as a sustaining innovation. This section also discusses how the Disruption Theory predicts how the incumbent firms of the established market will react to this innovation.

The relative location of the new entrants on the performance chart in the sustaining innovation is shown as star number one in Figure 5.

The scenario presented below assumes the following about the new RLV entrants as they enter the established suborbital payload market:

- The RLV new entrants come into the established suborbital payload market (small volume payloads needing 4-5 minutes of microgravity time or trajectory apogees of approximately 100 kilometers) with competitive pricing and profit-margin levels as compared to the incumbent firms in that market (i.e., the sounding rocket companies listed above and detailed in Appendix A).
- The performance (i.e., altitude of trajectory apogee, or time in microgravity) of the RLV entrants matches or exceeds that of the incumbent firms, thereby meeting the demands of the established customers.

Based on the graph shown in Figure 2, this sustaining innovation scenario, the relative location of the new entrants on the performance chart is shown as star #1 in Figure 5.

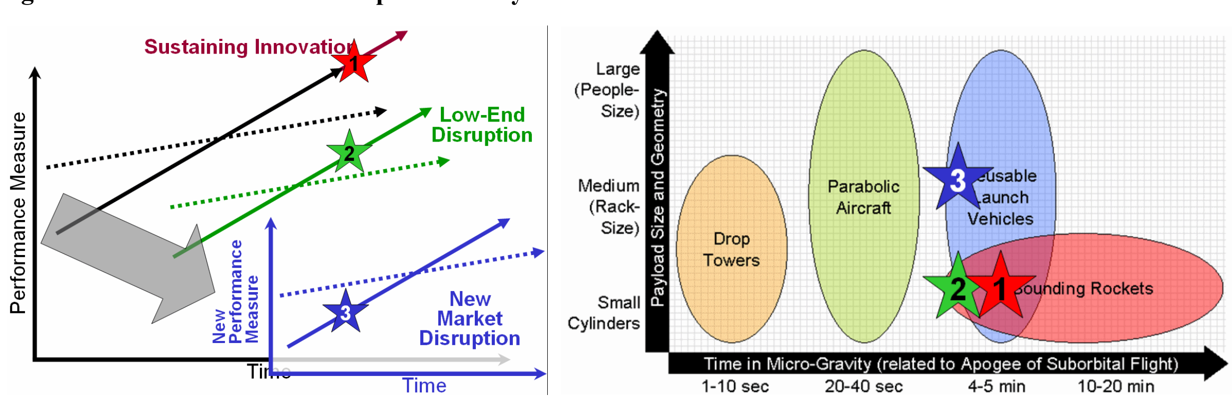
The "payload purposes" that may be impacted by the entrance of the RLVs to this market segment include the following:

- Small biological and physical science experiments that require 4-5 minutes of microgravity exposure.
- Small technology demonstrator payloads that require 4-5 minutes of microgravity exposure.
- Small technology demonstrator payloads that require exposure to the space environment that can sufficiently be achieved on a trajectory with an apogee altitude of approximately 100 kilometers.
- Small technology demonstrator payloads that require exposure to the launch environment provided by the specific RLV. Presumably, the trajectory apogee altitude is not a limiting requirement for these experiments.
- Small remote sensing (Earth observation) payloads that require a trajectory with an apogee altitude of approximately 100 kilometers.
- Small atmospheric observation payloads that require a trajectory with an apogee altitude of approximately 100 kilometers.
- Small novelty payloads that require a trajectory with an apogee altitude of approximately 100 kilometers or exposure to 4-5 minutes of microgravity.
- Small K-12 educational payloads that require a trajectory with an apogee altitude of approximately 100 kilometers or exposure to 4-5 minutes of microgravity.

Since the customers for the product being offered by the RLV new entrants are in the performance surplus portion of the market performance graph, they are being over-served (to some degree) by the incumbent firms and their basis of demand will be based on customer convenience and/or price. The services already offered in this region are typically highly modularized and commoditized.

In this situation, the competitive pricing of the new RLV entrants will be interesting only to the highest of the high-end market customers. Other customers will wish

Figure 5. Context of Three Disruption Theory Scenarios



they could pay less for what they actually require, instead of having to pay for more performance than they need.

Increased measures of customer performance, (e.g. ease of use, facilitated access to the payload, etc.) may attract some customers in low-end markets. High-end market customers will have internal resource allocation processes, and other “exit barriers”, that will keep them from easily converting from the established suppliers to the new entrants.

By employing a sustaining innovation strategy (i.e., entering the market at the performance high-end of the established market), the new entrant firm must necessarily address significant levels of both technology risk (by having to out-perform the established incumbent firms) and competition risk[12]. Since they are entering an established market and targeting a known customer base, marketing risk is low.

If the new entrants are successful at luring high-end market customers away from the established firms, they should be prepared for a competitive battle with the incumbents (as mentioned above). Surviving that, the most probable (and lucrative) exit strategy for a new entrant that successfully joins an established market would be a quick buy-out by one of the leading incumbents.

<u>Scenario #2. Low-End Disruptive Innovation</u>

This section discusses how the new RLV entrants may represent low-end disruptive innovations in the suborbital payload market. This section also discusses how the Disruption Theory predicts how the incumbent firms of the established market will react to this innovation.

12. Three quotes from Chapter 2 of *The Innovator's Solution*, “How Can We Beat Our Most Powerful Competitors?” are apropos here: (a) “The established competitors almost always win the battles of sustaining technology. Because this strategy entails making a better product that they can sell for higher profit margins to their best customers, the established competitors have powerful motivations to fight sustaining battles. And they have the resources to win.”; (b) “A sustaining-technology strategy is not a viable way to build new-growth businesses, however. If you create and attempt to sell a better product into an established market to capture established competitors' best customers, the competitors will be motivated to fight rather than to flee. This advice holds even when the entrant is a huge corporation with ostensibly deeper pockets than the incumbent.”; and (c) “If it is a sustaining innovation relative to the business model of a significant incumbent, you are picking a fight you are very unlikely to win.”.

The relative location of the new entrants on the performance chart in the low-end disruptive innovation is shown as star number two in Figure 5.

The scenario presented for this discussion assumes the following about the new RLV entrants as they enter the established suborbital payload market:

- The RLV new entrants come into the established suborbital payload market offering low-end performance (e.g., capable of carrying small payloads, providing access to substantially less than, and absolutely no more than 4-5 minutes of microgravity time, and to a maximum trajectory apogee of 100 kilometers) at a lower price to the customer and a lower profit-margin than the incumbent firms in that market.

This type of innovation will target low-end market customers including:

- Small biological and physical science experiments that require less than 4-5 minutes of microgravity exposure.
- Small technology demonstrator payloads that require less than 4 minutes of microgravity exposure.
- Small technology demonstrator payloads that require exposure to the space environment that can sufficiently be achieved on a trajectory with an apogee altitude less than 100 kilometers.
- Small technology demonstrator payloads that require exposure to the launch environment provided by the specific RLV. Presumably, the trajectory apogee altitude is not a limiting requirement for these experiments.
- Small remote sensing (Earth observation) payloads that require a trajectory with an apogee altitude less than 100 kilometers.
- Small atmospheric observation payloads that require a trajectory with an apogee altitude less than 100 kilometers.
- Small novelty payloads that require a trajectory with an apogee altitude less than 100 kilometers or exposure to less than 4 minutes of microgravity.
- Small K-12 educational payloads that require a trajectory with an apogee altitude less than 100 kilometers or exposure to less than 4 minutes of microgravity.

In this scenario, products are highly integrated (i.e., purpose-built, not modular) in order to maximize system performance (i.e., to minimize the performance gap between them and the incumbent firms).

The lower performance (i.e., functionality) of the new entrant RLVs, as well as their unproven track record of reliable operations over a long period of time, will be perceived by high-end market customers as weaknesses. Therefore, they will not be tempted to desert their existing launch providers to become customers of the "risky" and "low performing" RLVs.

Low-end market customers will also perceive the new entrants as risky. However, as a result of being over-served in the established market, low-end market customers will be happy with the reduced performance because it will cost them less than what the incumbent firms are charging. They might decide to "take a chance" with them because of the lower cost. Their basis of demand is determined by cost.

Incumbent firms will gladly cede the low-end market customer, who represent the segment of their overall business with the lowest profit-margins, to the new entrant firms and continue to expend their efforts on attracting more high-end (namely, high profit-margin) customers.

The high-end market customers may change providers once the RLVs can demonstrably match the performance of the incumbent firms, but even then their internal decision-making processes may prevent a shift to the new launch platforms.

By employing a low-end disruptive innovation strategy (i.e., entering the market at the performance low-end of the established market), the new entrant firm can minimize the levels of technology risk it must address, the amount of competitive risk it will face, and since the goal is to strip away low-end market customers from the incumbent firms, marketing risk is minimized as well. There is the opportunity, however, to attract first-time customers to the market due to the low-cost of the new entrant's product.

Scenario #3. New-Market Disruptive Innovation

This section discusses how the new RLV entrants may represent new-market disruptive innovations in the suborbital payload market. This section also discusses how the Disruption Theory predicts how the incumbent firms of the established market will react to this innovation.

The relative location of the new entrants on the performance chart in the new-market disruptive innovation is shown as star number three in Figure 5.

The scenario presented for this discussion assumes the following about the RLV new entrants as they enter a new suborbital payload market:

- The RLV new entrants come into a new suborbital payload market segment (e.g., medium- and large-sized payloads) where there are no incumbent firms.
- The performance of the RLV entrants may initially be lower (perhaps initially flying to an apogee altitude of 60 kilometers instead of 100 kilometers, thereby providing less than 4 minutes of microgravity time).
- Short turn-around time (due to operational simplicity), the time it takes to get a proposed experiment conducted, and intact recovery of the payloads are just three examples of new services and capabilities that the incumbent firms are not used to providing, and their customers are not used to receiving. This functionality is highlighted here as a possible basis for a new-market disruptive innovation.

The list of targeted non-consumers for the new-market disruptive innovation includes:

- Personal experience in microgravity
- Personal experience in space

At the beginning, the successful RLV new entrants will offer highly integrated, proprietary products. As time passes and other competitors enter, the disruption becomes a hybrid between the low-end and new-market varieties, and the products become more modular.

The challenge to the new entrant firms including overcoming "non-consumption" and needing to create a new value network (i.e., distribution channels for their product). The customers that will procure the service of the new-market RLVs can be considered to be the ideal customer, because they currently have nothing with which to compare the new product, they are easy to make happy (i.e., the performance hurdle is modest), and they absolutely need the new capability.

Since the customers for the product being offered by the RLV new entrants are all in the performance deficit portion of the market performance graph, their basis of demand will be predicated on functionality and/or reliability of the service. Customers are effectively desperate for any flight opportunity that fulfills their requirements, and will pay high prices to get them.

The new markets of medium- and large-sized payloads in microgravity (for minutes at a time) and space will attract non-consumers willing to pay high prices for a functionality that did not previously exist. First-to-market advantage will be significant in establishing and maintaining share of this market amongst the RLV firms that enter.

Incumbent firms in the established suborbital payload market (small-sized payloads) will be indifferent to the entry of the RLV firms because they will not perceive them as a threat. In order to compete with the RLVs they would effectively have to start their own RLV companies, but by the time they appreciate the strength of the new market, the RLV firms will have already stolen a significant amount of the small-size payload market share (starting with the low-end market customers, then followed by the high-end market customers) and the survival of the incumbent firms will be under serious threat.

A long-term projection of this scenario replaces the entire sounding rocket suborbital payload market at a given apogee altitude with RLVs, moving the sounding rockets to provide flight opportunities for payloads requiring higher and higher apogees (whatever the RLVs can't reach). As the performance (i.e. apogee altitude) of the RLVs increases, the sounding rockets are displaced from that market into the higher echelons of space. Ultimately, RLVs will replace all flight opportunities that are currently serviced by sounding rockets, and all the sounding rocket companies will be put out of business.

This scenario is an extreme, although not impossible, outcome predicted by the Disruption Theory, and could take decades to be realized.

CONCLUSION

Both the suborbital payload market and its customers are composed of many different segments. Market substitutes, in the forms of drop tower facilities and parabolic-trajectory aircraft, fill the needs of some customers, whereas others can only use sounding rockets. This is a great example of an established space market that is comprised of many components that do not go into space or even leave the ground. The advent of emerging commercial space companies and industries, most notably reusable launch vehicles (RLVs), represents an innovation in the suborbital payload market, and perhaps other markets as well.

By analyzing the suborbital payload market, listing its product providers and customers, graphing the operating domains, plotting the history of suborbital launches to the present day, and describing possible market entry scenarios, new entrant RLV companies to the suborbital payload market were investigated from the perspective of three types of innovations: sustaining innovations, low-end disruptive innovations, and new-market disruptive innovations.

The results of the scenario analyses are the following (and are summarized in Table 2 below):

- RLVs entering the established, small-payload, suborbital market (a sustaining innovation) at or above the current levels of performance offered by the incumbent firms may provide the best opportunity to identify possible customers, but it does not provide the best strategic position for the RLV companies with respect to the incumbent firms due to high technical and competitive risks.
- Other scenarios that may be sustaining innovations or new-market innovative disruptions, depending on how its framed, include launching medium- and/or large-sized payloads (including people) on RLVs to provide many minutes of microgravity exposure (an improvement of the microgravity time currently attained on parabolic-trajectory aircraft).
- A low-end disruption scenario considered involved offering RLV flights with lower performance and lower costs into the established market to begin luring away the low-end market customers who are over-served by the incumbent firms. In order to focus on their higher profit-margin business, the incumbent firms would gladly let the low-end (i.e. low profit-margin) market customers go to the new RLV entrant firms. Slowly, as the RLV companies gained operational experience and were able to increase the performance of their vehicles, more and more customers would desert the incumbent firms for the lower-priced RLVs. By the time the incumbent firms would decide to react to the up-and-coming threat of the new entrants, the chances of them regaining their market share would be greatly diminished.
- New-market disruptions include flying medium- and large-sized payloads (including people) on RLVs to provide exposure to space. (This is different than the previous item in which the purpose of the flight was exposure to microgravity only.) The new RLV entrants need to overcome a significant marketing risk (i.e., the identification of non-consumers) but would benefit from "first-to-market" advantages. The incumbent firms would ignore the new RLV entrants at first, and by the time they decided they might need to enter this new market segment (because their customers would start peeling away, beginning with the low-end market customers first, but slowly working their way through to the high-end clients) it would be too late for them to compete effectively.

Ultimately, three final conclusions of this discussion can be summarized as follows:

1. If the new entrant has a penchant to solving technical problems, then a new entrant company will be attracted to introducing a sustaining innovation to the established market place. This is case #1 as dis-

cussed in this paper. An expectation of this approach, as predicted by the Christensen Disruption Theory, is the fiercest of all commercially competitive environments among the three possible scenarios of innovation.

2. Given a successful track record of solving marketing problems, a new entrant company may be attracted to the introduction of a new market disruptive innovation. This approach, as described in scenario #3 of this paper, may required an ability to survive one or more failed attempts before the company is a commercial success.
3. If a decision were pending by government leaders regarding how they could best meet their mission goals while, at the same time, increasing their reliance upon and encouraging the development of a private suborbital transportation capability, what approach would Christensen's Disruption Theory suggest would make the best market entry point? It seems that the lowest overall risk would be through a low-end disruptive innovation, or scenario #2 as discussed in this report. Although government mission needs may not be immediately met (due to lower performance delivered by the new entrant), this approach provides the highest likelihood of both (eventual) accomplishment of mission goals and long-term industry success.

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Table 2. Summary Table of Disruption Theory Predictions

	Performance Chart Region	Market Reactions	Risks	Notes
Scenario 1. Sustaining Innovation	• Performance oversupply • Products are highly modular; commodities • Basis of demand: customer convenience & cost	• Incumbents: Will be highly motivated to compete with plentiful resources. • High-end market customers: like higher performance, but exit barriers may impede limited acceptance. • Low-end market customers: don't want or need excess performance	• Marketing: Low • Competitive: High • Technical: High	• Best exit is quick buy-out by incumbent. • Worst exit is competitive attack (95% of cases)
Scenario 2. Low-End Disruptive Innovation	• Performance deficit • New entrants are highly integrated • Basis of demand: functionality & reliability	• Incumbents: Will ignore RLVs, cede low-end customers to move up-market. • High-end market customers: Will ignore RLVs. • Low-end market customers: Low performance at low price OK. • Large first-to-market advantage	• Marketing: Low • Competitive: Low • Technical: Medium	• Incumbent's increasing RLV performance attracts established market from below.
Scenario 3. New Market Disruptive Innovation	• Performance deficit • New entrants are highly integrated • Basis of demand: functionality & reliability • Must create new value network (in all cases)	• Market Reaction: None • Customers are "Best" Customers: Had nothing before; Easy to please; They need you • Large first-to-market advantage	• Marketing: High (must overcome non-consumption) • Competitive: Low • Technical: Unknown	• Can transform into low-end disruption as competitors enter & performance increases.