Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand

THE TAURI GROUP

This study was jointly funded by
the Federal Aviation Administration Office of Commercial Space Transportation
and
Space Florida.

Table of Contents

List of Figures

List of Tables

Executive Summary

Suborbital reusable vehicles (SRVs) are creating a new spaceflight industry. SRVs are commercially developed reusable space vehicles that may carry humans or cargo. The companies developing these vehicles typically target high flight rates and relatively low costs. SRVs capable of carrying humans are in development and planned for operations in the next few years. SRVs that carry cargo are operational now, with more planned.

This study forecasts 10-year demand for SRVs. The goal of this study is to provide information for government and industry decision makers on the emerging SRV market by analyzing dynamics, trends, and areas of uncertainty in eight distinct markets SRVs could address. This study was jointly funded by the Federal Aviation Administration Office of Commercial Space Transportation (FAA/AST) and Space Florida, and conducted by The Tauri Group.

Suborbital Reusable Vehicles

Eleven SRVs are currently in active planning, development, or operation, by six companies. The payload capacity of these SRVs ranges from tens of kilograms to hundreds, with the largest currently planned vehicle capacity at about 700 kilograms. A number of SRVs can carry humans, with current designs for one to six passengers, in addition to one or two crew members in some cases. Some will also launch very small satellites.

Company	SRV	Seats*	Locker Equivalents (estimated)	Cargo (kg)	Price	Announced Operational Date
UP Aerospace	SpaceLoft XL	--	0.5	36	$350k per launch	2006 (actual)
Armadillo Aerospace	STIG A STIG B Hyperion	-- -- 2	1 2 12	10** 50** 200**	Not announced Not announced $102k per seat	2012 2013 2014
XCOR Aerospace	Lynx Mark I Lynx Mark II Lynx Mark III	1 1 1	3 3 28	120 120 770	$95k per seat $95k per seat $95k per seat, $500k for small sat. launch	2013 2013 2017
Virgin Galactic	SpaceShipTwo	6	36	600	$200k per seat	2013
Masten Space Systems	Xaero Xogdor	--	4	25	Not announced	2012 2013
Blue Origin	New Shepard	3+	5	120**	Not announced	Not announced

Table 1: SRV status details

* Maximum number of space flight participants, exclusive of crew (several vehicles are piloted)

** Net of payload infrastructure

Suborbital Reusable Vehicle Markets

This study analyzes SRV demand in eight markets, which were identified and grouped by similarity of applications, purpose, activities, and customers. Figure 1 summarizes and defines those markets.

COMMERCIAL HUMAN SPACEFLIGHT

Human spaceflight experiences for tourism or training

- Individuals
- Corporate
- Contests and promotions
- In-space personnel training

BASIC AND APPLIED RESEARCH

Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

- Biological and physical research
- Earth science
- Space science
- Human research

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION

Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

- Demonstrations requiring space/launch environment
- Hardware qualification and test

MEDIA AND PUBLIC RELATIONS

Using space to promote products, increase brand awareness, or film space-related content

- Film and television
- Media, advertising, and sponsorship
- Public relations and outreach
- Space novelties and memorabilia

EDUCATION

Providing opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space

- K-12 education
- University educational missions

SATELLITE DEPLOYMENT

The use of SRVs to launch small payloads into orbit

- Very small satellite launch

REMOTE SENSING

Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

- Commercial Earth imagery
- Civil Earth imagery
- Military surveillance

POINT-TO-POINT TRANSPORTATION

Future transportation of cargo or humans between different locations

- Fast package delivery
- High-speed passenger transportation (civil)
- High-speed troop transportation (military)

Figure 1: SRV market definitions

Methodology

One seat/cargo equivalent can equal =	1 seat
	3 1/3 lockers

Table 2: Seat/cargo equivalents

The Tauri Group combined primary research (more than 120 interviews, a survey of high net worth individuals, and a poll of suborbital researchers) and open source materials (such as market studies and data on analog markets, government budgets, and performance information on competing platforms) to build a full and objective picture of SRV market dynamics. The forecast results are in seat/cargo equivalents based on average capacity of SRVs (see Table 2).

Demand in each market was forecast for three scenarios:

- **Baseline scenario**: SRVs operate in a predictable political and economic environment that is relatively similar to today's. In this scenario, existing trends generate demand for SRVs.
- **Growth scenario**: This forecast reflects new dynamics emerging from marketing, branding, and research successes. Commercial Human Spaceflight has a transformative effect on consumer behavior, and more customers purchase SRV flights. SRV research results are highly productive and attract significant new government, international, and commercial interest for future experiments.
- **Constrained scenario**: SRVs operate in an environment of dramatic reduction in spending compared to today, due, for example, to worsened global economy.

Results

Total projected demand for SRVs, across all eight markets, grows from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the tenth year of the baseline case. (Year 1 represents the first year of regular SRV operations.) Demand under the growth scenario, which reflects increases due to factors such as marketing, research successes, and flight operations, grows from about 1,100 to more than 1,500 seat/cargo equivalents over ten years. The constrained scenario, which reflects significantly reduced consumer spending and government budgets, shows demand from about 200 to 250 seat/cargo equivalents per year (see Table 3).

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Baseline Scenario	373	390	405	421	438	451	489	501	517	533	4,518
Growth Scenario	1,096	1,127	1,169	1,223	1,260	1,299	1,394	1,445	1,529	1,592	13,134
Constrained Scenario	213	226	232	229	239	243	241	247	252	255	2,378

Table 3: Total projected demand for SRVs across all markets

Demand by Market

As shown in Figure 2 below, which compares forecasts for all markets by scenario, demand for SRVs is dominated by Commercial Human Spaceflight. Our analysis indicates that about 8,000 high net worth individuals from across the globe are sufficiently interested and have spending patterns likely to result in the purchase of a suborbital flight—one-third from the United States (based on global wealth distribution). The interested population will grow at the same rate as the high net worth population (about 2% annually). We estimate that about 40% of the interested, high net worth population, or 3,600 individuals, will fly within the 10-year forecast period.

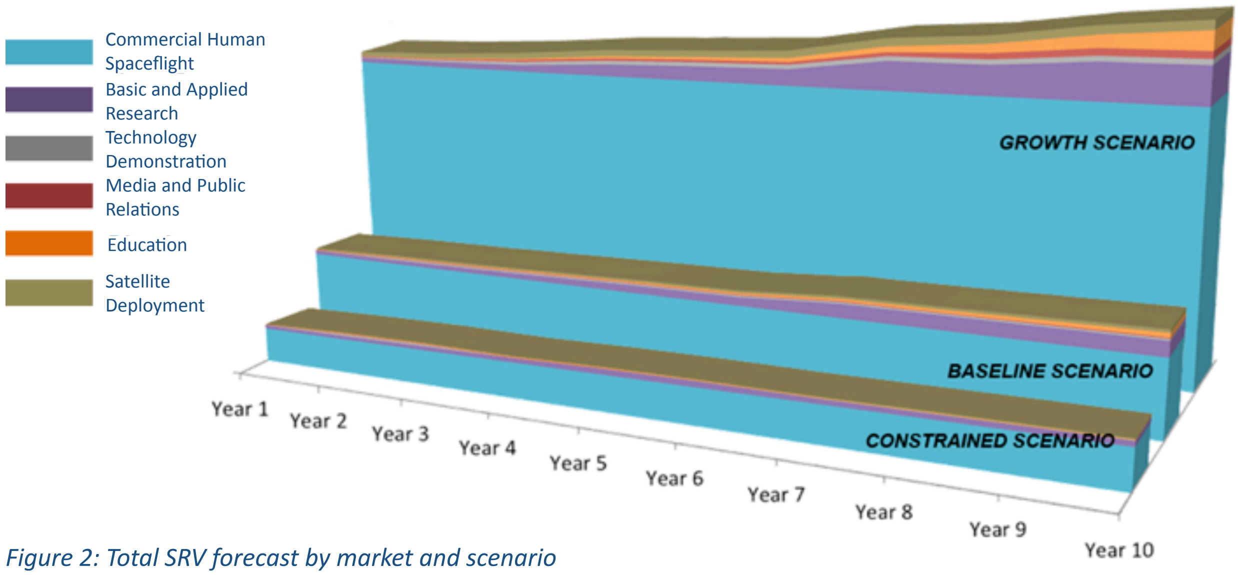

Figure 2: Total SRV forecast by market and scenario

We expect space enthusiasts outside the high net worth population will generate an additional 5% demand.

The resulting baseline forecast is 335 seats in the first year, growing to nearly 400 seats by year 10, totaling about 4,000 over 10 years. The growth scenario predicts a total of 11,000 seats, the constrained scenario a total of 2,000. (About 925 individuals currently have reservations on SRVs.)

Demand for Commercial Human Spaceflight is presented here as a relatively steady state in each scenario, reflecting current levels of interest in the population, assuming individuals are equally likely to choose to fly in any given year within the 10-year time frame.

This convention is useful because of the uncertainty associated with the dynamics of demand as it responds to future events. It is not to suggest that demand will always be steady state; demand may evolve in different, unpredictable ways. For example, demand may shift from the baseline level to the growth level after flight operations have begun. Demand may grow, as we have noted previously, more rapidly than predicted based on viral or "me too" effects, as a function of the social dynamics following successful launch experiences. Demand could decline for similar reasons. Figure 3 shows illustrative demand growth patterns that could emerge for Commercial Human Spaceflight.

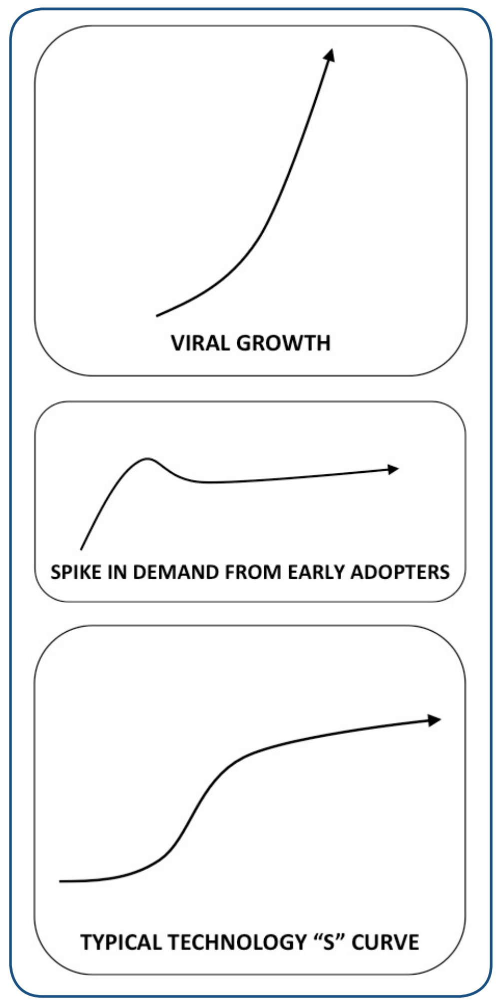

Figure 3: Possible trends over time -- individual demand for Commercial Human Spaceflight

If prices drop, demand will increase. Figure 4 is a demand curve for individuals with at least $5 million in investable assets, showing the effect of changing prices on demand. Additional demand (not shown) would result from individuals with lower levels of net worth.

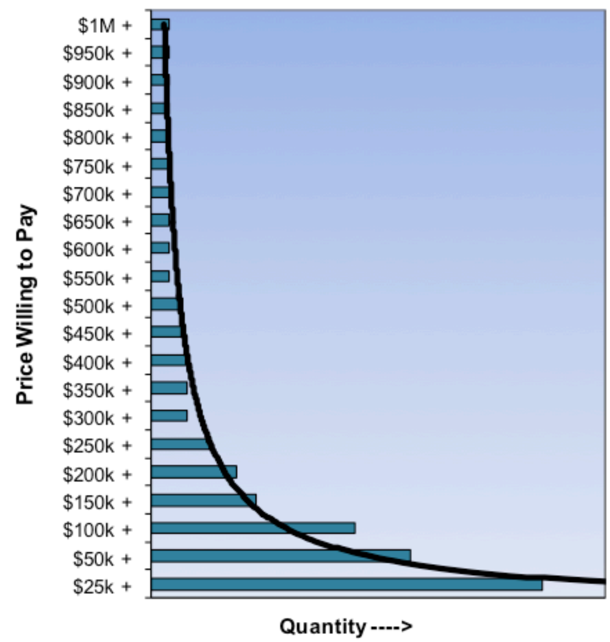

Figure 4: Price elasticity of suborbital tickets for individuals with $5M in investable assets

The second largest area of demand is Basic and Applied Research, funded primarily by government agencies, and also by research not-for-profits, universities, and commercial firms. Basic and Applied Research accounts for about 10% of baseline demand. SRVs can support a wide range of possible activities, but offer unique capability primarily in four areas: atmospheric research, suborbital astronomy, longitudinal human research, and microgravity. These areas enable investigations that would be of immediate interest to space and science government agencies. Commercial firms will seek to test SRVs as research platforms as reflected in the forecast. They could be a source of additional growth (beyond what is forecast) if an economically valuable application emerges. In the growth scenario, demand about doubles due to new government programs, doubled commercial activity, and more rapid uptake by international space agencies, driven by demonstrated research successes. In the constrained scenario, demand about halves.

The remaining 10% of demand is generated by Aerospace Technology Test and Demonstration, Education (which will see hundreds of schools and universities flying low cost, small payloads to provide students a learning tool), Satellite Deployment (which includes the launch of very small satellites), and Media and PR (through what we have predicted to be a small but influential number of flights for advertisements, documentaries, and television programming). In the growth scenario, demand in these markets doubles or triples. In the constrained scenario, demand is about half or less of baseline levels.

Two markets are not forecasted to drive launches. SRVs can provide a platform for Remote Sensing activities, but do not offer a competitive advantage over competing satellites, aircraft, and unmanned aerial vehicles (UAVs). Finally, in coming decades, SRVs could evolve into hypersonic airliners to support a market for Point-to-Point Transportation. However, this technology will not be available in the time horizon of this forecast.

Demand by User

Individuals

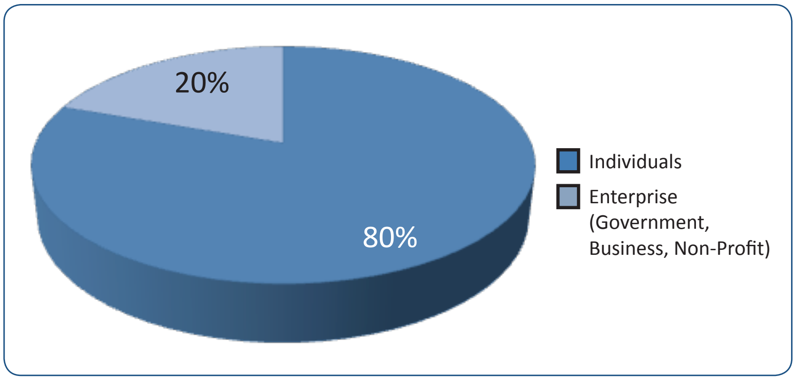

Figure 5: Enterprise demand and individual demand in baseline case

The majority of SRV demand comes from individuals (see Figure 5); the SRV market is a consumer market. Consequently, the capability and viability of SRV ventures will be heavily influenced by individual decision makers.

Unlike enterprise users who typically have lead times for decision making measured in years (reflecting annual budgeting processes and government program timelines), individuals can make purchasing decisions quickly. This market is likely to be sensitive to perceptions of risk, and how expectations and shared experiences of SRV flights disseminate.

The behavior of consumers in the future remains uncertain. Marketing and visibility resulting from the approach of flight operations, or successful and publicized flight experiences, could significantly – and rapidly – increase demand. Alternatively, those that have purchased tickets already may represent an early adopter population with different motivations and risk disposition from the broader market. At least some portion of tickets sold to date are refundable or deposits rather than full payments, creating a possibility that not all ticket holders will convert to passengers.

Enterprises

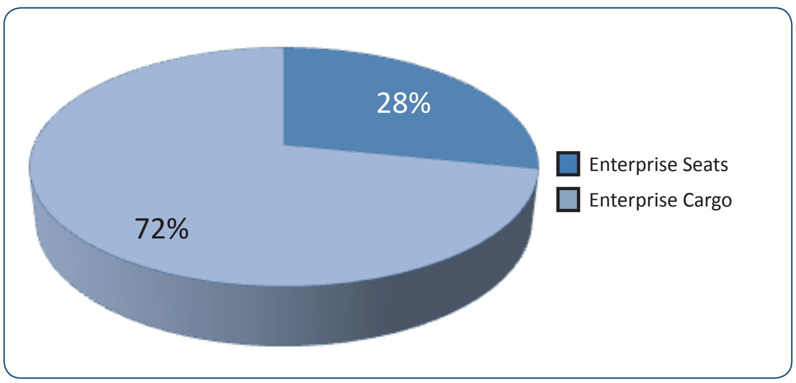

Figure 6: Enterprise demand by type of payload

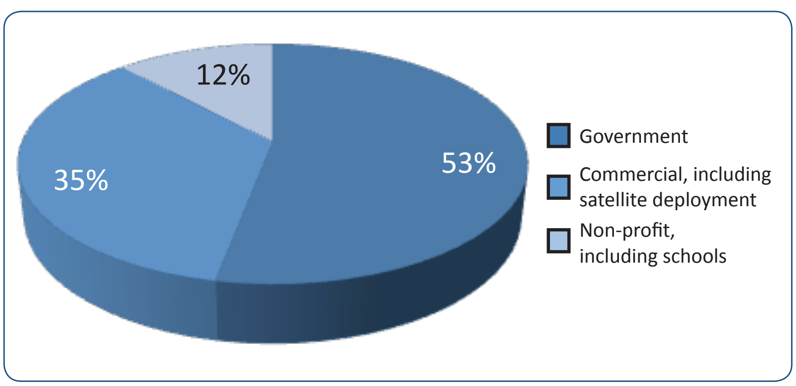

Figure 7: Enterprise demand by type of user

Enterprise users include government, commercial, non-profits, and school and university SRV users, and represents about a fifth of total forecasted SRV demand. Most enterprise demand is for cargo, rather than seats (see Figure 6). About half of enterprise demand is from government agencies, followed by commercial entities (more than one-third), with schools and non-profits accounting for the remainder (see Figure 7). Over 40% of government demand is NASA. (Note that this means that our forecast projects that NASA represents less than 5% of total SRV demand.) About 10% of enterprise demand is from non-US agencies, mainly in the Research and Technology Test and Demonstration markets. Finally, about one-third of enterprise demand is from commercial entities – about 30% Research, with the rest from Media and PR, Commercial Human Spaceflight, and very small satellite launches.

Revenue

Our forecast roughly translates a total of $600 million in demand over 10 years in the baseline case. The growth scenario totals $1.6 billion, and the constrained scenario totals $300 million.

There are important caveats to these estimates. They do not reflect all related expenditures associated with demand (such as, for example, budgets for developing experiments hardware and paying researchers, or revenues from spaceport activities for family and friends of those flying). They also do not represent predicted SRV flight revenues, but rather the potential revenue associated with SRV demand. The interplay of supply with demand is unaccounted for. For example, there is near-term demand for satellite launches at SRV prices and reflective of SRV capabilities, but no SRVs capable of launching satellites are anticipated until 2017.

Actual revenues will depend on when vehicles become operational, the pace of operations overall, the relative flight rates of providers, ancillary sources of revenue, and future price levels. If, in Year 1, reservations occurred at roughly the rate at which they have recently been announced (150 in 2011 and 185 in 2012, and a total of 925 since 2003), sales to fulfill our demand forecast in the baseline would grow at about 18% annually. In the growth scenario, sales would increase at about 40% each year. The constrained scenario would grow at about 4%. Announced historical reservations, compared to this possible trend of future reservations, are shown in Figure 8.

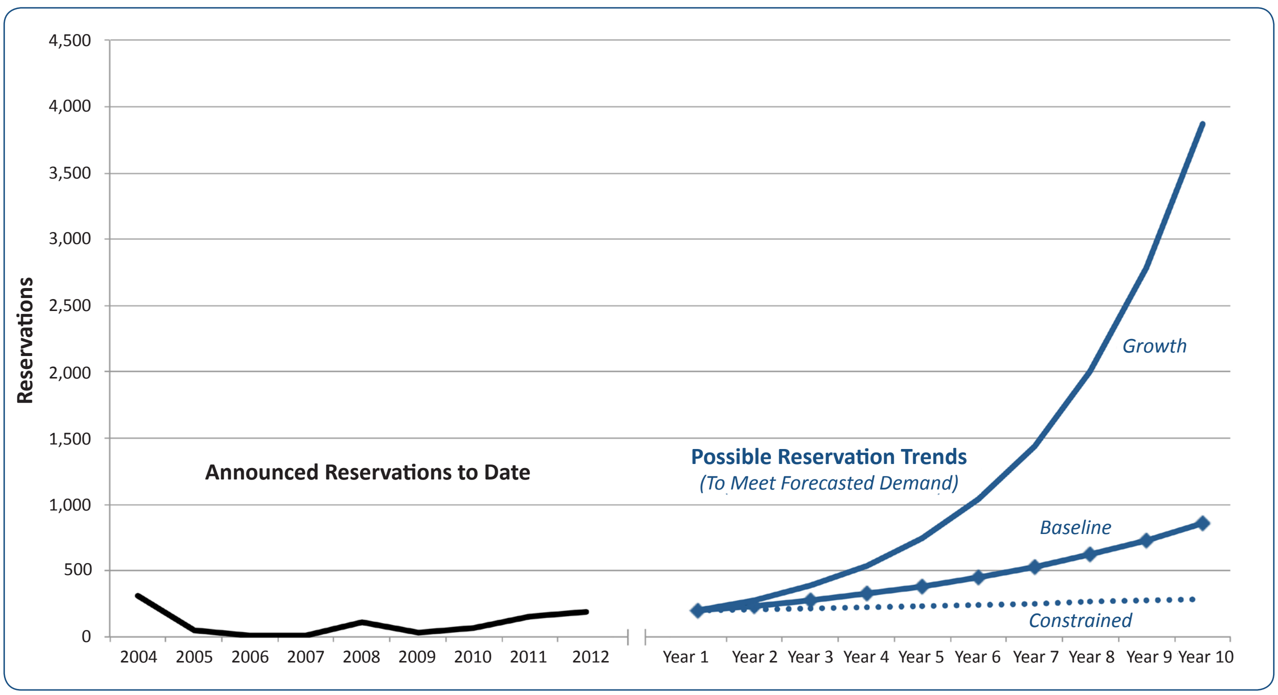

Figure 8: Possible reservations trend to meet forecasted demand

Major Uncertainties

The forecast predicts outcomes related to experiences that, for the most part, do not yet exist. If levels of SRV capability and performance vary from what is expected based on today's information, demand will change from predicted levels.

Forecast results are particularly sensitive to assumptions regarding future consumer behavior. The forecast assumes passengers fly once only, that a potential passenger has a 1/25 probability of flying in a given year (so 40% of interested passengers today will fly within the next 10 years), and that most (95%) passengers have net assets exceeding $5 million. Relaxing or strengthening any of these assumptions changes demand significantly.

Another sensitivity involves research outcomes. Research success and identification of a clear, related commercial application that requires sustained, ongoing SRV use could increase funding beyond the exploratory levels predicted.

The forecast reflects expectations about future government interest in SRVs. If SRV capabilities vary from current expectations, these levels of activity could be either higher or lower. Further, if NASA decision dynamics change, SRVs could be used for astronaut training, to replace sounding rockets to a greater degree, or for microgravity research integrated with ISS activities. The forecast also predicts that more than 50 international governments will begin to fund SRV research. National restrictions on access to SRVs could potentially limit funding from these governments. Alternatively, rapid uptake and greater activity from these nations could result in higher demand than predicted.

As an indicator of the revenue associated with estimated demand, we translated our forecast from seat/cargo equivalents at a rate of $123,000 per seat/cargo equivalent. This estimate reflects announced seat prices across vehicles in active development, extrapolated to all vehicles (including cargo-only vehicles) based on vehicle capacity. It is a rough estimate. No cargo prices (other than satellite deployment costs on an XCOR Lynx Mark III) have been announced, though some providers have stated informally that cargo costs align with seat costs for their vehicles. The mix of vehicles in operation will affect both demand and revenue. Vehicles are priced differently and have different capabilities.

Conclusion

Demand for suborbital flights is sustained and appears sufficient to support multiple providers. Total baseline demand over 10 years exceeds $600 million in SRV flight revenue, supporting daily flight activity. The baseline reflects predictable demand based on current trends and consumer interest. In the growth scenario, reflecting increased marketing, demonstrated research successes, increasing awareness, and greater consumer uptake, multiple flights per day generate $1.6 billion in revenue over 10 years. In a constrained scenario, where consumer and enterprise spending drop relative to today's trends, multiple weekly flights generate about $300 million over 10 years. Further potential could be realized through price reductions and unpredictable achievements such as major research discoveries, the identification of new commercial applications, the emergence of global brand value, and new government (especially military) uses for SRVs. Figure 9 presents a summary of the 10-year SRV demand forecast.

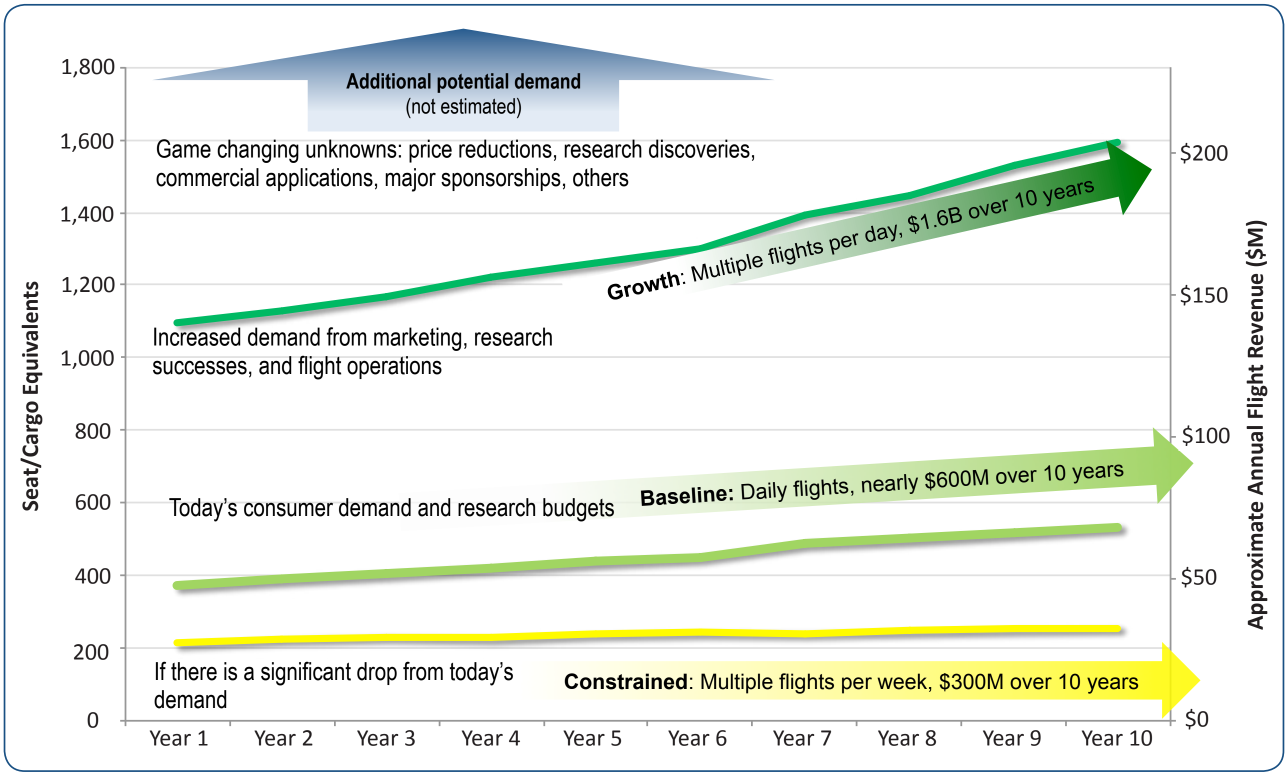

Figure 9: 10-year SRV demand forecast

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Suborbital Reusable Vehicles (SRVs): A 10-Year Forecast of Market Demand

Suborbital reusable vehicles (SRVs) are creating a new spaceflight industry. SRVs are commercially developed reusable space vehicles that may carry humans or cargo. The companies developing these vehicles typically target high flight rates and relatively low costs. SRVs capable of carrying humans are in development and planned for operations in the next few years. SRVs that carry cargo are operational now, with more planned.

This study forecasts 10-year demand for SRVs. The goal of this study is to provide information for government and industry decision makers on the emerging SRV market by analyzing market dynamics, especially areas of uncertainty and lack of awareness of SRV capabilities. This study was jointly funded by the Federal Aviation Administration Office of Commercial Space Transportation (FAA/AST) and Space Florida and conducted by The Tauri Group.

The study assessed eight SRV markets, with additional detail on submarkets. The markets are listed in Figure 10.

COMMERCIAL HUMAN SPACEFLIGHT
Human spaceflight experiences for tourism or training

BASIC AND APPLIED RESEARCH
Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION
Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

MEDIA AND PUBLIC RELATIONS
Using space to promote products, increase brand awareness, or film space-related content

EDUCATION
Providing opportunities to K-12 schools, colleges, universities, and graduate programs to increase access to and awareness of space

SATELLITE DEPLOYMENT
The use of SRVs to launch small payloads into orbit

REMOTE SENSING
Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

POINT-TO-POINT TRANSPORTATION
Future transportation of cargo or humans between different locations

Figure 10: SRV Markets

Purpose of the Forecast

The primary purpose of this forecast is to provide a comprehensive analysis of what is known about SRV markets. A thoughtful, disciplined forecast provides insight into trends, market dynamics, and areas of uncertainty. A broad focus on market dynamics, rather than a point estimate of the future, is particularly valuable for a new market or industry, where unpredictable and sometimes unknown factors shape outcomes. We have focused on aggregating, analyzing, and resolving information about future demand, with an emphasis on identifying uncertainties and areas where increased awareness of SRVs could affect the future. We highlight areas of significant uncertainty and unpredictability and show how different scenarios affect demand. Our goal is to provide a useful way to organize information about SRV demand and markets and a framework for thinking about—and managing—the future.

Methodology

We used a research- and analysis-based approach to forecast 10-year demand for SRVs. We assessed the capabilities of SRVs and researched and analyzed the resulting markets.

We used primary research and open-source materials (such as market studies and data on analog markets, government budgets, and performance information on competing platforms) to build a full and objective picture of SRV market dynamics. We conducted primary research using three techniques:

- We interviewed 120 potential SRV users and experts, including scientists and researchers, filmmakers, talent agents, insurers, investors, educators, astronauts, physicians, consultants, industry advocates, private-sector researchers, government program managers, and spaceflight providers. These interviews represent all sectors in this industry, and include about one-third in commercial organizations who may become customers, about 30% government, and the rest educators, non-profits, spaceports, and vehicle providers.
- We surveyed more than 200 high net worth individuals with at least $5 million in investable assets, in a randomized, scientific analysis, to estimate demand for SRV flights among customers with assets consistent with SRV prices.
- We polled about 60 suborbital researchers at two industry conferences: the Next Generation Suborbital Researcher's Conference in San Francisco and a space researcher's conference in Japan.

Based on this research, we analyzed each market and associated submarkets in terms of current and future activity, evaluating SRV market position based on SRV capabilities and compared to competing services, platforms, and methods (both terrestrial and space).

Our approach is summarized in Figure 11.

Each submarket was characterized in units relevant to that market segment:

- A locker equivalent, based on the standard sizes of Space Shuttle mid-deck lockers, EXpedite the PRocessing of Experiments to Space Station (EXPRESS) lockers, and NanoRacks, of about 2 cubic feet. Where needed, lockers were further subdivided into cubes, about the size of a CubeSat form factor (a 10cm cube), with 16 cubes per locker;
- Passenger seats, exclusive of crew, and standardized by number of individuals and not by their mass or volume; and
- Dedicated flights (for demand where, regardless of vehicle capacity, a dedicated flight would be required; an example is a research flight carrying a telescope requiring control of vehicle pointing and position; dedicated flights were estimated at 3 seats or 10 lockers).

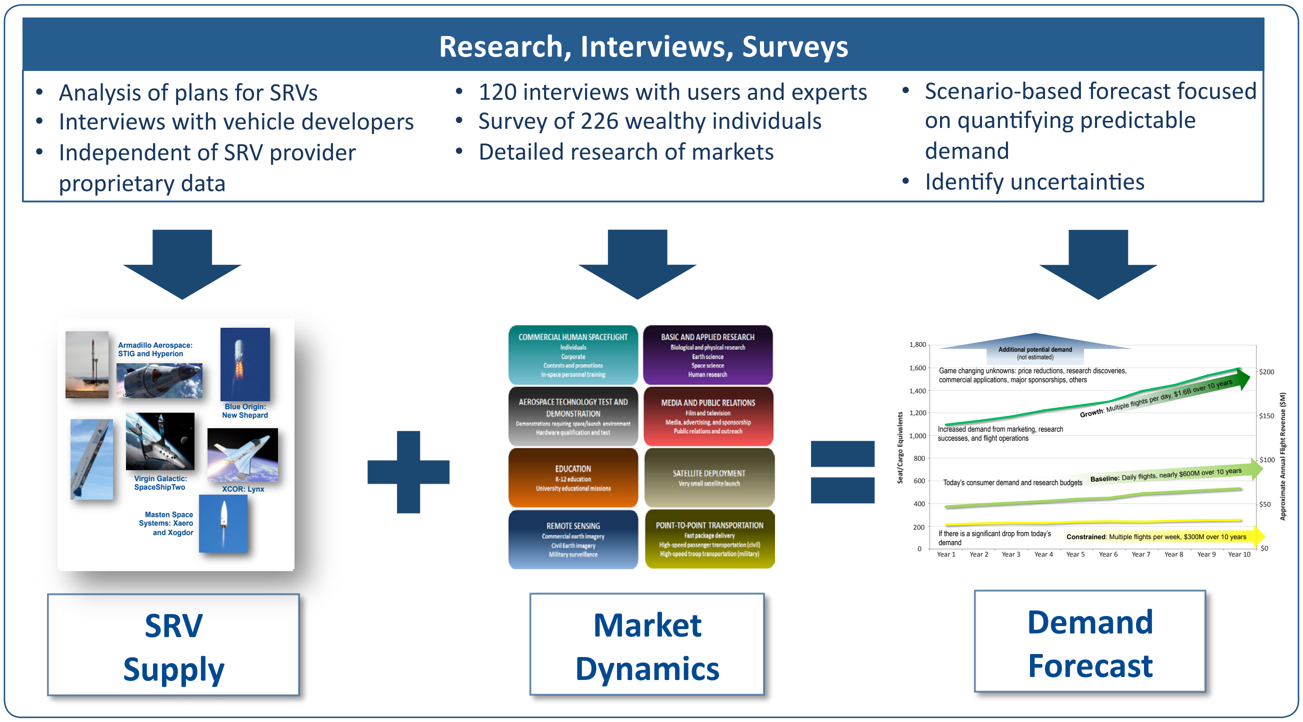


Figure 11: Forecast process

We aggregated each market into seat/cargo equivalents. We determined the seat/cargo equivalent using average cargo capacity compared to seats on proposed SRVs, resulting in the following conversion: one seat/cargo equivalent equals one seat or 3 1/3 lockers. This translation into seat/cargo equivalents allowed us to standardize and consolidate the forecasts across all markets, reflecting a mix of cargo, people, and dedicated flights.

One seat/cargo equivalent can equal =	1 seat
	3 1/3 lockers

Table 4: Seat/cargo equivalents

Scenarios

Demand in each market was forecast for three scenarios:

- **Baseline scenario**: SRVs operate in a predictable political and economic environment that is relatively similar to today's. In this scenario, existing trends generate demand for SRVs.
- **Growth scenario**: This forecast reflects new dynamics emerging from marketing, branding, and research successes. Commercial Human Spaceflight has a transformative effect on consumer behavior, and more customers purchase SRV flights. SRV research results are highly productive and attract significant new government, international, and commercial interest for future experiments.
- **Constrained scenario**: SRVs operate in an environment of dramatic reduction in spending compared to today, due, for example, to worsened global economy.

In addition to forecasted scenarios game changing unknowns including price reductions, viral consumer response, research discoveries, commercial applications, major sponsorships, and others could drive additional demand not estimated in this forecast.

In each scenario, we assume SRV prices remain at current levels and there is a general perception of safe operations of SRVs. (The effect of varying these assumptions is discussed.) Prices for cargo, which have typically not been announced, were estimated based on published prices for seats. An average price per seat, reflecting all providers who have announced seat prices, was estimated at $123,000.

The report also describes pathways beyond the assumptions of the growth scenario—unpredictable successes that might emerge from the development of dramatic changes in consumer response, new applications, new markets, or new capabilities in other industries. These are the difficult-to-predict breakthroughs and greenfield successes that entrepreneurs seek to enable.

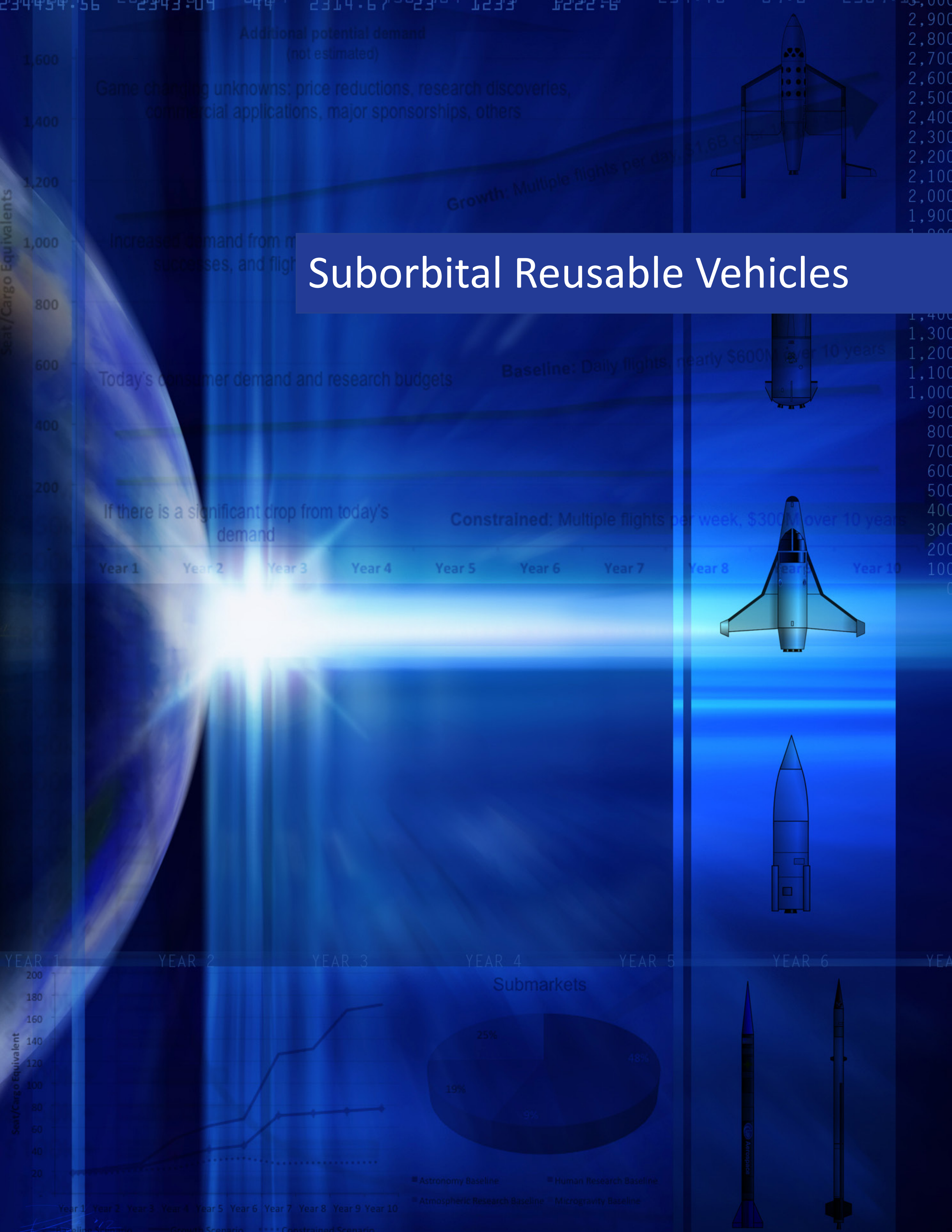
Year 1 of the forecast corresponds to the start of regular SRV operations, that includes human flights.

Uncertainty

Many factors affecting future demand cannot be fully predicted now. This study identifies factors with a significant effect on demand that will cause unknown future outcomes, that are likely to change, or that are difficult to quantify. The study discusses what is known today and the consequences of the uncertainty associated with these factors.

Lack of Awareness

Finally, the report identifies areas where SRVs may meet market needs, but where potential users of SRVs have limited awareness of SRVs or their capabilities.



Suborbital Reusable Vehicles

Suborbital Reusable Vehicles

SRVs typically cross the threshold of space (about 100 kilometers or 63 miles) and return, offering one to five minutes of microgravity at the apex of flight. They do not achieve orbit. Vehicle launch profiles vary between vertical takeoff and landing and horizontally launched winged vehicles.

Nine SRVs by six companies are currently in active planning, development, or operation (see Figure 12). The capacity of these SRVs ranges from tens of kilograms to hundreds, with the largest currently planned vehicle capacity at about 700 kilograms. A number of these vehicles can carry humans, with current designs for one to six passengers, in addition to one or two crew members in piloted vehicles. Some vehicles will also launch very small satellites (under about 15 kilograms). Table 5 provides additional detail on current proposed and operational SRVs.

Timing of Initial Operations

SRVs have been in development for years. Development timelines have lengthened and flight dates have been delayed for several vehicles. The time frame in which a mix of SRVs, including vehicles capable of carrying passengers, will achieve regular operations remains uncertain. To accommodate this uncertainty regarding SRV timing, the initial year of the study forecast (Year 1) corresponds to the first year of regular SRV operations, including SRVs capable of carrying people. The market dynamics and forecasted demand in this study remain relatively applicable with Year 1 occurring in the next several years. As time passes, changes in consumer perceptions, shifting government program budgets, the emergence of competing systems (such as high altitude balloons and commercial orbital capabilities), and other factors will increasingly change market dynamics and resulting demand.

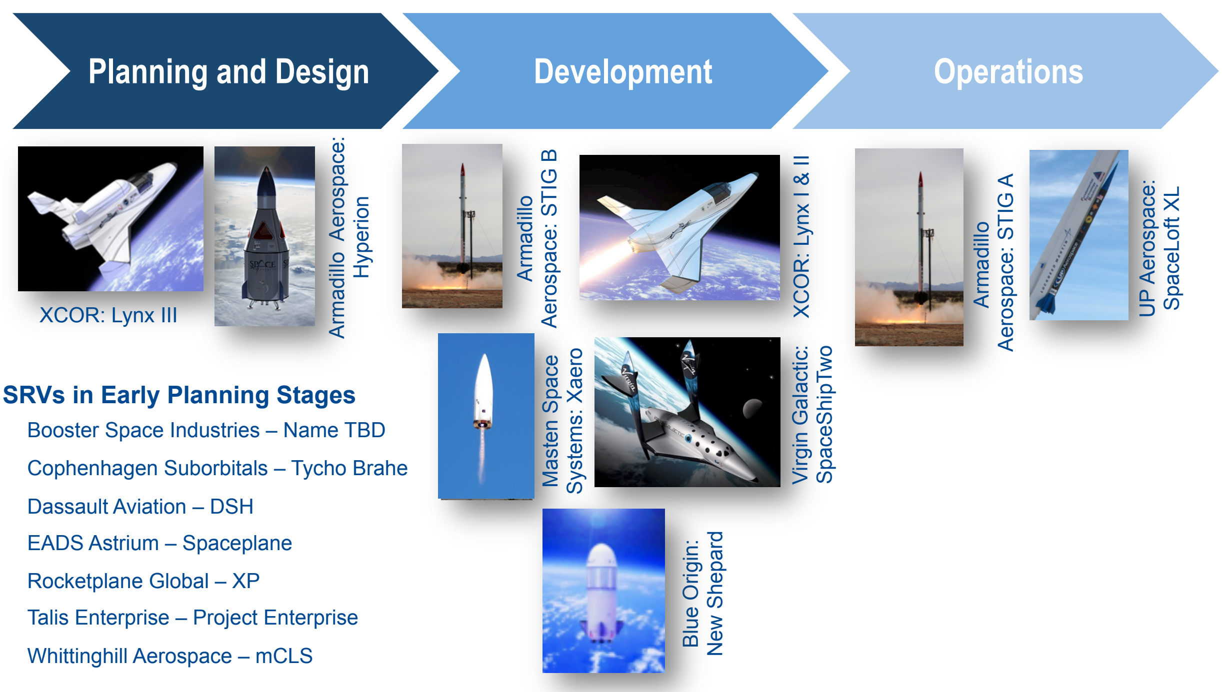


Figure 12: Status of SRVs

Company	SRV	Seats*	Locker Equivalents (estimated)	Cargo (kg)	Price	Announced Operational Date
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XCOR Aerospace	Lynx Mark I Lynx Mark II Lynx Mark III	1 1 1	3 3 28	120 120 770	$95k per seat $95k per seat $95k per seat, $500k for small sat. launch	2013 2013 2017
Virgin Galactic	SpaceShipTwo	6	36	600	$200k per seat	2013
Masten Space Systems	Xaero Xogdor	--	4	25	Not announced	2012 2013
Blue Origin	New Shepard	3+	5	120**	Not announced	Not announced

Table 5: SRV status details
* Maximum number of space flight participants, exclusive of crew (several vehicles are piloted)
** Net of payload infrastructure

Vehicle Operations

Vehicle providers have not provided details on how rapidly they will increase flight rates, but most vehicle operators target eventual operational rates in a range between once per week to multiple flights per day. These targeted rates are extremely high compared to historical space launch activity.

Perceptions of Safety

The analysis of demand presented herein assumes perceptions of appropriately safe SRV operations among stakeholders. These perceptions will be shaped as the industry evolves, reflecting the operational practices of SRV providers, marketing and communication messages, the regulatory environment, and many other factors. This evolving perception would be affected by a high-profile failure, near miss, or mishap, whether it happened with an operational SRV, a test vehicle, or even an orbital vehicle indirectly related to SRVs. The resulting change in perception of safety is highly uncertain. The type of event and timing are important considerations. Responses of the SRV industry (recognizing that the actions of any one firm are likely to affect perceptions of other firms), media, and regulators and other government actors are important as well. Future perceptions of safety and SRV user behavior regarding perceptions of safety are a significant source of uncertainty about future demand.

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Market Analysis

Suborbital Reusable Vehicle Markets

This study analyzes SRV demand in eight distinct markets, which we identified and grouped by similarity of applications, purpose, activities, and customers. Figure 13 summarizes and defines those markets and lists associated submarkets for each.

COMMERCIAL HUMAN SPACEFLIGHT

Human spaceflight experiences for tourism or training

Individuals
Corporate
Contests and promotions
In-space personnel training

BASIC AND APPLIED RESEARCH

Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

Biological and physical research
Earth science
Space science
Human research

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION

Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

Demonstrations requiring space/launch environment
Hardware qualification and test

MEDIA AND PUBLIC RELATIONS

Using space to promote products, increase brand awareness, or film space-related content

Film and television
Media, advertising, and sponsorship
Public relations and outreach
Space novelties and memorabilia

EDUCATION

Providing opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space

K-12 education
University educational missions

SATELLITE DEPLOYMENT

The use of SRVs to launch small payloads into orbit

Very small satellite launch

REMOTE SENSING

Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

Commercial Earth imagery
Civil Earth imagery
Military surveillance

POINT-TO-POINT TRANSPORTATION

Future transportation of cargo or humans between different locations

Fast package delivery
High-speed passenger transportation (civil)
High-speed troop transportation (military)

Figure 13: SRV market definitions

We have defined the Commercial Human Spaceflight market as human spaceflight experiences for tourism or training, with four submarkets.

- Individuals: Human spaceflight activities sometimes described as space tourism.
- Corporate: SRV flights as promotions for corporate customers or as a high-end incentive or reward.
- Contests and promotions: Providing seats as a prize. (Although the objectives may be similar to contests and promotions, activities such as using SRVs for an ad campaign or licensing with a provider for brand recognition are addressed in the Media and PR market.)
- In-space personnel training: Training for orbital flights.

We have defined Basic and Applied Research market as basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity.

- Biological and physical research: Experimental payloads to investigate biological and physical responses
- Earth science: Observations and measurements of the Earth and its systems
- Space science: Observations and measurements of the space environment
- Human research: Research investigating human physiological and psychological responses

(The Basic and Applied Research market is defined as focusing mainly on activities that expand the pool of knowledge. This is an important differentiator from markets with similar activities, such as Education, where the focus is on activities that use SRV flights as a learning tool for students, or Aerospace Technology Test and Demonstration, where the focus is on activities that verify that a payload (object, technology, system) was engineered correctly for the space environment. Intent may overlap. Some research payloads have secondary education objectives. Research instruments or experimental hardware may require test and demonstration flights. Typically, we have reflected the primary objective of an activity in assigning it to a market.)

We define the Aerospace Technology Test and Demonstration market as SRV activities to advance technology maturity or achieve space demonstration, qualification or certification, with two submarkets: demonstrations requiring space/launch environment, and hardware qualification and test. Aerospace technology test and demonstration includes technology payloads for atmospheric vehicles, launch vehicles, and in-space vehicles, including, for example, new systems for ISS.

We define the Media and Public Relations market as activities that use SRVs to promote products, increase brand awareness, or film space-related content, with four submarkets.

- Film and television: Filming on SRVs for space-themed entertainment
- Media advertising and sponsorship: Logos and advertisements placed on space hardware and commercials filmed in space. (This submarket includes all passenger seats purchased by companies associated with advertising or brand promotion with the exception of contests and promotions, which purchase seats for third parties.)
- Public relations and outreach: Awareness or recognition through association with SRVs.
- Space novelties and memorabilia: Objects that have flown in whole or in part in space and memorabilia associated with a particular space event or vehicle.

We define the Education market as SRV-provided opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space, with two submarkets.

- K-12 education: Payloads and activities for K-12 schools or students
- University educational missions: Payloads developed by university students. (University educational missions do not include university-developed missions paid for by government, non-profit, or commercial research organizations, nor missions paid with university funds that have primarily scientific objectives; these missions are included in the Basic and Applied Research market.)

We define the Satellite Deployment market as the use of SRVs to launch small payloads into orbit. (Includes all long-duration deployment of very small payloads into space regardless of intend application, e.g. remote sensing, education, technology demonstration, or basic and applied research.)

We define the Remote Sensing market as imaging the Earth and Earth's systems for commercial, civil government, or military applications. (Collection of remote sensing data for scientific research is typically considered Earth science and is included in Basic and Applied Research market.)

We define the Point-to-Point Transportation market as transportation of cargo or humans between distant locations, with three potential Point-to-Point Transportation submarkets: fast package delivery, high-speed passenger transportation, and high-speed troop transportation.

This section of the report addresses each of these markets in terms of:

- Market Dynamics
- How SRVs Fit into the Market
- Current SRV Activity
- SRV Demand Forecast
    - Forecast Methodology
    - Estimate of 10-Year Demand
    - Uncertainty
    - Lack of Awareness

Commercial Human Spaceflight

Commercial Human Spaceflight is the use of SRVs for tourism or training. Commercial Human Spaceflight can be grouped into four submarkets:

- Individuals;
- Firms using seats as incentives or rewards;
- Organizations offering seats in contests and promotions; and
- Space agencies or other space-related organizations using SRVs for in-space training.

COMMERCIAL HUMAN SPACEFLIGHT

Human spaceflight experiences for tourism or training

Individuals
Corporate
Contests and promotions
In-space personnel training

Market Dynamics

SRVs that carry humans will compete in a diverse consumer market of space travel, terrestrial space simulations, and non-space adventure and luxury tourism.

Only about 500 people have traveled to space, and few have traveled to space commercially. The vast majority were professional astronauts and cosmonauts on government missions. A small number of industrial researchers, a Japanese journalist, and a chemist from the United Kingdom (who won a contest to fly to Mir in 1991) have flown on a paid basis on U.S. (NASA) or Russian government flights. The last decade has seen the first leisure travelers to space. Since 2001, seven individuals have purchased eight orbital flights (one passenger flew twice) for approximately $20 to $35 million per flight.

Terrestrial options for space-related tourism include experiences that deliver key elements of the space experience, such as a view of the curvature of the Earth against the blackness of space or bursts of microgravity, using planes and balloons. About 6,000 people have flown on parabolic flights with the Zero-G Corporation (Zero-G) since 2004. It is estimated that over 40 MiG fighter jet "Edge of Space" flights occur annually. On the ground, the National Aerospace Training and Research (NASTAR) Center in Pennsylvania offers suborbital flight training and has trained over 115 future tourists. Table 6 summarizes terrestrial options that compete with spaceflight. (SRV flight and orbital flights are also included in the table for comparison.)

Space experiences compete with other types of high-end experiences. The "Top 10 Trips of a Lifetime" in the 2011 Virtuoso® "Travel Dreams" survey of affluent travelers identified a Virgin Galactic suborbital trip as one of the top 10 trips (See Figure 14).

Space experience options	Parabolic flight	High altitude balloon flight *(Proposed)*	High altitude jet flight	Suborbital flight *(Proposed)*	Orbital flight
Brief description	Flying on a passenger jet in a series of parabolic arcs to create brief periods of weightlessness	A balloon ride in a commercially built "gondola" to the upper reaches of the atmosphere	Flying with a pilot on a fighter jet to twice the altitude of a commercial airline flight	Flying on a commercially built suborbital spacecraft past the threshold of space	Launching into orbit for a multi-day stay aboard the International Space Station
Total flight duration	90 minutes	3 to 4 hours	45 minutes	2 hours	1 to 2 weeks
Weightlessness	30-second bursts for a total of 10 minutes	Brief periods of reduced gravity may be possible during descent	None	1 to 5 minutes	1 to 2 weeks
Required Training	1 hour briefing	1 hour briefing	Same-day training and medical checks	2 to 3 days of training and medical checks	3 to 6 months of training and medical checks
Passenger Capacity (per flight)	Up to 30 people	Up to 4 people	1 person	Up to 6 people	1 person
Price per person (not including transportation to launch site)	$5,200	$155,000	$25,000	$95,000 to $200,000	$50 million
Maximum altitude	34,000 feet (~6 miles)	118,000 feet (~22 miles)`	70,000 feet (~13 miles)	327,000 feet (~62 miles)	1 million feet (~200 miles)
View	Similar to the view from a commercial airliner	Curvature of the Earth, blackness of space, and thin blue layer of the atmosphere	Curvature of the Earth, blackness of space	Curvature of the Earth, blackness of space, and thin blue layer of the atmosphere	Orbit the entire Earth every 90 minutes

Table 6: Space-related tourism experiences (including SRVs)

Top 10 Trips of a Lifetime *(with illustrative costs added)*

1. Setting sail for a world cruise ($200K)
2. Sailing the Mediterranean on a private yacht ($750K/week for mega yacht rental for 12 passengers)
3. Calling on all seven continents ($100K)
4. Renting a European villa ($100K for a week in a castle on the French Riviera)
5. Visiting all seven New Wonders of the World ($350K)
6. Photographing the "big five" on African Safari ($30K)
7. Renting a private island ($120K)
8. **Blasting off on a Virgin Galactic flight ($200K)**
9. Chartering a private jet ($64K "Heaven and Earth" Smithsonian private jet expedition)
10. Dining through Paris' best restaurants ($10K)

Source: Virtuoso Life ® Magazine 2011 "Travel Dreams" survey http://www.virtuoso.com/thecompany/traveldreams2011/

Figure 14: Affluent travelers identified a suborbital flight as a trip of a lifetime

How SRVs Fit into the Market

Individuals

SRVs offer a combination of space experiences (weightlessness, view from space, and curvature of the Earth) combined with the rare opportunity to cross the threshold of space, at a price point significantly lower than commercially purchased orbital flights. SRV flights are expected to be more frequent and require less time and training than orbital flights.

Corporate

Corporate demand reflects the market potential of SRV flights as promotions for corporate customers or as a high-end incentive or reward. Suborbital flights may be attractive to firms by delivering an association with cutting-edge technology and cachet. SRV flights may not be appropriate as rewards or incentives if they are considered to be risky and are prohibited under corporate insurance coverage for senior executives, similar to activities such as skydiving or riding a motorcycle.

Executives of large companies often receive incentives comparably priced to a suborbital seat, including non-cash items such as personal training, private jet flights, and personal accounting assistance. However, the services in this cost range are generally related to increasing the productivity of the executive and the firm. More leisure-related incentives for high-performing employees, such as luxury vacations or high-end gifts, rarely reach prices comparable to suborbital seats.

There is some precedent for considering corporate rewards using SRVs: Zero-G regularly books parabolic flights to corporations rewarding employees. However, the price point is much lower than proposed suborbital ticket prices. The cost to charter an entire Zero-G flight (for up to 36 participants) is $165,000 or about $4,600 per employee.

Contests and promotions

SRV seats used for promotions or contests allow a third-party organization to associate its brand with spaceflight. These promotions can overlap with other space-related advertising and public relations activities. (Advertising and promotions related to public relations are covered in more detail in the Media and PR market.)

In-space personnel training

SRVs may be used to train personnel for orbital activities. SRVs potentially offer a longer duration of continuous microgravity than parabolic flights, frequent launches, and opportunities to train for challenging physical or medical situations.

Current SRV Activity

There are four passenger-capable SRVs in development (listed in Table 7).

Individuals

Companies offering services on these vehicles have booked a reported 925 reservations, with ticket prices ranging from $95,000 to $200,000. (The majority of announced reservations to date are for individuals, but do include some reservations for other applications such as research flights.) Confirmed ticket holders include celebrities and at least one family who purchased an entire flight for $1 million. According to recent announcements by Virgin Galactic, 35% to 40% of deposits originate from the United States, 15% from the UK, and 15% from the Asia-Pacific region. Active companies and announced reservation totals for flights are summarized in Table 7.

Company	System	Planned start	Reservations (as of June 2012)
Armadillo	Hyperion	2014	200
Blue Origin	New Shepard	TBD	Not revealed
Virgin Galactic	SpaceShipTwo	2013	550
XCOR	Lynx Mark II	2013	175
Total reservations			**925**

Table 7: SRV reservations to date

Corporate

Some current examples of corporate use of SRV flights as rewards include US Airways, KLM, and Virgin, which offer suborbital flights through frequent flyer programs. (Redemption on Virgin, for example, requires two million miles.)

Contests and promotions

At least 26 seats for suborbital flights have been given away through contests and promotions since 1998 (summarized in Table 8). This includes four seats on XCOR vehicles, one on Armadillo (through Space Adventures), nine through Space Adventures, two on Virgin Galactic, and two on Rocketplane. Zegrahm's Space Voyages gave away seven seats before being acquired by Space Adventures in 1999, and the Ansari X PRIZE gave away one seat as part of a 7UP® promotion in 2005 (vehicle unknown).

Responses to contests and promotions have varied. A 1998 promotion by Pepsi Japan/Pepsi Australia had 700,000 entries for 5 suborbital trip prizes. A 2005 Volvo promotion with Virgin Galactic during the Super Bowl resulted in 135,000 entries. Recently, the Seattle Space Needle Space Race 2012 gathered 50,000 entries.

There have been at least three attempts in the past to initiate spaceflight-related lotteries or raffles offering orbital and suborbital trips. Past spaceflight lottery attempts encountered difficulties, including legal constraints and what one past lottery organizer characterized as insufficient demand to cover the prize. A few new lotteries are in development and waiting for suborbital flights to begin regular operations.

In-space personnel training

Spacefaring nations maintain well-established terrestrial training facilities. Space agencies and several commercial orbital providers indicated in interviews that they consider existing terrestrial facilities sufficient for training requirements and that they do not include SRVs in their training plans. This may change as awareness of SRV capabilities increases, particularly as one commercial firm has announced plans to use SRVs for in-space personnel training. In June 2012, Excalibur Almaz, a company developing an orbital commercial human spaceflight vehicle, announced that it will train its crews on XCOR's SRV as a requirement for pre-mission training for its expeditions, which company announcements say will begin as early as 2015.

Title	Organization	Prize	Provider/ Broker	Year	Status	Contest Entry Details
Space Race 2012	Space Needle	1 seat	Armadillo	2012	1 winner from Tucson, Arizona	50,000 entered
Next Gen Suborbital Researchers Conference	SwRI	1 seat	XCOR	2012	1 winner from San Francisco, California	All conference participants entered into contest (~400)
DBA in Space	Red Gate	1 seat	Space Adventures	2011	1 winner from Canada; took cash option of $100K	5,500 entered
Launch of a Lifetime Sweepstakes	TripAlertz.com	2 seats	XCOR	2011	2 winners	Unknown
Guinness Experiences	Guinness	1 seat	Virgin Galactic	2009	1 winner from Florida	Unknown
Blast Off With Norton	Symantec	1 seat	Space Adventures	2009	1 winner from Chile	Unknown, global
"Break Ultime"	Nestle - France	1 seat	Rocketplane	2008	1 winner from France; receives €147,000 if not flown by deadline	Unknown
Vanishing Point	Microsoft & AMD	1 seat	Rocketplane	2007	1 winner from California	Unknown
Gillette	Gillette	1 seat	Space Adventures	2007	Unknown	Open only to Canadian citizens
Win a Trip to Space	New Scientist/ Audi	1 seat	XCOR	2007	1 winner from UK	2,400 entered
7UP	7UP	1 seat	Ansari X PRIZE (provider unknown)	2005	Unknown; winner receives $300,000 if not flown by deadline.	Unknown
Volvo	Volvo	1 seat	Virgin Galactic	2005	1 winner from Colorado	135,000 entered
Greatest Reward on Earth	FNB/eBucks (South Africa)	1 seat	Space Adventures	2005	Unknown	Open to individuals in South Africa
Space Ride Sweepstakes	Nidar	1 seat	Space Adventures	2005	Unknown	Unknown
Oracle Space Sweepstakes	Oracle	2 seats	Space Adventures	2004	1 winner from California (gave up seat because of tax burden); 1 winner from South Korea	Open to individuals in U.S., Canada, China, Singapore, Europe, Russia, South Africa, and UK
Volkswagen Brazil Sweepstakes	VW Brazil	1 seat	Space Adventures	2004	Unknown	Unknown
US Airways/ Space Adventures partnership	US Airways	1 seat	Space Adventures	2002	Unknown	Sweepstakes entry for each qualifying round-trip business flight on US Airways
Outer Space Trip Sweepstakes	Dole	1 seat	Zegrahm's Space Voyages	2000	1 winner from Midwest; selected alternate prize of $50,000	Unknown
2001 Space Tours	Pepsi Japan and Pepsi Australia	5 seats/ 1 seat	Zegrahm's Space Voyages	1998	Unknown	700,000 entered

Table 8: Summary of suborbital seats given away in contests and promotions

SRV Demand Forecast

The Tauri Group forecasted demand for each submarket based on the drivers of demand within each customer base. Methodology discussions by submarket are included in sidebars.

Individuals

Our assessment of overall demand for individuals includes estimates among two populations: high net worth individuals (those with net worth over $5 million), and space enthusiasts with lower levels of net worth. To gauge demand for suborbital travel among high net worth individuals, we conducted The Tauri Group 2012 Survey of High Net Worth Individuals. Analysis of the survey results reveals a relatively robust market of individuals willing to purchase suborbital flights. Results suggest there are enough customers willing to pay current prices (between $95,000 and $200,000) to constitute a sustained demand for suborbital flight.

Our analysis indicates that about 8,000 high net worth individuals from across the globe are sufficiently interested and have spending patterns likely to result in the purchase of a suborbital flight—one-third from the United States (based on global wealth distribution). The interested population will grow at the same rate as the high net worth population (about 2% annually). We estimate that about 40% of the likely to purchase high net worth population, or 3,600 individuals, will fly within the 10-year forecast period.

We expect space enthusiasts outside the high net worth population will generate demand for an additional 173 seats over 10 years. The resulting baseline forecast is 335 seats in the first year, growing to nearly 400 seats by year 10.

In the growth scenario, reflecting greater than anticipated interest in suborbital flight, 24,000 high net worth individuals are sufficiently interested and have spending patterns likely to result in purchase of a suborbital flight, with about 10,700 seeking to fly in the 10-year forecast time frame. Increasing demand is an additional 535 space enthusiasts likely to purchase flights. This results in just over 1,000 passengers in the base year and grows to over 1,200 by year 10. In the constrained scenario, reflecting reduced spending by consumers, there is still sustained demand around 200 seats per year throughout the 10-year forecast period.

Commercial Human Spaceflight Forecast Methodology: Individuals

To analyze the market for individuals, we estimated demand among high net worth individuals and demand among space enthusiasts with a lower net worth.

To estimate demand among high net worth individuals, The Tauri Group surveyed individuals with at least $5 million in investable assets to assess customer preferences. We received completed surveys from 226 individuals. Our intent was to survey a population with a level of wealth such that responses would be based on realistic purchasing dynamics. There is no definitive wealth threshold for this demographic; therefore, we identified the target of $5 million in investable assets. This was based on multiple sources of data that indicate, typically, individuals in the highest U.S. quintile spend about 4% of their incomes on leisure travel. (This puts a $95,000 suborbital ticket within a normal annual expenditure for individuals with about $2 million in income and higher). Additional data showed that high net worth individuals rarely spend more than 1% of their net worth on experiences.

All the respondents to the survey had a minimum of $5 million in investable assets. Thirty-eight percent of respondents had more than $10 million in investable assets. A summary of the survey respondents' net worth and investable assets can be found in Figure 15.

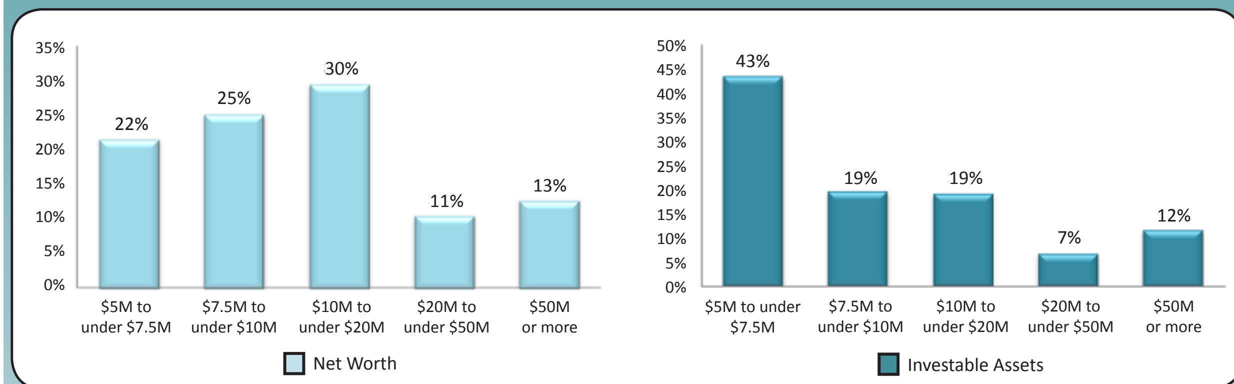


Figure 15: Net worth and investable assets of survey respondents

Our survey of high net worth individuals addressed interest in taking a suborbital flight and likelihood of purchasing a flight through a number of questions. Research suggests that individuals answer survey questions about hypothetical purchasing decisions differently than how they are actually likely to behave. (Different areas of the brain are used in making decisions than in answering questions about hypothetical decisions.) One method to overcome this problem is by asking questions multiple ways and interpreting intent based on the combination of answers to that set of responses. We asked multiple questions about purchasing SRVs throughout the survey to increase accuracy and provide enough data to determine individuals' consistent interest in taking a suborbital trip. The wealth threshold for survey respondents also addresses this concern. An individual who can realistically afford a flight will be more likely to have experience weighing purchasing decisions of a similar magnitude against alternative uses of those resources.

To assess whether the respondents were sufficiently interested in taking a suborbital flight, they had to offer the following four responses to survey questions:

- Extremely or very interested in taking a suborbital trip
- Likely to purchase a suborbital trip (alone or in addition to other spaceflight options)
- Willingness to pay $100,000 or more for a suborbital trip
- Ranked a suborbital trip highly compared to other options

Commercial Human Spaceflight Forecast Methodology: Individuals (continued)

Given that survey populations may overstate or understate spending in hypothetical purchase situations, we also asked respondents to answer the following open-ended questions related to past spending and imagined spending on a once-in-a-lifetime experience. We used responses to independently calculate likely spending patterns across the whole survey population and to serve as a predictor for likely purchases:

- How much can you imagine spending (per person) on a once in a lifetime trip? (Responses above $100,000 threshold)
- Most ever actually spent (per person) on a past trip or experience (Responses above $50,000 threshold in baseline)

We used the survey results to determine the likely percentage of the high net worth population interested in and likely to purchase a suborbital flight. Analysis of interest in taking a suborbital flight resulted in a probability of about 5%. The analysis of likelihood to spend an amount equivalent to current suborbital prices resulted in a probability of just under 5%. We multiplied these percentages to estimate the percentage of the population that is both sufficiently interested in suborbital experiences and likely to purchase flights.

We then applied the results to the global population with a net worth over $5 million, which is just over three million individuals in 2012, resulting in an estimate of about 8,000 people. The global population of individuals with a net worth of $5 million or more grows moderately over the forecast period at around 2% annually. (Note that our survey population was in the United States. Roughly one million of the world's three million individuals at this level of net worth live in the United States. We extrapolated our survey, which arguably predicts the behavior of U.S. citizens, to a world population. The world population may have a different interest level or purchasing dynamic than the U.S. population.)

To estimate how demand for seats would be spread over time, we assessed the average age of our survey population (about 55 years old) and assumed individuals make the decision to fly within 25 years, which would indicate flying before the age of 80 for the majority of the population. This results in about 40% of those interested and willing to pay for an SRV flight will fly over the 10-year forecast period.

The forecast is sensitive to this assumption about timing, which could vary significantly. If all individuals in the population today fly within the next 10 years, 10-year demand more than doubles. If individuals make this decision within a 50-year time frame, rather than a 25-year time frame, demand halves.

To estimate the space enthusiast portion of the market, The Tauri Group developed a percentage estimate keyed to high net worth demand; this estimate was based on an analogy to parabolic flight and other research and interview data. Roughly 4,500 individuals have flown on Zero-G flights at a per-person price around $5,000, for a total of $22,500,000 over nine years, or a rough average of $2,500,000 per year. (Some individuals were NASA-funded researchers, and about 1,400 educators have flown through grant programs.) If consumers spent as much on SRV flights as they have on Zero-G flights, and all those consumers fell into the lower net worth space enthusiast category, that would result in about 20 SRV seats per year. Another source of data we considered was poll responses from space educators and researchers, about their interest in purchasing an SRV flight, willingness to pay current prices, indications of ability to pay for a flight even as a financial stretch, and willingness to find financing for a flight. That data suggested interest but limited ability to purchase a ticket. Based on these assessments and interviews, we set the space enthusiast population at 5% of the wealthy population in each scenario.

The Tauri Group analyzed the averages of survey respondents' past spending on leisure trips or experiences against the averages of the most they could imagine spending on a once-in-a-lifetime trip. Figure 16 presents a comparison by age of these responses. Across all age groups, people could imagine spending significantly more than they had actually spent in the past. The disparity could point to an overstatement of willingness to pay in a future situation and helped inform our analysis and methodology for the baseline forecast.

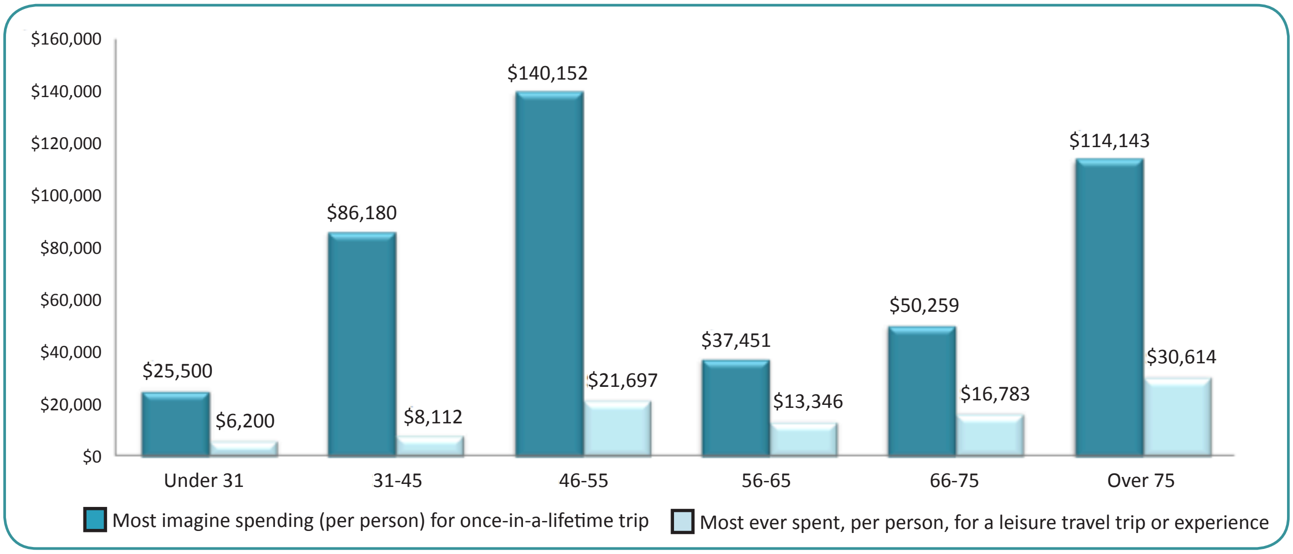


Figure 16: Across all age groups, respondents could imagine spending more than they have in the past. This could point to an overstatement of willingness to pay in a future situation.

In addition to SRV demand from high net worth individuals, some individuals with lower net worth will spend a large proportion of their assets to purchase an SRV flight or will even finance one. Little reliable data is available to predict the purchasing behavior of this population of space enthusiasts. Interviews with SRV providers indicated that among individuals who had already reserved seats on SRVs, there were some who fit in this space enthusiast category, but no financial demographic data is specifically available about ticketholders. Previous market surveys pointed to interest and stated intent to purchase among populations of net worth of $1 million and less, but predicting behavior from this data is difficult because of the problem associated with hypothetical responses and the lack of information about survey structure and interpretation.

Several, SRV providers feel that more individuals outside the $5 million population, than we predict, will seek to fly at current prices. On the other hand, interviews with travel organizations indicated that a wealthier population (above $5 million) might be the most reliable source of demand. One accredited space agent for Virgin Galactic indicated that having $10 million or more in dividend-yielding assets might be "the sweet spot," while another organization indicated that being able to take a trip twice was a good affordability indicator.

Our estimate shows about 173 space enthusiasts generating demand over 10 years, with 535 in the growth scenario and 94 in the constrained scenario.

Growth and Constrained Scenarios

In the growth scenario for Commercial Human Spaceflight, potential customers' interest in suborbital flight, growing as a result of factors like increased marketing, publicity surrounding the start of human flights, and positive flight experiences, is sufficient to encourage people to spend more dramatically than they have on previous experiences. With regard to our methodology for individual purchases, we relaxed our requirements on previous spending patterns, removing the threshold of having spent $50,000 or more on a previous leisure trip or experience, but keeping the "could imagine spending" threshold of $100,000 or more on a once-in-a-lifetime experience.

In the constrained scenario, the demand for Commercial Human Spaceflight is reduced by a worsening global economy. This scenario assumes potential customers will not significantly vary from their past spending patterns on leisure trips, even when the trip is a novelty once-in-lifetime experience like suborbital flight. This was reflected in an increase in the requirement on most previously spent on a leisure trip or experience to $100,000 (up from $50,000 in the baseline).

Corporate

We predict occasional corporate purchases as employee incentives or customer rewards, at the rate of one seat per year. Perceived risks of flying valued employees to space combined with an increased focus on reducing expenditures considered extravagant limits the viability of corporate sales within the forecast period. The growth scenario projects these purchases to happen more frequently at the rate of two per year; the constrained scenario remains unchanged.

Commercial Human Spaceflight Forecast Methodology: Corporate

To estimate corporate sales, The Tauri Group interviewed employee incentive providers and researched executive compensation and customer rewards programs. The incentive providers indicated that it was highly unusual for companies to spend $100,000 to $200,000 (i.e., current suborbital ticket prices) on a single employee. Further research revealed that although interest may be present, it might be difficult to justify the expense in the current environment of corporate austerity. There may also be an adverse perception of putting highly valued employees in a potentially risky activity.

With regard to customer rewards, multiple airlines have offered suborbital flights as part of frequent flyer programs in the past, but no redemptions of such awards have been announced. Amassing two million miles on Virgin Atlantic flights can get customers a Virgin Galactic ticket. KLM and US Airways have announced partnerships with suborbital providers, but suborbital flights do not currently appear on frequent flyer mile redemption pages.

Interview data indicated that corporate purchasers of seats for employee incentives were not likely to be early adopters of suborbital services. Given that corporate purchases and redemption of customer rewards will likely be occasional and opportunistic, we estimated 1 seat per year in the baseline and 2 seats per year in the growth scenario to reflect those enterprises that may seek the associated cachet of rewarding their employees or customers with a suborbital ride.

Contests and promotions

Contests and promotions will continue to generate on average two seats per year, in our estimate. There will be increased interest to offer seats through promotions in the first year of suborbital service, doubling activity to four seats, before returning to approximately two seats per year steady state. The growth scenario sees a higher introduction year at six seats. The constrained scenario has fewer seats purchased for contests and promotions, reflecting a tighter global economy, with three seats in the initial year followed by a steady state of one seat per year.

In-space personnel training

Currently, no space agencies have announced plans to use SRVs for astronaut training. During the forecast period, we predict that most space agencies will continue training with existing ground-based facilities and airborne assets. (A few interviewees predicted that NASA would change its plans and purchase SRV flights for astronaut training once operations begin, but the majority felt that NASA would continue with its current training programs.)

Most commercial launch firms have not included SRVs in their training plans, but one commercial space firm has announced plans to conduct commercial astronaut training on XCOR's SRVs. Excalibur Almaz is developing a lunar transport system by purchasing and refurbishing four Soviet-era crew capsules and two "space stations." A June 2012 press release from Excalibur Almaz indicated that training flights for lunar trips could start as early as 2015 and that up to three passengers per year could travel to the Moon at a cost of $150 million per seat. As part of the astronaut training for these lunar trips, each Moon passenger will fly on an XCOR suborbital flight.

In-space personnel training will generate on average three seats per year in both the baseline and growth scenarios. The main difference between the two scenarios focuses on the start of service for lunar missions. In the baseline scenario, we assumed the training for lunar tourism services begins within three years of initial SRV regular operations. The growth scenario sees introduction of lunar service in the same year as the introduction of suborbital service. The constrained scenario assumes that regular lunar service does not come to fruition and therefore no seats appear in the constrained forecast.

Commercial Human Spaceflight Forecast Methodology: Contests and Promotions

To build a demand estimate for contests, The Tauri Group interviewed past and current space travel lottery providers combined with additional research on the legal barriers related to conducting lotteries. Interviews with past space travel lottery organizers indicated that lotteries were not sustainable due to legal constraints (in many countries, but especially in the U.S.) and lack of demand for space travel lottery tickets. However, one current space travel lottery provider believes that interest in purchasing suborbital lottery tickets will increase once actual suborbital service commences.

To estimate the demand for suborbital seats that will be purchased to be given away in contests and promotions, The Tauri Group interviewed individuals involved with past promotions and collected additional research on suborbital seats given away as part of contests and promotions since 1998 to analyze historical trends that could be applied to future demand.

We used the historical average of suborbital seats (about two per year) that have been awarded through contests and promotions to forecast typical contest- and promotion-related demand in the future. To reflect increased interest at the beginning of flight operations, we estimate an increase in the first year of suborbital service to four seats in the baseline and six seats in the growth scenario (based on the highest number of seats given away in a single year).

Commercial Human Spaceflight Forecast Methodology: In-space personnel training

To build a demand estimate for in-space personnel training, The Tauri Group interviewed former astronauts, current suborbital providers, and individuals from other space-related organizations to determine the need for suborbital flights as a training ground for space experiences. Many interviewees noted the existence of a significant number of currently under-used facilities and assets that meet training needs. The Tauri Group also collected additional data on terrestrial space-related training facilities worldwide as well as information on NASA's astronaut training needs.

To estimate the demand for training for commercial orbital providers, we researched current announcements and modified service start dates in each scenario to reflect either on-time service start or delayed service start given typical industry practices for procuring launch vehicles.

Estimate of 10-Year Demand

Our analysis of individuals projects demand for 3,600 seats over the 10 years of the baseline forecast, with more than 95% of the purchases made by high net worth individuals from across the globe. The remaining 5% reflects space enthusiasts outside the high net worth threshold who will spend an atypical proportion of their assets (compared to other leisure or travel expenditures) or go into debt to purchase a seat.

The forecast for corporate sales includes one seat per year, resulting in a total of 10 seats over the baseline forecast.

Contests and promotions will continue to generate about two seats per year with an increase to four seats in the first year of operations reflecting increased interest. The total number of contest and promotions seats for the baseline forecast is 22.

The forecast for in-space personnel training includes 3 seats per year for lunar flights for a total of 24 seats over the baseline forecast period, based on the current plans of space agencies and likely timing of service introduction by commercial orbital providers. The growth scenario reflects 30 seats over the forecast period, assuming lunar operations begin the same time as suborbital.

In the growth scenario, the total number of seats, purchased across all Commercial Human Spaceflight submarkets over the 10-year forecast period, increases to over 11,300. In the constrained scenario, the number of seats purchased across all submarkets totals just over 2,000.

Figure 17, Figure 18, and Table 9 summarize the forecasts for the Commercial Human Spaceflight market.

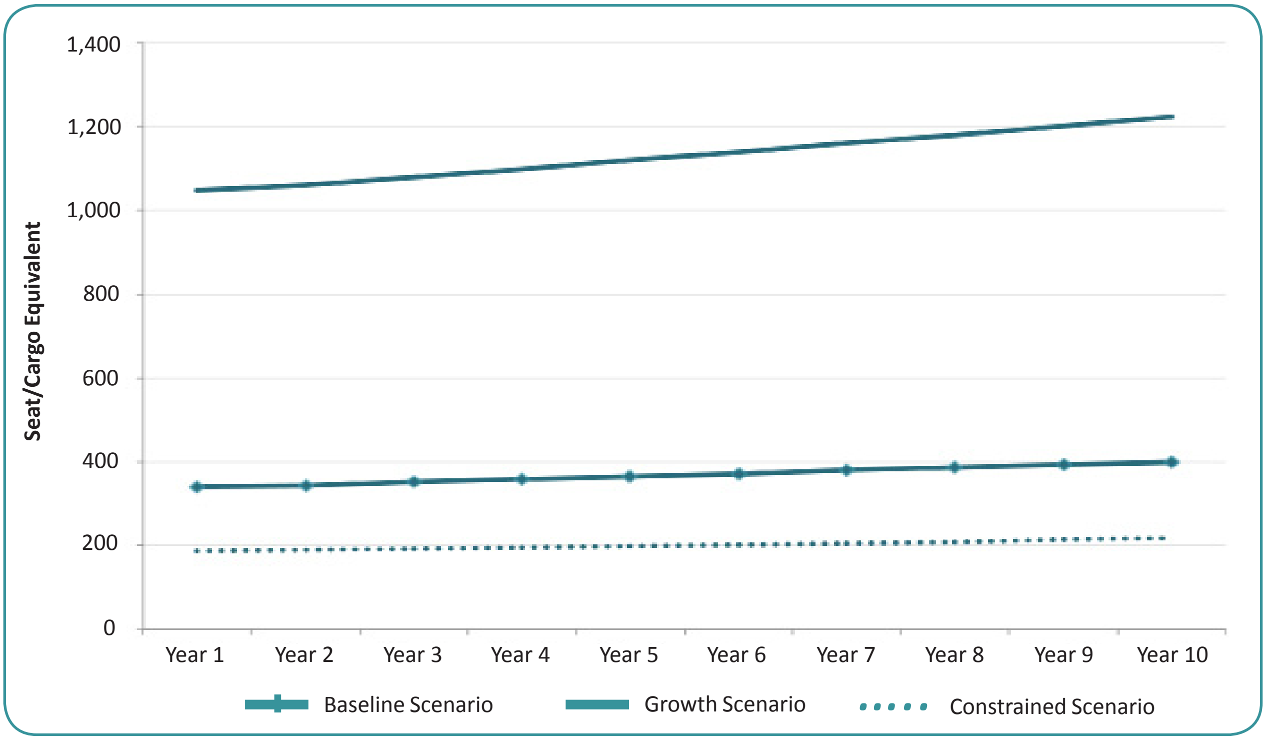


Figure 17: Baseline, Constrained, and Growth scenarios for Commercial Human Spaceflight

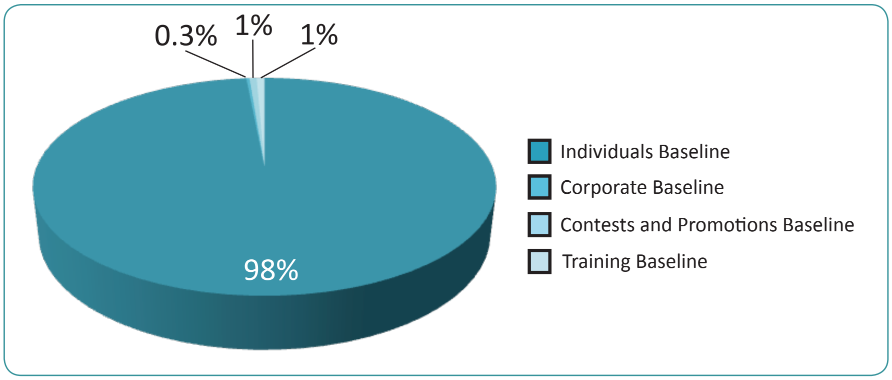


Figure 18: Commercial Human Spaceflight Baseline Submarket Share

Commercial Human Spaceflight	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	340	344	353	359	366	372	379	385	392	399
Growth Scenario	1,046	1,060	1,079	1,099	1,118	1,138	1,159	1,179	1,200	1,222
Constrained Scenario	187	188	191	195	198	202	205	209	213	216

Table 9: Commercial Human Spaceflight forecast in seat/cargo equivalents

Uncertainty

Demand for Commercial Human Spaceflight is presented here as relatively steady state in each scenario, reflecting current level of interest in the population, assuming individuals are equally likely to choose to fly in any given year within the 10-year time frame.

This convention is useful because of the uncertainty associated with the dynamics of demand as it responds to future events. It is not to suggest that demand will always be steady state; demand may evolve in different, unpredictable ways. For example, demand may shift from the baseline level to the growth level after flight operations have begun. Demand may grow, as we have noted previously, more rapidly than predicted based on viral or "me too" effects, as a function of the social dynamics following successful launch experiences. Demand could decline for similar reasons. Figure 19 shows illustrative demand growth patterns that could emerge for Commercial Human Spaceflight.

In addition, flight activity does not directly map to demand. In early operations, there will be insufficient flight opportunities to meet demand.

Our forecast assumes individual Commercial Human Spaceflight passengers fly once only, that only 40% of interested passengers today will fly within the next 10 years, and that most (95%) passengers have net assets exceeding $5 million. Relaxing any of these assumptions increases demand significantly. For example, if 80% of interested passengers fly in the next 10 years, the forecast doubles. If passengers with a net worth of $1 million rather than $5 million are commonplace, the addressable market increases dramatically.

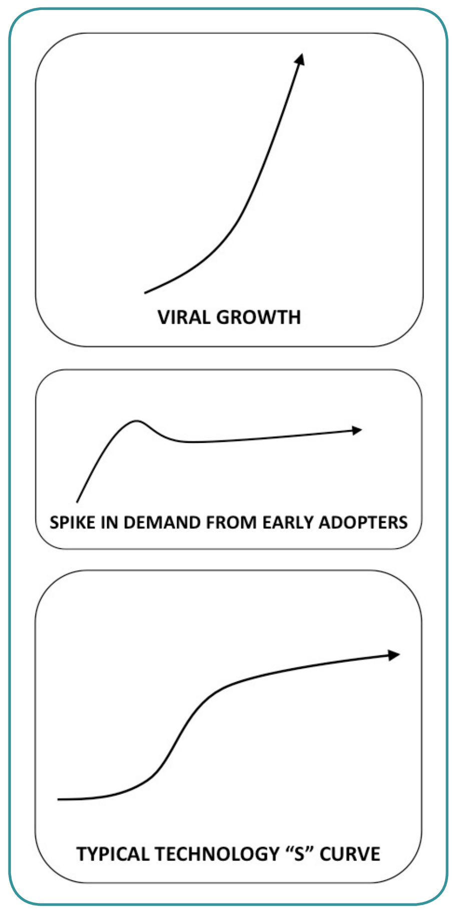


Figure 19: Possible trends over time -- individual demand for Commercial Human Spaceflight

It is unclear exactly how the number of current ticketholders relates to future trends. The approximately 925 tickets sold to date have been purchased before any flights, with limited advertising. Future purchases may be higher. On the other hand, some tickets are refundable, and some are held with deposits rather than full payment. This may create the possibility that some ticketholders may change their minds.

Our survey data suggests that about 7% of passengers care about flying early. (We asked if survey respondents would wish to be among the first 1,000 people to fly). In our baseline, that would create about 600 early adopters; in our growth scenario, about 1,700.

If all reservation holders fly, and ticket purchases in the future are at the same level, demand will fall between our baseline and growth scenarios.

This forecast assesses attitudes and behavior related to an experience that does not yet exist. The flight experience and other factors once operations start (awareness, marketing, perceptions of safety, and media coverage) will shape attitudes and behavior. Widespread enthusiasm for SRV flights could increase demand. Poor perceptions could dramatically reduce demand.

Demand from space enthusiasts who are willing to allocate a large portion of their resources for this experience is highly uncertain. We expect there will be individuals who value the experience enough to significantly change their spending behavior to afford the trip. However, predicting such changes in behavior is inherently uncertain.

The forecast projects demand from the global population with more than $5 million wealth based on a survey of U.S. ultra-high net worth individuals. Consequently, it includes citizens from nations that may not fly in the United States due to political concerns. For example, individuals from China represent about 6% of total demand in our forecast. In addition, differing purchasing behavior in other countries and cultures and regulatory requirements could play a factor in how the market develops. We have extrapolated international consumer behavior from a survey of U.S. consumers. This results in a distribution that is roughly consistent with what little has been published about ticketholder demographics—about one-third of our forecast population and one-third of Virgin Galactic ticket holders are from the United States However, it remains an uncertainty.

The forecast used current prices for forecast scenarios; if the prices for flights decrease, demand increases significantly among high net worth individuals, as indicated in Figure 20. (An increase in price would not have as large an impact.) Additional demand (not reflected in the demand curve in Figure 20) would result among individuals with a lower net worth if prices dropped.

Finally, uncertainty about timing of service debut may affect demand for suborbital flights. Providers have been careful to communicate that artificial deadlines in development compromise safety, but many have also consistently understated the amount of time it would take to develop these vehicles.

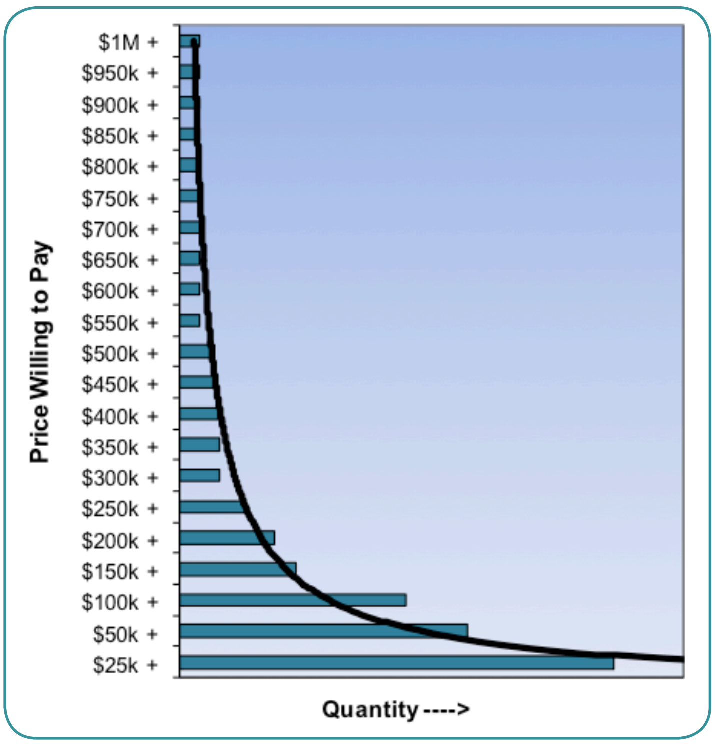


Figure 20: Price elasticity of suborbital tickets for individuals with $5M in investable assets

Lack of Awareness

Many survey respondents were not aware of SRV providers. This is likely to change as flight operations approach and companies increase marketing activities.

Few in the current space industry, either in government or commercial launch providers, were aware of SRV capabilities as an adjunct to terrestrial training for orbital activities.

Basic and Applied Research

SRVs can be used to conduct basic and applied research in a number of disciplines, leveraging the unique properties of, and access to, the space environment and microgravity.

SRVs can support many types of space-related research, generally grouped into four disciplines: space science, biological and physical research, Earth science, and human research. The SRV capabilities that are most useful for research are: access to the space environment (mainly for space science), access to microgravity (mainly for biological and physical research), transit through the upper atmosphere (mainly for Earth science), and access to diverse human populations undergoing phenomena such as rapid acceleration and deceleration (mainly for human research).

Market Dynamics

Space-related research can be broadly grouped into four disciplines, detailed in Figure 21.

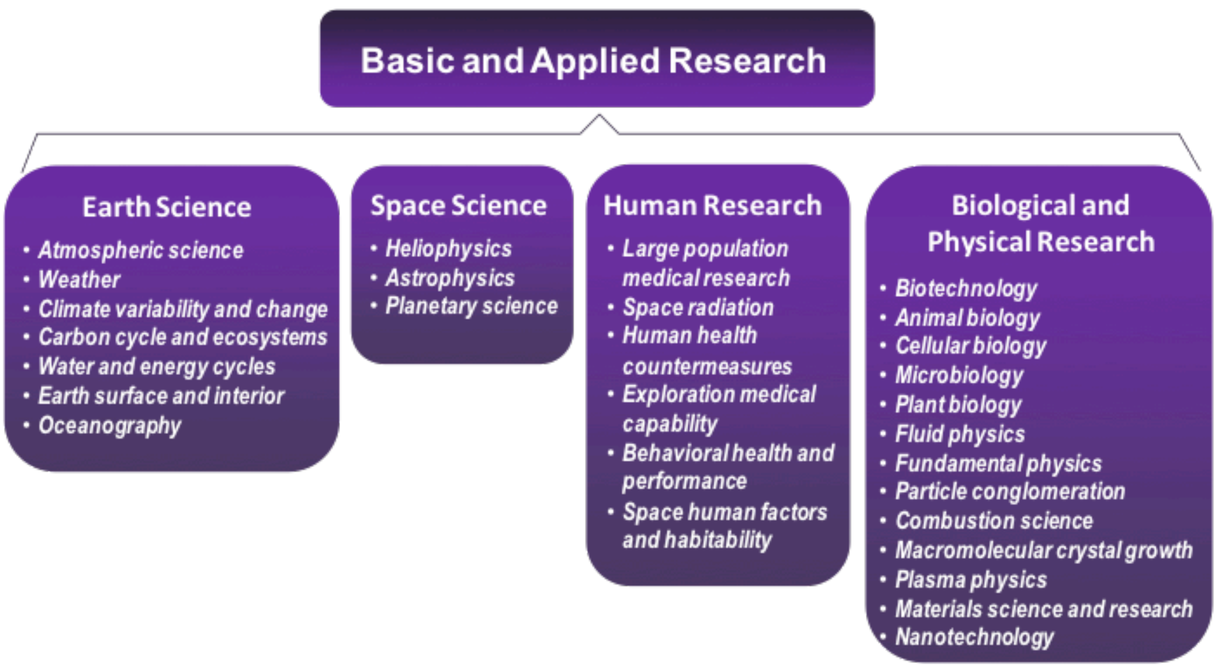


Figure 21: Basic and Applied Research disciplines

Most space-related research is currently conducted on orbital platforms, such as the International Space Station (ISS); high-altitude balloons; sounding rockets; drop towers; other terrestrial alternatives; and emerging commercial orbital vehicles.

Much, though not all, space-related research could also be conducted on SRVs, but a thorough review of space-related research application identified four specific research applications best match unique SRV capabilities and support a wide range of experiments:

- Atmospheric research – SRVs will allow researchers regular access to poorly understood upper reaches of the atmosphere to understand the dynamics that drive Earth's weather and climate.

- Suborbital astronomy – SRVs will allow researchers to conduct high-quality infrared (IR) and ultraviolet (UV) observations outside the atmosphere.
- Longitudinal human research – SRVs will enable studies of a diverse and large population of space travelers on frequent flights to understand the effects of microgravity and acceleration on the human body.
- Microgravity research – SRVs will offer a unique combination of attributes, including meaningful duration in high-quality microgravity, human tending, and lower cost.

For atmospheric research, suborbital astronomy, and longitudinal human research, SRVs provide unique capabilities that are better than existing platforms and enable specific research activities that cannot be conducted using (or that perform poorly on) current platforms. For microgravity research, SRVs provide a unique combination of capabilities with the potential to energize the research community and enable new research by attracting new organizations to microgravity research.

Government agencies are the primary funders of space-related basic and applied research, with active investments from multiple U.S. government agencies and international governments. Universities and non-profits also fund and participate in space-related research. See Table 10 for an overview of U.S. federal agencies and other organizations currently funding research that could be performed on SRVs. Each organization's research is mapped to the four SRV research applications identified above.

Build It and They Will Build It

SRVs are novel platforms that the research community is only beginning to incorporate into future plans. Initial experiments will include some terrestrial or orbital experiments only slightly modified for SRV applications. The future of the basic and applied research market will be driven by the success of new and innovative SRV-tailored experiments. Researchers will need to gain experience in SRV capabilities and invent new experiments that leverage SRVs as core research platforms.

Figure 22: Future SRV experiments have to be devised by researchers before demand can fully manifest

How SRVs Fit into the Market

SRVs are advantageous for research projects that cannot be conducted on other platforms or are better suited for SRVs, and for projects that can be conducted at a much lower cost on SRVs. In many cases, these research projects are in areas of active research, that currently funded (and using terrestrial analogs and orbital spacecraft). SRV capabilities are mapped to research areas in Table 11.

Atmospheric Research

SRV flight profiles provide an opportunity to measure the upper regions of the atmosphere (mesosphere and lower thermosphere), which are so difficult to study they are colloquially called the "ignorosphere." Unlike aircraft and balloons, the primary platforms for atmospheric research, SRVs offer capabilities to study the upper atmosphere. SRVs can also be used to measure the troposphere and stratosphere, which balloons and aircrafts are currently used to study. Sounding rockets can also be used to study the upper atmosphere, but at a high cost. Supported by demand from other markets, SRVs plan to fly far more frequently than sounding rockets. Inexpensive, integrated sensors on frequent SRV flights provide an opportunity to probe upper atmosphere dynamics and test weather and climate models. Given the flexibility of flight profiles and possibility for some diversity of launch locations (given multiple planned SRV spaceports), trajectories can be tailored to visit regions of interest within the range of proposed systems. Atmospheric sampling above 50 kilometers is a particular area of interest to the National Oceanic and Atmospheric Administration (NOAA) because of its mission to publically provide climate and weather data.

Organization	Microgravity Research	Atmospheric Science	Suborbital Astronomy	Human Research
NASA	☑	☑	☑	☑
	NASA funds research primarily through its Science Mission Directorate. Human and microgravity research is conducted through ISS research programs or terrestrial analogs. Atmospheric and astronomy research is conducted through the Earth, Heliophysics, Astrophysics, and Planetary Science divisions.			
National Science Foundation (NSF)	☑	☑	☑	
	NSF supports several relevant grants per year for applicable research projects. Currently, these primarily include data analysis and modeling for UV and IR astronomy conducted on orbital telescopes. NSF also supports terrestrial observatories.			
NOAA		☑		
	NOAA funds atmospheric research through the Office of Oceanic and Atmospheric Research, with about $50 million of a total $430 million annual budget supporting similar research activities on balloons and aircraft.			
National Institutes of Health (NIH)				☑
	NIH supports several related research grants to understand human biochemistry aligned with SRV capabilities (research investigating transitional responses to acceleration, currently using less well suited platforms including tilt tables, best rest, and animal studies).			
Department of Defense (DoD)		☑		
	DoD conducts atmospheric and space research, using military aircraft, evolved expendable launch vehicles (EELVs), missiles, and DoD-procured sounding rockets.			
Non-profits	☑	☑	☑	☑
	A small number of non-profits provide funding for basic and applied research applicable to SRVs. Southwest Research Institute, which has purchased several tended flights, is the most prominent example.			
Universities	☑	☑	☑	☑
	Government research funding for basic and applied research in these areas primarily flows to universities and university-affiliated laboratories. Universities often have a relatively small budget from non-federal sources that augments government research funding. Universities currently conduct basic and applied research using sounding rockets, terrestrial facilities, and orbital facilities. Since 2006, 58 universities have launched a sounding rocket payload: 21 in the United States, 23 in Europe, and 14 elsewhere.			
International	☑	☑	☑	☑
	Europe supports relevant research across all these areas, using the ISS, parabolic flights, and sounding rockets. The European Space Agency (ESA) sponsors experiments on 30 parabolic flights and about 4-5 sounding rockets per year, with the largest number of projects studying physics, especially microgravity experiments. Additional relevant research is conducted by agencies in Russia, China, Japan, India, and other nations.			

Table 10: Major funders/customers of Basic and Applied Research mapped to the four research applications well suited to SRVs

There are significant technical challenges to conducting atmospheric research on SRVs. Air samples during the ascent or descent phase are heated by the vehicle's transit, destroying some chemical species of interest. Further, most of the species of interest are in low concentrations, in the range of parts per millions or billions, and the length of time an SRV spends in an atmospheric layer may be too small to collect a large enough sample. Other types of atmospheric research such as measuring wind speeds and temperature profiles have similar technical challenges. New instruments and sampling techniques, some of which have already been proposed, will need to be developed to enable atmospheric research with SRVs.

SRV Research Applications	Relevant Research Areas	Key SRV Capabilities
Atmospheric Research	Atmospheric science, including weather and climate research	Travel through upper atmosphere
Suborbital Astronomy	Heliophysics, astrophysics, planetary science	Access to UV and IR spectrums that are scientifically useful and do not penetrate the atmosphere
Longitudinal Human Research	Physiological and psychological response to gravity transitions (acceleration and weightlessness)	Large sample pool, repetitive access to pilots; may also include limited single experiments
Microgravity Research	Broad range of research areas with common requirements for microgravity exposure. Examples include combustion, crystallization experiments of particles in a charged plasma, and interfacial fluid dynamics	1 to 5 minutes of microgravity

Table 11: Mapping of SRV Research Applications to SRV capabilities

Suborbital Astronomy

The ability of SRVs to travel above most of the Earth's atmosphere provides an opportunity for high-quality astronomical observations that can now be conducted only with orbital telescopes. SRV flights reach altitudes that provide access to ultraviolet (UV) and infrared (IR) spectra, which contain useful astronomical information. These spectra do not penetrate the atmosphere, so they cannot be viewed by ground-based telescopes. These spectra can be viewed by orbital observatories, but most orbiting telescopes have long waiting lists, making them less suited for quick response applications, like flybys of a newly discovered near-Earth object. Relatively low-cost SRV flights also provide an opportunity for launching inexpensive telescope payloads that may observe phenomena too risky for billion-dollar orbital telescopes, such as sun-grazing comet observations that could damage telescope optics.

Astronomy applications for SRVs will require interfaces for telescopes and a port or a hatch to open to the space environment. These are included in the baseline designs for some SRVs in development. Proposed SRV telescopes operate with human control, but automated systems could be developed in the near future.

There are challenging technical constraints to astronomical observations aboard an SRV. After exiting the atmosphere, suborbital astronomy requires both the vehicle and the telescope to quickly acquire the desired field of view, then actively and precisely control attitude to maximize observation time. Astronomical observations require precise pointing, trajectory, and timing, which will effectively require procurement of a dedicated flight, regardless of the telescope payload mass.

Other astronomical observing platforms, such as balloon telescope systems and airplane-mounted systems like the Stratospheric Observatory for Infrared Astronomy (SOFIA) (a joint NASA-German Aerospace Center (DLR) IR observatory), provide some access to UV and IR spectra but do not provide the same quality of observations as orbital and suborbital systems. These systems are funded by the same agencies that are likely to fund suborbital astronomy and may compete for available research resources.

Human Longitudinal Research

Researchers can leverage SRVs to understand the physiological responses to microgravity and acceleration transitions that occur over a few seconds or minutes, such as mechanical responses in the vascular system, cell structure, and chemical changes in immune pathways. These responses are poorly understood and occur on timescales that align with SRV flight duration. There may also be research activities designed to investigate pharmaceuticals or techniques that minimize the discomforts some passengers may experience on suborbital flight.

Conducting human research on SRVs has few technical challenges, but there are potential non-technical challenges. The extent to which suborbital passengers will wish to participate in research has yet to be determined. There are indications that at least some future SRV passengers are willing to participate in research. Small unobtrusive monitors to collect research data could help increase the number of volunteers. NASA has developed an unobtrusive medical harness for astronauts, and medical device manufacturers are refining monitoring technologies for terrestrial applications. Regulations regarding medical privacy and experiments on humans will apply to SRV research and could limit research activities.

Microgravity Research

SRVs are well suited to some niche applications for microgravity research. These include experiments that can use the one- to five-minute microgravity window and cannot be modeled with computer simulation, do not have adequate terrestrial research alternatives, or require human tending. SRVs can be useful for gaining insight into physical and biological phenomenon by removing gravity from the system. Experiments for suborbital microgravity can be designed for soft condensed matter, combustion, crystallization experiments of particles in a charged plasma, interfacial fluid dynamics, and other research areas. SRVs also provide frequent research opportunities at a lower cost and more accessibility than most orbital systems, albeit for a shorter microgravity duration.

One challenge to conducting microgravity research on SRVs is designing experiments that can effectively use one to five minutes of microgravity and cannot be effectively scaled for much shorter periods of microgravity in drop towers and parabolic flights. Another consideration for microgravity research on SRVs is ensuring a high-quality microgravity environment, which may require mitigating the effects of having passengers or other equipment aboard the SRV.

Current SRV Activity

NASA, non-profits, and universities are engaged in early stage research and development activities designed to encourage the initiation of the SRV research market. NASA anticipates using SRVs as a research platform to supplement current platforms, including sounding rockets, balloons, and aircraft. NASA's suborbital research program is planning to include SRVs as a platform for proposed research in upcoming Announcements of Opportunity. Experiments for SRVs will be peer reviewed and be included in the Office's portfolio of research.

Specialized non-profits like the Southwest Research Institute (SwRI) and the Planetary Science Institute are providing funding and playing a key role in developing near-term SRV research. SwRI supports suborbital research through internal research and development funds and has purchased eight seats from XCOR and Virgin Galactic for a range of biomedical, microgravity, and astronomy imaging experiments. The Planetary Science Institute is funding initial development of a joint project with The Citadel, The Military College of South Carolina, to launch a telescope on the XCOR Lynx. SwRI also jointly sponsors the annual Next Generation Suborbital Researchers Conference. In 2012, the third annual conference was attended by over 400 people, many of whom are researchers interested in using these vehicles.

Several SRV providers have connected with universities to begin exploring SRV capabilities for conducting university research. Masten and Blue Origin have allowed universities to launch research payloads on test flights of their vehicles. Purdue University, University of Central Florida, and Louisiana State University have conducted experiments in these initial tests. At least some of these flights were provided with no exchange of funds.

Basic and Applied Research Forecast Methodology

To assess interest in SRVs and predict future budgets for organizations conducting SRV-relevant research (NASA, NSF, NIH, NOAA, non-profits, universities, international entities, and DoD), The Tauri Group analyzed information from interviews and publications using three general methodologies: grant analysis, reviews of announced plans, and programmatic or budgetary analysis.

- Grant analysis: Analyzed current and past grants in research areas aligned with SRV capabilities (such as UV astronomy) and estimated future potential to fund similar research on SRVs. Total funding was assumed to grow at historical rates for related research, 1 to 4% annually depending on research area.
- Announced plans: Assumed all announced plans for SRV research (for example, SwRI research flight purchases) are fully funded; these plans were integrated into the forecast.
- Programmatic analysis: Identified likely funding sources and amounts by analyzing research goals and related activities of various organizations and funding associated with those goals. Funding is assumed to be low in initial years, consistent with proof of concept tests. Assumptions on future growth are based on successful demonstrations of research results.

Table 12 shows how these methodologies were applied to forecast demand for SRV flights within different domestic research agencies.

To forecast research activities outside the U.S., The Tauri Group identified about 50 nations likely to be interested in purchasing some SRV flights to support basic and applied research. Allocation of expenditure to SRV research is estimated by comparing aggregate research funding to U.S. funding, across all sectors and research areas. A proportional value for SRV research is estimated and applied to those countries likely to be interested in purchasing SRV flights. We conducted several interviews with international space research organizations that indicated there would likely be a "wait and see" strategy, which would likely take 5 to 6 years before wide adoption of SRVs as a research option. This time phasing is included in the baseline forecast.

Finally, the forecast reflects the cyclical nature of research programs. Government budget cycles, peer review cycles, research cycles, and publishing cycles are sequential activities, which typically range from two to five years and result in waves of adoption for SRV research. This forecast is built around three such waves: an initial three-year wave, a second three-year wave, and a four-year wave at the end of the forecast period. We analyzed programs individually and assigned activity to the first, second, or third wave based on current and future interests and budgets.

We applied this methodology to each of the four SRV research application areas that align with SRV capabilities.

Organization	Microgravity Research	Human Research	Suborbital Astronomy	Atmospheric Science
NASA	Announced plans (minimal activity)	Programmatic analysis	Announced plans, programmatic analysis (far term)	Announced plans, programmatic analysis (far term)
NSF	Grant analysis	Not applicable	Grant analysis, programmatic analysis (far term)	Programmatic analysis
NOAA	Not applicable	Not applicable	Not applicable	Announced plans, programmatic analysis (far term)
NIH	Not applicable	Grant analysis	Not applicable	Not applicable
Not for profit	Announced plans - SwRI	Programmatic analysis - NSBRI Announced plans - SwRI	Announced plans - SwRI, PSI	Not applicable
University	Announced plans, programmatic analysis	None	Announced plans, programmatic analysis	Announced plans, programmatic analysis

Table 12: Customization of Basic and Applied Research forecast methodology

SRV Demand Forecast

A mix of government agencies, universities, and non-profits, domestically and abroad, will support Basic and Applied Research on SRVs.

Suborbital Astronomy

Our forecast predicts that suborbital astronomy using SRVs will capture and grow NSF's UV and IR grant spending from current levels of $1 million to about $5 million in the last year of the forecast (about one-third of that will be spent on flights, with the remaining two-thirds on experiment hardware). This reflects NSF's current grants for UV and IR research (about $1 million per year) and interviews that suggest the demand for suborbital astronomy will grow, increasing to about 6% of the NSF astronomy research budget, or about $5 million, by the end of the forecast. NASA's funding for research relevant to suborbital astronomy derives from current efforts in its suborbital researchers program and NASA's Heliophysics, Planetary Science, and Astrophysics research divisions. As new projects start, funding will likely transition slowly from sounding rocket launches to SRVs (about one-third of relevant sounding rocket budgets) in the first few years of SRV operations. Funding will then hold fairly steady at about 1% of these research areas (about $4 million per year in year 10). We predict international demand will accelerate late in the forecast, reaching about 10% of domestic demand, and has potential to grow beyond the forecast time period as astronomy organizations outside the United States accept SRVs as a primary research platform.

In the growth scenario, a new joint NSF/NASA astronomy campaign with a budget of $21 million (with one-third spent on flights) is introduced by the last year of the forecast.

Atmospheric Research

Our forecast predicts demand for SRV atmospheric research will be driven by NOAA's interest in sampling data on daily, weekly, monthly, and yearly timescales. We project NOAA funding to use instruments integrated on SRV flights. We also anticipate NASA efforts to develop new instruments and augment satellite observations. NOAA currently spends about $50 million per year on balloon and aircraft atmospheric research and given sufficient time and demonstration of SRV capability, would consider SRVs as a third key platform. Interviews suggest that NOAA adoption will be slow. By the end of the forecast period, we project 5% of the research budget spent on aircraft and balloon experiments will be directed to SRVs, totaling $3 million in the last year of the forecast. We project NASA research will transition from an active sounding rocket atmospheric research program (and NASA airborne science program) to a share being held by SRVs. We assume 5% of NASA's $30 million budget for these programs will transition to SRVs, growing to a total of $3 million by year 10. Both programs are budget limited and fund a variety of research objectives; however, we expect a steady demand for a few studies a year.

In the growth scenario, a new NASA/NOAA program increases overall spending on SRV flights for atmospheric research to $20 million annually by the last year of the forecast.

Longitudinal Human Research

Longitudinal human research may be funded by NIH and the National Space Biomedical Research Institute (NSBRI), a non-profit science institute established by NASA in 1997 to research safe and productive human spaceflight. This research could start soon and grow to a large clinical research trial toward the end of the forecast. NIH's current research efforts using microgravity and analogs to understand human physiology supports about $2.7 million in grants per year, of which about 40% are well suited for transitioning to SRV platforms (or $1.7 million by the last year of the forecast, assuming average growth). In addition, 3% of NSBRI's annual budget, or up to $1.1 million, could be spent on research on SRVs. NASA will continue to conduct human research on the ISS and will not likely transition NASA funding for such experiments from the ISS to SRVs, as NASA has indicated that it is focusing its current resources on the ISS. However, there are some indications in communities that support ISS research, specifically the Center for the Advancement of Science in Space (CASIS), of interest in using SRVs to help support ISS human research.

The growth scenario sees a faster pace of growth in this research area by international researchers.

Microgravity Research

Our forecast of non-commercial microgravity research is driven primarily by internal research funding from universities, augmented by NSF and non-profits. University spending on SRV addressable microgravity experiments starts at about $200,000, reflecting small projects across several universities, and grows to over $500,000 in the last year of the forecast. University microgravity research is focused within two large research centers (Center for Microgravity Research and Education at the University of Central Florida and the Center for Microgravity and Materials Research at the University of Alabama, with internal funding less than $500,000 for research and center operations) with lower levels of research in about 20 smaller university programs.

NSF currently supports SRV-addressable microgravity research through grants. On average, about $125,000 in NSF grant funding per year is related to microgravity and applicable to SRVs. This funding will likely grow slowly to around $160,000 based on NSF budgets and historical growth rates.

NASA funding on microgravity research is projected to be limited to the NSBRI budget to conduct human microgravity experiments (captured in the longitudinal human research area above). The relatively low level of current microgravity research funding in the United States today suggests this will not be an area of U.S. government funding growth for SRVs. However, there is significant interest in microgravity research outside the United States; after 10 years, over half of predicted funding for SRV microgravity research will be sourced from outside the United States. The predicted overall funding level remains low, with SRVs serving a niche role in government microgravity research.

Within commercial microgravity research, numerous interviews with individuals from research-intensive industries, including biotech, pharmaceutical companies, and technology-focused venture capital firms, indicated there is no well-understood commercial application for microgravity research on SRVs. Research-focused interviewees typically said they did not anticipate commercial microgravity research on SRVs. More venture-focused interviewees predicted there would be some level of exploratory commercial research, to enable firms to gain insight into SRV capabilities and assess how those capabilities might benefit their research portfolios. We predict there will be a gradual growth of research by commercial firms globally, focused on "what if" SRV experiments. While experiment size and firm commitment will vary, typical budgets for exploratory projects such as these are likely to be from $10,000 to $30,000 per experiment. (Though not impossible, our research suggests it would be atypical for many firms to invest at much higher levels—$100,000 and above—on research projects without connection to clear commercial outcomes.) We predict exploratory commercial research will start slowly and increase to a total of about $5 million annually (about half on flight costs) with experiments by many companies. Research results and SRV performance may significantly increase or decrease this demand.

The growth scenario in this area reflects increased commercial interest in SRV research, growing to $10 million in the last year of the forecast, and increased interest from NASA, at about seven seats/cargo equivalents per year, reflecting one SRV demonstration per ISS experiment.

International

Initially, the U.S. government is projected to be the primary user of SRVs for basic and applied research, funding astronomy, atmospheric research, and longitudinal human research. Non-U.S. government and private entities have purchased exploratory research opportunities on SRVs. Non-U.S. government entities (i.e., other nation's governments) may take five to six years to implement larger standing SRV programs. Overall, nearly 50 nations appear to be potential users of SRVs for government-funded research, based on current research activities and budgets. By the end of the forecast period, the international demand could make up about 10% of each research area and as much as 50% of microgravity.

Estimate of 10-Year Demand

We forecast the number of SRV experiments will grow, driven by human research and microgravity experiments:

- Astronomy experiments are considerably more costly than either microgravity or human research and grow slowly up to 12 experiments a year. Because each astronomy mission requires a full flight, these experiments disproportionally drive flight rate, reaching 36 seat/cargo equivalents by the last year of the forecast.
- Atmospheric research begins slowly, as new techniques and instrumentation are developed, but quickly grows to at least one experiment per week, translating to 18 seat/cargo equivalents in the last year of the forecast.
- Human research experiments grow from 1.2 seat/cargo equivalents in the initial year to about 8 (300 experiments) after 10 years. These experiments are predominantly conducted on spaceflight crew and passengers and do not directly drive flight rates.
- Microgravity research grows from 9 seat/cargo equivalents to 16 (over 250 experiments) in 10 years. Almost all are inexpensive and small exploratory experiments by companies.

The growth scenario primarily reflects a change in SRV research interest, resulting from a mix of demonstrated high-quality science, government flexibility to initiate large research programs, and identified commercial applications. The growth scenario sees seat/cargo equivalents growing from 21 to 171 in the last year of the forecast.

The constrained scenario reflects constrained government budgets domestically and internationally and consequently, no SRV research funding by NSF, NIH, and NOAA and limited interest internationally. In the constrained scenario, there is low, but steady demand over the forecast period, starting at 18 seat/cargo equivalents and growing to 29 by year 10.

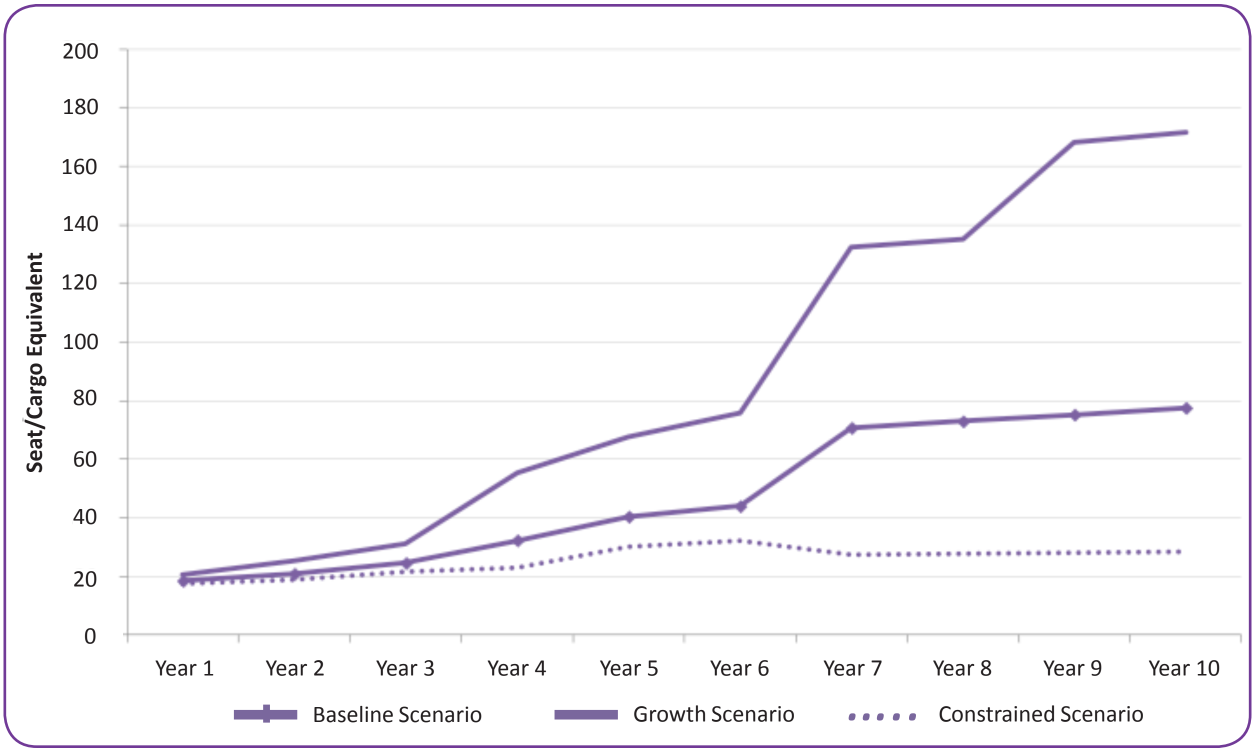


Figure 23: Baseline, growth, and constrained scenarios for Basic and Applied Research

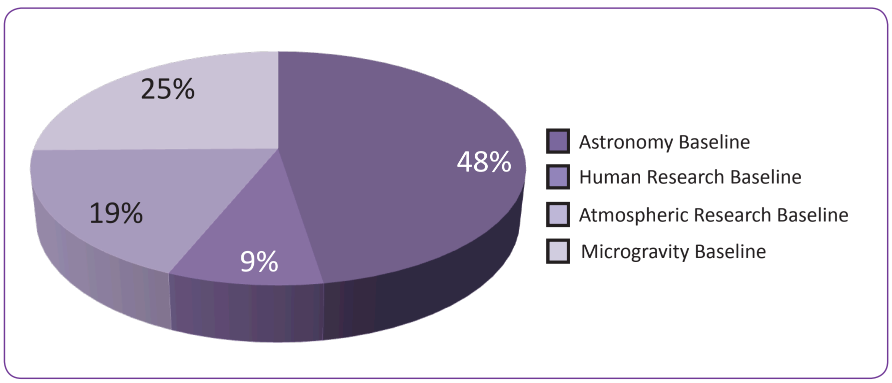


Figure 24: Basic and Applied Research Baseline Submarket Share

Basic and Applied Research	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	19	21	25	32	40	44	71	73	75	78
Growth Scenario	21	25	31	56	68	76	132	135	168	171
Constrained Scenario	18	19	22	23	30	32	28	28	28	29

Table 13: Basic and Applied Research forecast in seat/cargo equivalents

Uncertainty

Our forecast predicts exploratory, "what if" research by commercial companies globally, based on an anticipated desire by those companies to understand the capabilities and opportunities provided by SRVs for many types of microgravity research. No clear commercial applications are currently identified. Research success and increased interest could increase funding beyond the predicted $5 million to $10 million per year, while loss of interest in speculative research or poor performance by SRVs could limit commercial exploratory funding below these levels. Identification of a clear, related commercial application that requires sustained, ongoing SRV use may result in even larger spending levels.

Our forecast predicts modest research uptake based on existing budgets for related research. In the past, non-space research agencies (NSF, NIH, and to a lesser extent, NOAA) resisted funding space-based research, and it is unknown if this could have a large impact on future demand.

It is unclear what is the future relationship between SRV and ISS payloads. SRVs could be a step in conducting research on the ISS, or the conversion of the ISS to a National Laboratory could draw research and funding that would otherwise be directed to SRVs.

Some providers anticipate the introduction of SRVs will radically change the way government agencies procure research services. Under this scenario agencies, both domestic and international, that conduct space related research will quickly adopt SRVs. This will significantly increase SRV uptake.

Lack of Awareness

Agencies that have not traditionally funded space research, and whose research interests align with SRV capabilities, are generally not fully informed about SRVs, including NOAA, NIH, NSF, and new international actors. For NSF, increasing support and awareness in the peer review community for SRV-relevant research could result in additional consideration for future grants and increase available funding.

Commercial pharmaceutical, biotech, and other researchers were often unaware of SRVs, unaware of their capabilities, or uncertain about their likely performance levels. Increasing awareness could help identify commercial applications for research on SRVs.

Aerospace Technology Test and Demonstration

SRVs can be used in aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification.

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION

Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

Demonstrations requiring space/launch environment
Hardware qualification and test

In the Aerospace Technology Test and Demonstration market, technology payloads are tested or demonstrated on SRVs to qualify or obtain data on flight systems in development. Payloads can be at any level of maturity, but are most likely to be at the higher technology readiness levels (TRLs) of 5, 6, and 7, which require test or demonstration in relevant environments. In addition, SRVs provide opportunities to train new members of the workforce with hands-on management experience with flight systems.

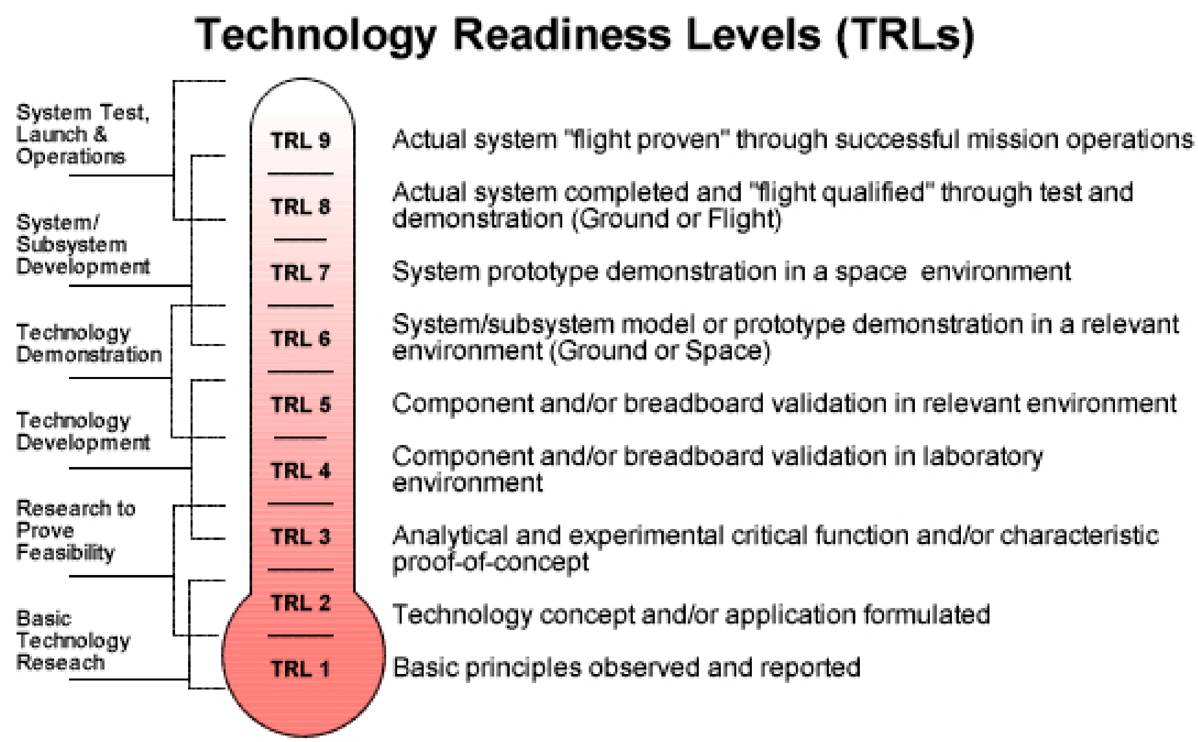


Figure 25: Technology Readiness Levels. SRVs can provide a relevant environment for space systems. Source: https://www.spacecomm.nasa.gov/spacecomm/programs/technology/default.cfm

Market Dynamics

Space agencies and companies currently conduct test and demonstration activities using terrestrial facilities and spaceflight (either in space or during launch and reentry trajectories).

Terrestrial facilities include rocket test stands, thermal chambers, vacuum chambers, drop towers, radiation chambers, vibration and acoustic stands, wind tunnels, and others. While specialized facilities such as advanced wind tunnels can be in high demand, for most test facilities there is excess capacity. In addition, advances in modeling capabilities have changed requirements for technology testing, reducing requirements for fidelity, duration, and frequency in some cases.

Spaceflight test and demonstration activities include those on sounding rockets, the ISS, and other government vehicles and platforms. NASA, in association with ISS partner nations, is the largest potential customer in this market. Average annual rates for NASA and ISS partner technology tests and demonstrations on these platforms are roughly 4 per year on sounding rockets, 24 per year on the ISS, and 10 per year on the Shuttle (no longer in service). These rates have grown each year at an average rate of about 7 to 8% for the Space Shuttle and ISS.

The DoD typically uses Evolved Expendable Launch Vehicles (EELVs), missiles, and sounding rockets like Terrier-Orion to fly technology test and demonstration payloads. Test and demonstration payloads flown on Terrier-Orion are predominantly associated with missile defense.

Commercial companies are developing new launch vehicles and orbital systems with components similar to, but often less complex, than NASA systems. These companies often use internal facilities to conduct terrestrial and in-space technology tests and demonstrations.

How SRVs Fit into the Market

SRVs are potentially capable of supporting many types of test and demonstration activities. The match between the test requirements and the platform capabilities will determine whether an SRV flight is better for a given test than another platform. Table 14 shows the types of test and demonstration activities typically conducted on a range of existing terrestrial and space platforms and activities that could potentially be conducted on planned and future variants of SRVs. As shown, SRVs align with orbital systems relatively well, and in most cases, SRVs are less expensive. In general, terrestrial technology tests and demonstrations are less expensive than SRVs, and some tests provide a better testing environment than SRVs.

SRVs provide a testing environment with microgravity, access to high altitudes, upper atmosphere aerodynamics, and the potential for human interaction. SRVs can provide access to similar thermal, radiation, and vacuum environments as orbital space systems. However, SRV performance in these environments is mitigated by the duration of exposure; these types of tests have to measure cumulative exposure over a long period of time. Table 15 shows the attributes of SRVs for several important test elements, compared to other platforms.

Due to similar, in some cases nearly identical, operating environments for SRVs and other aerospace hardware, there are several types of aerospace technologies suitable for testing on SRVs. These include human interfaces, mechanical systems with operational cycles around a few minutes, fluid systems, atmospheric sensors, avionics, and landing imaging systems. Due to relative costs and similarity of test environments, SRVs will most likely enable tests and demonstrations of technologies typically conducted on orbital and launch systems. Based on the types of technologies historically tested in space,

Platform / Environment	Micro-gravity	Radiation	Thermal	Vacuum	Vibration	Aero-dynamics	Altitude	Launch Loads	Human Factors
SRV	✓	✓	✓	✓		✓	✓		✓
Sounding Rocket	✓			✓	✓	✓	✓	✓	
Balloon								✓	
Aircraft	✓					✓			✓
Drop Tower	✓			✓					
Terrestrial Facilities		✓	✓	✓	✓	✓			✓
Orbital Systems	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sample Tests	pumps, turbines, hydraulics	shielding, electronic commun-ications	heat pipes, ablatives	valves, materials	structures, propellant systems	airframes, control surfaces	sensors	composites	suits, control panels

Table 14: Types of test and demonstration that can potentially be conducted on SRVs and other aerospace test and demonstration platforms

about 25% of orbital test and demonstration missions require capabilities that could be provided by SRVs. It is unclear whether SRVs will be used to space qualify orbital technologies. Most space systems need to be space-qualified before flight, but there is no clear definition of what is necessary for a system to become space-qualified. In general, satellite technologies are not ideally suited for testing on SRVs, because they require longer exposure to the space environment and often require exposure to the Van Allen belts.

Platforms	Environments					
	Max time in microgravity	Radiation, temperature, and vacuum	Max altitude	Typical payload mass	Human tended*	Cost
SRV	5 min	Good	110 km	200 kg	Yes/No	$500 + per kg (announced)
Sounding Rocket	20 min	Excellent	1600 km	A few hundred kg	No	$1M - $3.5M
Aircraft	30 seconds	Poor	30 km	1,000 kg	Yes/No	$2,500 - 250,000 (Zero-G) $13K - 40K/hr
Drop Tower	10 seconds	Poor	N/A	Grams to 500 kg	Yes	$1 - $10/kg-drop***
Terrestrial testing facilities	N/A	Good	N/A	Varies, can be very large	Yes	Varies
Orbital Flight	Days+	Excellent	400 km+	Thousands of kg	Yes/No	$10K + per kg**

Table 15: Comparison of SRV capabilities to other platforms

* Humans are useful for testing if there is enough time for modification between tests, or if they are a component of the system.

** Total development and testing costs of a few example ISS technology payloads run $1-4 million.

*** Typical research programs using drop towers are $200-300K for 150 data points (up to ~1,000 drops), which includes experiment design, drops, analysis, and all overhead costs.

Current SRV Activities

NASA's Flight Opportunities Program is the primary early adopter for SRV tests and demonstrations to "prime the pump" for future demonstration flights. The Flight Opportunities Program also supports technology payloads on SRV precursors and alternatives, like Masten's Xaero craft, balloons, and parabolic platforms. Through this program, NASA has procured payload capacity from Virgin Galactic, UP Aerospace, and several non-SRV platforms. The program projects 1 SRV flight in 2012 and 1 in 2013, flying a total of 37 payloads. Five payloads were selected for SRVs in March 2012, and an additional 14 were selected in July 2012.

SRV providers are conducting tests on their own vehicles, sometimes in conjunction with future customers (such as researchers) to demonstrate payload interfaces and refine future experiments. These internal tests represent the current extent of commercial and university SRV activities.

SRV Demand Forecast

NASA and other space agencies will likely be the major users of SRVs for test and demonstration, particularly for the next generation of human exploration systems. Over time, NASA will likely transition to SRVs for some (not all) SRV-suitable test and demonstration payloads. We project the transition will include all SRV-applicable test and demonstration payloads that were previously launched on sounding rockets, due to the lower costs of SRVs. NASA has shown initial support for SRVs by buying flight opportunities and supporting payloads. Based on interviews, we expect this support to continue. Half of the SRV-suitable payloads that were previously launched on the Shuttle are estimated to transition to SRVs, with the other half estimated to better match the capabilities provided by the ISS. In addition, an estimated one-sixth of payloads currently tested on the ISS do not require long-duration exposure for useful data. Consequently, about that proportion of ISS test and demonstration activities is projected to transition to SRVs.

In addition to demand identified in historical trends, significant additional growth could occur if NASA and international partners target SRVs as a stepping-stone for most applicable exploration technologies before demonstration on the ISS. There appears to be interest within NASA and CASIS (the sole manager of the International Space Station U.S. National Laboratory) in using SRVs as part of the development process for ISS payloads, but this is counterbalanced by a widespread concern within NASA about limited ISS budget and a desire to maximize allocation of resources to direct use of the ISS.

Although there are companies developing launch vehicles and orbital systems with technologies that could be tested on SRVs, we do not estimate commercial demand will be a significant driver of aerospace technology test and demonstration on SRVs. Interviews with commercial organizations developing new orbital technologies did not indicate interest or plans to conduct technology test or demonstration on SRVs. Interviews with terrestrial test and demonstration facilities noted limited commercial interest. This information may be proprietary, and projections of commercial demand from these interviews represent an uncertainty for this market.

Estimate of 10-Year Demand

The baseline forecast begins at 7 payloads, about 2 seat/cargo equivalents, in Year 1 and jumps to 30 payloads or 9 seat/cargo equivalents in Year 2. This rate remains steady throughout the forecast period. Figure 26 and Table 16 summarize the forecast demand for Aerospace Technology Test and Demonstration.

The growth scenario begins at 4 and grows to 25 seat/cargo equivalents. The constrained scenario drops from nine seat/cargo equivalents in Year 3 to one, after current programmed funding for NASA's Flight Opportunities Program ends, and stays level.

Aerospace Technology Test and Demonstration Forecast Methodology

To assess demand for technology test and demonstration payloads, The Tauri Group researched past SRV-relevant test and demonstration payloads on the ISS, Space Shuttle, and sounding rockets. Our research excludes terrestrial and parabolic payloads, which continue to be cheaper to test on terrestrial systems. SRV-suitable payloads include test and demonstration with humans, mechanical systems with operational cycles around a few minutes, fluid systems, atmospheric sensors, avionics, landing imaging systems, and other tests and demonstrations that align with SRV capabilities. This estimate also includes the historical growth rate of 7 to 8% from the ISS and Shuttle, with a quick ramp-up in the first three years, as budgets allow for transition of payloads to SRVs.

NASA's Fight Opportunities Program has made a commitment to support about 30 technology test and demonstration payloads per year. This level of effort fully addresses estimated demand from NASA and international partners based on historical activities through the period of the forecast and is used as the baseline forecast.

The baseline scenario reflects continued investment in orbital space technologies by NASA and partners, with somewhat increased recognition of the value of SRV test and demonstration within NASA. We did not find sustainable applications or customer bases for technology tests and demonstrations by DoD or commercial companies, outside those contracted by space agencies.

Growth and Constrained Scenarios

The growth scenario reflects full capture of Shuttle-applicable payloads and a significant increase in the movement of ISS payloads to SRVs at 50%. This scenario is a change from current test and demonstration activities, as it reduces a focus on ISS utilization as a technology test bed. Existing methods of partnership demonstrated on the ISS and Shuttle account for the demand from Europe, Japan, Russia, and other nations that typically partner with NASA. An additional flight per year is added to capture potential commercial growth, DoD technology test and demonstration activities, and additional international demand not identified in interviews.

The constrained scenario includes the continuation of the Flight Opportunities Program until 2014, followed by reduction of applicable sounding rocket payloads. This scenario results in three lockers per year, about one-third of a flight.

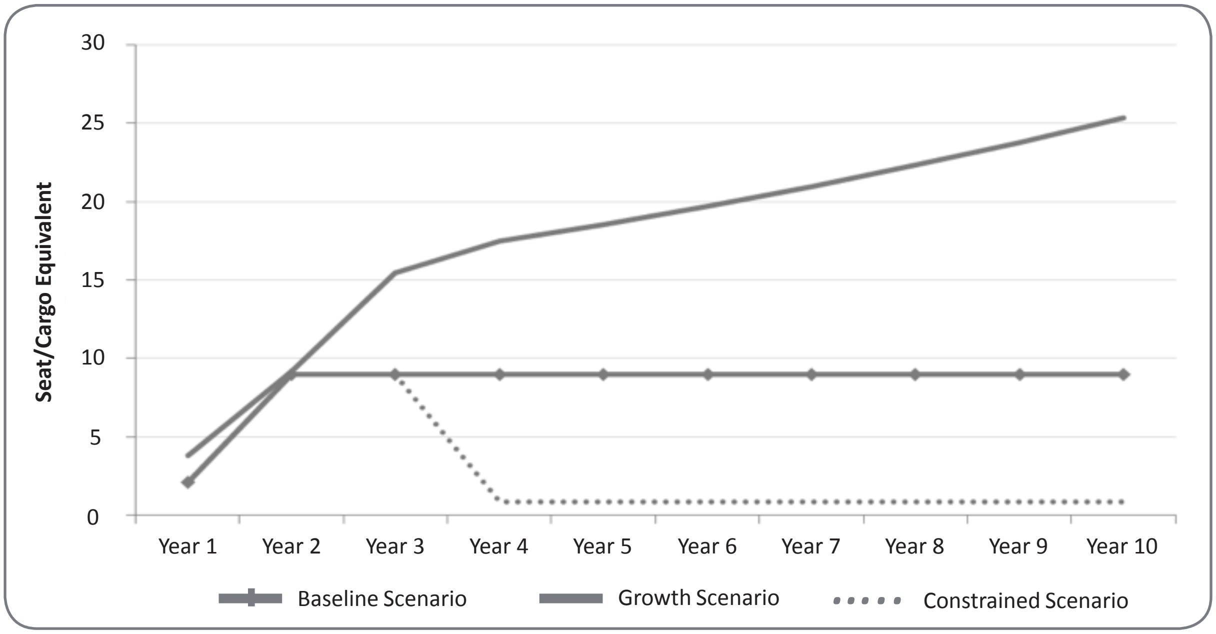


Figure 26: Baseline, Constrained, and Growth scenarios for Aerospace Technology Test and Demonstration

Aerospace Technology Test and Demonstration	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	2	9	9	9	9	9	9	9	9	9
Growth Scenario	4	9	15	17	19	20	21	22	24	25
Constrained Scenario	2	9	9	1	1	1	1	1	1	1

Table 16: Aerospace Technology Test and Demonstration forecast in seats/cargo equivalents

Uncertainty

The level of NASA test and demonstration activity may depart from the historical trends used here, either because NASA's program activities shift or SRVs are not found to be useful platforms for technology test and demonstration. NASA could decide to use SRVs to test and develop future human spaceflight exploration systems at a higher or lower rate than it has historically tested on other platforms.

Another uncertainty is the applicability of these flights to commercial orbital systems. There are a number of providers actively developing systems that could be tested or demonstrated on SRVs. Although interviews with providers did not indicate intent to test systems on SRVs, this information may be proprietary and remains unknown. The market could grow if SRVs are perceived to be useful and economical for testing and demonstrating particular orbital technology areas.

Lack of Awareness

The space community does not have clear standards or shared expectations regarding the value of SRVs for space qualifying technologies or system elements.

Media and Public Relations

The market for media, public relations, and novelties includes activities that use space to promote products, increase brand awareness, or film space-related content, typically to leverage associations with space. Submarkets include activities in:

- Film and television
- Media, advertising, and sponsorship
- Public relations and outreach
- Space novelties and memorabilia

MEDIA AND PUBLIC RELATIONS

Using space to promote products, increase brand awareness, or film space-related content

Film and television
Media, advertising, and sponsorship
Public relations and outreach
Space novelties and memorabilia

Market Dynamics

While space-themed advertising and memorabilia are ubiquitous, relatively little related activity has historically occurred in space or using space analogs (such as parabolic flights).

Film and Television

Space-themed entertainment is common and lucrative. About 5% of all major feature films have been space-related or contained scenes of people or objects in a microgravity environment, floating weightlessly. Of the top 50 domestic grossing movies of all time, 8 are space-related. Films and television programs actually filmed in space (or even in terrestrial analog environments) are less common.

No movies (excluding documentaries, discussed below) have been filmed in space. Instead, contemporary media effects use chroma keying and/or computer generated imagery (CGI) to achieve the illusion of space. There are a few instances of filming actors and scenes in microgravity environments (simulated terrestrially). The makers of Apollo 13 filmed 3 hours and 54 minutes of raw footage over 612 parabolas on a parabolic aircraft to simulate in-space scenes. More recently, Warner Brothers flew five flights on a Zero-G aircraft for research purposes in the development of The Matrix Reloaded and The Matrix Revolutions. They did not use the flights for filming.

Over the last 20 years, there have been at least 30 space-related documentaries, of which 7 were actually filmed in space using cameras sent to the ISS or on the Shuttle. Some of these films rank among the highest grossing documentaries. The Dream is Alive, a 1985 documentary about the Space Shuttle, is the highest grossing documentary on record, at $279 million in 2012 U.S. dollars. The 2002 documentary Space Station is the 5th highest grossing, and Hubble 3D is 16th.

NASA footage of space and space-themed content is used extensively in movies, television shows, and news programming, from sitcoms like The Big Bang Theory to Discovery Channel documentaries. Other high-profile uses of space in television include an orbital flight for Toyohire Akiyama, a Japanese journalist, who broadcast from Mir for a week in 1990. The Tokyo Broadcasting services paid a reported $12 to $28 million for the flight.

Advertising and Public Relations (PR)

Space-related advertising that may affect flight rate includes logos and advertisements placed on space hardware and commercials filmed in space, near space, or on parabolic flights. Public relations includes a broad array of activities, ranging from the recent Playboy and Virgin Galactic imagining of a Playboy Club in space, to the use of the SpaceX factory in the movie Iron Man 2. While these activities may generate revenue for companies, they often do not affect flight activities. Other proposed methods of space-related advertising include projections of logos into space or on the Moon or targeted missions whose media coverage is sponsored. Over the past 20 years, there have been an average of 1.25 space-related campaigns per year filmed on space vehicles or balloons. Costs for the flight have varied widely, ranging from several hundred dollars on a high-altitude balloon to several million for an orbital flight.

Year	Status	Cost	Type	Platform	Company	Description
1993	Cancelled	$500,000	Logo placement	Rocket	Columbia Pictures	To promote "The Last Action Hero" movie.
1996	Proposed; never filmed	No available data	TV commercial	Mir	Beefjerky.com	To promote "Final Frontier Jerky."
1996	Proposed; never completed	$750,000	Multi-media campaign	Shuttle	Coca-Cola	Soda fountain experiment.
1996	Proposed; never completed	$3,000,000	Multi-media campaign	Mir	Pepsi-Cola	Advertisement featuring cosmonauts.
1997	Filmed	$450,000	TV commercial	Mir	Tnuva (milk)	TV ad showing Mir cosmonaut Vasily Tsibliyev drinking Israeli milk.
1998	Filmed	No available data	TV program	Mir	Fisher Space Pen/QVC	Russian cosmonauts appeared live on the QVC shopping channel to promote the $32.75 Fisher Space Pen.
1999	Filmed	No available data	TV commercial	Mir	More.com	Commercial for the More.com online drugstore.
2001	Filmed	No available data	TV commercial	ISS	Radio Shack	Astronauts received Father's Day gifts from Radio Shack.
2001	Complete	$2,300,000	PR and Logo placement	Rocket (Proton) and ISS	Yum! Brands/ Pizza Hut	Pizza Hut delivered to space; also placed a logo on the side of a Proton rocket in 1999.
2001	Complete	$0	PR - Promotion	ISS	Beefjerky.com	To promote "Final Frontier Jerky," flew a small amount of jerky to the ISS.
2001	Complete	No available data	Logo placement	ISS	Kodak	A Kodak logo was placed outside of the ISS.
2004	Complete	$6,000,000	Multi-media campaign	Zero-G	Diet Rite	Yearlong campaign including sponsorship of The Biggest Looser, six-city "Go For Zero" tour, commercials, and associated PR.
2005	Filmed	No available data	TV commercial	ISS	Nissin Food Products Co	Commercial for instant ramen, part of Nissin’s “Cup Noodle No Border” campaign.
2006	Complete	$5,000,000	Multi-media campaign	ISS	Element 21	Russian cosmonaut hit a golf ball to promote Element 21's line of clubs.
2008	Filmed	$165,000	TV commercial	Zero-G	7-Up	Promoting the "Free Ticket to Space" sweepstakes.
2008	Filmed	$165,000	TV commercial	Zero-G	MasterCard	Briefly shows points for a Zero-G flight.
2009	Filmed	No available data	TV commercial	Balloon	Toshiba	Commercial touts Toshiba's HD cameras and LCD displays as "armchair viewing, redefined."
2011	Filmed	No available data	TV commercial	Balloon	CitiBank	Buying a weather balloon with points.
2011	Filmed	$165,000	TV commercial	Zero-G	Justin Bieber	"Someday" perfume commercial filmed on Zero-G.
2012	Ongoing	TBD	Sponsorship	Balloon	Red Bull	Sponsorship of the Red Bull Stratos high-altitude skydive.

Table 17: Examples of flight-related space advertising and PR efforts

Space Novelties and Memorabilia

Novelties are objects that have flown in whole or in part in space, whereas memorabilia is associated with a particular space event or vehicle, such as a Space Shuttle mission or the ISS.

Celestis Memorial Spaceflights is a service that will fly a portion of cremated remains into suborbital space, Earth orbit, onto the lunar surface, or into deep space. The company has flown its canisters on 11 launches (with 3 failures), carrying the remains of over 800 individuals (See Figure 27).

A number of small, dedicated memorabilia companies have met with mixed success. Space Wed, a wedding ring company, flew 50 sets of wedding rings into space in May of 2011, and has since distributed 3 of those sets through sales and contests. A company called "To Space," brokered sending custom payloads into space, such as business cards and personal items. While testing the Genesis II module, Bigelow Aerospace flew small personal items in space for a fee of $300, which were then visible while in space via a webcam on the company's website.

The novelty market is currently primarily served by sounding and orbital rockets. Memorabilia items are generally from civil orbital activities, such as the Shuttle, the ISS, or Mir. Most of the high-value space-flown artifacts sold at auction come from the Apollo era and the Soviet space program.

Spotlight: Celestis

- Celestis launches cremated remains into space
  - One gram (Flight Capsule)
  - Seven gram (Flight Module)
- Suborbital Celestis launches ("Earth Rise") start at $995 for a Flight Capsule, launched aboard UP Aerospace's Spaceloft XL
- The next Earth Rise is scheduled for launch on October 8, 2012

Figure 27: Celestis flies cremated remains to space

How SRVs Fit into the Market

SRVs represent a lower cost opportunity for some space-related Media and PR applications, compared to currently available orbital services, and are projected to be more frequently available. While not as cost-effective as parabolic flight or CGI, SRV flights can provide minutes of continuous microgravity (1-5 uninterrupted minutes, compared to ~22 seconds on parabolic flights) and access to the space environment. Emerging SRV brands may excite public interest and attract advertising opportunities. Advertising with SRVs can be done with commercials and print ads or by placing a logo or other branding element on or in the vehicle.

Despite the capabilities SRVs offer the Media and PR market, many limiting factors remain. Filming aboard vehicles is unlikely to be cost-competitive except in niche applications (such as documentaries and reality television). Currently, launches rarely attract a wide television audience, which suggests advertisements on SRVs would be limited to the passenger audience.

There has been initial activity in this market. At least one provider received a proposal to produce adult films during flight, which was declined. Television ads for other products have leveraged these vehicles, such as cross-promotional ads for Virgin Mobile. UP Aerospace has flown many of the space novelty payloads mentioned above, including space burials and space-flown wedding rings.

SRV Demand Forecast

Based on costs, historical data, and interviews, we project interest in producing films and TV programming on SRVs will be related to the novelty of the experience and the association with suborbital spaceflight. SRVs are attractive options, particularly for reality TV and documentaries. The film and TV baseline forecast predicts three documentaries filmed over the course of the study period, with one seat assumed per documentary. In addition, the baseline forecast predicts one seat per year for TV programming, similar to historical expenditures.

Advertising and PR possibilities depend on the SRV provider. Some suborbital companies will allow sponsorships, advertisements, and commercials on their vehicles, while others may limit third-party sponsorship due to brand maintenance. The advertising and PR baseline forecast projects one campaign per year, equivalent to one dedicated flight per year.

Given that SRVs can fly small payloads of space-flown novelties at a reduced cost, in our baseline forecast, SRVs will capture the currently existing demand for novelties.

Figure 28, Figure 29, and Table 18 summarize the forecast for Media and PR activities.

Estimate of 10-Year Demand

Baseline demand is relatively flat, averaging about 5 seat/cargo equivalents per year.

Uncertainty

The Media and PR market is highly uncertain. Interest could change dramatically depending on public response to SRV marketing, flight activity, and reports of flight experience. In particular, the timing of Media and PR activity could vary. There may be a near-term surge in interest that fades as suborbital flights become more common, or a gradual growth in brand recognition and value among SRV providers could increase activity. In addition, the number of seats or cargo capacity or revenue associated with an advertising campaign, documentary, or reality TV show can vary. Finally, Media and PR activities may drive other areas of demand, particularly Commercial Human Spaceflight.

Media and Public Relations Forecast Methodology

The media and public relations forecast separately analyzes markets for Film and TV, Advertising and PR, and Novelties and Memorabilia.

The Film and TV baseline forecast reflects interest in filming documentaries and television programming on SRVs, based on historic trends in space-based documentaries and previous uses of space or microgravity experiences for television. For the Film and TV forecast, we estimate about three documentaries filmed over the course of the study period. The baseline scenario also projects an average of approximately one seat per year for TV programming, similar to historical expenditures.

The Advertising and PR baseline reflects use of SRVs for advertising campaigns, based on historical trends. Over the past 20 years, there has been an average of 1 major spaceflight-related advertisement per year. The baseline forecast assumes a steady state of one campaign per year.

The Novelties and Memorabilia baseline reflects SRVs capturing the currently existing demand for novelties and non-historic memorabilia, estimated to be equivalent to the volume of one locker.

Growth and Constrained Scenarios

The Film and TV Growth scenario reflects a potential need for dedicated flights for documentaries, TV, and a feature film. Given that one feature film has used parabolic flights for filming, the Growth scenario anticipates one movie filmed on an SRV may occur during the study time frame. This demand would drive up the flight rate dramatically due to the duration of microgravity needed to film movie scenes.

The Novelty and Memorabilia growth scenario reflects more items flown due to increasing public interest.

The Media and Public Relations constrained scenario reflects less use of SRVs for filming, advertising, and flying novelties due to schedule uncertainty, risk perception, insurance issues, and less public interest as flights become routine and perceived as less novel, but does still include documentaries.

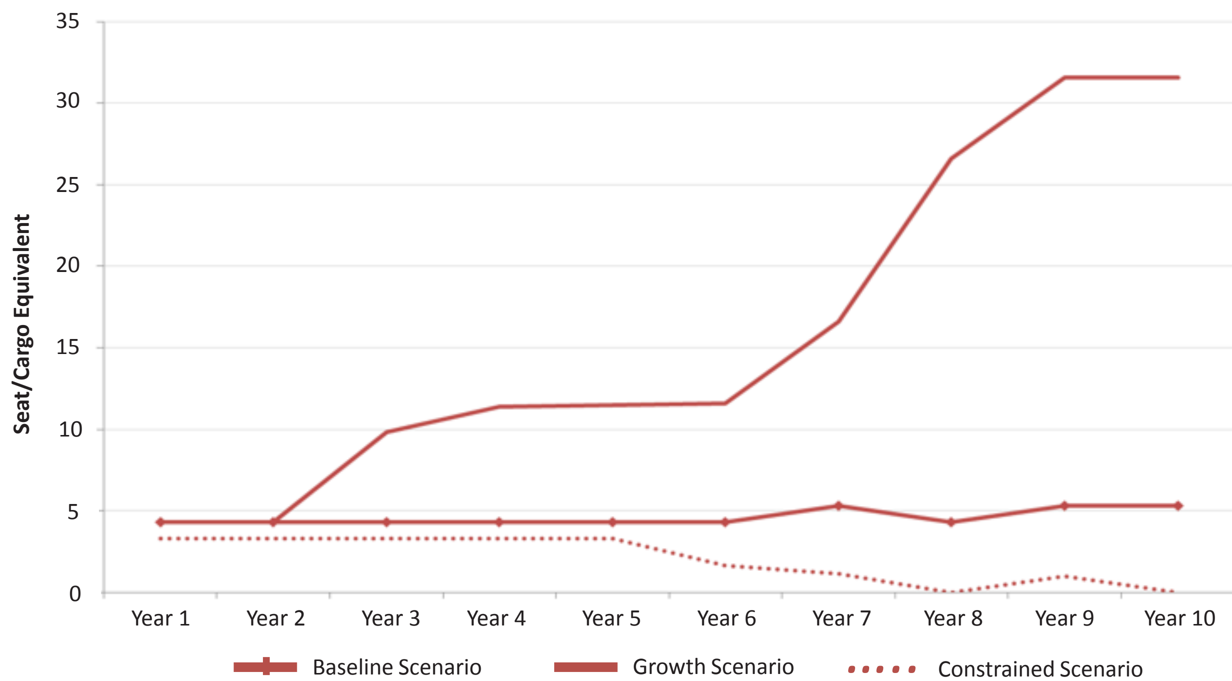


Figure 28: Baseline, Constrained, and Growth scenarios for Media & PR

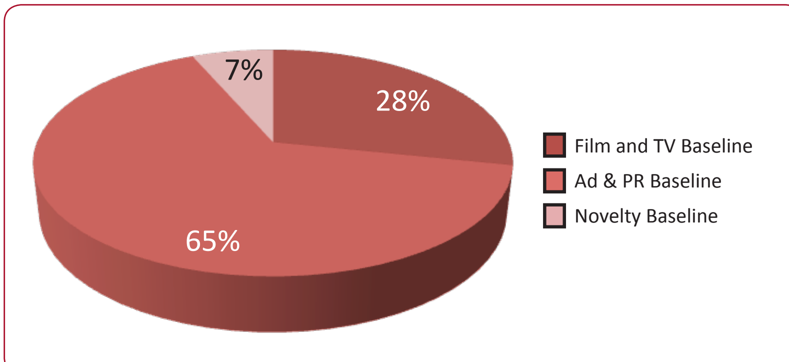


Figure 29: Media & PR Baseline Submarket Share

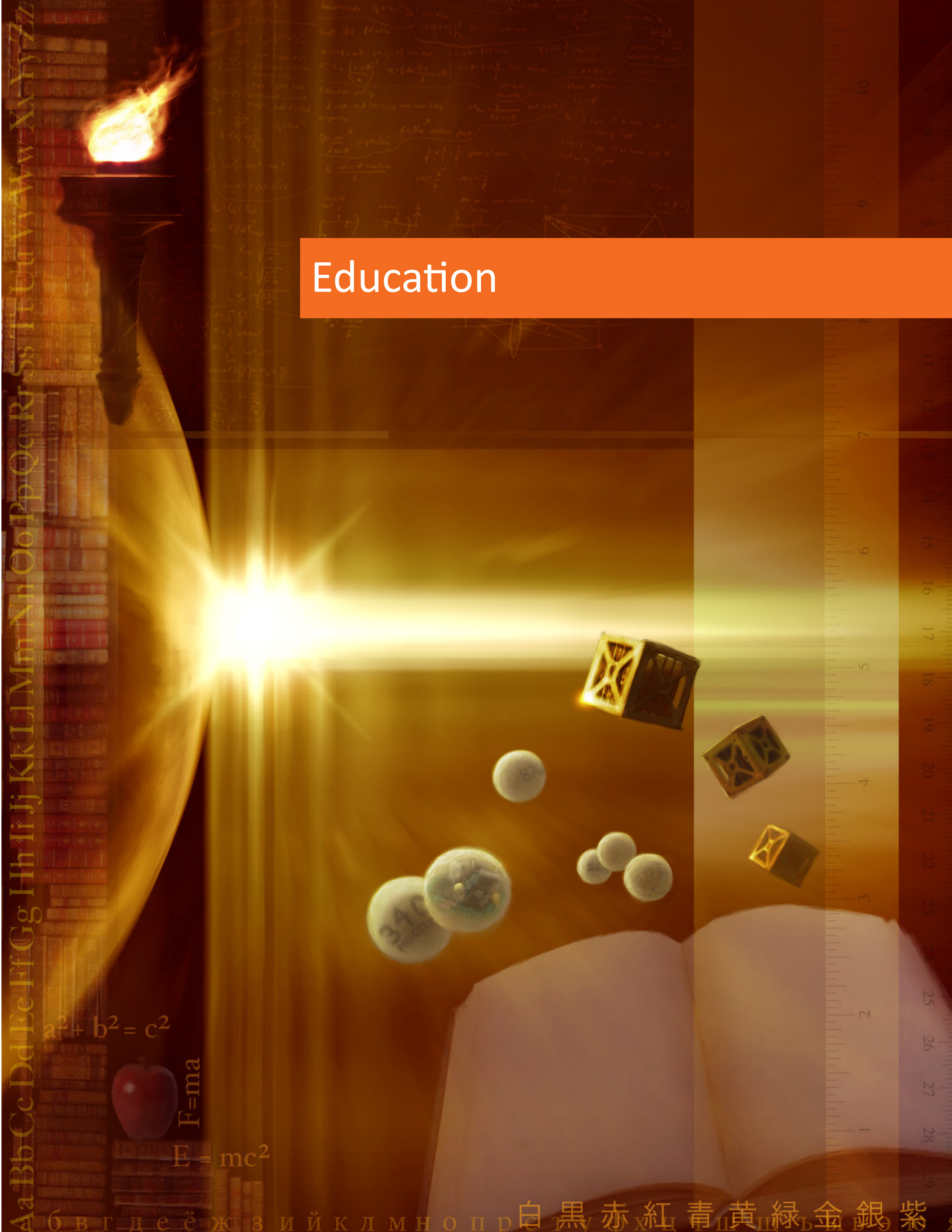
Media & PR, Novelties and Memorabilia	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	4	4	4	4	4	4	5	4	5	5
Growth Scenario	4	4	10	11	11	12	17	27	32	32
Constrained Scenario	3	3	3	3	3	2	1	-	1	-

Table 18: Media & PR forecast in seat/cargo equivalents

Lack of Awareness

There appears to be growing media and public relations awareness of SRVs. A number of vehicle providers indicated they have seen more interest in promotional activities than they anticipated, but at this early stage it has not turned into commitments for flights.

Education



EDUCATION

Providing opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space

K-12 education

University educational missions

SRVs provide opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space, especially through the flight and return of student-built payloads and teacher-in-space programs. Key attributes for schools are frequent flights that would align with school schedules and affordable costs for small payloads.

Market Dynamics

Space themes and information are used in many ways for education at all levels. This analysis focuses on uses of space that could drive flight rate: "build" projects (where students build and fly a payload) and other flight opportunities.

Existing space-related education build projects use small and large rockets, balloons, parabolic flights, amateur rockets, and the ISS. Student-built payloads are typically small, from ping-pong-ball-sized experiments to soda-can-sized and CubeSat form factors (a 10 cm cube). The costs range from $500 to $20,000 for K-12 and $500 to as much as $300,000 for universities. High costs in the upper range for universities include launch costs for CubeSats, although universities are often able to take advantage of government-sponsored complimentary rides to orbit as secondary payloads. There are several early stage projects already flown on SRVs or scheduled to do so.

Space-based education programs compete with non-space Science, Technology, Engineering, and Mathematics (STEM) build programs, of which there are many. These range from small programs, such as InvenTeams, with 15 teams currently participating to invent technological solutions to real-world problems, to large programs such as FutureCity, where over 35,000 students from 1,300 middle schools participate by planning and designing virtual cities with SimCity 4 software and building physical models.

One of the largest and widest known non-space STEM programs is the FIRST Robotics Competition. The non-profit FIRST (For Inspiration and Recognition of Science and Technology) organizes the annual 9-12 FIRST Robotics Competition, where students work as teams to build robots that compete in specific tasks, such as stacking bins or "playing" basketball. In its first 10 years, FIRST Robotics grew from 28 teams to 600 teams. In 2012, 2,343 teams competed (teams are typically 25 students), representing more than 58,000 students. The program is sponsored by a large number of corporations, institutions, and individuals, with over 3,500 total contributors. Costs per team vary from $6,000 to up to $30,000, depending on the number of competitions in which teams participate. Grants are available regionally. Nearly $14.8 million in college scholarships are distributed as incentives for the program. Additional K-12 and university activities are summarized in Table 19, Table 20, and Figure 30.

Space-based education programs at the university level are distinct from other university activities, such as space research or technology demonstration, because their key purpose is educational. These activities are often funded by the universities themselves and designed around the academic calendar, taking place over a semester or academic year.

Program	# of students impacted	Average teams/ classes as of 2011	Average payloads per year	Year of Inception	Initial participation	Measurable outcomes	Cost
Parabolic flights (flying payloads and teachers)	~1.5 million	N/A	N/A	2006	250 teachers	1,300 teacher graduates	~$5,000 per individual
Team America Rocketry Challenge (TARC)	7,000 per year; 60,000 since inception	600	Each team flies a rocket; top 100 invited to national competition	2002	873 teams	4 out of 5 participants said TARC has had a positive impact on their course of study	$500-$1,000
National Center for Earth and Space Education, Student Spaceflight Experiments Program (NCESSE SSEP)	~22,000 students per flight opportunity; on average, 4,530 actively involved in design	180	1 per community (on average, 16)	2010	53 schools	No available data	$19,500
Great Moonbuggy Race	~300 teams	28 (high school only)	Each team develops a buggy	1994	8 teams	No available data	$500 - $5,000
PongSats	Several hundred per flight; over 10,000 to date	N/A	6 to 10 missions per year; each mission can carry up to 300 PongSats	2002	16 PongSats	No available data	High altitude balloon flight is free

Table 19: Examples of K-12 space-related education

Program Type	Universities Typically Participating	Typical Mass	Typical Cost
High Altitude Balloon	15	1 kg – 1000 kg (many are CubeSat-sized)	~$9,000
CanSat	71	< 1 kg	$400 - $600
CubeSat	74	≤ 1.3 kg	~$50,000 - $350,000 for development and launch
Sounding Rocket	99	9 kg	$1,000 - $12,000 (RockSat-C)

Table 20: Examples of university space-related educational programs

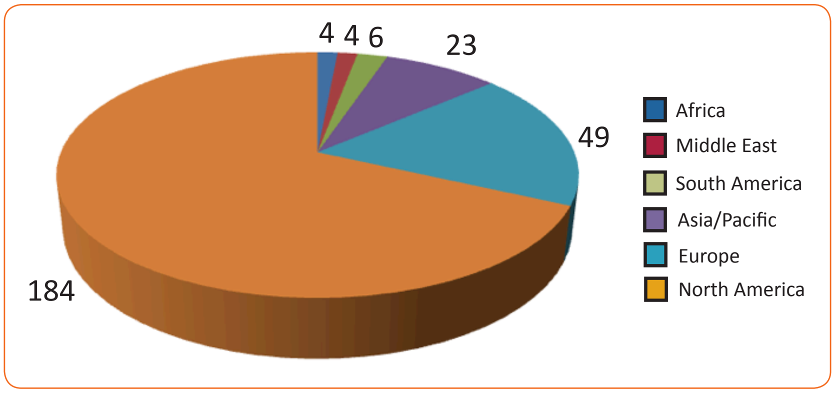


Figure 30: Universities participating in space-related educational programs by region

How SRVs Fit into the Market

SRVs can potentially enable novel and unprecedented levels of participation by students in space. The frequent launches could enable schools to align projects predictably with academic calendars, an important demand consideration for schools. Unlike what is typically the case with the ISS, payloads can be returned to students. Unlike parabolic flights or small rocket launches, the payloads will reach space. Costs to schools may be lower than orbital alternatives, depending on who is paying for the activity (space agencies often subsidize orbital education programs).

Potential programs, however, enter a crowded market characterized by constrained educational resources and some direct competition. Other space build programs offer free launches, such as NASA's CubeSat Launch initiative and Educational Launch of Nanosatellite programs. Developing awareness of the possibilities of SRV programs among science teachers is a marketing effort that may come with a high marketing cost for low-revenue transactions. SRV programs would need to be developed to align with existing curricula and would face competition from other non-space STEM programs. Finally, and critically, this competition is occurring in a market with increasingly tight budgets.

Current SRV Activities

There are several ongoing efforts to develop this market. In the state of Florida, an effort is underway to develop integrated curriculum modules that use SRV services and link those activities to state curriculum requirements. Several non-profit organizations have indicated their intention to participate in the industry through conference attendance and networking. The Space Frontier Foundation, a space industry advocacy organization, is sponsoring a non-profit project called "Teachers in Space" that will sponsor teachers to fly on SRVs. XCOR has donated, and Armadillo Aerospace has promised, a flight to this program, for a total of three seats.

The early uptake of these services has been mixed. UP Aerospace has, since 2009, launched educational payloads through the New Mexico Space Grant Consortium. The consortium includes 29 public high schools and 17 universities. These flights have been funded by NASA or New Mexico state funds. Separately, Blue Origin has begun an initial Flight Demonstration Program, with participation from Purdue University, University of Central Florida, and Louisiana State University. Garvey Spacecraft Corp. has offered to fly complimentary K-12 payloads but has not yet received substantial interest from schools.

SRV Demand Forecast

We forecast that K-12 schools will want to use SRVs for build projects and will be willing to pay to do so, if they are aware of the availability of SRVs and have a clear pathway to using them for students. Awareness and a preexisting pathway will both require investment to develop. SRVs are well suited for a major educational program similar to TARC or the FIRST Robotics Competition. K-12 educators will also fly on SRVs and will share their experience with students, similar to parabolic flights. The K-12 baseline forecast scenario assumes about 20 teams in the first full year of SRV operations will participate, similar to the participation in the initial year of FIRST Robotics. This grows to about 600 teams, the same level the FIRST Robotics competition and TARC achieved in 10 years. The baseline forecast also reflects the three initial teacher seats mentioned above, growing to 60 total seats for teachers over the 10-year forecast period, which is similar in expenditures to a previous program that flew 1,300 educators on Zero-G.

Universities that have launched space projects for education purposes in the past will either add SRVs to their launch options or transition from other options to SRVs. The university baseline forecast scenario includes involvement from about 15 universities—the current level of interest—in the initial year. This grows to 120 universities (currently involved in build projects such as CubeSats, RockSat-C, and CanSats) in the last year of the forecast.

Significant additional growth could occur if SRVs are able to build on the success of existing programs and attract more participants because payloads reach space. This growth could be constrained if educators do not gain awareness of suborbital spaceflight opportunities.

Education Forecast Methodology

To forecast the market for Education, the Tauri Group analyzed funding for K-12 schools and universities that participate in space activities and for the after school STEM programs mentioned above. The uptake and growth of the most successful of these programs was taken as a model for how this market could unfold.

The K-12 baseline forecast reflects education initiatives and efforts to include suborbital spaceflight activities in state curricula, but assumes other countries with STEM programs are likely to use indigenous space systems.

The university baseline forecast reflects use of SRVs for education payloads growing to about today's combined level of orbital, balloon, and parabolic flights.

Growth and Constrained Scenarios

The K-12 growth scenario reflects growth with a major education initiative similar to FIRST Robotics and TARC. This scenario requires a dedicated operating organization, corporate sponsorship, large prizes/scholarship fund, and outreach to schools. Growth reaches about 2,000 teams in 10 years, about the same as current FIRST participation. This growth also reflects growth in educator seats to 200 total, given the Space Frontier Foundation's stated goal for such a program.

The K-12 constrained scenario reflects minimal outreach and support to schools. The forecast represents a steady state of current activity, at about 20 teams per year.

The university growth scenario reflects strong use of SRVs due to high interest from students, given comparatively low cost for payloads that go to space. This grows to all 200 universities with indication of interest in space-related education (such as USRA participation or IAF membership) by the end of the forecast period.

The constrained scenario for university flights reflects light use of SRVs for education due to free alternatives such as NASA-sponsored balloon flights or CubeSat launches. This forecast includes no growth beyond current activities.

Estimate of 10-Year Demand

The baseline demand forecast for Education starts at 1 seat/cargo equivalent in Year 1 and grows to 26 seat/cargo equivalents in Year 10, for a total of 107 seat/cargo equivalents over the forecast period.

In the growth scenario, the forecast starts at 1 seat/cargo in Year 1 and grows to 99 in Year 10 for a total of 296 seat/cargo equivalents in the forecast period.

In the constrained scenario, the forecast starts at 1 seat/cargo equivalent in Year 1 and grows to 4 in Year 10, for a total of 33 in the forecast period. Figure 31, Figure 32, and Table 21 summarize the forecast projects for the education market.

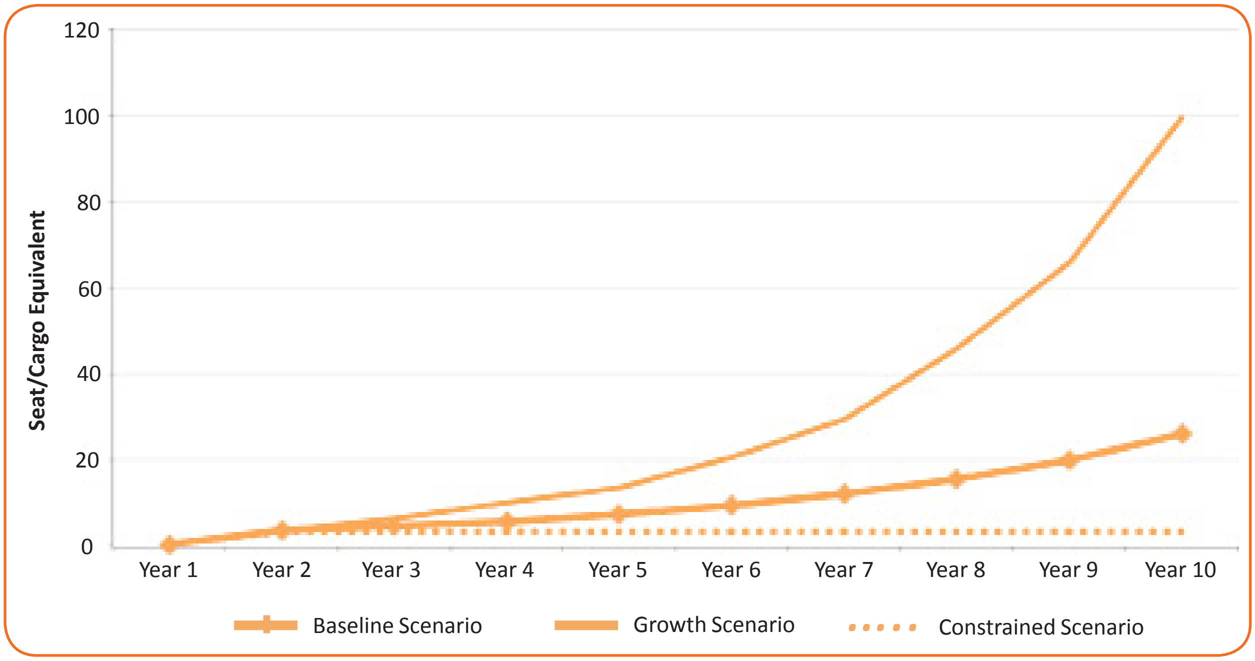


Figure 31: Baseline, Constrained, and Growth scenarios for Education

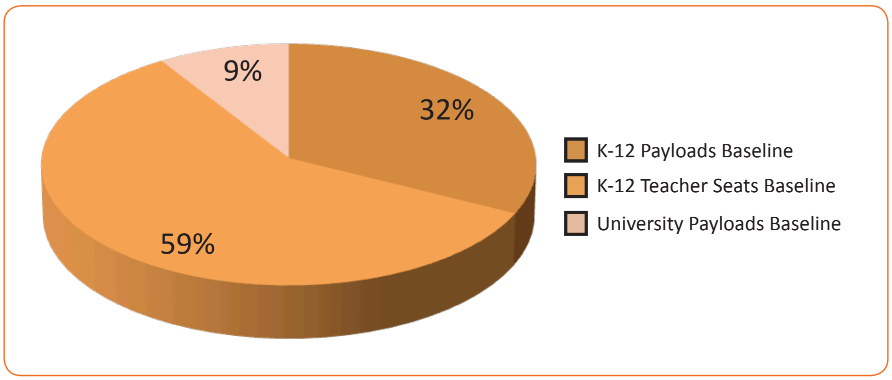


Figure 32: Education Baseline Submarket Share

Education	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	1	4	5	6	8	10	12	16	20	26
Growth Scenario	1	4	6	10	14	21	30	46	66	99
Constrained Scenario	1	4	4	4	4	4	4	4	4	4

Table 21: Education forecast in seat/cargo equivalents

Uncertainty

The forecast assumes effective coordination with schools through a non-profit or by SRV providers, with school-provided funding for SRV activities augmented by sponsorships and other resources. This model has been successfully demonstrated in other arenas. Although there is early activity by non-profits in the SRV arena, future outcomes could vary. Flight rate is not highly affected by such variation, because payload size for education payloads is assumed to be very small (typically about a 10 cm cube) based on similar existing payloads such as CanSats and CubeSats. Demand for larger payloads, up to locker-sized experiments for example, from university customers could increase flight rate (and would also require a higher financial commitment by universities). Alternatively, university demand may be where occasional government-sponsored free rides are available.

Lack of Awareness

Educators, particularly at the K-12 level, typically were unaware of SRVs. They were generally deeply interested in SRV potential after learning about their capabilities. Educators need easy on-ramp school participation that encompasses awareness and program support. Some of the specific elements of FIRST Robotics that enabled its rapid growth and success include scholarships, corporate sponsorship, a dedicated non-profit, incorporation into STEM curriculum, and marketing kits for educators and schools with tips on funding and how to get a team started.

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Satellite Deployment

SATELLITE DEPLOYMENT

The use of SRVs to launch small payloads into orbit

Very small satellite launch

SRV satellite deployment is the launch of very small satellites, mated to a propulsion stage, from SRVs. SRV capabilities in future vehicles may support launch of satellites under about 15 kilograms.

Market Dynamics

Today, very small satellites are used primarily for education and technology demonstrations by universities. Defense and civil agencies (domestic and international) are demonstrating new applications such as remote sensing, communications, and fractionated satellite architectures to support future systems. Types of very small satellites include single application satellites or large constellations of redundant satellites working together. SRV developers are envisioning second- or third-generation SRVs designed to launch very small satellites (around 15 kg) to low Earth orbit. Table 22 summarizes FAA-defined satellite categories and lists non-standard classifications emerging in popular usage for very small satellites that SRVs can launch.

Very small satellite deployment is an emerging market building on success of university payloads and growing interest from government customers. The market was revolutionized with the introduction of the Cubesat form factor (1 kg, a 10 cm cube) and the Poly-Picosatellite Orbital Deployer (P-POD) deployment system, which allows for rapid payload development and standard launch interfaces. From 2002 to 2011, 105 satellites under 15 kg were launched, primarily for universities in the United States. Germany and Japan, the next largest developers, each account for about 10% of the market. In 2012, 65 satellites worldwide (more than half the number launched over the previous decade) are currently manifested for launch as secondary payloads.

University demand for very small satellites (especially CubeSats), which traditionally dominates this market, is continuing to grow, especially in the international community. Only about 4% of planned very small satellites in the near future (through 2016) will be owned and operated by commercial companies.

Civil and defense agencies are increasing use of very small satellites and developing new capabilities and supporting infrastructure. The U.S. Army is in the process of developing a family of satellite systems under 25 kg (the Kestrel Eye imaging satellites and SNAP communication satellites). To support these satellites, the Army is also developing a dedicated launch vehicle for payloads 25 kg and under. DARPA is developing a fractionated architecture (the F6 program) for very small satellites. The National Reconnaissance Office (NRO) has a CubeSat program and has already purchased 10-20 CubeSats, with an option to purchase up to 50 total. NASA is supporting the CubeSat Launch Initiative that provides launch opportunities for university and civil payloads. These activities are mirrored globally as development of CubeSat and other very small satellites increases among international civil, military, and university customers.

FAA Categories	Mass and Non-Standard Classifications
Heavy	>20,000 lbs (9,072 kg)
Large	10,001 to 20,000 lbs (4,537 to 9,072 kg)
Intermediate	5,001 to 10,000 lbs (2,269 to 4,536 kg)
Medium	2,001 to 5,000 lbs (908 to 2,268 kg)
Small	201 to 2,000 lbs (92 to 907 kg)
Micro (up to 200 lbs [91 kg])	Includes "very small satellites" as defined in this report (under 15 kg). Emerging (informal) classifications for similar masses include: Nanosat: 1-10 kg (2-22 lbs) CubeSat: 1-2 kg (2-4 lbs) Picosat: 0.1-0.9 kg (0.2-1.9 lbs) Femtosat (Molesat): <0.1 kg

Table 22: FAA definitions for satellite masses

Over 90% of very small satellites have been deployed as piggyback payloads on existing launch vehicles. Currently, about one-third of the very small satellite deployments use low-cost, commercial launch vehicles, primarily Dnepr. As piggyback payloads, CubeSats can be deployed from specifically designed P-PODs, a standardized deployment system for sets of up to three CubeSats, reducing integration costs and risks. Larger payloads launch from a custom EELV Secondary Payload Adapter, Spaceflight Secondary Payload System, or other adapters that allow for many very small satellites to be launched together. Rarely, multiple very small satellites have been grouped to create a primary payload. Table 23 summarizes current options for the deployment of small payloads.

Deployment method	Vehicles	Payload Capability (kg)	Cost
SRV	Planned: Lynx III	Up to 12 kg	$500,000 for 12 kg
Secondary (Piggyback/ Rideshare) Payload	Dneper, PSLV, Falcon 9	Varies	$40,000 for 1 kg; $12.5M for small satellites
Small satellites grouped on a launch vehicle (existing)	One Shtil launch in 1998	Varies	Varies
Small satellite launch vehicles in development	Planned: SWORDS, KSLV 1 (Naro-1), Nanosat Launch Vehicle (NLV)	Generally 10 - 25 kg have been announced	~$1 million

Table 23: Options for small payload deployment

Over a dozen expendable launch vehicles specifically sized and designed to deploy very small satellites are in development internationally. These vehicles are intended to provide dedicated launch options with costs appropriate for launching very small satellites. Examples include the U.S. Army's Soldier Warfighter Operationally Responsive Deployer for Space (SWORDS), a nanosatellite launch vehicle, and DARPA's Airborne Launch Assist Space Access (ALASA) program. DARPA recently announced phase I contracts under the ALASA program, which included an award to Virgin Galactic that leverages the WhiteKnight2 carrier aircraft for an orbital launch system. Other examples include the Russian Angara, Korea Aerospace Research Institute (KARI) KSLV 1, Microcosm Inc.'s Sprite Mini-Lift Launch Vehicle, and several versions of Lockheed Martin's Athena.

How SRVs Fit into the Market

One SRV provider has announced plans to serve the very small satellite deployment market: XCOR, with its Lynx Mark III. The concept being discussed is a propulsion stage that carries very small satellites to low Earth orbit from the dorsal pod on a dedicated flight. The announced plans include a maximum payload of 12 kg, advertised costs of $500,000, and availability in 2017. (Several other SRV and orbital reusable companies plan to develop launch capabilities, such as Virgin's air launch concept. However, currently announced concepts do not use SRVs as the first stage.) This type of SRV capability would provide an opportunity for dedicated and responsive launch of new or replacement satellites.

While the market for very small satellite deployment is growing, there are many options for deploying satellites from existing launch platforms. This includes piggyback launches on larger vehicles as well as occasional dedicated flights for groups of very small satellites. Available deployment options differ according to the customer. Military and civil government customers frequently plan to include very small satellites as piggyback missions on existing planned launches, when appropriate. Universities and non-profits can purchase launch options from commercial providers and can take advantage of special programs, such as the NASA program that provides universities and civil agencies with launch opportunities on NASA-purchased vehicles.

SRV Demand Forecast

We forecast the demand for very small satellites will continue to increase through the end of the forecast. The total number of satellites 15 kg and under will grow to about 100 satellites worldwide in Year 10, with a total of 760 satellites launched over the 10-year forecast period. Future satellites are split relatively evenly between civil, military, and university, with about 4% of the market composed of commercial satellites. SRVs will capture a portion of these launches.

Most very small satellites will be co-manifested for SRV flights based on average mass for universities (3 kg), private (4 kg), and military and civil (5 kg). SRVs are unlikely to capture initial demand in this market segment, as there are no announced plans for a vehicle that can deploy satellites before 2017.

We project government agencies will continue to provide launches for university and civil satellites, limiting potential demand for SRVs. New military vehicles and continued piggyback launches of very small satellites on EELV, Falcon 9, and Dnepr will address some of the market through joint commercial initiatives or government-sponsored launches. We forecast SRVs will capture the segment of the market currently captured by low-cost commercial launch vehicles, growing to about 14 satellites per year.

Estimate of 10-Year Demand

The baseline demand forecast for Satellite Deployment starts at 7 seat/cargo equivalents in Year 1 and grows to 16 seat/cargo equivalents in Year 10, for a total of 117 seat/cargo equivalents in the forecast period.

In the growth scenario, the forecast starts at 21 seat/cargo equivalents and grows to 42, for a total of 318 seat/cargo equivalents in the forecast period.

In the constrained scenario, the forecast starts at 3 seat/cargo equivalents in Year 1 and grows to 6 in Year 10, for a total of 39 in the forecast period.

Note that demand begins in Year 1 (which could occur in 2013 or 2014), but a supply of satellite-launch-capable SRVs is not likely to exist until 2017 or later, based on current plans. Figure 33, Figure 34, and Table 24 summarize the forecast for small satellite launches.

Satellite Deployment Forecast Methodology

The baseline scenario reflects demand based on manifested and planned very small satellites adjusting for likely schedule changes. The market is projected to grow beyond 2016, driven by the adoption of the CubeSat form factor, increased international and government interest, and improved very small satellite technologies, which enable new applications. Demand for SRV launch of these satellites includes a market capture of 10 percent of civil and military very small satellites, reflecting individual technology demonstrations rather than large constellations. This demand also includes about one-third of all other very small satellites, reflecting the current rate of deployment by low-cost commercial launch options. The remaining satellites are launched on a combination of more expensive commercial launch vehicles and government vehicles, include very small satellites launched as large constellations, and include programs that provide discounted opportunities to universities like the NASA CubeSat Launch Initiative.

Growth and Constrained Scenarios

The growth scenario reflects a market where SRVs provide a very strong alternative to existing and planned orbital vehicles. In this scenario, the entire civil and military market is addressable by SRVs and results in about one-third of market capture.

The constrained scenario reflects continued growth in university demand, but commercial, civil, and military markets do not develop or are captured by other systems. Demand for very small satellites reflects a return to historic growth rates in this market (before the recent upturn in very small satellite deployments), translating into a growth rate of 1.5% (instead of 7.5% in the baseline) beyond 2016.

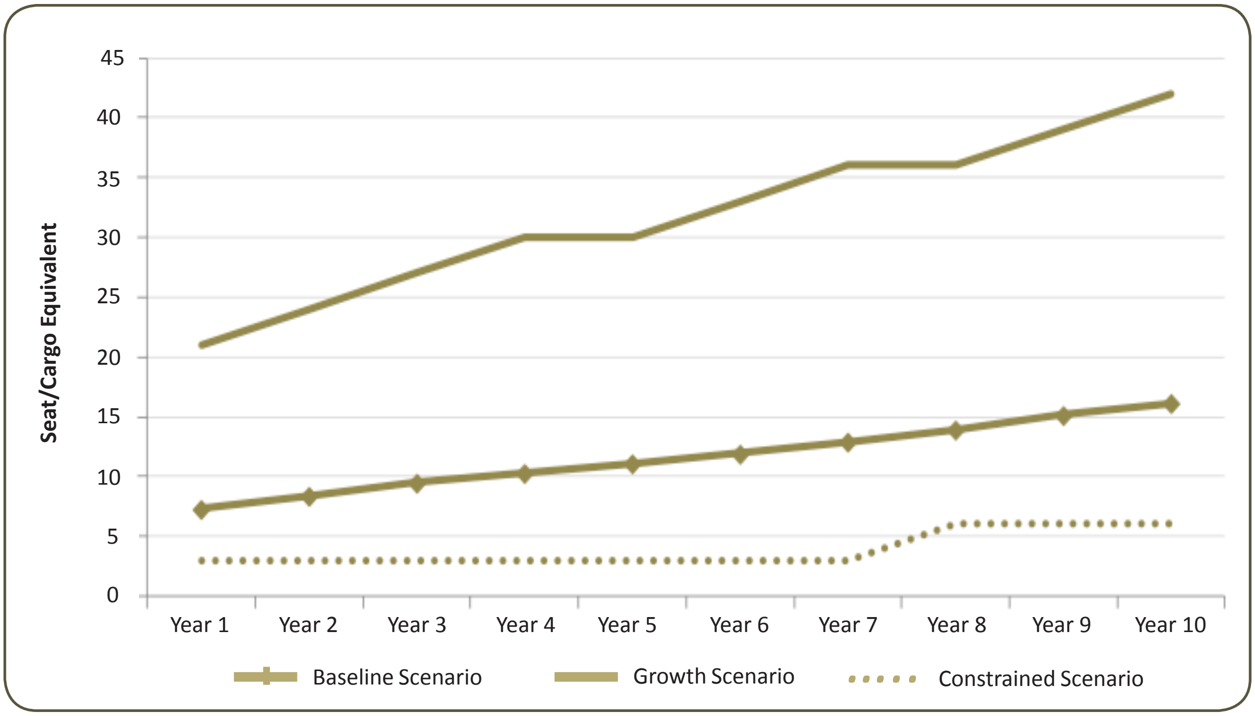


Figure 33: Baseline, Constrained, and Growth scenarios for Satellite Deployment

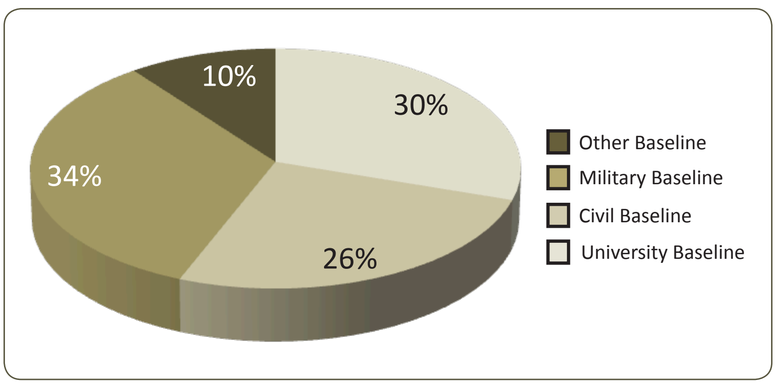


Figure 34: Satellite Deployment Baseline Submarket Share

Satellite Deployment	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	7	8	9	10	11	12	13	14	15	16
Growth Scenario	21	24	27	30	30	33	36	36	39	42
Constrained Scenario	3	3	3	3	3	3	3	6	6	6

Table 24: Satellite Deployment forecast in seat/cargo equivalents

Uncertainty

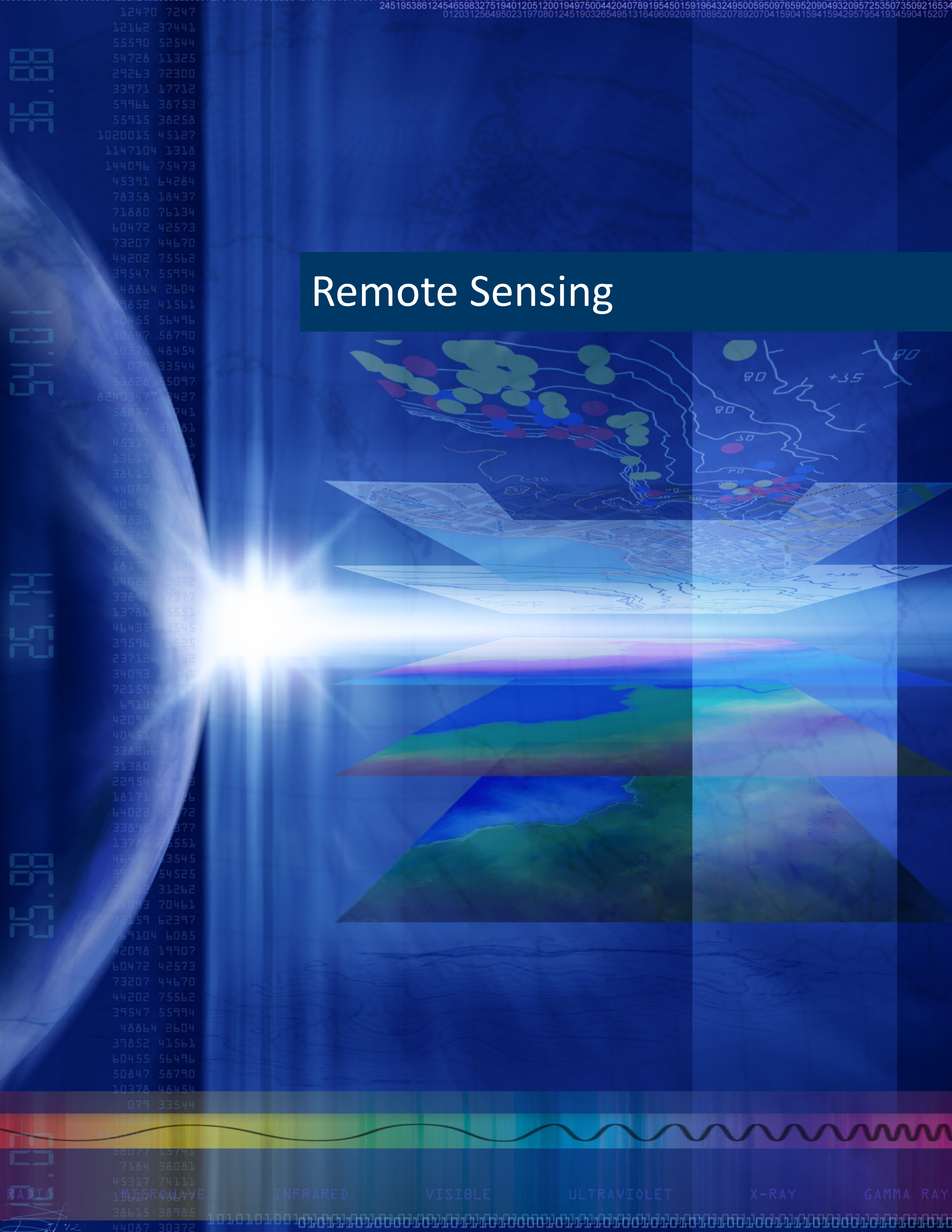
The timing of SRV systems capable of deploying satellites is the largest uncertainty in this market. The longer they take to develop, the more market capture will be reduced. Market capture could erode significantly if competing military systems deploy and capture all military demand before SRVs are available.

The baseline forecast assumes continued support for the NASA Cubesat Launch Initiative. This initiative helps energize the community, resulting in more payloads and providing more launches. If these launches continue to be provided as piggyback payloads on EELVs, this will reduce the number of very small satellites SRVs can launch.

Lack of Awareness

The U.S. Defense community is a potential customer for SRV satellite deployments in the near term. Ensuring that SRV capabilities are well understood and avoiding government overlap in developing capabilities may increase demand for SRVs. As noted earlier, SRV provider Virgin Galactic is already participating in DARPA's ALASA program.

Remote Sensing



The SRV remote sensing market is the use of SRVs for the acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications.

REMOTE SENSING

Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

Commercial Earth imagery
Civil Earth imagery
Military surveillance

Market Dynamics

SRVs would compete in a robust existing industry using satellite and aerial platforms, including unmanned aerial vehicles (UAVs). Table 25 compares these platforms.

Platform	Resolution	Swath Width	Revisit Time	Spectrum	Remarks
Aerial imagery (piloted)	Very high resolution (cm)	Tens of square kilometers	On demand	Any	• Establish market • Fights regulated • Overflight permission required • Moderate investment • High Cost per image
Aerial imagery (UAVs)	Very high resolution (cm)	Tens of square kilometers	On demand	Any	• Emerging market • Flights not formally regulated • Overflight permission required • Low investment • Moderate cost per image
SRVs	High resolution (m)	Hundreds of square kilometers	On demand	Any (due to short loiter time, may not be ideal for radar)	• Emerging market • Launch and reentry regulated (U.S.) • Overflight permission required • Moderate investment • High cost per image • Currently limited viewing area
Satellites	Low to high resolution (km to m)	Thousands of square kilometers	Days	Any	• Established market • Some regulation • No overflight permission required • Shutter control • High investment • Low cost per image • Revisit time can be enhanced by increasing number of satellites in one orbit

Table 25: Comparison of remote sensing platforms

The existing market for remote sensing is served by aerial and satellite platforms, both of which are well established, well known, and mature. In general, the information product is the differentiator, and the platform is irrelevant to the customer. Demand is driven by preferences in image type (panchromatic, hyperspectral, etc.), timeliness, accuracy, resolution, quality, and other parameters. Challenges for SRVs include overflight restrictions, the high velocities achieved, and fixed runways and logistics support that limit operating locations.

In military applications, the opportunity to view areas of interest from safe airspace is theoretically appealing. However, there are few, if any, areas of the world where this is currently a requirement. In addition to satellite imagery, there has been a large increase in the use of UAVs for intelligence, surveillance, and reconnaissance in the past decade. UAVs range in size and capabilities to fit a wide number of missions, including in hostile regions.

How SRVs Fit into the Market

SRVs create a potential market niche between aerial and satellite remote sensing in terms of swath width, resolution, and revisit time.

SRVs have potential applications in civil, commercial, and military remote sensing. Civil and commercial applications are similar to the many current remote sensing applications. A few examples are disaster management, border security, policy enforcement (such as fisheries), pipeline surveillance, commodity forecasting, competitive intelligence, and agriculture. For military applications, SRVs potentially offer a novel capability in a forward, deployed situation. SRVs could ascend in friendly airspace and achieve views into hostile territory without violating airspace restrictions or exposing the vehicle to the threat of engagement.

SRV Demand Forecast

Due to current robust, lower cost alternatives, limited interest identified during interviews, and advanced alternatives in development, we do not foresee a clear competitive advantage for SRVs in the remote sensing market. This market does not drive flight rates within the forecast time frame.

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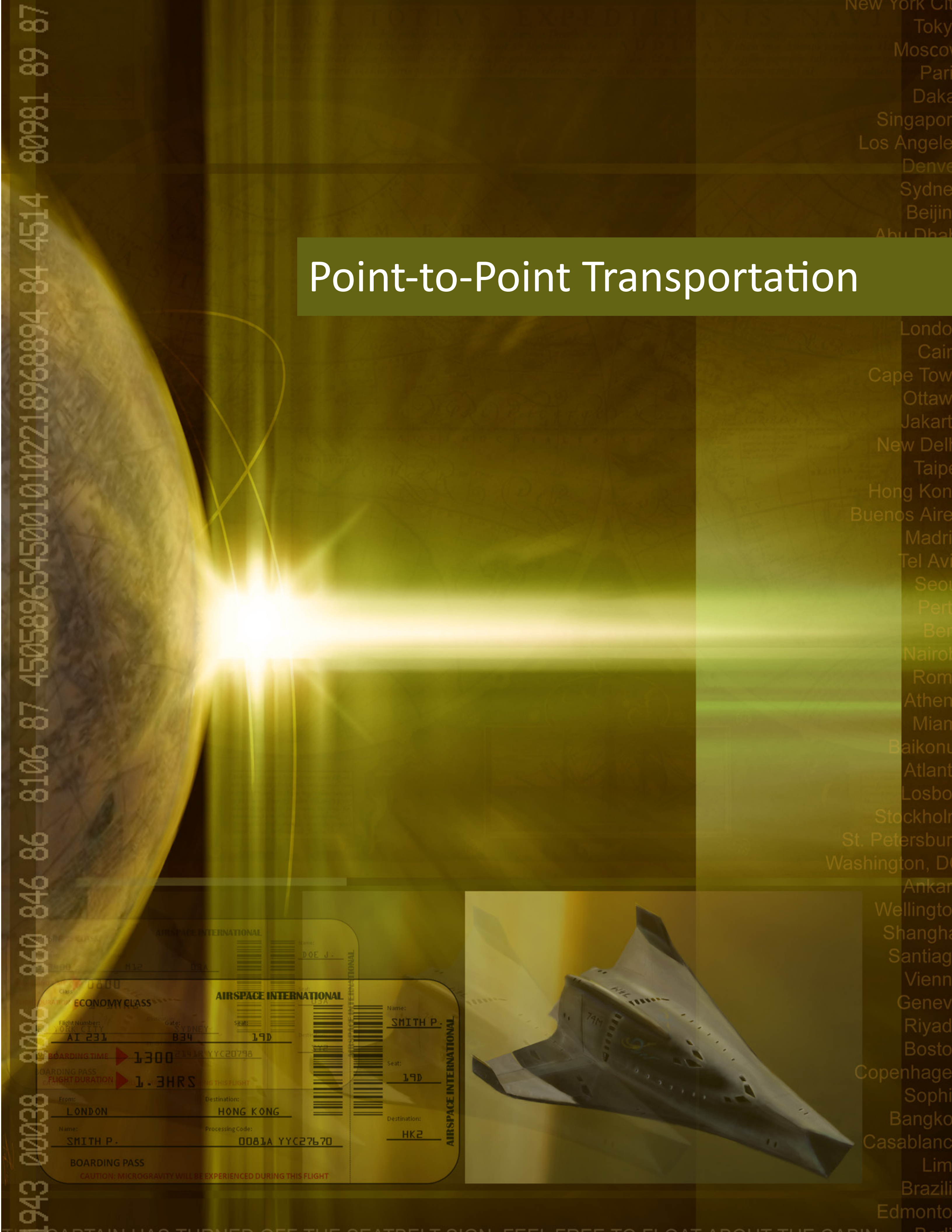
Point-to-Point Transportation



SRV point-to-point transportation (P2P) is transporting humans or cargo between locations through the space environment, achieving significant improvements to today's travel time between distant hubs. A trip from Washington DC to Tokyo, normally 14 hours in the air, could be accomplished in 2 hours.

While there is significant interest and effort in researching and developing the technologies necessary for P2P, long-distance P2P is unlikely to be operational within the study period of 10 years.

POINT-TO-POINT TRANSPORTATION

Future transportation of cargo or humans between different locations

Fast package delivery
High-speed passenger transportation (civil)
High-speed troop transportation (military)

Market Dynamics

The largest barrier to P2P is developing, maturing, and integrating technologies into capable systems.

The research and planning required for P2P is underway. Organizations such as the DoD, DARPA, Air Force Research Laboratory (AFRL), Boeing Phantom Works, NASA, the Aerospace Industries Association, and the FastForward study group have identified key enabling technology areas, including:

- Aerodynamics
- Hypersonics
- Guidance, navigation, and control
- Propulsion
- High-temperature materials and thermal protection systems
- Fuel/propellant storage
- Electrical power generation and storage
- System autonomy
- System integration
- Spaceport, ground, and range operations
- Ground test facilities

How SRVs Fit into the Market

Currently planned SRVs can be viewed as setting the stage for P2P, using future vehicles to transport high net worth individuals and executives, as well as high-value items, such as organs for transplant or fresh flowers and fish.

Current SRV Activity

Current SRV designs in development do not support long-distance P2P. Currently planned vehicles are not able to achieve the speeds and distances required for P2P. However, some companies, such as PlanetSpace and Reaction Engines Ltd., have said they are in the initial planning stages for developing P2P vehicles.

SRV Demand Forecast

Operational P2P is unlikely to occur during this study's forecast period. Key technical, logistical, legal/regulatory, and economic barriers must be overcome. In addition to the critical vehicle advances required, more knowledge of the hypersonic environment is needed. Logistically, a P2P infrastructure requires spaceports at each destination, with integration with other modes of transportation. Other challenges include integration with the U.S. National Aerospace System and Air Traffic Control system and international air systems, overflight restrictions, environmental regulations, insurance, and pricing/business case.

The Concorde was a supersonic transport, flown between 1976 and 2003. The Concorde's fast transport and high seat prices—flying between New York and London in under four hours for around $10,000 (U.S.) round trip—targeted corporate and high net worth individual travel markets. The Concorde demonstrates that many factors, in addition to technology, will define the successful business model for SRV P2P services.

The Concorde was retired in 2003 due to "nonprofitable commercial operation," which has been attributed to:

- Inefficient fuel use and fuel cost
- Environmental concerns
- Prohibition of flying over land in the United States
- The Paris crash in 2000 and costs to recertify (note that prior to the 2000 Paris crash, tire blow-outs and pieces falling off mid-flight were common)
- Impacts of 9/11 on the air travel industry
- High operations and maintenance cost

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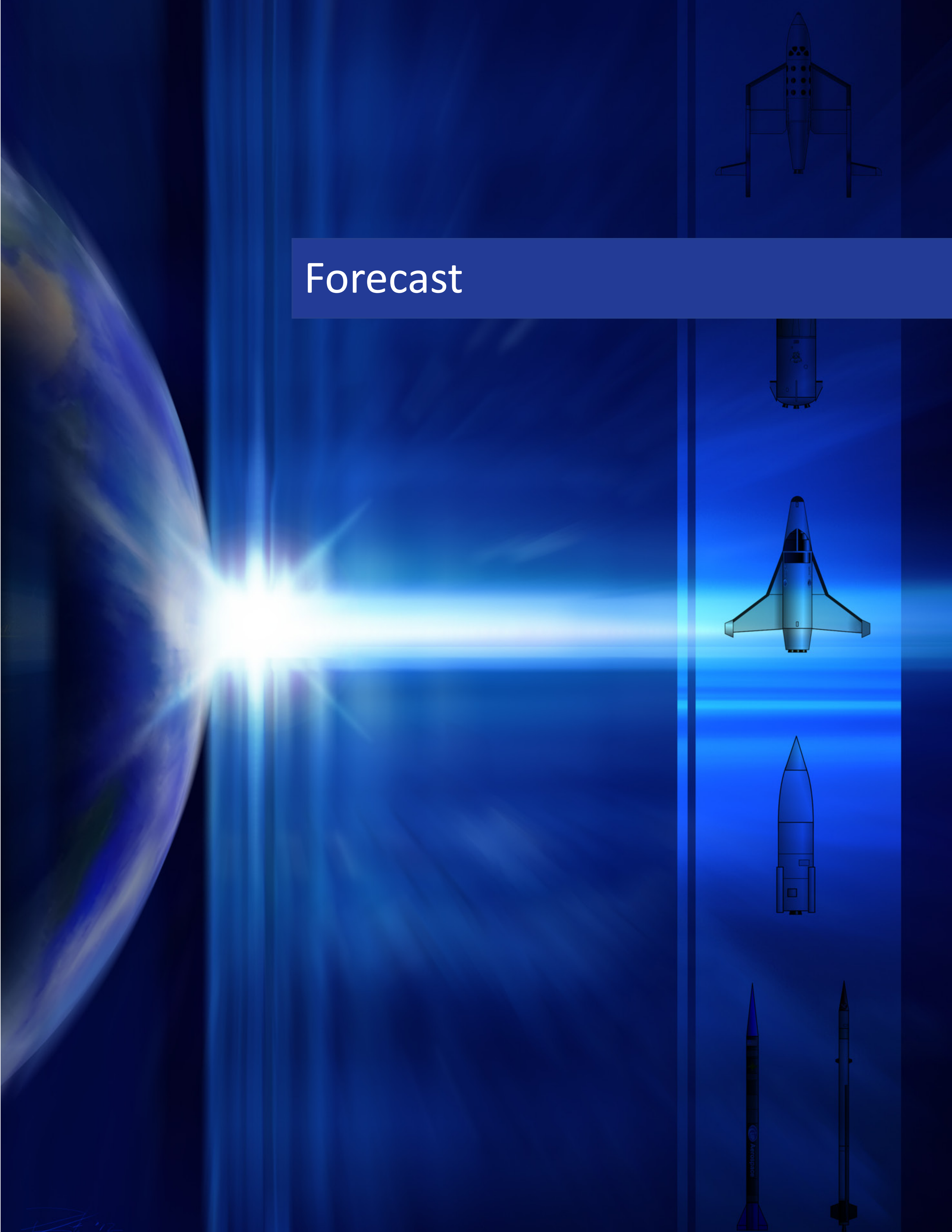
Forecast



Total projected demand for SRVs, across all 6 relevant markets, grows from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the tenth year of the baseline case. (Year 1 represents the first year of regular SRV operations.) Demand in the growth scenario, which reflects increases due to factors such as marketing, research successes, and positive response to flight operations, grows from about 1,100 to more than 1,500 seat/cargo equivalents over 10 years. The constrained scenario, which reflects significantly reduced consumer spending and government budgets, shows demand from about 200 to 250 seat/cargo equivalents per year (see Table 26).

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Baseline Scenario	373	390	405	421	438	451	489	501	517	533	4,518
Growth Scenario	1,096	1,127	1,169	1,223	1,260	1,299	1,394	1,445	1,529	1,592	13,134
Constrained Scenario	213	226	232	229	239	243	241	247	252	255	2,378

Table 26: Total projected demand for SRVs across all markets

Demand by Market

As shown in Figure 35 and Table 27, which compare forecasts for all markets by scenario, demand for SRVs is dominated by Commercial Human Spaceflight. More than 80% of forecasted demand in all scenarios results from individual leisure passengers. Those travelers are typically wealthy (with an estimated 95% having net worth in excess of $5 million) and from countries around the globe. About one-third are from the United States.

The second largest area of demand is Basic and Applied Research, funded by government agencies (about half) and by research non-profits, universities, and commercial firms. Research accounts for about 10% of baseline demand. Government research agencies will be particularly significant sources of funding for research in UV and IR astronomy, atmospheric research, microgravity research, and studies on large populations of humans flying on SRVs. Non-profit organizations have purchased research flights for early demonstrations of research applications. The research involvement of commercial firms reflects demand for "what-if" research to explore the potential of SRVs, rather than reflecting a single commercial research application for SRVs.

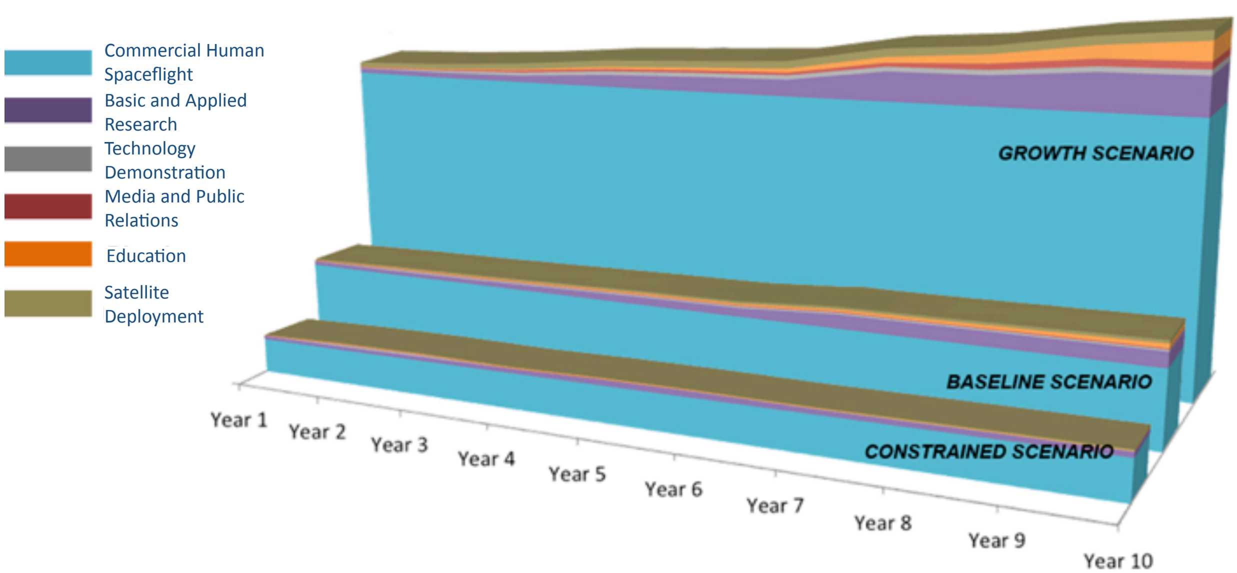


Figure 35: Total SRV forecast by market and scenario

The remaining markets generate demand for about 350 seat/cargo equivalents by the end of the forecast period—about 10% of total baseline demand from Satellite Deployment, Education, Aerospace Technology Test and Demonstration, and Media and Public Relations.

Growth Scenario

Demand in the growth scenario increases in all markets, with the largest increase (from nearly 4,000 seats over 10 years in the baseline to more than 11,000) in Commercial Human Spaceflight, which triples as a function of enhanced consumer interest and new spending patterns responding to SRV marketing and flight experience successes. The second largest market remains Research, with demand for nearly 900 seat/cargo equivalents over 10 years due to new government programs, doubled commercial activity, and more rapid uptake by international space agencies, driven by demonstrated research successes. In all other markets, demand doubles or triples.

Constrained Scenario

The constrained scenario sees demand fall to about half the baseline level, primarily as a result of reduced consumer demand. Ten-year Commercial Human Spaceflight demand in the constrained scenario is slightly more than double (about 2,000) the current number of ticket holders (925). Other markets reflect demand at about half baseline levels or less.

Figure 35 and Table 27 compare forecasts for all markets by scenario.

	Market	SEAT/CARGO EQUIVALENTS										
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
BASELINE	Commercial Human Spaceflight	340	344	353	359	366	372	379	385	392	399	**3,688**
	Basic and Applied Research	19	21	25	32	40	44	71	73	75	78	**477**
	Technology Demonstration	2	9	9	9	9	9	9	9	9	9	**83**
	Media and Public Relations	4	4	4	4	4	4	5	4	5	5	**46**
	Education	1	4	5	6	8	10	12	16	20	26	**107**
	Satellite Deployment	7	8	9	10	11	12	13	14	15	16	**117**
	TOTAL	373	390	405	421	438	451	489	501	517	533	**4,518**
GROWTH	Commercial Human Spaceflight	1,046	1,060	1,079	1,099	1,118	1,138	1,159	1,179	1,200	1,222	**11,300**
	Basic and Applied Research	21	25	31	56	68	76	132	135	168	171	**884**
	Technology Demonstration	4	9	15	17	19	20	21	22	24	25	**177**
	Media and Public Relations	4	4	10	11	11	12	17	27	32	32	**159**
	Education	1	4	6	10	14	21	30	46	66	99	**296**
	Satellite Deployment	21	24	27	30	30	33	36	36	39	42	**318**
	TOTAL	1,096	1,127	1,169	1,223	1,260	1,299	1,394	1,445	1,529	1,592	**13,134**
CONSTRAINED	Commercial Human Spaceflight	187	188	191	195	198	202	205	209	213	216	**2,003**
	Basic and Applied Research	18	19	22	23	30	32	28	28	28	29	**256**
	Technology Demonstration	2	9	9	1	1	1	1	1	1	1	**26**
	Media and Public Relations	3	3	3	3	3	2	1	0	1	0	**20**
	Education	1	4	4	4	4	4	4	4	4	4	**33**
	Satellite Deployment	3	3	3	3	3	3	3	6	6	6	**39**
	TOTAL	213	226	232	229	239	243	241	247	252	255	**2,378**

Table 27: SRV forecast details by market (Note: Totals may not add up exactly due to rounding)

Demand by Type of User

While a large part of the SRV forecast is consumer demand for human spaceflight, the market for enterprise sales—participation by businesses, governments, schools, and non-profits—is an important element of how the SRV activity will unfold. Demand among the enterprise users and individuals is fundamentally different in terms of the purchasing dynamics and intended applications. In the baseline scenario, enterprise demand is almost one-fifth of total demand (see Figure 36).

Individuals

The majority of SRV demand comes from individuals; the SRV market is a consumer market. Consequently, the capability and viability of SRV ventures will be heavily influenced by individual decision makers.

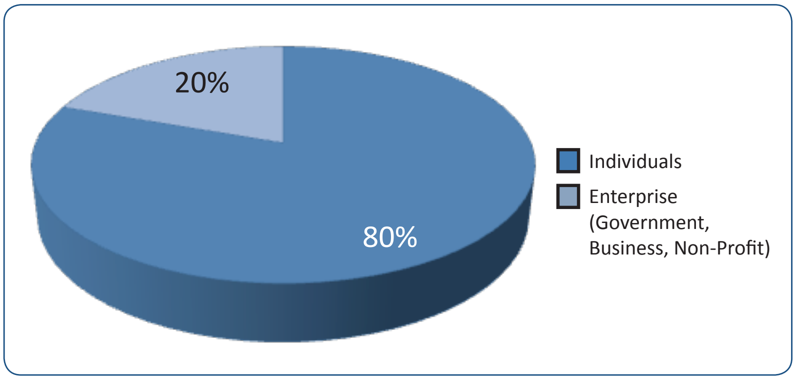


Figure 36: Enterprise demand and individual demand in baseline case

Demand in this market can develop, grow, or shrink rapidly. Unlike enterprise users whose lead times for decision making is typically measured in years (reflecting annual budgeting processes and government program timelines), individuals can make purchasing decisions quickly.

This market will be sensitive to perceptions of risk and how expectations and shared experiences of SRV flights disseminate. To date, most providers have not engaged in extensive marketing and public outreach, leaving significant room for providers to continue to shape and frame how the industry is perceived. Direct experiences of spaceflight have not yet occurred, either in operational launches carrying humans or in test launches of current vehicle configurations carrying humans. The first participants' public reviews could affect how the experience is perceived. Perceptions of risk will affect individual views of SRV flight, as well as alignment with other stakeholders (such as family members and business partners) and legal agreements and insurance.

The behavior of consumers in the future remains uncertain. Those that have already purchased tickets may represent an early adopter population, with different motivations and risk dispositions than the broader market. At least some portion of tickets sold to date are refundable or are deposits rather than full payments, creating a possibility that not all ticket holders will convert to passengers. Alternatively, marketing and visibility resulting from the approach of flight operations, or successful and publicized flight experiences, could significantly – and rapidly – increase demand.

Enterprises

Enterprise demand includes government, commercial, non-profits, and school and university SRV users. Enterprises represent about one-fifth of total forecasted SRV demand.

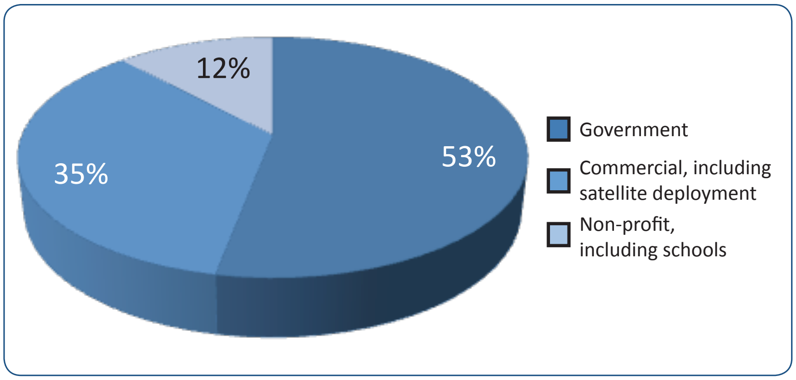


Figure 37: Enterprise demand by type of user

Figure 37 shows enterprise demand by user. About half is government agencies, followed by commercial entities (more than one-third), with schools and non-profits accounting for the remaining 12%. Over 40% of government demand is NASA. (Note that this means that our forecast projects that NASA represents less than 5% of total SRV demand). About 10% is non-U.S. agencies, mainly in the Research and Technology Test and Demonstration markets.

Demand from commercial entities is about 30% Research, 15% Media and PR, 18% Commercial Human Spaceflight, with the rest from very small satellite launches.

Figure 38 shows enterprise demand by payload. About 70% of enterprise demand is for cargo payloads (distinct from seats). These are primarily research payloads and sensors but also include satellite deployment and media payloads. About 30% of enterprise demand is for seats, in markets including Research (researchers on tended experiment flights), Education (teachers in space), Media and PR, and the enterprise elements of Commercial Human Spaceflight (corporate contests, incentives, and training flights).

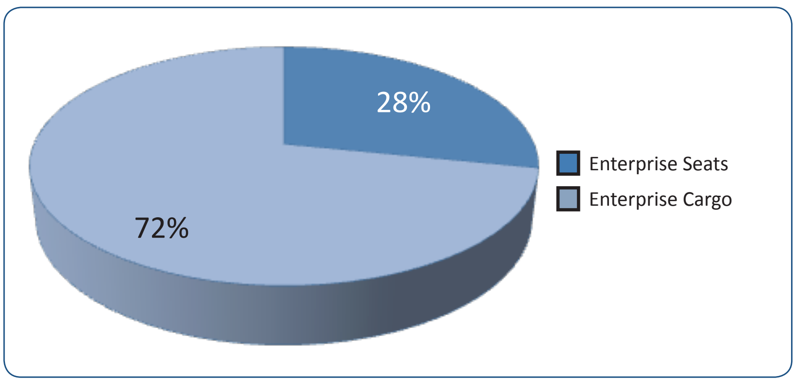


Figure 38: Enterprise demand by type of payload

Figure 39 summarizes overall demand among enterprise customers by market area. More than half of enterprise demand is in the Basic and Applied Research market. Though the footprint of forecasted Education activities is large, involving hundreds of schools and universities, the resulting flight rate is relatively modest, mainly reflecting very small student payloads. Education totals about 12% of the enterprise demand. Media and PR (including television and sponsorships), and corporate promotions and contests in Commercial Human Spaceflight, comprise about 11% of the enterprise demand. Technology Test and Demonstration comprises an additional 10%.

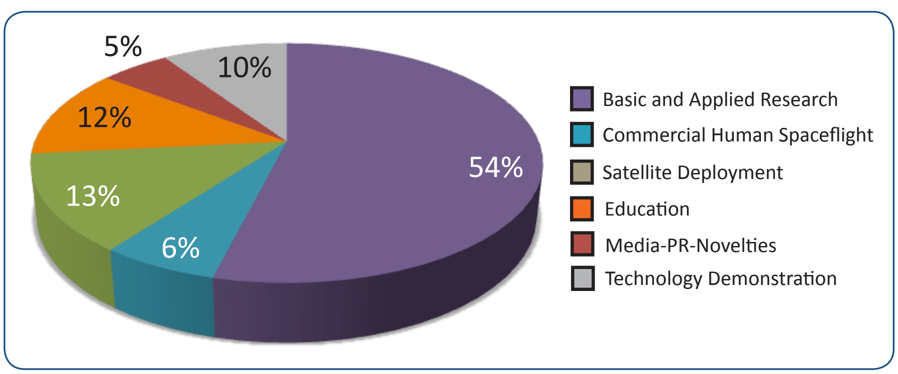


Figure 39: Overall demand among enterprise customers by market area

Type of SRV Payload

Across markets, 86% of total demand is for seats and 14% for cargo. Commercial Human Spaceflight, Research, Media and PR, and Education include demand for seats. The demand for cargo is about 60% from Research, and the rest is from very small satellite deployment, Media and PR, Education, and Aerospace Technology Test and Demonstration.

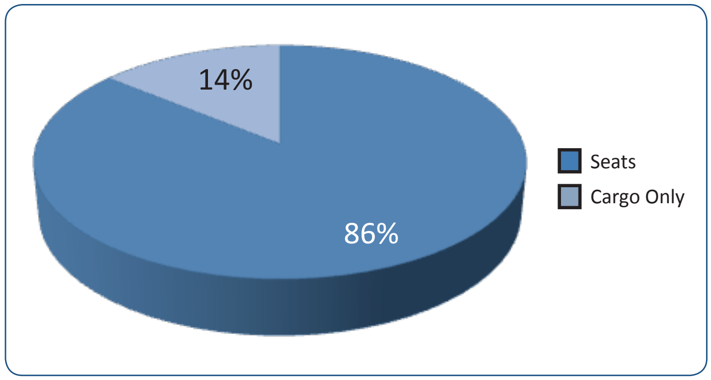


Figure 40: SRV seats versus cargo

Revenue

As an indicator of the revenue associated with estimated demand, we translated our forecast from seat/cargo equivalents at a rate of $123,000 per seat/cargo equivalent. This estimate reflects announced seat prices across vehicles in active development, extrapolated to all vehicles (including cargo-only vehicles) based on vehicle capacity. It is a rough estimate. No cargo prices (other than satellite deployment costs on an XCOR Lynx Mark III) have been announced, though some providers have stated informally that cargo costs align with seat costs for their vehicles. The mix of vehicles in operation will affect both demand and revenue. Vehicles are priced differently and have different capabilities.

Our forecast roughly translates a total of $600 million in demand over 10 years in the baseline case. The growth scenario totals $1.6 billion, and the constrained scenario totals $300 million.

There are important caveats to these estimates. They do not reflect all related expenditures associated with demand (such as, for example, budgets for developing experiments hardware and paying researchers, or revenues from spaceport activities for family and friends of those flying). They also do not represent predicted SRV flight revenues, but rather the potential revenue associated with SRV demand. The interplay of supply with demand is unaccounted for. For example, there is near-term demand for satellite launches at SRV prices and reflective of SRV capabilities, but no SRVs capable of launching satellites are anticipated until 2017.

Actual revenues will depend on when vehicles become operational, the pace of operations overall, the relative flight rates of providers, ancillary sources of revenue, and future price levels. If, in Year 1, reservations occurred at roughly the rate at which they have recently been announced (150 in 2011 and 185 in 2012, and a total of 925 since 2003), sales to fulfill our demand forecast in the baseline would grow at about 18% annually. In the growth scenario, sales would increase at about 40% each year. The constrained scenario would grow at about 4%. Announced historical reservations, compared to this possible trend of future reservations, are shown in Figure 41.

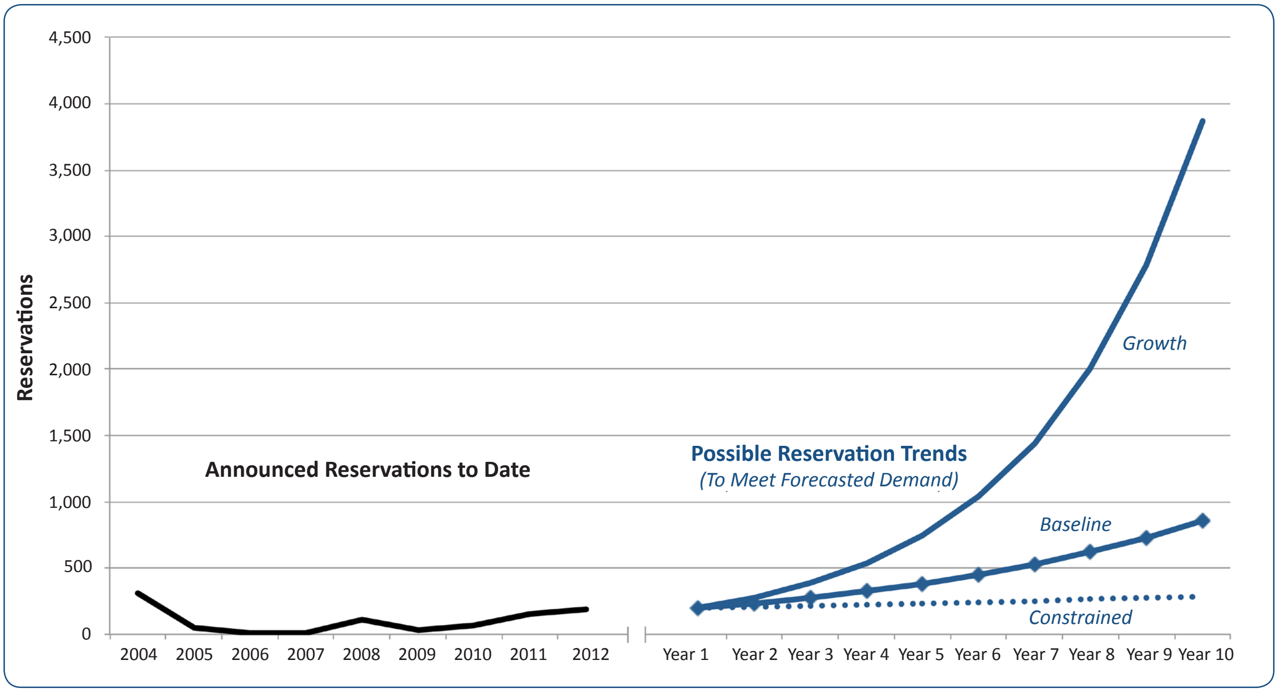


Figure 41: Possible reservations trend to meet forecasted demand

Summary of Major Uncertainties

The forecast predicts outcomes related to experiences that, for the most part, do not yet exist. Human spaceflight on SRVs and demonstration of research capabilities of new SRVs will shape attitudes and behavior and may change outcomes, as will other factors such as general awareness, perceptions of safety, and media posture. If levels of SRV capability and performance vary from what is expected based on today's information, demand will change from predicted levels.

Forecast results are particularly sensitive to assumptions regarding future consumer behavior. The forecast assumes passengers fly once only, that a potential passenger has a 1/25 probability of flying in a given year (so 40% of interested passengers today will fly within the next 10 years), and that most (95%) passengers have net assets exceeding $5 million. Relaxing or strengthening any of these assumptions changes demand significantly. For example, if 80% of interested passengers fly in the next 10 years, the forecast doubles. If passengers with a net worth of $1M rather than $5M are commonplace, the addressable market increases dramatically. If SRV flight experiences disappoint early adopters, or even a small but vocal or influential subset, demand could erode.

About one-third all projected enterprise demand comes from commercial firms. The forecast predicts exploratory, "what if" research by commercial companies globally. This forecast reflects that no clear commercial applications have been identified, but anticipates that companies will want to understand the capabilities and opportunities provided by SRVs for many types of microgravity research. Research success and identification of a clear, related commercial application that requires sustained, ongoing SRV use could increase funding beyond the $2.5 million to $5 million per year in annual commercial research spending on SRV flights. Loss of interest in speculative research or poor performance by SRV research payload investments could limit commercial exploratory funding below these levels.

Television, film, advertising, and public relations activities are highly changeable, because they are driven by the complex dynamics of social networks, brand identity, and market position that are difficult to predict, particularly before flight operations have begun. The decisions of a single individual, such as a particular producer or content developer, can also affect these dynamics.

Finally, the forecast reflects expectations about future government interest in SRVs. In the United States, the forecast predicts modest funding will transfer from existing platforms for astronomy, atmospherics, human research, and microgravity to SRVs, with funding from agencies that historically spend little on space research (including NSF, NIH, and NOAA). This reflects anticipated quality, responsiveness, and pricing of SRV capabilities relative to alternatives in these areas. If SRV capabilities vary from current expectations, these levels of activity could be either higher or lower. While NASA is predicted to be a user of SRVs, a number of NASA programs aligned with SRV capabilities are not assumed to transition to SRVs in the baseline forecast. If NASA decision dynamics change, SRVs could be used for astronaut training, to replace sounding rockets to a greater degree, or for microgravity research integrated with ISS activities. The forecast also predicts that more than 50 international governments will begin to fund SRV research. National restrictions on access to SRVs could potentially limit funding from these governments. Alternatively, rapid uptake and greater activity from these nations could result in higher demand than predicted.

Limited Awareness of SRVs

Many potential SRV users are not fully aware of the anticipated availability of SRVs or their projected capabilities. While awareness will grow organically as operations begin, and deliberately as SRV providers increase marketing and outreach, our research identified areas of limited customer familiarity that may benefit from targeted efforts to increase awareness.

Existing space-knowledgeable researchers may not be aware of SRV capabilities as research platforms—in particular, how SRVs might perform as an adjunct to platforms such as the ISS. Researchers also have questions on the details of SRV performance and would value data from instrumented flights (for example, accelerometer readings). Non-space researchers, even in potentially relevant areas such as pharmaceuticals or biotechnology, often have no knowledge of SRVs, much less how SRVs could help advance their specific research.

Educators at K-12 schools, who often have no knowledge of SRVs (or even of broader current space activities), are intrigued when informed about SRVs and the possibilities of student-built space payloads at school-accessible price points.

Some potential government users are aware of SRV capabilities, and certain programs within NASA, DARPA, and other agencies seek to make early use of them. Among other government users, there is potential overlap of existing government capabilities with new SRV capabilities, amid limited awareness of how SRVs might meet their needs. One example is very small satellite deployment. Although some SRV companies are involved with DARPA's program already, other programs are not considering SRVs. Other examples include sounding rocket research and astronaut training. A related instance involves commercial orbital platform developers, who are aware of SRVs but do not view them as fitting into their development or test programs. Finally, there is a general lack of knowledge within the space community regarding how SRV technology payloads will support TRL advancement. There may be an opportunity for recognition of SRV-flown technologies as space-demonstrated or space-qualified.

Conclusion

Demand for suborbital flights is sustained and appears sufficient to support multiple providers. Demand encompasses commercial human spaceflight, research, education, satellite deployment, and media and public relations activities. The total baseline demand over 10 years exceeds $600 million in SRV flight revenue, supporting daily flight activity. The baseline reflects predictable demand based on current trends and consumer interest. In a growth scenario, reflecting increased marketing, demonstrated research successes, increasing awareness, and greater consumer uptake, multiple flights per day generate $1.6 billion in revenue over 10 years. In a constrained scenario, where consumer and enterprise spending drop relative to today's trends, multiple weekly flights generate about $300 million over 10 years. Further potential could be realized through price reductions and unpredictable achievements, such as major research discoveries, the identification of new commercial applications, the emergence of global brand value, and new government (especially military) uses for SRVs. Uncertainty is embedded in the forecast, as it predicts outcomes related to experiences that, for the most part, do not yet exist. Human spaceflight on SRVs and demonstrated research capabilities of new SRVs will shape attitudes and behavior and change outcomes, as will other factors such as general awareness, perceptions of safety, and media posture. Figure 42 presents a summary of the 10-year SRV demand forecast.

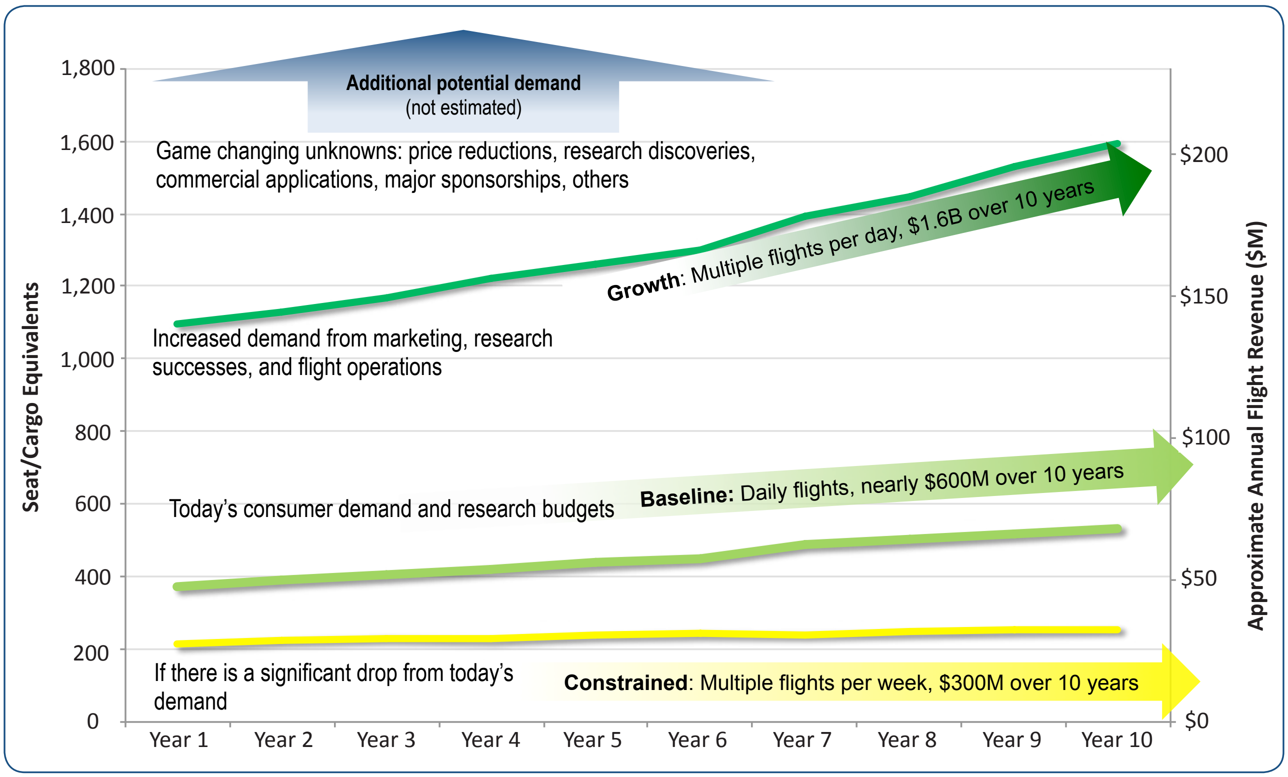


Figure 42: 10-year SRV demand forecast

Acronyms

AFRL	Air Force Research Laboratory
ALASA	Airborne Launch Assist Space Access
CASIS	Center for the Advancement of Science in Space
CGI	computer generated imagery
cm	centimeters
DARPA	Defense Advanced Research Projects Agency
DLR	German Aerospace Center
DoD	Department of Defense
EELV	Evolved Expendable Launch Vehicle
EXPRESS	EXpedite The PRocessing of Experiments to Space Station
FAA/AST	Federal Aviation Administration Office of Commercial Space Transportation
IR	Infrared
ISS	International Space Station
KARI	Korea Aerospace Research Institute
Kg	Kilograms
Km	Kilometers
m	meters
M	Million
NASA	National Aeronautics and Space Administration
NASTAR	The National Aerospace Training and Research Center
NCESSE SSEP	National Center for Earth and Space Education, Student Spaceflight Experiments Program
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NRO	National Reconnaissance Office
NSBRI	National Space Biomedical Research Institute
NSF	National Science Foundation
P2P	point-to-point transportation
P-POD	Poly-Picosatellite Orbital Deployer
PR	Public relations
SNAP	Secure Internet Protocol/Non-secure Internal Protocol Access Point
SOFIA	Stratospheric Observatory for Infrared Astronomy
SRV	Suborbital reusable vehicle
STEM	Science, Technology, Engineering, and Mathematics
SWORDS	Soldier Warfighter Operationally Responsive Deployer for Space
SwRI	Southwest Research Institute
TARC	Team America Rocketry Challenge
TRL	technology readiness level
TV	Television
U.S.	United States
UAVs	unmanned aerial vehicles
UV	Ultraviolet

Artwork courtesy of Phil Smith.

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