Futron

NASA ASCENT Study Final Report

Volume I – Main Report

31 Jan. 2003

ASCENT Study Final Report – Volume I

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Analysis of Space Concepts Enabled by New Transportation (ASCENT)

Ascent · Illustration by Phil Smith
Acrylic on masonite · 24" x 11" · 2003

Executive Summary

The Futron Analysis of Space Concepts Enabled by New Transportation (ASCENT) Study was a major undertaking on the part of NASA Marshall Space Flight Center (MSFC) and Futron Corporation designed to provide the best possible estimates of global launch vehicle demand for the next twenty years via the research, analysis and forecasting of current and future space markets and applications. It is a reassessment, with significant improvements in modeling approach and data collection methods, of the findings of the Commercial Space Transportation Study (CSTS) of a decade ago (which was the previous milestone space market study). The ASCENT Study was performed over a 20-month period from June 2001 to January 2003. This report describes the major findings from the Study.

The models and approaches of the Study were imbued from the outset with a heavy dose of pragmatism and market realism. Many “old favorite” space markets, such as space solar power generation to the Earth, were not included in the 20-year forecast because they did not meet the rigorous and realistic criteria established by Futron for the evaluation of evolving markets. A strict rule of business reality was applied to prevent the forecasting of any markets, for example, whose existence depends on other markets not yet established. For instance, one cannot have a space colony before an established public space travel business exists. A careful review of the history of terrestrial infrastructures also provided useful perspectives in considering the parallels in the space domain. Futron was careful in assessing the degree to which, and the speed by which, totally new space markets could be developed and brought into existence by an enabling new technology, such as a Reusable Launch Vehicle (RLV).

The ASCENT Study also attempted to integrate space-related economic activity with traditional economic data classifications. The space industry today is still a very small sector of the total economy. In the U.S., space industries such as satellite manufacturing, satellite services, launch vehicle manufacturing and ground equipment generated total revenues of only U.S. $36.5 billion in 2001. For the space industry to be heard, and remain relevant to the average person, it must become connected to its associated terrestrial business sectors, which generally represent a much larger economic constituency. This is one of the services that the ASCENT Study provides. All sectors in the Study were related to their terrestrial counterparts through the use of North American Industrial Classification System (NAICS) codes that are used to classify establishments by the type of activity in which they are primarily engaged and thus aid the comparability of establishment data that describe various facets of the U.S. economy.

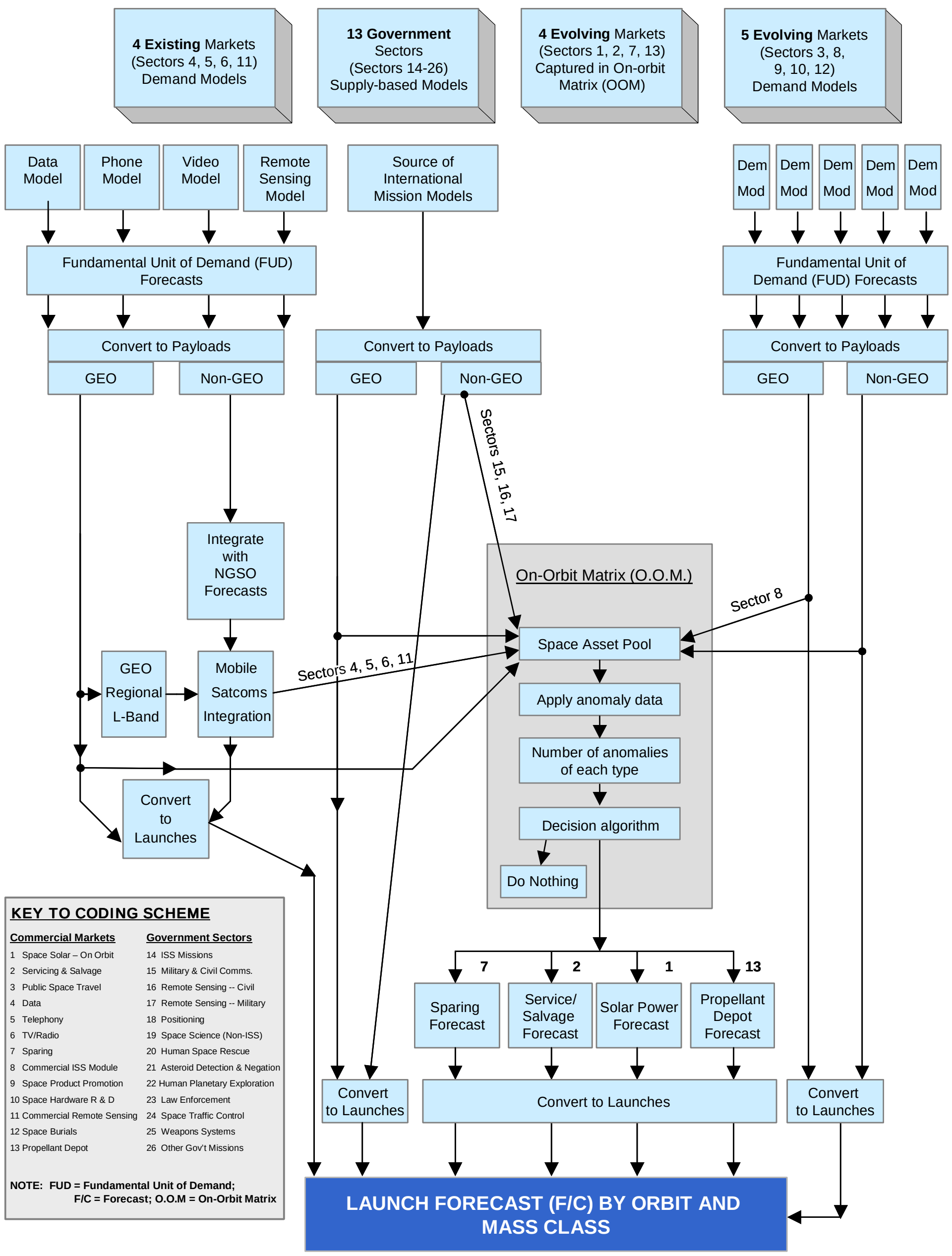
Also, the ASCENT Study assesses the *global* demand for launch vehicles. Space is an increasingly competitive global marketplace. Launch systems today are likely to have major components from several different countries, and the systems are more likely than not to be sold by a multinational partnership or joint venture. No longer are the days when a launch vehicle is manufactured, assembled, and launched within the boundaries of a single nation. The ASCENT Study takes this reality into account and determined launch demand through a comprehensive analysis of over 200 countries.

In addition, the ASCENT Study encompasses *commercial and government* demand for launch services. What used to be the purview of a few space-faring governments is now the bustling and dynamic environment for a myriad of businesses, with telecommunications still the dominant player. Most launch systems are used by both government organizations and private business. Thus, ASCENT covers both customer segments to determine total, worldwide demand for launch services over the next 20 years.

Lastly, the ASCENT Study was performed according to objective and time-tested market forecasting techniques. Futron is neither an advocate for nor an opponent against any particular launch vehicle or architecture. Futron's goal in this Study was to accurately determine the demand for launches. It was not the objective of the Study to support or pre-select any launch vehicle or acquisition strategy.

Figure E 1 shows an overview of the demand model process used in the ASCENT Study, including an insight into the 26 separate market sectors that were individually evaluated. The figure also introduces a common data model, known as the On-Orbit Matrix (OOM), which uses historical data to project life cycles and anomalies of existing and forecasted on-orbit assets. The OOM ensures that there is no double-counting of market opportunities between the Evolving Markets geared towards on-orbit asset management that all depend upon the same on-orbit infrastructure.

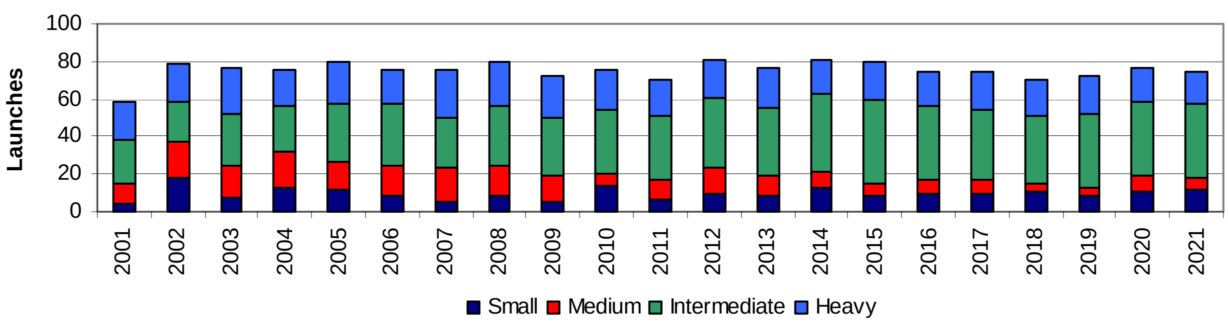
Figure E 1: Overall ASCENT Study Launch Forecast Methodology



So, what was learned from all the data gathering and modeling work? The dose of pragmatism produces some sobering outlooks. Because of a number of factors (e.g., the world economic situation, terrestrial competitor challenges, satellite technology improvements such as on-orbit lifetime and better data compression), the traditional bedrock market of telecommunications only provides moderate growth in launch demand through the forecast period. There are some regional differences, with some Asian telecommunications markets providing more growth opportunities than those in the United States in the first decade, and demand for Internet-over-satellite services experiencing strong growth during certain parts of the forecast. But, generally, the outlook is fairly stable with no discontinuities in terms of growth (or decline). With the possible exception of China and India, the various national space budgets also provide little room for optimism on the launch scene.

Figure E 2 shows the overall result that aggregate global launch vehicle demand remains relatively flat at between about 70 and 80 launches a year throughout the whole period of the ASCENT Study, totaling around 1,500 launches over the 20-year forecast period. In the detail of the full report, it becomes clear that even this modestly flat forecast depends on some new market sectors emerging. Without the launch demand generated by these new businesses, (notably public space travel), there would be a rather rapid decline of the launch industry during the second decade of the forecast period.

Figure E 2: Baseline Forecast for All Sectors

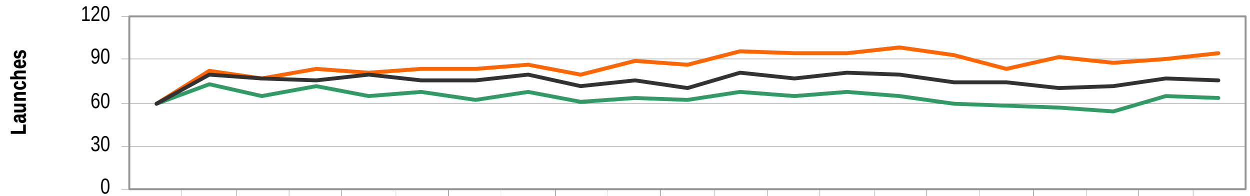


The forecast also indicates a gradual switch from medium to intermediate class launches and a steady increase of commercial market share from a quarter to half of launches, and the continued erosion of U.S. market share of all launches from the 40% down to the 25% level.

In forecasting circles, a 20-year projection of anything is quite a challenge. Therefore, Futron has taken great care to documenting the assumptions, and making visible the demand-modeling process, so that others may later recast the forecasts under different circumstances. Having said that, Futron has nevertheless endeavored to provide the best possible assessment of future launch vehicle demand, based on thousands of researched key variables, and this is described as the Baseline Case.

In order to arrive at some feel for the level of possible non- price driven variations in the Baseline Case forecast, a Robust and Constrained Case were also developed, driven by variations in key variables which have an inherent uncertainty, such as the length of time to market saturation for new commercial markets. Figure E 3 provides a comparison of the results of the three cases at an aggregate level, showing the constrained scenario almost as low as 50 launches a year, and a robust scenario that reaches almost 100 launches a year by the end of the forecast period.

Figure E 3: Baseline, Robust and Constrained Forecasts of Launches for All ASCENT Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	59	82	77	83	81	83	84	86	80	89	86	96	94	95	98	93	83	92	87	91	95
Constrained	59	73	65	72	65	68	62	67	61	64	62	68	65	67	65	60	58	57	54	65	63
Baseline	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

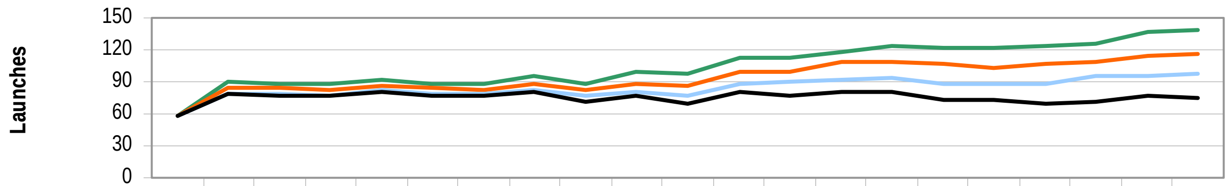
The changes in assumption that produced the spread of outcomes of Figure E 3 did not include changes to launch prices. Thus, in each case above, Baseline, Robust and Constrained launch prices were assumed to be more or less constant over the forecast period. It was the next major objective of the ASCENT Study to try and understand the way in which launch demand varies with launch price. This has been one of the most profound and controversial issues within the launch industry for decades. There have been many previous attempts at addressing the price elasticity of launch demand, including the CSTS referred to earlier. Most of these studies have included “magic number” assertions about a significant increase in launch demand that is experienced once the “magic number” price is achieved. This magic number has usually been expressed in terms of “dollars per pound to orbit.” Figures such as $1,000/lb, $500/lb or $300/lb to Low Earth Orbit (LEO) are regularly quoted in studies and launch industry planning sessions as the number that will enable/produce huge increases in demand for launches. What does the ASCENT Study tell us about this? It tells us that there is no “magic number”! It even challenges the way that the question is usually posed.

For one thing, launch prices today are very different in each market sector, proving that there is no single magic number. For example, in some sectors the launch price is already close to $1,000/lb, while in other sectors it is much higher. Thus, the ASCENT Study approach to understanding launch vehicle price elasticity of demand was first performed at an individual market segment level, before the results are aggregated. Also, the analysis was performed on a basis of “percentage price reduction” rather than at absolute targets of dollars per pound to orbit, and the full report provides a set of translation charts for converting between percent changes to absolute prices within each sector. So, for each sector there is a different starting point when prices are reduced.

Furthermore, the Study demonstrates conclusively that there is a dramatic variation between market sectors with regard to price elasticity of demand to launch prices. Most of today’s markets, both commercial and governmental, are virtually unaffected by even massive reductions in launch prices. This is demonstrated in the ASCENT Study by introducing the concept of launch price “gearing factors” in the respective industry sectors (gearing factors are described in more detail later in the report). In television broadcasting, for instance, only 0.7% of the end user price paid for TV programs is traceable to launch cost. In other words, even if launch costs zero, it would only make a difference of seven tenths of one percent in the cost of providing TV programs. This critical gearing factor is provided for all markets in the ASCENT Study Report.

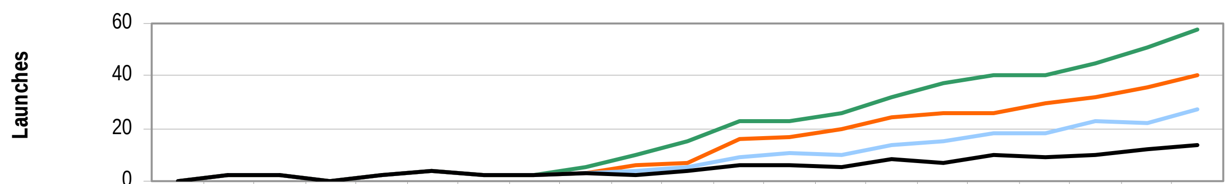
In the case of Government sectors, there are other reasons, documented in the Study, why launch demand is virtually insensitive to launch price. Figure E 4 shows the overall effect of reductions of launch price on demand for launches for all market sectors in aggregate. Even after a 75% reduction in launch prices, launch demand has not even doubled from the Baseline level after twenty years.

Figure E 4: Price Impact on Launch Forecasts for All ASCENT Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	59	90	89	88	92	89	88	95	89	99	97	113	112	118	123	122	121	123	126	136	138
50% Reduction	59	85	84	83	87	84	83	89	83	88	86	100	100	108	109	106	103	107	109	114	116
25% Reduction	59	79	79	77	82	78	78	83	77	81	77	88	90	91	94	89	89	88	95	95	98
Baseline	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

Figure E 5: Price Impact on Launch Forecasts for Evolving Commercial Market Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	2	2	0	2	4	2	2	5	10	15	23	23	26	32	37	40	40	45	51	58
50% Reduction	0	2	2	0	2	4	2	2	3	6	7	16	17	20	24	26	26	30	32	36	40
25% Reduction	0	2	2	0	2	4	2	2	3	4	5	9	11	10	14	15	18	18	23	22	27
Baseline	0	2	2	0	2	4	2	2	3	2	4	6	6	5	8	7	10	9	10	12	14

However, underneath the aggregate level of launch demand, some individual markets in the Evolving Commercial Market Sector experience a more profound increase in demand from launch price reductions. Figure E 5 shows this much greater sensitivity in launch demand to launch prices in the Evolving Commercial Market Sectors. The increased sensitivity in the Evolving sectors is largely driven by the public space travel market. Figure E 6 provides the launch price elasticity of demand curves for each of the sectors, and for the total aggregate marketplace. There is a wealth of inferences that can be made by launch industry executives from the information in Figure E 6 regarding the impact of across the board price cuts to the effect of certain pricing strategies.

Figure E 6: Price Elasticity of Demand by Sector Type

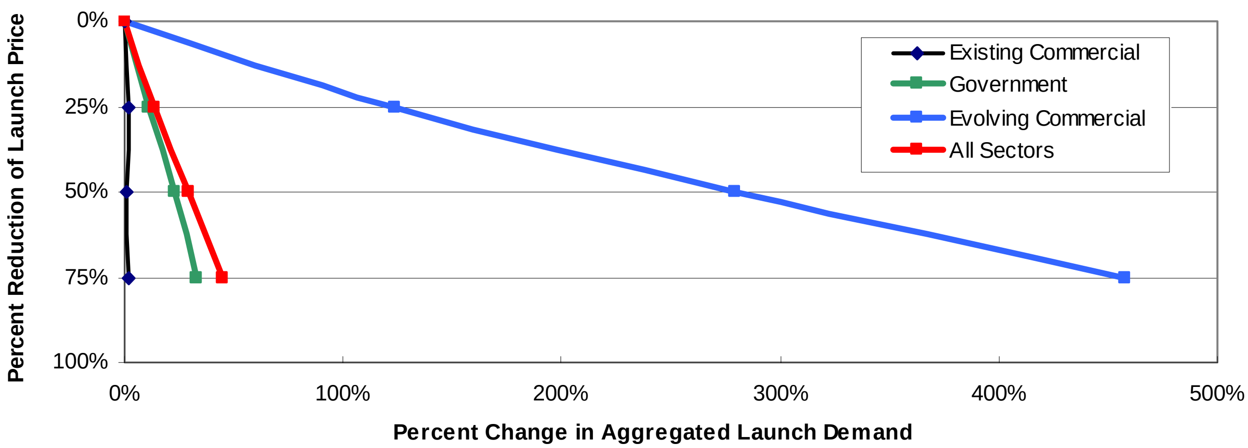
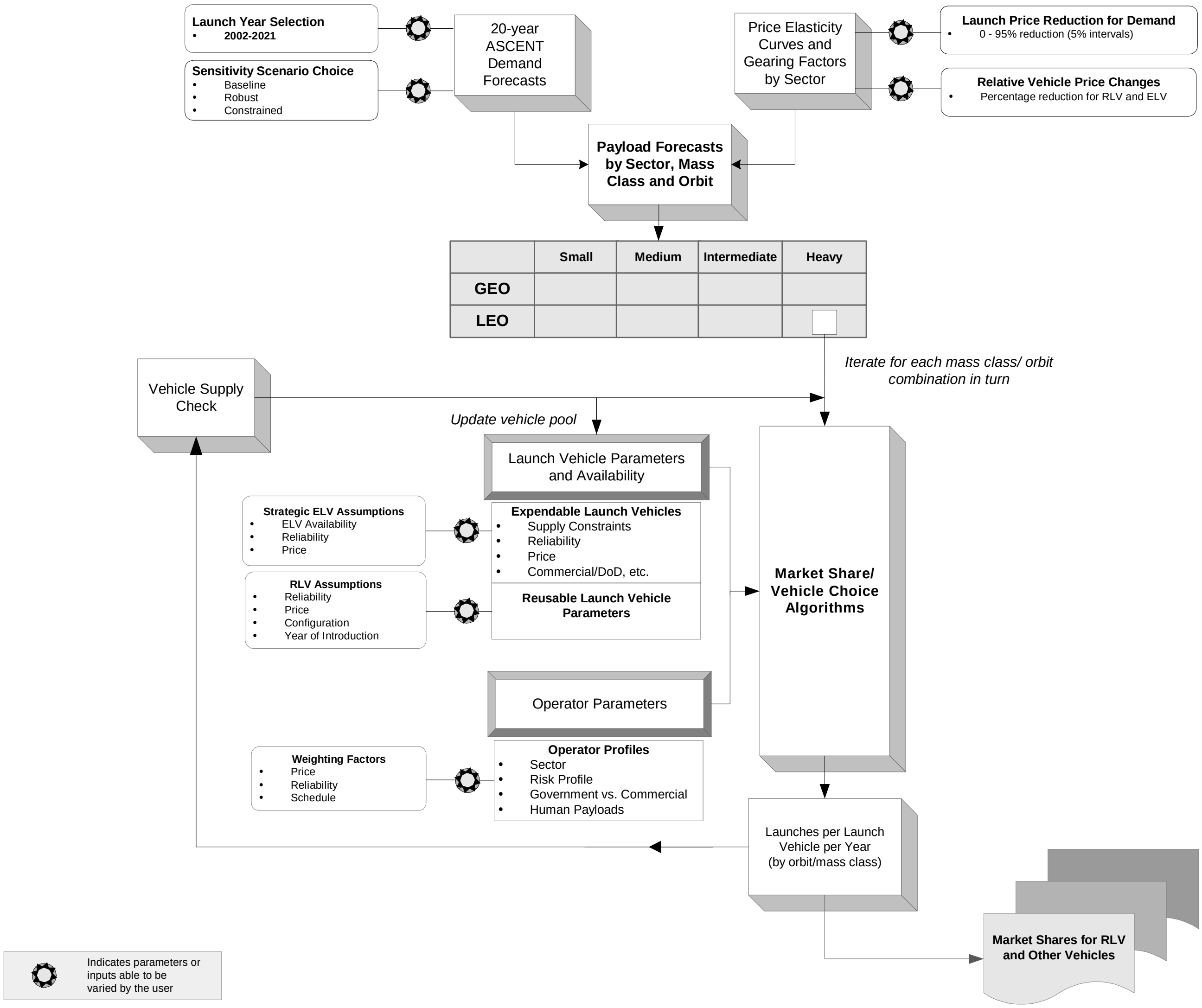


Figure E 7 graphically describes the ASCENT Study Market Share Model, which was originally conceived to be a tool for evaluating certain 2nd Generation RLV designs and architectures. The Model is driven by the forecasts of launch vehicle demand provided by the methodology shown in Figure E1. The Market Share Model calculates the market share that each vehicle will get in the global launcher marketplace, based on complex algorithms relating to each vehicle attributes, payload characteristics, and customer buying preferences. It must be noted that market share analyses are notoriously difficult to accurately perform due to the uncertainty associated with company strategies and tactics and market responses to differing product offerings. However, Futron ran the model several times using historical payload manifests, and the model produced a very good 70% fit test during these historical runs. Thus, Futron had confidence in applying the Market Share Model to forecasted demand to determine future market share.

In the real world, operators buy a given launch vehicle for a great many interrelated reasons and not all of them can be included in a model. Nevertheless, procurement processes tend to follow a certain inevitable logic, and the vehicle choice algorithms at the heart of the ASCENT Market Share Model have been developed as a result of a thorough study of real world procurements (seen from the perspective both of the launch vehicle manufacturer and of the purchasing operator). The weighting of the different factors in the decision process varies from sector to sector depending on the kind of buyer (e.g., whether entrepreneurial or risk-averse), which enables a higher level of fidelity in the market share calculations.

In each of the forecast years, the model requires a set of available launch vehicles from which to make the choices, although a default set of vehicles has been pre-programmed into the Model. It is also possible to include hypothetical vehicles that are not yet available, and determine how much their market share would vary with changes in key parameters, such as reliability, schedule and price flexibility, and payload capacity. Such hypothetical vehicles could include RLV's, whether of US or non-US origin.

Figure E 7: ASCENT Market Share Model



What insights do we learn from initial use of the ASCENT Study Market Share Model? Does it give guidance on the impact of introducing an RLV into a market of Expendable Launch Vehicles (ELV), and can it explore the mitigating effects of various strategic repositioning moves by ELV manufacturers? In answer to these questions, it must be noted that the work of the ASCENT Study ends with the delivery of the Market Share Model to NASA MSFC. Moreover, as this project ends, the exact definition of a Second Generation RLV remains uncertain. Thus, any findings generated from the Market Share Model are preliminary and somewhat academic in nature.

However, as a demonstration of the Model's capability, Figure E 8 is included to show the kind of results that the model can deliver for the Base Case forecast and current and soon-to-be-introduced launchers. While there are peaks and valleys among the various space-faring nations, there are no major trends, although there is a gradual erosion of US market share by Russian vehicles (most likely due to their relatively high reliability and lower price).

Figure E 8: Baseline Before RLV - Number of Launches

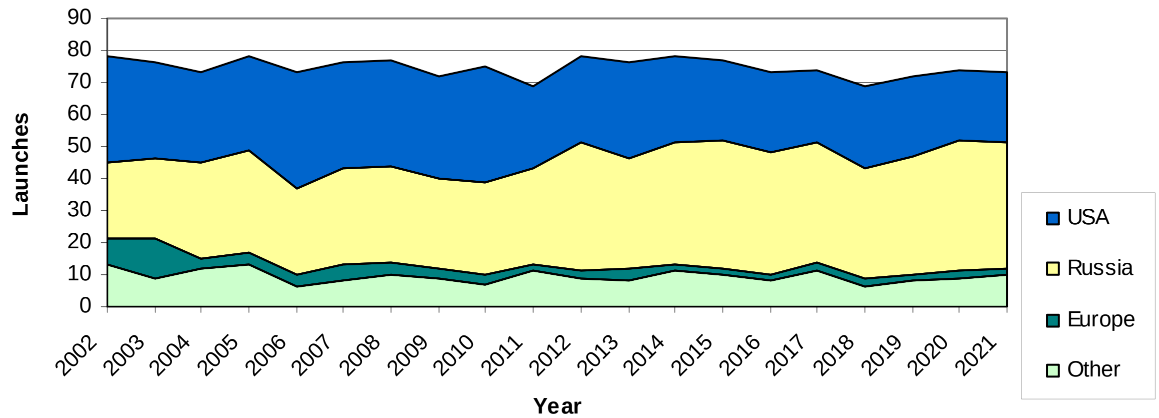
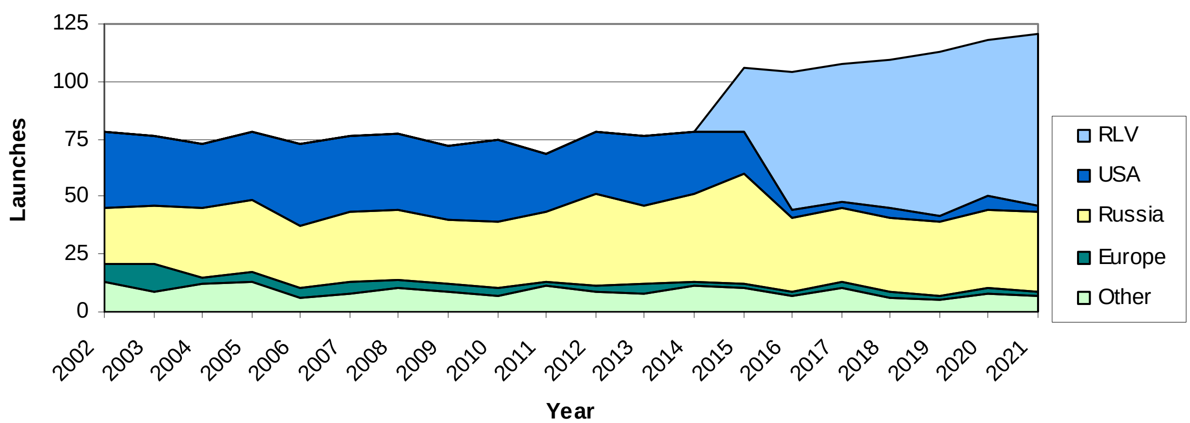


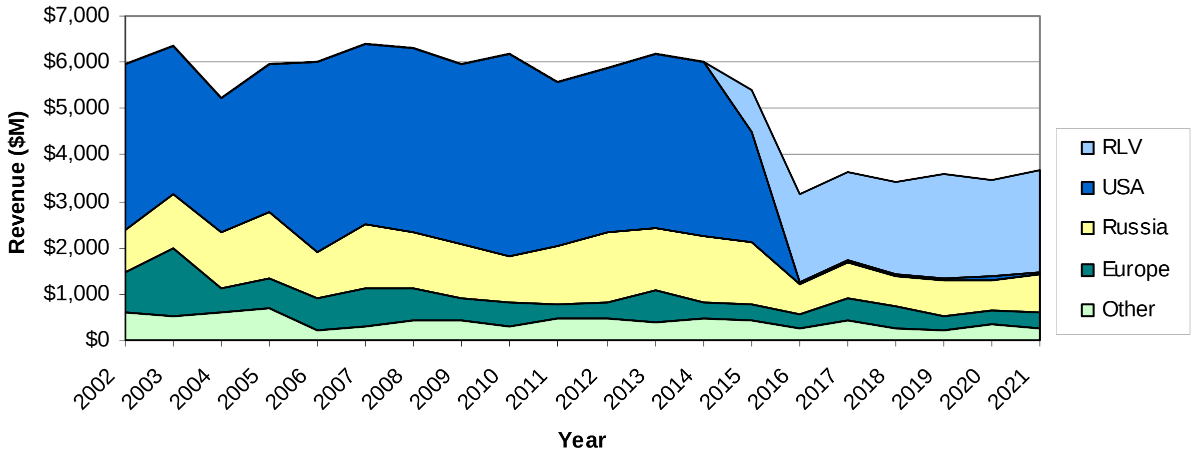
Figure E 9 displays the effect of running the same set of input parameters with the addition of an RLV with attributes similar to the original goals of the 2nd Generation RLV as defined by NASA's Space Launch Initiative (SLI). There is a massive and almost immediate impact created following the 2015 introduction date of an Intermediate/Heavy class RLV. It shows that (depending how defined) a single RLV could take almost 70 of the 120 launches by the end of the forecast period. The presumed RLV characteristics score, both separately and in combination, higher than the competing ELV parameters in every respect (i.e., price, reliability, schedule flexibility, crew-carrying capability), which produces the dramatic effects. Yet, even so, the RLV does not take everything. With the RLV assumptions that were loaded into the model, it turns out that the RLV was not the best solution for some customers. It was not the best, for example, for those with small payloads. Furthermore, the RLV was defined for this test run as a US RLV, and certain foreign government payloads continue to demand to be launched using their indigenous launch capabilities.

Figure E 9: Introduction of RLV – Number of Launches



The cases described in Figure E 8 and Figure E 9 are simply test runs of the ASCENT Study Market Share Model. Other cases can be run that address various strategic pricing and positioning responses from the ELV manufacturers (some are included in the full report). The Model also produces revenue projections (also included in the full report) such as those seen in Figure E 10, and can be used to assess the key business case elements for a potential RLV program.

Figure E 10: Introduction of RLV – Total Launch Revenue



At the simple level of the assumptions used for the model test runs, the introduction of an RLV removes much of the demand for existing expendable launch vehicles, without commensurately increasing the overall market demand enough to maintain the previous total industry revenue levels. There is, of course, some increase in the total demand due to the price reduction the RLV would bring to the market.

One market that could change this equation is public space travel. If an RLV could be designed to take advantage of the public space market and carry, say, 10 or more passengers, then the unit prices per passenger would drop to the point that there would be a demand for ever more launches of the RLV, and further RLV's would be required. The launch price gearing factor is so high for public space travel that there is a direct benefit from price reductions that would rapidly lead to increases of demand for launches. A Commercial ISS Module and a Propellant Depot could also begin to be feasible if RLV design targets are achieved.

1. Introduction

NASA MSFC awarded contract NAS8-01095 to Futron Corporation, Bethesda, MD, with an execution period from June 1, 2001 through January 31, 2003. This became known as the Futron ASCENT Study, and this document is its Final Report. The original focus for the work, generated through NASA's Space Launch Initiative was to establish the likely launch vehicle market a future Second Generation RLV could serve. The work, however, transcends the SLI focus and provides the best possible estimates of world launch vehicle demand for the next twenty years.

The ASCENT Study is a major undertaking designed to provide the best possible estimates of world launch vehicle demand for the next 20 years . . .

The ASCENT Study involved massive amounts of data gathering, and the associated development of an array of market analyses and models, culminating in the ASCENT Study Market Share Model. This model allows planners to investigate the impact on launch vehicle market shares in the global marketplace when ELV and RLV design parameters and pricing are varied.

It is almost a decade since the last comparable study, known as the Commercial Space Transportation Study (CSTS), was conducted. The ASCENT Study builds on that former work, while bringing many significant advances to the thoroughness and fidelity of the approach. First of all, the ASCENT Study was able to incorporate the real world experience and lessons learned from the subsequent years since CSTS was accomplished. During that time, satellite mobile LEO constellations came and went, data transmission moved inexorably towards broadband and the first steps of public space travel were evidenced. In addition, more market sectors were evaluated. The ASCENT Study addresses 42 distinct sectors (many of which in themselves contain important sub-sectors). Thirteen Commercial and 13 Government sectors are quantified. All of them are global. A further 16 markets, that are not expected to start generating launch business in the next twenty years, were also captured qualitatively. The forecasts for the commercial sectors are generated using a true demand-based approach that goes back to the fundamental units of demand of the commercial service (e.g., minutes of telephony), and a robust price elasticity of demand methodology. Government markets, throughout the world, are assessed and incorporated via an understanding of their supply-based mission plans. All the data used by Futron in generating these forecasts was assembled from public domain sources and its own internal company databases.

Wherever possible, the aim was to develop common methodologies to facilitate understanding and cross-comparisons, and to that end assumptions are stated explicitly with their source. The ASCENT Study makes pragmatic choices so that the effort is focused realistically on the 20-year period of the forecast, while nevertheless providing a reference base for those wishing to conduct longer-term market assessments beyond 2021. A further feature that has been added to make the Study more valuable to a range of potential users is the linking of all space markets to their terrestrial counterparts by means of macroeconomic indicator codes (i.e., NAICS codes). Finally, a user-friendly ASCENT Study Market Share Model has been developed, which is described herein (and via a separate User Guide previously delivered). The model enables planners at NASA, or at launch vehicle manufacturers, to assess the likely consequences of a range of strategic decisions, taken either by themselves or by competitors, related to launch vehicle pricing and other attributes of their vehicles. The model is fuelled with the price elasticity data determined during the ASCENT Study and therefore provides a very realistic means of evaluating strategic scenarios, which may or may not include RLV alternatives, whether of US or other origins.

This Final Report is presented in two volumes. The main findings, at the launch vehicle level, are included in Volume I, while Volume II is an Appendix of working data and assumptions at the market sector level. There were 11 highly detailed interim deliverable reports generated in the course of the 20-month ASCENT Study, and this Final Report cannot possibly record or replace all of that constituent detail. The aim of this report is to pull together the results of the Study, including only as much methodological detail as would prove useful for future users to understand the factors considered, and the key driving assumptions made.

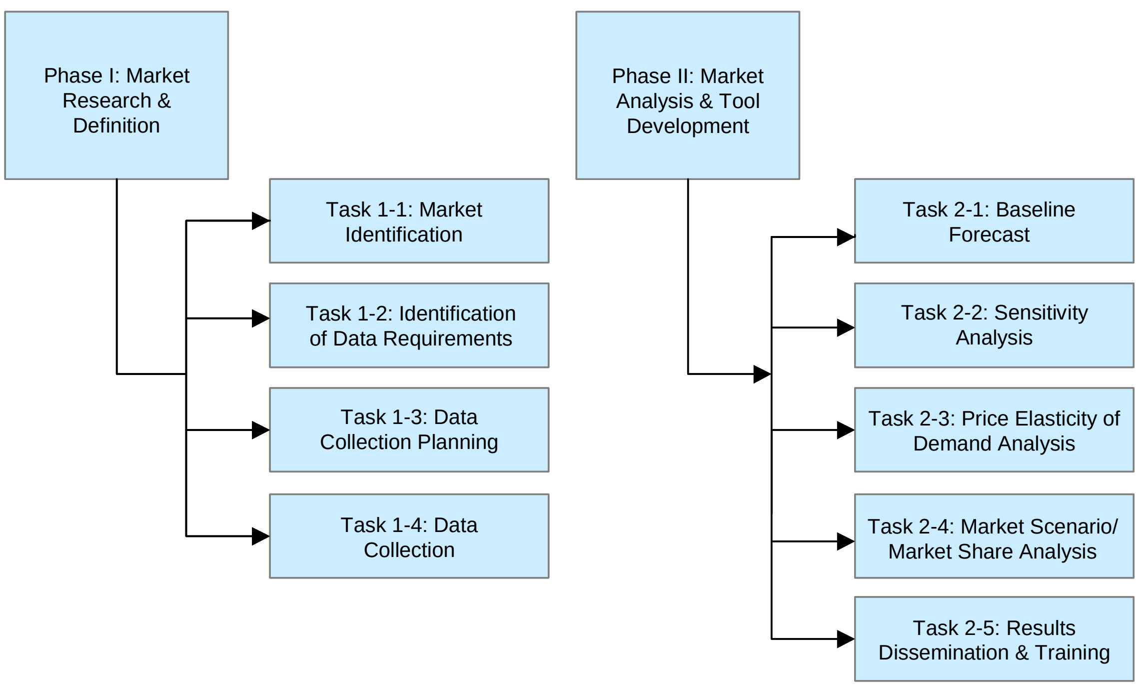
2. Overall ASCENT Study and Model Design

The ASCENT Study was designed as a data collection, modeling and analysis exercise, and the contract was split as shown in Figure 2-1 into a data collection phase (Phase I) and a modeling phase (Phase II). The requirement was to produce twenty-year forecasts of launch vehicle demand that were global in extent and which embraced both the commercial and government sectors. At its simplest, the ASCENT Study modeling process moves in three steps from markets to payloads to launches, and then a final modeling step produces shares of launches to individual launch vehicles.

The ASCENT Study produces a comprehensive database of market data that feeds launch vehicle supply and demand models . . .

Figure 2-1 describes the overall process of the combined two phases of the Study. After the Baseline forecast was completed as part of Phase II, sensitivity, price elasticity and market share analyses were performed.

Figure 2-1: ASCENT Study Overview



To derive the forecasts of Task 2-1 and Task 2-2, a detailed sector-by-sector series of demand models was developed (described later in section 7). These demand forecasts were then fed into a price elasticity model, using the price elasticity of demand curves (described later, in Section 9) to complete the requirements of Task 2-3. The final step of market share analysis, for Task 2-4, was conducted using the ASCENT Study Market Share Model (described later in Section 11).

3. Year 2001 Base Data

Before forecasting the changes to demand due to launch price changes, it is important to have a clear understanding of launch prices today . . .

One of the main tenets of the SLI/Second Generation RLV design was to produce a vehicle with a capability of offering flights to LEO at $1,000 per pound, with this being linked to an assumed price of $10,000 per pound to LEO today.

Of course, it is important before doing price elasticity work to have a good understanding of the start point on the price elasticity of demand curve represented by today's markets. There was plenty of evidence that current prices for many kinds of missions are already well below the $10,000 per pound assumed by NASA as the current price level. Therefore, some analysis has been performed to establish the initial pricing framework that underlies the Baseline forecasts. All pricing information used in the ASCENT study was found in the public domain, and has been converted to 2001 dollars.

An initial analysis by individual vehicle produces values of price per pound to LEO throughout the '90s varying from around $14,000 per pound for a Pegasus XL down to as low as $1,400 per pound for a Zenit 2. Table 3-1 represents the price per pound when utilizing the maximum advertised capacities of launch vehicles. Often a payload's mass is less than the maximum capacity listed for the vehicle, resulting in a higher effective price per pound. Under certain circumstances, a payload's mass may even exceed the stated maximum capacity. This is possible if less reserve propellant is used and the payload's own propulsion system makes final adjustments to the orbit. Because of this wide range of variances, the information has been summarized into Table 3-1 to show the range averaged over mass classes, and to indicate differences due to country of origin. For comparison, the Shuttle figures are also included.

Table 3-1 Current Price per Pound to LEO by Vehicle Mass Class (utilizing maximum published capacity)

Vehicle Class	LEO		GTO	
	Western	*Non-Western**	*Western*	*Non-Western**
Small	$8,445	$3,208	$18,841	N/A
Medium/Intermediate	$4,994	$2,407	$12,133	$9,843
Heavy	$4,440	$1,946	$17,032	$6,967
Shuttle (assume 8 flights/yr)‡	$4,729	--	$23,060	--
Shuttle (assume 4 flights/yr)‡	$9,458	--	$46,120	--

*The Zenit 3SL is considered a non-Western launch vehicle because of its Ukrainian and Russian heritage.
‡Assumes a constant Shuttle operations budget of $2.4 billion annually
Mass class definitions can be found in Volume II of this report.

Focusing on the variations in price per pound to orbit by market sector provides yet another perspective. This perspective has the advantage of leading directly to an interaction within the sector models of demand. Table 3-2 shows the price per pound to LEO inherent in today's Existing markets and assumed explicitly in the models for Evolving markets in the Baseline case. Existing and Evolving markets are defined in Section 5, as are the detailed market sectors listed in Table 3-2.

Table 3-2: Current Launch Price per Pound by Market Sector (in 2001 dollars)

Sector	$ Per pound to LEO	$ Per pound to GSO	Notes
Telephony	$8,816	$13,830	Average effective price per pound (launch price divided by payload masses) from telecom launches 1996-2001. LEO Based on Iridium and Globalstar
Data	$8,816	$13,830	
TV/Radio	N/A	$13,830	
Commercial Satellite Remote Sensing	$17,198	$28,758	Wide variety of payload sizes and vehicles-vehicle capacity often in excess of payload mass
Public Space Travel	$2,993	N/A	Based on Soyuz capsule
Commercial ISS Module	$10,000	N/A	Pressurized cargo
Space Product Promotion	($29)	N/A	Revenue represents an offset of $29/ lb
Space Hardware R&D	$10,000	N/A	Based on Shuttle
Space Burial	$13,832	N/A	Based on Pegasus vehicle
On-orbit Sparing	$4,200	$11,500	Based on commercial telecom markets: vehicle price divided by capacity
Orbital Asset Servicing and Salvage	$4,200	$11,500	
Space Solar Power (on orbit uses)	$4,000	N/A	Assumes heavy launch vehicle to LEO
Propellant Depot	$4,000	N/A	Assumes heavy launch vehicle to LEO
Government	$22,577	$30,088	For US and European government payloads on ELV's 1996-2001. Titan IV, with the largest effective $/lb, is responsible for the high average

Because there is such a mixture of starting prices among the different sectors assumed in today's markets and throughout the Baseline, it is not a simple matter to relate percentage decreases in price levels to the resulting absolute values of price per pound to LEO. Thus, two further tables are provided to assist in the correlation. Table 3-3 allows the correlation to be carried out when aggregate forecast results are presented using the categorization of Existing Commercial, Evolving Commercial and Government markets, although there is a wide range for the conversion factors.

Table 3-3: Baseline Launch Price Ranges and Implicit Price Reductions to Absolute Dollars per Pound to LEO

Sector	Baseline Range of $/ lb to LEO	Implicit Price Reduction to Achieve:	
		$1,000/ lb	$500/ lb
Existing Commercial	$3,846 - $7,692*	74-87%	87-93%
Government	$7,255 - $60,187	86-98%	93-99%
Evolving Commercial	$2,993 - $13,832	67-93%	83-96%

*LEO equivalent launch price (GEO/2.6) for commercial GEO telecom satellites. Iridium & Globalstar averaged $8,816 /lb.
Sector definitions are provided in Section 5 of this report.

Table 3-4 is a more robust translation table, which gives the conversion factor between percentage price reduction and absolute values of price per pound to LEO, when expressed by mission type.

Table 3-4: Baseline Launch Price Ranges and Implicit Price Reductions by Mission Type

Sector	Baseline Range of $/ lb	Implicit Price Reduction to Achieve:	
		$1,000/ lb	$500/ lb
GEO	$7,039 - $80,346	86-99%	93-99%
NGSO / LEO	$3,535 - $60,187	72-98%	86-99%
LEO Public Space Travel	$2,993	67%	83%
ISS Crewed	$10,000	90%	95%
ISS Uncrewed	$4,000	75%	88%

One of the implications of this analysis is to show that it does not take a factor of ten reduction in price to LEO (a goal identified by SLI for a 2nd Generation RLV) to arrive at $1,000 per pound. Moreover, such prices are almost being achieved already for some sectors. If, however, the subsequent analysis is presented on the basis of standardized percentage price changes, then this will ensure that the balance of prices that exist in today's markets will persist across the sectors in the forecasts also. And if it is subsequently required for some purpose to focus on specific price per pound to orbit values (even though it has been demonstrated that such a simplification has very little meaning in the real commercial world), then a translation may be carried out using the tables in this section.

4. Industry Economic Data

Futron collected and organized the identified markets covered in the ASCENT Study into a standard industrial classification scheme. This was accomplished through the use of the North American Industrial Classification System (NAICS) that has recently replaced the Standard Industrial Classification (SIC) system.[1]

Care has been taken to relate sectors in the ASCENT Study to their terrestrial counterparts, by using NAICS codes. This produces a number of benefits . . .

The application of the NAICS classification scheme provides three distinct benefits. First, the alignment and categorization of space markets with their terrestrial analogs emphasizes the parallels between terrestrial business and what have in the past been regarded as "special" space businesses. The application of the NAICS classification has the effect of "normalizing" future space businesses, and of anchoring them to their traditional terrestrial counterparts. The NAICS-based categorization also facilitates the analysis of terrestrial competition for space markets because terrestrial economic databases are organized in a similar manner. Lastly, the process eliminates double counting of markets during the latter stages of Futron's analysis.

The space business sector is not large when compared with the economy in total. Table 4.1 gives a breakdown. For this reason it is helpful to view each space market sector (described in Section 5) in terms of an extension of their associated terrestrial businesses.

Table 4-1: Size of U.S. Commercial Space Industry in 2001

Industry	Revenues (U.S. $ billions)
Satellite Services	$15.9
Satellite Manufacturing	$5.5
Launch Vehicle Manufacturing and Services	$1.7
Ground Equipment Manufacturing	$13.4

Source: Satellite Industry Association

For each of the market sectors, the appropriate reference to the size of the related U.S. sector to which they are most related has been provided in Volume II.

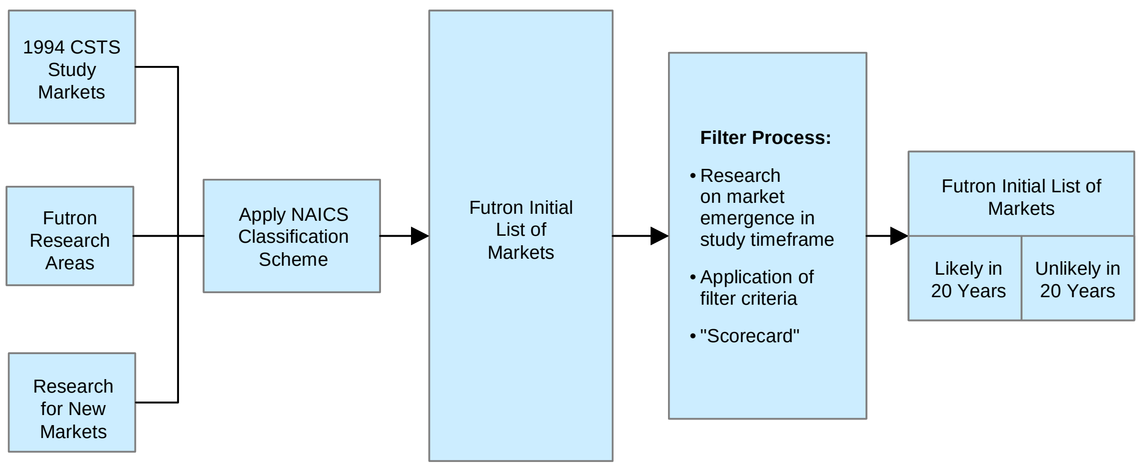
[1] Further information on NAICS codes can be found at http://www.census.gov/epcd/www/naics.html

5. Market Segmentation

Figure 5-1 summarizes Futron's approach for the identification and selection of markets for analysis as part of the ASCENT study. The process began with three starting points: (1) a review of the markets included in the CSTS, (2) the inclusion of Futron research areas such as satellite broadband applications, and (3) research to find previously unidentified space applications and markets that may emerge during the next 20 years. All the work of the ASCENT Study addresses global markets.

The market sectors in the ASCENT Study have been selected and defined following a careful process of screening to avoid double counting of demand . . .

Figure 5-1: Futron Approach for ASCENT Market Identification



The next stage was to apply a filter process to the initial list of markets in order to identify those markets that were likely to exist within the study timeframe (i.e., the next 20 years). This filtration process was intended to ensure that rigorous analysis was applied to those markets that are most likely to occur in the timeframe of the study.

The filtering process employed the use of specific criteria applied to each market in order to separate the initial list into two categories, "Likely to exist in 20 years" and "Unlikely to exist in 20 years." The filter criteria are shown in Table 5-1.

Table 5-1: Filter Criteria Applied to Markets Selected for Analysis

Market Categories	Filter Criteria
Likely to exist in 20 years	Current application or market exists
	Follow-on application of current in-orbit assets
	Minor technology hurdles that can be overcome in market timeline
Unlikely to exist in 20 years	Significant technology hurdles
	Requires new space assets unlike those to date
	Significant regulatory or environmental policy barriers
	Strong terrestrial competition
	Follow-on applications enabled by markets that do not yet exist

Of particular concern during the filter process was an attempt to find references that could give an indication of market timing and the triggers that would be necessary in order for the market sector to have a business potential within the study timeframe. The Futron team, using a data collection template, focused on obtaining a pragmatic assessment of whether each respective market sector identified could emerge before the end of the 20-year period being studied.

A Second Generation RLV is projected in this study to become operational towards the end of the study timeframe; therefore, the markets placed in the "unlikely" list could possibly have a significant part to play during the later decades of operation of the new vehicle. For this reason, Futron did not entirely discard those sectors designated as unlikely to occur in 20 years, but has instead provided qualitative analysis of those markets, which are included in the "Emerging Markets" section of Volume II.

List of Markets Analyzed

Table 5-2 provides the markets and government sectors that are covered in this Study. Existing and Evolving Markets (column 1) represent the "likely" category of Table 5-1. The Emerging Markets (column 2) represent the "unlikely" category, and therefore only received qualitative treatment in the Study.

No attempt was made in the case of Government Missions to divide them into "likely" and "unlikely" categories within the next 20 years, as the decisions to pursue such missions will be political – rather than demand-based.

All of the original CSTS markets are included, and 5 new ones have been added – on-orbit construction, vacuum-deposition processing, on-orbit sparing, on-orbit education, and weapons systems. Some original sectors were combined (e.g., digital movie distribution became part of Data Markets), while others were further separated out for more accurate analysis such as Space Solar Power which now receives separate treatment for in-orbit uses and terrestrially. Definitions of all of these sectors were carefully developed to ensure there would be no overlap or double counting during the forecasting process. These definitions are included in the sector descriptions in Volume II.

Table 5-2: ASCENT Market Sectors and NAICS Codes

Likely to Exist Within ASCENT Forecast Period	Unlikely to Exist Within ASCENT Forecast Period	Related Terrestrial Industry	
Existing and Evolving Markets	**Emerging Markets**	**NAICS Industry Sectors**	**NAICS Industry Sector Code**
	Space Agriculture	Agriculture, Forestry, Fishing & Hunting	11
	Non-Terrestrial Mining: Asteroid and Lunar Resources	Mining	21
Space Solar Power: On-orbit Uses Propellant Depot	Space Solar Power: Terrestrial Uses	Utilities	22
	On-orbit Construction	Construction	23
	Space Crystal Growth (includes Biotechnology, Drug Production, Epitaxy) Vacuum Deposition Processing	Manufacturing	31-33
Orbital Asset Servicing and Salvage (includes Retail Space Auctions)		Retail Trade	44-45
Public Space Travel (transportation and tour operators)		Transportation and Warehousing	48-49
Data Markets (includes Digital Movie Distribution and Distance Education) Telephone Markets Television /Radio Markets (includes DARS)		Information	51
On-orbit Sparing		Finance and Insurance	52
Commercial ISS Module (includes Orbiting Movie Studio)	Space Settlements	Real Estate and Rental and Leasing	53
Space Product Promotion Space Hardware R&D Commercial Satellite Remote Sensing	Orbiting Billboards	Professional, Scientific, and Technical Services (includes Advertising under "Professional Services")	54
	Hazardous Waste Disposal Space Debris Management	Administrative and Support and Waste Management and Remediation Services	56
	On-orbit Education	Educational Services	61
	Space Hospitals	Health Care and Social Assistance	62
	Space Athletic Events Artificial Space Phenomena Space Theme Park	Arts, Entertainment, and Recreation	71
	Public Space Travel (hotels)	Accommodation and Food Services	72
Space Burials		Other Services (except Public Administration)	81

Government Sectors	NAICS Industry Sector	NAICS Industry Sector Code
ISS Missions Military Communications Government Satellite Remote Sensing (includes Earth Resources and Meteorology) Military Satellite Remote Sensing (includes Intelligence and Treaty Verification) Positioning Space Science Human Space Rescue Asteroid Detection/Negation Human Planetary Exploration Law Enforcement Space Traffic Control Weapons Systems Other Government Missions	Public Administration	92

6. Data Collection and Archiving Process

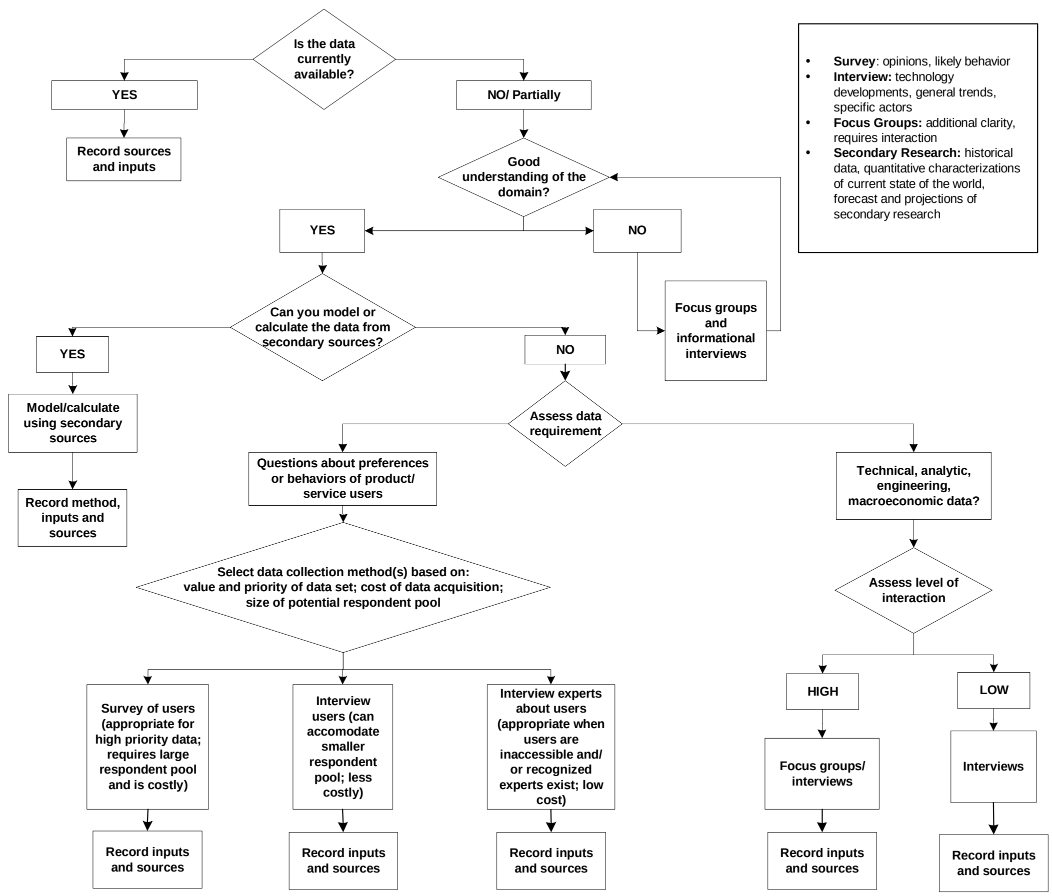
The ASCENT Study data was collected via primary research using interviews and surveys as well as secondary research; all of which has been archived to facilitate further work . . .

Futron performed extensive data collection to fuel the later analysis tasks. A checklist was used to ensure that there was a definite use for the data in the models, and that the basic business models for commercial sectors were understood before the modeling began. The conceptual business model information is included in Volume II for each sector.

Standard Methodology Selection Mechanism

In order to simplify and standardize the market data research process, and to ensure that the best method was used for collecting each data item, a standard methodology filter was developed and introduced, and is shown in Figure 6-1.

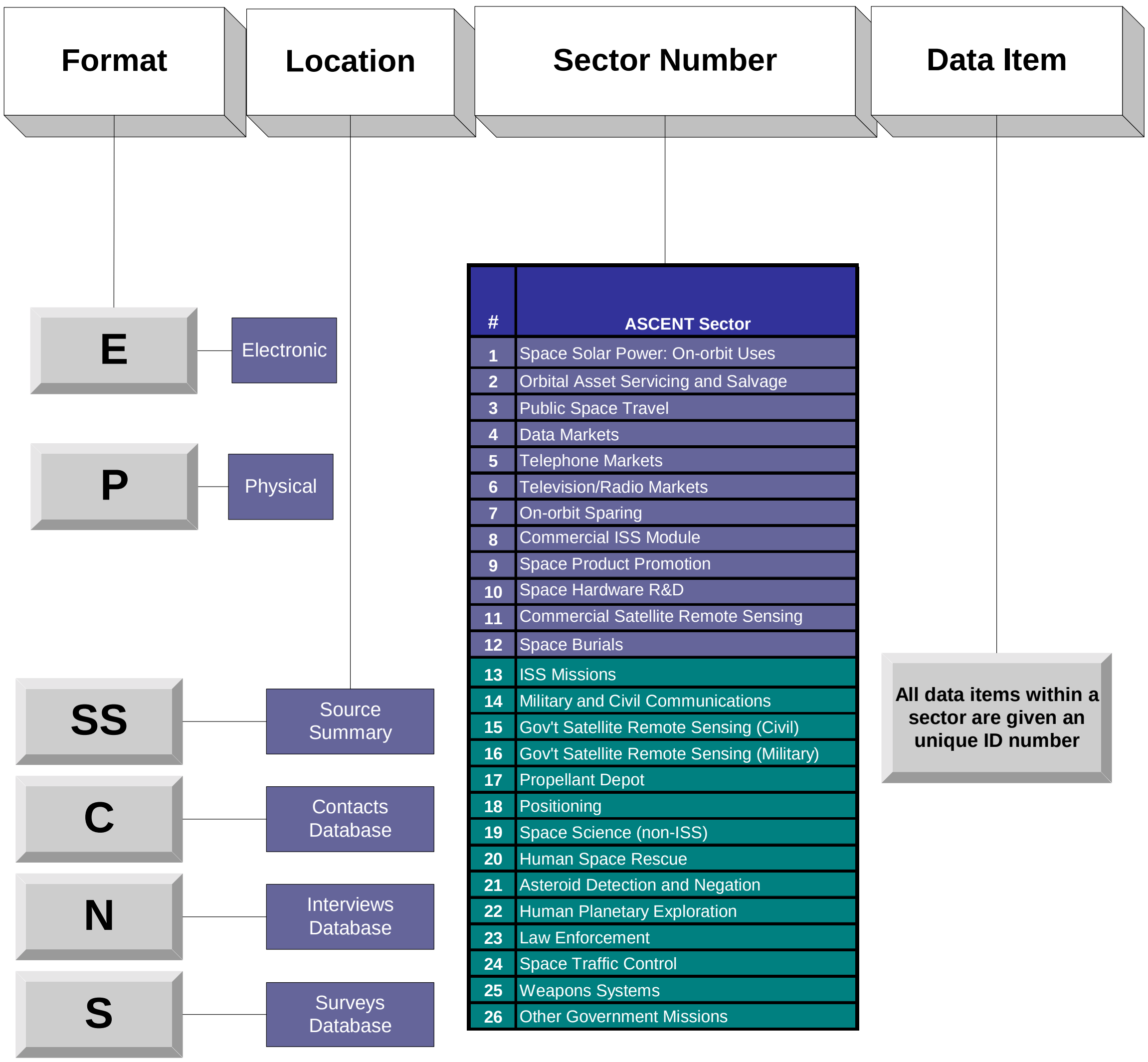
Figure 6-1: Standard Data Collection Method Selection



Coding Scheme

The data collected for the ASCENT Study was compiled in a logical manner for ease of use in forecasting the resulting launch vehicle markets. The archiving process was developed in parallel for the physical files and for the relational databases within the electronic filing system. A unified coding scheme was developed to uniquely identify a piece of source data to facilitate future tracking. This coding scheme is therefore the key to external access to the data inventory, and is used in all of the data tabulations for each market or government sector described in the Bibliography in Volume II. Figure 6-2 provides an explanation of the coding scheme. Approximately 400 articles and documents were researched, more than 30 interviews conducted, and a series of surveys administered during Phase I of the ASCENT Study.

Figure 6-2: ASCENT Study Data Inventory Coding Scheme

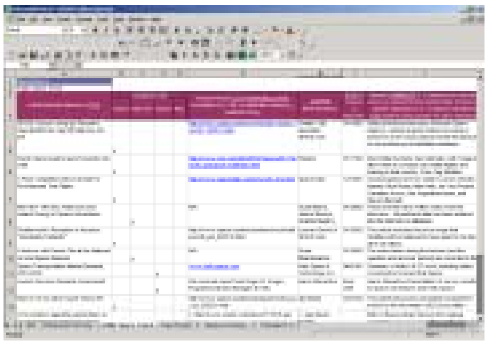


Examples:				
E-N-3-5	E	N	3	5
	Electronic	Interviews Database	Public Space Travel	Interview Number
P-SS-13-7	P	SS	13	7
	Physical	Source Summary File	ISS Missions	Source Number

Note: The sector numbering for the data inventory differs from the coding scheme later introduced in Figure 7-2.

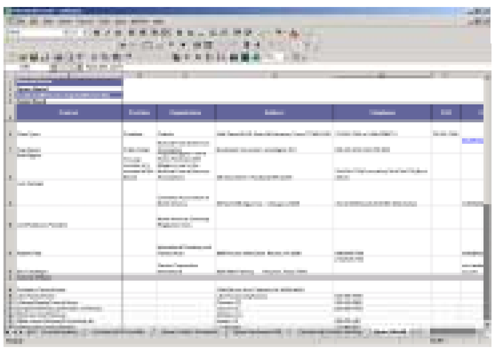
Figure 6-3 explains the data formats within the electronic ASCENT Study Data Inventory. Volume II provides information on how to access the data and models of the ASCENT Study.

Figure 6-3: Electronic Archive for ASCENT Study



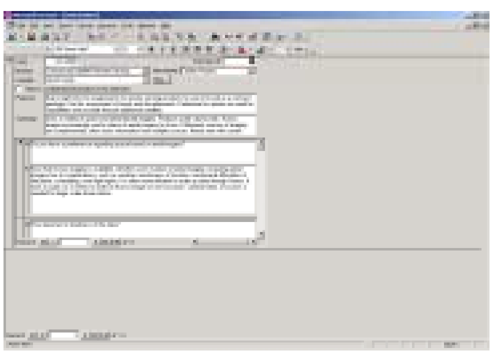
ASCENT Source Summary Spreadsheet (In MS Excel)
Captures data from periodicals, websites, interviews, reports, and miscellaneous sources (email, phone calls, etc). Forty-two worksheets (one for each ASCENT sector) ensure easy cataloguing and retrieval by subject matter for use in forecasting activities.
Data captured includes:

- Title
- Author
- Date of source
- Source location
- Summary of source (and relevance to the ASCENT Study)



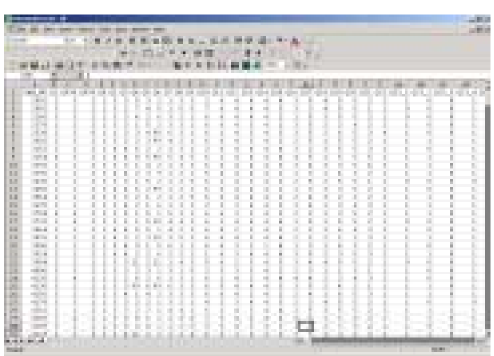
ASCENT Contacts Database (In MS Excel)
Captures contact information for relevent sources by ASCENT sector. Forty-two worksheets (one for each ASCENT sector) ensure easy cataloguing of new contacts and retrieval of contact information for on-going data collection activities.
Data captured includes:

- Name of expert
- Contact information
- Contact record



ASCENT Interviews Database (In MS Access)
Captures information gathered via interviews. Flexible question/answer format allows easy entry of new information from on-going data collection activities. Queries can be made by ASCENT sector, question or interviewee.
Data captured includes:

- Name of interviewers/interviewees
- Date of interview
- Purpose of interview
- Specific questions and answers from interview
- Summary field



ASCENT Survey Results Databases (In MS Excel)
These workbooks capture information gathered via surveys (both external and internal) for Public Space Travel and Commercial Satellite Remote Sentsing.

7. Standardized Forecasting Process

A standardized approach to demand forecasting has been applied to all the sectors quantified in the ASCENT Study . . .

Forecasting of current and future commercial space markets in the ASCENT Study focused on determining the effect on launches. In order to forecast the commercial, demand-driven sectors' effect on launches, the link between the demand for service at the end-user level and launch demand had to be understood. Once the link was understood in each sector, end-user demand for service was converted to payloads and the payloads were then manifested into launches. For the Government sectors, a different approach was used whereby demand was determined by aggregating the respective forecasts contained in mission models from world governments.

Identification and Discussion of Common Forecasting Elements

The first step of the process was forecasting the demand at end-user levels for each of the commercial sectors. In order to understand how the various data elements fit into the forecasts, and to determine the common elements and dependencies between them, it was necessary to create conceptual frameworks for each market. These are provided in Volume II. These conceptual frameworks were based on widely accepted methods for determining market demand.

Figure 7-1 shows the generic approach used for the demand-based forecasts and identifies four elements that are common to all forecasts.

Item 1 refers to the units to be forecasted for each market. These are closely related to the fundamental units of demand (FUD), the quantity of the underlying demand for a product or service. Forecasting units represent the quantity of products or services as provided by the supplier. For example, consumers of data transmission services demand bandwidth capacity; satellite operators lease transponders.

Item 2 refers to the start year. For Existing markets, this data is obtainable from a historical analysis. For Evolving markets, however, determining the future start date requires careful analysis of supply-side investments, availability of necessary supporting infrastructure, and an assessment of when the proposed price range for the product or service is likely to fall within the affordable range.

Item 3 refers to the range of target markets that are related to different price levels for the product or service, typically obtained from survey results or affordability analyses. The actual forecast generally follows an S-curve, which never actually reaches the target market although it can become close enough for practical purposes.

Item 4 addresses the rate at which the take-up curve approaches the target market. In the initial years, the rate is limited by manufacturing supply constraints, and then the curve reaches a maximum growth rate associated with enthusiastic early adopters. The rate then begins to decline as it becomes increasingly harder to find marginal users willing to pay the associated price for the product or service. Typically, the shape of the S-curve for any given market may be determined by comparison with historical examples of analogous markets. Data is available, for instance, to show the S-curve characteristics of the cellular telephone industry, or laptop computer acceptance, or the vacation industry.

Figure 7-1: Key Aspects of Common Forecasting Approach

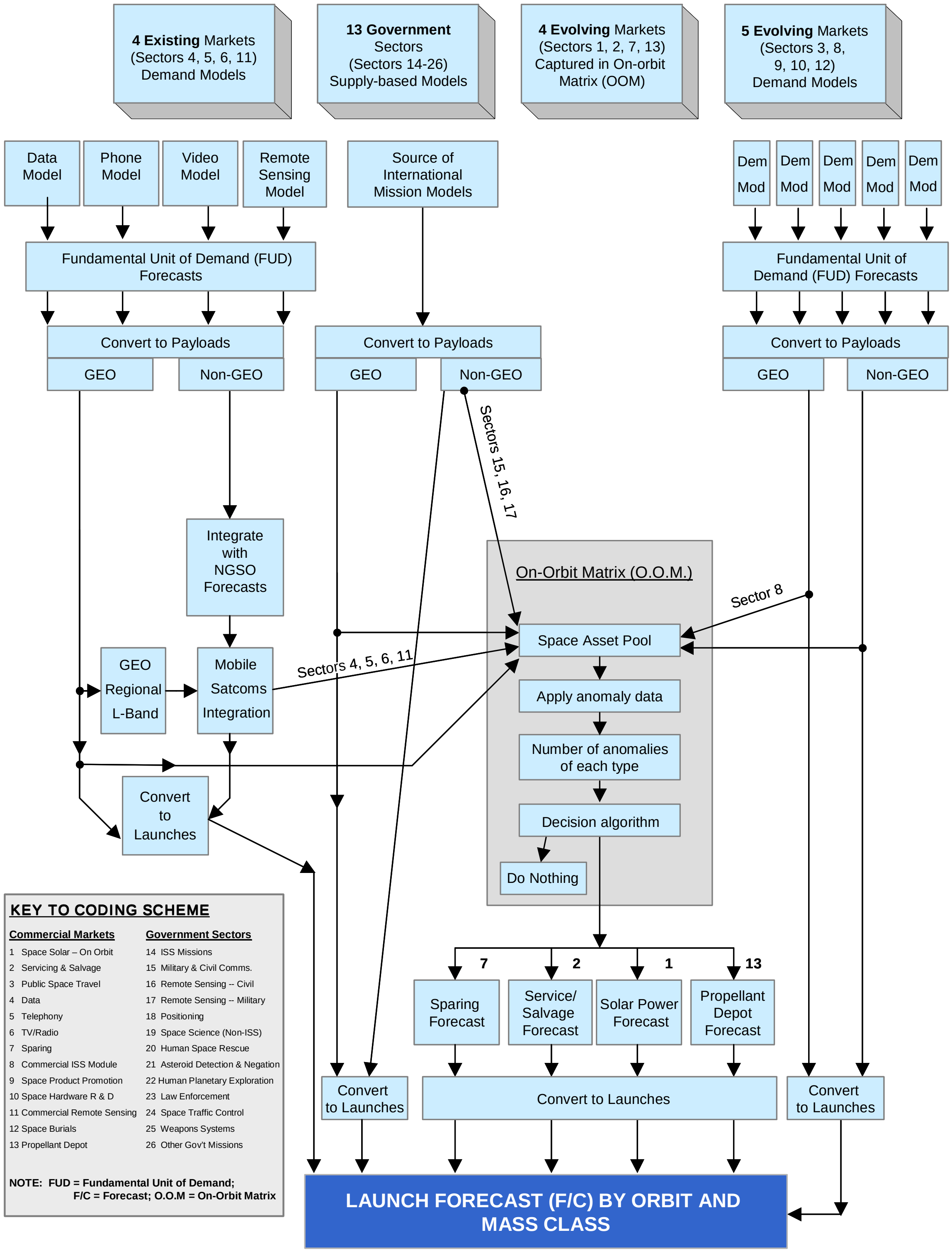
Refer to Volume II for the S-curve parameters used for each of the forecasted commercial markets. Each of the market sectors was forecasted separately. The demand forecast models used the Fisher-Pry version of the logistic curve:

$f = 0.5\ [1 + \tanh a(t - t_0)]$ where

- f = the degree of market saturation
- t = time
- t_0 = time to 50% market saturation and,
- a = slope coefficient.

Figure 7-2 shows how each of these forecasts, together with the supply-based government forecasts, were brought together to provide the resulting 20-year launch vehicle demand projections. Note that a number of the sectors operate on a common infrastructure of on-orbit assets, and the ASCENT Study therefore created the On-Orbit Matrix (OOM) to keep track of these common elements throughout the forecasting process. Separate forecasts are generated for each mass class and orbit type.

Figure 7-2: Overall ASCENT Study Launch Forecast Methodology



8. Baseline Forecasts

Figures 8-1 through 8-6 graphically display the 20-year launch forecasts by orbital mission, by year, and by mass class and in SLI-defined missions specified by NASA. Table 8-1 provides the specific numbers represented by the graphs. Each constituent demand sector forecast is included in Volume II.

The Baseline forecasts represent the most likely outcome in terms of launch vehicle usage over the next twenty years. Sensitivity runs estimate the non-price generated variations in the forecasts. . .

1,523 launches are forecasted during the 20-year period, which averages approximately 76 per year.

There are many differences between the first and second half of the forecast; however, one of the primary factors influencing the growth in the second half is the public space travel market.

Figure 8-1: Baseline Launch Forecast for All Sectors

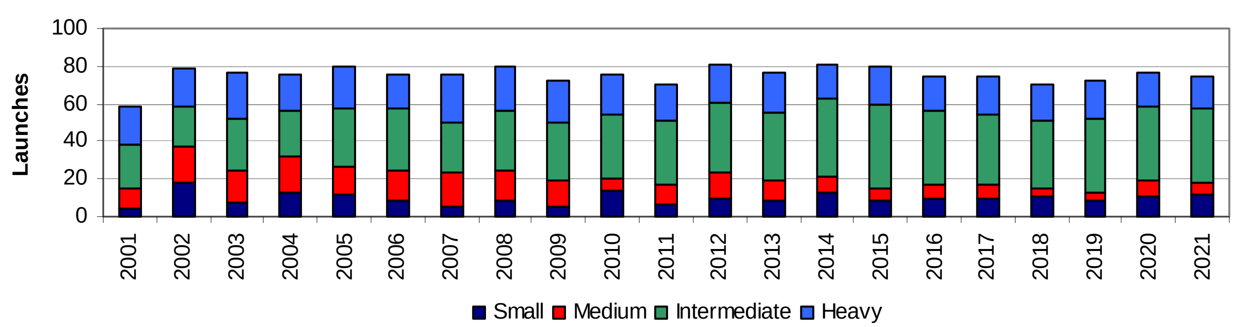


Figure 8-2: Baseline Launch Forecast for GEO Sectors

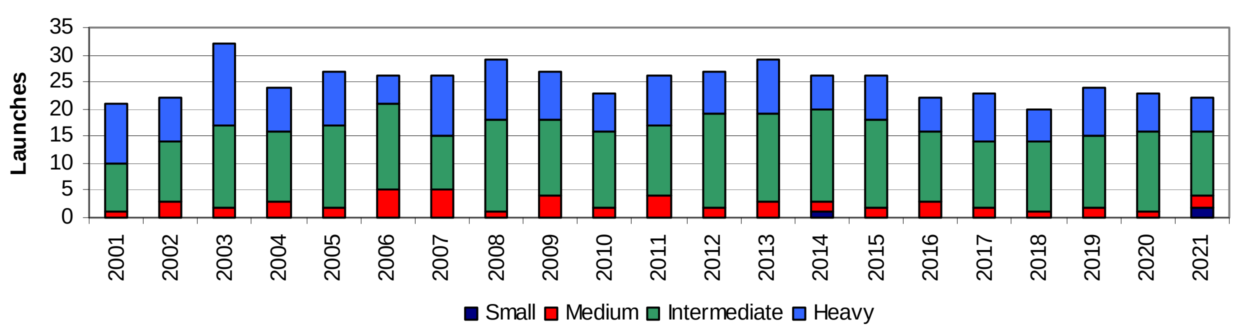
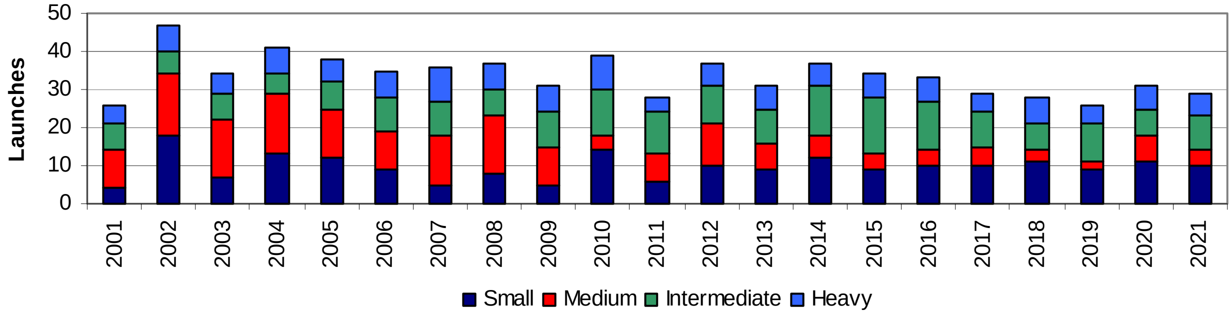


Figure 8-3: Baseline Launch Forecast for Non-Geosynchronous Orbit (NGSO) /LEO Sectors



*NGSO/LEO launches do not include the crewed and uncrewed missions to the ISS

Figure 8-4: Baseline Launch Forecast for LEO Public Space Travel Sector

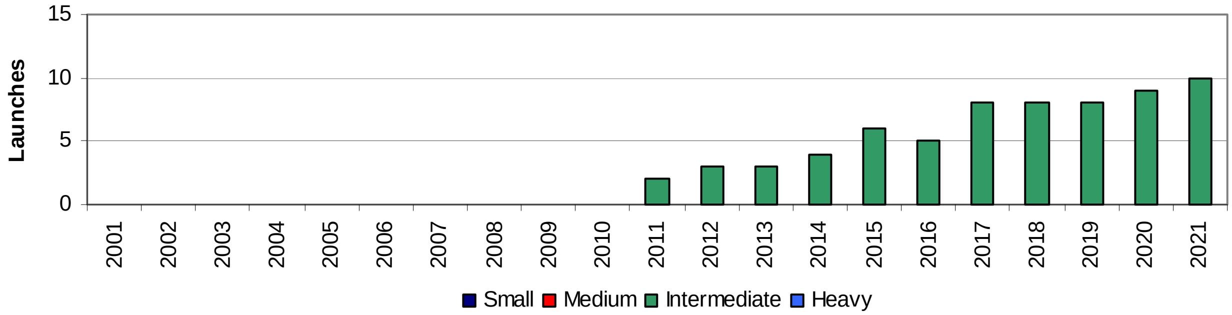


Figure 8-5: Baseline Launch Forecast for ISS Crewed Sectors

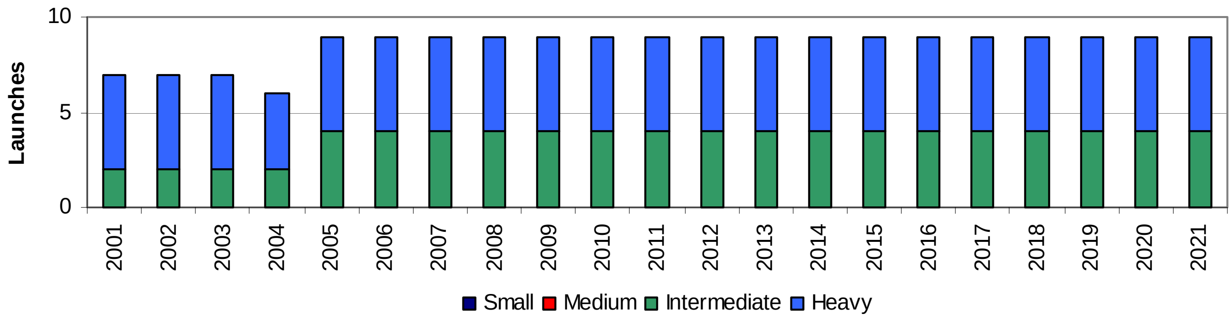


Figure 8-6: Baseline Launch Forecast for ISS Uncrewed Sectors

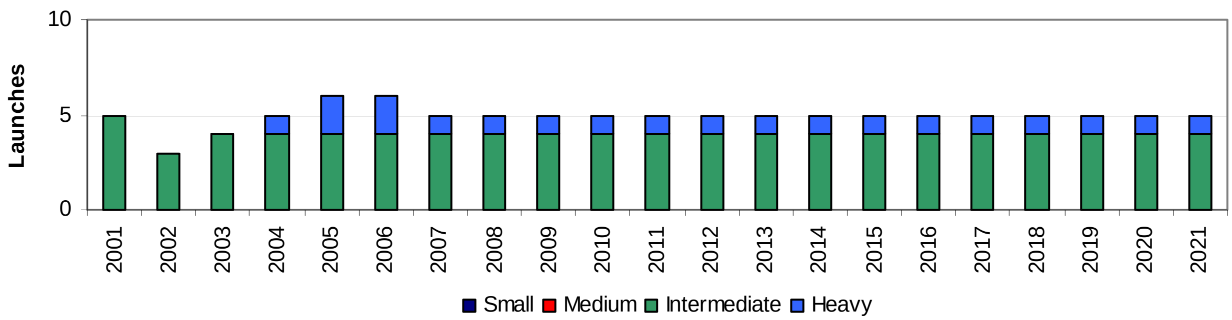


Table 8-1: Baseline Forecast of Launches by Vehicle Mass Class

GEO	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Medium	1	3	2	3	2	5	5	1	4	2	4	2	3	2	2	3	2	1	2	1	2
Intermediate	9	11	15	13	15	16	10	17	14	14	13	17	16	17	16	13	12	13	13	15	12
Heavy	11	8	15	8	10	5	11	11	9	7	9	8	10	6	8	6	9	6	9	7	6
Total	21	22	32	24	27	26	26	29	27	23	26	27	29	26	26	22	23	20	24	23	22

NGSO/LEO*	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	4	18	7	13	12	9	5	8	5	14	6	10	9	12	9	10	10	11	9	11	10
Medium	10	16	15	16	13	10	13	15	10	4	7	11	7	6	4	4	5	3	2	7	4
Intermediate	7	6	7	5	7	9	9	7	9	12	11	10	9	13	15	13	9	7	10	7	9
Heavy	5	7	5	7	6	7	9	7	7	9	4	6	6	6	6	6	5	7	5	6	6
Total	26	47	34	41	38	35	36	37	31	39	28	37	31	37	34	33	29	28	26	31	29

Public Space Travel	2001	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intermediate	0	0	0	0	0	0	0	0	0	0	2	3	3	4	6	5	8	8	8	9	10
Heavy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	2	3	3	4	6	5	8	8	8	9	10

ISS Crewed	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intermediate	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Heavy	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total	7	7	7	6	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9

ISS Uncrewed	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intermediate	5	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Heavy	0	0	0	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	5	3	4	5	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Total Launches	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	4	18	7	13	12	9	5	8	5	14	6	10	9	13	9	10	10	11	9	11	12
Medium	11	19	17	19	15	15	18	16	14	6	11	13	10	8	6	7	7	4	4	8	6
Intermediate	23	22	28	24	30	33	27	32	31	34	34	38	36	42	45	39	37	36	39	39	39
Heavy	21	20	25	20	23	19	26	24	22	22	19	20	22	18	20	18	20	19	20	19	18
Total	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

**NGSO/LEO launches do not include the crewed and uncrewed missions to the ISS.*

The results show a fairly resilient small and heavy launch demand, with a gradual shift from medium to intermediate launch demand, mainly in the government sector, which is also a reflection of the demise of various LEO telecommunications ventures in recent years.

Figures 8-7 through 8-10 take the same forecast information and present it with a different breakdown, which shows the aggregated market sectors. There is a gradual increase of the commercial share of launches throughout the period, starting at around 25% and reaching about 50% by 2021. Also the growth in the second decade of the Evolving sectors demand makes feasible the continuation of an annual global launch rate of between 60 and 80 launches per year throughout the 20-year period. Within this Evolving sector, public space travel is the main demand driver. Table 8-2 captures this same information in tabular form.

The key assumptions that drive these outcomes are provided for each of the constituent market segments in Volume II. Some of the main drivers include:

- *Commercial GEO sectors: (Telephony, TV, Data Markets):* a rather low level prospect until the end of the decade when launches are needed to replace satellites and constellations currently on orbit

- *Commercial NGSO:* Due to difficulties encountered by LEO telecommunications ventures (e.g., Iridium, Globalstar, ICO and others), only one replenishment constellation is required during the forecast period.

- *Government Missions:* The aggregation of all the mission models results in a slow gradual decline of the sector.

Figure 8-7: Baseline Launch Forecast for All Sectors

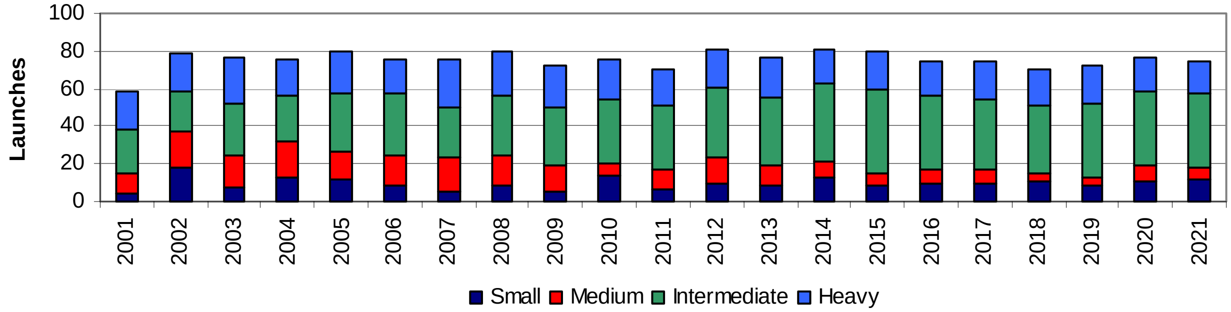


Figure 8-8: Baseline Launch Forecast for Existing Sectors

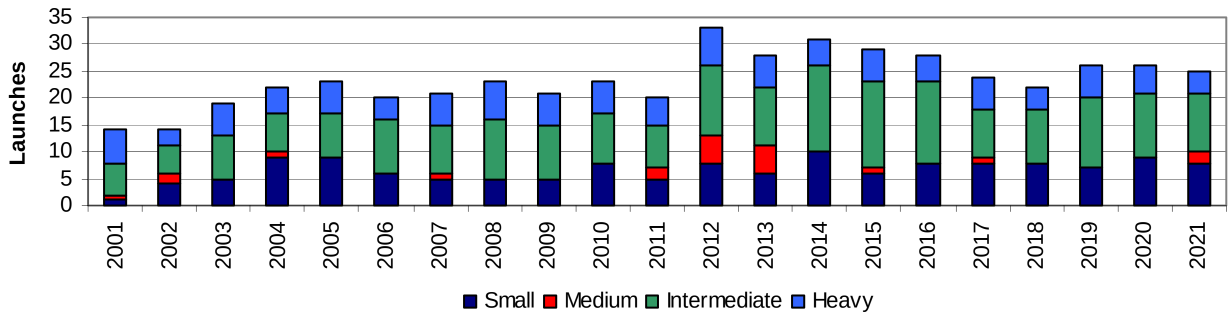


Figure 8-9: Baseline Launch Forecast for Government Sectors

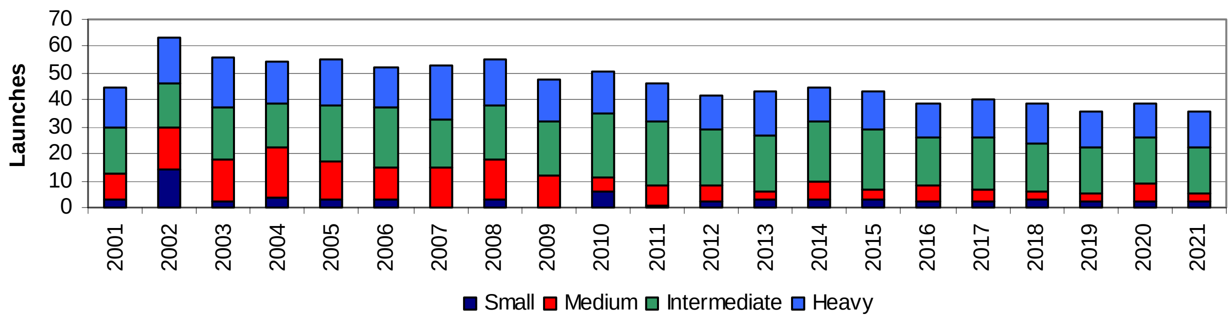


Figure 8-10: Baseline Launch Forecast for Evolving Sectors

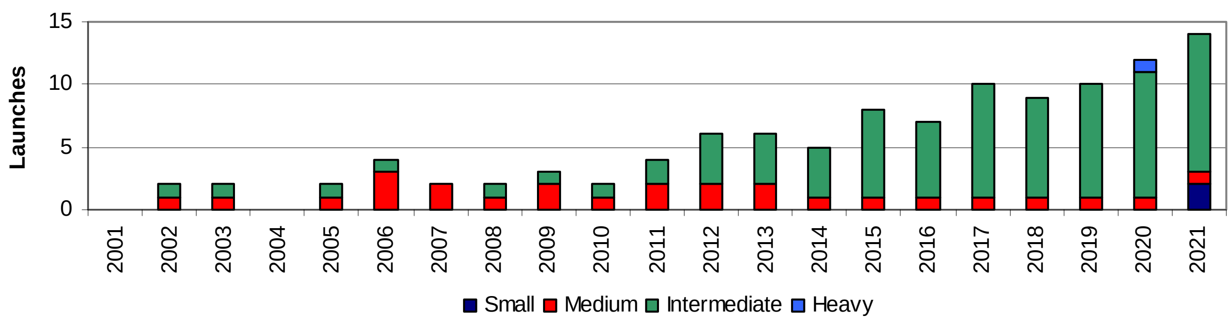


Table 8-2: Baseline Forecast of Launches by Sectors and by Mass Class

Existing	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	1	4	5	9	9	6	5	5	5	8	5	8	6	10	6	8	8	8	7	9	8
Medium	1	2	-	1	-	-	1	-	-	-	2	5	5	-	1	-	1	-	-	-	2
Intermediate	6	5	8	7	8	10	9	11	10	9	8	13	11	16	16	15	9	10	13	12	11
Heavy	6	3	6	5	6	4	6	7	6	6	5	7	6	5	6	5	6	4	6	5	4
Total	14	14	19	22	23	20	21	23	21	23	20	33	28	31	29	28	24	22	26	26	25

Government	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	3	14	2	4	3	3	-	3	-	6	1	2	3	3	3	2	2	3	2	2	2
Medium	10	16	16	18	14	12	15	15	12	5	7	6	3	7	4	6	5	3	3	7	3
Intermediate	17	16	19	17	21	22	18	20	20	24	24	21	21	22	22	18	19	18	17	17	17
Heavy	15	17	19	15	17	15	20	17	16	16	14	13	16	13	14	13	14	15	14	13	14
Total	45	63	56	54	55	52	53	55	48	51	46	42	43	45	43	39	40	39	36	39	36

Evolving	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Medium	-	1	1	-	1	3	2	1	2	1	2	2	2	1	1	1	1	1	1	1	1
Intermediate	-	1	1	-	1	1	-	1	1	1	2	4	4	4	7	6	9	8	9	10	11
Heavy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Total	0	2	2	0	2	4	2	2	3	2	4	6	6	5	8	7	10	9	10	12	14

All Sectors	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Small	4	18	7	13	12	9	5	8	5	14	6	10	9	13	9	10	10	11	9	11	12
Medium	11	19	17	19	15	15	18	16	14	6	11	13	10	8	6	7	7	4	4	8	6
Intermediate	23	22	28	24	30	33	27	32	31	34	34	38	36	42	45	39	37	36	39	39	39
Heavy	21	20	25	20	23	19	26	24	22	22	19	20	22	18	20	18	20	19	20	19	18
Total	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

Market Drivers and Inhibitors

The Baseline forecast presented earlier shows Futron's best assessment of the likely demand for launches for the next 20 years. However, inherent in any forecast are assumptions about the effect that market drivers and inhibitors will have on the element being forecasted.

Consequently, Futron analyzed these market drivers and inhibitors for each market sector (both commercial and government), isolated the key assumptions, and varied the assumptions to provide a range of likely outcomes, as opposed to the point solution of the Baseline forecast. Futron then generated two additional forecasts – a Robust forecast reflecting generally more optimistic assumptions than those uses in the Baseline forecast, and a Constrained forecast where the overall outcome is less positive than the Baseline forecast.

There was not a general across-the-board assumption of a standard increase for the Robust forecast, or a standard decrease for the Constrained forecast. The interpretation of the Robust and Constrained forecasts were done on a sector-by-sector basis and are shown in Tables 8-3, 8-4 and 8-5. Figures 8-11 through 8-14 show the effect of the differing assumptions on the Baseline forecast.

Table 8-3: Summary of Main Market Drivers and Inhibitors – Existing Commercial Markets

Sector	Sensitivity Parameter	Range of Sensitivity Values		
		Baseline	Robust	Constrained
Telephony Markets	Trunking markets: Percentage of traffic over satellite	Base values	Increased % carried over satellite	Decreased % carried over satellite
	End-user markets: Long term growth of telecommunications infrastructure	Base values	Demand met earlier due to faster infrastructure growth	Demand met later due to slower infrastructure growth
Data Communications Markets	Last mile considerations: Growth rate in average bandwidth per user; growth in number of broadband connections; data compression ratio per transponder	Base values	Increase growth rates in bandwidth demanded	Decrease growth rates in bandwidth demanded; increased data compression
	ISP to backbone: Growth rate in national bandwidth	Base values	Increase growth rates in bandwidth demanded	Decrease growth rates in bandwidth demanded; increased data compression
Television and Radio Markets	Revenues per subscriber	Base values	Increase revenue per subscriber	Decrease revenue per subscriber
	Transponder costs	Base values	Decrease transponder cost	Increase transponder cost
	Emergence of high definition and interactive TV	Base values	Assume growth in high definition and interactive TV	Less growth in high definition and interactive TV
Commercial Satellite Remote Sensing	Life cycle cost estimate for Landsat-like payload (possibility of using smaller satellite bus in future)	Life cycle cost $747M	Life cycle cost $204M	Life cycle cost $747M
	Percent of remote sensing industry that is satellite imagery sales	Imagery sales =10%	Imagery sales =15%	Imagery sales =9%

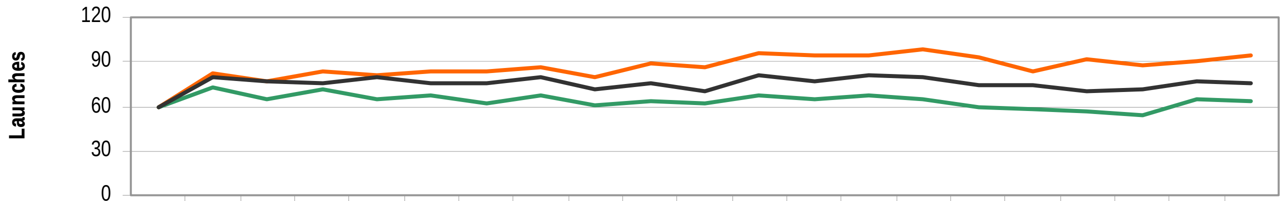
Table 8-4: Summary of Main Market Drivers and Inhibitors – Evolving Commercial Markets

Sector	Sensitivity Parameter	Range of Sensitivity Values		
		Baseline	Robust	Constrained
Public Space Travel	Estimated time to market maturity	Market maturity in 60 years	Market maturity in 50 years	Market maturity in 70 years
	"Pioneering" discount	Baseline value	Reduced "pioneering" discount	Increased "pioneering" discount
Commercial ISS Module	Cost of module	$100 M	$85 M	$115 M
Space Product Promotion	Viewership for launches	Current rate	Matches growth with Superbowl viewership growth rate for past 30 years	Limits viewership to audiences viewing launches in person (about 9,000)
Space Hardware R&D	Percent of commercial internal research and development (IR&D) projects that require in-space testing (i.e., cannot be simulated on ground)	5%	15%	5%
Space Burial	Scattering rate of cremated remains (dependent on Western vs. Eastern burial practices)	Baseline values	30% Western; 5% Eastern	15% Western; 0.5% Eastern
	Percentage of population with interest in space (dependent on spacefaring status)	1% spacefaring; 0.01% non-spacefaring	5% spacefaring; 1% non-spacefaring	5% spacefaring; 1% non-spacefaring
	Estimated time to market maturity	34 years	30 years	40 years
On-Orbit Sparing	Dependent upon the forecasts and related assumptions for other ASCENT markets	Baseline values	See changes in other ASCENT markets	See changes in other ASCENT markets
Orbital Asset Servicing and Salvage	Development cost	Base cost	50% decrease in development cost (i.e., greater government subsidy)	50% increase in development cost
	Manufacturing cost	Base cost	No change	20% increase
	Propulsion choice (use or non-use of depot)	Uses propellant depot	Uses advanced on-orbit propulsion eliminating need for propellant depot	Uses propellant depot
Space Solar Power: On-Orbit Uses	Cost fraction of a terrestrial system (assume satellite is a scaled-down version of a terrestrial system)	10%	5%	20%
Propellant Depot	Development and manufacturing costs	$450 M	$150 M	$650 M

Table 8-5: Summary of Main Market Drivers and Inhibitors – Government Missions

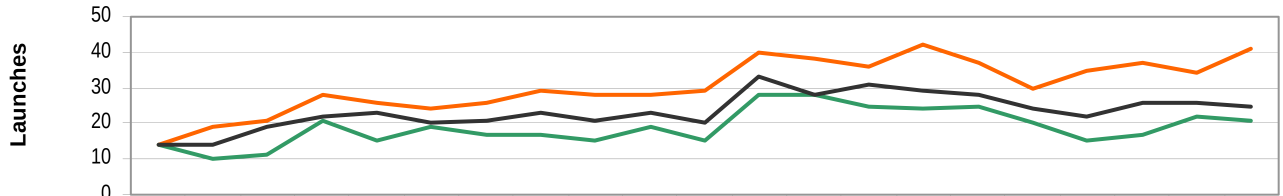
Sector	Sensitivity Parameter	Range of Sensitivity Values		
		Baseline	**Robust**	**Constrained**
ISS Missions	Number of flights per year of: *Shuttle*	5 Shuttle	6 Shuttle	4 Shuttle
	Soyuz	2 Soyuz; increase to 4	2 Soyuz; increase to 4	2 Soyuz
	European ATV	1 ATV	1 ATV	1 ATV until 2013
	Japanese HTV	0 HTV	1 HTV every other year after 2004	0 HTV
Military and Civil Communications	Maturity/funding of satellite programs	Funding approved; status information available	Add programs with ambitious schedule but with chance of getting funded	Some systems delayed due to schedule; some systems cancelled due to insufficient funding; remainder unchanged
Government Satellite Remote Sensing (Civil)	Maturity/funding of satellite programs	Funding approved; status information available	Number of follow-on satellites slightly increased	Number of follow-on satellites slightly decreased
Government Satellite Remote Sensing (Military)	Maturity/funding of satellite programs	Funding approved; status information available	Unchanged	SBIRS High and SBIRS Low delayed
Positioning	Maturity/funding of satellite programs	Navstar, Glonass, Galileo constellations, plus other national payloads	Increased replacement payloads	GPS 2F and GPS 3 delayed, Indian SBAS cancelled, Glonass K replacements reduced
Space Science (Non-ISS)	Maturity/funding of satellite programs	Funding approved; status information available; projected follow-ons included	Add programs with unknown funding status (e.g., uncrewed lunar flights by China and India)	Delete systems with unknown funding
Human Space Rescue	Number of dedicated human rescue flights	None forecasted	None forecasted	None forecasted
Asteroid Detection and Negation	Number of dedicated satellites for asteroid detection and negation	One payload forecasted	No change	No change
Human Space Exploration (Non-ISS)	Number of human crewed flights worldwide	ISS flights	No change	ISS flights
		China: 2-3 Shenzhou flights per year; Salyut-like station by 2010	No change	*China:* 2 Shenzhou flights per year; Salyut-like station by 2015
Law Enforcement	Number of dedicated satellites for law enforcement	None forecasted	None forecasted	None forecasted
Space Traffic Control	Number of dedicated satellites for space traffic control	None forecasted	None forecasted	None forecasted
Weapons Systems	Number of weapons payloads known via public sources	One U.S. microsat laser system expected	Add Chinese system in every other year starting in 2010	No change
Other Government Missions	Number of non-ISS Shuttle flights, demonstrators, other unique flights	1-2 per year	1-2 per year, with additional small payloads	No change

Figure 8-11: Baseline, Robust and Constrained Forecasts of Launches for All ASCENT Sectors



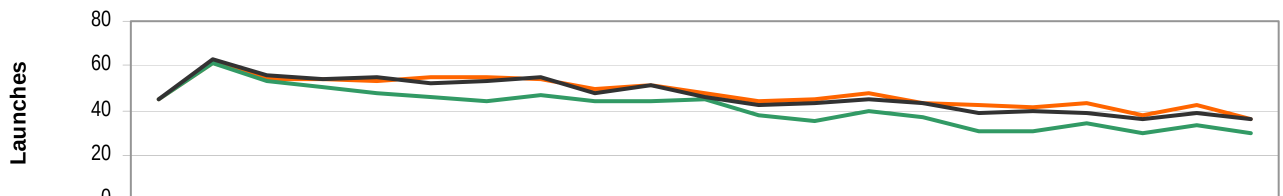
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	59	82	77	83	81	83	84	86	80	89	86	96	94	95	98	93	83	92	87	91	95
Constrained	59	73	65	72	65	68	62	67	61	64	62	68	65	67	65	60	58	57	54	65	63
Baseline	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

Figure 8-12: Baseline, Robust and Constrained Launch Forecasts for Existing Commercial Sectors



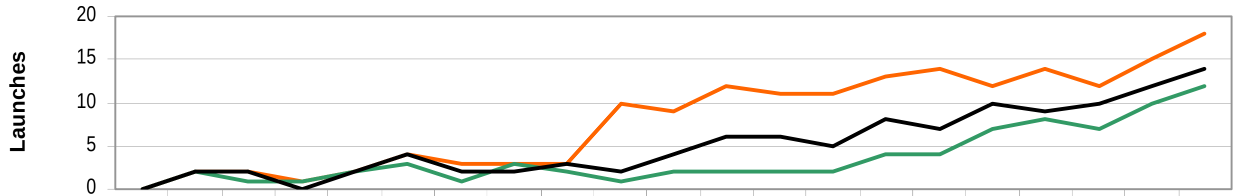
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	14	19	21	28	26	24	26	29	28	28	29	40	38	36	42	37	30	35	37	34	41
Constrained	14	10	11	21	15	19	17	17	15	19	15	28	28	25	24	25	20	15	17	22	21
Baseline	14	14	19	22	23	20	21	23	21	23	20	33	28	31	29	28	24	22	26	26	25

Figure 8-13: Baseline, Robust and Constrained Launch Forecasts for Government Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	45	61	54	54	53	55	55	54	49	51	48	44	45	48	43	42	41	43	38	42	36
Constrained	45	61	53	50	48	46	44	47	44	44	45	38	35	40	37	31	31	34	30	33	30
Baseline	45	63	56	54	55	52	53	55	48	51	46	42	43	45	43	39	40	39	36	39	36

Figure 8-14: Baseline, Robust and Constrained Launch Forecasts for Evolving Commercial Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	2	2	1	2	4	3	3	3	10	9	12	11	11	13	14	12	14	12	15	18
Constrained	0	2	1	1	2	3	1	3	2	1	2	2	2	2	4	4	7	8	7	10	12
Baseline	0	2	2	0	2	4	2	2	3	2	4	6	6	5	8	7	10	9	10	12	14

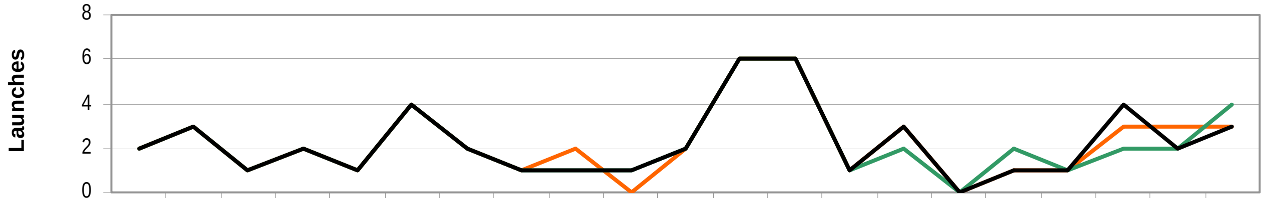
Note that there is not always an equal allocation of forecasting risk on the upside and downside for an individual sector, particularly when that sector is already well known. The object of the sensitivity analysis was to bound the most realistic of likely outcomes, and this does not necessarily imply that the Robust and Constrained Case range of results straddle the Baseline forecasts equally above and below the demand line. But it does ensure that the sensitivity exercise captures the most probable range of overall outcomes.

The results of the sensitivity analysis are as might be expected. The sectors that are already well known (i.e., Existing and Government) show the least variation. The sectors that do not yet exist (i.e., Evolving) show the most variation. The overall effect suggests slightly less upside potential than downside risk with the year 2021 launches ranging between 63 and 95 a year. In the 20 years of the Baseline forecast there are 1,523 launches. The Robust forecast adds 232 launches, and the Constrained forecast removes 242 of them.

Figures 8-15 through 8-40 show the constituent sector variations resulting from the changes in assumptions in Tables 8-3 through 8-5. Launches, of course, can only be measured in integer terms, and so only when aggregate underlying demand changes enough to trigger a unit change is an additional launch shown. Some sectors that had zero launch demand in the Baseline do show some late-term launches in the Robust forecast.

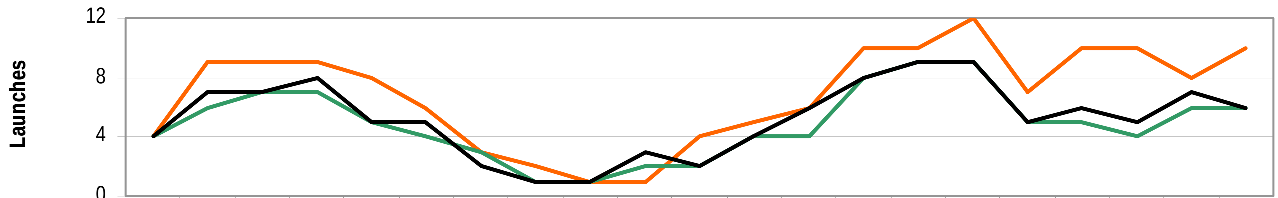
Baseline, Robust and Constrained Launch Forecasts by Commercial Market Sector

Figure 8-15: Launch Forecasts - Telephone Markets



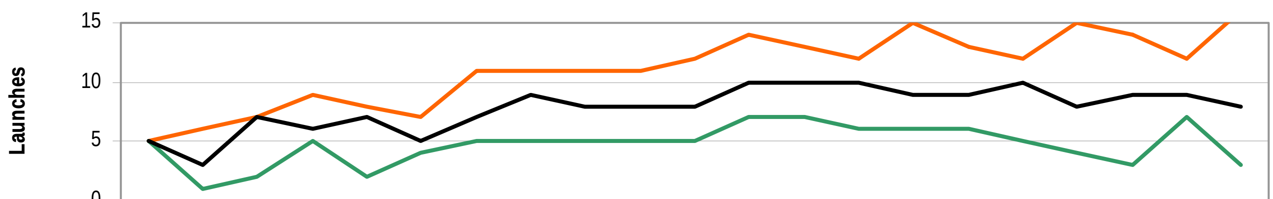
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	2	3	1	2	1	4	2	1	2	0	2	6	6	1	3	0	1	1	3	3	3
Constrained	2	3	1	2	1	4	2	1	1	1	2	6	6	1	2	0	2	1	2	2	4
Baseline	2	3	1	2	1	4	2	1	1	1	2	6	6	1	3	0	1	1	4	2	3

Figure 8-16: Launch Forecasts – Data Markets



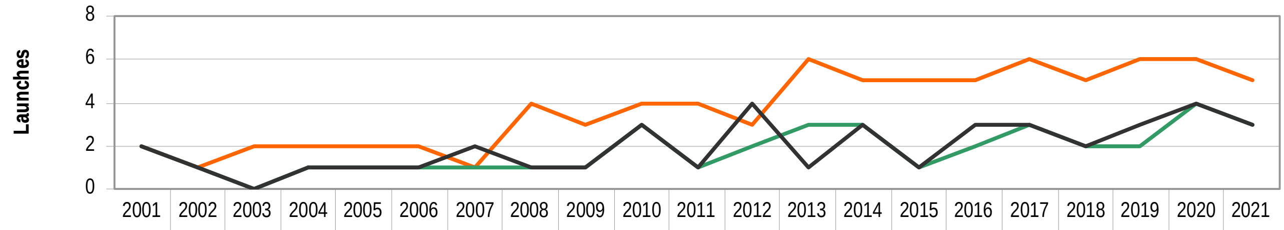
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	4	9	9	9	8	6	3	2	1	1	4	5	6	10	10	12	7	10	10	8	10
Constrained	4	6	7	7	5	4	3	1	1	2	2	4	4	8	9	9	5	5	4	6	6
Baseline	4	7	7	8	5	5	2	1	1	3	2	4	6	8	9	9	5	6	5	7	6

Figure 8-17: Launch Forecasts – Television and Radio Markets



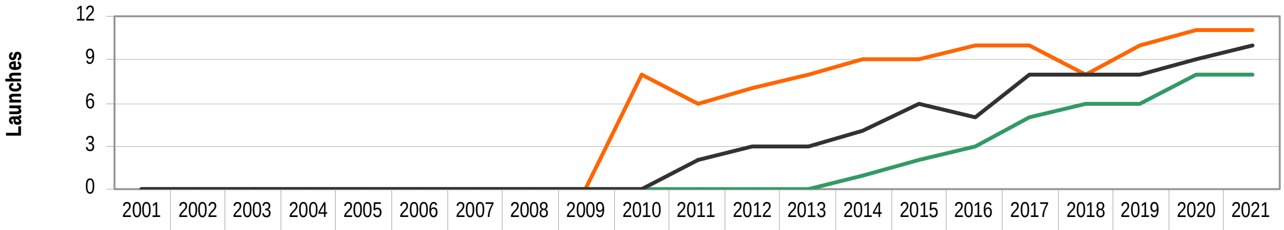
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	5	6	7	9	8	7	11	11	11	11	12	14	13	12	15	13	12	15	14	12	16
Constrained	5	1	2	5	2	4	5	5	5	5	5	7	7	6	6	6	5	4	3	7	3
Baseline	5	3	7	6	7	5	7	9	8	8	8	10	10	10	9	9	10	8	9	9	8

Figure 8-18: Launch Forecasts – Commercial Satellite Remote Sensing



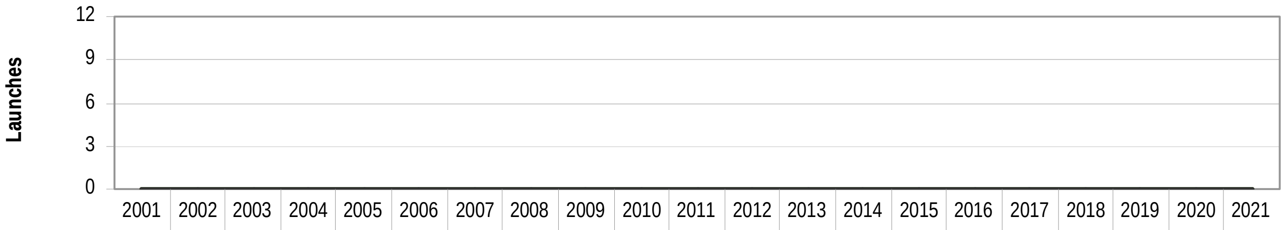
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	2	1	2	2	2	2	1	4	3	4	4	3	6	5	5	5	6	5	6	6	5
Constrained	2	1	0	1	1	1	1	1	1	3	1	2	3	3	1	2	3	2	2	4	3
Baseline	2	1	0	1	1	1	2	1	1	3	1	4	1	3	1	3	3	2	3	4	3

Figure 8-19: Launch Forecasts - Public Space Travel



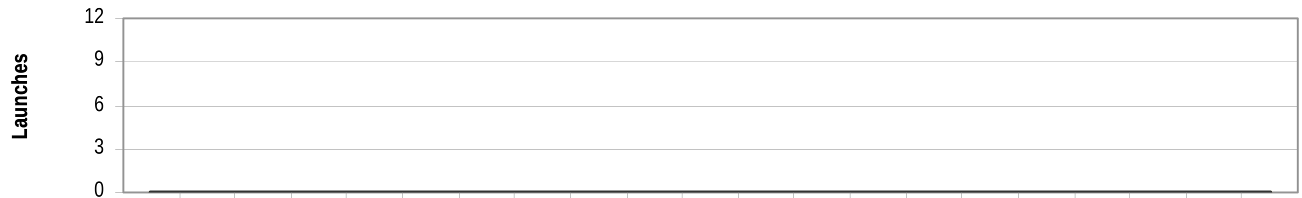
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	8	6	7	8	9	9	10	10	8	10	11	11
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	5	6	6	8	8
Baseline	0	0	0	0	0	0	0	0	0	0	2	3	3	4	6	5	8	8	8	9	10

Figure 8-20: Launch Forecasts – Commercial ISS Module



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-21: Launch Forecasts - Space Product Promotion



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

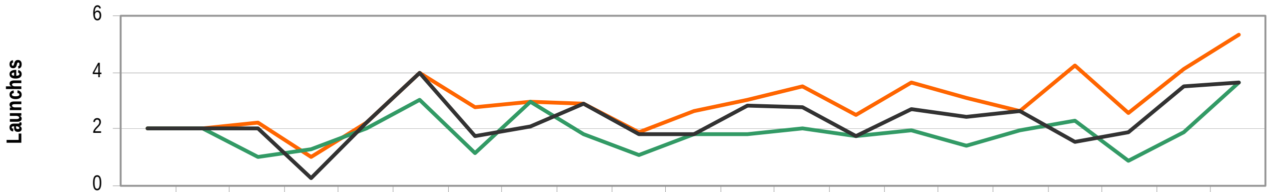
Figure 8-22: Launch Forecasts - Space Hardware R&D

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-23: Launch Forecasts - Space Burial

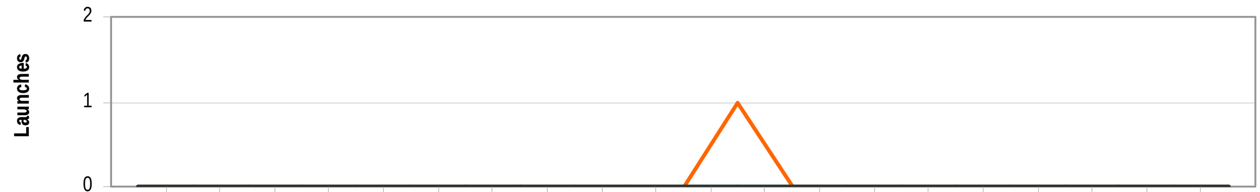
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Figure 8-24: Launch Forecasts – On-orbit Sparing



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	2	2	2	1	2	4	3	3	3	2	3	3	4	2	4	3	3	4	3	4	5
Constrained	2	2	1	1	2	3	1	3	2	1	2	2	2	2	2	1	2	2	1	2	4
Baseline	2	2	2	0	2	4	2	2	3	2	2	3	3	2	3	2	3	2	2	3	4

Figure 8-25: Launch Forecasts - Orbital Asset Servicing and Salvage

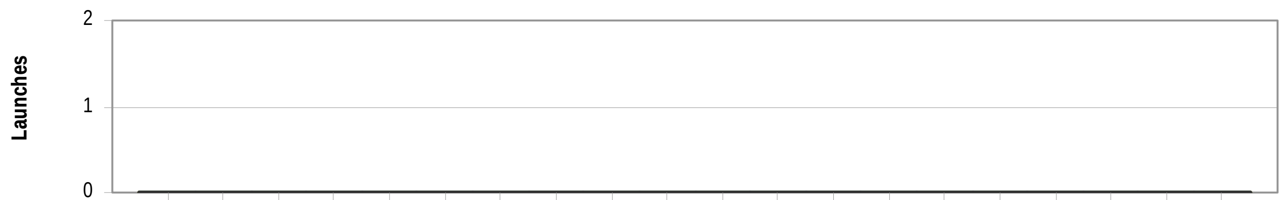


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-26: Launch Forecasts - Space Solar Power: On-orbit Uses

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

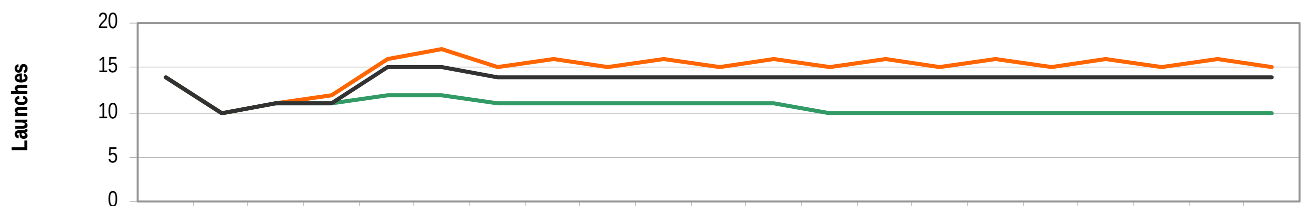
Figure 8-27: Launch Forecasts – Propellant Depot



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

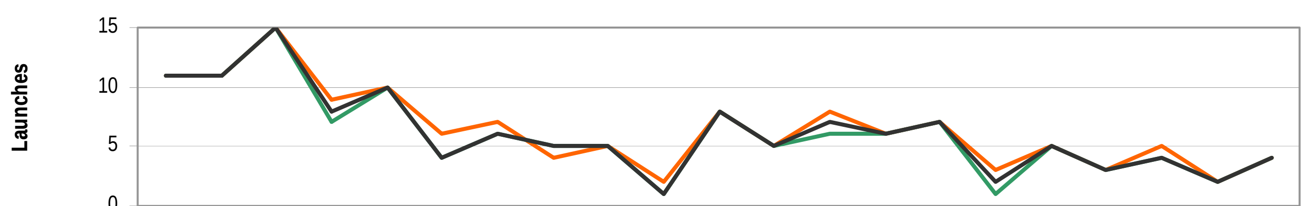
Baseline, Robust and Constrained Launch Forecasts for Government Sectors

Figure 8-28: Launch Forecasts - ISS Missions



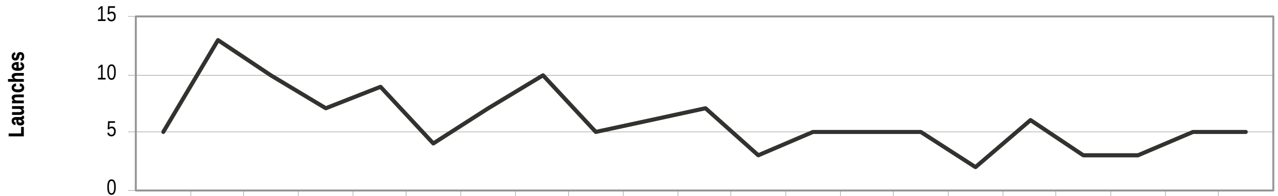
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	14	10	11	12	16	17	15	16	15	16	15	16	15	16	15	16	15	16	15	16	15
Constrained	14	10	11	11	12	12	11	11	11	11	11	11	10	10	10	10	10	10	10	10	10
Baseline	14	10	11	11	15	15	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Figure 8-29: Launch Forecasts - Military and Civil Communications



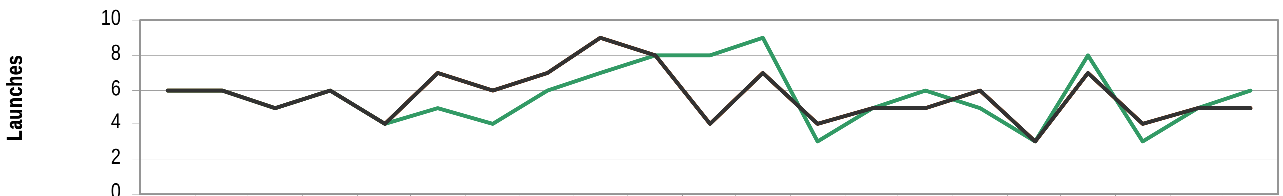
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	11	11	15	9	10	6	7	4	5	2	8	5	8	6	7	3	5	3	5	2	4
Constrained	11	11	15	7	10	4	6	5	5	1	8	5	6	6	7	1	5	3	4	2	4
Baseline	11	11	15	8	10	4	6	5	5	1	8	5	7	6	7	2	5	3	4	2	4

Figure 8-30: Launch Forecasts –Government Satellite Remote Sensing (Civil)



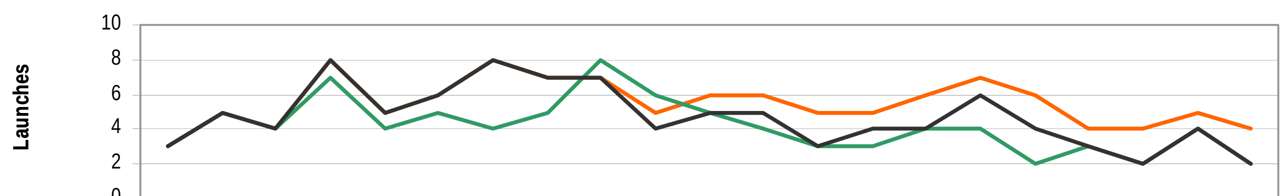
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	5	13	10	7	9	4	7	10	5	6	7	3	5	5	5	2	6	3	3	5	5
Constrained	5	13	10	7	9	4	7	10	5	6	7	3	5	5	5	2	6	3	3	5	5
Baseline	5	13	10	7	9	4	7	10	5	6	7	3	5	5	5	2	6	3	3	5	5

Figure 8-31: Launch Forecasts - Government Satellite Remote Sensing (Military)



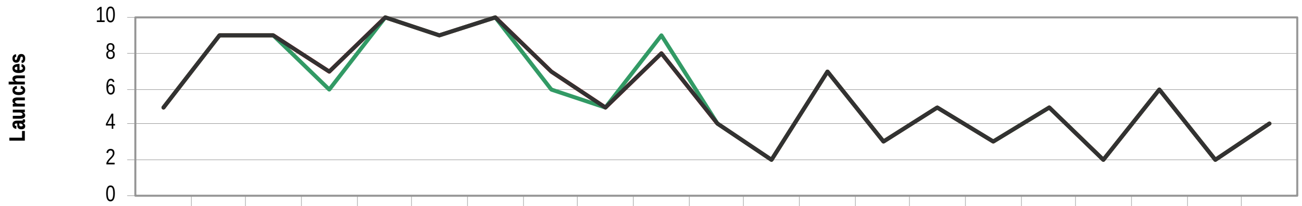
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	6	6	5	6	4	7	6	7	9	8	4	7	4	5	5	6	3	7	4	5	5
Constrained	6	6	5	6	4	5	4	6	7	8	8	9	3	5	6	5	3	8	3	5	6
Baseline	6	6	5	6	4	7	6	7	9	8	4	7	4	5	5	6	3	7	4	5	5

Figure 8-32: Launch Forecasts – Positioning



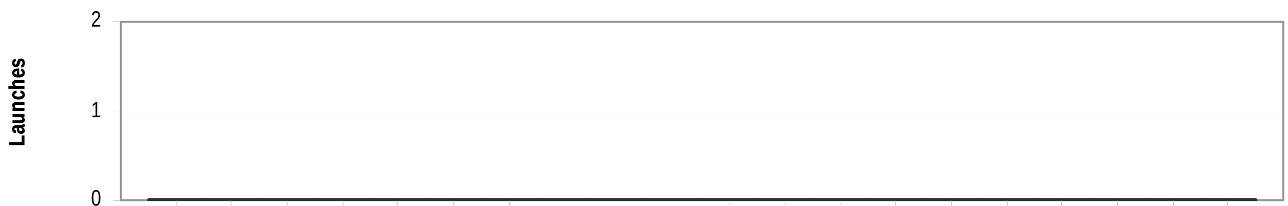
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	3	5	4	8	5	6	8	7	7	5	6	6	5	5	6	7	6	4	4	5	4
Constrained	3	5	4	7	4	5	4	5	8	6	5	4	3	3	4	4	2	3	2	4	2
Baseline	3	5	4	8	5	6	8	7	7	4	5	5	3	4	4	6	4	3	2	4	2

Figure 8-33: Launch Forecasts - Space Science (Non-ISS)



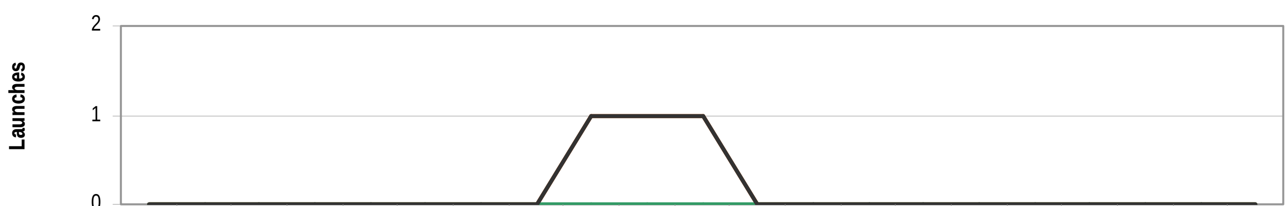
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	5	9	9	7	10	9	10	7	5	8	4	2	7	3	5	3	5	2	6	2	4
Constrained	5	9	9	6	10	9	10	6	5	9	4	2	7	3	5	3	5	2	6	2	4
Baseline	5	9	9	7	10	9	10	7	5	8	4	2	7	3	5	3	5	2	6	2	4

Figure 8-34: Launch Forecasts - Human Space Rescue



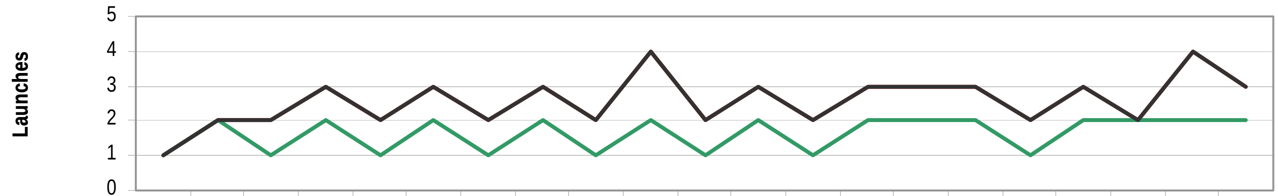
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-35: Launch Forecasts - Asteroid Detection and Negation



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Figure 8-36: Launch Forecasts - Human Space Exploration



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	1	2	2	3	2	3	2	3	2	4	2	3	2	3	3	3	2	3	2	4	3
Constrained	1	2	1	2	1	2	1	2	1	2	1	2	1	2	2	2	1	2	2	2	2
Baseline	1	2	2	3	2	3	2	3	2	4	2	3	2	3	3	3	2	3	2	4	3

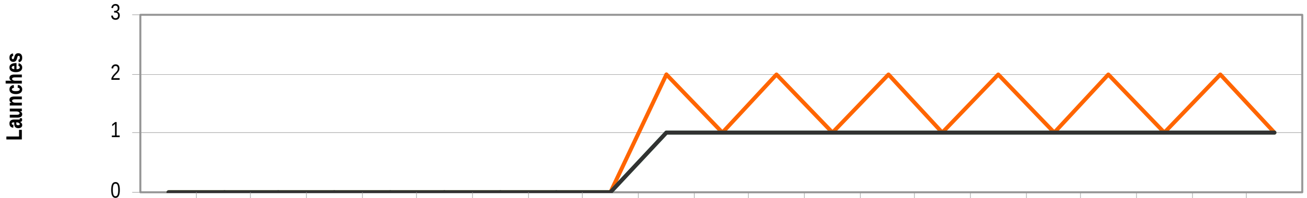
Figure 8-37: Launch Forecasts - Law Enforcement

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-38: Launch Forecasts - Space Traffic Control

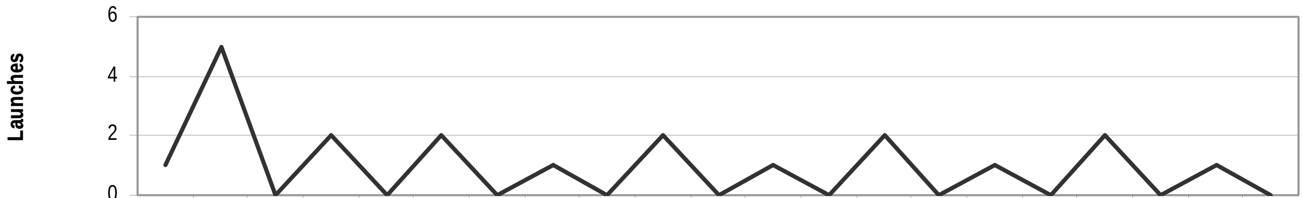
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Constrained	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-39: Launch Forecasts - Weapons Systems



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	0	0	0	0	0	0	0	0	0	2	1	2	1	2	1	2	1	2	1	2	1
Constrained	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Baseline	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1

Figure 8-40: Launch Forecasts - Other Government Missions



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Robust	1	5	0	2	0	2	0	1	0	2	0	1	0	2	0	1	0	2	0	1	0
Constrained	1	5	0	2	0	2	0	1	0	2	0	1	0	2	0	1	0	2	0	1	0
Baseline	1	5	0	2	0	2	0	1	0	2	0	1	0	2	0	1	0	2	0	1	0

9. Launch Price Impacts

The ASCENT Study produces high fidelity price elasticity of demand information for all markets. Most current markets benefit very little from even major reductions in launch price . . .

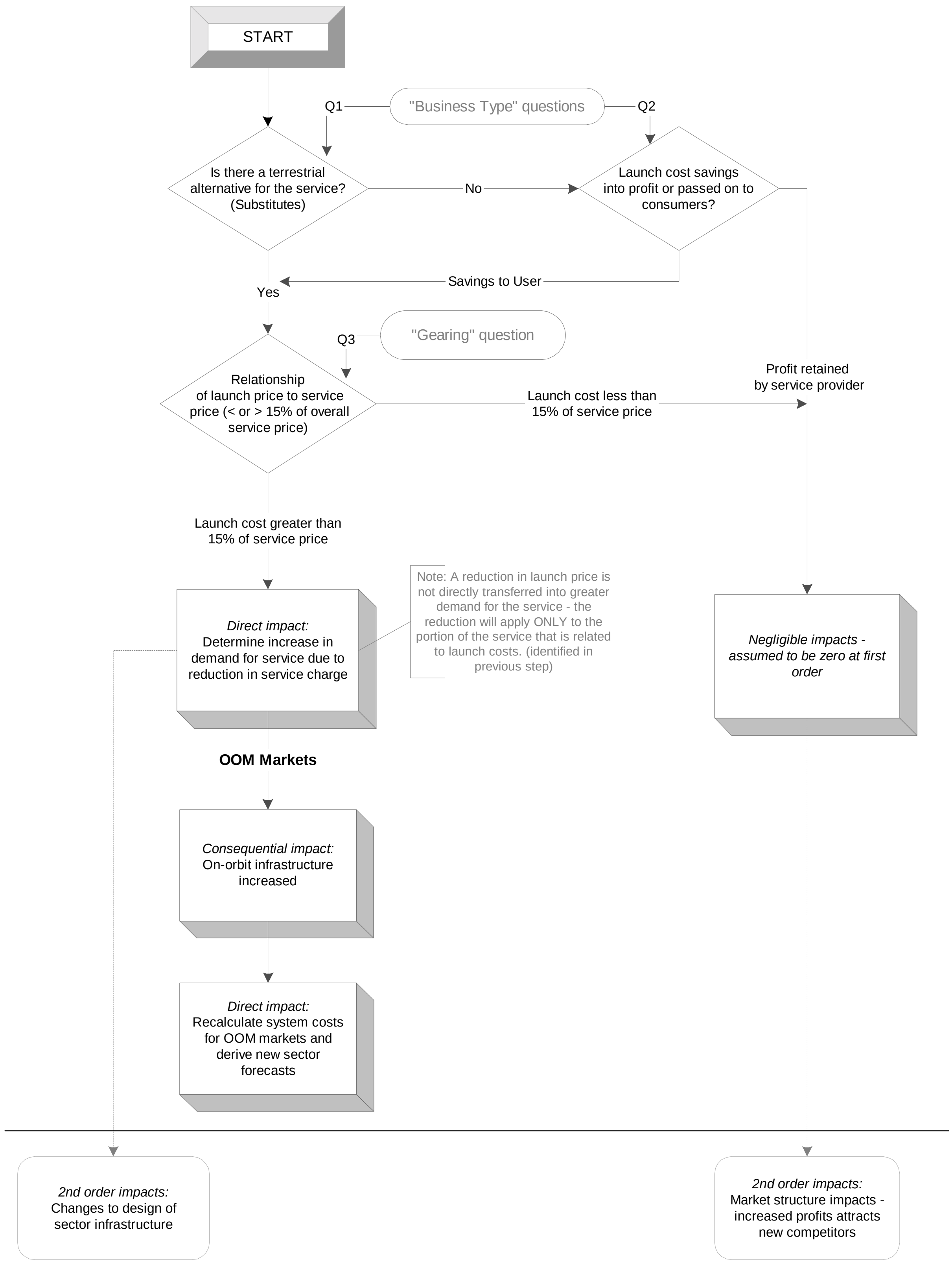
Figure 9-1 shows the approach taken in the ASCENT Study to forecasting the price elasticity of demand to launch prices. There are two key concepts that need to be fully understood to give meaning and value to the results of the analysis.

The first of these concepts is represented by the Gearing Question (Q3), which is introduced about a third of the way into the model flow chart. For many mature market sectors, launch costs are a relatively insignificant part of the cost picture that supports the end-user service. In such a situation, even a massive drop in launch costs will not be noticed by the end users, and therefore there will be no consequential growth in the sector business, and by extrapolation, no incremental increase in launch demand beyond that described in the Baseline forecasts. Table 9-1 below describes how this works out in practice for each of the markets being studied in the ASCENT Study. As a practical matter, and to avoid artificially computing minute changes that would produce results of a magnitude lost in the general noise level of other data assumptions, a figure of 15% was determined for use in the model as the critical gearing factor for this purpose. Thus, if even a 75% drop in launch price only produces less than 10% reduction in the price to an end user, this is regarded as within the noise level to that end user, and an assumption is made that it will not therefore result in any increased launch demand. For gearing ratios above 15%, then the fully detailed incremental demand calculation is carried out in the model.

A second important concept, with possibly far-reaching implications, is represented by the horizontal line at the bottom of Figure 9-1 that separates second order pricing impacts from the analysis being performed above the line. Above the line, the analysis proceeds along a traditional economic price elasticity of demand approach. A given drop in launch price produces an increase in launch demand (geared down by the gearing factor described above). Those markets that are covered by the On–Orbit Matrix (OOM) have two first order impacts; firstly the on-orbit infrastructure itself is increased due to the impact of price reductions in the other sector markets; then the reduced launch prices result in lower costs to provide the OOM architecture elements (such as the propellant depot), thus making it easier to achieve a breakeven for the respective businesses of the OOM. So, the first order impacts capture all the demand changes that one would expect from classical economic theory, when launch prices are reduced.

However, this may miss some developments of a more revolutionary nature, and Section 10 of this report addresses the implications of such considerations, especially when a new technology like a RLV could introduce dramatic price and other changes when introduced. At this stage however, it should simply be noted that the first order forecasts assume no changes to the design of spacecraft being offered to the market, but simply a change in their number. Other second order impacts, also described in Section 10, could include structural changes in the end-user provider marketplace; the first order price elasticity impacts assume no change in the number of service providers, but simply a change in their cost base. Only first-order impacts have been forecasted in the ASCENT Study.

Figure 9-1: Generic Approach to Commercial Sector Price Elasticity of Demand to Launch Price



Volume II provides detailed cost gearing breakdown information for all the commercial sectors. Table 9-1 below summarizes these findings. It can be seen that the following sectors have a gearing factor that is so low that it will not result in incremental launches for even a massive launch price change: Telephony, Data, TV, Space Hardware R&D, and On Orbit Sparing.

Table 9-1: Launch Price Gearing Factors for Commercial Sectors

Sector	Launch Price Gearing Factor
Telephony	0.2%
Data Communications	3%
Television and Radio	0.7%
Commercial Satellite Remote Sensing	25%
Public Space Travel	34%
Commercial ISS Module	73%
Space Product Promotion	1.5%
Space Hardware R&D	2%
Space Burial	18%
On Orbit Sparing	13%
Orbital Asset Servicing and Salvage	58%
Space Solar Power (On Orbit Uses)	35%
Propellant Depot	19%

The main reason for this result is that, for the mature existing markets, the end user is now removed from the launch operation by so many layers of commercial added value endeavor, in a series of vertical markets, that the other cost factors dominate the eventual end user service prices. Note, however, that certain of the markets are relatively highly geared: Public Space Travel, Commercial ISS Module, Orbital Asset Servicing and Salvage and Space Solar Power (On Orbit Uses). It is these more highly geared markets that will potentially benefit most from the reduction of launch prices to be evaluated in this study.

For the government sectors, a different treatment of launch vehicle price elasticity of demand was required. Table 9-2 details for each sector how launch vehicle price changes may affect demand for launch services. As is seen in the Table, most government markets are generally insensitive to launch cost.

Table 9-2: Summary of Launch Price Impacts on Government Sectors

Government Sector	Price Sensitivity Implications (Y/N)	Rationale
Positioning	N	The number of GPS satellites required is dependent on technical parameters, and launch price is not likely to be a major factor in system design in the near-term.
Civil Remote Sensing	N	Government-funded civil remote sensing programs are not expected to be dramatically affected by a reduction in launch prices. It is assumed that governments will begin to depend on commercial remote sensing for routine operations in the future, and that high-cost or innovative technology initiatives will remain in the purview of some governmental agencies.
Military Remote Sensing	N	Since military intelligence satellites are deemed critical to national security, launch prices are not considered a major factor in determining the number of satellites procured in the near-term.
Military-Civil Communications	N	Since government telecommunication satellites are deemed critical to human spaceflight and national security, launch prices are not considered a major factor in determining the number of satellites procured in the near-term. It is possible that some governments may elect to launch robust NGSO telecommunication systems if the launch price dropped significantly. However, no evidence of such a program is publicly available, and is therefore not included in the forecast.
ISS Missions	N	A reduction in launch prices for missions to resupply ISS are considered desirable and is currently being pursued, but a significant drop is not expected to increase the number of flights to the station in the near-term.
Space Weapons	N	No space weapon platforms are projected for launch during the baseline 2002-2021 timeframe. A reduction in launch prices is not expected to change the forecast.
Space Traffic Control	N	No dedicated space traffic control platforms are projected for launch during the baseline 2002-2021 timeframe. A reduction in launch prices is not expected to change the forecast.
Law Enforcement	N	No dedicated law enforcement platforms are projected for launch during the baseline 2002-2021 timeframe. A reduction in launch prices is not expected to change the forecast.
Human Space Exploration	N	Human exploration missions are inherently costly, and it is assumed adjustments in launch price will have a relatively minor impact on programs during the forecast period. It should be noted that few human space exploration missions are projected during the baseline forecast period 2002-2011: ISS missions (discussed above), non-ISS Space Shuttle missions (counted in Other Government Missions below), and China's Shenzhou program (counted in Human Space Exploration).

Summary of Launch Price Impacts on Government Sectors (continued)

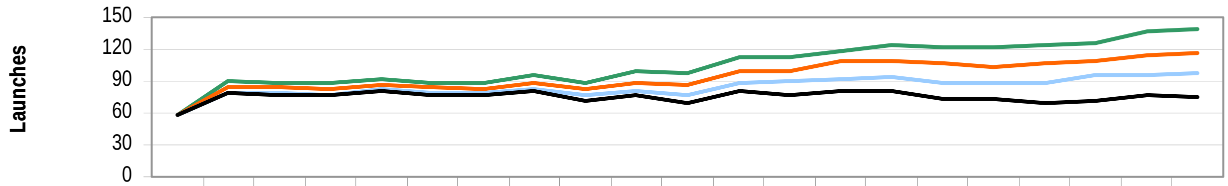
Government Sector	Price Sensitivity Implications (Y/N)	Rationale
Space Science (non-ISS)	N	Space science missions funded by government agencies continue despite the high cost of launch. It is expected that the number of science missions will not markedly increase if launch prices drop significantly. However, science payloads funded through universities are likely to increase in number due to a relatively modest drop in launch prices (counted in Other Government Missions below because such payloads represent a fraction of the different mission types pursued by universities).
Human Space Rescue	N	No dedicated human space rescue programs are projected for launch during the baseline 2002-2021 timeframe. A reduction in launch prices is not expected to change the forecast.
Asteroid Detection and Negation	N	Only one dedicated asteroid detection and negation system is projected during the baseline 2002-2021 forecast. It is assumed that a reduction in launch prices will not spur development of such systems until technical and political issues are finalized.
Other Government Missions	Yes	This category includes hybrid missions and non-specific university payloads (procured with the use of grants or other funding sources), and technology demonstrators funded by organizations like the Defense Advanced Research Projects Office (DARPA). These payload providers procure or produce very small satellites for low per-unit prices, but must contend with very high launch prices. To offset the price burden, several microsats are launched at the same time. Research indicates that even a modest drop in launch prices will significantly increase the number of multi-manifested microsats launched per year.

Once the price sensitivities described in Tables 9-1 and 9-2 are taken into account, the resulting impacts can be seen in Figures 9-2 through 9-5 which record the aggregate results of this first order price change analysis. An aspect of these results worth noting is the integer nature of forecasted launches. Thus, no increases are reported in launch vehicle demand until such time as enough change is generated to produce a whole extra launch. There is also an implicit supply-demand match in the forecast process, and no consideration is introduced to evaluate whether the manufacturing community will be able to produce the quantities of launch vehicles required by the demand forecasts; this may be a particularly important caveat in the case of public space travel. Table 9-3 gives a tabular summary.

Overall, Figure 9-2 demonstrates that price decreases do not result in dramatic increases in demand. The total number of launches over the 20-year period increases from 1,523 in the Baseline forecast to 1,708 with a 25% price reduction, to 1,924 with a 50% price reduction, and to 2,148 with a 75% launch price reduction.

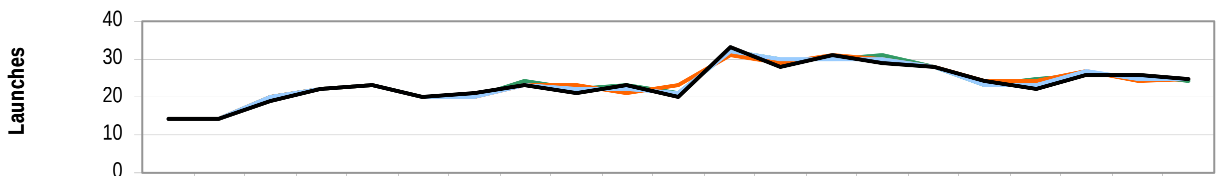
The low gearing factors of all current commercial and government sectors result in relatively little change to the launch forecasts even with massive launch price reductions. Recall that Tables 3-1 through 3-4 provide conversion charts so that the absolute implied launch prices may be calculated from the percent reductions in this section. However, the Evolving sector, shown in Figure 9-5, is much more highly geared, and therefore derives benefit from the launch price reductions – the number of launches in 2021 is 4 times greater than the Baseline value at the 75% price reduction level. In terms of real dollars, a 75% price reduction in this sector would translate to a price range of $750 - $3500 per pound to orbit. Half of the demand in this sector comes from Public Space Travel. The other sector that is significantly affected by price changes is the highly geared Commercial ISS Module market. This sector had zero launches forecasted in the Baseline, or even in the Robust sensitivity case, so this is an indication of the possible enabling of a new market by a Next Generation RLV producing significantly lower launch prices. The Propellant Depot also begins to generate demand for launches.

Figure 9-2: Price Impact on Launch Forecasts for all ASCENT sectors



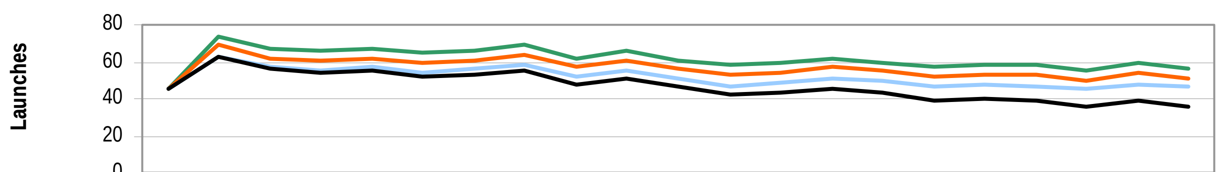
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	59	90	89	88	92	89	88	95	89	99	97	113	112	118	123	122	121	123	126	136	138
50% Reduction	59	85	84	83	87	84	83	89	83	88	86	100	100	108	109	106	103	107	109	114	116
25% Reduction	59	79	79	77	82	78	78	83	77	81	77	88	90	91	94	89	89	88	95	95	98
Baseline	59	79	77	76	80	76	76	80	72	76	70	81	77	81	80	74	74	70	72	77	75

Figure 9-3: Price Impact on Launch Forecasts for Existing Commercial Market Sectors



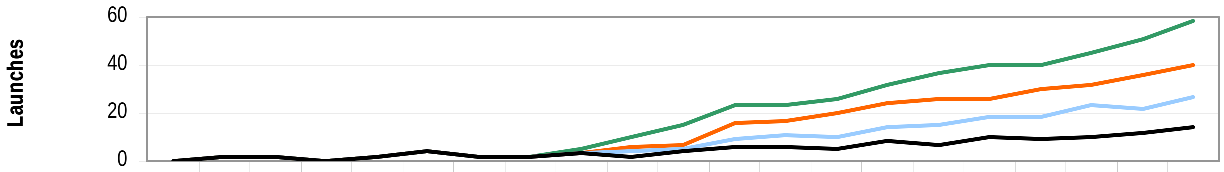
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	14	14	20	22	23	20	20	24	22	23	21	32	30	30	31	28	23	25	26	26	24
50% Reduction	14	14	20	22	23	20	20	23	23	21	23	31	29	31	30	28	24	24	27	24	25
25% Reduction	14	14	20	22	23	20	20	23	22	22	21	32	30	30	30	28	23	23	27	25	25
Baseline	14	14	19	22	23	20	21	23	21	23	20	33	28	31	29	28	24	22	26	26	25

Figure 9-4: Price Impact on Launch Forecasts for Government Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	45	74	67	66	67	65	66	69	62	66	61	58	59	62	60	57	58	58	55	59	56
50% Reduction	45	69	62	61	62	60	61	64	57	61	56	53	54	57	55	52	53	53	50	54	51
25% Reduction	45	63	57	55	57	54	56	58	52	55	51	47	49	51	50	46	48	47	45	48	46
Baseline	45	63	56	54	55	52	53	55	48	51	46	42	43	45	43	39	40	39	36	39	36

Figure 9-5: Price Impact on Launch Forecasts for Evolving Commercial Market Sectors



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	2	2	0	2	4	2	2	5	10	15	23	23	26	32	37	40	40	45	51	58
50% Reduction	0	2	2	0	2	4	2	2	3	6	7	16	17	20	24	26	26	30	32	36	40
25% Reduction	0	2	2	0	2	4	2	2	3	4	5	9	11	10	14	15	18	18	23	22	27
Baseline	0	2	2	0	2	4	2	2	3	2	4	6	6	5	8	7	10	9	10	12	14

Table 9-3: Summary of Price Change Impact by Sector Type and Incremental Analysis

	Baseline: Total Launches through Year 2021	75% Reduction Case	Delta	Proportion of Total Delta
Existing	478	484	6	1%
Government	935	1245	310	50%
Evolving	110	419	309	49%
Total	1523	2148	625	--

Table 9-4 provides the overall results broken down by payload mass class, and we can see that the largest increases occur for Intermediate class launches to NGSO/LEO and for Public Space Travel.

Table 9-4: Increased Launches by Mass Class in Year 2021

	75% Reduction	50% Reduction	25% Reduction	Baseline
GEO				
Small	2	2	2	2
Medium	2	2	2	2
Intermediate	12	12	12	12
Heavy	6	6	6	6
Total	22	22	22	22
NGSO/LEO				
Small	31	26	20	10
Medium	4	4	4	4
Intermediate	36	24	16	9
Heavy	8	8	8	6
Total	79	62	48	29
Public Space Travel				
Small	0	0	0	0
Medium	0	0	0	0
Intermediate	23	18	14	10
Heavy	0	0	0	0
Total	23	18	14	10
ISS Crewed				
Small	0	0	0	0
Medium	0	0	0	0
Intermediate	4	4	4	4
Heavy	5	5	5	5
Total	9	9	9	9
ISS Uncrewed				
Small	0	0	0	0
Medium	0	0	0	0
Intermediate	4	4	4	4
Heavy	1	1	1	1
Total	5	5	5	5
Total				
Small	33	28	22	13
Medium	6	6	6	7
Intermediate	79	62	50	31
Heavy	20	20	20	18
Total	138	116	98	69

A massive reduction in launch price is required to produce a significant increase in launches. Figure 9-6 displays the price elasticity of demand for each of the three market sector types: Existing Commercial, Government, and Evolving Commercial. Figure 9-7 displays the same data in terms of total launches over the forecast period. The sum of all three sectors is included for comparison. It is fairly clear that a first order analysis does not produce much in the way of step functions or dramatic changes. Even at very large price reductions (75%), the overall increase in launch demand is only 45%. Reduced launch cost has essentially no effect on the Existing Commercial sectors. The greatest increase comes from the Evolving Commercial markets. Except for Public Space Travel, the Evolving markets have essentially zero launches at baseline launch prices.

Figure 9-6: Price Elasticity of Demand Change by Sector Type

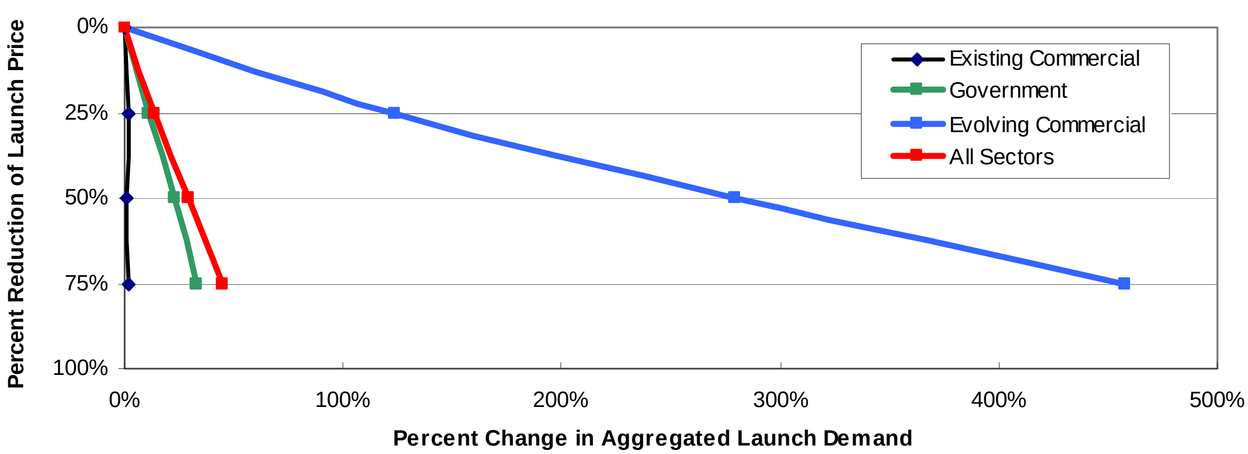


Figure 9-7: Price Elasticity of Demand by Sector Type in Total Launches Over 20 year Forecast Period

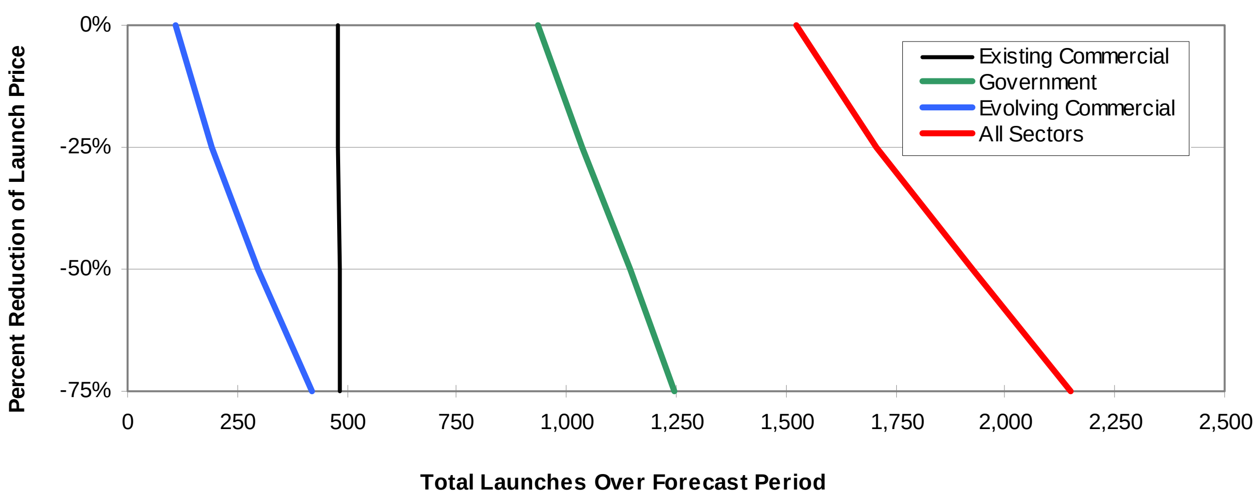


Table 9-5 shows the effect of reduced launch price in terms of number of launches, and Table 9-6 summarizes, for convenience, which sectors are included in each of the three market sector groups.

Table 9-5: Price Elasticity of Demand in Number of Launches and Percent Change over 20-year Forecast

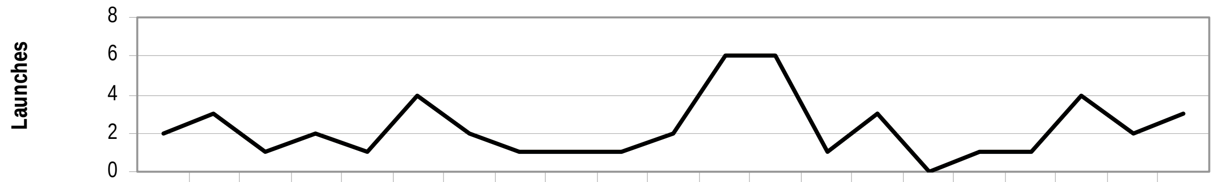
Market Sector Type	Launches at Baseline Launch Price	Launches at 25% Price Reduction	Launches at 50% Price Reduction	Launches at 75% Price Reduction
Existing Commercial	478	480 0%	482 1%	484 1%
Government	935	1035 11%	1145 22%	1245 33%
Evolving Commercial	110	193 75%	297 170%	419 281%
Total	1523	1708 12%	1924 26%	2148 41%

Table 9-6: Market Sector Type Groupings

Market Sector Type	Market Sector
Existing Commercial	Telephony Television & Radio Data Communications Commercial Satellite Remote Sensing On-orbit Sparing
Government	Positioning Civil Remote Sensing Military Remote Sensing Military-Civil Communications ISS Missions Space Weapons Space Traffic Control Law Enforcement Human Space Exploration Space Science (non-ISS) Human Space Rescue Asteroid Detection and Negation Other Government Missions
Evolving Commercial	Public Space Travel Commercial ISS Module Space Product Promotion Space Hardware R&D Space Burial Orbital Asset Servicing and Salvage Space Solar Power (on-orbit uses) Propellant Depot

Figures 9-8 through 9-21 provide the background detail on the price sensitivity of the commercial sectors and of the only government sector that exhibits any response to price change of launch vehicles. Volume II contains the sector-by-sector gearing factor analyses that drive these forecasts.

Figure 9-8: Telephony Markets



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	2	3	1	2	1	4	2	1	1	1	2	6	6	1	3	0	1	1	4	2	3
50% Reduction	2	3	1	2	1	4	2	1	1	1	2	6	6	1	3	0	1	1	4	2	3
25% Reduction	2	3	1	2	1	4	2	1	1	1	2	6	6	1	3	0	1	1	4	2	3
Baseline	2	3	1	2	1	4	2	1	1	1	2	6	6	1	3	0	1	1	4	2	3

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes an average price level of $8,820/lb to LEO and an average price level of $13,830/lb to GEO orbit. This represents the effective price per pound by dividing vehicle price by payload mass.

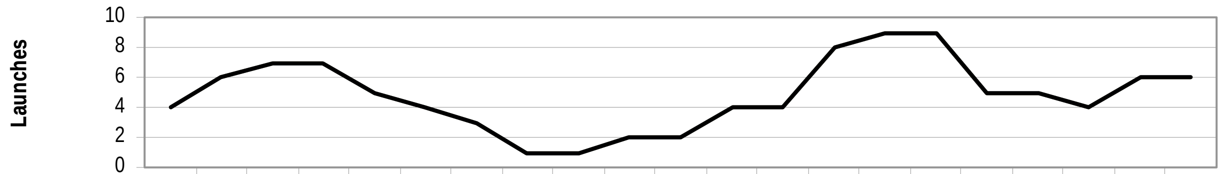
Price Elasticity of Demand Assumptions

The gearing factor for this market is 0.2%. Therefore, a 100% reduction in launch prices would have a minute reduction in service price, leaving the market without any significant change. The market is therefore assumed to be completely inelastic to launch price.

Results of Price Elasticity Analysis

There are no first order effects on the telephony market as a result of a change in launch price. For this sector, to reach $1,000/ lb requires a reduction of 76%, and to reach $500/ lb requires a reduction of 88%.

Figure 9-9: Data Communications Markets



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	4	6	7	7	5	4	3	1	1	2	2	4	4	8	9	9	5	5	4	6	6
50% Reduction	4	6	7	7	5	4	3	1	1	2	2	4	4	8	9	9	5	5	4	6	6
25% Reduction	4	6	7	7	5	4	3	1	1	2	2	4	4	8	9	9	5	5	4	6	6
Baseline	4	6	7	7	5	4	3	1	1	2	2	4	4	8	9	9	5	5	4	6	6

Baseline Case Market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes an average price level of $8,820/lb to LEO and an average price level of $13,830/lb to GEO orbit. This represents the effective price per pound by dividing vehicle price by payload mass.

Price Elasticity of Demand Assumptions

The gearing factor for this market is 3%. A 100% reduction in launch prices would have a minute reduction in service price, leaving the market without any significant change. The market is therefore assumed to be completely inelastic to launch price.

Results of Price Elasticity Analysis

There are no first order effects on the telephony market as a result of a change in launch price. For this sector, to reach $1,000/ lb requires a reduction of 76%, and to reach $500/ lb requires a reduction of 88%.

Figure 9-10: Television and Radio Markets

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	5	1	2	5	2	4	5	5	5	5	5	7	7	6	6	6	5	4	3	7	3
50% Reduction	5	1	2	5	2	4	5	5	5	5	5	7	7	6	6	6	5	4	3	7	3
25% Reduction	5	1	2	5	2	4	5	5	5	5	5	7	7	6	6	6	5	4	3	7	3
Baseline	5	1	2	5	2	4	5	5	5	5	5	7	7	6	6	6	5	4	3	7	3

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes an average price level of $8,820/lb to LEO and an average price level of $13,830/lb to GEO orbit. This represents the effective price per pound by dividing vehicle price by payload mass.

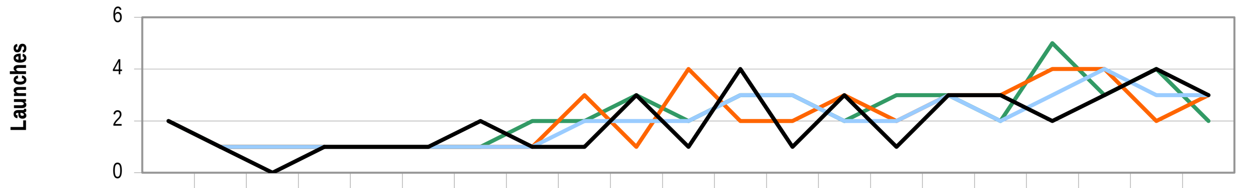
Price Elasticity of Demand Assumptions

The gearing factor for this market is 0.7%. Therefore, a 100% reduction in launch prices would have a minute reduction in service price, leaving the market without any significant change. The market is therefore assumed to be completely inelastic to launch price.

Results of Price Elasticity Analysis

There are no first order effects on the telephony market as a result of a change in launch price. For this sector, to reach $1,000/ lb requires a reduction of 76%, and to reach $500/ lb requires a reduction of 88%.

Figure 9-11: Commercial Satellite Remote Sensing



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	2	1	1	1	1	1	1	2	2	3	2	3	3	2	3	3	2	5	3	4	2
50% Reduction	2	1	1	1	1	1	1	1	3	1	4	2	2	3	2	3	3	4	4	2	3
25% Reduction	2	1	1	1	1	1	1	1	2	2	2	3	3	2	2	3	2	3	4	3	3
Baseline	2	1	0	1	1	1	2	1	1	3	1	4	1	3	1	3	3	2	3	4	3

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes a price level of $17,200 /lb to LEO. The effective price per pound (vehicle price divided by payload launch mass) tends to be quite high for this market. Two reasons that help explain this is that remote sensing satellites tend to be launched on smaller vehicles which are more expensive on a dollar-per-pound basis, and most remote sensing satellites are placed in a polar orbit and a vehicle at a given price launches less mass to polar orbits than to equatorial orbits. Also, the effective price per pound varies greatly among satellites for different imagery types.

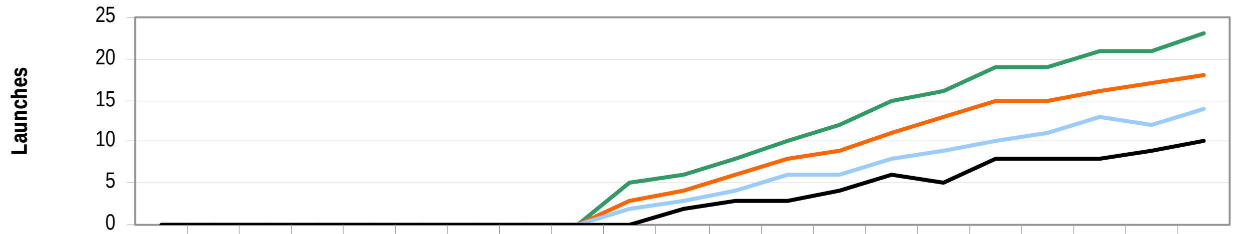
Price Elasticity of Demand Assumptions

The gearing factor for this market is 25%. The gearing factor represents the fraction of life cycle cost that is launch cost. The gearing factor varies considerably among satellites of different imagery types. Life cycle cost includes the spacecraft, ground systems, launch, and operations over the lifetime of the satellite.

Results of Price Elasticity Analysis

For this sector, to reach $1,000/ lb requires a reduction of 94%. On average, a given percent change in launch price will result in the ability to drop the price for imagery by 25% of that amount; however, the gearing factor varies among the different imagery types. Applying the elasticity curve for imagery, a reduction in imagery price results in an increase in demand to raise total revenue by up to 4% above the Baseline. Further reductions in price are not sufficiently offset by increased sales and total revenue begins to decline. That is why a 50% reduction in launch price actually results in two fewer launches over the forecast period compared to a 25% reduction, assuming the cost savings continue to be passed on the customer.

Figure 9-12: Public Space Travel



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	5	6	8	10	12	15	16	19	19	21	21	23
50% Reduction	0	0	0	0	0	0	0	0	0	3	4	6	8	9	11	13	15	15	16	17	18
25% Reduction	0	0	0	0	0	0	0	0	0	2	3	4	6	6	8	9	10	11	13	12	14
Baseline	0	0	0	0	0	0	0	0	0	0	2	3	3	4	6	5	8	8	8	9	10

Baseline Case Market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes a price level of $2,990/lb to LEO. The price is based on historical published price per pound data for Soyuz launches.

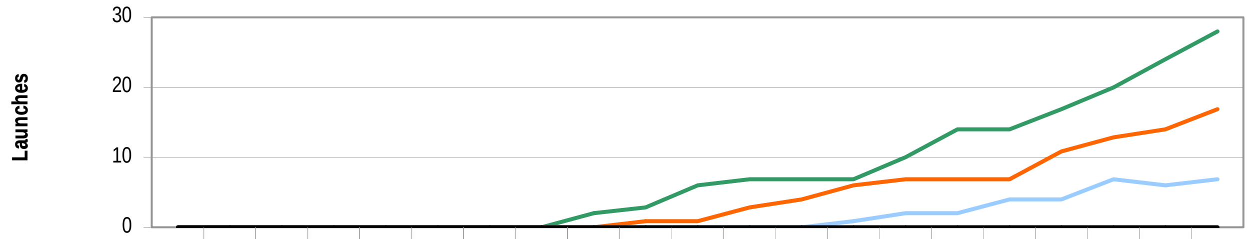
Price Elasticity of Demand Assumptions

The gearing factor for the public space travel market is 34%. Futron estimates that, in addition to Soyuz launch costs, the remaining portion of the current ticket price is allocated to Soyuz capsule costs, training costs and various contracting fees.

Results of Price Elasticity Analysis

A 66% reduction in Soyuz vehicle launch costs would be required in order to reach $1,000/ lb. The first order effects of a decrease in launch cost are apparent for public space travel, in that, as the price for service decreases, interest, and thus demand increases.

Figure 9-13: Commercial ISS Module



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	2	3	6	7	7	7	10	14	14	17	20	24	28
50% Reduction	0	0	0	0	0	0	0	0	0	1	1	3	4	6	7	7	7	11	13	14	17
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	4	4	7	6	7
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes a price level of $10,000 /lb to LEO. The baseline price reflects Shuttle costs for deploying a module and for servicing flights. A baseline of about $9,700/ lb is used for Progress vehicle flights. (Cost of Progress vehicle and launcher divided by maximum pressurized cargo capacity)

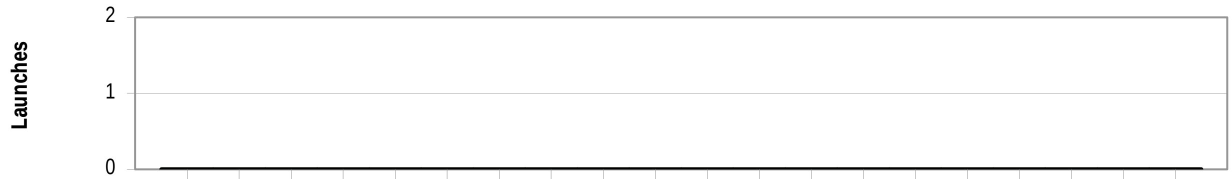
Price Elasticity of Demand Assumptions

The gearing factor for this market is 73%. The reduction in launch price has the greatest effect on the cost of servicing flights (transporting experiments to and from the module). When the launch price is sufficiently lowered, the cost of the module itself and other operations costs become the most important cost elements.

Results of Price Elasticity Analysis

For this sector, to reach $1,000/ lb requires a reduction of 90%. The forecast for proteomics research (the largest expected share of microgravity research) shows robust growth such that it supports a module and servicing flights in the out years if the cost of servicing flights is sufficiently reduced. Extreme drops in launch price could accommodate additional modules.

Figure 9-14: Space Product Promotion



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

The Space Product Promotion model is revenue-based; projecting the amount of launch cost offset resulting from advertising or paid promotions. The model assumes that advertisers would be willing to pay the same dollar amount per viewer for a space-related event as for Superbowl advertising. Assuming that advertisers would be willing to spend 5 to 10 cents per viewer per minute of exposure, the model projects offsets of between $300 and $600 per pound. Using data from the Pizza Hut logo placement event in 1999, the figure drops to only $19 per pound.

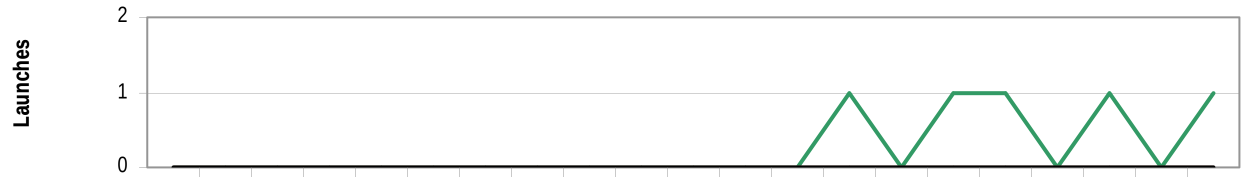
Price Elasticity of Demand Assumptions

The gearing factor for this market is 1.5%.

Results of Price Elasticity Analysis

To reach $1,000 per pound offset from advertising or paid promotions, the number of advertisers would need to increase, as well as the exposure (viewers). Until significantly more consumers view launch events, it is unlikely that this market will provide a significant offset to launch costs.

Figure 9-15: Space Hardware R&D



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes a price level of $10,000 /lb to LEO. Baseline price is based on Shuttle costs.

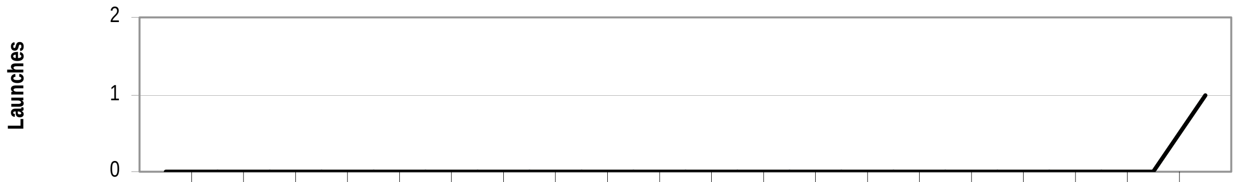
Price Elasticity of Demand Assumptions

The gearing factor for this market is 2%. Space qualifying new spacecraft components can be done mostly on the ground using vacuum chambers, sun simulators, and other facilities. Only components that must be tested in prolonged microgravity, such as components involving fluids (loop heat pipes) and inflatable structures are tested in space on dedicated payloads.

Results of Price Elasticity Analysis

For this sector, to reach $1,000/ lb requires a reduction of 90%. Satellite manufacturers place little value on in-space testing in cases where ground-based testing techniques are well understood. In-space testing data is a “nice-to-have” piece of information but is not strictly necessary. With a significant reduction in launch price, satellite manufacturers will use a relatively unchanging IR&D budget to deploy more test payloads. Only the fraction of test payloads that generate dedicated launches are shown here.

Figure 9-16: Space Burial



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes a price level of $13,830 per pound to LEO. Space burial payloads have traditionally flown as secondary or “piggyback” payloads on either Pegasus or Taurus launch vehicles. The Pegasus launch vehicle cost per pound to LEO was assumed for the forecast. The price is based on historical published price per pound data for Pegasus launches.

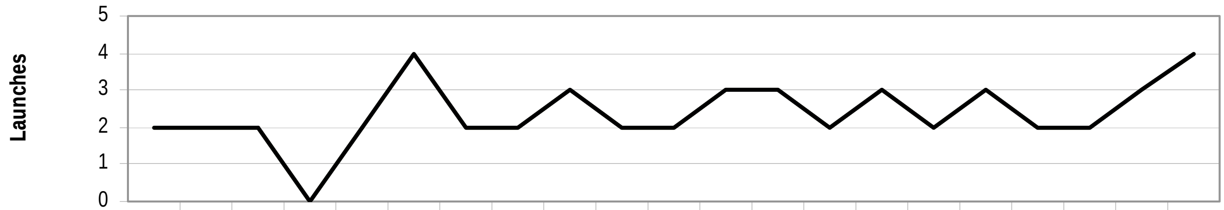
Price Elasticity of Demand Assumptions

The gearing factor for this market is 18%. Futron estimates that in addition to Pegasus launch costs, the remaining portion (82%) of the current service price is allocated to various operational and service-related fees for provision of space burial services.

Results of Price Elasticity Analysis

For this sector, to reach $1,000/ lb requires a reduction of 93%. The first order effects of a decrease in launch price on space burials are modestly apparent in that as the price for service decreases demand for service does increase slightly.

Figure 9-17: On-orbit Sparing



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	2	2	2	0	2	4	2	2	3	2	2	3	3	2	3	2	3	2	2	3	4
50% Reduction	2	2	2	0	2	4	2	2	3	2	2	3	3	2	3	2	3	2	2	3	4
25% Reduction	2	2	2	0	2	4	2	2	3	2	2	3	3	2	3	2	3	2	2	3	4
Baseline	2	2	2	0	2	4	2	2	3	2	2	3	3	2	3	2	3	2	2	3	4

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Baseline forecast assumes an average price level of $4,200/lb to LEO and an average price level of $11,500/lb to GEO orbit. This was derived by studying the price divided by capacity for an array of LEO and GEO launch vehicles.

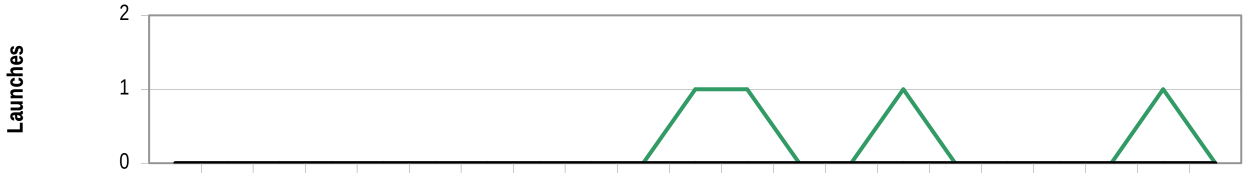
Price Elasticity of Demand Assumptions

The gearing factor for this market is 13%. Therefore, even a 100% reduction in launch prices would have only a 13% reduction in service price, leaving the market without any significant change. The market is therefore assumed to be completely inelastic to launch price.

Results of Price Elasticity Analysis

There are no first order effects on the on-orbit sparing market as a result of a change in launch price. For this sector, to reach $1,000/ lb requires a reduction of 76%, and to reach $500/ lb requires a reduction of 88%.

Figure 9-18: Orbital Asset Servicing and Salvage



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case Market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

The Baseline forecast assumes a price level of $150,000,000 per launch to GEO; this is based on the launch cost for the Delta IV. A launch discount is applied to those launches dedicated to fuel.

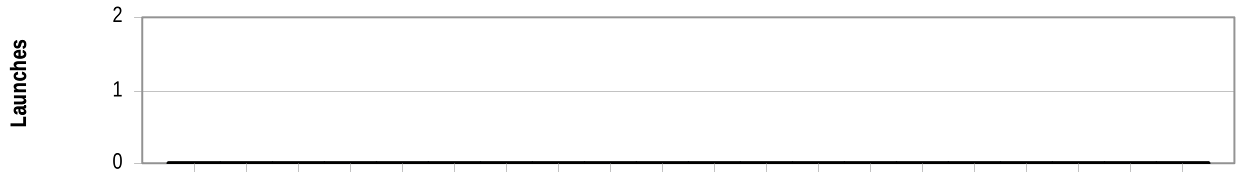
Price Elasticity of Demand Assumptions

Total cost of the system includes space segment development and manufacturing, operations based on a 15-year design life, finance costs, and launch costs. Launch costs are comprised of delivering required fuel to the propellant depot and a single heavy launch for the servicing vehicle. Baseline launch costs represent 58% of the total cost of an orbital service and salvage service. A $1000 launch price would represent an 81% reduction.

Results of Price Elasticity Analysis

The Service and Salvage market becomes cost efficient at a 60% reduction in Baseline launch prices. This market can only exist if the Propellant Depot system is operational. Since the Propellant Depot is cost efficient at a 5% reduction of the baseline launch price this is not an issue. Only one launch is required before the first service can be provided, additional fuel drives the remainder of the launches. Futron has estimated that this market could be launched in 2012.

Figure 9-19: Space Solar Power (On-orbit Uses)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

The solar power satellites designed for on-orbit use are large enough to completely fill launches, therefore it makes more sense to consider the total cost of a heavy vehicle. Baseline forecast assumes a price level of $150,000,000 per launch to GEO; this figure is based on the launch cost for the Delta IV.

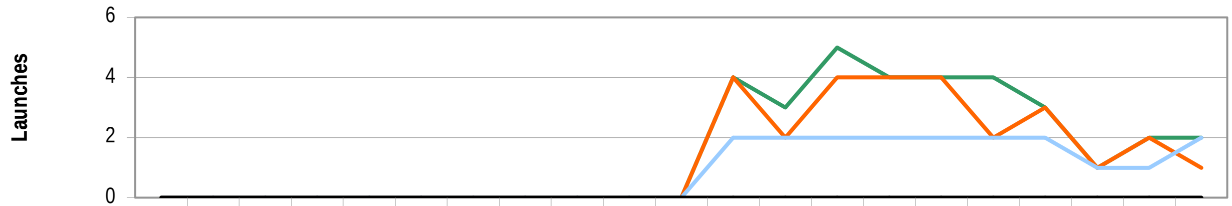
Price Elasticity of Demand Assumptions

The gearing factor for this market is 35%.

Results of Price Elasticity Analysis

Space solar power provision to on-orbit assets is a very expensive service primarily due to the size of the satellites; it would take 140 launches to launch the entire system. Futron's model works such that until there is enough demand to pay for the system none of the 140 launches take place. Once there is enough forecasted demand the entire system is launched. The SSP market becomes cost effective at a 90% reduction in baseline launch price. Only below this price point could a large enough market exist to pay for the entire SSP system, triggering 140 launches between 2017 and 2021.

Figure 9-20: Propellant Depot



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	0	0	0	0	0	0	0	0	0	0	0	4	3	5	4	4	4	3	1	2	2
50% Reduction	0	0	0	0	0	0	0	0	0	0	0	4	2	4	4	4	2	3	1	2	1
25% Reduction	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	1	1	2
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

Futron has defined the Baseline launch price as $165M. The initial propellant depot launch would require a modified launch vehicle that is larger than a Delta IV or Atlas V which Futron assumed would increase the launch price by 40%. Fuel and transfer/maneuver vehicle launches would be cheaper launches because a high-risk launch would be acceptable; Futron assumed this would decrease the launch price on these launches by 10%.

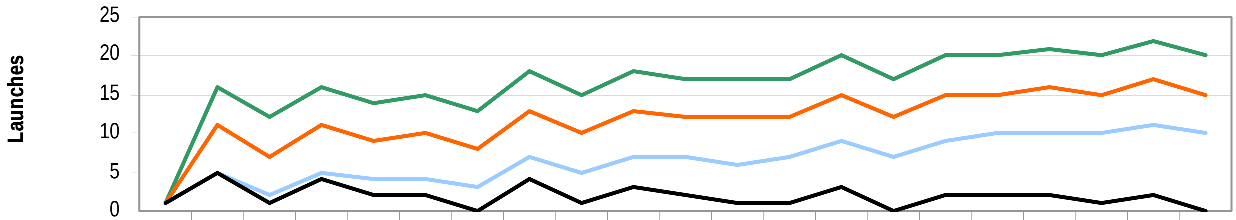
Price Elasticity of Demand Assumptions

The launch costs represent 19% of the total cost of a propellant depot system at Baseline costs and includes launches for the propellant depot station, orbital transfer/maneuver vehicle, and propellant. A $1,000 /lb launch price is a 20% reduction.

Results of Price Elasticity Analysis

The propellant depot market becomes cost efficient at a 5% reduction in baseline price. Futron has estimated that the Propellant Depot could be launched in 2012 with service available by 2013. The Propellant Depot System only requires one launch for the first service to be provided; additional fuel and maneuver/transfer vehicles drive the remainder of the launches.

Figure 9-21: Government- Other Government Missions



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75% Reduction	1	16	12	16	14	15	13	18	15	18	17	17	17	20	17	20	20	21	20	22	20
50% Reduction	1	11	7	11	9	10	8	13	10	13	12	12	12	15	12	15	15	16	15	17	15
25% Reduction	1	5	2	5	4	4	3	7	5	7	7	6	7	9	7	9	10	10	10	11	10
Baseline	1	5	1	4	2	2	0	4	1	3	2	1	1	3	0	2	2	2	1	2	0

Baseline Case market Assumptions

For Baseline Case market information and assumptions refer to Volume II.

Baseline Price Assumptions

The Other Government Missions category includes a) non-ISS dedicated Shuttle launches, b) advanced space technology demonstrators, c) telemetry packages for new launch vehicles, and d) micro and small payloads for space technology development and student projects. Only launches of the latter group have the potential of being affected by reductions in launch price during the forecast period. The Baseline forecast shows no dedicated launches for these payloads beyond 2002. Micro and small payloads dedicated to communications, remote sensing and science have been counted elsewhere in the forecast, and launches of these payloads are not likely to be affected significantly by a reduction in launch prices during the forecast period. Current price per pound for a small launch vehicle is about $15,000.

Price Elasticity of Demand Assumptions

Currently, it is not cost effective to dedicate a launch for micro and small payloads, regardless of mission. However, with a reduction in launch prices and multi-manifesting, an increase in the number of “disposable” micro and small missions is likely, translating to a steady increase in the number of dedicated small launches. Examples of such missions include student projects (high school and university) and government space technology development projects requiring multiple small platforms.

Results of Price Elasticity Analysis

Beyond the Baseline forecast, each launch accounts for five multi-manifested micro and/or small payloads. With a 75% reduction in launch price, micro and small satellites dedicated to certain government agency programs and student projects are expected to peak at 100 payloads during the forecast period, or approximately 20 dedicated small launches.

10. Strategic Implications of an RLV

A fully reusable launch vehicle (RLV) would be a revolutionary technology, bringing simultaneous benefits of price, reliability and schedule flexibility that would impact traditional launch businesses. . .

The price reductions explained in Section 9 were assumed to come about as a consequence of the introduction of more efficient access to space. This was defined for the purposes of the ASCENT Study as the fully reusable launch vehicle known as the Second Generation RLV.

The analysis in the previous sections has assumed that nothing is done to change the design of spacecraft as a result of the launch price reductions introduced by the emergence of an RLV. The forecasts have merely followed the classical economic theory, and have resulted in an increase of launches of the same kinds of satellites as in the Baseline case. However, Figure 9-1 indicates that there could well be second order impacts to consider in future studies. Furthermore, as well as possible new designs of spacecraft, there could be implications in terms of the numbers of competitors joining the end user markets. An RLV is a revolutionary technology, which could produce changes that go beyond those that have been quantified in the ASCENT Study.

Not only would the introduction of an RLV bring lower launch costs, but it would provide more reliability (and hence a change in insurance premiums) and a facility to either enable servicing of payloads in orbit (whether LEO or GEO payloads brought down to RLV altitude by tug), or to possibly bring objects back from orbit for refurbishment and subsequent re-launch. Furthermore, if the OOM markets, such as a Propellant Depot, are to function as businesses, it will be necessary to ensure that future generations of satellites are designed to take into account their specific needs. There could also be impacts on satellite design life, cost of production, and testing procedures or standards.

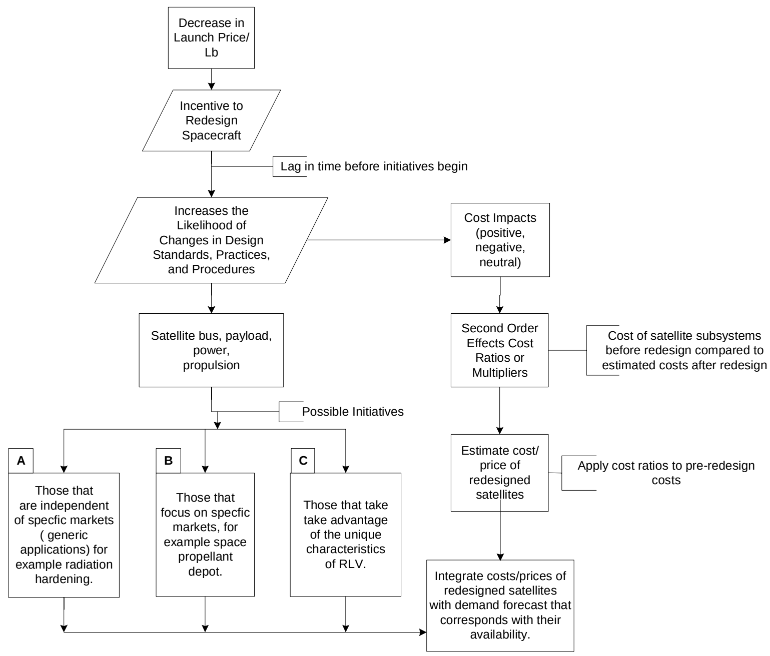
We can make some observations about the timeline. The kinds of changes described above would probably require major redesigns of the satellite architectures in place today. New generations of commercial satellite buses take a long time to be introduced. Table 10-1 below gives some consideration to timing parameters for making and introducing the design changes described above.

Table 10-1: Second Order Effects – Notional Timescale for Introduction of Redesigned Satellites

Milestone Event	Time	Cumulative Time
Time period while RLV is proven	10 years	10 years
Time period for satellite system redesign	3 years	13 years
Build of first flight model	2 years	15 years
Sale and introduction for first operator	2 years	17 years
Period until 8% of GEO satellites are replaced	3 years	20 years
Period until 50% of GEO satellites are replaced	15 years	35 years

If the assumptions in the table are correct, then the implications are that it is unlikely that many of the second order effect related design changes would find their way into the space infrastructure before the very end of the 20-year period being forecasted in the ASCENT Study. To quantify these second order effects, various alternative scenarios would need to be examined that contain the necessary combinations of second order developments within each scenario, as demonstrated in Figure 10-1, which offers a possible generic approach for conducting the work when required.

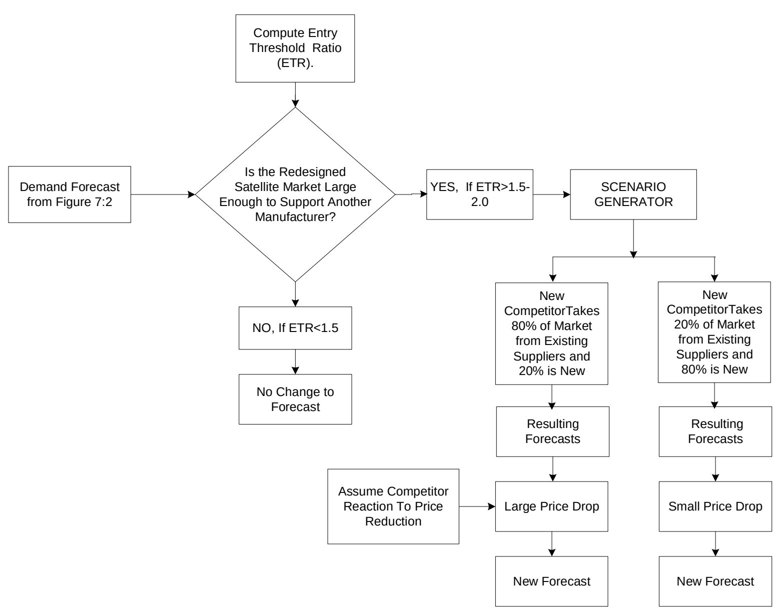
Figure 10-1: Potential Process for Evaluating Impact of Second Order Spacecraft Design Changes



There are other possible second order impacts discussed at the outset of this section; a possible change to the competitive end user marketplace, if the dramatically reduced launch costs of an RLV were to make these sectors more profitable. The timeline for such structural change is unlikely to take effect until the last quarter of the forecasted time period (because the profitability of the end user sector will not start to become apparent until the RLV's are flying and are launching the new generations of satellites).

A preliminary approach that might be applied to analyzing this is provided in Figure 10-2, with use of the Entry Threshold Ratio (ETR) from classical economic theory to determine when a new competitor might enter the operator marketplace.

Figure 10-2: Potential Process for Evaluating Second Order Effects - Market Structure Changes



11. Market Share of an RLV

The Market Share Model demonstrates powerfully how a new technology such as an RLV has the potential to totally re-shape the launch vehicle market and re-capture lost U.S. market share.

The ASCENT Study Market Share Model enables manufacturers and operators of launch vehicles to evaluate the impact on market share of a range of strategic alternatives . . .

Figure 11-1 shows how the ASCENT Market Share Model has been constructed, and uses the forecasts described in earlier sections as inputs. The model uses a selection algorithm to decide, for each combination of launch vehicle mass class and orbit capacity in any given year, which launch vehicle will be chosen to satisfy the demand. It does this by comparing a pool of available launch vehicles, (defined by their key characteristics of reliability, price, schedule, flexibility, country of origin and whether rated for human cargo) with the potential array of operators (with their inherent priorities and weighting factors which differ from market to market, and between types of operators). Table 11-1 shows the vehicle database parameters, while Table 11-2 summarizes the operator types.

Figure 11-1: ASCENT Market Share Model

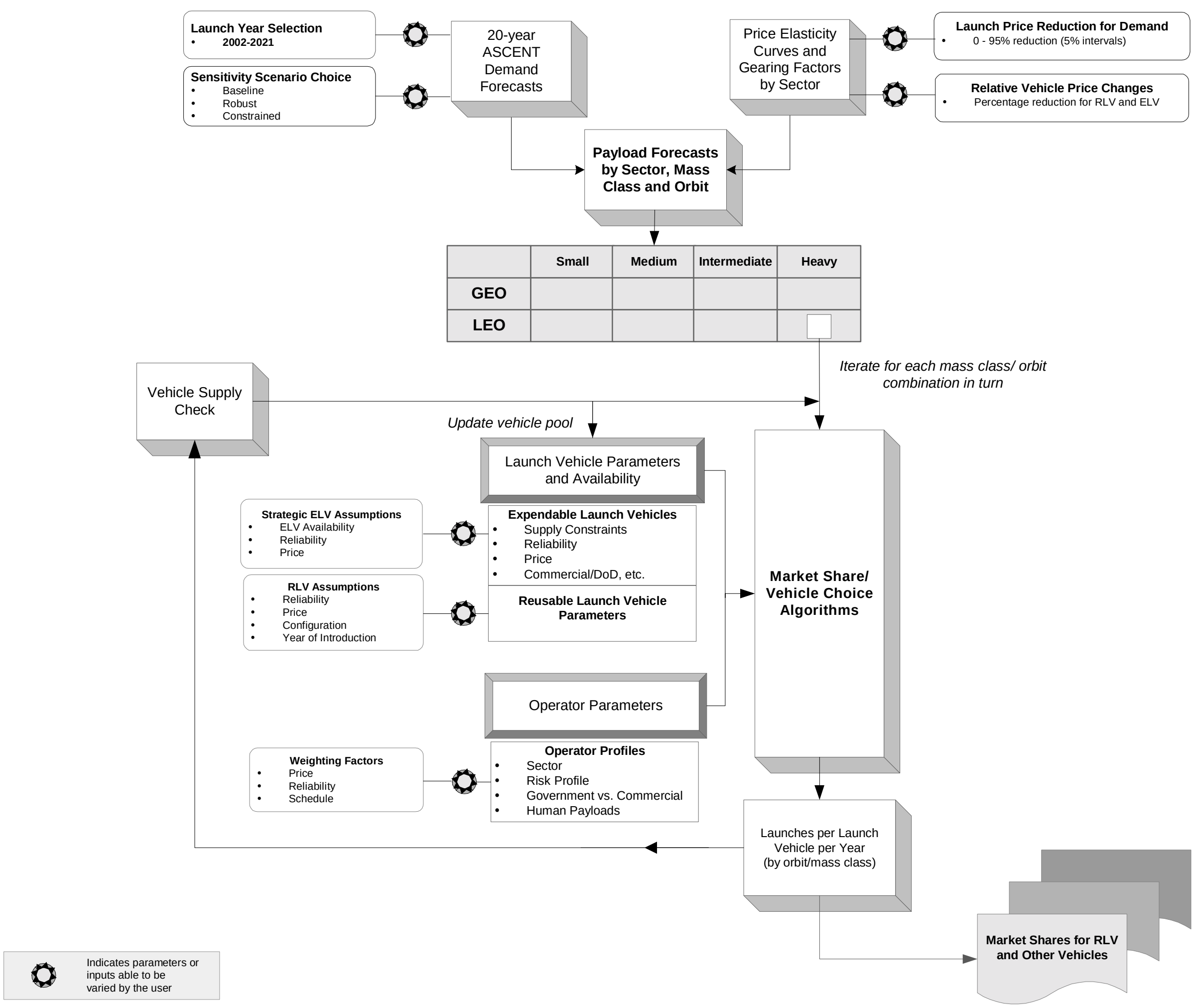


Table 11-1: Vehicle Database Parameters

Parameter	Default Values/ Function
Vehicle Family	Name
Country/ Region	Russia, US, Europe, China, Japan, India, Brazil, Israel, etc.
Introduction Year	Year or N/A if unknown, unknown entries will be assumed to be 2005
Retirement Year	Year or N/A if unknown, unknown entries will be assumed to be 2021
Launch Price (Millions $)	Launch Price or N/A; N/A entries will be calculated based on market price and launch capacity
Geosynchronous Transfer Orbit (GTO) Capacity Class	Capacity to GTO or N/A if not a GTO-capable vehicle
LEO Equatorial Capacity Class	Capacity to LEO or N/A if not a LEO vehicle
Launch Attempts 01/01/97 to 11/7/02	Number for vehicles with flight history, else reliability will default to assumptions on input sheet
Success and Partial 01/01/97 to 11/7/02	Number for vehicles with flight history, else reliability will default to assumptions on input sheet
Return Capability	0=ELV no human capacity; 1=ELV w/human capacity; 2=RLV no human capacity; 3=RLV w/ human capacity; 4=RLV w/ cargo and human capacity
ISS Serviceable	"Station" if vehicle can service ISS, otherwise left empty
Commercially Available	Y/N
Maximum number of Launches per Year	Number based on vehicle analysis
Allocation Percent	This number will prevent all of a vehicle's launches from being allocated to one market, the lower the %, the more spread out the launches will be
Launch Throughput Adjustment Percent	Percent of maximum launches that vehicles will likely achieve
Scheduling Rating	1=standard lead time; 2=short lead time (assumed for RLV)

Table 11-2: Operator Type Classification

Type	Example(s)
Existing commercial: risk averse	Intelsat, PanAmSat
Existing commercial: entrepreneur	Iridium, Globalstar, Commercial Remote Sensing
Government (by country)	DoD, other govt. programs
Evolving commercial	Space Hardware R&D, Commercial ISS
Evolving commercial crewed	Public Space Travel

Table 11-3: Vehicle Selection Scoring Method

Customer Types	Vehicle Selection Factors					
	Reliability	Price	Availability/Scheduling	Government Requirement	Government Preference	Human Delivery Required
Evolving Commercial	50%	30%	20%			N
Evolving Commercial Crewed	90%	5%	5%			Y
Existing Commercial Entrepreneur	20%	70%	10%			N
Existing Commercial Risk Averse	85%	5%	10%			N
US Government	40%	40%	20%	US		N
US Crewed ISS	90%	5%	5%	US		Y
US Crewed Non-ISS	90%	5%	5%	US		Y
US Uncrewed ISS	60%	25%	15%	US		N
Russia Government	40%	40%	20%	Russia		N
Russia Crewed ISS	90%	5%	5%	Russia		Y
Russia Crewed Non-ISS	90%	5%	5%	Russia		Y
Russia Uncrewed ISS	60%	25%	15%	Russia		N
Europe Government	40%	40%	20%	Europe		N
Europe Uncrewed ISS	60%	25%	15%	Europe		N
China Government	40%	40%	20%	China		N
China Crewed Non-ISS	90%	5%	5%	China		Y
Japan Government	40%	40%	20%	Japan		N
India Government	40%	40%	20%	India		N
Israel Government	40%	40%	20%		Israel	N
Brazil Government	40%	40%	20%		Brazil	N
Other Government	20%	70%	10%			N

Table 11-3 gives the values used in the scoring method. These values were tested against historical actual shares. Note that there are differing weightings for different customer types. The values included in the table are based on industry procurement experience and provided the best fit during the model test and historical verification runs. The country of origin of a vehicle only has an impact on the selection criterion with respect to Government missions. It is assumed (and it is known to be the practice) that to commercial users, the launching country is not an important element in a vehicle choice. However, it is possible to account for political or regulatory considerations by toggling the commercial availability of a vehicle. For example, Chinese vehicles were toggled as not commercially available for the cases described in this Section.

Note also that the vehicle input sheet provides several ways to differentiate the RLV from the ELVs. There are the inherent lower prices and increased reliability of the RLV, but also the model takes into account the improvements to users represented by the more rapid ordering schedule for a launch on the RLV. Other matters, such as insurance changes and/or Net Present Value (NPV) benefits of the progress payments stream for a RLV, may be included as variations in the effective RLV price.

For missions requiring a crew, the algorithm selects from among those vehicles identified as being able to carry a crew (human rated). The user may toggle on or off the crew carrying capability of any vehicle. Current crew-carrying vehicles in the database are assumed to be Shuttle, Soyuz, the Long March 2F (Long March Heavy), and two hypothetical RLVs.

For the model runs described in this section, a database of 48 launch vehicles (with availability varying year to year) was derived from public domain industry data that included declared prices (further detail can be found in Volume II). For currently available vehicles, actual reliability data was used; for new vehicles, the perceived relative reliability curve assumptions of Table 11-4 were used; derived from Futron research of historical launch vehicle performance and customer perceptions.

Table 11-4: ELV Reliability Curve Assumptions

Flight Number	Perceived Reliability (%)
1-8	85%
9-14	87%
15-25	88%
26-39	91%
40-70	92%
71 +	94%

Two notional U.S. RLVs were also added to the launch vehicle table, with an operational date of 2015 and 100% reliability; one in the intermediate class and the other in the heavy class. A maximum annual launch rate of 100 was assumed and a price curve based on STS experience. $1,000/lb to LEO was the SLI assumption at the full flight rate. The corresponding values at 70, 60, and 50 flights a year were estimated to be $1,150/lb, $1,325/lb and $1,550/lb respectively.

Strategic Variables and Case Scenarios

An RLV with the kind of reliability, pricing and operability characteristics suggested by SLI program goals would represent a revolutionary introduction to the launch vehicle market place. It would inevitably result in a major reconfiguring of ELV offerings and prices by the ELV manufacturers as a strategic response. This reconfiguration would be global. From a modeling standpoint, in order to keep the interactions simple and be able to identify the impacts at each stage of the process, the introduction of the RLV was analyzed in a stepwise process.

First, ELV market shares were determined before any RLV was assumed to be introduced. This scenario is called **CASE 1**. With no RLV, the forecast input is simply the Baseline forecast at current launch prices.

CASE 2 demonstrates the effect of introducing an RLV in the year 2015 with no strategic response from the ELV manufacturers. While not necessarily a realistic scenario, this case is useful in two respects. First, it tests the ability of the ASCENT Study Market Share Model to assign launches based on the more favorable price, scheduling, and reliability parameters of the RLVs. Second, it sets the ideal upper limit for the RLV market share against which other scenarios can be compared. With the introduction of the RLVs, the global average launch price is greatly reduced. Average launch price is determined by the price of the RLVs and their relative market share to the ELVs.

CASE 3 describes a limited strategic response by ELV manufacturers. In this scenario, all of the ELVs are assumed to continue to be offered after the RLV is introduced, but they take a 25% price cut across the board. It is known that launch vehicle prices in general were reduced by about a third during the 1990's, so this assumption may be sustainable if ELV manufacturers are able to introduce further manufacturing efficiencies in the expectation of an arriving RLV offering.

CASE 4 describes a maximum strategic response in which ELV prices are cut by 50% with the introduction of the RLVs. While it is unlikely that all ELVs could sustain a 50% price reduction, for the purposes of this test run all ELVs were left in the vehicle pool.

Table 11-5 describes the resulting combinations of inputs and assumptions used in each of the four Cases.

Table 11-5: Input Values for Model Scenario Runs

Case	Assumed ELV Price to LEO	ELV Market Share	Estimated RLV Flight Rate	Assumed RLV Price at Flight Rate	RLV Market Share	Average Market Prices
1	Current Price* ($8,000/lb)	100%	N/A	N/A	0%	Current Price* ($8,000/lb)
2	$8,000/lb	38%	70/yr	$1,150/lb	62%	$3,700/lb
3	$6,000/lb	40%	60/yr	$1,325/lb	60%	$3,200/lb
4	$4,000/lb	57%	50/yr	$1,550/lb	43%	$3,000/lb

*Assumed average

Results of Model Scenario Runs

Figures 11-2 through 11-13 show the model results in terms of market share, absolute number of launches, and estimated revenue produced.

CASE 1: NO RLVS INTRODUCED

Figure 11-2: Baseline Before RLV - Normalized Launches

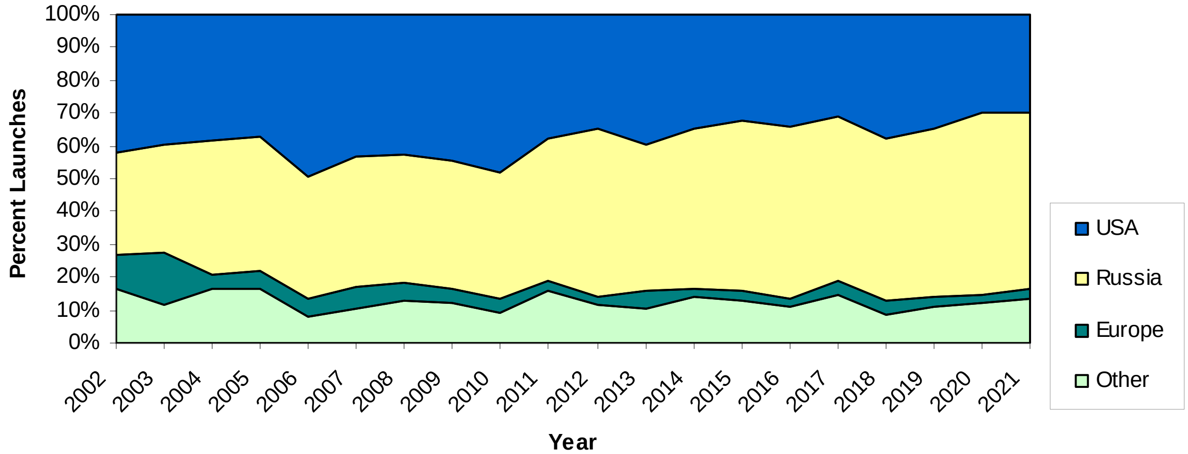


Figure 11-3: Baseline Before RLV - Number of Launches

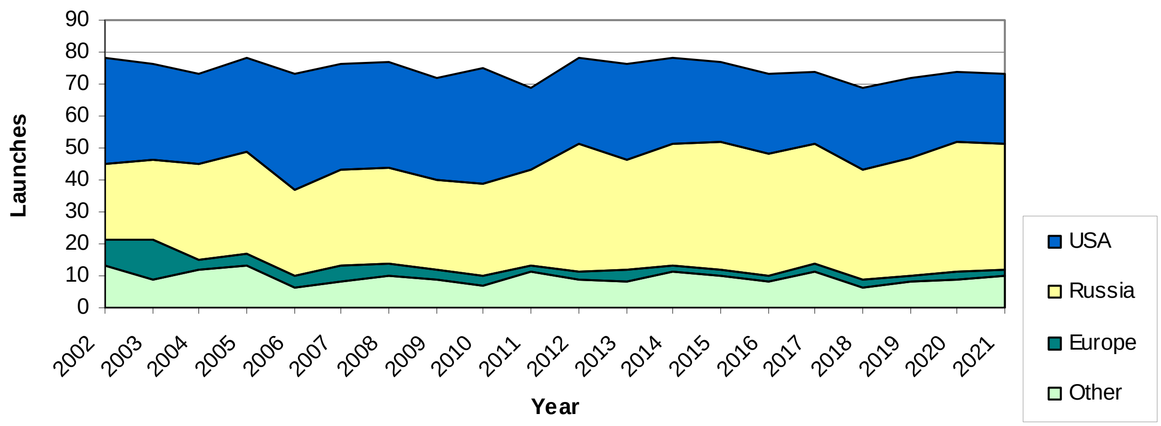
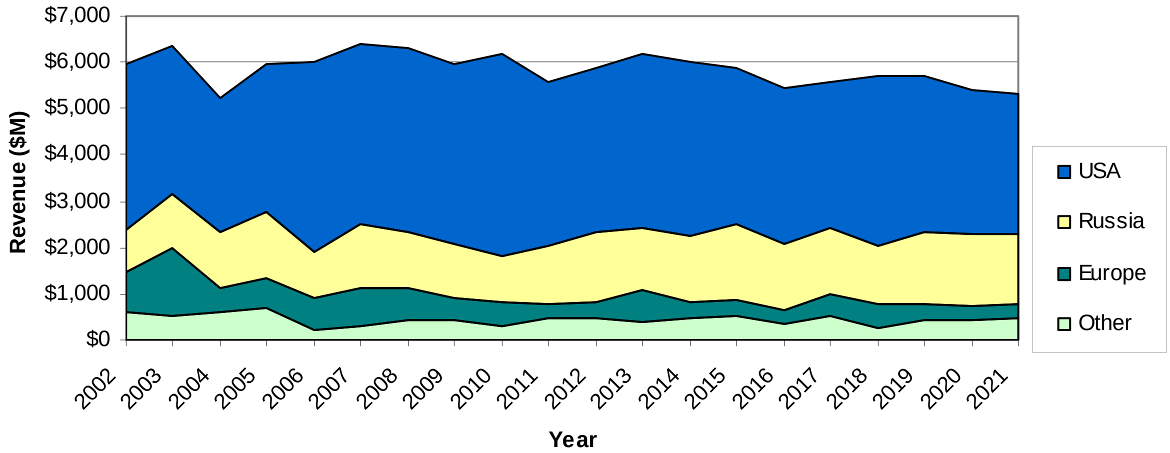


Figure 11-4: Baseline Before RLV - Total Launch Revenues



Several interesting outcomes are apparent from these charts. First of all, there is a good onwards trend of the historical share record. We note, for instance, that the Russian share of launches continues to grow with time while the U.S. share of total launches declines to 30%. Lower prices and a long track record for the Russian vehicles helps them to gain market share. The ASCENT Study Market Share Model can accommodate new assumptions about rising prices or reduced throughput capacity if users wish to explore such possibilities, but for this case no such change in assumptions about Russian vehicles are made.

CASE 2: INTRODUCTION OF RLVS WITH NO STRATEGIC RESPONSE

Figure 11-5: Introduction of RLV - Normalized Launches

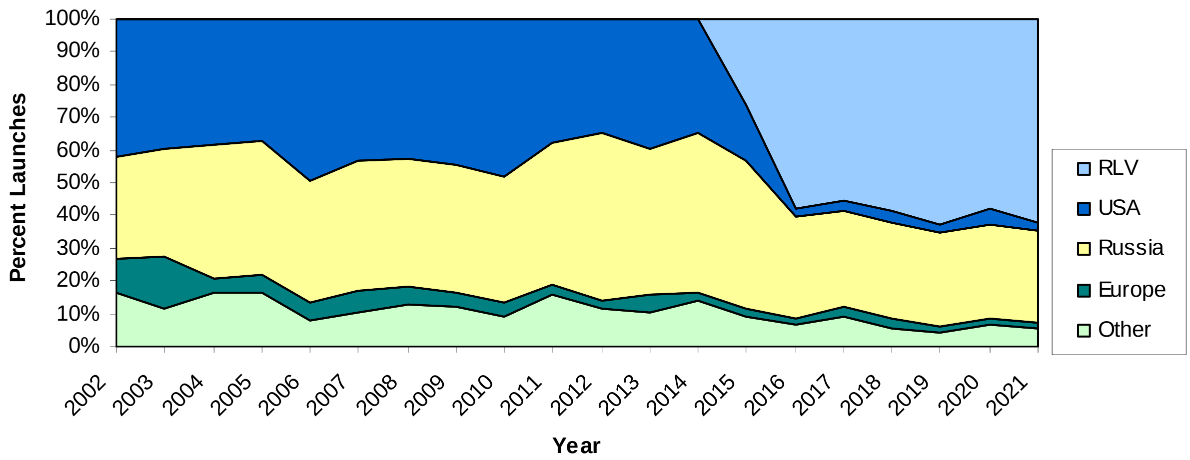


Figure 11-6: Introduction of RLV - Number of Launches

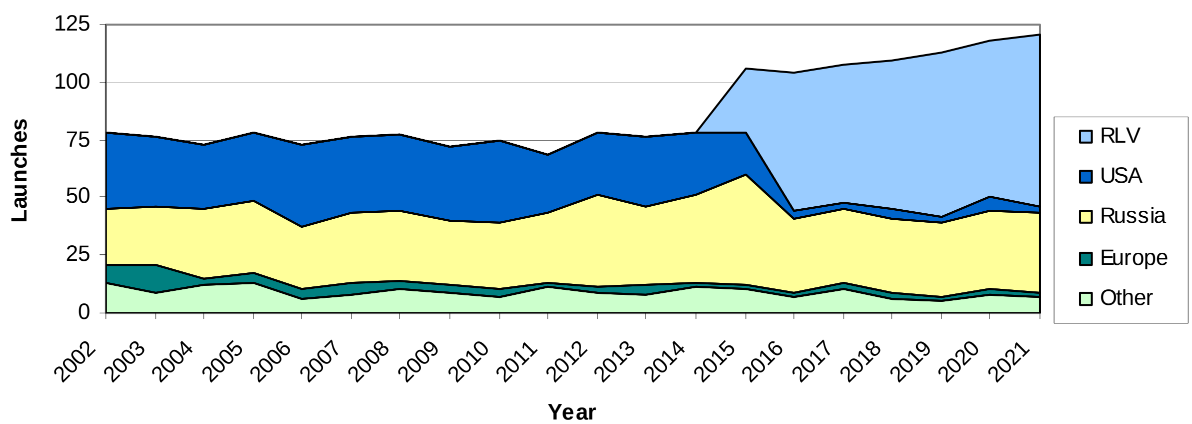
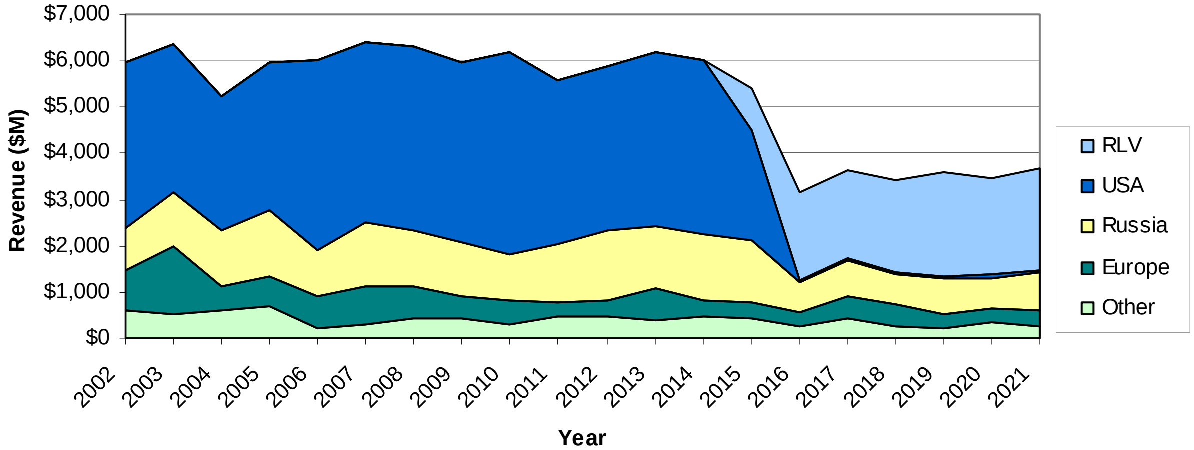


Figure 11-7: Introduction of RLV - Total Launch Revenues



The **CASE 2** analyses produced the following observations. An obvious result is a large wedge of RLV flights are introduced very rapidly as soon as the RLVs are available. The RLV outranks all U.S. ELVs on price, reliability, throughput, and scheduling. Nearly all US launches go to the RLV, as do nearly all commercial launches. Foreign government missions continue to be launched on indigenous vehicles, as do the few U.S. payloads that are too small for the assumed RLV.

The most striking observation is the decline in launch industry revenue with the introduction of the RLV. Lower launch costs do not stimulate sufficient demand to result in an overall increase in revenue. On the contrary, total industry revenues fall by half from around U.S. $6 billion to just about U.S.$ 3 billion.

The U.S. share of the global launch market does dramatically increase, however, on the introduction of the U.S. RLV. For the year 2021, the U.S. share of launches in the Baseline case was 30%; in Case 2 that share increases to 62%.

CASE 3: INTRODUCTION OF RLV'S WITH LIMITED STRATEGIC RESPONSE

Figure 11-8: Limited Strategic Response - Normalized Launches

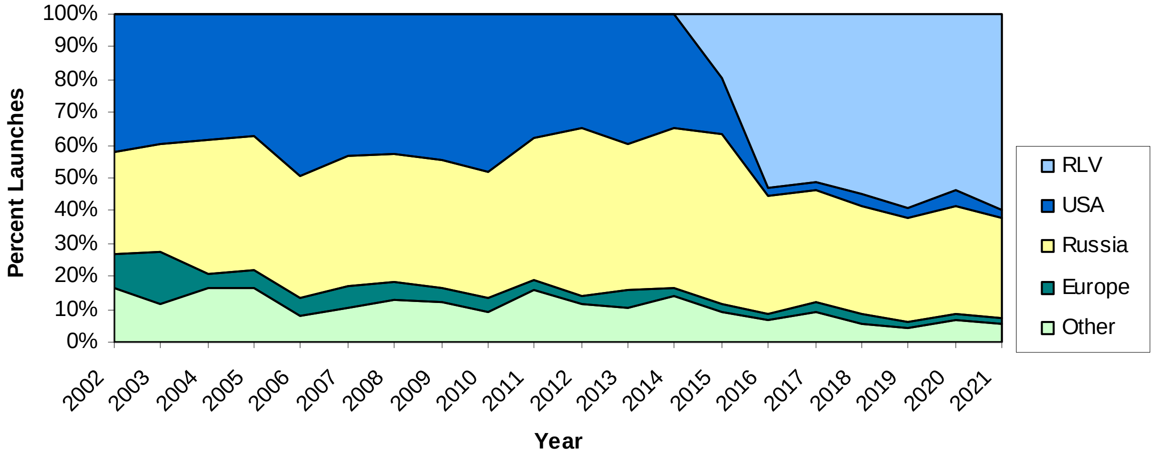


Figure 11-9: Limited Strategic Response - Number of Launches

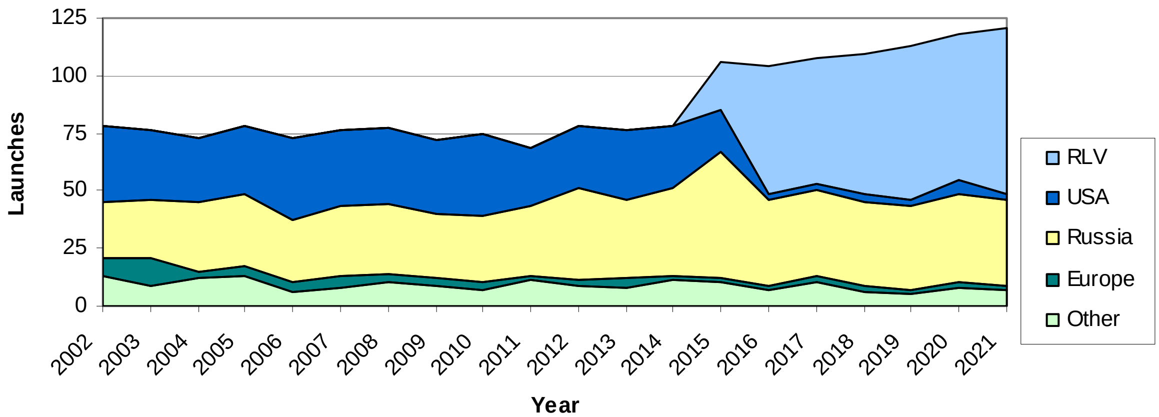
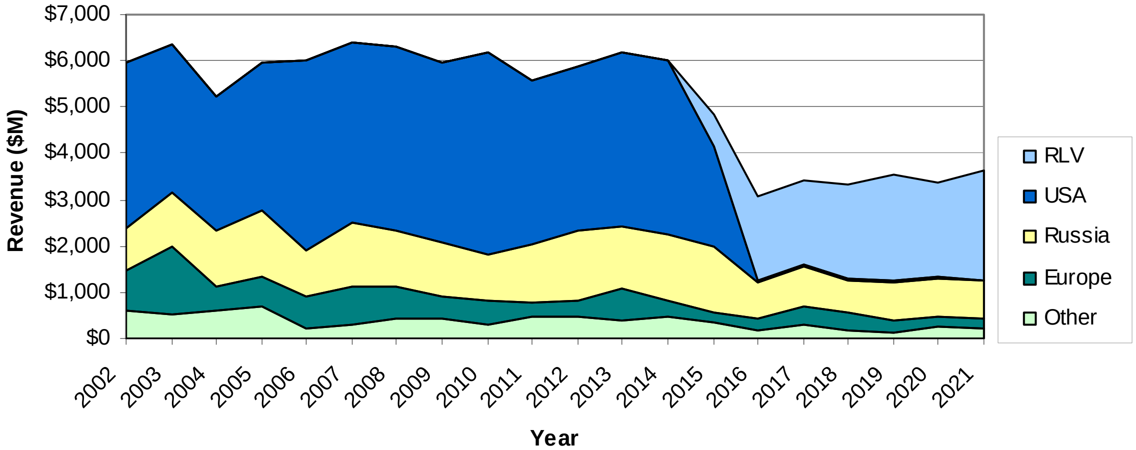


Figure 11-10: Limited Strategic Response - Total Launch Revenues



In this case with a limited strategic response, these results show that when all ELVs reduce their price by 25%, the RLV market share declines from 62% in 2021 for **CASE 2** to 60% in 2021 for **CASE 3.** This translates into 2 to 6 fewer RLV flights per year. The only U.S. ELV to not be outranked by the RLV is in the small lift category. The RLV is now operating at a price level just under 1/4 the average ELV price, which also explains the reduction in market share from the previous case. In terms of overall industry revenue, **CASE 3** produces even less revenue than **CASE 2**.

CASE 4: INTRODUCTION OF RLVS WITH MAXIMUM STRATEGIC RESPONSE

Figure 11-11: Maximum Strategic Response - Normalized Launches

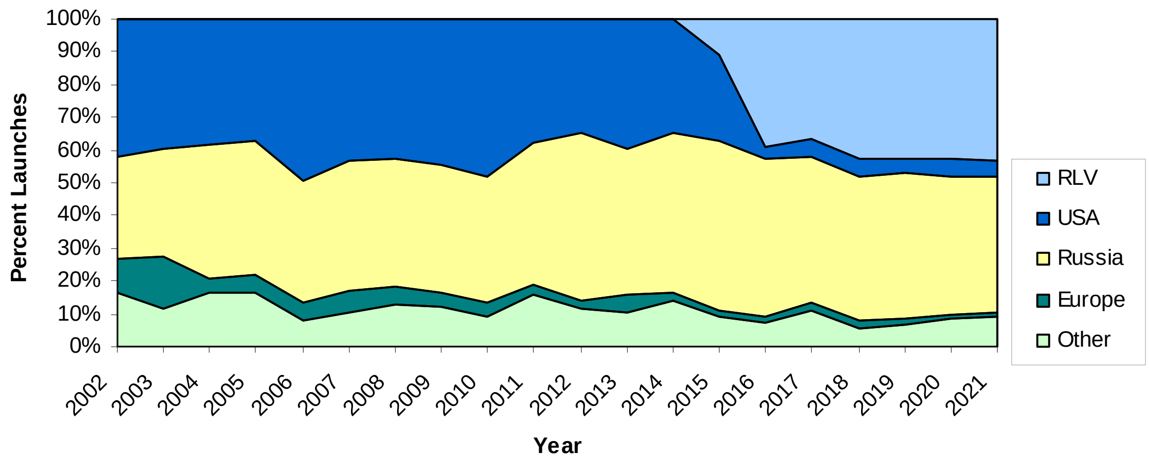


Figure 11-12: Maximum Strategic Response - Number of Launches

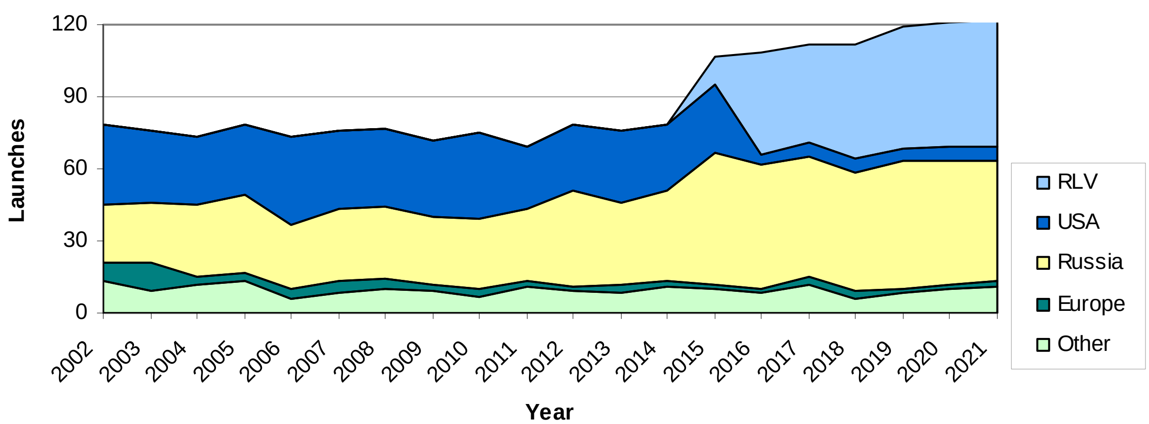
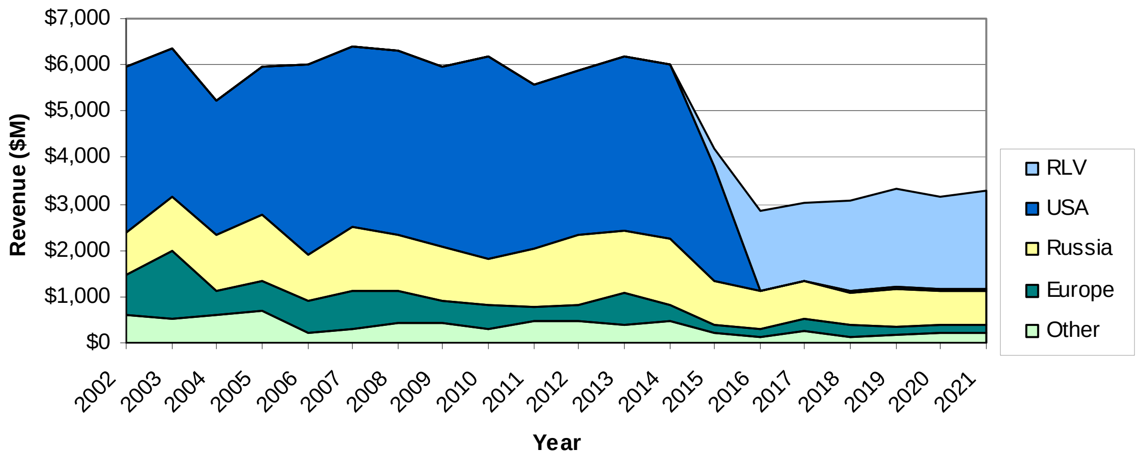


Figure 11-13: Maximum Strategic Response - Total Launch Revenues



In this scenario, ELVs are able to reclaim some market share from the RLV since the gap between RLV and ELV prices is smaller. RLV market share has decreased from 60% in **CASE 3** to 43% in **CASE 4**. As in **CASE 3**, the U.S. ELVs able to compete for launches are only in the small category. Revenue in **CASE 4** continues to decline, producing between $60 M and $230 M less in a given year compared to **CASE 3,** and the global industry total falling briefly below the U.S. $3 billion level.

12. Conclusions

Launch rates are not expected to vary dramatically over the next twenty years. New market sectors such as Public Space Travel will fuel growth in the second decade. Introduction of a true RLV, whether by the U.S or by another country, will significantly impact the traditional launch industry. . .

The ASCENT Study has delivered some major insights and provided a database, a set of forecasts, and a model that can continue to be useful for many years to come for a whole range of planning tasks in the space industry.

The methods and data used were soundly based and the analyses pragmatic; only markets that can realistically exist in the forecast period were included. The classification of the commercial markets into Existing, Evolving and Emerging market segments and the translation to terrestrial markets brings powerful new perspectives. The Study also provided a much-needed understanding of pricing in today's launch market, revealing great diversity. Within the range of assumptions stated explicitly throughout this work, five main findings emerged from the ASCENT Study:

1. Overall global launch demand over the next 20 years will be flat with between 70 and 80 launches per year (with 76 launches per year being the mean);
2. Sensitivity runs on the Baseline forecast demonstrate that the uncertainty associated with the forecast is relatively modest. A Robust forecast increased launches by about 15% over the 20-year period, and a Constrained forecast reduced launches by approximately 16%.
3. The only potential growth sector, despite the exorbitant current prices, is Public Space Travel, which accounts for 13% of launches by 2021. The industry needs to pay serious attention to this opportunity, particularly since the demand for this service is highly price sensitive, and the terrestrial tourism industry is such a significant part of the global economy.
4. Overall price elasticity of demand to launch price is low. There is virtually no impact on any of today's Existing markets and no overall "magic number" that triggers a demand step function.
5. The country or company that introduces an RLV with the right characteristics takes the lion's share of the launch market, with a flight rate of up to 80 flights a year being possible.

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