Federal Aviation Administration

2015 Commercial Space Transportation Forecasts

April 2015

FAA Commercial Space Transportation (AST) and the Commercial Space Transportation Advisory Committee (COMSTAC)

About the FAA Office of Commercial Space Transportation

The Federal Aviation Administration's Office of Commercial Space Transportation (FAA AST) licenses and regulates U.S. commercial space launch and reentry activity, as well as the operation of non-federal launch and reentry sites, as authorized by Executive Order 12465 and Title 51 United States Code, Subtitle V, Chapter 509 (formerly the Commercial Space Launch Act). FAA AST's mission is to ensure public health and safety and the safety of property while protecting the national security and foreign policy interests of the United States during commercial launch and reentry operations. In addition, FAA AST is directed to encourage, facilitate, and promote commercial space launches and reentries. Additional information concerning commercial space transportation can be found on FAA AST's website:

http://www.faa.gov/go/ast

Cover: A United Launch Alliance Delta IV Heavy vehicle launches from LC-37 at Cape Canaveral Air Force Station, Florida carrying Lockheed Martin's Orion test vehicle on December 5, 2014. This FAA AST-licensed flight took place in support of NASA's human spaceflight program. Image Credit: NASA

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EXECUTIVE SUMMARY

The Federal Aviation Administration's Office of Commercial Space Transportation (FAA AST) and the Commercial Space Transportation Advisory Committee (COMSTAC) have prepared forecasts of global demand for commercial space launch services in 2015 through 2024.

The 2015 Commercial Space Transportation Forecasts report (the Report) is in two sections:

- The *COMSTAC 2015 Commercial Geosynchronous Orbit (GSO) Launch Demand Forecast*, which projects demand for commercial satellites that operate in GSO and the resulting commercial launch demand to GSO. As a result of the realignment of issuance dates of the Report, this year's GSO Launch Demand Forecast only considers the three-year outlook; and

- The FAA's *2015 Commercial Space Transportation Forecast for Non-Geosynchronous Orbits (NGSO)*, which projects commercial launch demand for satellites to NGSO, such as low Earth orbit (LEO), medium Earth orbit (MEO), elliptical (ELI) orbits, and external (EXT) trajectories beyond orbits around the Earth.

The Report projects an average of 17 commercial GSO launches for 2015 through 2017 and 13.1 NGSO launches for 2014 through 2023. Figure 1 shows the combined GSO and NGSO Historical Launches and Launch Forecast. It reflects the three-year near-term combined forecast, consistent with this year's three-year GSO forecast outlook. Table 1 shows the number of GSO and NGSO payloads and launches projected from 2015 through 2024.

It is important to distinguish between forecast demand and the number of satellites actually launched. Launch vehicle and satellite programs are complex, and susceptible to delays, which generally makes the forecast demand for launches the upper limit of actual launches in the near-term forecast.

Figure 1. Combined 2015 GSO and NGSO Historical Launches and Launch Forecasts

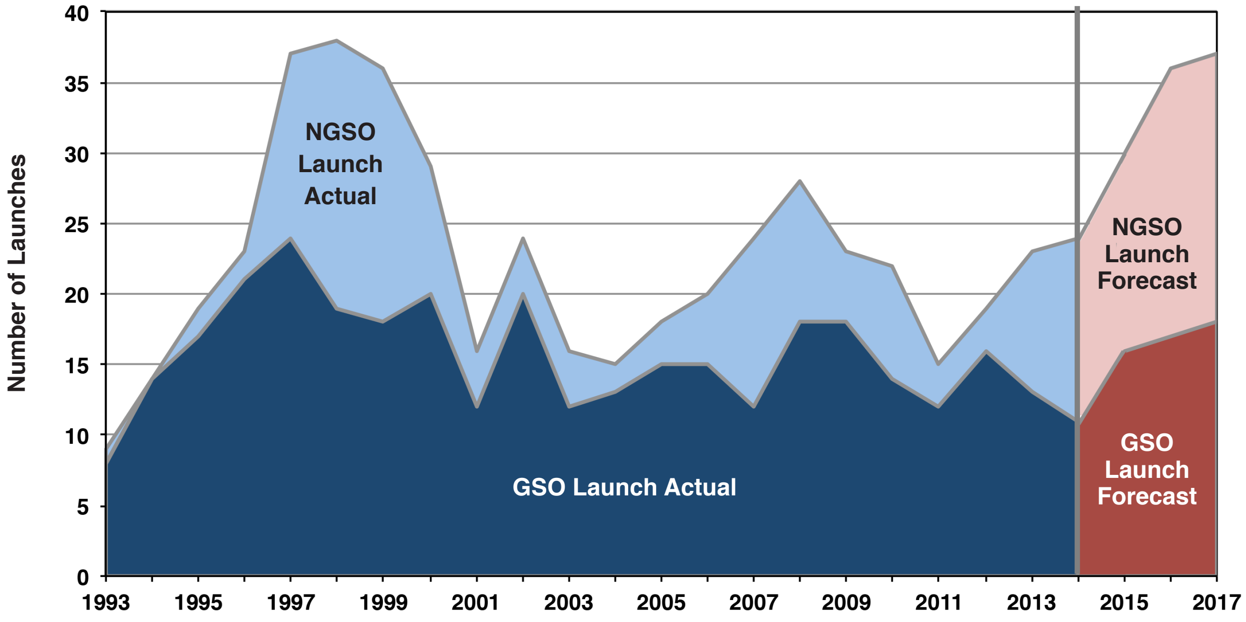


Table 1. Commercial Space Transportation Payload and Launch Forecasts

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total	Avg.
Payloads												
GSO Forecast (COMSTAC)	24	25	26	--	--	--	--	--	--	--	75	25.0*
NGSO Forecast (FAA)	65	136	151	104	92	92	87	86	87	86	986	98.6
Total Payloads	**89**	**161**	**177**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Launches												
GSO Medium-to-Heavy	16	17	18	--	--	--	--	--	--	--	51	17.0*
NGSO Medium-to-Heavy	13	17	15	13	11	10	10	10	10	10	119	11.9
NGSO Small	1	2	4	2	1	0	1	0	1	0	12	1.2
Total Launches	**30**	**36**	**37**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**

* For this edition of the Report, the GSO forecast is limited to the period 2015-2017.

The GSO market remains stable with a projected demand of 25 satellites per year for the period 2015 – 2017, up from last year's average of 22.3 for the period 2014 – 2016. Figure 2 shows the 2015 GSO Historical Launches and Launch Forecast. Thirty-nine percent of GSO satellites projected to launch from 2015 – 2017 are in the heaviest mass class (above 5,400 kg). At the same time, seven percent of the satellites in the same period are in the lowest mass class (below 2,500 kg). In 2015, unaddressable launches remained at the comparably high level—launch contracts that were not open to international (including U.S.) competition—as Chinese and Russian government-owned aerospace companies routinely package satellites, launches, and financing together. The satellite services market is generally robust, and new launch vehicle options will affect the dynamics of the launch industry. Operators are cautious about the impact of the economy on their plans but are generally satisfied with satellite and launch vehicle offerings.

Figure 2. 2015 GSO Historical Launches and Launch Forecast

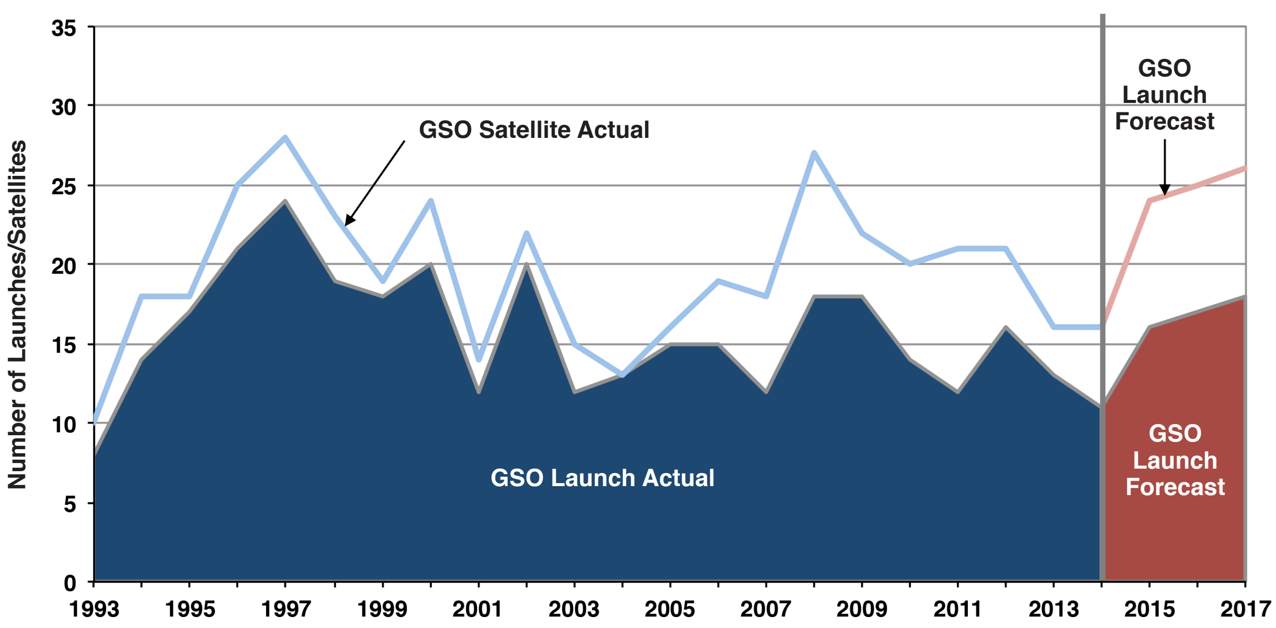
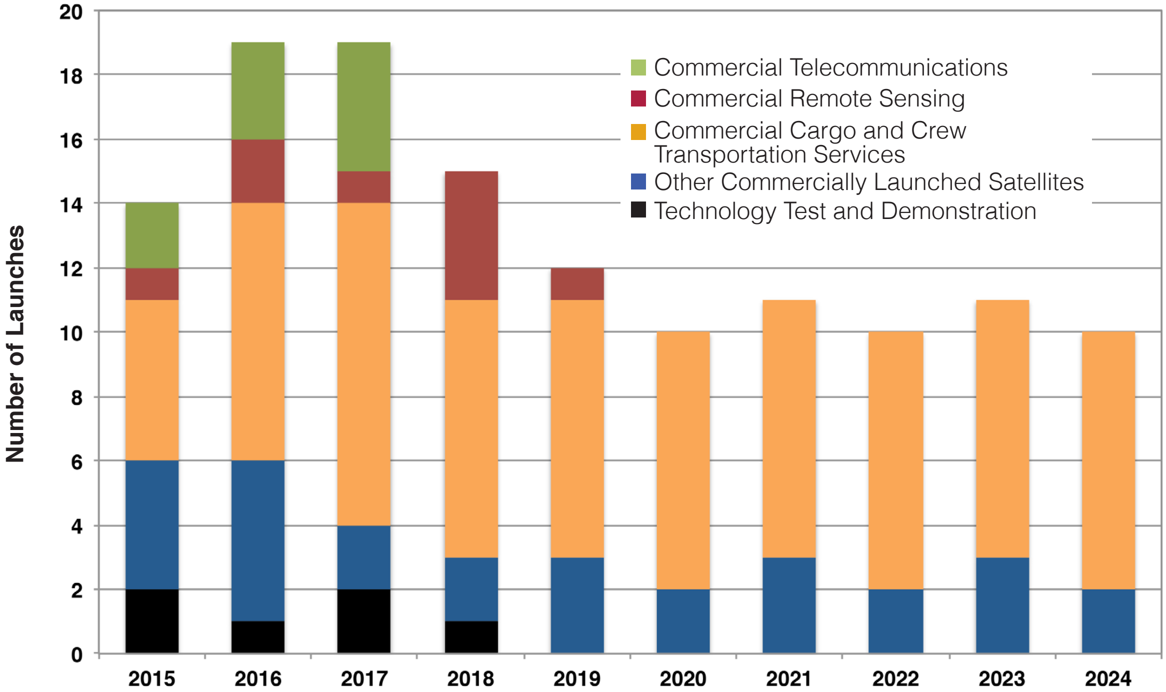


Figure 3. Projected NGSO Launches from 2015-2024



The demand for commercial NGSO launches is expected to be at a comparably high level as major NGSO telecommunication constellations are replenished and NASA ISS commercial crew and cargo resupply missions become more regular. The annual average of NGSO commercial launches is expected to grow from an annual average of seven launches a year over the last ten years to about 11.9 launches annually. From 2015 – 2024, 986 payloads are projected to launch commercially, driving only 131 launches with multi-manifesting, reflecting an industry planning to launch more micro- and small-class payloads in clusters, instead of increasing the demand for individual launches. Figure 3 shows the projected NGSO launches for the next 10 years. The launches in the next 10 years are predominantly commercial launches to the ISS, which require medium-to-heavy vehicles. Ninety-one percent of all commercial NGSO launches during the forecast period will launch on medium-to-heavy vehicles. The relatively higher number of small launches is due to Skybox Imaging's plans to use Minotaur C to deploy its constellation and the first test flights of four newly developed commercial small launch vehicles in 2015 – 2017, to be introduced for commercial launch services in the following years. From 2015 – 2018 the report forecasts a number of small commercial satellites to be launched as Iridium, ORBCOMM, Planet Labs, and Skybox all deploy their constellations. The number of these small multi-manifested satellites drops off towards the end of the forecast, but the number of launches remains relatively steady as NASA begins its commercial crew program.

The two sections that follow—GSO and NGSO—provide detailed information on the two market segments.

COMSTAC 2015 COMMERCIAL GEOSYNCHRONOUS ORBIT LAUNCH DEMAND FORECAST

SUMMARY

The Commercial Space Transportation Advisory Committee (COMSTAC) for the Office of Commercial Space Transportation of the Federal Aviation Administration (FAA AST) compiled the 2015 Commercial Geosynchronous Orbit (GSO) Launch Demand Forecast (the Report). This year's Report is the 23rd annual forecast of global demand for commercial GSO satellites and launches addressable by the U.S. space launch industry—that is, launches open to internationally competitive (including U.S.) launch service procurement. The Report provides a detailed analysis of satellites scheduled for launch in the next three years and a broader forecast of launch demand for the subsequent seven years. The Report is intended to assist the U.S. Government (USG) in resource planning, and FAA AST for licensing and in efforts to foster commercial space launch capability in the United States. As a result of the realignment of issuance dates of the Report, this year's Report only considers the three-year outlook.

Both satellite and launch demand forecasts are included in the Report. The satellite demand is a forecast of the number of addressable commercial GSO satellites that operators expect will be launched. The launch demand is determined by the number of addressable satellites to be launched adjusted by the number of satellites projected to be launched together on a single launch vehicle, referred to in the Report as "dual-manifest" launches.

Figure 4 provides a summary of the forecast, showing annual projected satellites and launches. Table 2 provides the corresponding values, including the projected number of dual-manifested launches.

Figure 4. Forecast Commercial GSO Satellite and Launch Demand

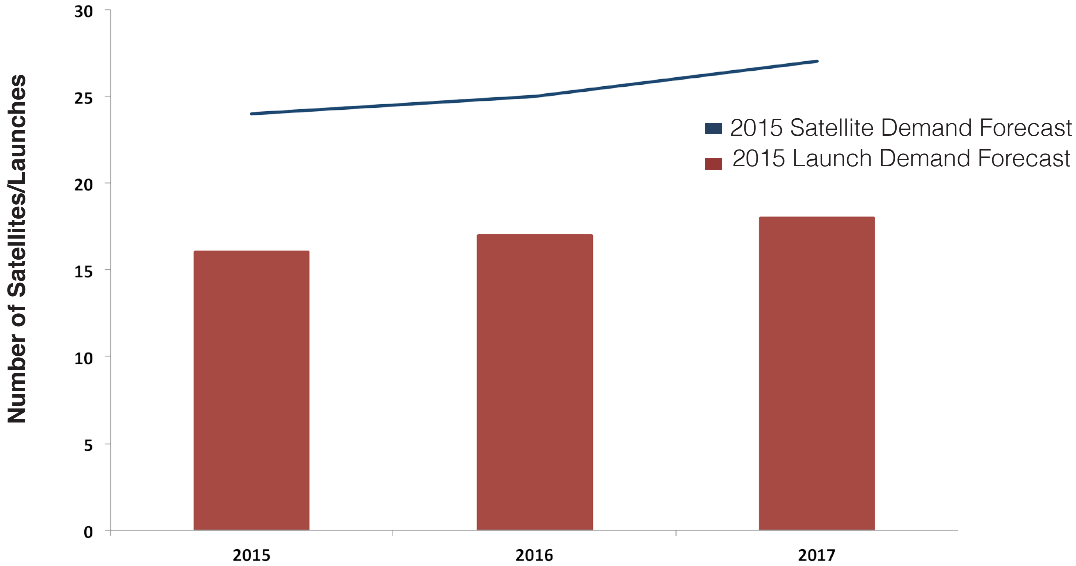


Table 2. Forecast Commercial GSO Satellite and Launch Demand

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total	Average
Satellite Demand	24	25	26	--	--	--	--	--	--	--	75	25.0
Launch Demand	16	17	18	--	--	--	--	--	--	--	51	17.0
Dual Launch Demand	8	8	9	--	--	--	--	--	--	--	25	8.3

The key findings of this Report are:

- The 2015 COMSTAC GSO forecast projects 24 addressable commercial GSO satellites on 16 launches in 2015 and an annual average of 25 satellites on 17 launches for the period from 2015 through 2017.
- The number of addressable satellites launched in 2014 (16 satellites) remained the same from 2013, continuing a pattern of satellite delays and launch failures.
- The average number of satellites to be launched in the next three years has increased from last year's Report, from 22.6 in 2014 to 25 in 2015, the number of launches has increased slightly, from 16.3 in 2014 to 17 in 2015, representing a reduction in the overall percentage of dual-manifest launches.
- The satellite services market is generally robust, and new launch vehicle options have altered the dynamics of the launch industry.

It is important to distinguish between forecast demand and the number of satellites that are actually launched. Satellite programs are susceptible to delays, so the forecast demand is an upper limit on the number of satellites that may actually be launched. To account for these differences, the forecast team developed a "launch realization factor." This factor is based on historical data comparing actual satellites launched with predicted satellite demand from previous reports. This factor is then applied to the near-term forecast to provide a range of satellites reasonably expected to be launched. For example, while 24 satellites are projected to be launched in 2015, applying the realization factor adjusts this to a range of 19 to 24 satellites.

HISTORY OF THE REPORT

In 1993, the U.S. Department of Transportation requested that COMSTAC annually prepare a commercial GSO satellite launch demand forecast to present the commercial space industry's view of future space launch requirements. COMSTAC works with U.S. launch service providers, satellite manufacturers, and satellite service providers to develop the forecast. A Forecast Team of COMSTAC members and industry experts, listed in Table 3, compiled this year's Report.

Table 3. 2015 GSO Forecast Team

Forecast Team Member	Affiliated Company
Lisa Hague	The Aerospace Corp.
Liz Driscoll	Aerojet Rocketdyne
Aaron Lewis	Arianespace
Raymond Wong	Boeing
Chris Ellerhorst	LMCLS
Peter Stier	Sea Launch
Alan Keisner	SpaceX
Ta Ratana	SSL
Phil Smith	The Tauri Group
Keith Karuntzos	ULA
Chris Kunstadter	XL Insurance

One of the goals of FAA AST is to foster a healthy commercial space launch capability in the United States. In order to do this, FAA AST must understand the scope and trends of global commercial spaceflight demand. In addition, FAA AST must be able to plan for and allocate resources which may be necessary to carry out its responsibilities in licensing commercial U.S. space launches. This Report provides necessary data to FAA AST for these purposes.

FORECAST METHODOLOGY

The Report is updated annually, using inputs from commercial satellite operators, satellite manufacturers and launch service providers. In order to align the Report with calendar year launch activity, this Report is an interim report—future reports will be issued as soon as possible after the end of the calendar year. The next report—the 2016 Report—will be issued in January 2016. As a result, this current Report does not include the extensive out-year analysis and market sentiment surveys that have been in previous reports—these will once again be included in the next and subsequent reports.

The methodology for developing the forecast has remained consistent throughout its history. The Forecast Team, through FAA AST, requests projections of satellites to be launched over the next 10 years from global satellite operators, satellite manufacturers, and launch service providers. This includes a projection of these organizations' launch plans as well as a broad, industry-wide estimate of total GSO launches. In addition, input is sought on a variety of factors that might affect satellite and launch demand.

The Forecast Team, using this input as well as public sources (e.g., satellite operator and launch provider web sites), and the team's own industry knowledge, develops the near-term forecast, covering the next three years (2015 – 2017).

Other factors that were considered in developing the forecast include:

- Publicly-announced satellite and launch contracts
- Projected planned and replenishment missions
- Growth in demand from new and existing services and applications
- Availability of financing and insurance
- Potential consolidation among operators
- New launch vehicle capabilities
- Hosted payload opportunities

The production cycle for today's satellites is typically two to three years, but it can be longer for heavier or more complex satellites. Orders within a two- to three-year horizon are thus generally reliable. Satellite orders more than three years out can be difficult to identify, as many of these programs are in early stages of planning or procurement. Beyond five years, new markets and new uses of satellite technology may emerge that are currently unanticipated.

COMSTAC COMMERCIAL GSO LAUNCH DEMAND FORECAST RESULTS

Addressable vs. Unaddressable

To clarify which launch opportunities can be "addressed" by U.S. launch providers, satellite launches are classified as either "addressable" or "unaddressable." Addressable, in the context of this Report, is defined as commercial GSO satellite launches that are open to an internationally competitive (including U.S.) launch service procurement process. Satellites and launches bundled in government-to-government deals, launches captive to particular launch service providers, and others that are not internationally competed are classified as unaddressable.

The number of unaddressable launches has increased from the 2014 forecast, as Chinese, Indian, Japanese and Russian government-owned or -supported aerospace companies continued packaging satellites, launches, financing and insurance for commercial satellites on a strategic, non-competitive basis. Figure 5 and Table 4 compare the numbers of addressable and unaddressable satellites since 2005.

Figure 5. Addressable and Unaddressable Satellites since 2005

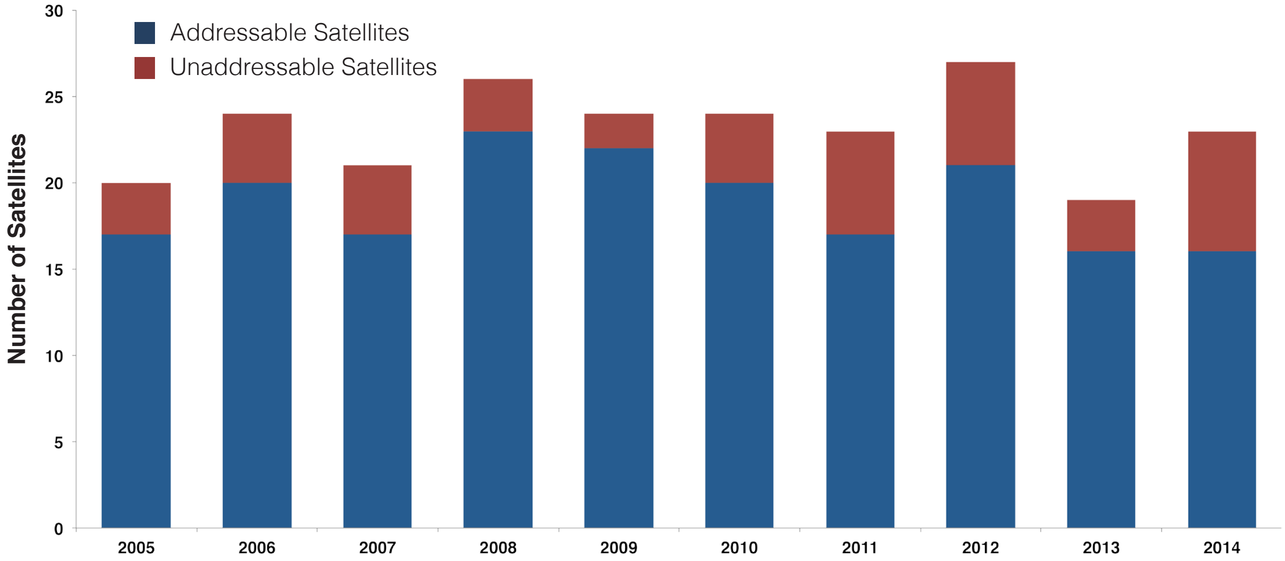


Table 4. Addressable and Unaddressable Satellites Since 2005

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Addressable	17	20	17	23	22	20	17	21	16	16
Unaddressable	3	4	4	3	2	4	6	6	3	7
Total	**20**	**24**	**21**	**26**	**24**	**24**	**23**	**27**	**19**	**23**

Mass Classes

One of the primary metrics for determining launch requirements is satellite mass. Mass classes based on ranges of satellite masses are used to analyze developments in satellite and launch demand. Four mass classes are currently used, as shown in Table 5.

Table 5. Satellite Mass Class Categorization

Class	Separated Mass	Representative Satellite Bus Models
Medium	Below 2,500 kg (<5,510 lbm)	Lockheed Martin A-2100, Orbital GEOStar, Boeing BSS-702, SSL-1300
Intermediate	2,500 - 4,200 kg (5,510 - 9,260 lbm)	A-2100, IAI Amos, MELCO DS-2000, GEOStar, SSL-1300, Thales SB-4000
Heavy	4,200 - 5,400 kg (9,260 - 11,905 lbm)	Astrium ES-3000, BSS-702, IAI Amos, A-2100, DS-2000, GEOStar, SSL-1300, SB-4000
Extra Heavy	Above 5,400 kg (>11,905 lbm)	ES-3000, BSS-702, A-2100, SSL-1300, SB-4000

The upper limit of the smallest mass class was increased in 2008 from 2,200 kg to 2,500 kg. This adjustment captured the growth in mass of the smallest commercial GSO satellites being manufactured. As an example, Orbital's GEOStar 2 bus, which dominated the lower end of the mass scale in previous years, has recently been used for satellites in excess of 3,200 kg, which fall in the intermediate mass class range. Unaddressable launches in this smallest class abound, with one to four medium class satellites being launched in most years.

One technical development that has affected the trend towards increasing satellite mass is the development of satellites using electric propulsion rather than chemical propulsion (such as liquid apogee motors) for orbit-raising. By reducing the mass of propellant used for orbit-raising, which in many cases is greater than the dry mass of the satellite, the satellite can carry a significantly larger payload. Alternatively, by keeping the satellite mass low, two satellites, each with the payload capacity of a large satellite, can be launched together.

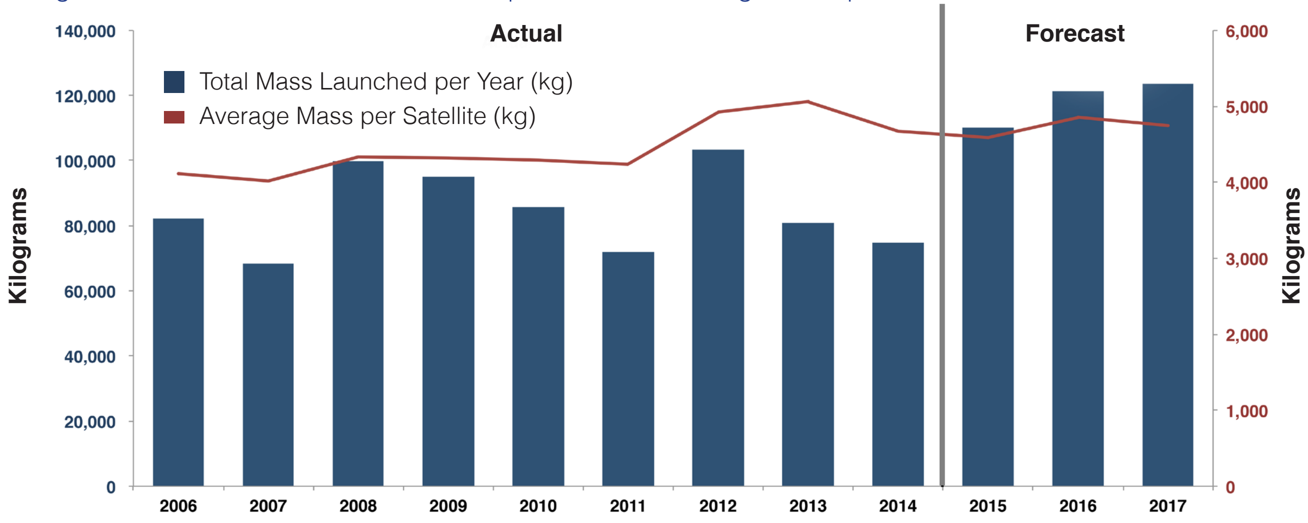
Using electric propulsion increases the time required for orbit-raising—months rather than days. Nonetheless, in many cases, the benefits of the mass and launch cost savings outweigh the delay in achieving final orbital position.

In 2012, Boeing signed a contract with Asia Broadcast Satellite (ABS) and Satmex for four all-electric design 702SP satellites. Since then, most other manufacturers of commercial communications satellites have indicated they already have—or will offer—that technology to their customers in the near future. With the advent of all-electric propulsion satellites, this smaller mass class is expected to grow in the next three years.

Table 6. Total Satellite Mass Launched per Year and Average Mass per Satellite

	Actual									Forecast		
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Mass Launched per Year (kg)	82,235	68,241	99,692	94,921	85,724	72,068	103,499	80,921	74,752	110,137	121,302	123,514
Average Mass per Satellite (kg)	4,112	4,014	4,334	4,315	4,286	4,239	4,929	5,058	4,672	4,589	4,852	4,751

Figure 6. Total Satellite Mass Launched per Year and Average Mass per Satellite



Likewise, the heaviest mass class continues to dominate, with 38 percent of satellites launched in 2014 falling into this mass class. As the smallest mass class grows slightly, the extra-heavy mass class is expected to remain relatively high at 39 percent of the satellites projected for launch from 2015 through 2017.

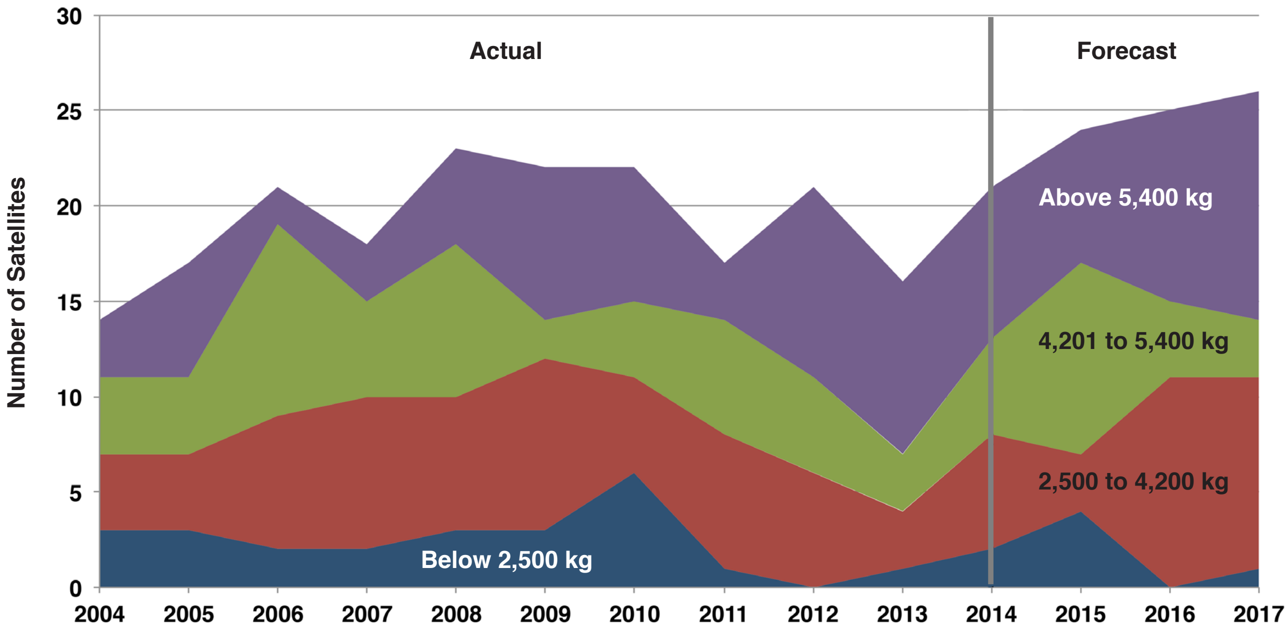
Figure 6 and Table 6 show the total mass launched per year and the average mass per satellite launched. The total mass launched per year correlates with the number of satellites launched per year. The average mass of satellites launched in the past nine years was 4,440 kg, reaching a new high of over 5,000 kg in 2013. The average mass in 2015 is expected to reduce slightly. The 24 satellites scheduled for launch in 2015 have a mass of 110,137 kg, for an expected average satellite mass of 4,589 kg.

Figure 7 and Table 7 show the trends in satellite mass class distribution.

Table 7. Trends in Satellite Mass Class Distribution

	Actual									Forecast			Total 2015 to 2017	Avg. 2015 to 2017	% of Total 2015 to 2017
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017			
Above 5,400 kg	2	3	5	8	7	3	10	9	8	7	10	12	29	9.7	39%
4,201 - 5,400 kg	10	5	8	2	4	6	5	3	5	10	4	3	17	5.7	23%
2,500 - 4,200 kg	7	8	7	9	5	7	6	3	6	3	11	10	24	8.0	32%
Below 2,500 kg	2	2	3	3	6	1	0	1	2	4	0	1	5	1.7	7%
Total	**21**	**18**	**23**	**22**	**22**	**17**	**21**	**16**	**21**	**24**	**25**	**26**	**75**	**25.1**	**100%**

Figure 7. Trends in Satellite Mass Class Distribution



Dual-Manifesting

Several launch services providers are capable of lofting two satellites simultaneously into geosynchronous transfer orbit (GTO). Demand analysis for launch vehicles must take into consideration this capability. Care must be taken in that inclusion into the forecast must be based upon the addressability of each of the satellites flown. A launch vehicle such as Ariane 5 or Falcon 9, which has the launch services competitively procured for both satellites, is included in the forecast and counted as a dual manifested launch. A vehicle such as Proton, which may have only one of the two satellite launch services contracts competitively procured, is also included in the forecast, but counted as a single launch. Proton has flown several dual launches, but typically one spacecraft is a Russian domestic or government satellite. A Proton which launches two Russian domestic satellites is not counted in the forecast, as these satellites are not open for competition to launch services providers. Such Russian, Chinese, and Indian launches flying on domestic launch vehicles are counted in the non-addressable market.

The Ariane 5 vehicle has been launching dual-manifested, competitively-procured, commercial launch services missions for more than a dozen years. Typically, a satellite of 5,000-6,000 kg flies in the upper slot, along with a satellite of 2,000-3,500 kg in the lower slot. Arianespace has the capacity to conduct up to seven commercial dual manifested launches per year depending upon backlog, demand, and requirements to fly European government satellites such as European Space Agency (ESA) missions. The forecast team determined the near-term number of dual manifest launches on Ariane 5 by assessing the existing backlog of satellites through 2017. In 2012, Ariane 5 flew seven missions, six of which were dual launches and one ESA ATV resupply mission to ISS. In 2013 Ariane 5 flew four missions, with three of these being dual launches and one ESA ATV resupply mission to ISS. In 2014 Ariane 5 flew six missions, with five being dual missions, along with the last ESA ATV cargo resupply mission to ISS. Ariane 5 is expected to fly seven times per year in each of the next several years, with 5-7 of these being dual missions.

Proton has flown several dual-manifested missions of small 1,000-2,000 kg satellites which are injected directly into GSO. These have typically been paired with a Russian-built (unaddressable) satellite. In 2012 Proton flew two dual manifest missions. One carried a small addressable satellite with a small Russian-built (unaddressable) satellite. As noted above, this is counted as one launch of one addressable satellite. The other dual launch carried two Russian satellites. This launch is noted as unaddressable, since the launch services was not open for competition. In 2014 Proton flew two dual missions. One flight paired an addressable satellite with a Russian satellite. Again, this mission is counted as one launch. The other mission flew two small Russian satellites. Once again, this mission is not counted, as the satellite launch services were un-addressable. It appears that one dual launch mission will be flown every other year on Proton. Proton also flies triple Russian GLONASS navigation satellite missions. These are not counted in the Forecast, as they are non-commercial launches.

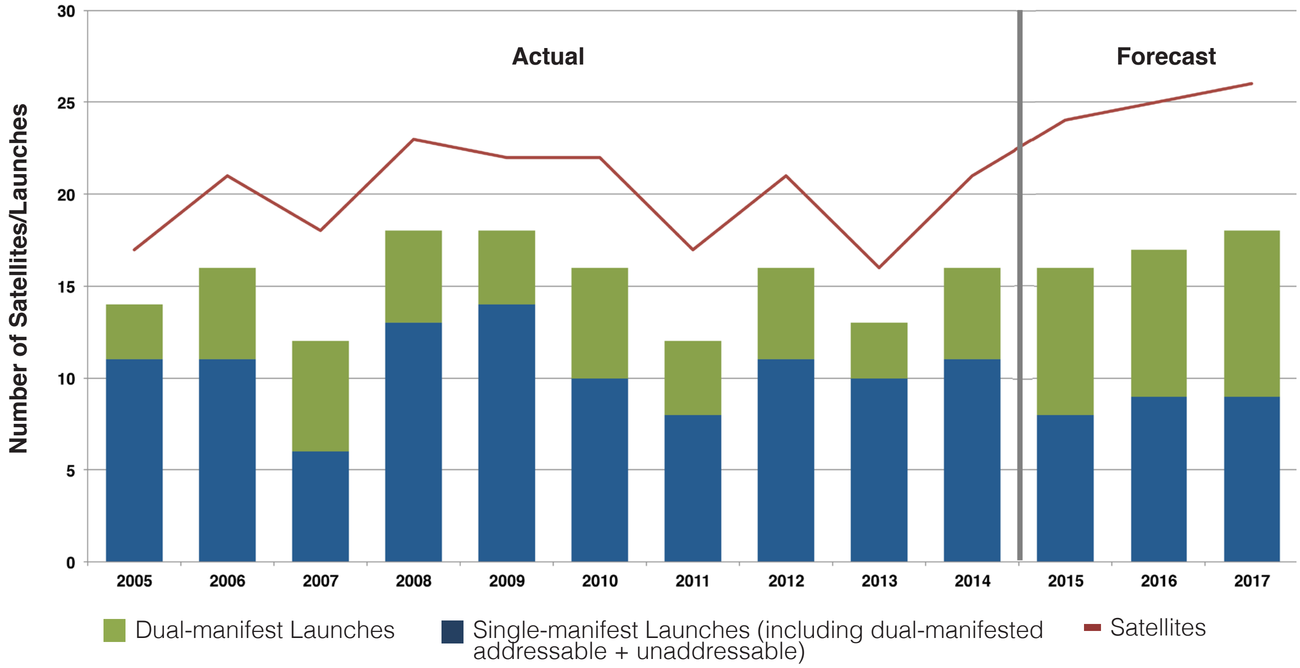
Falcon 9 has flown one dual mission to GTO in 2015, and has another scheduled for later in the year. These missions are small 2,000-2,500 kg Boeing-built electric propulsion satellites for Asia Broadcast Satellite and Eutelsat.

Dual-manifesting of two communications satellites in the 5,000+ kg heavy and/or extra heavy mass classes is not yet available. Arianespace typically attempts to match satellites that together have a total effective mass of up to 10,000 kg. Arianespace has terminated its plans for a Mid-Life Evolution upgrade which would have been capable of carrying two 5,000 kg satellites, in favor of developing Ariane 6 for debut in 2020 – 2021. The larger Ariane 6 configuration with four solid rocket boosters will be able to carry up to 11,000 kg to GTO. International Launch Services (ILS) plans to phase out Proton and replace it with Angara 5 in 2020. Angara 5 may carry up to 7,500 kg to GTO, so will likely be used to fly two small satellites directly into GSO, as Proton does now. The debut of the Falcon Heavy launch vehicle in late 2015, with 21,200 kg capability to GTO, may also permit dual manifesting of large communications satellites in the future.

From a spacecraft technology development perspective, however, the introduction of electric propulsion technology may reverse the growth trend in overall satellite mass, thus enabling more dual manifesting on existing launch vehicles.

Figure 8 presents the 2015 single- and dual-manifest satellite and launch demand forecast from 2015 through 2017, and the actual launch statistics from 2004 through 2014. After the next three years, the number of addressable dual manifest launches may stabilize at seven per year. The transition to new and replacement launch vehicles is not expected to impact the number of dual manifest launches over the remainder of this decade.

Figure 8. Dual Manifesting and Launch Demand



Launch Vehicle Availability For GEO Satellites

One key aspect agreed upon by the COMSTAC working group was the number of available launches for GEO commercial satellites during the forecast period (2015 – 2017), as shown in Table 1. This helped the team to forecast the satellites to be launched in a given year or moved to the following year due to supply constraints for a particular launch vehicle. The following is a quick summary of launch vehicle providers' manifest outlook, also summarized in Table 8:

Ariane: Ariane 5 is fully booked for 2015 and 2016, but there are slots available for 2017.

Atlas: Lockheed Martin Commercial Launch Services (LMCLS) has one GEO commercial launch (Mexsat in 2015) during the forecast period. Though they have a busy manifest with USG launches through United Launch Alliance (ULA), there are some slot openings in 2016 and 2017 for potential commercial launches.

Falcon 9 and Falcon Heavy: SpaceX is fully manifested for 2015, with some openings left in 2016 and 2017. We expect their throughput to increase after their Texas launch pad is operational for commercial programs in the second half of 2016.

H-IIA: Mitsubishi Heavy Industries Launch Services (MHI) has secured one GEO commercial launch (Telesat Telstar 12V in 2016) during the forecast period. It is assumed they could accommodate additional GEO commercial launches during this period.

Proton: It is assumed ILS was will have a full backlog for 2015 with some openings for launches in the 2016 – 2017 timeframe.

Sea Launch: There are currently no launches scheduled for Sea Launch during the forecast period.

Table 8. Launch Manufacturer Throughput for GEO Commercial Satellites per Year

Launch Vehicle	Expected Number of Launches 2015	2016	2017
Ariane 5	6-7	6-7	~8
Atlas V	1-3	1-3	1-3
Falcon 9/Falcon Heavy	5	7-8	~10
H-IIA/B	1-3	1-3	1-3
Proton M	~5	~5	~5
Zenit 3SL	0	~2	~4
Total Launches	**18-23**	**22-28**	**29-33**
Total Satellites Launched*	**26-32**	**28-35**	**37-41**

* Assumes all Ariane 5s are dual launches, and includes two dual launches for Falcon 9/Falcon Heavy.

Electric Propulsion

One technical development that has affected the satellite mass trend is the development of satellites using electric propulsion rather than chemical propulsion (such as liquid apogee motors) for orbit-raising. By reducing the mass of propellant used for orbit-raising, which in many cases is greater than the dry mass of the satellite, the satellite can carry a significantly larger payload. Alternatively, by keeping the satellite mass low, two satellites, each with the payload capacity of a large satellite, can be launched together.

The use of electric propulsion to decrease propellant mass has gradually increased over the last few decades. In the early 1980s, satellite manufacturers began implementing arcjets and resistojets, early forms of electric propulsion, initially for north-south station keeping (NSSK). Using more efficient electric propulsion allowed satellite manufacturers to increase payload capability or extend satellite life while maintaining the same launch mass. Gradually, newer electric propulsion technology such as gridded ion engines and hall thrusters were introduced and electric propulsion began to carry more of the propulsion load for commercial spacecraft – east-west station keeping, momentum dumping and even some orbit topping.

While these technological advancements provided increased capability for satellite manufacturers and operators, they did not substantially change the launch market. In the last few years, however, two significant events occurred that have kicked off a more dramatic change with satellites now planning to conduct the entire orbit raising with electric propulsion. In 2010, the Advanced Extremely High Frequency (AEHF) satellite had an anomaly with its main propulsion system and used the high power Hall thruster on board to complete the majority of its orbit raising. This was the first flight demonstration of electric propulsion for orbit raising and the first flight of a high powered (4.5kW) hall thruster. In 2012, Boeing signed a contract with ABS and Satmex (now Eutelsat) for four all-electric 702SP satellites. These events paved the way for more widespread adoption of EP for orbit raising. Since then, most manufacturers of commercial communications satellites have indicated they already have—or will offer—that technology to their customers in the near future.

The use of electric propulsion provides a powerful trade for satellite operators and manufacturers. By significantly reducing the mass of propellant used for orbit raising, they can either increase the payload capability while maintaining the same launch mass or maintain the same capability at a reduced launch mass enabling lower cost launch vehicles, or dual-manifesting. Electric propulsion operates at a lower thrust than traditional chemical propulsion, increasing the time required for orbit-raising—months rather than days. The actual time required for orbit raising varies based on the type and power of the EP device. With increasing available power and high power EP options being developed, the trip time can be decreased, though still not approaching the short time required for chemical orbit raising. In many cases, the benefits of increased capability or launch cost savings outweigh the delay in achieving final orbital position.

Prior to the use of electric propulsion for orbit raising, separated mass was a good proxy for satellite capability. The adoption of EP for orbit raising changes that dynamic as two satellites with similar payload capabilities may have dramatically different separated masses, depending on whether EP or chemical orbit raising is used. Additionally, as operators trade capability and/or launch mass against time-to-orbit they may choose to use a mix of EP and chemical orbit raising (hybrid propulsion) rather than simply bifurcating the satellites to all chemical or all EP. While launch mass will still drive the selection of launch vehicle, other indicators such as dry mass or spacecraft or payload power may be better indicators of launch capability. With more widespread use of EP, it is also likely that there will be an increased demand for dual launch capability and smaller launch vehicles.

Payload Power As An Indicator Of Separated Mass

Major satellite manufacturers have been pushing electric- and hybrid-propulsion designs for the last several years. The fully electric propulsion (EP) systems offer superior power to mass ratio. Hybrid systems typical employ a chemical main satellite thruster for orbit raising followed by electric propulsion for station keeping. Compared to the traditional chemical propulsion system, all-electric and hybrid satellites are significantly lighter in terms of separated mass. The full chemical propulsion system represents close to half of the satellite separated mass, but with the addition of electric propulsion (hybrid or full EP), the proportion of propulsion mass (fuel and hardware) to the separated mass drops by a factor of four or more, depending on the type of EP used.

In the last several years, more operators are considering the use of EP to reduce the launch costs on satellites with high power payloads (>8 kW). Eutelsat 172B, SES-12 and SES-14 are recent examples of awarded satellites in this category. These satellites have a higher payload power to separated mass ratio than their traditional chemical propulsion counterparts. The opposite trend is seen with modern high-throughput satellites (HTS), which are primarily driven by mass rather than power. HTS satellites have significantly more hardware due to their spot beam design and frequency reuse capability, but often have amplifiers that are backed-off several decibels (dB). This means satellites with HTS payloads tend to have a lower power to mass ratio than their bent-pipe counterparts.

As more hybrid, full EP and HTS satellites are ordered, it will become increasingly difficult to use payload power as a gauge for industry separated mass trends. The increase use of channelizers for HTS and non-HTS applications will also impact power and mass. Launch costs, availability, and the option for single or dual launches are key aspects for operators to consider when choosing a satellite. All of these factors will skew the data away from the general trend of payload power increasing with separated mass for traditional chemical propulsion, bent-pipe payloads.

INDUSTRY STRUCTURAL CHANGES

Russian Space Industry Consolidation

Following a string of reliability issues with the Proton launch vehicle (notably the July 2013 Proton failure carrying three satellites for the GLONASS navigation system), the Russian space industry has continued to undergo a major consolidation of its massive space industrial complex. Under a 2013 presidential decree by President Putin, the Russian state began consolidating scores of space hardware developers and manufacturers into a single, large holding company called United Rocket and Space Corporation (URSC). The stated objective of the industry consolidation is to reduce costs in the industry by eliminating excess manufacturing capacity, reduce Russian reliance on foreign (e.g., Ukrainian) components, increase production efficiency, and introduce a unified technical policy aiming to improve quality control issues that have been the primary culprit in several Russian launch and satellite failures in recent years. URSC is planned to include as many as 43 formerly-independent organizations, and includes major Russian space contractors such as Khrunichev State Research and Production Space Center, RSC Energia, TsSKB Progress, and NPO Lavochkin. The nation's federal space agency, Roscosmos, was initially planned to remain separate as the federal procurement office and system integration body responsible for the country's space programs. However, as announced in February 2015, President Putin approved plans to merge Roscosmos with URSC, thus creating a single entity that will act as both the federal space customer and the space contractor. The impact of this consolidation on the commercial marketplace continues to play out. However, given that ILS did not sell a single commercial Proton launch in 2014, it is clear that the commercial satellite operator community has decided to wait to see how the industry changes settle out. Along with reliability concerns and industry consolidation, Western sanctions stemming from the Russian-Ukrainian conflict have also contributed to the large drop off in the commercial marketplace in Russia.

Impact Of The Russia-Ukraine Conflict

Along with other major global industries (such as Energy and Finance), the global space industry has been directly impacted by the Russia-Ukraine conflict, as both Russia and Ukraine are major space-faring nations, each with a strong space industry and history. One of the largest impacts to the commercial space industry thus far has been the unclear future of commercial launch provider Sea Launch, which uses the Russian-Ukrainian Zenit SL rocket, and is majority owned by Russia's newly formed URSC (via RSC Energia). The two-stage Zenit incorporates a Ukrainian first stage and a Russian upper stage to launch large communications satellites. The future of the Sea Launch organization remains in discussion, including the possibility of the firm switching to an all-Russian built launch vehicle.

Another impact of the crisis has been the near-term pullback of ILS Proton's role in the commercial launch marketplace. The firm announced that it is reducing its annual commercial sales targets from 7-8 commercial launches a year to 3-4 a year, citing reliability concerns, market dynamics, and geopolitical impacts. Both Sea Launch and ILS have announced workforce reductions as they work through their respective business transitions. The geopolitical impacts to Sea Launch and ILS has reduced the global commercial launch capacity available to commercial operators, and has thus opened opportunities for other launch providers (Arianespace, SpaceX, LMCLS, MHI, etc.) to increase their commercial market share.

A further effect of the Russia-Ukraine crisis has been the future use of Russian RD-180 engines. The United States National Defense Authorization Act for Fiscal Year 2015 restricted the use of RD-180 engines for launches of any Department of Defense national security missions beyond 2019. The RD-180 engine (built by NPO Energomash) powers the ULA-built Atlas V series of launch vehicles, which has historically been the workhorse launch vehicle for USG launches, and is marketed to the commercial satellite industry by Lockheed Martin Commercial Launch Services. Discussions between the U.S. Air Force and the U.S. Congress regarding the appropriate timeline of continued use of the RD-180 until a domestic replacement engine is fully developed and qualified are on-going. The current law, however, is silent with respect to commercial and civil space use of RD-180 engines on Atlas V rockets; thus Atlas V availability to the commercial market remains unaffected.

Europe Vertically Integrates: Airbus-Safran Launchers

In the summer of 2014, Europe's Airbus Group and Safran first announced plans to create an equally-owned joint venture for launch vehicles called Airbus Safran Launchers. The new joint venture combines Airbus' launcher production activities (as the current builder of the Ariane 5) with Safran's rocket engine operations. The vertical integration move aims to increase the competitiveness of the European Ariane launch system in the fight for future market share with SpaceX. The joint venture will combine the two companies' space launcher activities to cut costs and increase supply chain efficiencies, similar to how commercial Airbus aircraft are built today. Notably, the new Airbus Safran Launchers joint venture will also become the majority owner of Paris-based satellite launch provider Arianespace which currently markets the Ariane 5, Soyuz, and Vega launch vehicles. The joint venture proposal won regulatory approval from the European Commission at the end of November 2014, and by the end of 2015 will assume total control of the design and future production, operation and commercial sales of the next-generation Ariane 6 launcher. The final design of the next-generation Ariane 6 launch vehicle was approved by the ESA Ministerial Council in December 2014, favoring a liquid-fueled core booster with large solid rocket boosters in two different configurations, and has an initial launch capability in 2020. The Ariane 62 configuration utilizes two P120 solid boosters, and is intended for dedicated government and scientific missions, while the Ariane 64 configuration utilizes four P120 solid boosters, and is intended for commercial dual-satellite launches.

NEAR-TERM DEMAND FORECAST

Table 9 shows the satellites projected to be launched in the next three years. The projections for 2015 – 2017 show an increase in the number of satellites to be launched over the previous three years (2012 – 2014).

Table 9. Commercial GSO Satellite Near-Term Manifest

	2015			2016			2017		
Total	**24**			**25**			**26**		
Below 2,500 kg	**4**			**0**			**1**		
	DM	ABS 2A	Falcon 9					SES 15	TBD
	DM	ABS 3A	Falcon 9						
	DM	Eutelsat 115WB	Falcon 9						
	DM	Eutelsat 117WB	Falcon 9						
2,500 - 4,200 kg	**3**			**11**			**10**		
	DM	GSAT 15	Ariane 5	DM	Arsat 2	Ariane 5	DM	Al Yah 3	Ariane 5
	DM	Intelsat 34	Ariane 5	DM	BRISAT	Ariane 5	DM	Eutelsat 172B	Ariane 5
	DM	Sky Mexico 1	Ariane 5	DM	GSAT 17	Ariane 5	DM	Hylas 4	Ariane 5
				DM	GSAT 18	Ariane 5	DM	INSAT 3DR	Ariane 5
				DM	Hispasat AG1	Ariane 5	DM	Telkom 3S	Ariane 5
				DM	Intelsat 36	Ariane 5		BulgariaSat	Falcon 9
				DM	JCSAT 15	Ariane 5		Amazonas 5	TBD
				DM	Koreasat 7	Ariane 5		Azerspace 2/ Intelsat 38	TBD
					JCSAT 16	Falcon 9		BSat 4a	TBD
					Koreasat 5R	Falcon 9		SES 14	TBD
					Thaicom 8	Falcon 9			
4,201 - 5,400 kg	**10**			**4**			**3**		
	DM	DSN 1/JCSAT SB 8	Ariane 5		AMOS 6	Falcon 9		SES 12	Ariane 5
	DM	Sicral 2	Ariane 5		Es'Hail 2	Falcon 9		SES 16/Govsat	TBD
	DM	Thor 7	Ariane 5		SES 10	Falcon 9		BCLP	TBD
		Mexsat 2	Atlas V		Telstar 12V	H-IIA			
		JCSAT 14	Falcon 9						
		SES 9	Falcon 9						
		Turkment 520E/ Monaco	Falcon 9						
		Eutelsat 9B	Proton M						
		Mexsat 1	Proton M						
		Turksat 4B	Proton M						
Above 5,400 kg	**7**			**10**			**12**		
	DM	BADR 7/Arabsat 6B	Ariane 5	DM	EchoStar XVIII	Ariane 5	DM	Jabiru 1/Measat 3C	Ariane 5
	DM	DIRECTV 15	Ariane 5	DM	EchoStar XIX/ Jupiter 2	Ariane 5	DM	SGDC 1	Ariane 5
	DM	Eutelsat 8WB	Ariane 5	DM	Eutelsat 65WA	Ariane 5	DM	Sky Brasil 1/ Intelsat 32E	Ariane 5
	DM	NBN 1A	Ariane 5	DM	Intelsat 29E	Ariane 5	DM	PSN 6	Falcon 9
	DM	Star One C4	Ariane 5	DM	Intelsat 33E	Ariane 5		EchoStar 105/SES 11	Falcon 9
		Inmarsat 5F2	Proton M	DM	NBN 1B	Ariane 5		Europasat/HellasSat 3	Falcon 9
		Inmarsat 5F3	Proton M		Star One D1	Ariane 5		Intelsat 35E	Falcon Heavy
					Inmarsat 5F4	Falcon Heavy		Viasat 2	Falcon Heavy
					Intelsat 31/DLA 2	Proton M		Asiasat 9	Proton M
					EchoStar XXI/DISH T2	Proton M		APStar 5C/Telstar 18V	TBD
								EchoStar XXIII/ CMBSTAR	TBD
								Hispasat 1F	TBD

DM = Potential Dual-Manifested Satellites
* = Satellite proposed, not yet identified publicly

COMSTAC DEMAND PROJECTION VS. ACTUAL LAUNCHES REALIZED

Factors That Affect Satellite Launch Realization

The estimated demand for satellite launches is historically larger than the number of satellites that will actually be launched in a year. Some factors that contribute to the difference between forecast and realized launches are:

- Satellite technical issues: Satellite manufacturers may have manufacturing, supplier, or component issues that delay the delivery of a satellite. On-ground and in-orbit anomalies can affect the delivery of satellites under construction until fleet-wide issues (such as commonality of parts, processes, and systems) are resolved. Delays in delivery of spacecraft to the launch site then impact the scheduling of launches.

- Launch vehicle technical issues: Launch vehicle manufacturers and launch service providers may have manufacturing, supplier, or component issues that cause launch delays. Recovery from launch anomalies and failures can also significantly affect launch schedules. Delays have a cascading effect on subsequent launches, and some science missions have specific launch windows that, if missed, may result in lengthy delays and manifest issues.

- Weather: Inclement weather, including ground winds, flight winds, cloud cover, lightning, and ocean currents often cause launch delays, though these are typically short-term (on the order of days).

- Range availability issues: The lack of launch range availability due to prioritized government missions, schedule conflicts with other launch providers, launch site maintenance, and other range-related issues can cause launch delays.

- Dual-manifesting: Dual-manifesting requires that two satellites are delivered to the launch site on time. A delay on one satellite results in a launch delay for the other satellite and subsequent satellites. Payload compatibility issues (such as mass mismatch, technical differences, and differing orbit insertion requirements) can also cause delays.

- Business issues: Corporate reprioritization, changing strategies and markets, and inability to obtain financing may delay or cancel satellite programs; however, this can free up launch slots for other customers.

- Regulatory issues: Export compliance, FCC or international licensing, and frequency coordination can cause delays, launch vehicle shifts, and satellite program cancellations. U.S. government policy regarding satellite and launch vehicle export control can make it difficult for U.S. satellite manufacturers and launch vehicle operators to work with international customers.

- Geopolitical issues: Temporary economic sanctions that affect U.S. satellites launching from foreign launch sites, or from vehicles with foreign components may cause delays in export licensing approvals of satellites and launch related services.

Projecting Actual Satellites Launched Using A Realization Factor

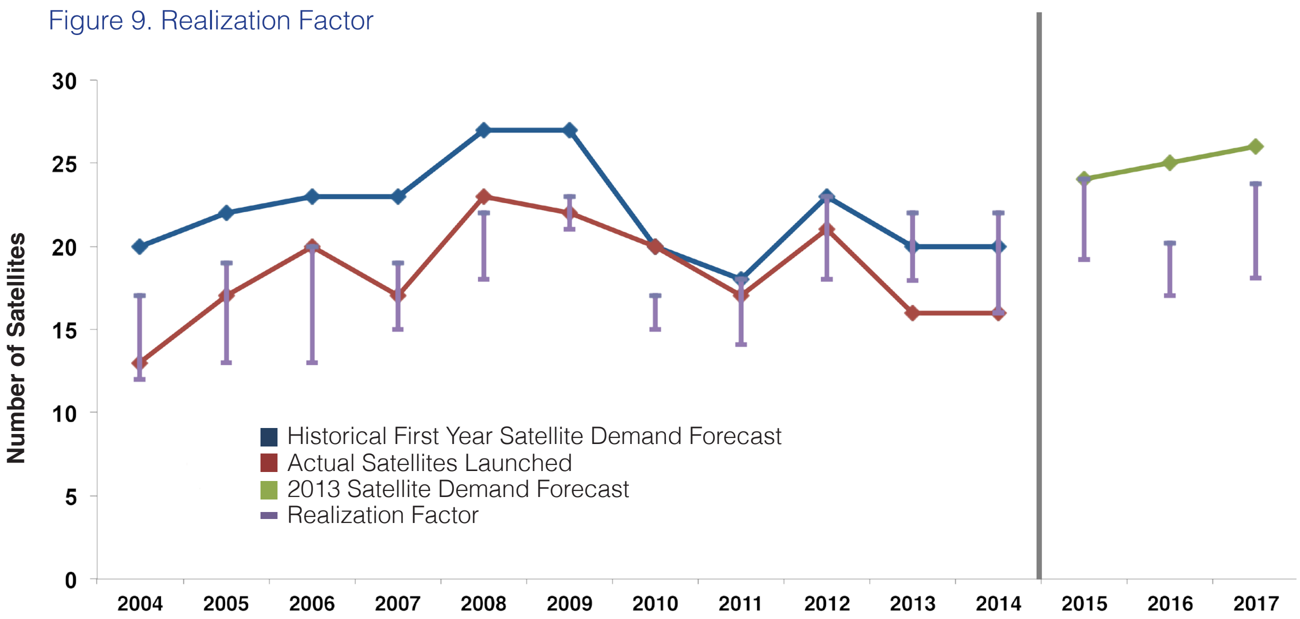
Over the history of this Report, the forecast demand for satellites and launches has almost always exceeded the number of satellites and launches actually accomplished in each of the first three years of a forecast period. To better estimate the number of near- term satellites that will be launched, the near-term demand is adjusted by a "realization factor." This factor is derived by comparing forecast satellite launches with actual satellites launched in the five years prior to the current Report.

The range of satellite launches expected to be realized is calculated by multiplying the near-term forecast by the highest and lowest variations of forecast versus actual over the preceding five years. Since 1993, the actual number of satellites launched in the first year of the forecast was 58 percent to 100 percent of the forecast number, with an average of 80 percent. For the past five years, the range was 80 percent to 100 percent, with an average of 89 percent. Based on this methodology, while 24 satellites are forecast for launch in 2015, the expected realization for 2015 is 19 to 24 satellites.

The consistent overestimation illustrates the "bow-wave" effect of the forecast: survey respondents list satellites that were planned to be launched the previous year but slipped into the subsequent year, without compensating for the subsequent year's satellite launches concurrently slipping forward.

The calculation becomes less precise for the second out-year. The forecast has almost always overestimated the actual launches two years hence. Since 1993, the actual realization for the second out-year ranged from 48 percent to 105 percent, with an average of 76 percent. For the past five years, the range was 68 percent to 95 percent, with an average of 78 percent. Using the same methodology, while 26 satellites are forecast to be launched in 2016, the expected realization for 2016 is 17 to 20 satellites.

Figure 9. Realization Factor



Since the launch realization factor was added to the Report in 2002, the actual number of satellites launched has usually fallen within the launch realization range, demonstrating the robustness of the realization factor methodology.

As shown in Figure 9, the 2014 report forecast 20 satellites for launch in 2014, with a realization range of 16 to 22 satellites. Indeed, 16 satellites were actually launched in 2014.

CONCLUSIONS

The 2015 COMSTAC GSO forecast projects that the average annual number of satellites to be launched during the next three years reflects an increase from last year's Report, from 22.6 in 2014 to 25 in 2015. Correspondingly, the number of launches has increased slightly, from 16.3 in 2014 to 17 in 2015. The projected increase in launches represents a reduction in the overall percentage of dual-manifest launches.

Overall, it is expected that the annual number of addressable GSO satellites, and the number of supporting launches, will remain relatively flat during the next three years. However, new satellite technologies and new launch vehicles will impact the industry during the next decade. COMSTAC will study how much these factors will make a difference to the space industry on an annual basis as part of its forecasting efforts. Two major examples that are being focused on include electric propulsion satellites and the introduction of new launch vehicles. Lower-mass electric propulsion satellites, the first dedicated versions of which were launched in early 2015 by a Falcon 9 in a dual manifested configuration, may shift the total number of GSO satellites launched in the coming decade to a higher annual average. New vehicles are planned for introduction between now and 2024, including the Angara 5, Ariane 6, Falcon Heavy, MHI's H-X replacement to the H-IIA, and ULA's Next Generation Launch Vehicle replacing the Atlas V, among others, and these will spur shifts in market share. Indeed, such a shift has already been seen during the past two years with the introduction of the Falcon 9 and the reduction in bookings for Proton M.

Despite these unfolding changes, the satellite services industry remains robust. Steady growth is expected in terms of demand for telecommunication services provided by GSO satellite operators, and this will translate into healthy demand for launch services.

2015 COMMERCIAL SPACE TRANSPORTATION FORECAST FOR NON-GEOSYNCHRONOUS ORBITS

INTRODUCTION

The 2015 Commercial Space Transportation Forecast for Non-Geosynchronous Orbits (the Report) is developed by the Federal Aviation Administration's Office of Commercial Space Transportation (FAA AST). This Report projects commercial launch demand for all space systems deployed to non-geosynchronous orbits (NGSO), including low Earth orbit (LEO), medium Earth orbit (MEO), elliptical orbits (ELI), and external trajectories (EXT) to the Moon or other solar system destinations. First compiled in 1994, the forecast assesses payloads most likely to seek commercial launch services during the next 10 years. Commercial launches, as defined for this report, include those whose services are sought on the international market. It also includes U.S. domestic commercial launch services licensed by the FAA, such as commercial launches to the International Space Station (ISS).

The 2015 report helps U.S. industry, as well as the USG, understand the scope and trends of global commercial spaceflight demand. It also assists FAA AST in licensing and planning.

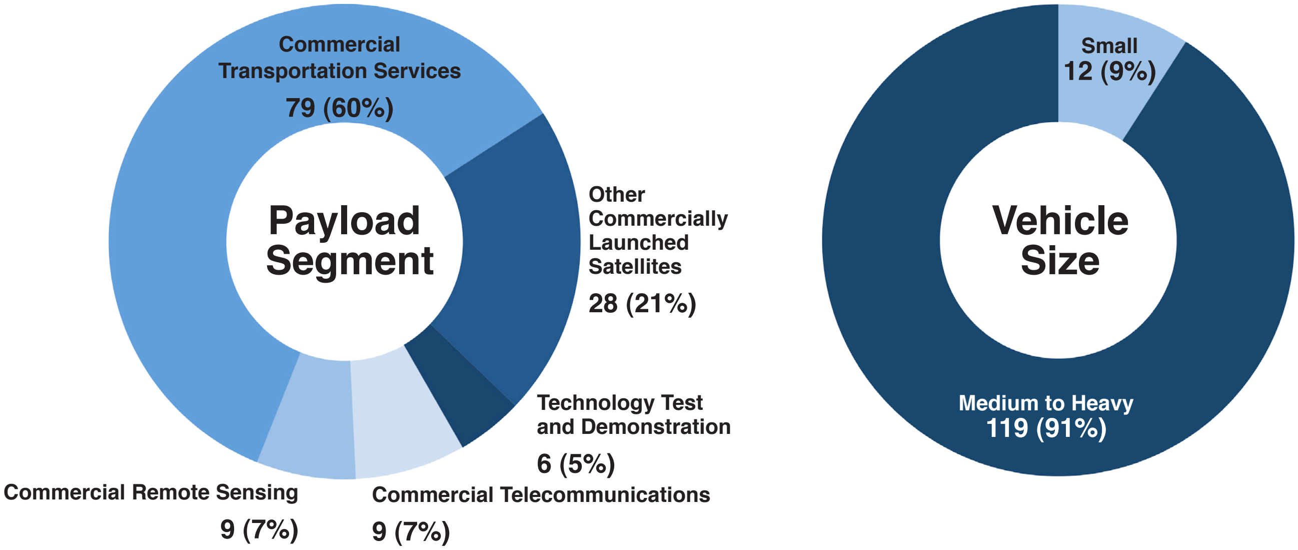
SUMMARY

The report projects an average demand of 13.1 launches per year worldwide during the period 2015 through 2024. The launch demand peaks in 2016, with 19 launches, due to the continued deployment of Iridium constellation, Skybox Imaging planning for one flight on Minotaur C for a total of six satellites (four Skybox satellites will also be launched as secondary payloads on a Vega); eight commercial crew and cargo launches to the ISS; five launches for other payloads launched commercially, and one test launch of a new small launch vehicle Fire Fly Alpha. For the telecommunications sector, a drop in launch demand is expected in 2018, when the Iridium NEXT telecommunication constellation finishes deployment. From 2015 – 2018 the report forecasts a number of small commercial satellites to be launched when operators such as Iridium, ORBCOMM, Planet Labs, and Skybox all deploy their constellations. The number of small multi-manifested satellites drops off towards the end of the forecast, but the number of launches remains relatively steady as NASA begins its commercial crew program.

The average of 13.1 launches a year is consistent with the last year's forecast. The number of NGSO commercial launches is relatively small compared to the total number of NGSO launches per year. For the last 10 years, there has been an average of 49 NGSO launches per year. Fourteen percent of these launches (approximately seven launches per year) were commercial. This calculation includes the 13 commercial NGSO launches in 2014, double the annual average of six in the preceding 10 years. This forecast predicts that the annual commercial NGSO launch numbers will remain consistent with the 2014 numbers and more than double the pre-2014 historical annual averages.

Launch demand is divided into two vehicle capacity groups, with an average of 11.9 medium-to-heavy vehicle launches per year and 1.2 small vehicle launches per year for 2015 – 2024. The launches in the next 10 years are predominantly commercial launches to the ISS which require medium-to-heavy vehicles. Ninety one percent of all commercial NGSO launches during the forecast period will launch on medium-to-heavy vehicles. Compared to last year's report, the number of small launches has increased, and the number of medium-to-heavy launches has decreased slightly. The increase in small launches is due to Skybox Imaging's plans to use Minotaur C to deploy its constellation and the first test flights of four newly developed commercial small launch vehicles in 2015 – 2017, to be introduced for commercial launch services in the following years. Historically, the relatively higher price of small vehicle launches, availability of multiple-manifest launch services and commercial payload brokerage and integration services for secondary payloads, as well as other factors discussed in the Satellite and Launch Forecast Trends section have resulted in the use of fewer small vehicle launches. If these dynamics change, there could be a bifurcation in launch demand between the demand for heavy vehicles for commercial crew and cargo and large satellites and a demand for smaller vehicles for the smaller (>100 kg) remote sensing and telecommunication satellites. Figure 10 depicts the launch distribution by payload segment type and vehicle size.

Figure 10. Distribution of Forecasted Launches by Payload Segment and Vehicle Size

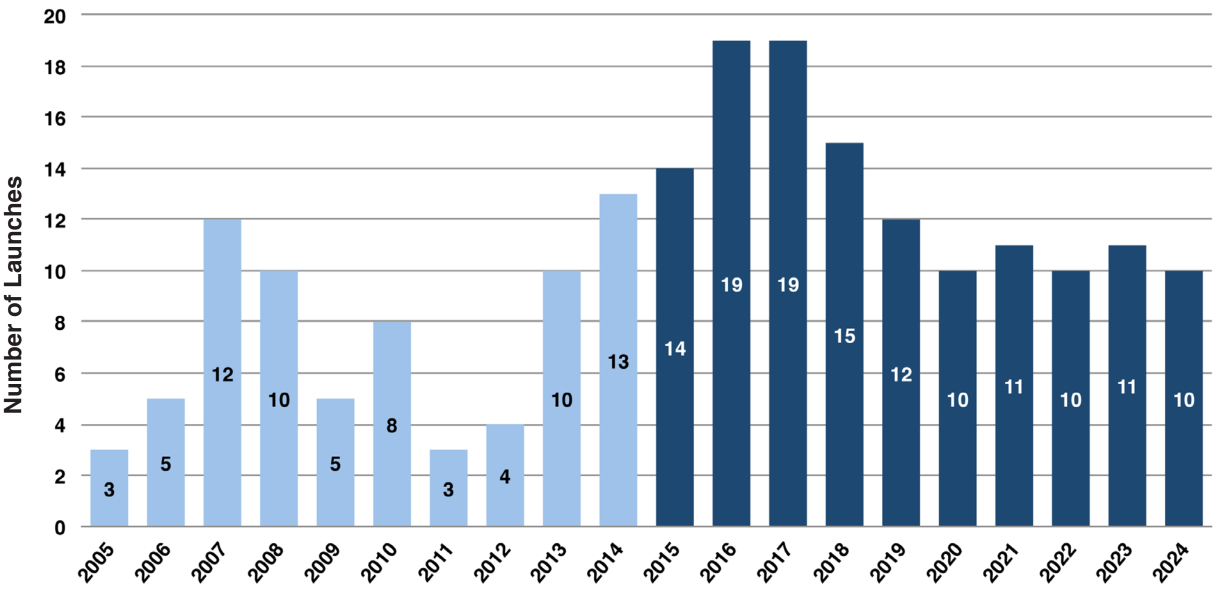


Sixty percent of the NGSO launches projected for the next 10 years are for commercial crew and cargo to the ISS. The commercial crew launches to the ISS are scheduled for spacecraft still in development, and all of these launches partly rely on government funding subject to annual appropriations; therefore, technical or financial issues could potentially delay the ISS crew launches. After commercial crew and cargo flights to the ISS, Other Commercially Launched Satellites, which is predominantly government satellites launched commercially, is the second largest market, comprising 21 percent of the launch market. Commercial remote sensing and telecommunications segments comprise seven percent of the launch market each. Telecommunications market is expected to significantly drop off in 2018 when the orbital assets of the telecommunications constellations, such as Iridium and ORBCOMM are fully replaced.

Beginning with 2014 and during the next 10 years, the annual launch rate is considerably higher than in the previous decade (see Figure 11). Commercial space transportation, emerging commercial remote sensing, and telecommunications constellation replenishments drive this increase. Last year's report predicted 13 launches for 2014 and 13 launches occurred. It is almost double the 10-year historical annual average of 7 commercial NGSO flights.

The near-term launch projection (2015 – 2018) is based on publicly announced launch demand. Table 10 identifies all NGSO satellites manifested for 2015 through 2018 that drive a launch. The Report projects 14 NGSO launches for 2015 and 19 launches for 2016. However, applying a realization factor, the actual NGSO launches are more likely to be between 7-9 in 2015 and 9-14 in 2016. This factor is based on the difference between projected launches and actual launches in the five years before the year of the Report and is only applied to 2015 and 2016. Last year's report predicted 13 launches for 2014 and 13 launches occurred; although, it is more common that a portion of launches announced for a given year get delayed for technical, financial, or other reasons. The mid- and far-term launch projections (2019 – 2024) are based on publically available information from satellite service providers, correspondence with service providers, and estimates of when the existing satellites will reach end of orbit life and require replacement.

Figure 11. Commercial NGSO Launch History and Projected Launch Plans



FORECAST METHODOLOGY

This Report is based on FAA AST research and discussions with the U.S. commercial space industry, including satellite service providers, spacecraft manufacturers, launch service providers, system operators, government offices, and independent analysts. The Report examines progress for publicly announced payloads (satellites, space vehicles, and other spacecraft) and considers the following factors:

- Financing;
- Regulatory developments;
- Spacecraft manufacturing and launch services contracts;
- Investor confidence;
- Competition from space and terrestrial sectors; and
- Overall economic conditions.

This Report includes five payload segments, defined by the type of service the spacecraft offer:

- Commercial Telecommunications;
- Commercial Remote Sensing;
- Commercial Cargo and Crew Transportation Services, including cargo and human spaceflight;
- Other Commercially Launched Satellites; and
- Technology Test and Demonstration.

Future deployments of payloads that have not yet been announced are projected based on market trends, the status of payloads currently on orbit, and the economic conditions of potential payload developers and operators. Follow-on systems and replacement satellites for existing systems are evaluated on a case-by-case basis. In some cases, expected future activity is beyond the timeframe of the Report or is not known with enough certainty to merit inclusion in the NGSO forecast model. For the Other Commercially Launched Satellites market, the forecast used near-term primary payloads generating individual commercial launches in the model and estimated future years based on historical and near-term activity. The projected launches for commercial cargo and crew transportation services were based on the National Aeronautics and Space Administration (NASA) 2015 ISS traffic model and manifested launches for cargo and human spaceflight.

Table 10. Near-Term NGSO Manifest of Identified Primary Payloads*

Service Type	2015	2016	2017	2018
Commercial Telecommunications Satellites	ORBCOMM (8) - Falcon 9	Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
	Iridium (2) - Dnepr	Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
		Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
			Iridium (10) - Falcon 9	
Commercial Remote Sensing Satellites	DMC3 (3) - PSLV	WorldView 4 - Atlas V	EROS C - TBD	TSX-NG - TBD
		SkySat (6) - Minotaur		RCM (3) - Falcon 9
		SkySat (4) - Vega		HySpec 1 - TBD
				HySpec 2 - TBD
Commercial Cargo and Crew Transportation Services**	Orb 4 - Atlas V	Orb 5 - Antares (new)	Orb 8 - Antares (new)	CRS TBD - TBD
	Spx 5 - Falcon 9	Orb 6 - Antares (new)	CRS TBD - TBD	CRS TBD - TBD
	Spx 6 - Falcon 9	Orb 7 - Antares (new)	CRS TBD - TBD	CRS TBD - TBD
	Spx 7 - Falcon 9	Spx 9 - Falcon 9	CRS TBD - TBD	CRS TBD - TBD
	Spx 8 - Falcon 9	Spx 10 - Falcon 9	CRS TBD - TBD	CRS TBD - TBD
		Spx 11 - Falcon 9	CRS TBD - TBD	CRS TBD - TBD
		Spx 12 - Falcon 9	CRS TBD - TBD	Crew flight - TBD
		Dragon V2 uncrewed test - Falcon 9	Dragon V2 crewed test - Falcon 9	Crew flight - TBD
			CST-100 uncrewed test - Atlas V	
			CST-100 crewed test - Atlas V	
Other Commercially Launched Satellites	SAOCOM 1A - Falcon 9	DragonLab - Falcon 9	DubaiSat 3 - Dnepr	DragonLab - Falcon 9
	Kompsat 3A - Falcon 9	Formosat 5 - Falcon 9	TBD (govt) - TBD	EnMAP - PSLV
	PAZ - Dnepr	SAOCOM 1B - Falcon 9		
	Ingenio - TBD	Gokturk 1 - Vega		
		Perusat - Vega		
Technology Test and Demonstration Launches	Test - Electron	Test - Alpha	Test - GOLauncher	Test - Stratolaunch
	Test - Falcon Heavy		Test - LauncherOne	
Total Payloads (primary/secondary)	**65 (14/51)**	**136 (19/115)**	**151 (19/132)**	**104 (15/89)**
Total Launches	**14**	**19**	**19**	**15**
Launch Realization Factor Applied	**7-9**	**9-14**	**--**	**--**

* Near-term NGSO payloads and launches are based on information obtained from discussions with launch providers, satellite manufacturers, system operators, government offices, and independent analysts. Launch dates could vary between publicly available information and information gathered from other sources.
** The Commercial Cargo and Crew Transportation Services near-term NGSO manifest is based on the NASA FY 2015 ISS traffic model (February 2015).

NGSO PAYLOAD MARKET SEGMENTS

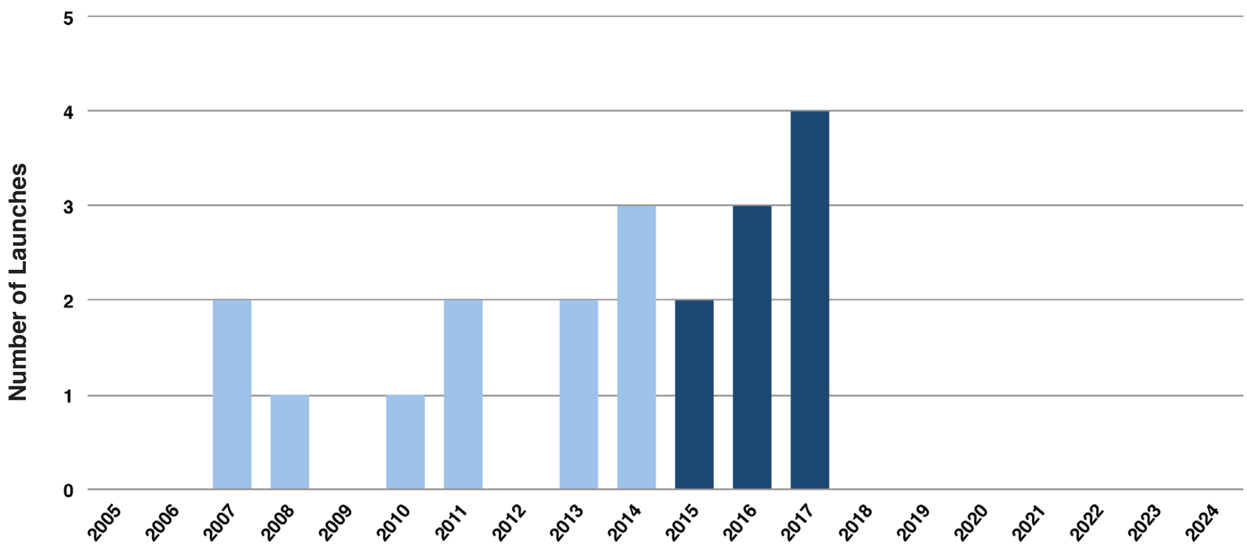
COMMERCIAL TELECOMMUNICATION SATELLITES

The NGSO telecommunications satellite market is based on large constellations of small-to-medium-sized satellites that provide global or near-global communications coverage. The constellations can be divided into three major categories based on the frequencies the satellites use: narrowband (historically also known as Little LEO), wideband (aka Big LEO), and broadband.

Telecommunications Launch Demand Summary

From 2014 through 2017, between three and four launches of NGSO telecommunications satellites will occur each year. There will be three launches in 2014, as ORBCOMM and the emerging MEO Ka-band broadband operator O3b launch their satellites, and there will be four launches in 2015 and three launches a year in 2016 and 2017, as Iridium replaces its satellites and ORBCOMM launches additional satellites. The first two Iridium NEXT satellites are currently planned to launch on a Dnepr rocket in 2015. One ORBCOMM and seven Iridium NEXT launches are planned for the Falcon 9 vehicle. Operators intend to finish the replacement of their constellations before 2018, so no telecommunications launches are projected for the subsequent years. Figure 13 provides a representation of telecommunications launch history and projected launch plans.

Figure 12. Commercial Telecommunications Launch History and Projected Launch Plans



2015	2016	2017	2018
ORBCOMM (8) - Falcon 9	Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
Iridium (2) - Dnepr	Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
	Iridium (10) - Falcon 9	Iridium (10) - Falcon 9	
		Iridium (10) - Falcon 9	

Narrowband NGSO Telecommunications Systems

Narrowband LEO systems (see Table 11) operate at frequencies below 1GHz. These systems provide narrowband data communications, such as email, two way paging, and simple messaging for automated meter reading, vehicle fleet tracking, and other remote data monitoring applications. ORBCOMM is the only fully operational narrowband system. Another system, AprizeStar, is partially operational, will reach its capacity when the full constellation is deployed. The AprizeStar deployment schedule is dependent on the availability of funding and revenue generated by the satellites currently on orbit.

Table 11. Narrowband Systems

System/ Operator	Prime Contractor	Satellites		Orbit Type	First Launch	Status
		Operational	Mass kg (lb)			
Operational						
ORBCOMM/ ORBCOMM Inc.	Orbital Sciences Corp. (1st Gen.) SNC (2nd Gen.)	30	43 (95) (1st Gen.) 142 (313) (2nd Gen.)	LEO	1997	First six 2nd generation (OG2) satellites launched in 2014. Eight more scheduled for a 2015 launch on a Falcon 9.
Under Development						
AIS/ SpaceQuest and ExactEarth	SpaceQuest	7	14 (30)	LEO	2002	The company expects to continue launching satellites and possibly hosted payloads depending on available funding and affordable launch opportunities.

Wideband NGSO Telecommunications Systems

Wideband LEO systems (see Table 12) use frequencies in the range of 1.6–2.5 GHz (L- and S-band frequencies). Wideband systems provide mobile voice telephony and data services. The two wideband systems Globalstar and Iridium are on orbit and operational.

Table 12. Wideband Systems

System/ Operator	Prime Contractor	Satellites		Orbit Type	First Launch	Status
		Operational	Mass kg (lb)			
Operational						
Globalstar	Space Systems Loral (1st Gen.) Thales Alenia Space (2nd Gen.)	45	447 (985) (1st Gen.) 700 (1,543) (2nd Gen.)	LEO	1998	Six additional satellites ordered from Thales Alenia Space in September 2012. No launch contract or tentative launch plans announced at this time.
Iridium	Motorola (Iridium) Thales Alenia Space (Iridium NEXT)	71	680 (1,500) Iridium 800 (1,763) Iridium NEXT	LEO	1997	Multiple launches of Iridium NEXT constellation to begin in late 2015.

Broadband NGSO Telecommunications Systems

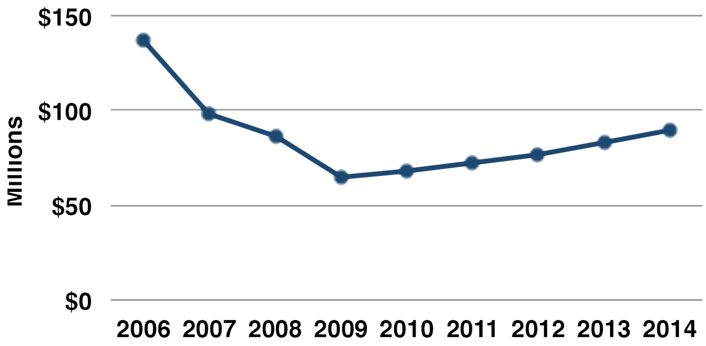
Broadband systems (see Table 13) reside in NGSO and provide high-speed data services at Ka- and Ku-band frequencies. O3b Networks Ltd. accomplished an initial deployment of its first four satellites in 2013.

Table 13. Broadband Systems

System/ Operator	Prime Contractor	Satellites		Orbit Type	First Launch	Status
		Operational	Mass kg (lb)			
Under Development						
O3b/O3b Networks Ltd.	Thales Alenia Space	12	700 (1,540)	MEO	2013	The first four satellites of the constellation launched in 2013. Eight more deployed in 2014. Follow-on satellites are likely, but no construction or launch schedule announced at this time.

Globalstar

Figure 13. Publicly Reported Globalstar Annual Revenue



Globalstar, Inc. is a publicly traded wideband system operator primarily serving the commercial global satellite voice and data markets. Full service offering began in 2000.

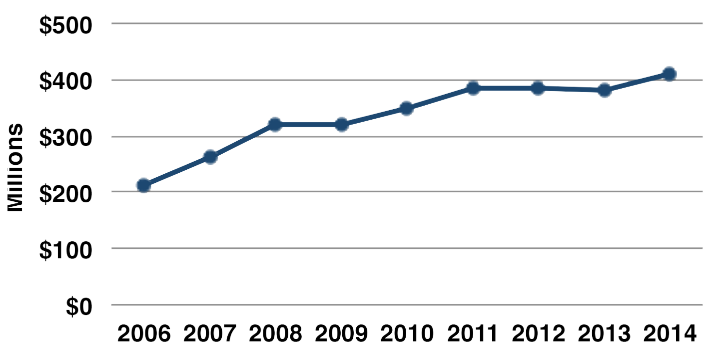
Arianespace, through its Starsem affiliate, launched 24 Globalstar second generation satellites. The first six satellites were launched into orbit in 2010, the next 12 launched in 2011, and the remaining six in February 2013. All launches were from Baikonur, Kazakhstan on Soyuz rockets carrying six satellites per launch. Globalstar reported significant improvement in service availability, quality, and revenue (see Figure 13) after the new generation satellites came online.

Thales Alenia Space (TAS) developed and built the 25 second generation satellites (including one ground spare) for Globalstar. Together with the eight first generation replacement satellites launched in 2007, Globalstar has a 32-satellite system since the initial deployment of its new constellation concluded.

Globalstar reported it is in negotiations with TAS for an option of manufacturing 23 additional satellites in the coming years. The spacecraft would be spares for the existing fleet and launch as needed. An order for manufacturing of the first six was placed with TAS in September 2012. Currently, there is no launch contract for these additional satellites, and any launch would be contingent on the health of the satellites on orbit.

Iridium

Figure 14. Publicly Reported Iridium Annual Revenue



Iridium Communications Inc. is the successor to the original Iridium LLC that built and launched the Iridium satellite constellation in the late 1990s. Iridium Communications Inc. owns and operates a constellation of 72 operational commercial communications satellites: 66 active spacecraft and 6 orbiting functional spares. These satellites comprise a fully operational system to provide service until at least 2015. In 2010, Iridium selected TAS as the prime contractor for the system development of a second generation satellite constellation, named Iridium NEXT. Each satellite in the new constellation can carry a hosted payload in addition to the primary communications payload.

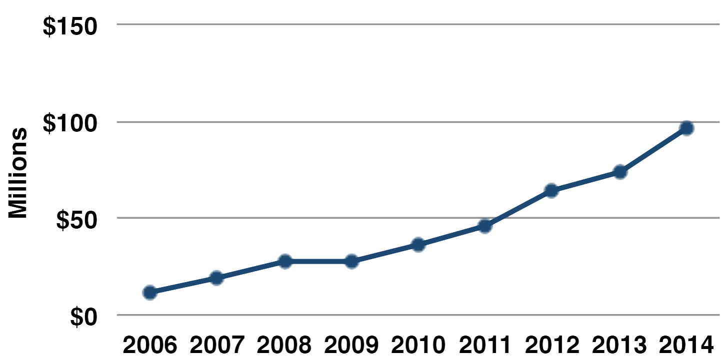
Iridium announced that SpaceX will be the primary launch provider for Iridium

NEXT. Iridium also signed a contract with International Space Company Kosmotras (provider of the Dnepr launch vehicle) to be a supplemental provider of launch services for Iridium NEXT. The company reportedly plans to launch 72 satellites (66 to enter active service and 6 to serve as on-orbit spares) during a 3-year period scheduled to begin in 2015. The first two Iridium NEXT satellites are currently planned to launch on a Dnepr rocket in late 2015. The rest of the Iridium NEXT constellation will launch on seven Falcon 9 launches carrying 10 satellites each. Nine Iridium NEXT satellites will remain ground spares. Iridium revenues are presented in Figure 14.

ORBCOMM

Between 1995 and 1999, ORBCOMM deployed a narrowband constellation of 35 satellites, most are still operational today. It is the only company to have fully deployed a system that provides low-bandwidth packet data services worldwide. ORBCOMM focuses on providing data services for machine-to-machine (M2M) applications.

Figure 15. Publicly Reported ORBCOMM Annual Revenue



ORBCOMM's plans for replacing its current constellation are underway. Six satellites of the second generation (OG2) constellation were launched aboard SpaceX's Falcon 9 in 2014. Eight more are scheduled to be launched, also by a Falcon 9, in 2015. All satellites in the constellation include automatic identification system (AIS) payloads. ORBCOMM ordered the satellites in 2008 from Sierra Nevada Corporation (SNC), with subcontractors Boeing and ITT Corporation.

ORBCOMM revenues are presented in Figure 15.

Aprize Satellite

SpaceQuest plans to manufacture and deploy a 12-satellite system, depending on funding opportunities and customer demand for data communication and AIS data service. A total of 10 AprizeSat satellites weighing 11 to 14 kg (30 lb) each, were launched as secondary payloads on Russian Dnepr vehicles, two satellites a year in 2002, 2004, 2009, 2011, 2013, and 2014. The company plans to launch two more Aprize satellites in 2016 and in 2017 as secondary payloads on the Dnepr launch vehicle provided it is still available for commercial launch.

O3b

O3b Networks, headquartered in St. John, Jersey, Channel Islands, provides broadband connectivity to underserved parts of the world with support and funding from high profile investors, including, Google, HSBC, Liberty Global, and major GEO commercial satellite operator SES.

The O3b constellation operates in the Ka-band in an equatorial orbit with a minimum of five satellites to cover +/- 45 degrees of latitude around the Equator.

Offering to bridge the gap between current satellites and fiber optic cables, O3b Networks provides fiber-like trunking capacity to telecommunications operators, backhaul directly to cellular and WiMAX towers, and connectivity to mobile and maritime clients, in partnership with Harris CapRock.

TAS is under contract to build 16 communications satellites for O3b, 12 of which have been successfully deployed. More satellites can be added as needed to meet demand.

Startup Broadband Ventures Planned for NGSO

Several entrepreneurs have announced plans to launch multi-satellite LEO broadband constellations and revolutionize the delivery of internet access to customers, especially in remote and underserved regions.

SpaceX submitted to international regulators the documentation for a 4,000-satellite broadband Internet LEO constellation, claimed to begin initial service within five years. The information on the ITU filing is not available at this time, as well as any information on the radio frequencies the LEO constellation would use to provide the internet connectivity.

OneWeb LLC, formerly called WorldVu Satellites, is developing 650 to 900 125-kg satellites operating in LEO at 1,200 km altitude, each providing an eight Gbps Ku-band Internet access to residential and mobile customers. OneWeb founder Greg Wyler reported that the company is currently reviewing potential bidders for manufacturing the satellites and would select a prime contractor in spring of 2015. Earlier, Greg Wyler founded O3b, a 12-satellite MEO broadband constellation, also characterized in this Report. In early 2015, OneWeb announced that launch provider Virgin Galactic and wireless electronics company Qualcomm will become OneWeb's major investors. OneWeb is reported to have plans to start launching satellites as early as 2017 and achieve deployment of a functional initial constellation by 2019.

LeoSat, a company founded by former Schlumberger executives Cliff Anders and Phil Marlar, plans a constellation of 80 to 120 small high-throughput Ka-band satellites to form a global fixed, maritime, and mobile Internet service provider. The

Table 14. Commercial Telecommunications Satellite Systems' Design Life

Satellite System	1st Generation Satellite Design Life	Current Status	2nd or Current Generation Satellite Design Life
Globalstar	7.5 years	Most of the satellites on orbit, operational	15 years
Iridium	5 years	Most of the satellites on orbit, operational	10 years (design), 15 years (projected)
ORBCOMM	4 years	Most of the satellites on orbit, operational	More than 5 years
Aprize Satellite	N/A	10 on orbit, 8 in service, launching more to complete system	10 years
O3b Network	N/A	Most of the satellites on orbit, operational	10 years

company aims at offering initial service by 2019. It has selected European satellite manufacturer Thales Alenia Space to perform a one-year cost study of its planned LEO constellation.

At least six more filings from such jurisdictions as Canada, France, Liechtenstein, and Norway for similar LEO satellite constellations operating in different parts of the VHF-, UHF-, X-, Ku-, and Ka-band spectrum were recently made with the ITU. The ITU filings are made on behalf of countries, and the six applicant organizations form the four countries have not been disclosed.

Although at least two of the above satellite projects are backed by launch providers, all of them are currently in their initial planning and development phases, and no launch contracts have been announced. Depending on the final design of the spacecraft and the constellations, the launch schedule, number of launches and number of spacecraft per launch may vary significantly. Also, any existing launch plans of any of these constellations may be delayed or significantly altered because of the frequency coordination procedures within the ITU, which can potentially be problematic, especially concerning interference with the existing Ku- and Ka-band GEO satellite systems. Launches of these satellites have not been included in this forecast, while respective launch projections will be included in the future reports as these satellite system designs mature and firm launch plans are announced for them.

Telecommunications Satellite Fleet Replacement after 2022

NGSO telecommunications satellites launched in the 1990s and early 2000s had an estimated design life of four (ORBCOMM) to seven and a half (Globalstar) years (see Table 14). However, the majority of these satellites are still on orbit and continue to provide telecommunications services; most of the first generation Globalstar, Iridium, and ORBCOMM constellations have exceeded their design life by two to three times. For financial reasons, many of the satellites were not replaced when their estimated design life ended. Operators were able to continue providing services until second generation spacecraft were ready.

Now most of the satellites launched or prepared for launch by NGSO communications satellite operators have an estimated design life of up to 15 years, which places the estimated replacement dates beyond the time period covered by the forecast. The exception is ORBCOMM, with a minimum design life estimate of a conservative five years. If any of these satellites need to be replaced within the 2015-2024 period, they will likely be launched as piggyback payloads, unlikely to generate demand for a dedicated launch.

COMMERCIAL REMOTE SENSING SATELLITES

Remote sensing refers to any orbital platform with sensors trained on Earth to gather data across the electromagnetic spectrum for geographic analysis, military use, meteorology, climatology, or other uses. The remote sensing industry generally comprises three markets:

- Aerial imagery
- Satellite imagery
- Value-added services, including geographic information systems (GIS)

GIS consists of images obtained from aircraft or satellites integrated with layers of information, usually customized according to user needs. It constitutes the largest part of the industry both in terms of demand and revenue generation.

The satellite imagery market is composed of companies that acquire and operate their own remote sensing satellites. These include Airbus Defense and Space, BlackBridge, DigitalGlobe, DMC International Imaging, ImageSat, MDA Geospatial Services, Planet Labs, and Skybox Imaging. New companies, like Spire and HySpecIQ, are expected to deploy satellites during the forecast period. For all of these companies, GIS products and services are the main generator of revenue. In some cases, imagery obtained from government satellites is made available to customers through a GIS company. For example, imagery from two Pleiades satellites operated by the French government is made available through Airbus Defense and Space. In other cases, the operation of remote sensing satellites, the imagery obtained from them, and the sales of GIS products and services is managed through a public-private partnership (PPP). The TerraSAR-X and TanDEM-X satellites are managed by a PPP that includes the German Space Agency (DLR) and Airbus Defense and Space.

The remote sensing forecast also includes radio occultation satellite systems designed for weather forecasting. This capability does not depend on imagery, but rather radio signals generated by global position system satellites that transit the Earth's atmosphere. The behavior of these radio signals, such as the magnitude of refraction and Doppler shift, can reveal details about the atmosphere's temperature, pressure and water vapor content in support of weather forecasting. PlanetiQ, GeoOptics, and Spire represent newly established companies seeking to deploy constellations of satellites to provide this kind of service.

This forecast captures only commercial remote sensing satellite companies that procure internationally competed launches. For organizations that depend on a particular launch provider, either because of a commitment to a national industrial base or through a previously established agreement with the launch provider, the launch is not considered internationally competed.

The major companies operating or actively developing remote sensing satellites across the globe are profiled below in Table 15. These satellites have been or are likely to be launched commercially.

Table 15. Commercial Remote Sensing Systems

System	Operator	Manufacturer	Satellites	Mass kg (lb)	Highest Resolution (m)	Revisit Time (hrs.)	Launch Year
CICERO	GeoOptics	GeoOptics/ Laboratory for Atmospheric and Space Physics	CICERO (24)	TBD	N/A - Radio Occultation	24	TBD
Deimos Perseus	Dauria Aerospace and Elecnor Deimos	Dauria Aerospace/ Canopus	Deimos 1 Deimos 2 Perseus (8)	120 (265) 300 (661) < 10 (22)	22 0.75 TBD	24 24 TBD	2009 2014 TBD
DMC3	DMC International Imaging Ltd.	SSTL	DMC3 (3)	350 (771)	1	24	2015
Dove	Planet Labs Inc.	Planet Labs Inc.	Dove (100+)	< 10 (22)	3-5	24	2013
EROS	ImageSat International	Israel Aerospace Industries	EROS A EROS B EROS C	280 (617) 350 (771) 350 (771)	1.5 0.7 0.7	24-288 24-288 24-288	2000 2006 2017
GeoEye	DigitalGlobe	General Dynamics Lockheed Martin	GeoEye 1	907 (2,000)	0.41	50-199	2008
HySpec	HySpecIQ	Boeing	HySpec (2)	600 (1,324)	TBD	TBD	2018
IKONOS	DigitalGlobe	Lockheed Martin	IKONOS	816 (1,800)	1	< 72	1999
PlanetIQ	PlanetIQ	TBD	18	20 (44)	N/A - Radio Occultation	24	TBD
OmniEarth	OmniEarth	Draper Labs/ Dynetics/ Harris	18	110 (243)	TBD	24	TBD
RADARSAT	MDA	MDA	RADARSAT 2 RCM (3)	2,195 (4,840) 1,200 (2,645)	3 TBD	48-72 TBD	2007 2018
RapidEye	BlackBridge	MDA	RapidEye (5) RapidEye NG (5)	150 (330) TBD	6.5 TBD	24 24	2008 2019
SkySat	SkyBox Imaging	SkyBox Imaging/ Space Systems Loral	SkySat (24)	91 (200)	< 1	< 24	2013
Spire	Spire	TBD	120	< 10 (22)	N/A - Radio Occultation	24	TBD
TerraSAR-X and TanDEM-X	BMBF/DLR/ Astrium (Airbus)	Astrium (Airbus)	TerraSAR-X TanDEM-X TerraSAR-NG	1,023 (2,255) 1,023 (2,255) TBD	3 0.5 0.25	264 264 264	2007 2010 2018
WorldView	DigitalGlobe	Ball Aerospace	WorldView 1 WorldView 2 WorldView 3 WorldView 4	2,500 (5,510) 2,800 (6,175) 2,800 (6,175) 2,087 (4,601)	0.5 0.5 0.3 0.25	41-130 26-89 < 24 < 72	2007 2009 2014 2016

Licenses issued by the U.S. National Oceanic and Atmospheric Administration

The U.S. National Oceanic and Atmospheric Administration (NOAA) licenses U.S. commercial remote sensing systems in accordance with the Land Remote Sensing Policy Act of 1992. There have been 48 remote sensing licenses issued or amended since 1993 (see Appendix). An unprecidented eleven licenses were issued in 2014 and two in early 2015 (see Table 16). In February 2015, the USG authorized the sale of 30-centimeter (11.8-inch) resolution imagery by U.S. satellite remote sensing companies. DigitalGlobe's WorldView-3 satellite, launched in 2014 and currently in service, is the only U.S. commercial satellite with sensors capable of this resolution.

Table 16. NOAA Remote Sensing Licenses Issued in 2014

Licensee	Date License Granted or Updated	Remarks
BlackSkyGlobal	2/5/2014	License issued for BlackSky Demonstration Satellites System.
Salish Kootenai College	3/6/2014	License issued for BisonSat.
Planet Labs Inc.	5/7/2014	Licenses issued for Flock 1b and Flock 1c.
Tempus Global Data, Inc.	7/15/2014	License issued for Tempus.
California Polytechnic State University	9/10/2014	License issued for ExoCube.
University of Texas at Austin	9/10/2014	License issued for Bevo 2.
University of Texas at Austin	9/23/2014	License issued for RACE.
Planet Labs Inc.	10/15/2014	License issued for Flock 1d.
The Planetary Society	10/15/2014	License issued for LightSail A.
University of New Mexico	2014	License issued for ORS Squared. Satellite dismantled and repurposed following indefinite delay of launch vehicle.

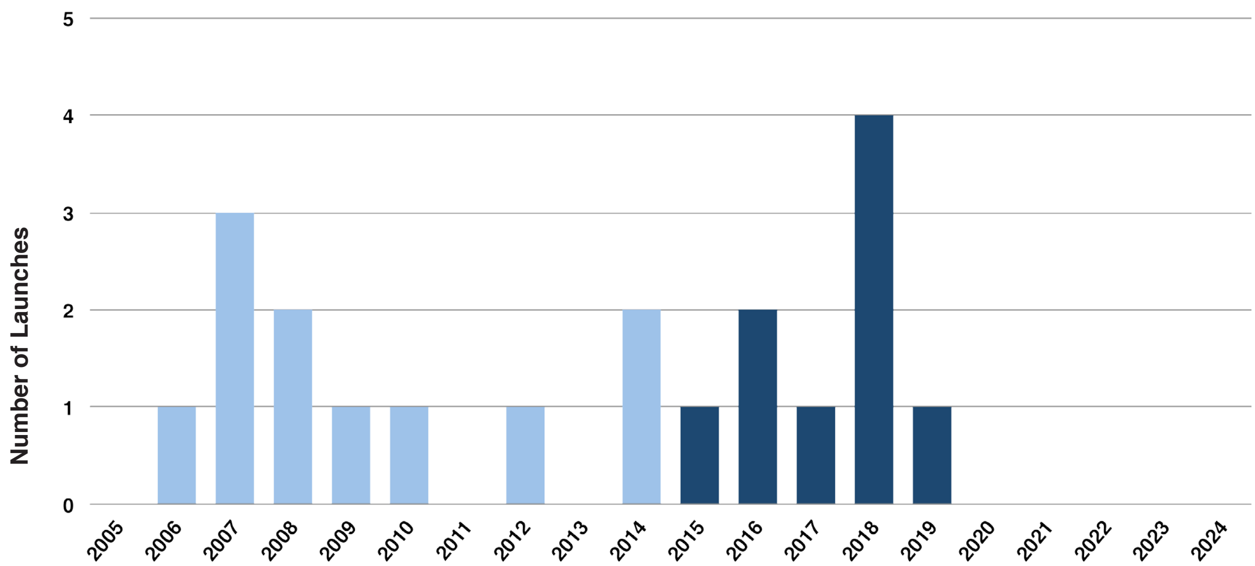
Remote Sensing Launch Demand Summary

Since 1999, the commercial satellite remote sensing industry has been characterized by relatively stable satellite replacement schedules, generating about one to two launches per year. Peaks in the number of launches can be seen during 2016 through 2019, reflecting projected deployment of satellites operated by Airbus Defense and Space, BlackBridge, DigitalGlobe, ImageSat, MDA, Planet Labs, and Skybox. Figure 16 provides a launch history and projected launch plans for commercial remote sensing satellites.

Nearly 800 commercial remote sensing satellites are projected to be launched through 2024. The vast majority of these will be microsatellites, including CubeSats, specifically those operated by Planet Labs. In most cases, these will be launched in clusters as secondary payloads, meaning that they do not generate launches. This may change as very small launch vehicles (those with LEO capacities below 200 kg, or 441 lb) become available during the next few years. Thus far, no launch contracts using these new vehicles have been publicly announced.

Commercial remote sensing satellites in the near-term portion of this Report (2015 – 2018) have been announced by their respective companies, are under construction, and are scheduled for a launch. Satellites projected for the latter portion of the Report (2019 – 2024) are based on published statements regarding the service lives of satellites currently operating on orbit.

Figure 16. Commercial Remote Sensing Launch History and Projected Launch Plans



2015	2016	2017	2018
DMC3 (3) - PSLV	WorldView 4 - Atlas V	EROS C - TBD	TSX-NG - TBD
	SkySat (6) - Minotaur C		RCM (3) - Falcon 9
			HySpec 1 - TBD
			HySpec 2 - TBD

Airbus Defense and Space

Airbus Defense and Space (Airbus) operates the French remote sensing constellation, Satellite Pour l'Observation de la Terre (SPOT) and the German synthetic aperture radar (SAR) remote sensing missions TerraSAR-X and TanDEM-X. It also handles sales of imagery obtained by two Pléiades satellites operated by CNES, the DEIMOS-1 satellite operated by DMC International Imaging on behalf of the Spanish government, and Formosat-2 operated by the government of Taiwan.

The TerraSAR-X and TanDEM-X missions are public private partnerships between the DLR, the German Federal Ministry of Education and Research and Airbus. DLR operates the two identical satellites and is responsible for the scientific use of the data. Airbus holds the exclusive commercial exploitation rights for imagery acquired by TerraSAR-X and TanDEM-X.

The TerraSAR-X Mission is performed by two satellites, TerraSAR-X and TanDEM-X, each contributing a part of the imaging resources. The TanDEM-X Mission uses the same two satellites to perform close formation flight with distances of 200 meters. The two satellites will fly in this formation until 2015, though both satellites are expected to remain in service until 2018 (TerraSAR-X) and 2020 (TanDEM-X). The goal of the TanDEM-X Mission is to generate a homogeneous, high-quality global digital elevation model. The first TerraSAR-X satellite launched aboard a Russian Dnepr vehicle in 2007. The second TerraSAR-X satellite was launched in 2010, also aboard a Dnepr.

Work is currently underway for a second generation of SAR satellites called TerraSAR-X Next Generation. The launch is planned for launch in 2018. No launch vehicle has been selected. DLR and Airbus are also discussing a next generation of satellites beyond the 2018 timeframe to replace the first generation TerraSAR-X satellites. These are not included in the Report because system definition has not started. As with TerraSAR-X and TanDEM-X, imagery from these future satellites is expected to be available for scientific and commercial purposes.

The Centre National d'Etudes Spatiales (CNES), France's space agency, was majority shareholder of SPOT Image until 2009, when responsibility for the system transferred to EADS Astrium; in 2011 the company formed the Geo Information Division to specifically manage the SPOT satellites and data sales. EADS Astrium has since acquired and built SPOT-6 and SPOT-7, the former launched in 2013 and the latter launched in 2014. In 2014, through mergers, EADS Astrium became part of Airbus Group, and SPOT-7 (renamed Azersky) was sold to Azercosmos, based in Azerbaijan. The SPOT constellation consists of four operational satellites, SPOT-4, launched in 1998, SPOT-5, launched in 2002, SPOT-6 launched in 2012, and SPOT-7 launched in 2014. The launch of SPOT-7 is not included in the forecast because it was not internationally competed; like SPOT-6, SPOT-7 was launched aboard a PSLV as a result of a partnership between CNES and the Indian Space Research Organization (ISRO).

BlackBridge

Berlin-based BlackBridge operates the RapidEye constellation of five satellites and provides GIS imagery based on imagery acquired from its satellites. RapidEye AG changed its name to BlackBridge in November 2013. The company has additional offices in Luxembourg, Canada, and the United States.

The BlackBridge satellites provide wide-area, repetitive coverage and 5-meter-pixel-size multi-spectral imagery. MacDonald, Dettwiler and Associates (MDA) was the prime contractor for the development of the satellites, responsible for design and implementation. MDA subcontracted Surrey Satellite Ltd (SSTL) in the UK to supply the bus and integrate the satellites whereas Jena-Optronik from Germany provided the camera payloads. All five satellites were launched aboard a Dnepr launch vehicle from Baikonur, Kazakhstan on August 29, 2008. The constellation is expected to remain in service until at least 2019, four years beyond the designed service life.

In 2014, BlackBridge announced plans for a follow-on constellation of five satellites planned for launch in 2019. BlackBridge secured $22 million (Canadian dollars) in funding from the Bank of Montreal and the Business Development Bank of Canada for the development of its follow on constellation.

BlackSky Global, LLC

In 2014, U.S.-based BlackSky Global was issued a NOAA license authorizing deployment of an "Earth observation satellite system." The system, which is planned for launch in 2015, will feature one or more satellites in a polar orbit with an altitude of between 450 and 600 kilometers (280 and 373 miles). Because no technical details have been made public, the BlackSky system is not included in the forecast.

Dauria Aerospace-Elecnor Deimos

In mid-2014, Dauria Aerospace and Elecnor Deimos announced a joint partnership to develop Perseus, an 8-microsatellite remote sensing constellation. These satellites, manufactured by Canopus Systems LLC, will carry multispectral sensors. Elecnor Deimos currently operates Deimos-1, a commercial remote sensing satellite deployed in 2009, and Deimos-2, launched in 2014. DX-1, a Dauria-operated satellite also launched in 2014, is a technology development platform being used to inform the design of the Perseus constellation. Dauria received a $20 million investment from I2BF Global Ventures in October 2013 to support the Perseus constellation.

The first two microsatellites of the Perseus constellation, Perseus-M1 and Perseus-M2, were launched with Deimos-2 along with a large number of other microsatellites for other operators. The remaining six satellites are under construction; however, delays in delivery are expected following reorganization at Canopus during 2014. These satellites are not expected to generate dedicated launches during the forecast period.

DigitalGlobe

Founded in 1992, DigitalGlobe is a commercial high-resolution remote sensing satellite operator and GIS provider headquartered in Longmont, Colorado. The company operates imaging satellites and provides GIS products using satellite and aerial imagery. Following a merger with GeoEye, Inc. on January 31, 2013, DigitalGlobe currently operates four remote sensing satellites: GeoEye-1, WorldView-1, WorldView-2, and WorldView-3. The company's next satellite, WorldView-4 (formerly GeoEye-2), is currently in storage awaiting launch in mid-2016 aboard an Atlas V 401 vehicle.

WorldView-3 was launched in August 2014 and is expected to have a service life of up to 12 years. DigitalGlobe's three other satellites, GeoEye-1, WorldView-1, and WorldView-2, are expected to reach the end of their depreciable lives in 2018, 2020, and 2022, respectively. IKONOS, launched in 1999, is scheduled for retirement in 2015.

The U.S. National Geospatial-Intelligence Agency (NGA) partially funded the development of the current generation of DigitalGlobe (including the former GeoEye) satellites. In 2010, NGA awarded both DigitalGlobe and GeoEye 10-year contracts worth up to $7.35 billion as part of the EnhancedView program. These contracts extended NGA's ability to tap imagery from the private sector and help guarantee the availability of commercial remote sensing products through the decade. In July 2012, due to planned cuts to the EnhancedView budget, DigitalGlobe and GeoEye announced plans to merge, a process completed in January 2013.

DMC International Imaging

DMC International Imaging, Ltd. (DMCii), based in the United Kingdom, operates the Disaster Monitoring Constellation (DMC) on behalf of governments that provide the satellites. DMCii is a wholly owned subsidiary of SSTL. The constellation's primary purpose is to distribute imagery for commercial and humanitarian purposes.

The original DMC constellation (Alsat-1, Beijing-1, BilSat, Nigeriasat-1, and UK-DMC1) became fully operational in 2006, with satellites evenly distributed in a single sun-synchronous orbit (SSO). Four additional satellites were launched between 2009 and 2011, and the current retinue of operating satellites include China's Beijing-1, Nigeria's Nigeriasat-2 and NX, Spain's DEIMOS-1, and the United Kingdom's UK-DMC2. The satellites orbit at an altitude of 700 kilometers (435 miles). Nigeria's satellites Nigeriasat-2 and NX were launched in 2011 and represent the latest members of the DMC constellation.

In June 2011, DMCii signed a seven-year deal with China-based Twenty First Century Aerospace Technology Company Ltd. (21AT) to lease the imaging capacity aboard a three-satellite constellation called DMC3. The lease allows 21AT to obtain timely imagery without procuring and operating a constellation themselves. The constellation, designed and manufactured by SSTL, will be owned and operated by DMCii and is projected to launch in 2015 aboard an Indian PSLV-XL vehicle. Each DMC3 satellite will provide one-meter panchromatic and four-meter multispectral imaging.

GeoOptics Inc.

GeoOptics is a relatively new company seeking to develop a constellation of small satellites. The satellites, called CICERO (Community Initiative for Continuous Earth Remote Observation), are not equipped with imaging sensors; instead, they will collect environmental earth observation data like temperature, air pressure, and water vapor by measuring the attenuation of signal-strength from global navigation satellite system (GNSS) satellites (like the U.S. Navstar Global Positioning System) as their L-band signal enters and exits the atmosphere in a proven process called radio occultation. GeoOptics has been working with the University of Colorado Laboratory for Atmospheric and Space Physics (LASP) on the development of the satellites since 2010.

GeoOptics aims to have an operational constellation of 24 satellites by the end of 2018. GeoOptics plans to have all the satellites launched by smallsat launch providers such as Virgin Galactic's LauncherOne system. However, because the company has not yet announced sufficient financing for the space-based segment, these launches are not included in the forecast.

HySpecIQ

U.S.-based HySpecIQ is planning to initially deploy a block of two satellites capable of providing visible and short wave infrared hyperspectral (over 200 bands) imagery and GIS products for sale. The company was issued a NOAA license in February 2015 and has received commitments from The Boeing Company and several private equity companies for the first installment of funding support. HySpec-1 and HySpec-2 are being built by Boeing using the 502 Phoenix satellite bus under a contract signed in September 2014. The satellites will have a mass of about 600 kilograms (1,324 pounds) each and are projected to launch on separate launch vehicles in 2018.

ImageSat International NV

Israel-based ImageSat, founded as West Indian Space in 1997 and officially a Curacao company, provides commercial sub-meter resolution imagery with the Earth Remote Observation Satellite (EROS) family of satellites. Like many remote sensing companies, ImageSat's major customers are governments. Israel Aerospace Industries Ltd. (IAI) manufactures the EROS satellites, and ELBIT-Electro Optics Industries develops the imaging system.

ImageSat currently operates two satellites, EROS A and EROS B. EROS A launched in December 2000 aboard a Russian Start-1 small launch vehicle and should continue to operate until at least 2015, five years beyond its projected service life. EROS B launched aboard a Start-1 in 2006 and should continue to operate until 2022.

IAI is currently building the EROS-C satellite. Though no launch year has been selected, it is expected that EROS-C will be launched in 2017 aboard a small vehicle. EROS-C is designed to have a service life of about ten years.

MacDonald, Dettwiler and Associates (MDA)

MDA built and operates RADARSAT-2. The company is a commercial provider of advanced geospatial information products derived from the high-resolution RADARSAT-1 (no longer in service) and RADARSAT-2 satellites. It also markets and sells data derived from commercial optical satellites and from aerial systems.

RADARSAT-1 was launched on November 4, 1995, aboard a Delta II launch vehicle. The satellite, which was operated by the Canadian Space Agency (CSA), was retired in 2013. RADARSAT-2 launched aboard a Starsem Soyuz intermediate vehicle on December 14, 2007 and remains healthy. RADARSAT-2 features a SAR system capable of producing imagery with 1-meter resolution.

To provide space-based radar data continuity, the Government of Canada, through the CSA, proposed the three-satellite RADARSAT Constellation Mission (RCM). In March 2010, the CSA authorized MDA to perform the Phase C design phase of the RCA program, after MDA successfully completed Phases A and B. In January 2013, CSA signed a CAD $706-million contract with MDA for the construction, launch and initial operations of the three RCM satellites. In July 2013, MDA secured a launch reservation with SpaceX for the launch of all three satellites aboard a Falcon 9 vehicle in 2018.

OmniEarth

U.S-based OmniEarth aims to deploy a constellation of 18 small satellites designed to provide high-resolution, multispectral imagery on a subscription basis. In addition to GIS, the company plans to provide change detection services for commercial and government clients. The proposed 110-kilogram (243-pound) satellites are designed by Dynetics, with Harris Corporation responsible for marketing hosted payload opportunities. The satellites will feature a communications downlink of more than 1.2 gigabytes per second and will be able to store about one terabyte of data, a unique capability among commercial remote sensing companies operating small satellites. The effort is expected to cost about $250 million.

OmniEarth satellites will likely be launched as secondary payloads. However, they may also be launched as primary payloads on smallsat launch vehicles. Because these vehicles have not yet flown, and no launch contracts have been publicly announced, dedicated launches for OmniEarth are not included in this forecast.

PlanetiQ

PlanetiQ, established in 2012, plans to operate 18 microsatellites to provide weather, climate, and space weather data. The satellites are not equipped with imaging sensors; instead, they will collect atmospheric data including temperature, pressure and water vapor by measuring the bending of signals broadcast from global navigation satellite systems (like the U.S. Navstar Global Positioning System) in a proven process called radio occultation.

The mass of each satellite is 20 kg (44 lb). The current plan is to launch 12 satellites by 2017 with 18 total by 2020, all likely to be secondary payloads. PlanetiQ is currently raising funds to support construction of the constellation.

Planet Labs Inc.

Planet Labs Inc., based in California, is a remote sensing and GIS company focused on producing and operating a fleet of 150 very small satellites. The satellite platform is a 3U CubeSat, the sensor focal length is capable of producing images with resolutions of 3 to 5 meters, which is still adequate for environmental monitoring, change detection, and other applications. The large number of very small satellites ensures global coverage for a relatively small investment. Planet Labs raised $52 million in 2013, and $70 million in 2015.

Planet Labs built four prototype Dove satellites, launched as secondary payloads in 2013. In January 2014, 28 Dove satellites, collectively called Flock-1, were launched aboard an Antares vehicle provided by Orbital Sciences Corporation. The satellites were stored within the Cygnus cargo transfer vehicle that berthed with the ISS on January 12, 2014. Once attached to the ISS, the satellites were transferred to the Japanese Kibo module, where a special dispenser was used to eject two satellites at a time into orbit the following month. This method was duplicated in subsequent launches of 28 satellites aboard a Cygnus in July (Flock 1b). Flock 1c consisted of 11 satellites and these were launched by a Dnepr vehicle provided by ISC Kosmotras. Flock 1d, consisting of 26 satellites, was lost when the Antares vehicle experienced a launch failure. Flock 1d' consisted of two satellites, and these were carried to ISS aboard a Dragon cargo capsule in January 2015. The next batch of 28 satellites (Flock 1e) is planned for launch in April 2015 aboard a Falcon 9. The satellites will be carried within the Dragon cargo capsule for transfer to the ISS Kibo module.

The forecast includes 101 operational satellites deployed during 2013 – 2015, followed by 75 satellites each year throughout the forecast period to replenish the constellation since each satellite has a service life of 2 to 4 years, except for satellites launched from the ISS, which have an orbital lifetime of 6 to 9 months. However, none of these satellites are expected to drive a launch since it is likely all satellites will be deployed as secondary payloads.

Skybox Imaging

Skybox Imaging, Inc., based in Mountain View, California, is a new entrant to the commercial satellite remote sensing industry. The company obtained a NOAA license for SkySat-1 on April 20, 2010, and has applied to amend the license to include a second satellite, SkySat-2. SkySat-1 launched in 2013 aboard a Dnepr vehicle along with several other satellites. SkySat-2 launched as secondary satellite aboard a Soyuz 2 in 2014. The long-term goal is to field a 24-satellite constellation. Space Systems Loral is building the first 13 of these satellites under a contract signed in February 2014.

The forecast for Skybox begins with the projected launch of SkySat-3 in 2015 aboard a PSLV. Ten SkySat satellites will follow in 2016; six will launch together aboard an Orbital Sciences Corporation Minotaur-C and four will launch aboard an Arianespace Vega along with an undisclosed primary payload. Skybox has also been in discussions with Virgin Galactic for the launch of satellites aboard LauncherOne, a new small-class launch vehicle. Since this vehicle can only carry one SkySat at a time, the forecast projects that three SkySat satellites will be launched individually in 2017.

Spire

Spire (formerly Nanosatisfi) is a U.S.-based company focused on delivering maritime and weather data to enterprise and public sector clients via its planned constellation of CubeSats that will operate in LEO. Spire satellites will capture and aggregate signals from the already entrenched automatic identification system (AIS) onboard most commercial maritime vessels—and using technology similar to that from the successful FormoSat-3/ COSMIC public sector mission, Spire will deploy GNSS radio occultation capability onboard its satellites to measure and track global weather profiles at scale. Spire's constellation will provide a 20-minute revisit time to any point on Earth (on average), diminishing further as it adds to its initial satellite deployments. Curren t plans call for an initial constellation of 20 3U CubeSats during the 2015 – 2016 timeframe, with 100 3U CubeSats in orbit by 2018 – 2019.

Within 12-months of its founding, Spire built and deployed the world's first crowd funded satellite, a CubeSat called Ardusat, which was successfully launched in 2013. It launched two additional Ardusats and the Lemur-1 demonstration satellite that same year. In 2014, Spire raised $25 million in investor funding, bringing its total funding to about $29 million. Ardusat was spun off from Spire as a separate company to pursue further education applications, and has since successfully raised a $1 million round of funding from outside investors.

Spire satellites will likely be launched as secondary payloads. However, they may also be launched as primary payloads on small satellite launch vehicles. Because these vehicles have not yet flown, and no launch contracts have been publicly announced, dedicated launches of Spire satellites are not included in this forecast.

COMMERCIAL CARGO AND CREW TRANSPORTATION SERVICES

Commercial cargo and crew transportation capabilities include commercial launches of cargo and humans to LEO, the Moon, or other solar system destinations. Specifically, commercial cargo and crew transportation captures commercial crew and cargo services in support of NASA's mission and other private industry efforts that may require cargo and crew flights, such as space stations, tourism, privately sponsored scientific expeditions, and the prospecting and mining of non-terrestrial resources.

Commercial Cargo and Crew Transportation Services Launch Demand Summary

Seventy-nine commercial cargo and crew launches are projected from 2015 to 2024, as compared to 78 launches in last year's Report. All the launches forecasted in the next ten years are in support of commercial crew and cargo resupply to the ISS. Two payloads, Bigelow Aerospace's BEAM and Planetary Resources' Arkyd 100, will be launched as secondary payloads and do not generate launches.

Figure 17. Commercial Cargo and Crew Transportation Services Launch History and Projected Launch Plans

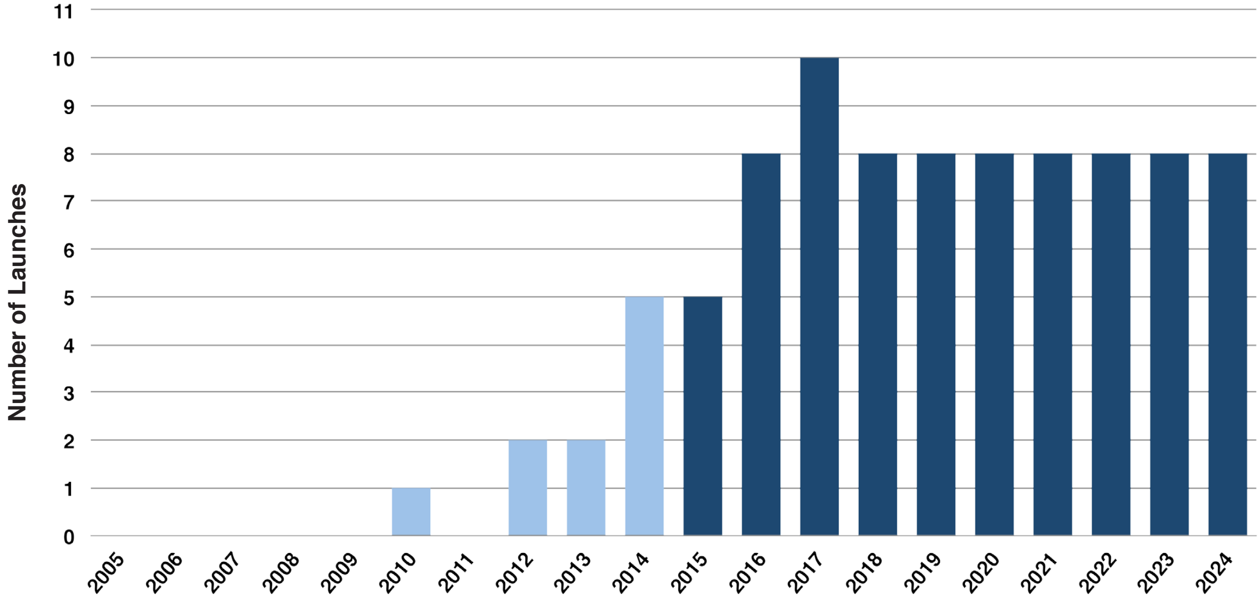
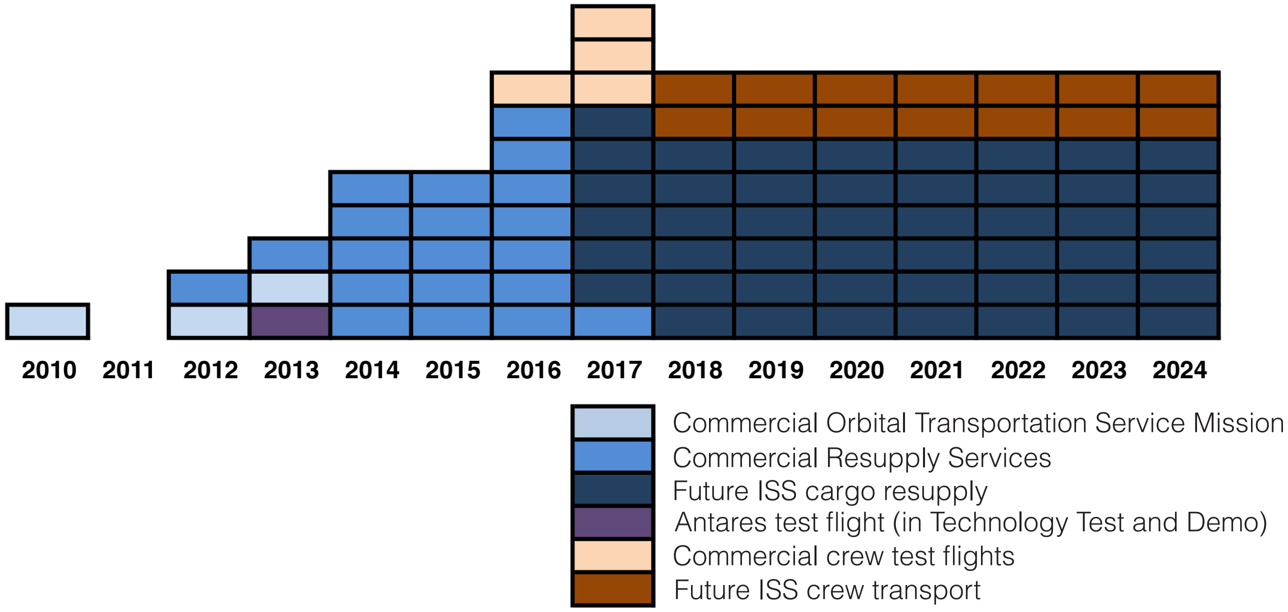


Figure 17 provides a launch history and projected launch plans for commercial cargo and crew transportation services.

Figure 18 shows the distribution of ISS commercial cargo and crew flights from 2015 to 2024. Note that the first test flights of Falcon 9 and Antares were not funded by NASA and are captured in the forecast section entitled Technology Test and Demonstration Launches.

Figure 18. NASA Commercial Crew and Cargo Projections



Sources: NASA Mission Launches, February 5, 2015 and the FY 2016 NASA Budget Estimates.

NASA COTS

In 2006, NASA announced the COTS program. COTS focused on the development and demonstration of commercial cargo transportation systems. Total Space Act Agreement (SAA) funding under this program was $889 million. Under COTS, SpaceX developed the intermediate Falcon 9 launch vehicle and the Dragon spacecraft. Orbital Sciences Corporation developed the Cygnus spacecraft and the medium-class Antares launch vehicle. SpaceX completed its COTS milestones in 2012. Orbital's test flight of Antares launched on April 21, 2013, carrying a Cygnus mass simulator. The company conducted its COTS demonstration mission in September 2013, featuring a fully operational Cygnus that berthed with the ISS. The successful completion of this mission concluded NASA's COTS program.

NASA CRS

In 2008, NASA awarded two CRS contracts to SpaceX and Orbital. SpaceX won a contract valued at $1.6 billion for 12 flights through 2015, and Orbital won a $1.9 billion contract for 8 flights during the same period. Operational flights began in October 2012, with the successful launch of SpaceX's Dragon resupplying the ISS. Orbital's resupply missions began in January 2014. NASA anticipates awarding a second commercial resupply services contract in 2015. Companies expected to

Table 17. NASA Commercial Crew and Cargo Awards

Program	Year of Space Act Agreement	Value of Space Act Agreement	Companies	Vehicles and Technologies
COTS	2006	$396 million	SpaceX	Dragon
COTS	2006	$207 million	Kistler*	K-1
COTS	2008	$288 million	Orbital	Cygnus
CRS	2008	$1.6 billion	SpaceX	Dragon (12 flights)
CRS	2008	$1.9 billion	Orbital	Cygnus (8 flights)
CCDev	2010	$20 million	Sierra Nevada Corp.	Dream Chaser
CCDev	2010	$18 million	Boeing	CST-100
CCDev	2010	$6.7 million	United Launch Alliance (ULA)	Atlas V human rating
CCDev	2010	$3.7 million	Blue Origin	Launch abort systems
CCDev	2010	$1.4 million	Paragon Space	Life support
CCDev2	2011	$112.9 million	Boeing	CST-100 design maturation
CCDev2	2011	$105.6 million	Sierra Nevada Corp.	Dream Chaser design maturation
CCDev2	2011	$75 million	SpaceX	Crewed Dragon development
CCDev2	2011	$22 million	Blue Origin	Launch abort systems
CCDev2	2011	Unfunded	ULA	Atlas V human rating
CCDev2	2011	Unfunded	ATK/Astrium	Liberty development
CCDev2	2011	Unfunded	Excalibur Almaz	Spacecraft development
CCiCAP	2012	$460 million	Boeing	CST-100 crewed maturation
CCiCAP	2012	$440 million	SpaceX	Dragon V2 maturation
CCiCAP	2012	$212.5 million	Sierra Nevada Corp.	Dream Chaser crewed maturation
CPC	2012	$10 million	Boeing	Crew Certification
CPC	2012	$10 million	Sierra Nevada Corp.	Crew Certification
CPC	2012	$10 million	SpaceX	Crew Certification
CCtCap	2014	$4.2 billion	Boeing	Final development phase of CST-100
CCtCap	2014	$2.6 billion	SpaceX	Final development phase of Dragon V2

** In 2007, NASA terminated the Space Act Agreement with Kistler due to the company's technical and financial shortfalls.*

submit bids include SpaceX, Orbital ATK, Lockheed Martin, and Sierra Nevada Corporation. CRS missions account for six flights to the ISS each year through 2024, though NASA is projecting seven such flights each year in 2016 and 2017.

NASA Commercial Crew

To stimulate commercial development of a crew transportation capability, NASA initiated the Commercial Crew Development (CCDev) effort in 2010 with $50 million of 2009 American Recovery and Reinvestment Act funding. CCDev focused on development of commercial space transportation concepts and enabling capabilities. The 2010 CCDev awardees were Blue Origin, Boeing, Paragon Space Development Corporation, Sierra Nevada Corporation, and United Launch Alliance (ULA).

In 2011, after completion of the initial CCDev effort, NASA continued investing in commercial crew transportation development with a second competition known as CCDev2. This follow-on effort further advanced commercial crew space transportation system concepts, maturing the design and development of system elements such as launch vehicles and spacecraft. Blue Origin, Boeing, Sierra Nevada Corporation (SNC), and SpaceX won awards totaling $315 million. Additionally, NASA awarded unfunded agreements to provide limited technical assistance for advancement of commercial crew space transportation to ULA; Alliant Techsystems (ATK, now Orbital ATK); and Excalibur Almaz, Inc.

In 2012, NASA announced the next phase of commercial crew development, Commercial Crew Integrated Capability (CCiCAP). This new initiative is to facilitate industry's development of an integrated crew transportation system. CCiCap is expected to result in significant maturation of commercial crew transportation systems. Boeing, SpaceX, and Sierra Nevada Corporation won awards totaling over $1.1 billion. In December 2012, NASA awarded $30 million in Certification Products Contracts (CPC) to Boeing, Sierra Nevada, and SpaceX. Under this contract, each of these companies will work toward certifying its spacecraft as safe to carry humans to the ISS. In September 2014, NASA awarded contracts under the Commercial Crew Transportation Capability (CCtCap) to Boeing for the CST-100 (up to $4.2 billion) and SpaceX for the Dragon V2 (up to $2.6 billion). Under CCtCap, the final design, development, test, and evaluation activities necessary to achieve NASA's certification of a Crew Transportation System (CTS) will be conducted. SNC's Dream Chaser concept was not selected.

Table 17 describes NASA COTS, CRS, and CCDev Awards.

Bigelow Aerospace

Nevada-based Bigelow Aerospace is developing expandable space habitat technology to support a variety of public and private activities including commercial space stations in LEO and human spaceflight missions beyond LEO. Its manufacturing plant, which occupies 31,731 square meters, is located in North Las Vegas, Nevada. Bigelow Aerospace has launched two prototype spacecraft, Genesis I and Genesis II, on separate Russian Dnepr launch vehicles in 2006 and 2007, respectively. Bigelow Aerospace used these missions to validate its habitat designs and engineering in an actual on-orbit environment.

Bigelow Aerospace is currently developing the Bigelow Expandable Activity Module (BEAM), a technology pathfinder system for the ISS. In December of 2012, NASA awarded Bigelow Aerospace a $17.8 million contract to develop the BEAM, which will launch on the eighth SpaceX CRS flight in 2015. The BEAM is scheduled for a nominal two-year technology demonstration period, wherein ISS crewmembers will gather data on the performance of the module. The BEAM mission period may be extended by NASA, and at the end of its life, the BEAM will be jettisoned from the ISS and will burn up during reentry.

Bigelow Aerospace has also been continuing work on full-scale expandable modules. Specifically, the company is developing the BA 330, which will offer 330 cubic meters of internal volume and can accommodate a crew of up to six, and the BA 2100 or 'Olympus', which will provide roughly 2,100 cubic meters of internal volume. In 2013, Bigelow Aerospace announced that it could modify the BA 330 in a number of ways depending on mission needs. The BA 330-DS would be designed for missions beyond LEO requiring additional radiation shielding. The BA 330-MDS would be designed for surface installations on the Moon. Finally, Bigelow Aerospace is considering a version of the BA 2100 that could carry spacecraft as well as crew, using a large airlock to facilitate transfers. These modules can be linked together to form space stations, and can also be linked together with any of a variety of tugs that the company intends to provide, including a Standard Transit Tug, a Solar Generator Tug, a Docking Node Transporter, and a Spacecraft Capture Tug.

Bigelow Aerospace is also involved in crew transportation. The company is a member of the Boeing CCDev team working on the CST-100 reusable in-space crew transport vehicle.

Planetary Resources

In April 2012, Planetary Resources, Inc., a company formed by Space Adventures founder Eric Anderson and X PRIZE Chairman Peter Diamandis, introduced its plans to mine near-Earth asteroids for raw materials. In its initial efforts, Planetary Resources is focusing on telescopes designed to identify resource-rich targets. It has entered into an agreement with Virgin Galactic to launch several constellations of Arkyd-100 Series LEO space telescopes on Virgin Galactic's LauncherOne. LauncherOne is still under development with commercial flights estimated to begin in 2016. The company's 15-kilogram Arkyd-100 telescope will be launched as a secondary payload in 2015. Follow on systems are not projected beyond the first launch pending additional public data on funding.

Other Potential Sources of Future Launch Demand

Several other efforts have been pursued in recent years that will require commercial crew and cargo transportation, or may in the future. Some of these, Inspiration Mars Foundation and Space Adventures, have enough funding to press forward with mission planning and even hardware development. Other efforts like Excalibur Almaz and Golden Spike have raised limited funds. At this time, no substantial additional funding has been raised and no launch contracts have been announced, so launch demand associated with these companies is not included in the forecast.

Excalibur Almaz

Excalibur Almaz, Limited (EAL), an Isle of Man company, planned to use elements of a legacy Soviet military space program known as Almaz. EAL's key partners are NPO Mashinostroyenia (the original developer of Almaz), Airbus Group, and Japan Manned Space Systems Corporation. The system included four three-person reusable return vehicles (RRV) and two Salyut-type Almaz orbital space stations that can stay on-orbit autonomously for one week or dock with the ISS. One of the RRVs was to be equipped as an unmanned microgravity laboratory to assist with science flights to LEO. NASA awarded EAL an unfunded SAA for commercial crew transportation as part of CCDev2 activities, and was the first company to complete all of its SAA milestones. EAL intended to begin revenue-generating flights as early as the fourth quarter of 2015. However, in early 2015, the unused hardware was shipped out of the Isle of Man as the EAL's storage lease had expired, bringing the company's future into question.

Golden Spike Company

The Golden Spike Company formed to offer private human expeditions to the surface of the Moon by 2019 or 2020. The company's president is former NASA Associate Administrator for Science Alan Stern. Golden Spike estimates the cost for a two-person lunar surface mission will start at $1.4 billion for the first mission, and $1.6 billion for increasingly ambitious subsequent missions. Golden Spike contracted with Northrop Grumman for the design of a new lunar lander capable of carrying two crewmembers.

Google Lunar X PRIZE

The Google Lunar X PRIZE is a $30 million purse open to teams from around the world. To win the grand prize of $20 million, private teams (those with no more than 10 percent in government funding) must land a robot safely on the Moon; move 500 meters on, above, or below the Moon's surface; and send back high definition video before the December 31st, 2016 deadline.

Inspiration Mars

The Inspiration Mars Foundation originally hoped to mount a privately funded crewed Mars flyby mission originally planned for 2018. By early 2014, this objective slipped to 2021 and for a time included NASA's Space Launch System (SLS) as part of its architecture. The project aims to take advantage of a planetary alignment that will allow a Mars flyby and return in 501 days. The foundation plans to use a single SLS launch to send a Dual Use Upper Stage (DUUS) and a modified Cygnus module into LEO. The SLS and DUUS are currently being developed by NASA. The Cygnus module is provided by Orbital Sciences Corporation as a cargo transport to ISS. A second launch, using a smaller vehicle like an Atlas V or Delta IV, will send a crew of two aboard an NASA's Orion spacecraft. Inspiration Mars Foundation Chairman Dennis Tito will fund mission development for the first two years, during which time additional fundraising and support will be garnered. Due to a lack of public information regarding funding and technical progress, the proposed Inspiration Mars mission is not included in the forecast.

Space Adventures

Space Adventures, a broker for space tourism and expeditions, indicated in 2011 that it was in the late planning stages for a three-person expedition to circumnavigate the Moon. Two of the individuals will pay for their seats, while a third will be a Roscosmos cosmonaut. This effort will include two separate launches, one of a Proton-M carrying a Block-DM lunar transfer stage, and one of a Soyuz with two crew members. The ticket price for each of the seats is rumored to be about $150 million. The company has indicated that at least one ticket has been sold and that the other is in final negotiations. However, conflicting information from Russian industry sources and a lack of announced launch contracts means that this lunar mission is not included in the forecast.

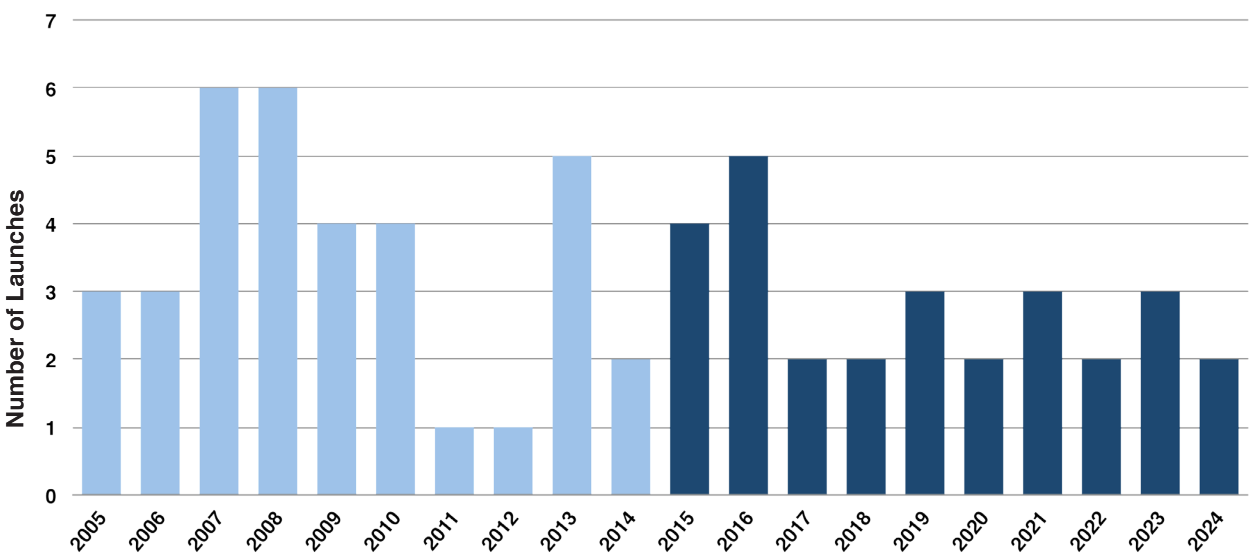
Stratolaunch Systems-Sierra Nevada Corporation

Following NASA's September 2014 CCtCap awards, SNC vowed to continue development of its Dream Chaser vehicle. A joint effort between Stratolaunch Systems and SNC emerged late in 2014, in which a scaled down version of Dream Chaser capable of carrying two crew members may be launched around 2019. The spaceplane would be carried into orbit using Stratolaunch's Eagle system, featuring a large aircraft called Roc as the first stage and an Orbital ATK solid motor second stage with a LEO capacity of at least 5,000 kilograms called Thunderbolt. This particular test launch is not included in the forecast as few technical details have been released publicly.

OTHER COMMERCIALLY LAUNCHED SATELLITES

This section contains predominantly government satellites launched commercially. It also includes university payloads that are scientific, education, or outreach. Though many government missions do not commercially procure or obtain commercial licenses for their launches, there are select missions that do, particularly by governments without domestic launch capabilities.

Figure 19. Other Commercially Launched Satellites Launch History and Projected Launch Plans



2015	2016	2017	2018
SAOCOM 1A - Falcon 9	DragonLab - Falcon 9	DubaiSat 3 - Dnepr	DragonLab - Falcon 9
Kompsat 3A - Dnepr	Formosat 5 - Falcon 9	TBD (Govt) - TBD	EnMAP - PSLV
PAZ - Dnepr	SAOCOM 1B - Falcon 9		
Ingenio - TBD	Gokturk 1 - Vega		
	Perusat - Vega		

In previous reports, Other Commercially Launched Satellites were discussed in the sections "Science and Engineering – Basic and Applied Research" and "Other Payloads Launched Commercially." These sections are now combined to provide a complete picture of the market of commercial launches procured by governments. Government Earth observation and remote sensing programs and scientific missions are significant customers of commercial launch services to NGSO.

Other Commercially Launched Satellites Demand Summary

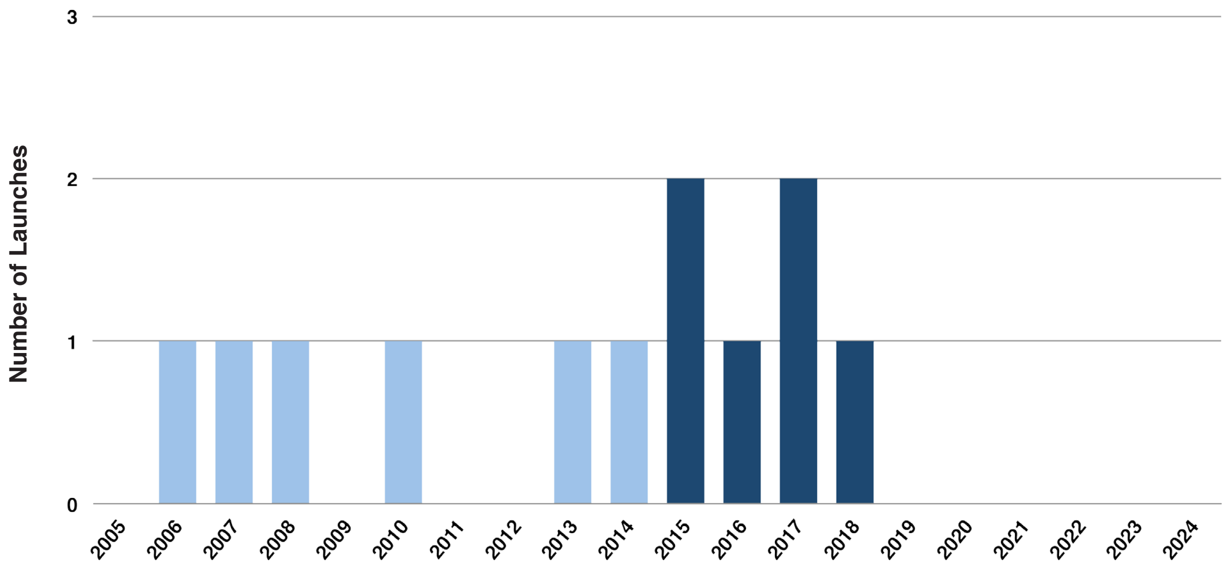
The market characterization of the near term (2015-2018) includes 12 manifested launches. For the period 2019-2024, the application of a forecasting method projects 15 launches for an average of 2.5 in each of the six out years. Figure 19 provides a launch history and projected launch plan demands for Other Commercially Launched Satellites.

Technology Test and Demonstration Launches

Technology test and demonstration launches are conducted to test primarily new launch and space vehicles. By their nature, these are not events taking place on a regular basis. Figure 20 provides a launch history and projected launch plans for technology test and demonstration launches.

The inaugural launch of SpaceX's Falcon Heavy launch vehicle is now planned for launch in 2015. The Report also includes the technology test and demonstration launches of new small class commercial launch vehicles Rocket Lab Electron, Fire Fly Alpha, GOLauncher, LauncherOne, and Stratolaunch. Test fights of other new orbital launch vehicles currently in development are anticipated in the same time frame and are not reflected in this forecast as intended primarily for launching government missions.

Figure 20. Technology Test and Demonstration Launch History and Projected Launch Plans



2015	2016	2017	2018
Rocket Lab Electron test flight	Fire Fly Alpha test flight	GOLauncher test flight	Stratolaunch test flight
Falcon Heavy test flight		Virgin Galactic LauncherOne test flight	

SATELLITE AND LAUNCH FORECAST TRENDS

While the demand for commercial GEO launches is expected to stay relatively steady, that for commercial NGSO launches is expected to increase relatively significantly as major NGSO telecommunication constellations are replenished and NASA ISS commercial crew and cargo resupply missions become more regular. The annual average of NGSO commercial launches is expected to grow from an annual average of seven launches a year to over 13 launches annually.

From 2015 to 2024, 986 payloads are projected to launch commercially, driving 131 launches with multi-manifesting. Figures 21 and 22 show the payloads and launches projected from 2015 to 2024.

Figure 21. Payload Projections

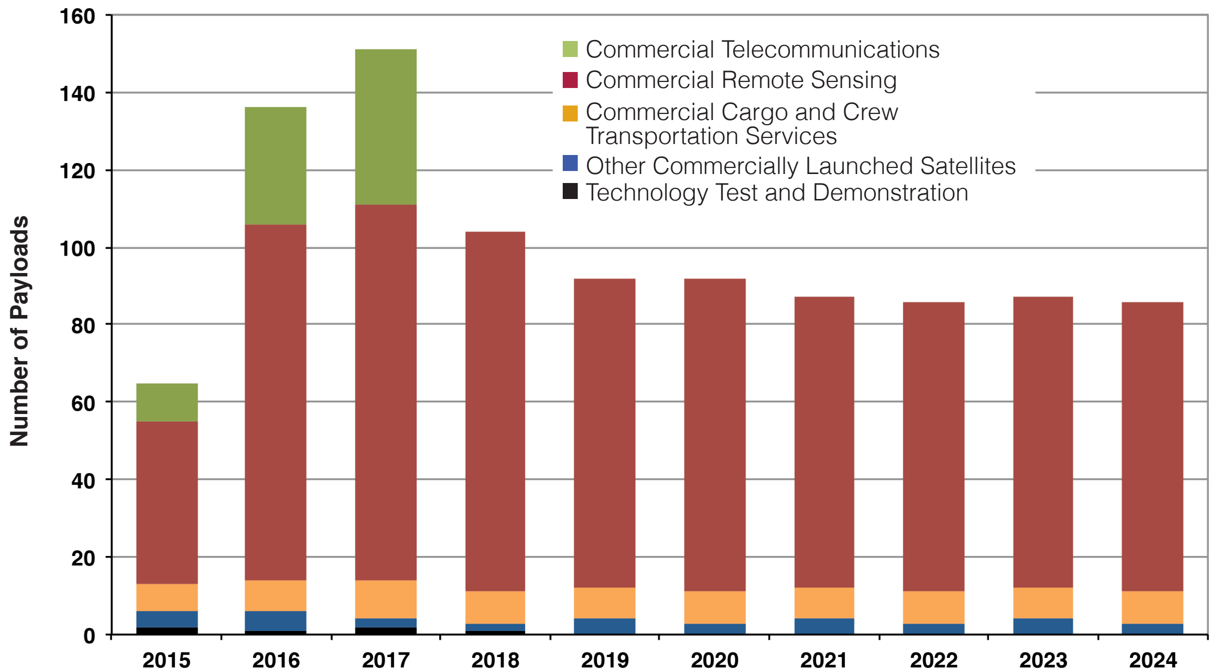


Table 18 provides the specific numbers of payloads and launches for each segment.

Sixty percent of the predicted launches over the next 10 years are for commercial transportation services. As noted earlier, many of these launches take place on newly developed vehicles. These missions also partly rely on government funding subject to annual appropriations.

Other Commercially Launched Satellites account for 21 percent of launches over the next 10 years. These include a steady stream of basic and applied research and non-commercial remote sensing payloads primarily from countries without indigenous launch capabilities.

The commercial remote sensing accounts for seven percent of the launches. Demand projected in this Report is lower than a year ago mainly due to commercial

Figure 22. Launch Projections

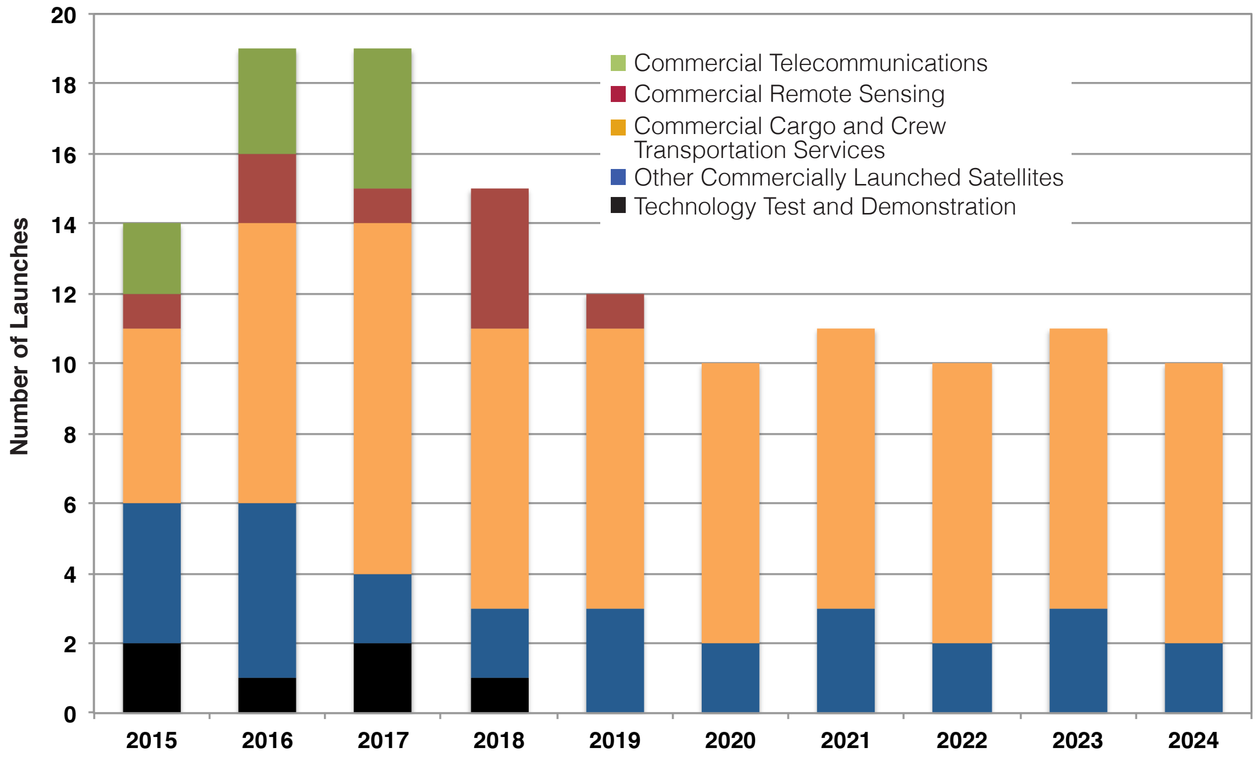


Table 18. Payload and Launch Projections

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total	Avg.
Payloads												
Commercial Telecommunications	10	30	40	0	0	0	0	0	0	0	80	8.0
Commercial Remote Sensing	42	92	97	93	80	81	75	75	75	75	785	78.5
Commercial Cargo and Crew Transportation Services	7	8	10	8	8	8	8	8	8	8	81	8.1
Other Commercially Launched Satellites	4	5	2	2	4	3	4	3	4	3	34	3.4
Technology Test and Demonstration	2	1	2	1	0	0	0	0	0	0	6	0.6
Total Payloads	**65**	**136**	**151**	**104**	**92**	**92**	**87**	**86**	**87**	**86**	**986**	**98.6**
Launches												
Medium-to-Heavy Vehicles	13	17	15	13	11	10	10	10	10	10	119	11.9
Small Vehicles	1	2	4	2	1	0	1	0	1	0	12	1.2
Total Launches	**14**	**19**	**18**	**15**	**12**	**10**	**11**	**10**	**11**	**10**	**131**	**13.1**

remote sensing companies like Skybox Imaging reconsidering launches of individual satellites by small vehicles and opting for multi-manifest launches.

Seven percent of the launches are for commercial telecommunications. There is a peak of telecommunications launches from 2015 – 2017 as Iridium replaces its satellites. No launches of telecommunications primary payloads are forecasted from 2018 – 2022, after the replacement constellations are completed.

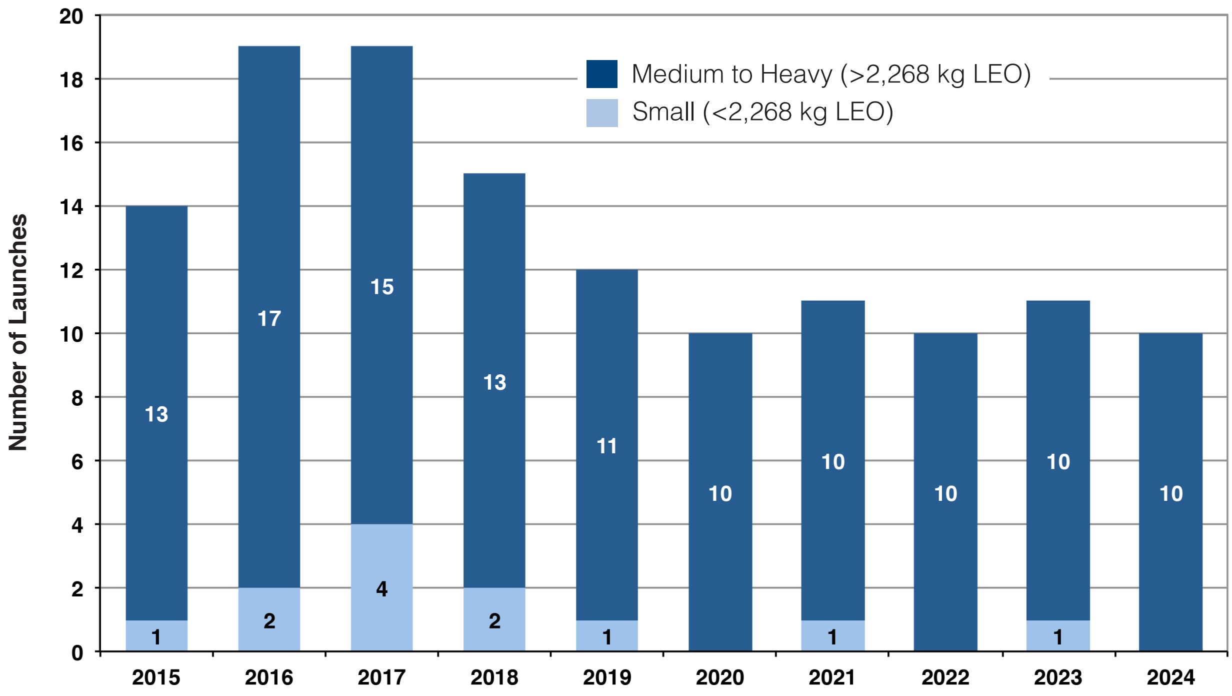
The technology test and demonstration segment accounts for five percent of launches over the next 10 years, including six launches of new technology test and demonstration missions.

There are 131 launches projected, comprising 12 small vehicles and 119 medium-to-heavy vehicles. On average, 1.2 launches take place on small vehicles and 11.9 launches on medium-to-heavy vehicles every year.

Launch demand divided among launch vehicle mass classes is depicted in Figure 23. The relatively high cost of a dedicated launch on a small launch vehicle compared to a secondary or piggyback payload on a larger vehicle has kept the demand for small launch vehicles low. This dynamic is beginning to change as new small vehicle systems like Virgin Galactic's LauncherOne become available. In the mean time, smaller payloads continue to use larger launch vehicles carrying primary missions on both commercial and non-commercial basis and offering affordable multi-manifest launch options for secondary payloads.

Many small payload operators are tied to government funding or national launch capabilities (e.g., small European missions launched by Vega or U.S. university missions getting free rides through programs like NASA's ELaNa). Intermediary companies (such as SpaceFlight Services, Commercial Space Technologies Ltd.,

Figure 23. Launch Vehicle Projections



and some others) offering brokerage services and pooling together clusters of secondary payloads to be launched together on a single launch vehicle have made the business of booking flights for secondary payloads more organized and predictable.

Table 19 provides the distribution of launches among the market segments.

Table 19. Distribution of Launches among Market Segments

Market Segment	Payloads	Launch Demand		
		Small	Medium-to-Heavy	Total
Commercial Telecommunications	80	0	9	9
Commercial Remote Sensing	785	4	5	9
Commercial Cargo and Crew Transportation Services	81	0	79	79
Other Commercially Launched Satellites	34	4	24	28
Technology Test and Demonstration	6	4	2	6
Total	**986**	**12**	**119**	**131**

APPENDIX 1: VEHICLE SIZES AND ORBITS

Small launch vehicles are defined as those with a payload capacity of less than 2,268 kg (5,000 lb) at 185 km (100 mi) altitude and a 28.5-degree inclination. Medium-to-heavy launch vehicles are capable of carrying more than 2,269 kilograms at 185 km altitude and a 28.5-degree inclination.

Commercial NGSO systems use a variety of orbits:

Low Earth orbits (LEO) range from 160-2,400 km (100-1,500 mi) in altitude, varying between a zero degree inclination for equatorial coverage and a 101 degree inclination for global coverage.

Medium Earth orbits (MEO) begin at 2,400 km (1,500 mi) in altitude and are typically at a 45-degree inclination to allow global coverage with fewer high-powered satellites. However, MEO is often a term applied to any orbit between LEO and GSO.

Elliptical orbits (ELI, also known as highly elliptical orbits, or HEO) have apogees ranging from 7,600 km (4,725 mi) to 35,497 km (22,000 mi) in altitude and up to a 116.5-degree inclination, allowing satellites to "hang" over certain regions on Earth, such as North America.

External or non-geocentric orbits (EXT) are centered on a celestial body other than Earth. They differ from ELI orbits in that they are not closed loops around Earth, and a spacecraft in EXT will not return to an Earth orbit. In some cases, this term is used for payloads intended to reach another celestial body, such as the Moon.

APPENDIX 2: MASS CLASSES FOR GSO AND NGSO PAYLOADS

Table 20. Mass Classes for GSO and NGSO Payloads

Class Name	Kilograms (kg)	Pounds (lb)
Femto	0.01 - 0.1	0.02 - 0.2
Pico	0.09 - 1	0.19 - 2
Nano	1.1 - 10	3 - 22
Micro	11 - 200	23 - 441
Mini	201 - 600	442 - 1,323
Small	601 - 1,200	1,324 - 2,646
Medium	1,201 - 2,500	2,647 - 5,512
Intermediate	2,501 - 4,200	5,513 - 9,259
Large	4,201 - 5,400	9,260 - 11,905
Heavy	5,401 - 7,000	11,906 - 15,432
Extra Heavy	>7,001	>15,433

APPENDIX 3: ACRONYMS

ABS	Asia Broadcast Satellite
AIS	Automatic Identification System
ADF	Australian Defense Force
AEHF	Advanced Extremely High Frequency
ATK	Alliant Technologies (since 2015, Orbital ATK)
ATV	Automated Transfer Vehicle
BEAM	Bigelow Expandable Activity Module
BMBF	Federal Ministry of Education and Research
CAST	Chinese Academy of Space Technology
CCAFS	Cape Canaveral Air Force Station
CCDev	Commercial Crew Development
CCiCap	Commercial Crew Integrated Capacity
CCtCap	Commercial Crew Transportation Capability
CEO	Chief Executive Officer
COMSTAC	Commercial Space Transportation Advisory Committee
COTS	Commercial Orbital Transportation Services
CPC	Certification Product Contract
CRS	Commercial Resupply Services
CSA	Canadian Space Agency
CST-100	Crew Space Transportation-100
CY	Calendar Year
DARS	Digital Audio Radio Service
DBS	Direct Broadcasting Services
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German space agency)
DMC	Disaster Monitoring Constellation
DMCii	DMC International Imaging, Ltd.
DTH	Direct-to-Home
EADS	European Aeronautic Defence and Space Company (since 2015, Aribus Group)
EAL	Excalibur Almaz, Ltd.
ECA	Export Credit Agency
EDRS	European Data Relay System
EGNOS	European Geostationary Navigation Overlay Service
ELaNa	Educational Launch of Nanosatellites
ELI	Highly Elliptical Orbit
EP	Electric Propulsion
EROS	Earth Remote Observation Satellite

ESA	European Space Agency
EXIM	Export-Import Band
EXT	External or Non-Geocentric Orbit
FAA AST	Federal Aviation Administration, Office of Commercial SpaceTransportation
FCC	Federal Communications Commission
FY	Fiscal Year
FSS	Fixed Satellite Services
GEO	Geosynchronus Orbit
GIS	Geographic Information Systems
GMW	GeoMetWatch
GPS	Global Positioning System
GSLV	Geosynchronous Satellite Launch Vehicle
GSO	Geostationary Orbit (sometimes geosynchronous)
GTO	Geosynchronous Transfer Orbit
HDTV	High Definition Television Services
HEO	Highly Elliptical Orbit
HPA	Hosted Payload Alliance
HTS	High Throughput Satellite
ICL	Imperial College London
ILS	International Launch Services
IPO	Initial Public Offering
ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
ITT	International Telephone & Telegraph
ITU	International Telecommunications Union
KARI	Korea Aerospace Research Institute
KSLV	Korean Space Launch Vehicle
LEO	Low Earth Orbit
LCRD	Laser Communications Relay Demonstration
LLC	Limited Liability Company
MELCO	Mitsubishi Electric Company
MEO	Medium Earth Orbit
MHI	Mitsubishi Heavy Industries, Ltd.
MPCV	Multi Purpose Crew Vehicle
MSS	Mobile Satellite Services
NASA	National Aeronautics and Space Administration
NEC	Nippon Electric Company

NGA	National Geospatial-Intelligence Agency
NGSO	Non-Geosynchronous Orbits
NOAA	National Oceanic and Atmospheric Administration
NSSK	North-South Station Keeping
O3b	Other Three Billion Networks, Ltd.
OHB	Orbitale Hochtechnologie Bremen
Orbital	Orbital Sciences Corporation (since 2015, Orbital ATK)
PSLV	Polar Satellite Launch Vehicle
RCM	RADARSAT Constellation Mission
RRV	Reusable Return Vehicle
SAA	Space Act Agreement
SAR	Synthetic Aperture Radar
SBAS	Satellite-Based Augmentation Systems
SNC	Sierra Nevada Corporation
SpaceX	Space Exploration Technologies Corporation
SPOT	Satellite Pour l'Observation de la Terre
SSL	Space Systems Loral
SSO	Sun-Synchronous Orbit
SSTL	Surrey Satellite Technology Limited
TBD	To Be Determined
TSX	TerraSAR X-band
UAE	United Arab Emirates
UHF	Ultra-High Frequency
ULA	United Launch Alliance
URSC	United Rocket and Space Corporation
USG	U.S. Government
USLM	United States Munitions List
USAF	United States Air Force
WAAS	Wide Area Augmentation System

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