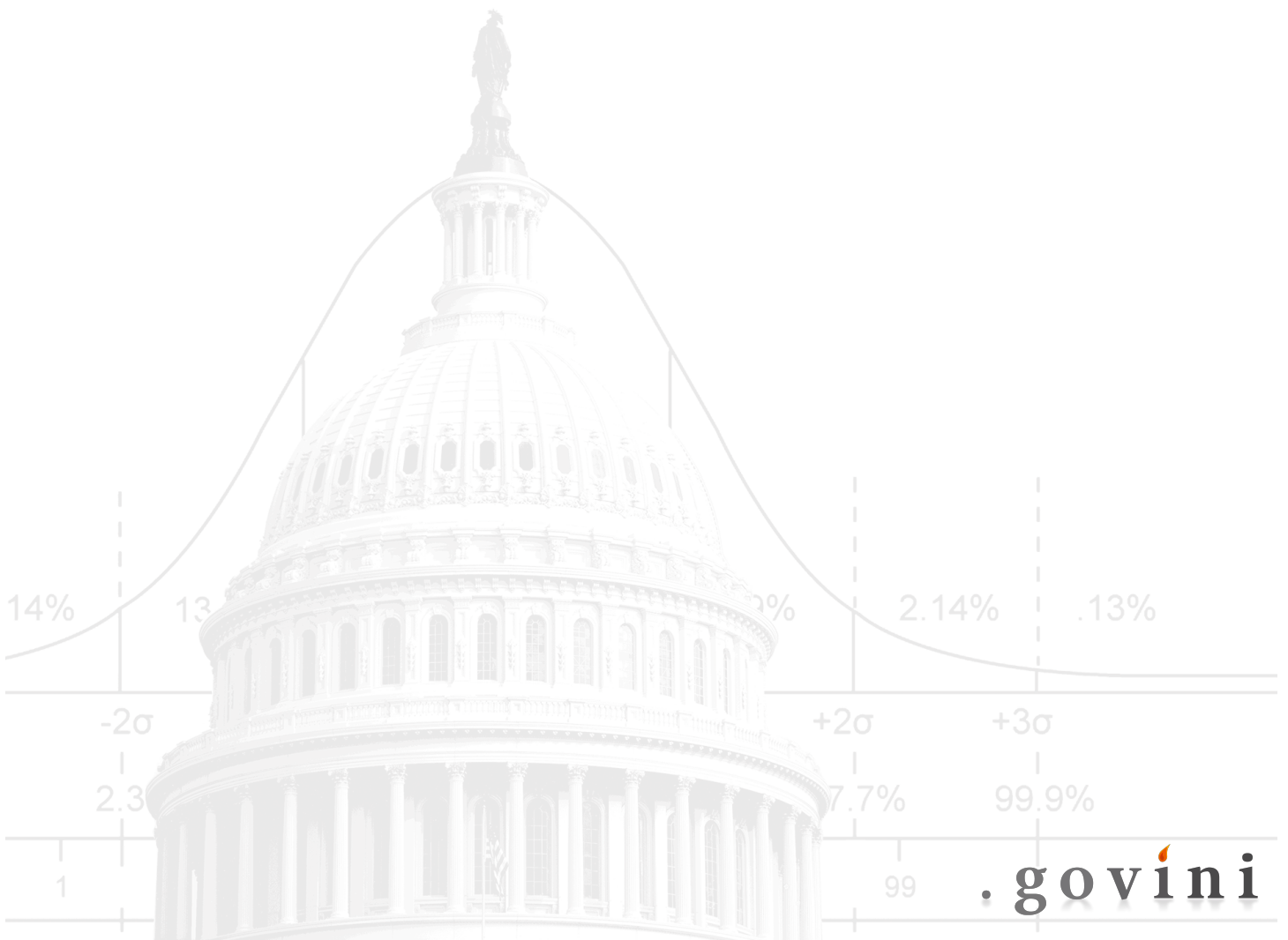


SPACE PLATFORMS & HYPERSONIC TECHNOLOGIES TAXONOMY

Foreword by

Col. Terry Virts, USAF (Ret)

Commander of the International Space Station, Expedition 43



COMPANIES INCLUDED

Aerojet Rocketdyne
Arctic Slope Regional Corporation
Association of Universities for Research in Astronomy
BAE Systems Inc.
Ball Aerospace & Technologies Corp.
Baylor University
Bigelow Space Operations
Blue Origin
Boeing Co. (BA)
Caltech
Chenega Corp.
General Dynamics Corp. (GD)
Harris Corp.
Iridium Satellite Communications Inc.
Johns Hopkins University
K2 Energy Solutions Inc.
L3 Technologies Inc. (LLL)
Leidos Inc. (LDOS)
Lockheed Martin Co. (LMT)
QinetiQ PLC (QQ)
Massachusetts Institute of Technology
Miltec Corp.
Northrop Grumman Corp. (NOC)
Orbital ATK
Raytheon Co. (RTN)
Russia Space Agency
SAIC Corp. (SAIC)
SGT Inc.
Sierra Lobo Inc.
Sierra Nevada Corp.
SpaceX
The Aerospace Corp.
United Launch Alliance
United Technologies Corp.
Universities Space Research Association
University Corp for Atmospheric Research
University of Alabama in Huntsville
University of California
University of Maryland
Williams International

AGENCIES INCLUDED

Air Force
Army
Defense-Wide Agencies
NASA
Navy
NOAA

TABLE OF CONTENTS

Foreword	1
Introduction	6
Key Findings	6
Contract Market Overview	7
Launch Vehicles	9
Human Space Missions	11
Space Science	13
National Security Satellites	15
Earth Observation	17
Hypersonic Technologies	18
Contract Market Top-15 Vendors	21
Contract Market Concentration	22
Contract Market Agencies	23
Space-Related Grants	24
Space-Related Patents	25
Hypersonic Technologies Patents	26
Conclusion	27
Methodology	27

FOREWORD

Col. Terry Virts, USAF (Ret)

Commander of the International Space Station, Expedition 43

In 1998 I flew an F-16 to Corsica, France, for an airshow. It was a good deal for me, especially since I was a rare American who spoke French. During the course of interacting with locals who were there to see all of the various NATO aircraft on display, I will never forget one gentleman. He was in his seventies and did not speak a word of English – he had probably lived his entire life in the countryside of that island. He came up to me with eyes full of admiration and told me in French “you are American! You went to the moon!” In the middle of rural France, the one thing that had impressed this gentleman – what he admired most about our country – was our success during the Apollo missions. His reaction really stuck with me, and it is a reaction that I have since seen in people around the globe. American success in space matters – it matters for our economy, it matters for our scientific knowledge, and it matters for our security. To achieve success, policymakers and stakeholders should better understand the future space economy, assess current issues related to chosen missions, and analyze recent advances that could shape military space policies and procedures. They should also consider creating a “Space Force” to act within the space domain.

Future Space Economy

Watching the two first stage boosters return to base and land in formation following the launch of the SpaceX’s Falcon Heavy really got me excited about space for the first time in a long time. It was like something out of a 1950s science fiction movie. Intellectually I understand that reusability is simply an economic factor and does not inherently enable any new space exploration, but, in the words of Tom Wolfe in *Right Stuff*, “no bucks, no Buck Rodgers.” The economics of spaceflight, which largely come down to the economics of launch, is the primary driver as to what can be done. If we are to do great things in the coming decades in space, in my estimation it will have to be by “New Space” companies like SpaceX, Blue Origin, Bigelow, et al.

Launches only occur if there is a destination or mission, and most of these involve an unmanned satellite of some type. In the same way the launch industry has been disrupted, I think the satellite industry is ripe for disruption by a SpaceX-like entrant. This is already occurring in the small satellite segment with universities and companies like Tyvak Nano-Satellite Systems leading the charge, but has yet to occur within the multi-billion dollar large and medium satellite segments. Because of the complex nature of our largest satellites, I expect they will continue to be built by traditional contractors for the foreseeable future. However, once the medium and small sized segments evolve to cheaper, “New Space” manufacturers, the applications for the military and scientific communities will be immense.

Another very exciting prospect for the private space sector is in human space flight. One company, Bigelow Space Operations, was recently created to run private space stations in earth orbit. The company’s B330 station has about one third the habitable volume of the ISS, can be launched on a single Atlas V because of the use of proprietary inflatable technology, and

is planned for launch in less than four years. If this station is successful it will revolutionize the ability to perform research in space – companies will be able to get their experiments flown more quickly, and promising technologies like human tissue growth and silicon chip manufacturing will have capacity in space that simply does not exist today. Significantly for launch innovators like Boeing and SpaceX, Bigelow could drive real demand for multiple crew flights per year, which could leverage the NASA Commercial Crew contracts for both companies. This would greatly expand a NASA contract that currently only calls for one flight per year per contractor.

Space Tourism is another sector that has generated a lot of press but not very much Federal contract spending, and will significantly grow in the next few years. Virgin Galactic has been working on its Space Ship 2 for over a decade, and after a fatal accident and several setbacks, the company appears poised to fly to space soon. Blue Origin is readying their New Shepherd rocket and capsule and plans to be flying paying passengers to space in the not-too-distant future. Both of these companies will offer suborbital flights lasting minutes not hours, and plan to charge affordable prices for a large portion of the world's middle class. Another kind of space tourism will be offered by World View, a Tucson-based company that will fly their customers to an altitude of over 100,000 feet where they will see the blackness of space. This low cost, if limited, access to space could potentially find customers in various governments around the world.

Scientific Knowledge and Exploration

Long-term space goals need to be set, and decisions to delay defining these goals adversely affects our current set of missions. Long-term planning is important for apex missions, such as Apollo, because they are dependent on other missions, like Mercury and Gemini, for advances in technology and procedures. Mercury encompassed the “can we fly in space?” phase; Gemini was the “test and develop the technologies and operational techniques that we need” phase; and Apollo was the final phase. If our nation's long-term “New Apollo” goal is to fly humans to Mars with regularity, then the ISS could be serving as a Mercury-like program – it has shown that we can live and work in space for long durations. A “New Gemini” program is needed to develop other key technologies to help achieve bold missions, such as the ability to land and assemble multiple modules on the surface of a planet; launch capsules to high speed rendezvous with transfer vehicles; use nuclear power for both space propulsion and surface operations, etc. Those with the power to do so need to help steer policy toward long-term space goals that stakeholders can work on, and this will help drive near- and long-term missions.

Another issue that NASA faces is the cost of funding the heavy-lift Space Launch System (SLS), but private launch technologies could help. By using the SLS to launch crew (on the Orion spacecraft), and not simply cargo, NASA will underutilize the launch vehicle and “lose” roughly 25 tons of cargo capacity per launch required by the human capsule. The agency has also been spending significant time and funds to have it rated for human space flight, going against one of the prime lessons from the Columbia accident – namely to “separate crew from cargo” by launching crew on smaller, safer rockets. Adding to the cost of SLS, NASA chose to replace the rocket's kerosene-fueled engines with RS-25 Space Shuttle Main Engines, some of the most expensive rocket engines ever made. These factors will alter the cost curve of the SLS and make it a less-economical vehicle for space deliveries. Privately developed launch vehicles such as SpaceX's Falcon Heavy and Blue Origin's New Glenn are significantly less costly than the SLS, and, though they can only lift half the payload, offer order-of-magnitude reductions in cost.

Military Space Developments

There are many exciting developments happening in military space today. First and foremost is a sea-change in launch capabilities. Non-traditional aerospace companies like SpaceX and Blue Origin are well on their way to completely disrupting the launch segment. At a recent conference on the economics of space flight at Goldman Sachs, a colleague estimated that these developments could bring down launch costs up to 30 percent in the coming decade while others have estimated this to be near 50 percent. Falcon 9 is gaining market share in all segments of the space launch industry from the commercial sector, NASA and military, and is doing so at the expense of Atlas, Delta, and Russian/European launch vehicles. A new Vulcan rocket, potentially powered by a Blue Origin BE-4 engine, or a more traditional Aerojet Rocketdyne engine, will also likely pick up a significant part of our nation's military launch market.

Hypersonic technologies and small satellites will significantly impact the battlespace. Hypersonics are on the cusp of moving from "science project" to operational status in the near-term. Developing cost-effective hypersonic vehicles will change the nature of warfare by allowing commanders to hit targets much more rapidly, shrinking their decision loops. They will also allow stakeholders to minimize costly and politically challenging forward basing. At the same time, small satellite technologies will allow us to maintain persistence in space with less vulnerability to a few "magic bullet" anti-satellite weapons.

There may be creative and non-traditional opportunities for partnerships between the Department of Defense (DoD) and the private sector within the Space Platforms and Hypersonic Technologies markets. Blue Origin's New Shepherd hypersonic vehicle will fly a suborbital trajectory with only a few minutes of weightlessness, which may be a more cost-effective testing platform for the DoD. NASA's Commercial Crew program may end up with excess capacity as it ferries astronauts to and from the International Space Station, which could give the DoD a unique and potentially innovative capability for space-based missions that would not exist had the military had to develop it on its own human spaceflight program.

Space Force

Space is a relatively new domain for our armed services, and evolving national needs necessitate creating a new Space Force, separate from the Air Force. Having spent nearly three decades as an Air Force Pilot, with 17 of those years in Air Force Space Command, I can say unequivocally that Air and Space are completely unrelated domains, in the same way that land is a separate domain from the sea. The skills that pilots and ground crews have to get airplanes airborne and to their target or destination are completely different than the skills that space operators have in launching and operating space vehicles. This is apparent by examining culture, mission sets, and recent developments.

One characteristic that is clear within each branch of the armed services is a common culture. Army personnel share a common operational mentality, training, and understanding that applies to all soldiers whether infantry, armor, artillery, or aviators. Similarly, the Navy leverages a common culture to focus on projecting power from the sea. "Air" and "space" operators usually spend their whole careers in completely different stovepipes of the Air Force, and they speak a different language and have a different culture that becomes evident, for example, at promotion boards. As a domain, space is now mature enough that many officers and enlisted members spend their entire careers as members of Air Force Space Command.

The benefits of making a separate Space Force are myriad. First, there would be institutional efficiencies gained. Today there are space forces in the Army, Navy, and Air Force, as well as intelligence agencies. Combining many of them into a Space Force would reduce duplication. It would also allow “the right hand to talk to the left hand,” knocking down bureaucratic barriers inherent when multiple government agencies – each with its own chain of command and institutional self-interests – are forced to work together. The taxpayer would get more value for his or her tax dollar, and our joint forces would have a better integrated space component.

There are several missions that should be consolidated in the Space Force. Launch and satellite operations should be included along with land-based ICBMs and missile defense forces. The seaborne components of these functions should remain with the Navy and airborne components with the Air Force, but the overall mission of missile defense should be integrated and led by the Space Force. The guiding principle should be if something needs to be launched to, intercepted or operated in, or returned from space, then the Space Force should be the lead.

The Space Platforms & Hypersonic Technologies Taxonomy

Govini’s Space Platforms & Hypersonic Technologies Taxonomy provides very unique insights into these multi-billion dollar markets. The analysis synthesizes a tremendous amount of Federal unclassified contracting, grants, and international patent data into useful information that provides a deeper understanding of the space economy and Hypersonic Technologies. The unique approach and market classification allows stakeholders to analyze the last seven years since the final Space Shuttle launch to help assess the trajectory of Space-based Platforms and Hypersonic Technologies. It also helps interested parties understand the importance of intellectual property trends vis-à-vis near peers.

Although so much has changed in the past five years, I believe that the near future will change even more for the military, civil, and private sectors. As we approach the fiftieth anniversary of Apollo 11 I am certain we will hear complaints about how we have not returned to the moon, and I am hopeful this frustration can be channeled to make the next 50 years even more exciting than the last.

The space sector is in an era of unprecedented transition since the dawn of the space-age. The twentieth century paradigm of government-funded large programs driving space innovation and momentum is being shifted toward a radically different era of private sector innovation driving the future of space exploration and operations. It is an exciting time to be in the aerospace business, and our government leaders need to take notice, understand, and adapt if we are to maintain our status as world-leader in space.

Check Six.

SPACE PLATFORMS & HYPERSONIC TECHNOLOGIES TAXONOMY

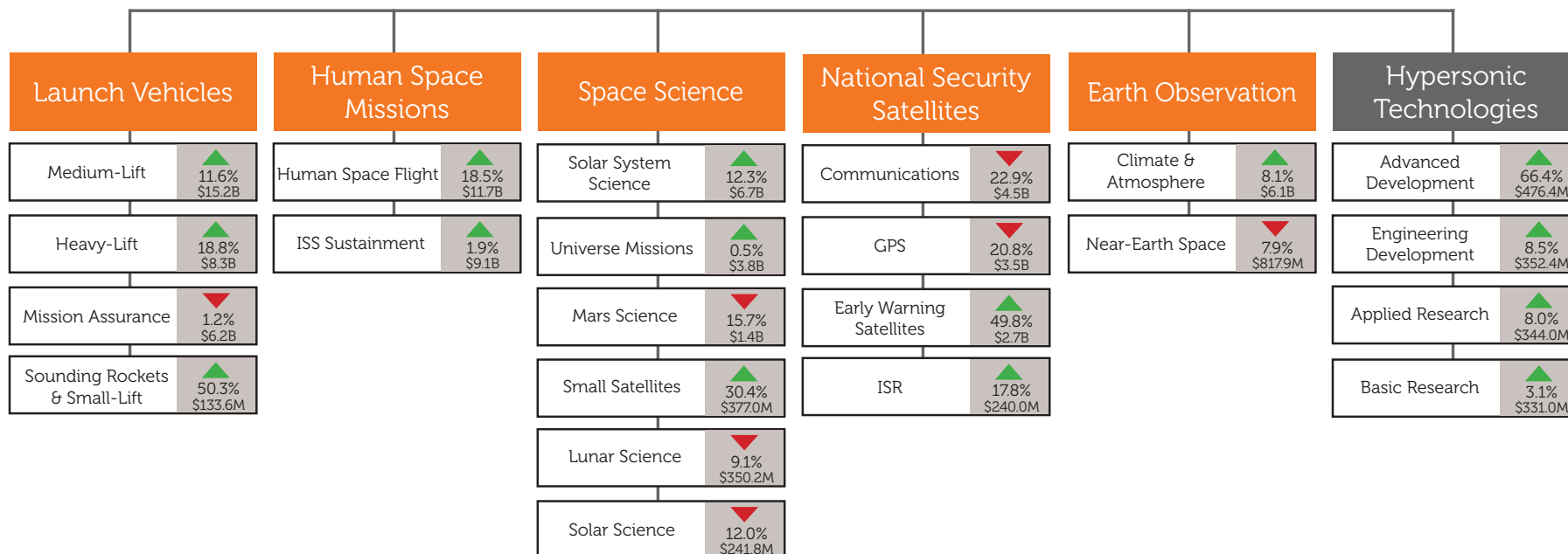


Exhibit 1: Govini's Space Platforms and Hypersonic Technologies Taxonomy consists of five Space Platforms markets (orange boxes) and one Hypersonic Technologies market (gray box) that broadly define Federal Space and Hypersonic applications. Beneath these markets are 22 sub-segments (white boxes) that constitute specific mission areas. This organizing structure is designed to deliver insights ranging from high-level spending trends to more granular details on individual programs. FY11 through FY17 spending and the corresponding seven-year compound annual growth rate (CAGR) are noted for each sub-segment.

INTRODUCTION

Since the last launch by the Space Shuttle program in July 2011, the Space Platforms and Hypersonic Technologies markets have been in transition as stakeholders vie to accomplish a wide array of missions. The Federal government helped shape these markets by leveraging contracts for specific missions and capabilities as well as issuing grants to augment and advance technological capabilities. Private enterprise and academic consortiums used these to help power their research and deliver new products. Each contributed to the robust and evolving Space Platforms and Hypersonic Technologies markets today.

This analytic report explores the market trends and competitive landscape within the \$83.0 billion Space Platforms and Hypersonic Technologies markets from FY11 through FY17. It includes a proprietary dataset of unclassified Federal contract obligations from this time period that is organized into a clear taxonomical structure. The structure was defined by examining multiple data sets across current and past Space and Hypersonic Technologies missions. Grants and international patents data were also analyzed to better understand the nature of core science and research within these markets.

Key Findings

- Federal contract obligations for Space Platforms and Hypersonics totaled \$83 billion and collectively grew at a 5.7 percent CAGR from FY11 through FY17
- Lockheed Martin (18.2 percent), United Launch Alliance (ULA) – a joint venture between Lockheed Martin and Boeing – (17.6 percent), and Boeing (14.3 percent) captured more than half of all Space Platforms and Hypersonic Technologies contract obligations
- Launch Vehicles market spending was 36 percent of all Space Platforms and Hypersonic Technologies spending from FY11 through FY17 and accounted for \$29.9 billion of the total market
- The largest market sub-segment was Medium-Lift Launch Vehicles, which accounted for 18.4 percent of all spending from FY11 through FY17, and the fastest growing market sub-segment was Advanced Development in the Hypersonics Technologies market with a 66.4 percent CAGR
- The Sounding Rockets & Small-Lift and Small Satellites market sub-segments grew by 50 percent and 30 percent CAGRs respectively, reflecting the increased interest in small-sized Space and lift technologies
- Five new companies became top-15 vendors between FY11 and FY17, SpaceX, United Technologies, Harris, SGT, and Raytheon
- Larger more mature markets, such as Launch Vehicles and Human Space Missions, tend to be more concentrated among the top vendors, which is indicative of barriers to entry, how mature the market is, and where within the product development lifecycle dependent components reside
- NASA and Air Force were the primary funding agencies for the Space Platforms and Hypersonic Technologies markets
- Global stakeholders are filing more Space Platforms and Hypersonic Technologies patent applications to protect their intellectual property (IP) in China, which suggests the country's markets are growing in importance

Medium-Lift is the Largest Sub-Segment Across All Markets

The combined Space Platforms and Hypersonic Technologies markets has grown at a 5.6 percent CAGR since FY11, and each market and sub-segment exhibited different trends. The largest sub-segment over this time period was Medium-Lift with a total size of \$14.8 billion in obligations while the fastest growing sub-segment was Advanced Development within the Hypersonic Technologies market with a 66.4 percent CAGR.

The Medium Lift sub-segment was the largest of the 22 individual markets analyzed and buoyed the \$29.9 billion Launch Vehicles market. The market sub-segment also grew at a CAGR of 11.6 percent from FY11 through FY17 compared to a CAGR of 10.7 percent for the overall Launch Vehicles market. Federal unclassified investments in the Medium-Lift sub-segment were largely tied to satellite deliveries using the ULA Evolved Expendable Launch Vehicle (EELV) family of rockets.

The Advanced Development sub-segment within the Hypersonic Technologies market grew at the fastest rate among all sub-segments. Although it is relatively small compared to peer sub-segments, the high year-over-year growth for Advanced Development signals that technologies are nearing final engineering and development, which indicates growing maturity.

The second-largest individual sub-segment was Human Space Flight, which grew at a 18.5 percent CAGR over the time period. Obligations for the sub-segment totaled \$11.6 billion, and the market was a clear priority. Spending on Human Space Flight outpaced growth in Medium-Lift technologies and are critical for accomplishing NASA's manned mission goals.

Space Platforms & Hypersonic Technologies Markets

- Launch Vehicles
- Space Science
- Earth Observation
- Human Space Missions
- National Security Satellites
- Hypersonic Technologies

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

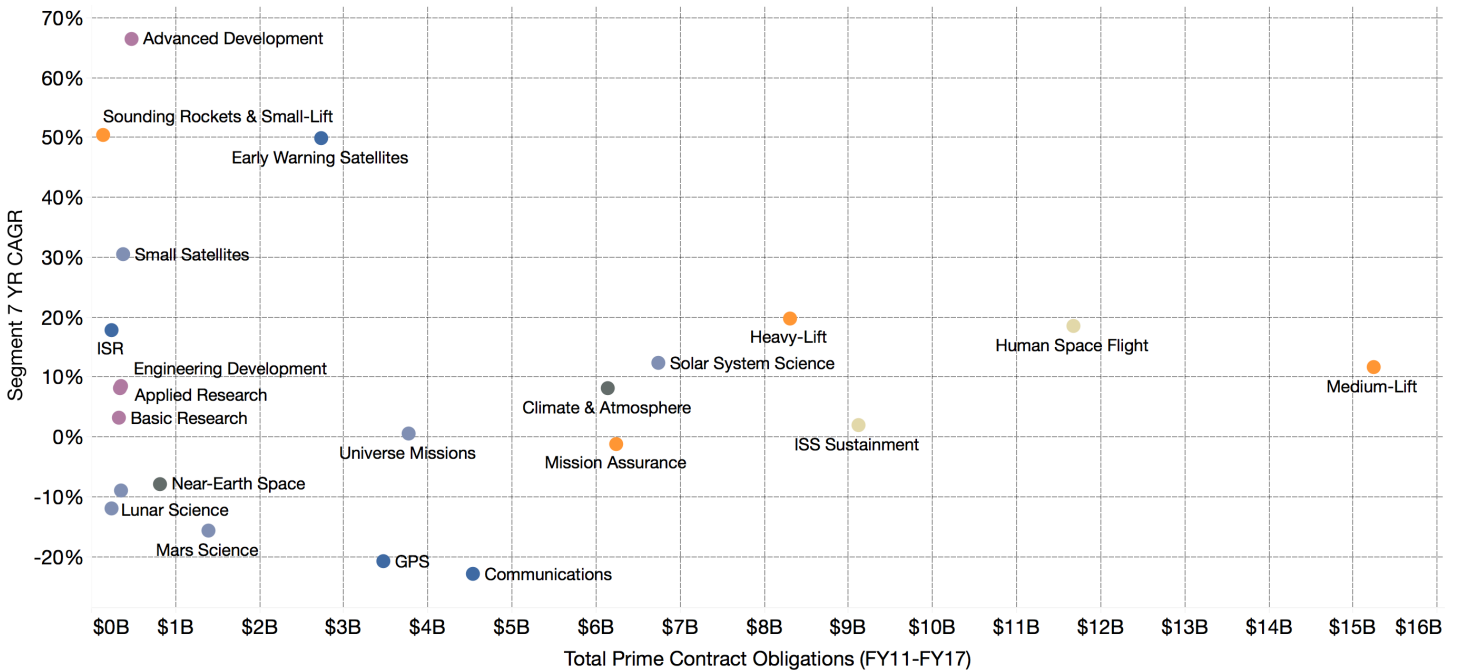


Exhibit 2: The Medium-Lift sub-segment within the Launch Vehicles market was the largest from FY11 through FY17 with more than \$15 billion in obligations. Although relatively small in terms of overall contract obligations, the fastest growing sub-segments over the same time period were Hypersonic Technologies Advanced Development, Sounding Rockets & Small-Lift, and Early Warning Satellites.

Lockheed Martin and Boeing Capture Half of the Space Platforms Market

Federal spending on Space Platforms and Hypersonic Technologies increased year-over-year from FY11 through FY17, outside of a small decrease in FY15. This was mainly caused by a decrease in National Security Satellites contracts for Wideband Global SATCOM (WGS), as well as GEO-5 and GEO-6 of the Space Based Infrared System (SBIRS).

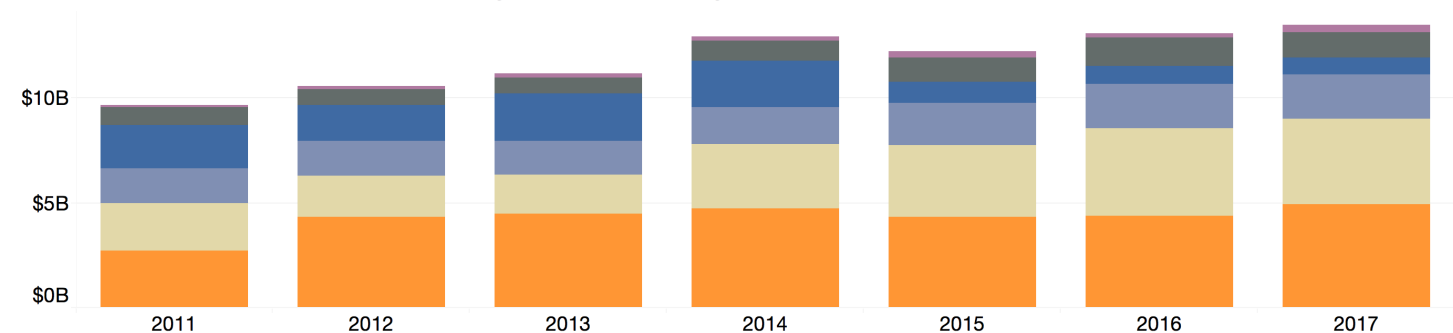
Three companies captured half of the \$83.0 billion total Space Platforms and Hypersonic Technologies markets from FY11 through FY17. Lockheed Martin led with 18.2 percent, followed closely by ULA – a joint venture between Lockheed Martin and Boeing – with 17.6 percent, and Boeing with 14.3 percent.

The growth and size of the two largest markets, Launch Vehicles and Human Space Missions, contributed to the emergence of new or combined companies within them. SpaceX, which was founded in 2002 and began performing Commercial Orbital Transportation Services in 2005, emerged as the third largest company by contract capture in the Human Space Missions market. The company's Falcon 9 rocket will continue to play an increasingly important role in this market and adjacent ones, such as satellite delivery within Medium-Lift, as it aims to increase launch efficiencies. Additional "New Space" vendors, such as Blue Origin and Virgin Galactic, may yet emerge as significant players within Launch Vehicles and Human Space Missions markets as their offerings become increasingly more viable. In November 2017, Orbital ATK's shareholders agreed to the company's acquisition by Northrop Grumman, creating a combined company with complementary market competencies.

Space Platforms & Hypersonic Technologies Markets

- Launch Vehicles
- Space Science
- Earth Observation
- Human Space Missions
- National Security Satellites
- Hypersonic Technologies

Space Platforms & Hypersonic Technologies Contract Obligations by Market



Space Platforms & Hypersonic Technologies Vendor Landscape by Market

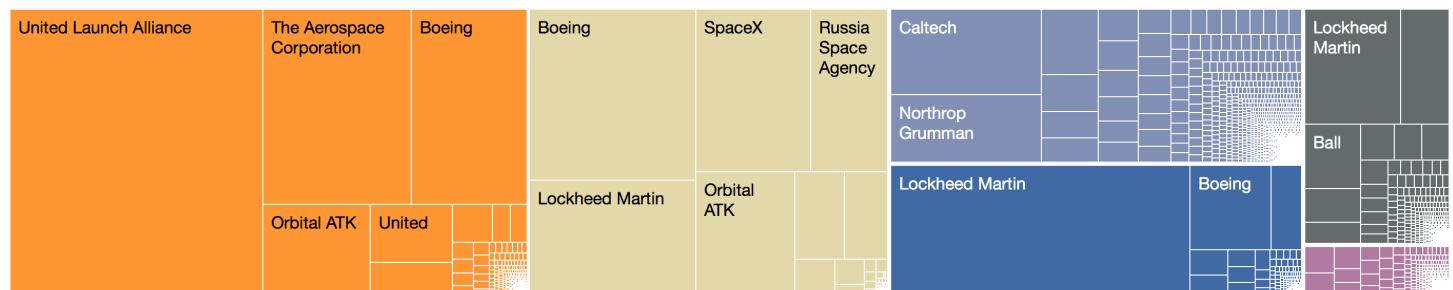


Exhibit 3: The overall Space and Hypersonics Technologies markets grew between FY11 and FY17 at a CAGR of 5.6 percent. The largest vendors continue to control a significant portion of each market segment, and they continue to grow and change. For instance, Northrop Grumman announced its \$9.2 billion acquisition of Orbital ATK in September 2017, and Orbital ATK itself was formed by the \$5 billion merger of Orbital Sciences Corp. and Alliant Techsystems (ATK), which was finalized in early 2015.

Medium-Lift Technologies are the Backbone of the Launch Vehicles Market

The Launch Vehicles market was the largest within the Space Platforms and Hypersonic Technologies markets from FY11 through FY17. In total, \$29.7 billion dollars were obligated to rockets used for Department of Defense (DoD) and NASA satellite deliveries and future lift capabilities. Within this market, Medium-Lift technologies were the largest spending area and accounted for \$15.2 billion in obligations over the same time period.

Medium-Lift launch vehicles were the preferred launch capability for Federal satellite deliveries and grew at a 11.6 percent CAGR over the seven-year period. Heavy-Lift capabilities follow in contract obligations with \$8.3 billion and had a seven-year CAGR of 19.8 percent. The strong growth in Heavy-Lift technologies was attributed to NASA's Space Launch System (SLS), which is set to carry the Orion Module and deliver other critical space assets. Mission Assurance services contracts, which include independent third party stress testing, declined at a -1.2 percent CAGR over the same time period and obligations totaled \$6.2 billion.

The Sounding Rockets & Small-Lift segment grew the most within the market with a 50.3 percent CAGR despite remaining a relatively small sub-segment with \$133 million in spending from FY11 through FY17. These technologies enable accelerated launch schedules for specialized scientific missions previously accomplished by bundling payloads aboard medium-lift platforms with restrictive launch timelines.

Launch Vehicles Segments

- Medium-Lift
- Heavy-Lift
- Mission Assurance
- Sounding Rockets & Small-Lift

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

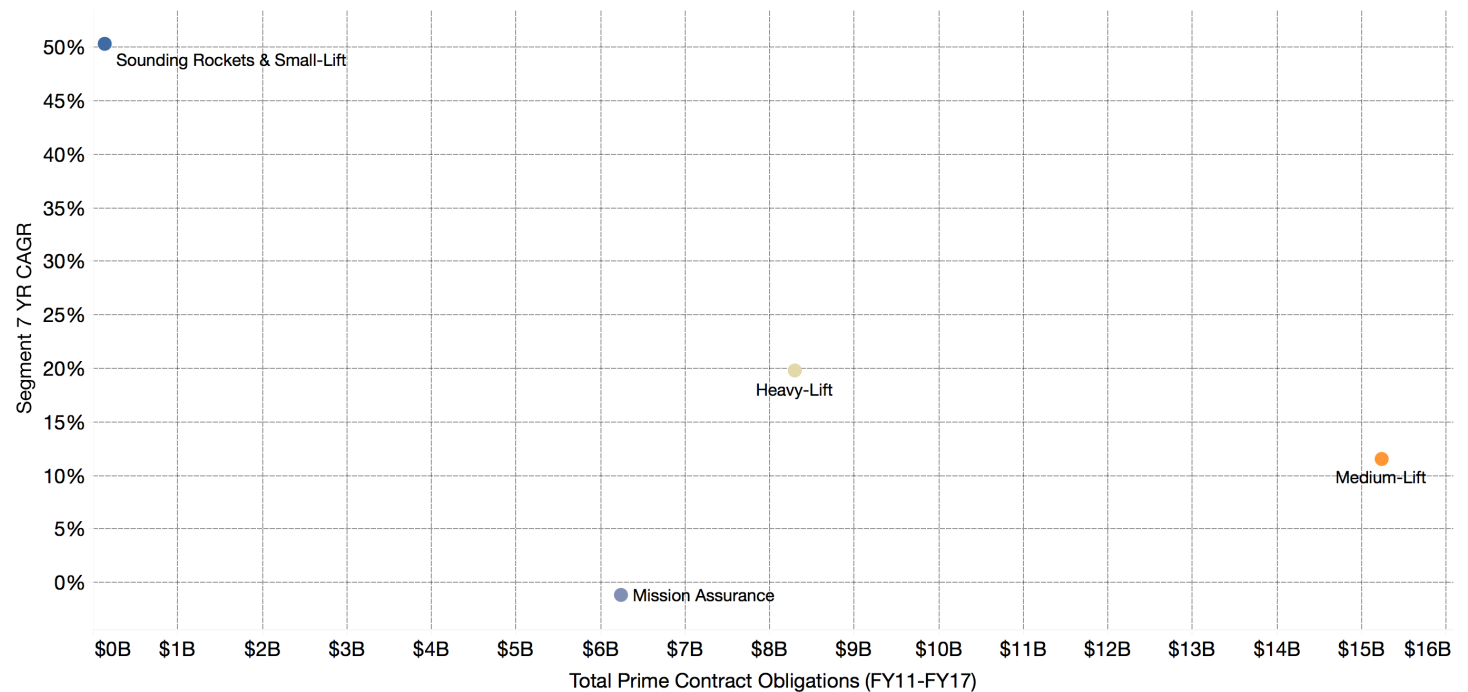


Exhibit 4: The Launch Vehicles market totaled \$29.9 billion over the seven-year period. The Medium-Lift sub-segment accounted for \$15.2 billion of the market. Sounding Rockets & Small-Lift technologies were small at \$133 million but experienced the most growth in the market with a 50.3 percent CAGR.

United Launch Alliance (ULA) is the Vendor of Choice for Delivering Space Platforms

The Launch Vehicles market experienced a major increase in obligations during FY12, and this was caused by a 59.7 percent increases in the ULA EELV program, which includes the Ares V and Delta IV rockets. Over the last seven years, ULA was the clear market leader with 48.9 percent of the total market share.

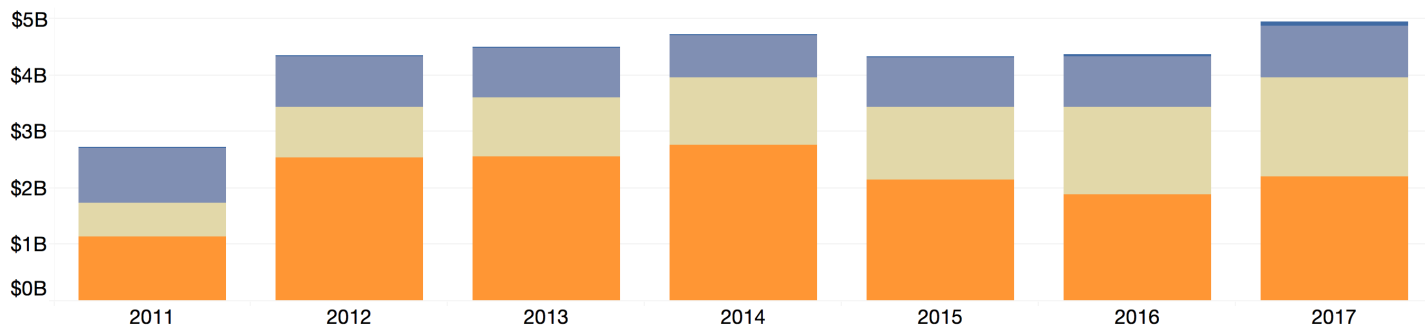
Heavy-Lift capabilities were the second largest Launch Vehicles sub-segment with contract obligations totaling \$8.3 billion from FY11 through FY17. The Heavy-Lift sub-segment was led by Boeing and Orbital ATK for their developments on the SLS. The Heavy-Lift market is expected to become increasingly more competitive as ULA develops its heavy-capacity Vulcan rocket potentially powered by Blue Origin’s BE-4 engine by the mid-2020s. Another critical development within the sub-segment is the continued maturation of SpaceX’s Falcon Heavy system, which completed its maiden flight on February 6, 2018.

The relatively small Sounding Rockets & Small-Lift sub-segment experienced significant growth during the FY11 through FY17 time frame. This growth was attributed to the NASA Sounding Rocket Operations Contract with Orbital ATK. Outside Orbital ATK, universities make up 28.2 percent of the \$134 million Sounding Rockets & Small-Lift sub-segment.

Launch Vehicles Segments

■ Medium-Lift
 ■ Heavy-Lift
 ■ Mission Assurance
 ■ Sounding Rockets & Small-Lift

Launch Vehicles Annual Contract Obligations



Launch Vehicles Vendor Landscape

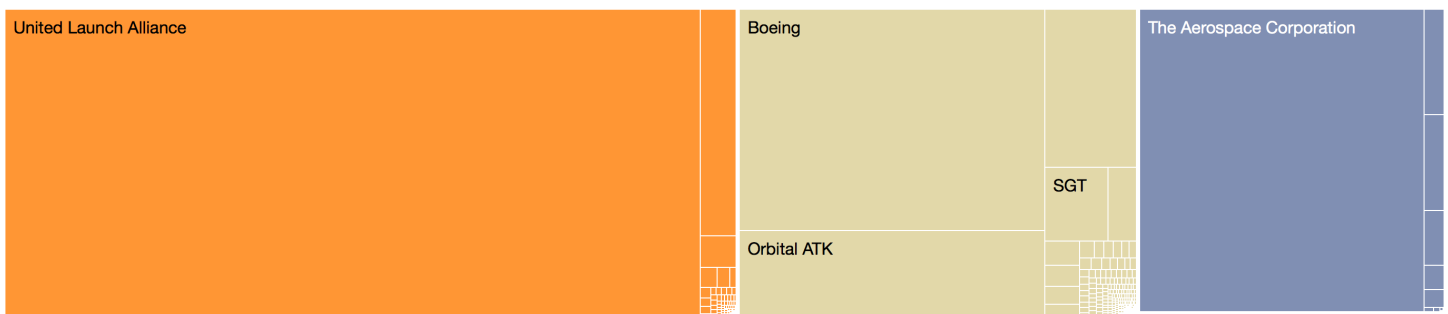


Exhibit 5: ULA was the lead vendor in the Launch Vehicles market capturing \$14.6 billion in FY11 through FY17 driven by their performance in the Medium-Lift segment. The Heavy-Lift sub-segment saw significant growth at a 19.8 percent CAGR attributed largely toward developments of the Space Launch System (SLS).

Human Space Flight Capabilities are the Spending Priority for Future Space Missions

Sending humans to explore the Moon, Mars, and deep space remains a priority mission for NASA, and the technologies required to accomplish these missions saw increased investment over the past four years. To that end, NASA invested \$20.8 billion on technologies needed to facilitate manned-missions planned for the 2020s and beyond.

Investments in Human Space Flight was the second largest sub-segment in the Space Platforms and Hypersonic Technologies markets from FY11 through FY17, totaling \$11.7 billion and growing by a 18.5 percent CAGR. NASA continues to make developments on Exploration Mission (EM) 1 and 2 for the Orion spacecraft, which aims to establish an orbiting station around the Moon. These missions will continue to be a priority spending area as NASA aims to complete the Orion and Commercial Crew Program in the 2020s.

International Space Station (ISS) Sustainment contracts represent the second sub-segment in the Human Space Missions market. The ISS Sustainment sub-segment consists of launches and payloads needed to maintain and resupply the International Space Station. Contract obligations for the sub-segment totaled \$9.1 billion from FY11 through FY17 and grew at a 1.9 percent CAGR. Spending within the sub-segment remained fairly stable but may be poised for a shake-up as the Trump Administration proposed ending Federal funding for the ISS mission and transitioning it toward privatization by the mid 2020s.

Human Space Missions Segments

■ Human Space Flight ■ ISS Sustainment

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

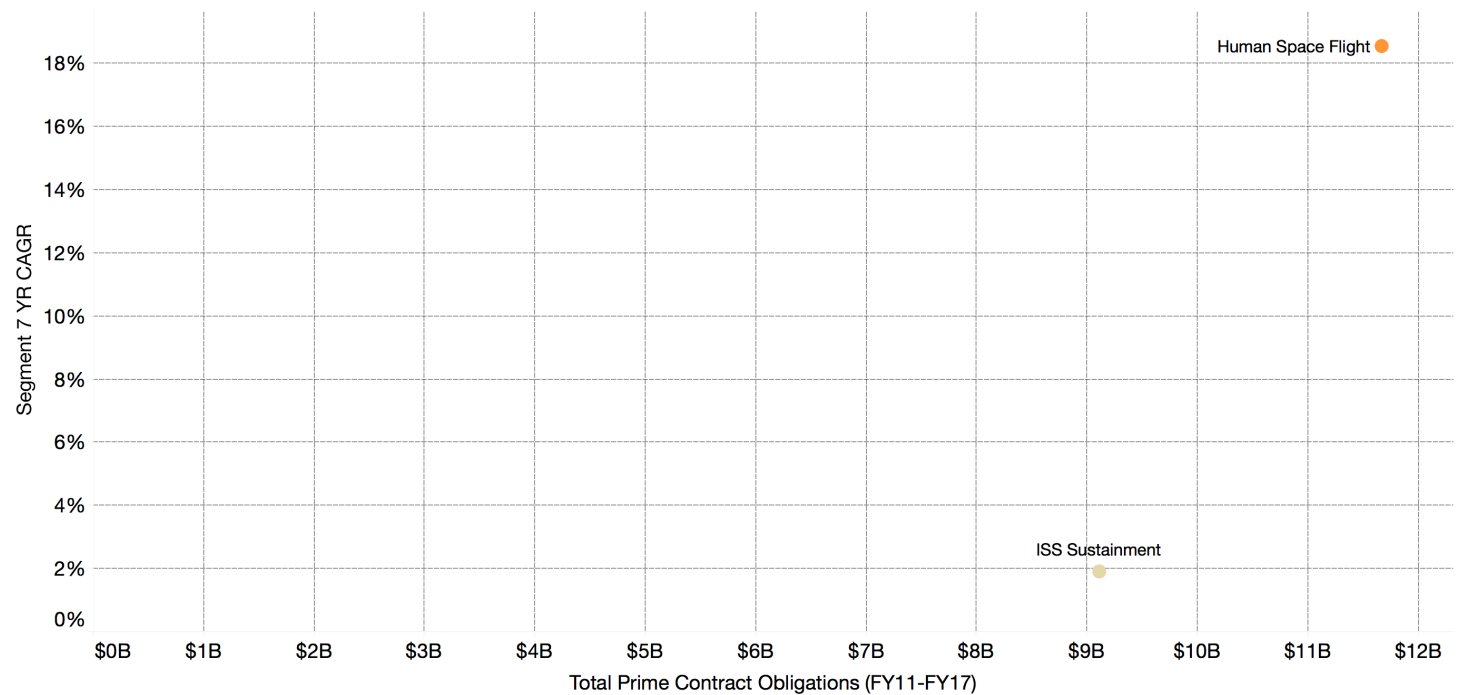


Exhibit 6: The Human Space Missions market totaled \$20.8 billion in FY11 through FY17. Growth in the market was mostly tied to advancements in the Human Space Flight sub-segment which grew at a 18.5 percent CAGR over the seven-year period. ISS Sustainment contracts remained stable at a 1.9 percent CAGR.

Human Space Missions will be Centered around Four Key Companies

NASA made major investments in manned-missions over the examined time period. The Human Space Missions market experienced its largest increase in contract obligations in FY14, with an increase in obligations toward the Orion spacecraft and the Commercial Crew Program. These programs, coupled with additional Human Space Flight efforts between NASA and the Russia Space Agency, indicate the importance of future manned missions for the Federal government. The total Human Space Missions market grew at a 10.4 percent CAGR from FY11 through FY17, and topline spending more than doubled since FY13.

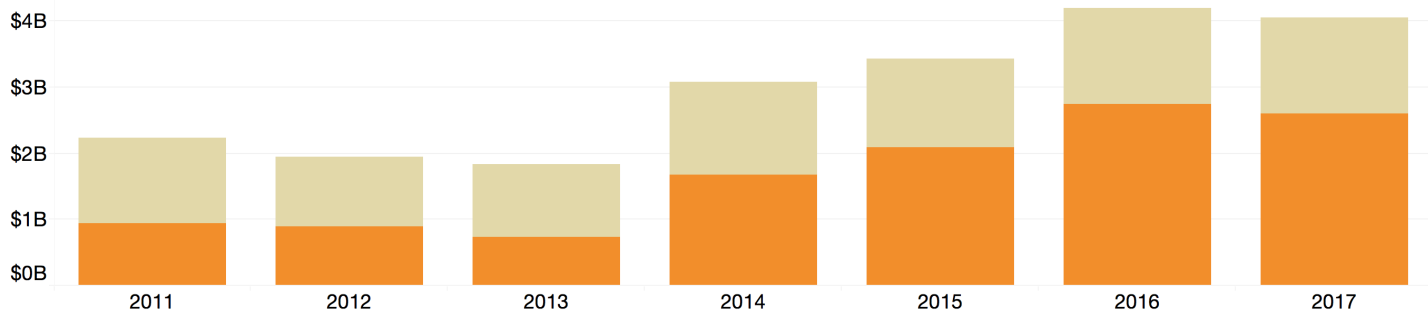
Lockheed Martin’s Orion spacecraft is one of the keys to future Human Space Missions. The spacecraft will be the primary platform for transporting astronauts beyond lower earth orbit, to the Moon, and eventually to asteroids and Mars. Orion’s second flight, EM-1, is scheduled to launch in November 2018 and will also serve as the maiden flight for the Space Launch System. The manned EM-2 will follow and is set to launch in 2023.

Boeing, SpaceX, and Orbital ATK have also captured significant portions the Human Space Missions. Both Boeing and SpaceX were bolstered by their Commercial Crew Program in the Human Space Flight sub-segment and their ISS Sustainment contracts. Boeing remains the incumbent vendor for sustaining and upgrading the ISS while Orbital ATK awards are concentrated within ISS resupply missions, a program it share duties with SpaceX.

Human Space Missions Segments

■ Human Space Flight ■ ISS Sustainment

Human Space Missions Annual Contract Obligations



Human Space Missions Vendor Landscape

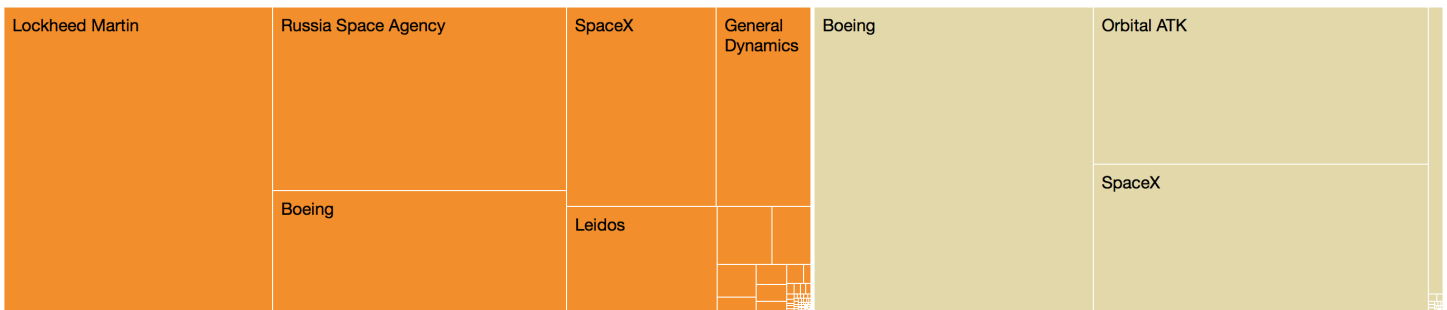


Exhibit 7: Boeing was the lead vendor across the the Human Space Missions market bolstered by their ISS Sustainment contracts and developments on the Commercial Crew Program. Lockheed Martin led the Human Space Flight sub-segment bolstered by their development of the Orion spacecraft. SpaceX is the only other vendor besides Boeing with a significant foothold in the Human Space Missions market where they have completed ISS resupply missions as well as made developments on the Commercial Crew Program.

Space Science is Focused on Studying Celestial Bodies Within the Solar System

The Space Science market totaled \$12.9 billion from FY11 through FY17. The market includes satellites, spacecraft, and instrumentation designed to study a variety of astronomical topics. The Solar System Science sub-segment is the largest in the Space Science market with contracts totaling \$6.7 billion from FY11 through FY17. Solar System Science includes contracts for developing scientific systems that study the celestial bodies within the solar system.

The second largest sub-segment in the Space Science market was Universe Missions. The sub-segment is comprised of spacecraft designed to study subjects beyond our solar system, including exoplanets, black holes, star systems, the interstellar medium, and other cosmic phenomena. Contracts for Universe Missions totaled \$3.8 billion over the seven-year period and remained stable with a 0.5 percent CAGR.

The Small Satellites sub-segment experienced the most growth in this market with a 30.4 percent CAGR. An increasingly technologically viable capability, the Small Satellites market includes developmental efforts to miniaturize satellite buses at scale. As agencies look to incorporate more commercial approaches into the scientific community, small satellites can bring cost efficiencies and increase the rate of innovation for scientific instruments in space.

Other sub-segments include Mars Science, Lunar Science, and Solar Science, which declined at -15.7 percent, -9.1 percent, and -11.9 percent CAGRs, respectively. As NASA became increasingly focused on crewed missions to the Moon and Mars since FY11, developments for long-distance robotic data-collecting systems, such as martian or lunar rovers, waned.

Space Science Segments

- Solar System Science
- Lunar Science
- Small Satellites
- Universe Missions
- Mars Science
- Solar Science

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

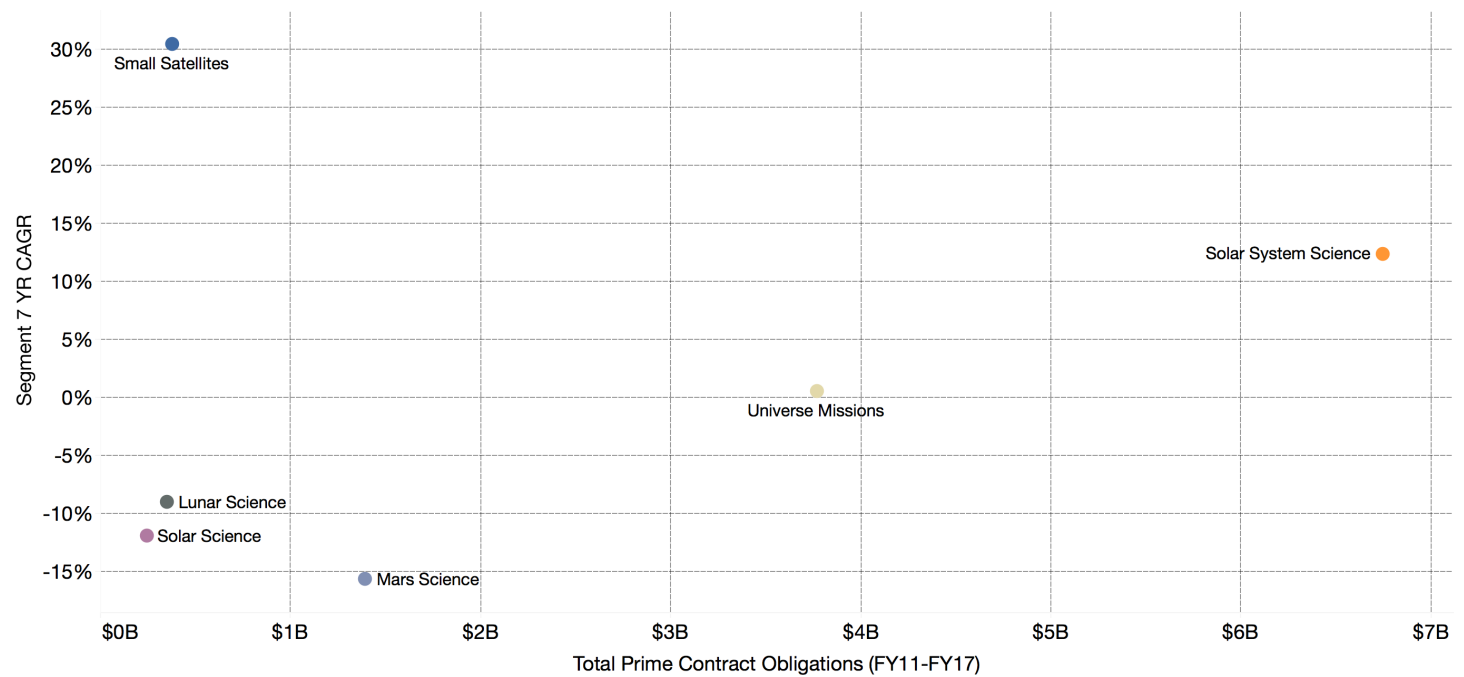


Exhibit 8: Solar System Science was the priority spending sub-segment in FY11 through FY17, accounting for \$6.7 billion out of the \$12.9 billion Space Science market. Small Satellites were the fastest growing sub-segment with a 30.4 percent CAGR, nearly ten times the market growth rate in percentage points.

The James Webb Space Telescope was the Largest Space Science Investment

Solar System Science programs were the priority sub-segment in the Space Science market. The Solar System Science sub-segment accounted for 52.4 percent of the total Space Science market from FY11 through FY17. Solar System Science awards included Lockheed Martin’s performance on the OSIRIS-REx mission to collect an asteroid sample and return it to Earth. Other notable projects included contracts for Europa Clipper and Juno to study several moons and characteristics of Jupiter.

Universe Missions were another important research area for NASA. Northrop Grumman led the market through the development of the James Webb Space Telescope (JWST), which was the single largest program in the Space Science market. JWST is the designated successor to the aging Hubble Space Telescope, and is designed to study the furthest limits of known-space. The launch of JWST has been beset by delays since its original planned launch in 2007 and remains delayed through 2020.

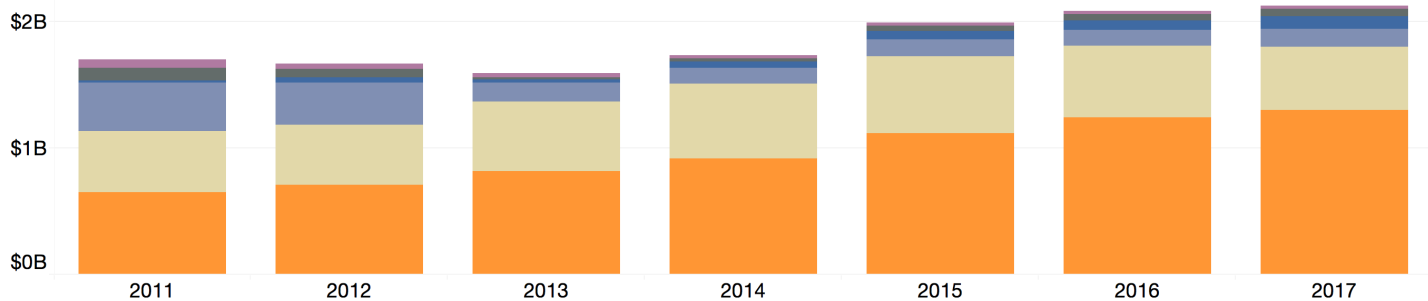
Aside from major NASA platforms, the fast-growing Small Satellites market yields an evolving vendor and agency landscape. Orbital ATK leads the market with the development of the STPSat-6, an experimental cubesat for the DoD Space Technology Program (STP). The STP aims to develop small satellites that will serve as testbeds for future defense space technologies.

Across the Space Science market the top vendor was the Jet Propulsion Laboratory at Caltech, which captured 20.6 percent of the market. A mainstay research laboratory for NASA, the portfolio of Caltech is comprised of the Europa Clipper, Juno, and Curiosity Rover missions. Moreover, the university was the lead vendor in half of the Space Sciences segments, and remains a critical component of NASA astronomical and cosmological studies.

Space Science Segments

- Solar System Science
- Mars Science
- Lunar Science
- Universe Missions
- Small Satellites
- Solar Science

Space Science Annual Contract Obligations



Space Science Vendor Landscape

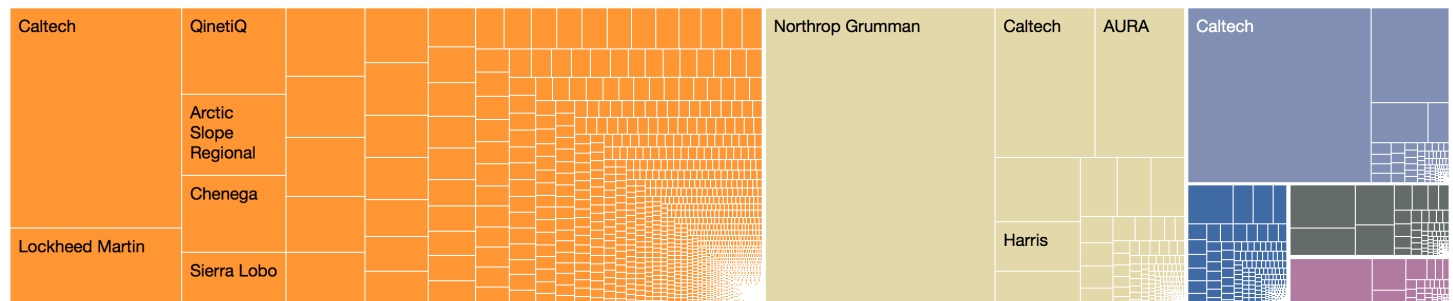


Exhibit 9: Caltech captured 20.6 percent of the total Space Science market. Other key players include Northrop Grumman in the Universe Missions sub-segment whose position is tied to their construction of the JWST.

Unclassified Obligations for National Security Satellites are Waning

National Security Satellites are fundamental assets for ensuring national security and almost entirely fall under the purview of the DoD. Govini taxonomized the market into four mission sub-segments, Communications, Global Positioning System (GPS), Intelligence Surveillance and Reconnaissance (ISR), and Early Warning Satellites. The total National Security Satellites market totaled \$10.9 billion from FY11 through FY17.

Early Warning Satellites experienced the most growth in the market during the seven years analyzed with a 49.8 percent CAGR and contract obligations totaling \$2.7 billion. Lockheed Martin’s SBIRS program drove the spending increase as the DoD invested in satellite constellations critical to enabling U.S. missile defense systems.

ISR was the smallest sub-segment in the market with \$239 million in unclassified contract obligations, and it grew at a 17.8 percent CAGR over the period. The relatively low amount of Federal spending is likely due to the highly-classified nature of many national security satellites. Unclassified data reflects only portions spending for the Space Based Space Surveillance (SBSS) mission, a recently launched system designed to monitor and track objects in Earth’s orbit.

The National Security Satellites market declined at a -14.3 percent CAGR from FY11 through FY17. This may be due to a shift toward classified launch and sustainment awards or an unclear mandate related to augmenting and replacing existing satellites. Communications satellites received \$4.5 billion during the time frame, the most obligations within the market, and had the largest decline in contracts over the seven-year period with a -22.9 percent CAGR. GPS satellites also declined significantly with a -20.8 percent CAGR.

National Security Satellites Segments

- Communications
- GPS
- Early Warning Satellites
- ISR

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

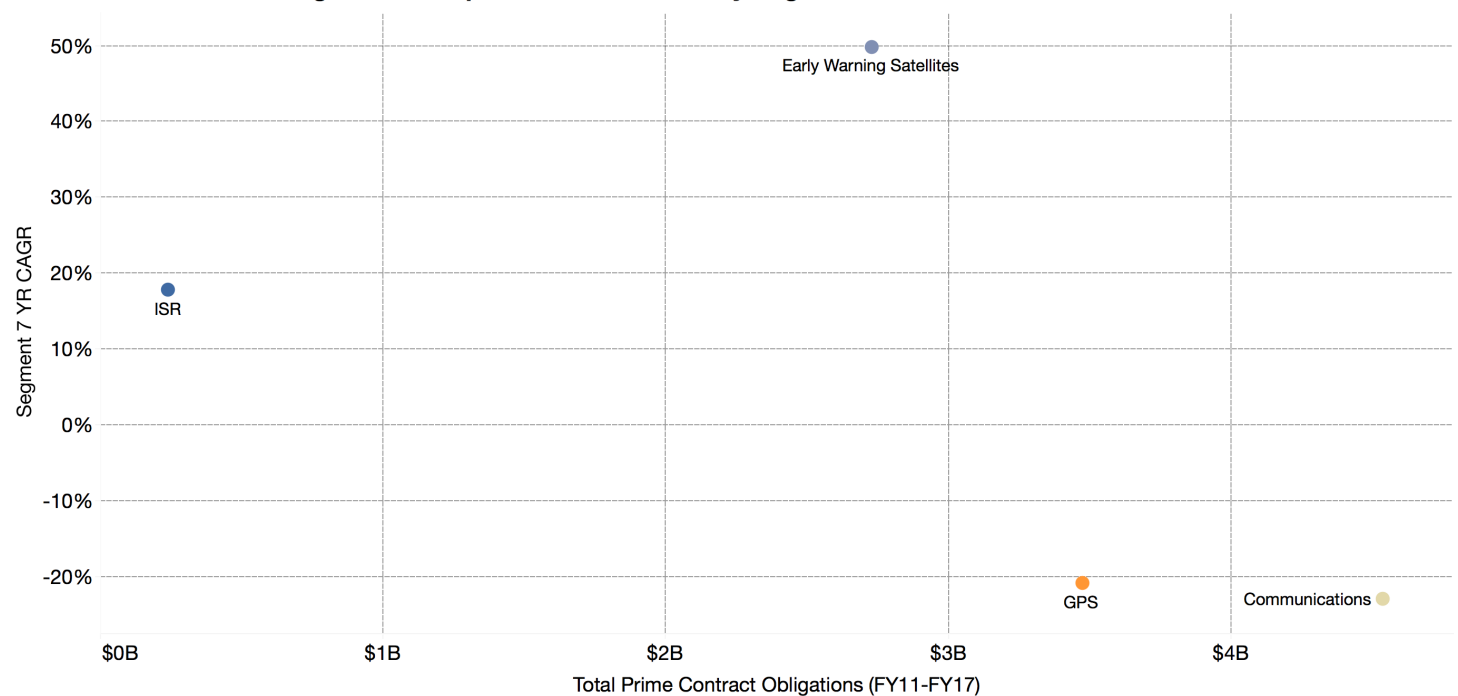


Exhibit 10: Out of the \$10.9 billion National Security Satellites market, the Communications sub-segment accounted for \$4.5 billion in obligations. The Communications sub-segment also experienced the strongest decline at a -22.9 percent. Early Warning Satellites saw the strongest growth over the time frame at a 49.8 percent CAGR.

Legacy Defense Satellites Will Require a New Approach To Replacement

The Communications sub-segment within the National Security Satellites market was the largest spending area at \$4.5 billion. Major communications programs include the Mobile User Objective System (MUOS), WGS, and Advanced Extremely High Frequency (AEHF) systems. Design and construction of these systems took place between FY11 and FY13 and was led by Lockheed Martin and Boeing. Final FY18 appropriations funded \$600 million for two new WGS satellites in addition to the Pentagon’s FY18 requests. The funds could disrupt any plans to shift toward a more commercial approach for satellite communications.

GPS satellites also experienced a sizeable decline in unclassified Federal contract obligations with a -20.8 percent CAGR from FY11 through FY17. The Federal government’s current constellation of GPS satellites consist of Block IIR, IIR-M, and IIF satellites manufactured by Lockheed Martin, which captured 94.4 percent of the GPS satellites market during the examined time frame.

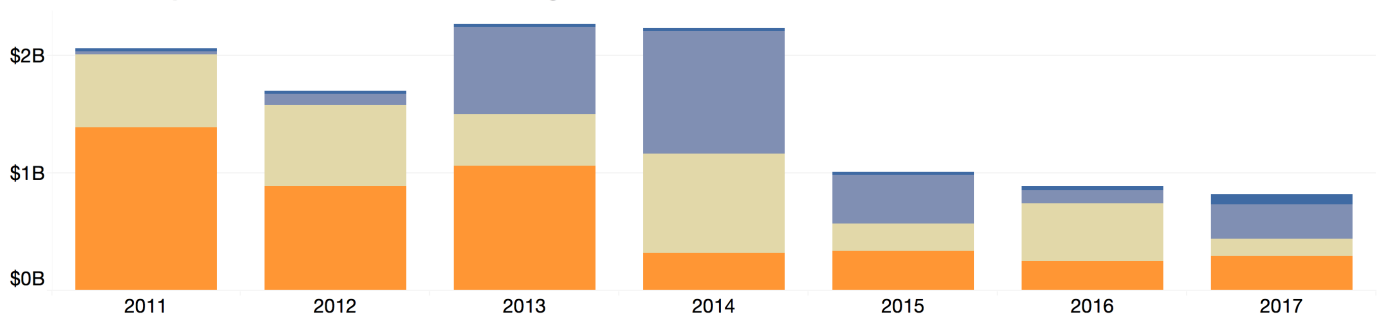
The Air Force already solicited the construction and launch of 22 more Block IIIIF satellites over the next five years in addition to the 12 planned Block IIIA satellites set to begin launching in May 2018. The expected 34 satellite Block III constellation will replace and augment the existing 31 Block II Lockheed satellites currently in orbit in an effort that could reverse declining contract spending for GPS satellites.

Obligations for Early Warning Satellites grew at a 49.8 percent CAGR, the most over the seven-year period. Growth was driven by development and sustainment contracts for Lockheed Martin’s SBIRS satellites. The increased spending in the Early Warning Satellites sub-segment is reflective of the costs of maintaining and augmenting the SBIRS program which totaled \$2.7 billion in Federal obligations from FY11 through FY17. Spending toward these contracts may be a topic of concern for DoD as it seeks newer, cheaper, and more resilient technologies across space operations.

National Security Satellites Segments

■ Communications
 ■ GPS
 ■ Early Warning Satellites
 ■ ISR

National Security Satellites Annual Contract Obligations



National Security Satellites Vendor Landscape

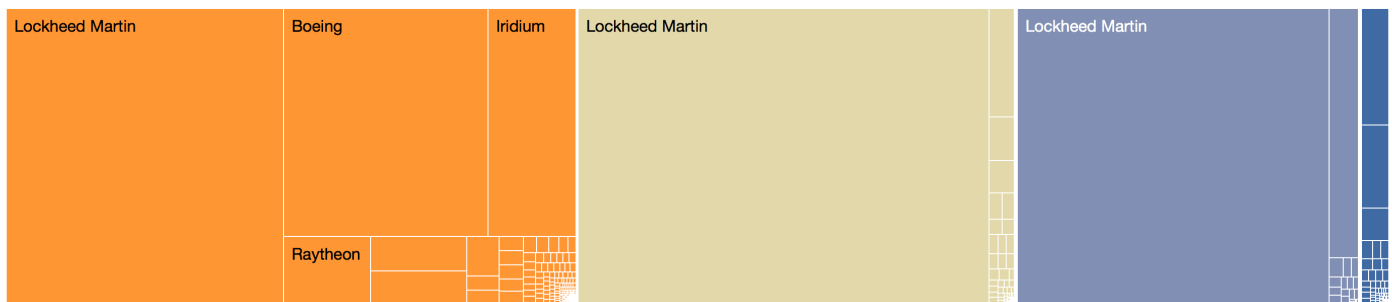


Exhibit 11: Lockheed Martin is the clear market leader in the National Security Satellite market capturing 72.7 percent of the market. Lockheed Martin’s development of key programs like AEHF, GPS blocks, and SBIRS have given the company a commanding position in the market. The declining market reflects DoD’s need for future platforms in order to accomplish their national security priorities.

Collecting More Robust Climate & Atmosphere Data is a Spending Priority

Earth Observation remains a key function for satellites and space instruments in efforts to further study the planet. The Earth Observation market totaled \$6.9 billion from FY11 through FY17 and is broken into two sub-segments, Climate & Atmosphere and Near-Earth Space.

Climate & Atmosphere satellites are designed to gather meteorological or topographical data and imagery of Earth. The data provided by these systems is crucial for national weather monitoring and forecasting. This sub-segment was the priority spending area in the Earth Observation market with contracts totaling \$6.1 billion from FY11 through FY17. The market grew at a 8.1 percent CAGR for the seven-year period reflecting the Federal government’s increased interest in enhancing the nation’s meteorological space assets.

Near-Earth Space Platforms observe interactions occurring in the outer regions of Earth’s gravitational field inclusive of the Magnetosphere, Ionosphere, Solar Wind, the Van Allen Belts, and other regions beyond the Karman Line. These spacecraft are important in advancing the scientific community’s understanding of the mechanics between Earth, Moon, and Sun interactions. This sub-segment had a lower amount of contract spending than the Climate & Atmosphere sub-segment with \$817 million over the seven-year period. Additionally, the sub-segment declined at a -7.9 percent CAGR over the same time period. The decline in spending implies an increasing prioritization of systems that aid in the direct study of Earth instead of those aiding the study of the space around it.

Earth Observation Segments

■ Climate & Atmosphere ■ Near-Earth Space

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

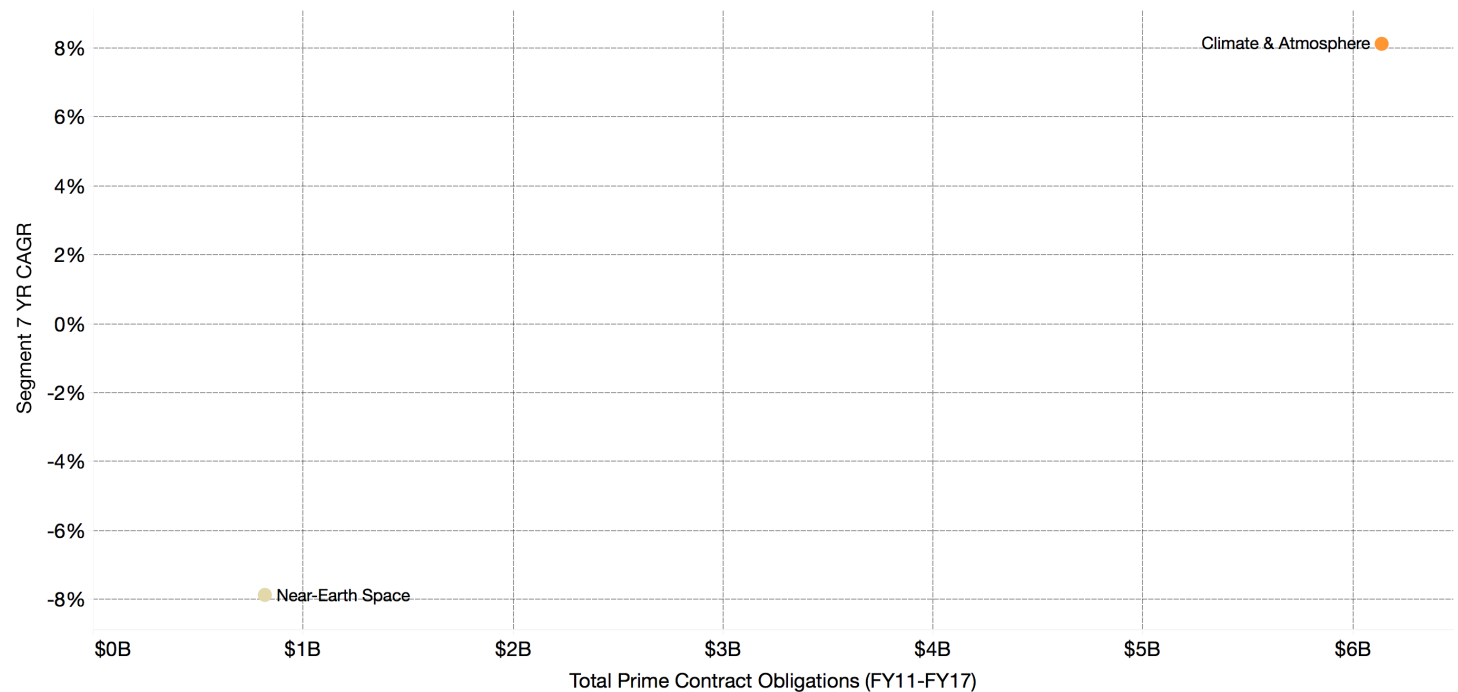


Exhibit 12: Climate & Atmosphere Space Platforms were the spending priority at \$6.1 billion in FY11 through FY17 within the \$6.9 billion Earth Observation market. The Climate & Atmosphere sub-segment also grew at a 8.1 percent CAGR over the seven-year period. Near-Earth Space contracts accounted for \$817 million in obligations and declined at a -7.9 percent CAGR.

The GOES System and JPSS are the Focal Point of Earth Observation Spending

Increased investments in climate and atmosphere programs drove growth in the Earth Observation market since FY14. The increased contract spending was targeted at several major Climate & Atmosphere sub-segment projects including the Geostationary Operational Environmental Satellite (GOES) system, Joint Polar Satellite System (JPSS) and its accompanying Ozone Mapping Profiler Suite (OMPS) instrument, the Gravity Recovery and Climate Experiment Follow-on (GRACE-FO), and the NASA ISRO Synthetic Aperture Radar (NISAR).

The majority of the increase was captured by Lockheed Martin to complete developments on the first satellite of the GOES-R mission, which launched in November of 2016. The advanced forecasting capabilities of the GOES-R system will be complemented by the Ball Aerospace and Northrop Grumman-designed JPSS, which is comprised of the Suomi NPP and NOAA-20 satellites. Other major Climate & Atmosphere projects included GRACE-FO and the Orbiting Carbon Observatory-2 (OCO-2), both of which were contracted through NASA’s Jet Propulsion Laboratory, a FFRDC operated by Caltech.

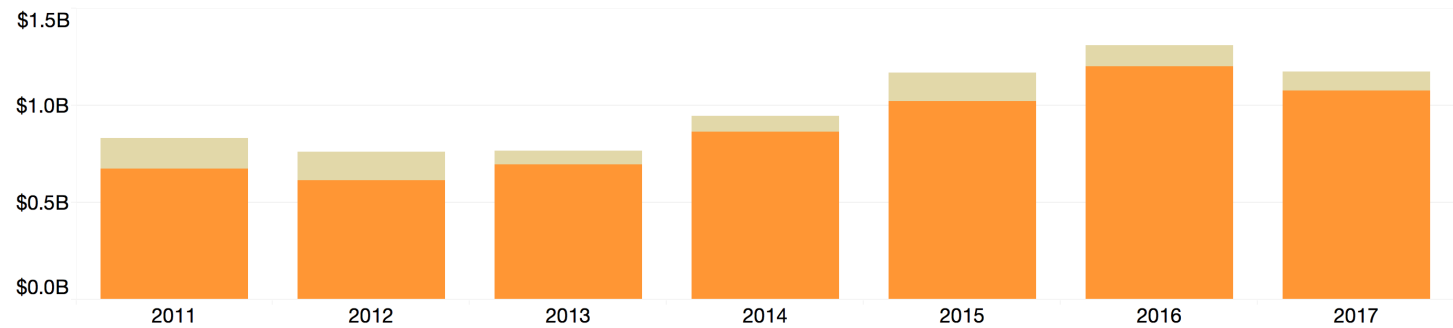
The University of California (UC) is the lead vendor for near-Earth space instrument development. UC served as the lead vendor for several major systems including the Ionospheric Connection Explorer (ICON) and the Time History of Events and Macroscale Interactions During Substorms (THEMIS).

Augmenting and replacing legacy Climate & Atmosphere observing platforms will continue to be the priority spending area in the Earth Observation market as the U.S. completes the GOES-R constellation to enhance its predictive weather and natural disaster capabilities.

Earth Observation Segments

■ Climate & Atmosphere ■ Near-Earth Space

Earth Observation Annual Contract Obligations



Earth Observation Vendor Landscape

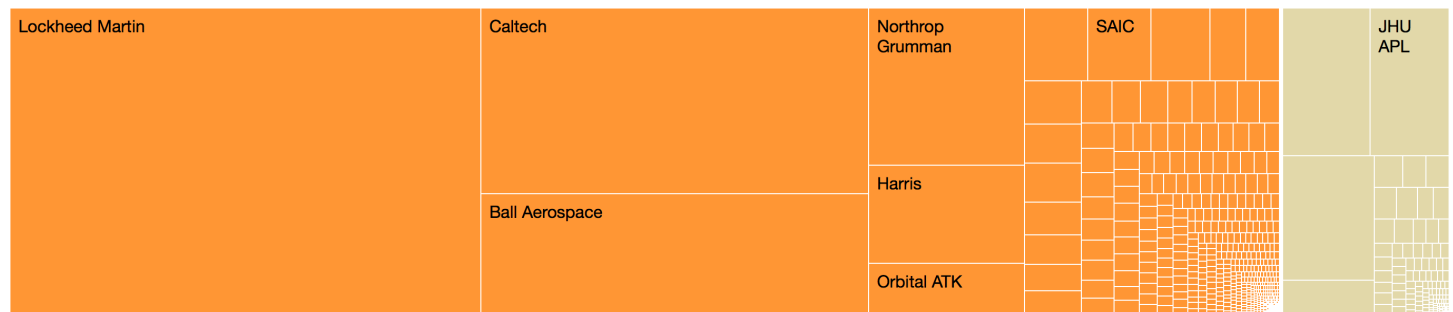


Exhibit 13: Lockheed Martin’s performance on the GOES-R system positioned the company as the top vendor in the total Earth Observation market. Other with notable programs in the growing Climate & Atmosphere sub-segment include Caltech’s GRACE-FO and Ball Aerospace and Northrop Grumman’s performance on the JPSS.

Hypersonic Technologies are Maturing from Concepts to Production-Ready Capabilities

Global development of Hypersonic Technologies garnered increased attention as near-peer competitors China and Russia move to bolster national interests. The Hypersonic Technologies market includes the development of new propulsion technologies, advanced materials, glide bodies, and hypersonic projectiles like electromagnetic railguns. The market is divided into four sub-segments that trace technologies from basic research to applied research then to advanced development and engineering development as Hypersonic Technologies mature into usable products.

Despite its high profile, Hypersonic Technologies have a relatively small footprint within unclassified contract obligations. The Hypersonics Technologies market totaled \$1.5 billion from FY11 through FY17, or 1.8 percent of the total Space Platforms and Hypersonic Technologies markets.

Obligations for Hypersonic Technologies increased significantly as they became more operationalized, resulting in a 17.9 percent CAGR from FY11 through FY17, the fastest growth rate of any market. Measured in phases of Research and Development (R&D), the Advanced Development sub-segment experienced the most growth with a 66.4 percent CAGR over the same period. As capabilities move from Basic Research to Applied Research to Advanced Development and finally to Engineering Development in the R&D lifecycle, they move closer to becoming production-ready. The growth in Advanced Development reflects the maturing nature and increasing prioritization of Hypersonic Technologies.

Hypersonic Technologies Segments

- Advanced Development
- Engineering Development
- Applied Research
- Basic Research

Total Prime Contract Obligations Compared to 7 YR CAGR by Segment

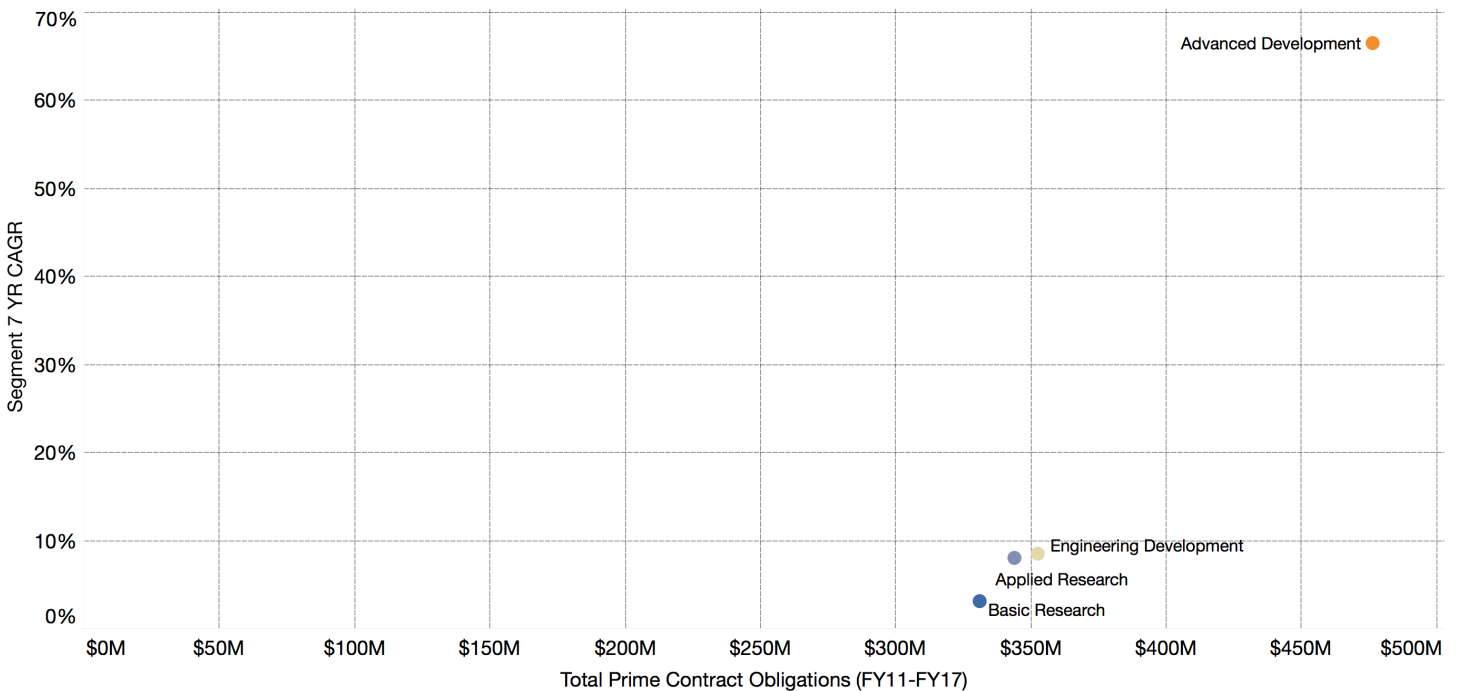


Exhibit 14: Advanced Development was the largest sub-segment at \$476 million in the \$1.5 billion Hypersonic Technologies market in FY11 - FY17. The sub-segment also experienced significant growth at a 66.4 percent CAGR as obligations towards the HAWC and TGB programs increased.

Advanced Development Growth in Hypersonic Technologies Accelerates Deployment

The Federal government used a diversified approach for its investments in the Hypersonic Technologies market relative to its Space Platforms market peers. Traditional aerospace integrators, propulsion technology companies, and universities are all present in the market and vendors are mainly entrenched within one specific phase of the R&D lifecycle.

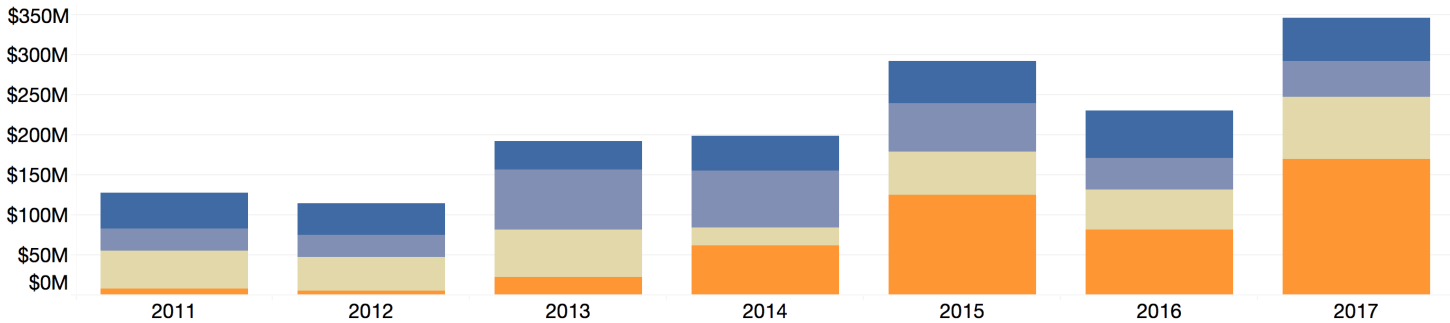
Engineering Development is the most advanced phase of the lifecycle so the most mature technologies exist within the sub-segment. It accounted for 23.4 percent of the market and grew at a 8.5 percent CAGR from FY11 through FY17. Engineering Development is comprised of electromagnetic railgun and booster technologies provided by traditional aerospace and defense contractors such as Johns Hopkins University Applied Physics Laboratory (JHU APL), Orbital ATK, and Northrop Grumman.

Advanced Development is the fastest growing sub-segment and also received the most Federal contract obligations. The sub-segment is home to near-mature future technologies, such as Raytheon and Lockheed Martin’s Hypersonic Air-Breathing Weapon (HAWC) and the Tactical Boost Glide (TBG), which accounted for most of the sub-segment’s spending. The two projects continued to serve as the primary platforms for advancing the nation’s portfolio of future hypersonic weapons and can be expected to continue to do so as they mature. Additionally, Lockheed’s recently awarded Quiet Supersonic Transport demonstration contract for NASA and the air-launched hypersonic strike weapon managed by Air Force mark substantial investments in hypersonic capabilities.

Hypersonic Technologies Segments

■ Advanced Development
 ■ Engineering Development
 ■ Applied Research
 ■ Basic Research

Hypersonic Technologies Annual Contract Obligations



Hypersonic Technologies Vendor Landscape

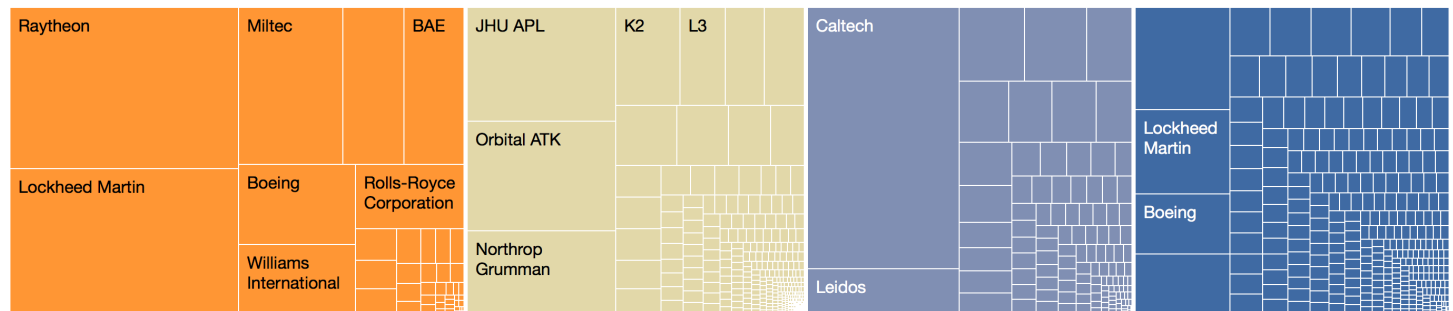


Exhibit 15: The Hypersonic Technologies competitive landscape is diverse with lead vendors including Raytheon, Lockheed Martin, JHU APL, Caltech, and other large research organizations and integrators. Advanced Development received the most obligations in the market at \$476 million where Raytheon and Lockheed Martin lead developments on the HAWC and TGB.

SpaceX Emerged as Top-Five Vendor in Last Seven Years

Several shifts among the top 15 vendors within the Space Platforms and Hypersonic Technologies markets occurred from FY11 through FY17. There was churn amongst the vendors as new companies entered and exited the market along with changes among the top five contractors.

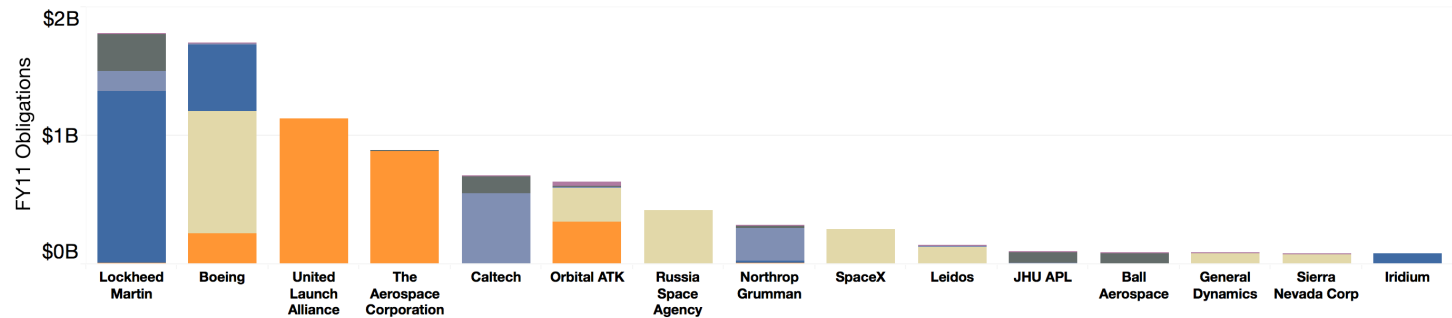
In total, five new companies became top 15 vendors between FY11 and FY17. SpaceX emerged as the fourth largest vendor in FY17 leading the wave of “New Space” vendors leveraging organic growth and disruptive technologies. Other more established vendors, such as United Technologies Corp, pivoted toward Federal Space Platform and Hypersonic Technology markets. UTC became a top-15 vendor in FY17 selling booster technology for NASA’s SLS. Raytheon became the only FY17 top-15 vendor by winning a majority of its obligations within the Hypersonic Technologies sub-market. The top-five landscape will undergo another significant change upon the finalization of Northrop Grumman’s acquisition of Orbital ATK which will give the combined entity a significant presence in scientific payload design and launch capabilities, including development of the Next Generation Launch rocket using Space Shuttle Solid Rocket Booster technology.

The top five vendors underwent several shifts in the seven years from FY11 through FY17. United Launch Alliance surpassed Boeing and became the top overall vendor by leveraging its Launch Vehicles technologies. Lockheed Martin diversified its Space Science and National Security Satellites focused portfolio in FY11 by supporting NASA’s Orion spacecraft program. SpaceX entered the top five by successfully developing technologies for ISS resupply mission and the Commercial Crew Program – areas with immense growth potential and applicability to other space markets.

Top 15 Vendors for Space Platforms & Hypersonic Technologies in FY11 vs. FY17

- Launch Vehicles
- Human Space Missions
- National Security Satellites
- Space Science
- Earth Observation
- Hypersonic Technologies

FY11 Top 15 Vendors



FY17 Top 15 Vendors

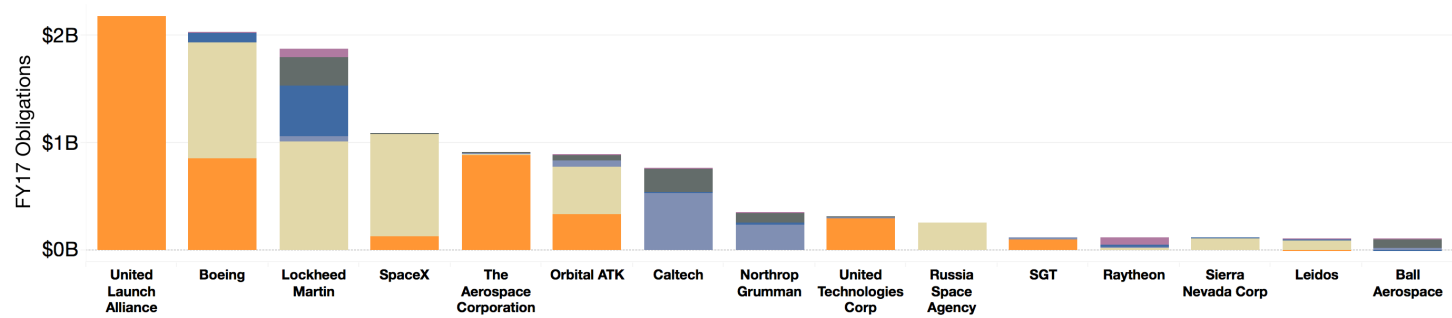


Exhibit 16: Between FY11 and FY17 there were five new entrants to the top vendor landscape within the Space Platforms and Hypersonic Technologies markets: SpaceX, United Technologies, Harris, SGT, and Raytheon. ULA became the largest vendor in FY17 by leveraging its Launch Vehicles technologies.

Vendor Fragmentation is Greater in Smaller Markets

Concentration within the Space Platforms and Hypersonic Technologies markets can provide clues for understanding the dynamics of each.

Larger more mature markets tend to be more concentrated among the top five vendors. Launch Vehicles, the largest market, has a high overall top-five vendor concentration. Human Space Missions, a similar and adjacent market, also has a high overall concentration. This may be because technological, regulatory, and financial barriers to entry prevent new entrants despite the fact that spending within both make them the number one and two overall markets. It could also be a sign that most market share growth occurs through mergers and acquisitions. National Security Satellites, a medium-sized market, is also very concentrated among the top five vendors, but Lockheed Martin alone captured 72.7 percent of all spending within it from FY11 through FY17. The emergence of SpaceX as a top competitor within the Launch Vehicles market is evidence that the availability of capital may provide enough incentive for new entrants to overcome barriers to entry.

The Space Science, Earth Observation, and Hypersonic Technology markets are much less concentrated among each market's top-five vendors by Federal unclassified contract obligations. This vendor fragmentation could be a sign that each market contains many firms focused on products within the early stages of development. Further, it may be reflective of the scientific community's continual need for new technologies to complete future missions that small innovators are well-positioned to provide.

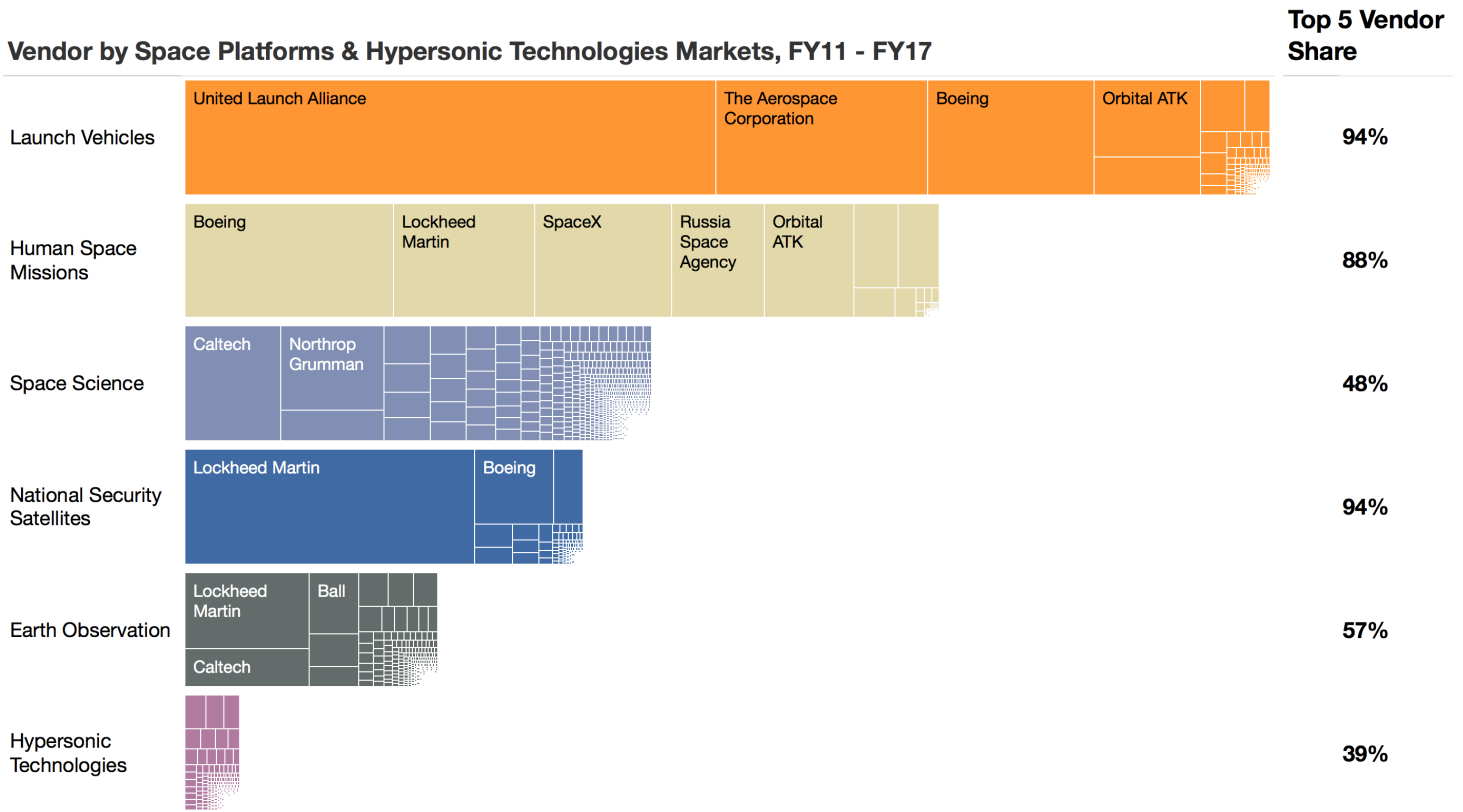


Exhibit 17: Market segments with greater amounts of Federal contract obligations tend to be more concentrated than smaller ones. Smaller segments tend to a more diversified landscape. Contributing factors could be barriers to entry and product maturity.

NASA and Air Force are Primary Funding Agencies for the Nation’s Space Operations

A majority of the Space Platforms and Hypersonic Technologies markets were funded by NASA and the Air Force from FY11 through FY17. Total NASA funding exceeded \$48.7 billion, or 58.7 percent of all obligations, and Air Force funding reached \$27.0 billion, or 32.6 percent of all obligations. Combined, the agencies represented more than 91 percent of all Space Platforms and Hypersonic Technologies contracts.

NASA funded nearly all of the Human Space Missions and Space Science markets and most of the Earth Observation market. Within each of these segments the agency had a positive CAGR from FY11 through FY17. NASA’s space priorities clearly lie within the Human Space Missions market where the agency is the sole funding entity. The future of NASA’s space capabilities will depend sending humans into reaches of space they have never been before.

The Air Force contributed \$18.6 billion toward the Launch Vehicles market sub-segment and \$7.6 billion toward the National Security Satellites market from FY11 through FY17, accounting for a majority of both. The significant drop in spending within the National Security Satellites market in FY15 can be mainly attributed to a reduction in Air Force obligations related to the WGS system and SBIRS.

Funding Agency

- NASA
- Air Force
- Defense-Wide Agencies
- NOAA
- Navy
- Army

Space Platforms & Hypersonic Technologies by Agency Funding

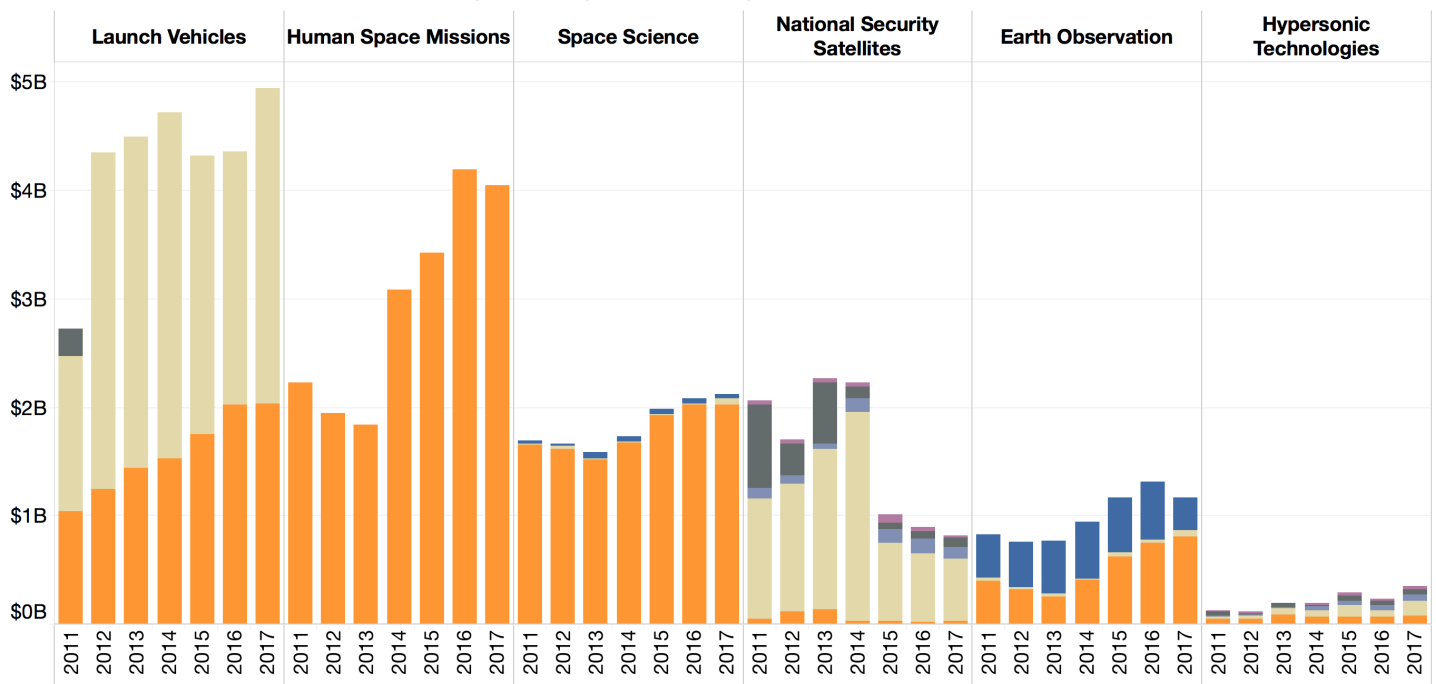


Exhibit 18: NASA and the Air Force funded 91.3 percent of the Space Platforms and Hypersonic Technologies markets from FY11 through FY17. Agency footprints within each market are reflective of each agency’s respective space priority missions.

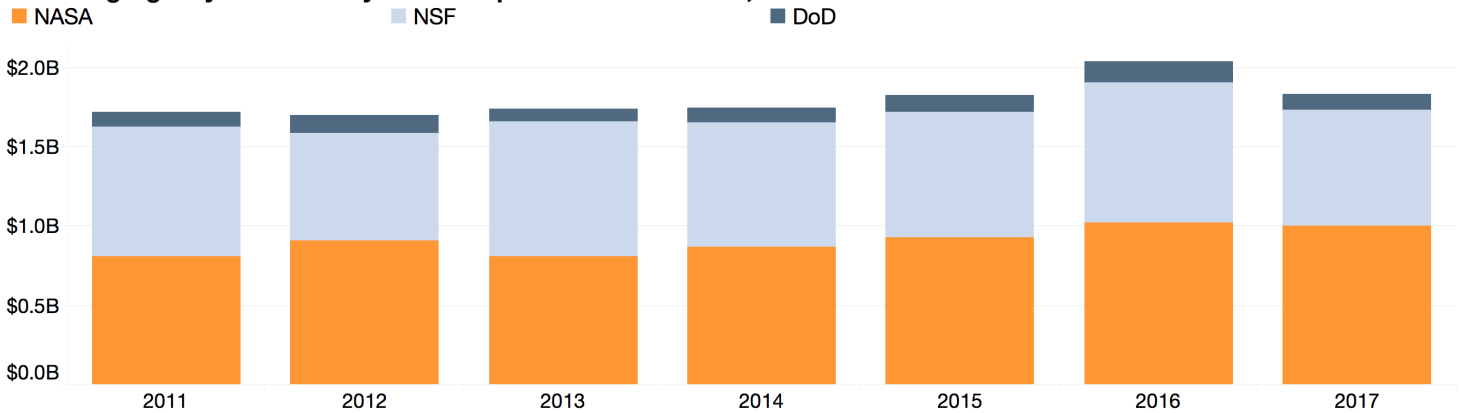
Research Consortiums Account for the Vast Majority of Space-Related Grants

Among other stated priorities, the White House released a fact sheet on the new National Space Strategy in March 2018 that seeks to support the advancement America’s scientific knowledge. To that effort, grants remain a prominent funding mechanism for space-related research at academic institutions and consortiums. Overall Federal funding levels for space-related grants remained relatively stable from FY11 through FY17 as grants grew at a 1.0 percent CAGR and totaled \$12.6 billion. Funding from NASA accounted for 50.1 percent of all grants, the largest share over the same period. DoD grants accounted for 5.7 percent of federally funded space grants, the smallest portion among peer agencies.

The recipient of the most NASA grants was the Universities Space Research Association, a consortium of more than 350 universities that seeks to help government sponsors with research, technology development, management, and workforce development. The University of Maryland received the most NASA grants for an individual university.

The National Science Foundation (NSF) awarded more than \$5.5 billion worth of grants from FY11 through FY17. The top three NSF grant recipients were all academic consortiums and accounted for 42.8 percent of the NSF’s space-related grants over this same time period. Caltech, which was a top-15 Space Platforms and Hypersonic Technologies vendor from FY11 through FY17, received the most NSF grants destined for an individual university.

Awarding Agency for Federally Funded Space-Related Grants, FY11 - FY17



Space-Related Grant Recipient by Awarding Agency, FY11 - FY17

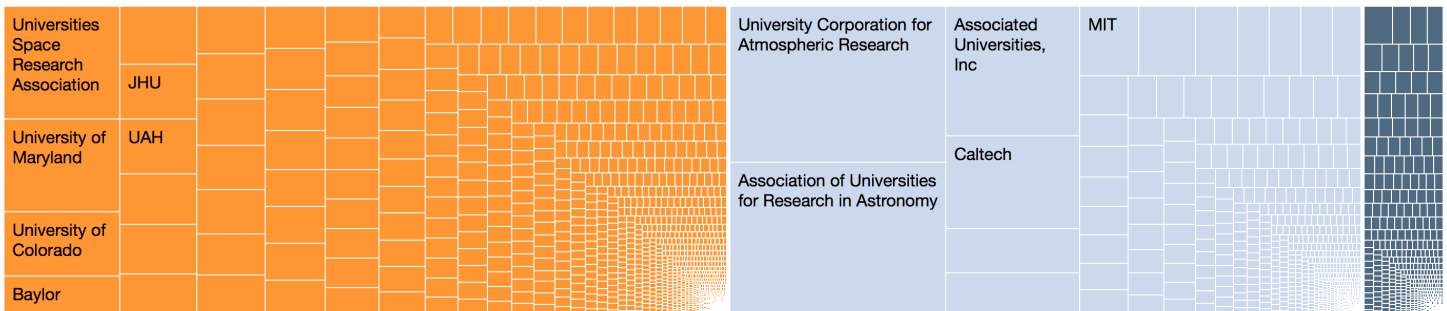


Exhibit 19: Federally funded grants grew at a 1.0 percent CAGR from FY11 through FY17. The largest recipients of grants were the University Corporation for Atmospheric Research, Association of Universities for Research in Astronomy, and Universities Space Research Association.

Patent Applications Filed in China for Space-Related Technology are Increasing

The number of patent applications filed within countries can provide insights into the dynamics of each country's market. Specifically, volumes can indicate whether or not the market is valued by entities seeking to spend time and money to publicly protect intellectual property rights within it. Govini analyzed over 270 thousand space-related technology patent records from 40 countries from FY11 through FY16. The growing number of patents filed in China contrasted with a recent downward trend in the total number of filings within other countries.

The number of space-related technology patent applications filed in China rose year-over-year from FY11 through FY16 for a total growth rate of 13.3 percent. Though this is not necessarily an indication of new Chinese space-based intellectual property generation as filings between countries are not mutually exclusive. It can indicate the emerging importance of global competitors securing their intellectual property within China. This trend suggests that patent holders are increasingly comfortable with the country's patent regime or see value in filing for patents to generate revenue. Either way, the growth indicates that China is becoming a more important economy for space-related technologies.

The rise in the number of patent application filings within China contrasts with a recent decline in worldwide patent filings. The total number global space-related technology patent filings declined from a six-year peak in FY13 in each year through FY16. This could be a macro level indication that the public space-related technology market is becoming more mature, or that more international stakeholders are shifting toward keeping patentable ideas top secret.

Space-Related Technology Patents by Country and Year of Application Filing, FY11 - FY16

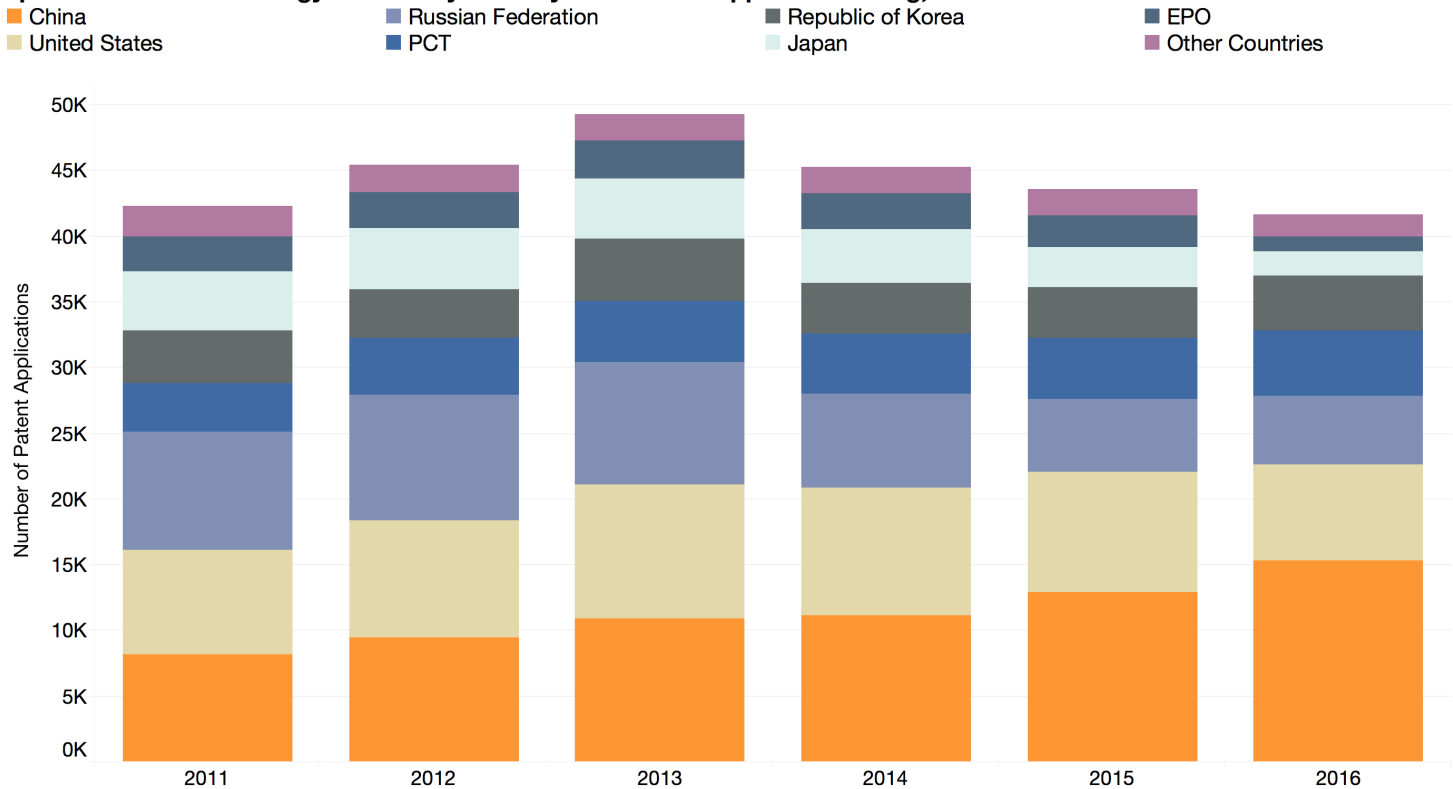


Exhibit 20: Space-related technology patents filed in China rose year-over-year from FY11 through FY16 for a total growth rate of 13.3 percent. Worldwide space-related patent filings peaked in FY13 before declining 15.8 percent by FY16.

Interest in Chinese Hypersonic Patents Indicates Emerging Market Importance

Patents for Hypersonic Technologies were small in comparison to the Space-Related Technology patents market with patent applications totaling just over 20 thousand over FY11 through FY16. Patents for Hypersonic Technologies tell a similar story to Space-Related Technologies patents.

Patent filings in China accelerated tremendously, growing at a 23.9 percent CAGR over the six-year period. The growth comes as the global industrial base increasingly prioritizes securing their intellectual property in the Chinese market. Applications filed in the U.S. and Russia for Hypersonics have declined at a -7.4 and -10.4 percent CAGR respectively.

Hypersonic technologies in the U.S. are maturing. Advancing Hypersonic Technologies beyond the concept stage and creating production ready hypersonics like the HAWC and TGB could account for the decline in U.S. patent filings. Interest in securing these technologies in rival foreign markets, especially China, could account for the increase in Chinese-filed patent applications.

Hypersonic Technologies Patents by Country and Year of Application Filing, FY11 - FY17

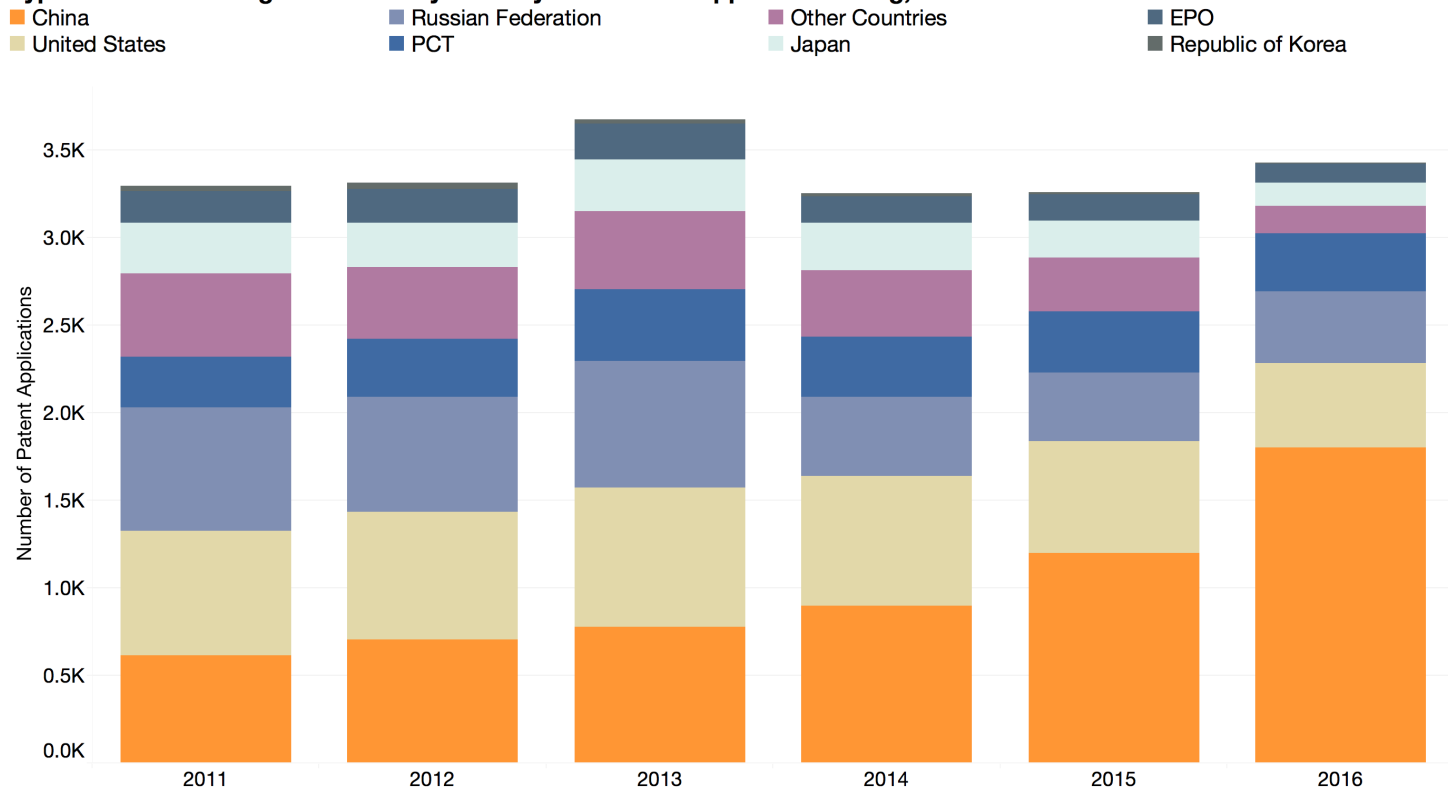


Exhibit 21: Govini identified 20,216 patent applications filed in 40 countries across six years. Patents applied for in China grew at a 23.9 percent CAGR possibly driven by the global markets desire to secure their IP in the Chinese market. Patents applied for in the U.S. and Russia declined at a combined CAGR of -8.9 over the time period.

Conclusion

The Space Platforms and Hypersonic Technologies markets represent a dynamic and complex set of mission sets with varying scopes and objectives. From national security to human exploration of the cosmos, the sub-segments represented within Govini's taxonomy represent both the current needs and future aspirations of public and private stakeholders. By analyzing Federal contracts, grants, and international patents data one can better understand the past and what is necessary for the future.

The Federal government continued to launch the Space Platforms and Hypersonic Technologies markets to new heights. It obligated more than \$83.0 billion in contracts across six mission-oriented markets and 22 sub-segments from FY11 through FY17, and the availability of these funds contributed to important vendor developments, such as the emergence of new ones or consolidation of established ones. Additional funds awarded through grants to academic institutions and consortiums nurtured a steady stream of talent and new patentable ideas that are currently being used to further Space and Hypersonic Technologies.

The future of Space Platforms and Hypersonic Technologies is bright. Emerging companies like SpaceX and traditional market-leading companies like Lockheed Martin and Boeing will continue to help drive the spacecraft and launch innovations needed to accomplish human space and other missions. Similarly, creating more defensible space assets that are critical to our national security will need these innovative technologies.

Academic institutions and consortiums will push the bounds of science and create critical technologies needed for new and updates to legacy systems. Paralleling national efforts, international entities will play an increasingly important role in future missions as stakeholders vie for leadership positions in the scientific and defense realms. One could expect innovation and new milestones to mirror this increased attention and investment.

It is an interesting time for the Space Platform and Hypersonic Technologies markets, and mankind is on the brink of a new age of scientific discovery. After six years of growth and transition, these markets are on the cusp of even more change as policymakers and scientists prepare to guide and provide the means to carry out bolder missions. Missions to Mars, asteroids, and other celestial objects are being studied and prepared for. Monitoring and understanding these developments will continue to be important for stakeholders that seek to remain or become relevant.

Methodology

Govini creates decision-grade information that allows clients to better understand and solve their most difficult problems. Govini uses a unique taxonomic approach to break markets into components and notable participants to provide insights available through its Strategic Intelligence Platform. These analytic reports are designed to synthesize unique datasets, such as Federal Government contract obligations, international patents, and Federal grants, in order for stakeholders to better understand the intricacies of given markets.

Govini is a big data and analytics firm committed to transforming the business of government through data science. Govini's insights and analyses are utilized by Federal Agencies, Federal Contractors, Private Equity Firms and Hedge Funds to guide their strategies and uncover opportunities. Govini was founded in 2011 and has offices in Arlington, Virginia and San Francisco, California.