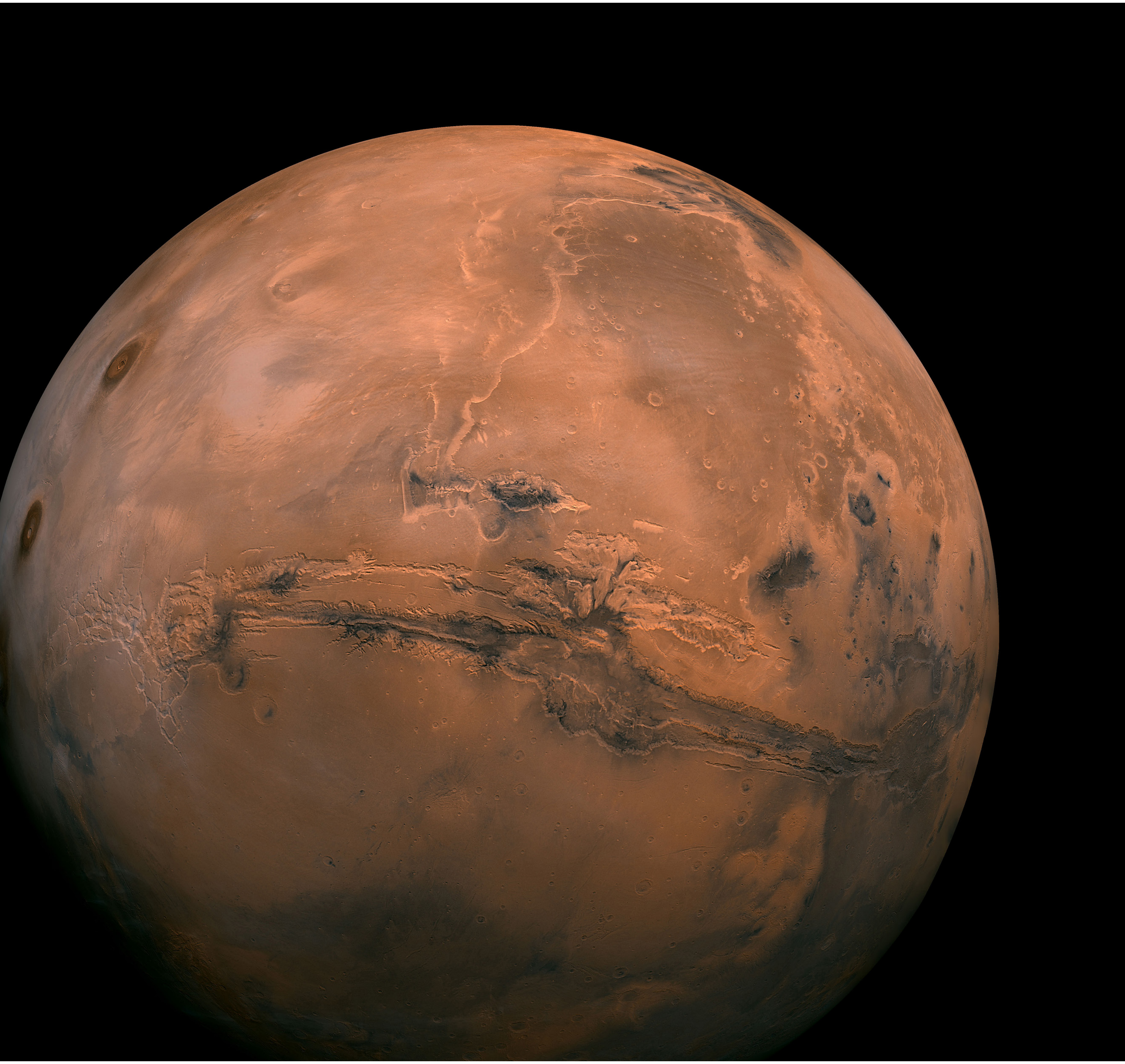
THE SPACE REPORT

SPACE FOUNDATION

THE AUTHORITATIVE GUIDE TO GLOBAL SPACE ACTIVITY

2020 Q2



2019 GLOBAL SPACE ECONOMY | CORONAVIRUS AND THE SPACE INDUSTRY | 2019 SPACECRAFT ANALYSIS

Small Satellite Mass Categories

Femtosatellite: 0.001 – 0.01 kilograms
Picosatellite: 0.01 – 1 kilograms
Nanosatellite: 1 – 10 kilograms
Microsatellite: 10 – 100 kilograms
Minisatellite: 100 – 180 kilograms

Note: 1 kilogram equals 2.21 pounds

Source: "What are Smallsats and Cubesats." NASA. February 26, 2015. https://www.nasa.gov/content/what-are-smallsats-and-cubesats (Accessed March 10, 2019).

Common Cubesat Useful Volume Dimensions and Masses

1U: 10x10x10 centimeters/1.33 kilograms
1.5U: 10x10x15 centimeters/2 kilograms
2U: 10x10x20 centimeters/2.66 kilograms
3U: 10x10x30 centimeters/4 kilograms
6U: 10x20x30 centimeters/8 kilograms
12U: 20x20x30 centimeters/16 kilograms

Note: 1 centimeter equals .39 inches. 1 kilogram equals 2.21 pounds.

Source: "Cubesat Design Specification," Revision 13. California Polytechnic State University, San Luis Obispo. April 6, 2015. https://www.cubesat.org/s/cds_rev13_final2.pdf (Accessed March 10, 2019).

Primary Mission Segment Descriptions

Civil Government: Government-sponsored space products and services provided to the public, usually for little or no profit.

Commercial: Products and/or services sold to the public, using little or no public investment for running the business and mission.

Military: Government-sponsored missions and products serving a nation's defense and/or power projection.

Common Orbit Descriptions

- **Low Earth Orbit (LEO)** is commonly accepted as being between 200 and 2,000 kilometers above the Earth's surface. Spacecraft in LEO make one complete revolution of the Earth in about a 90-minute window.
- **Medium Earth Orbit (MEO)** is the region of space around the Earth above LEO (2,000 kilometers) and below geosynchronous orbit (35,790 km). The orbital period (time for one orbit) of MEO satellites ranges from about two to 12 hours. The most common use for satellites in this region is for navigation, such as the United States' Global Positioning System (GPS).
- **Geosynchronous Equatorial Orbit (GEO)** is a region in which a satellite orbits at approximately 35,790 kilometers above the Earth's surface. At this altitude, the orbital period is equal to the period of one rotation of the Earth. By orbiting at the same rate in the same direction as Earth, the satellite appears stationary relative to the surface of the Earth. This is effective for communications satellites. In addition, geostationary satellites provide a "big picture" view, enabling coverage of weather events. This is especially useful for monitoring large, severe storms and tropical cyclones.
- **Polar Orbit** refers to spacecraft at near polar inclination (80 to 90 degrees) and an altitude of 700 to 800 kilometers. Many polar-orbiting spacecraft are in a **Sun-Synchronous Orbit (SSO)**, in which a satellite passes over the equator and each latitude on the Earth's surface at the same local time every day, meaning that the satellite is overhead at essentially the same time throughout all seasons of the year. This feature enables collection of data at regular intervals and consistent times, conditions that are particularly useful for making long-term comparisons.
- **Highly Elliptical Orbits (HEO)** are characterized by a relatively low-altitude perigee (the orbital point closest to Earth) and an extremely high-altitude apogee (the orbital point farthest from Earth). These extremely elongated orbits have the advantage of long periods of visibility on the planet's surface, which can exceed 12 hours near apogee. These elliptical orbits are useful for communications satellites.
- **GEO Transfer Orbit (GTO)** is an elliptical orbit of the Earth, with the perigee in the LEO region and apogee in the GEO region. This orbit is generally a transfer path after launch to LEO by launch vehicles carrying a payload for GEO.

This methodology and algorithm is used to classify orbits based on their most recent orbital elements. It is not meant to classify other special orbits (heliocentric, planetocentric, selenocentric, barycentric, solar system escape, etc.).

Q2

SPACE FOUNDATION

THE SPACE REPORT

www.SpaceFoundation.org | For more information, please contact:

Space Foundation HQ:
+1.719.576.8000
4425 Arrowswest Drive, Colorado Springs, CO 80907

Washington, DC:
1700 North Moore Street, Suite 1105, Arlington, VA 22209

SPACE FOUNDATION

THE SPACE REPORT

THE AUTHORITATIVE GUIDE TO GLOBAL SPACE ACTIVITY

2 0 2 0 **Q2**

TABLE OF CONTENTS

ABOUT THE COVER IMAGE:

This mosaic of Mars is a compilation of images captured by the Viking Orbiter 1. NASA is scheduled to launch the Mars Perseverance rover to gather data and advance scientific and geographic understanding of the planet.

Credit: NASA/JPL-Caltech

Introduction to *The Space Report* | Quarter 2

If ever there were a time for Hope, Perseverance, and Ingenuity, it is now.

Within days of each other in July, three missions to Mars are scheduled to launch, a momentous achievement in space exploration that comes as the global death toll from COVID-19 surpassed 651,000 worldwide and approximately 147,000 in the United States.

Hope came first. On July 19, the United Arab Emirates, assisted by a Japanese rocket and launch from the Tanegashima Space Center, lofted a probe named Hope, or Al Amal in Arabic. The mission is the first interplanetary undertaking for an Arab nation. The probe is expected to orbit Mars for a year to gather atmospheric data.

Perseverance and Ingenuity are scheduled to follow. Propelled by a United Launch Alliance Atlas V rocket, NASA's Perseverance rover is set to launch July 30 from Cape Canaveral. Perseverance will explore the Red Planet for evidence of microbial life, analyze the atmosphere in more detail, and gather rocks for a possible return to Earth. Ingenuity is the onboard helicopter poised to become the first aircraft flown on another planet.

A third mission to Mars launched a week before the scheduled liftoff of Perseverance. China's Tianwen-1 launched aboard a Long March-5 rocket from the Wenchang Space Launch Center. That mission, too, will explore the planet's surface.

These missions reflect years of shared scientific purpose on Earth — a combination of education, communication and planning that holds the promise of furthering our knowledge of the universe and advancing life on Earth.

Throughout this quarterly edition of *The Space Report*, the body of research and analysis provides ample evidence of the growth last year of the space industry, the benefits space products provide to daily life on Earth, and the growing commitment many nations have to their presence in space.

Those leading the way are inviting others. During a July Space Foundation webinar "Roving the Red Planet," NASA Administrator Jim Bridenstine welcomed any nation willing to enter space. "We need more partners," he encouraged.

The Space Report 2020 Q2 provides insight and analysis about what is happening across a variety of sectors in the space industry. The data compiled is from 2019, well before coronavirus became a global economic issue.

Here's what you'll find in this issue:

1 | The Space Economy

The global space economy grew more than $9 billion in 2019, reaching $423.80 billion worldwide. Commercial revenue, totaling more than $336 billion, held steady at approximately 80% of the total economy.

Governments collectively contributed $86.9 billion to the global space economy in 2019, a 1% increase over 2018 and a 16% increase over the previous decade. Defense spending composed approximately 37% of governmental space spending in 2019, with civil government initiatives utilizing the remaining 63%. Preliminary commercial figures place governmental space spending at 20.5% of the 2019 global space economy figure.

Of this investment, 54% can be attributed to U.S. government spending, with budget analysis of 32 other countries comprising the remaining 46%. The U.S. space budget in 2019 increased by 1.8% in the civil sector but decreased by approximately 9% in the defense sector, yielding an overall 3.8% reduction in U.S. space spending. Notably, 2019 marked one of only three years in the past decade where U.S. civil space spending outpaced military space spending.

Non-U.S. nations invested $40.2 billion in space in 2019, a 7.2% increase over the previous year and a 44% increase over the preceding decade. Of non-U.S. government space spending, 24% was allocated to defense activities, with the remaining 76% allocated to civil initiatives. Preliminary commercial figures reveal that non-U.S. government spending constituted 9.5% of the global space economy in 2019.

2 | Space Workforce

In 2019, the European space workforce included an estimated 47,895 employees working on design, development, and manufacturing of space assets. This is 6.2% larger than 2018, when the workforce included 45,117. A small portion of this increase is due to the addition of six new countries to the annual survey conducted by Eurospace, the European space industry association. These new additions — Bulgaria, Cyprus, Latvia, Lithuania, Romania, and Slovakia — accounted for 313 employees, 0.7% of the total European workforce.

More than 80% of the European workforce is based in just five nations: France, Germany, Italy, Spain, and the United Kingdom. All five of these nations have experienced double-digit growth in the size of their workforce from 2014 to 2019, and all but Italy also grew from 2018 to 2019.

Europe's space workforce grew faster in 2019 than those in the U.S., Japan, or India. Those nations showed growth of 2-2.4%.

3 | Space Infrastructure

Three nations accounted for 72% (333) of the 466 spacecraft deployed in 2019: The U.S., China, and Russia. U.S. operators deployed 258 spacecraft in 2019, or 55% of 466 spacecraft. This percentage is an increase for the U.S. compared to 2018 when the U.S. sent 39% (180 spacecraft) into orbit of that year's total number of deployed spacecraft. China's space operators followed with 49 spacecraft, 9% of all spacecraft deployed in 2019, a decrease from 2018 when China took a 16% share of total deployed spacecraft (73). Russia accounted for the remaining 26 spacecraft (6% of 2019's spacecraft deployments). Those deployments are an increase for Russia from 2018 when they deployed 21 spacecraft and accounted for a 4.5% share.

4 | Space Products and Innovation

Innovation and rapid product development by space companies have been on full display during the global response to the coronavirus pandemic. Companies around the world have introduced new ventilators, developed personal protection equipment, and put remote sensing satellite capabilities to use in tracking data relevant to environmental and societal changes in recent months.

Sometimes, the disasters that befall us are weather-related. Fortunately, scientists are using a multitude of resources to learn more about severe weather, including remote sensing satellites that monitor the Earth from space and provide weather alerts in as little as 15 minutes. New satellite technology is providing advancements in climate and water quality data collection.

As you read this report

The data presented is a quarterly snapshot of global space activity.
To learn more, updates from *The Space Report* are available on a subscription basis, as are data sets that are not included in this document. To find the data you need, sign up today at:

TheSpaceReport.org

1.0 Introduction | *Space is a global enterprise, with companies, private backers, and nations around the world investing in commercial, civil and defense space sectors. In 2019, well before the global coronavirus pandemic began shaking investor confidence, delaying launches, and leading to sweeping unemployment, the global space economy continued to grow in financial commitment and expand into new enterprises.*

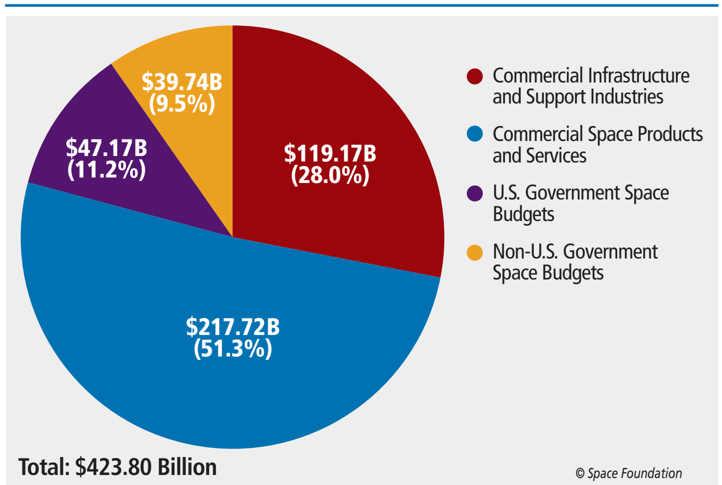
The European Space Agency and the software corporation SAP put final signatures in May 2019 to an agreement establishing the World Space Alliance, which will create commercial programs for sharing satellite Earth observation data.
Credit: ESA

EXHIBIT 1a. Topics Covered in The Space Economy

1.1 The 2019 Global Space Economy

From 2018 to 2019, according to research and analysis by Space Foundation, commercial and government spending increased more than $9 billion to $423.80 billion for 2019, a 2.2% increase over the prior year and a 73% increase over the past decade, when the total was $245.06 billion.

EXHIBIT 1b. Global Space Activity, 2019



Commercial spending continued to account for almost 80% of total spending, climbing to $336.89 billion in 2019. A more detailed analysis of commercial revenue activity will be available in *The Space Report 2020, Quarter Three.*

In this quarterly report, the economic analysis focuses on government spending. Though only 20.5% of the total global space economy, government spending illustrates the continuing democratization of space. Where once Russia and the United States dominated — and remain at the forefront still — they are joined now by dozens of nations that view space as an economic driver and launch pad for improved quality of life for their citizens.

Space Foundation builds the annual global space economy figure upon extensive internal and external research into governmental and commercial space markets. In 2019, the Research & Analysis team pulled government space budgets from the federal documents and public statements of 33 key nations in the civil sector and eight in the defense sector to compile its estimate for government space investment globally.

Efforts are also undertaken to isolate spending into individual classifications. For example, European Space Agency (ESA) and EUMETSAT contributions are subtracted from national space budgets for member states to avoid double-counting the budget of each agency. All non-U.S. national military spending is similarly removed and incorporated into non-U.S. military space. In some cases, due to a lack of publicly available data or classified military data, Space Foundation develops estimates for U.S. and non-U.S. military space spending, the space spending of three additional U.S. civil agencies, and Chinese space spending.

1.2 Government Space Investment

Across the globe, nations and international government organizations invested in space infrastructure and activities in 2019, collectively contributing $86.9 billion to the global space economy. This figure represents a 1% increase over a revised 2018 figure of $86 billion and a 16% increase over the previous decade.

U.S. government spending accounted for 54% of all government space budgets in 2019. The other 46% is derived from space spending by 32 other countries.

Defense spending composed approximately 37% of governmental space spending in 2019, with civil government initiatives utilizing the remaining 63%. The numbered sections below analyze government investment on a country-level by sector and detail Space Foundation's figure for global government space spending in 2019.

1.3 U.S. Government Space Investment

The U.S. government has ramped up defense and civil space activities dramatically in the past three years. At the advice of the National Space Council after its first meeting in October 2017,[1] President Trump signed *Space Policy Directive-1* in December 2017, formerly declaring U.S. aspirations to establish an "integrated program with private sector partners for a human return to the Moon, followed by missions to Mars and beyond."[2] This led to the development of a National Space Strategy in March 2018 with four major goals: transition the U.S. to "more resilient space architectures;" strengthen deterrence and defense-based threat responses with space components; improve foundational U.S. space capabilities, structures, and processes; "foster conducive domestic and international environments" for space economic and technological development.[3] *Space Policy Directive-2* in May 2018 directed a number of agencies to reform and streamline the licensing of the commercial space industry.[4] *Space Policy Directive-3,* in June 2018, initiated the development of "new approach to space traffic management (STM)."[5] Most recently, *Space Policy Directive-4* in February 2019 authorized the Space Force,[6] an agency formally established on Dec. 20, 2019, under the Fiscal Year 2020 National Defense Authorization Act (FY 2020 NDAA) as a separate branch of the Armed Forces within the Department of the Air Force.[7]

EXHIBIT 1c. U.S. Government Agency Space Budgets, 2019

Agency	Budget
Department of Defense (DoD)*	$23.049B
National Aeronautics and Space Administration (NASA)	$21.500B
Department of the Interior (DOI) (including USGS)*	$0.078B
Department of Energy (DOE)*	$0.180B
National Science Foundation (NSF)*	$0.610B
National Oceanic and Atmospheric Administration (NOAA)	$1.699B
Department Of Transportation (DOT)	$0.036B
United States Department of Agriculture (USDA)*	$0.017B
Total	**$47.169B**

**Space Foundation estimate*
Source: Space Foundation Database

Moving beyond legislation into appropriations, the U.S. space budget in 2019 increased 1.8% in the civil sector but decreased approximately 9% in the defense sector, yielding an overall 3.8% reduction in U.S. space spending. Five of the seven U.S. civil agencies identified as conducting space activities increased their space investment in 2019, constituting collectively 47.5% of all U.S. space spending: National Aeronautics and Space Administration (NASA), Department of Transportation (DOT), Department of Energy (DOE), United States Department of Agriculture (USDA), and National Science Foundation (NSF). The Department of Interior (DOI)'s minimal size (0.2% of total U.S. space spending) and rate of reduction (0.4%) cannot sufficiently explain the overall

EXHIBIT 1d. U.S. Government Space Spending, 2019

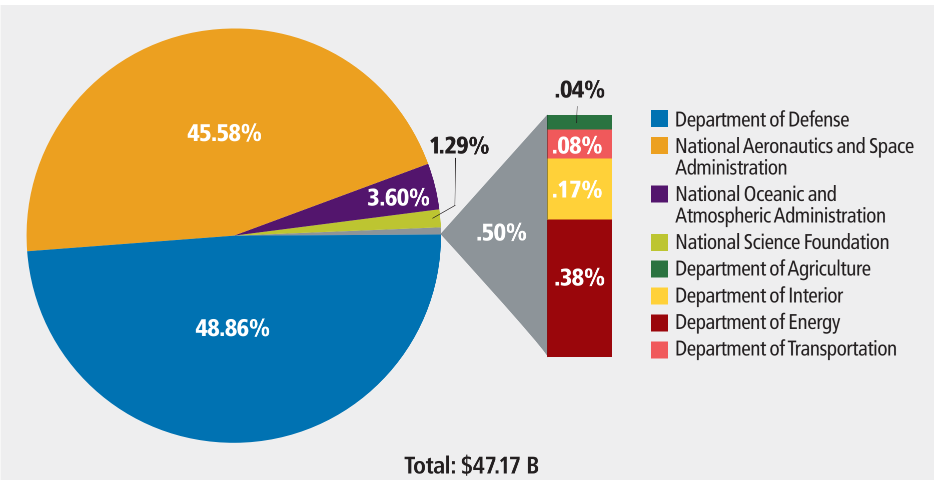
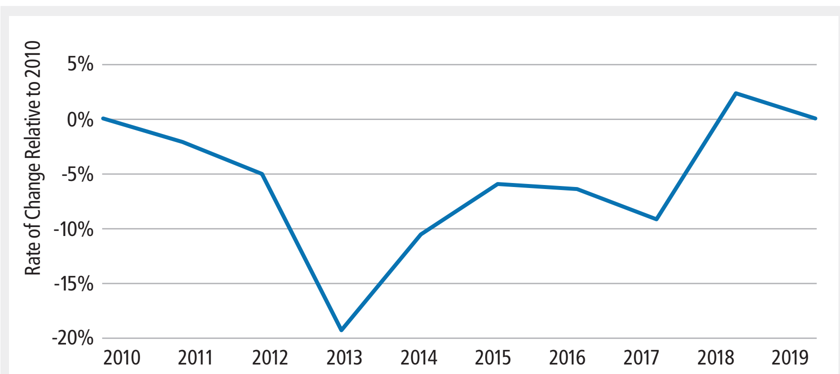


EXHIBIT 1e. Rate of Change in U.S. Government Space Spending, 2010-2019



Source: Space Foundation Database

reduction in U.S. space spending. Instead, the overall decrease in U.S. space spending can be attributed to the remaining two U.S. agencies with space investments: National Oceanic and Atmospheric Administration (NOAA) and Department of Defense (DoD). For detailed information of the space spending of each agency, look to the agency-level sections that follow.

As a result of these shifts, a few interesting trends have emerged. Notably, the U.S. space budget is approximately 0.1% lower than a decade ago. Relative to 2010, a single year enacted greater space spending — 2018. Furthermore, 2019 marked one of only three years in the past decade where U.S. civil space spending outpaced military space spending, all of which occurred in the past four years.

1.3.1 U.S. Military Space Investment

Determining U.S. military space spending is difficult due to the classified nature of as much as 23% of the Department of Defense (DoD) budget, as in the case of the Research Development, Test & Evaluation Program (RDT&E). Despite the release of two space directives over the course of 2018 calling for new programs and initiatives, the *2018 Aeronautics and Space Report of the President* recorded a 22% reduction in DoD space spending over the previous year.[8] A separate line-item analysis by Space Foundation of DoD space spending, however, shows a 22% increase in DoD space spending for 2018. For purposes of 2019, the Foundation stayed with the line-item analysis, which matches previous methodologies. The 2019 *Aeronautics and Space Report of the President* has not yet been released.

Space Foundation calculated total U.S. military space spending in 2019 by applying the change in identifiable DoD unclassified military space programs to a revised 2018 total DoD space spending figure. Line item analysis revealed that unclassified DoD space spending decreased more than 14% in 2019. Tabulated alongside classified spending and assuming classified and unclassified spending shifted by equitable degrees, this produced an estimated average 9% reduction in DoD space spending between 2018 and 2019 — yielding a 2019 figure of $23 billion.[9]

In this analysis, unclassified space-related procurement operations decreased in funding by 34% and classified procurement decreased 4%. Operations and maintenance funding decreased 10%. The only sector of the DoD budget that grew in 2019 (6%) was the RDT&E Program, 48% of the growth of which can be attributed to new line items such as the National Space Defense Center and the National Security Space Launch Program (SPACE).[10]

The U.S. government has signaled support for expanding U.S. space defense activities in future years. In its FY2020 budget, the DoD asked for $306 million split between its three new primary areas of investment: the Space Force, the U.S. Space Command, and the Space Development Agency.[11] According to the Congressional Research Service, the DoD requested $14.1 billion for U.S. space defense activities in FY2020, a 15% increase from 2019.[12] The DoD in February requested even more in the space domain in its FY2021 budget request, announcing a petition for $18 billion.[13] Classified funds beyond these figures are not released publicly but are a component of Space Foundation's U.S. defense spending estimation.

1.3.2 U.S. Civil Government Space Investment

Apart from the DoD, seven U.S. agencies conduct civil space activities: NASA, NOAA, the NSF, the Department of Energy, the Department of Interior, the USDA, and the DOT. The space activities of these agencies provide data and services that enable many aspects of life in the U.S., such as agricultural optimization, and further U.S. space ambitions through such efforts as deep space exploration. The allocations of these agencies comprised 51% of U.S. space spending in 2019, a 1.8% increase over 2018 to reach $24.1 billion.

1.3.2.1 NASA

NASA is the primary civil agency coordinating U.S. science and technology research related to air and space, including deep space exploration and participation in the International Space Station (ISS).

NASA funding in 2019 increased by 3.7%, growing to $21.5 billion from a 2018 figure of $20.7 billion.[14] This figure represents the highest real-year figure in NASA history[15] and an 8% increase over the president's request, a sign of wider governmental support for aspects of U.S. space science ambitions.[16]

EXHIBIT 1f. National Aeronautics and Space Administration (NASA) Budget, 2017–2020

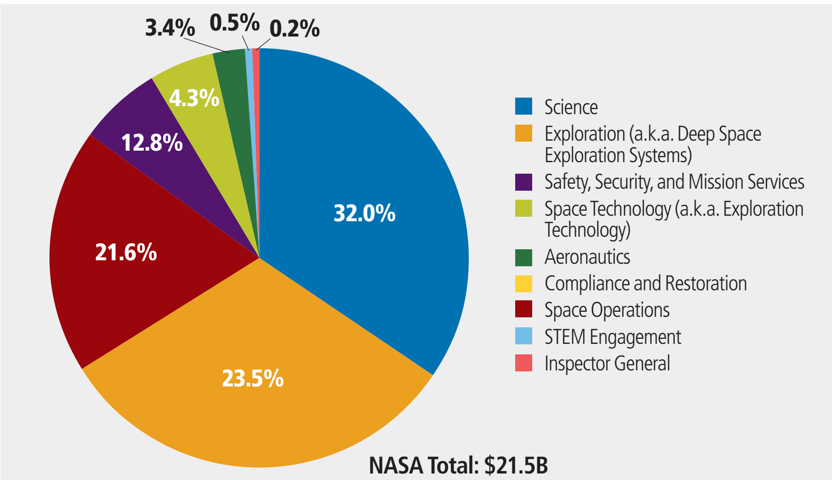
Budget Authority, dollars in millions	FY 2017 Actual[1]	FY 2018 Actual [2]	FY 2019 Actual[3]	FY 2020 Spending Plan[4]	Year-to-Year Change 2018-2019
Science	**5,762.0**	**6,221.5**	**6,886.6**	**7,138.9**	**10.9%**
Earth Science	1,908.0	1,921.0	1,931.0	1,971.8	0.5%
Planetary Science	1,828.0	2,217.9	2,746.7	2,713.4	23.8%
Astrophysics	783.0	850.4	1,191.1	1,306.2	40.1%
Heliophysics	675.0	688.5	712.7	724.5	3.5%
James Webb Space Telescope	569.0	533.7	305.1	423.0	-42.8%
Aeronautics	**656.0**	**690.0**	**724.8**	**783.9**	**5.0%**
Space Technology (a.k.a. Exploration Technology)	**687.0**	**760.0**	**926.9**	**1,100.0**	**22.0%**
Exploration (a.k.a. Deep Space Exploration Systems)	**4,324.0**	**4,790.0**	**5,044.8**	**5,959.8**	**5.3%**
Human Exploration Capabilites (a.k.a. Exploration Systems Development)	3,929.0	4,395.0	4,086.8	4,512.8	-7.0%
Exploration Research and Development	395.0	395.0	958.0	1,447.0	142.5%
Space Operations	**4,943.0**	**4,749.2**	**4,640.4**	**4,142.3**	**-2.3%**
International Space Station	1,451.0	1,493.0	1,490.3	1,521.1	-0.2%
Space Transportation	2,589.0	2,345.8	2,109.7	1,746.2	-10.1%
Space and Flight Support	903.0	910.3	1,000.4	859.9	9.9%
Commercial LEO Development	–	–	40.0	15.0	
STEM Engagement	**100.0**	**100.0**	**110.0**	**120.0**	**10.0%**
Safety, Security, and Mission Services	**2,769.0**	**2,826.9**	**2,755.0**	**2,973.3**	**-2.5%**
Center Management and Operations	–	1,983.4	–	2,007.4	
Agency Management and Operations	–	843.5	–	965.9	
Construction and Environmental Compliance and Restoration	**485.0**	**569.5**	**372.2**	**429.1**	**-34.6%**
Construction of Facilities	–	483.1	279.3	354.4	-38.5%
Environmental Compliance and Restoration	–	86.4	74.9	74.7	-13.3%
Inspector General	**38.0**	**39.0**	**39.3**	41.7	0.8%
NASA Total	**19,762.0**	**20,736.1**	**21,500.0**	**22,689.0**	**3.7%**

[1] FY 2017 reflects funding amounts specified in Public Law 115-31, Consolidated Appropriations Act, 2017, as executed under the Agency's FY 2017 Operating Plan.
[2] FY 2018 reflects funding amounts specified in Public Law 115-41, Consolidated Appropriations Act, 2018, as executed under the Agency's FY2018 Operating Plan. Table does not reflect emergency supplemental funds also appropriated in FY 2018, totaling $81.3 million.
[3] FY 2019 reflects total discretionary funding amounts specified in Public Law 116-006, Consolidated Appropriations Act, 2019, as adjusted by NASA's FY 2019 Operating Plan.
[4] FY 2020 reflects only funding amounts specified in Public Law 116-93 and Public Law 116-136, executed under the NASA FY 2020 Spending Plan.
Source: NASA

NASA allocated the largest share, 32%, of its 2019 budget to science programs, supporting missions researching Earth's systems in addition to those of Jupiter, Mars, and the Sun.[17] NASA spent 24% of its budget on Deep Space Exploration Systems, which includes the development of the Space Launch System (SLS), Orion capsule, and Exploration Ground Systems (EGS) behind the planned Exploration Mission 1 (EM-1) and Exploration Mission 2 (EM-2) to the Moon. NASA allocated an additional 22% to space operations, which includes activities aboard the International Space Station (ISS).[18, 19]

In a reflection of the diverse aspirations of the agency, six of the eight major NASA budget authorities grew in 2019.[20] The NASA line item with the most significant gain was Exploration Systems Development (143%), the component of Deep Space Exploration Systems advancing the Gateway lunar project partnerships and coordinating the development of "reusable human lunar landing architecture."[21] This line item represents 19% of the NASA Exploration budget, which includes Human Exploration Capabilities and grew by 5.3% in 2019.[22] Other line items with significant growth include Astrophysics (40%) and Planetary Science (24%) under the science budget authority and Space Technology (22%), also known as Exploration Technology.

EXHIBIT 1g. **Share of National Aeronautics and Space Administration (NASA) Budget by Budgetary Authority, 2019**



Note: FY 2019 reflects total discretionary funding amounts specified in Public Law 116-006, Consolidated Appropriations Act, 2019, as adjusted by NASA's FY 2019 Operating Plan.
Source: NASA

Recent accomplishments and future plans of the agency are groundbreaking and ambitious. Last year saw uncrewed tests of capsules from NASA Commercial Crew partners Boeing and SpaceX,[23] with SpaceX successfully launching the first commercial crewed capsule to the ISS in May 2020.[24] Another major NASA launch is scheduled for July 30, 2020 — that of the Mars 2020 Perseverance Rover, a process twice delayed due to technical issues.[25, 26] On October 20, 2020, NASA's OSIRIS-Rex is slated to touch down on the asteroid Bennu to collect samples for a 2023 return to Earth, a process that was delayed from August due to coronavirus-related constraints.[27, 28]

Looking out further, based on directives from the White House, NASA's Artemis program is working to send the first woman and next man to the Moon by 2024 to establish infrastructure for a permanent human presence there within the next decade "to uncover new scientific discoveries and lay the foundation for private companies to build a lunar economy," according to a NASA overview.[29] A major Artemis milestone in 2020 will be the "Green Run" test of all four engines of the SLS core stage, a term referring to the simultaneous operation of all the hardware components for the first time.[30] As for the budget implications, these plans are projected to cost more than a NASA's governmental allocation would cover by 2021, which Bill Gerstenmaier, NASA associate administrator for Human Exploration and Operations, suggested could come at the cost of "cuts internal to the agency."[31] Nonetheless, the NASA budget is projected to grow by 33% from 2019 to reach a peak of $28.6 billion by 2023.[32]

1.3.2.2 NOAA

The National Oceanic and Atmospheric Administration, under the U.S. Department of Commerce, spent $1.7 billion on space-related activities in 2019, a 19% decrease from the previous year.[33]

NOAA oversees Environmental Satellite Observing Systems, the National Centers for Environmental Information (NCEI), and the National Environmental Satellite, Data, and Information Service (NESDIS). The latter garnered 85.7% of NOAA spending in 2019. NESDIS managed international and commercial partnerships in addition to the operation of the GOES-R mission, [34, 35] the ocean monitoring satellite Jason-3,[36] and the weather monitoring satellite DSCOVR.[37] Also incorporated under NESDIS is the Office of Space Commerce, which "seeks to leverage commercial space capabilities to capitalize on available extramural expertise, to improve weather forecasting, to diversify NOAA's portfolio of data collection capabilities, to promote U.S. space commerce and the industrial base, and to pursue enhancements in mission areas, program schedules, and costs."[38] The remainder went to Environmental Satellite Observing Systems (10.7%) and NCEI (3.6%), which manages and interprets more than 25 petabytes of atmospheric, coastal, geophysical, and oceanic data to support industry and agriculture and develop new products.[39, 40]

NOAA's reduction in funds can be attributed in large part to a planned 19% decrease in the NESDIS budget as development of NOAA's next generation polar-orbiting and geostationary weather satellites ramps down.[41]

One of these phased-out programs is COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) or Formosat-3, a 14-year collaboration between NOAA, Taiwan's National Space Organization (NSPO), and a number of other organizations that, upon its launch in 2006, utilized groundbreaking radio techniques to improve space and terrestrial weather prediction.[42] Operated out of Taiwan, the program served as a springboard for the COSMIC-2/Formosat-7 mission, which launched out of Cape Canaveral in June 2019 and will further enhance meteorological prediction.[43]

1.3.2.3 National Science Foundation

NSF funding increased 10% in 2019, which was reflected in Space Foundation's 2019 estimate of $610 million for NSF's space-related spending.[44]

The NSF has a stake in space across a number of divisions, projects, and continents. The Division of Astronomical Sciences (AST) operates astronomical facilities such as the National Radio Astronomy Observatory (NRAO), the Arecibo Observatory (AO), the National Optical Astronomy Observatory (NOAO), the National Solar Observatory (NSO), and the Gemini Observatory. The Division of Physics (PHY) operates the Laser Interferometer Gravitational-Wave Observatory (LIGO). The Office of Polar Programs (OPP) conducts full-scale observations at the U.S. Amundsen-Scott South Pole Station.

Lastly, the Atmospheric and Geospace Science Division (AGS), comprised of a Geospace Section (GS) and an Atmosphere Section (AS), supports space science research programs; NOAA's COSMIC mission; the Geospace Facilities (GF) program; the Weather Research (SWR) program; the Solar-Terrestrial Research (STR) program; the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) program; and the Geospace Environment Modeling (GEM) program.[45]

Publicized space activities of the NSF in 2019 included a collaboration with SpaceX to ensure the company's Starlink satellite network limits interference in the radio astronomy band[46] and the solicitation of proposals for Faculty Development in the Space Sciences (FDSS)[47] and Next Generation Software for Data-driven Models of Space Weather with Quantified Uncertainties (SWQU),[48] in line with the U.S. government's *National Space Weather Strategy and Action Plan* released in March 2019.[49]

1.3.2.4 U.S. Departments of Energy, Interior, and Agriculture

Of total U.S. civil space spending in 2019, 1.1% was allocated across three agencies: the Department of Energy (DOE), the Department of Interior (DOI), and the Department of Agriculture (USDA). Collectively, these agencies spent $275 million on U.S. civil space activities in 2019, an increase of 1.9% over 2018.

The DOE space budget grew 2.4% in 2019, reaching approximately $179.7 million. Organizations with space initiatives within DOE include the National Nuclear Security Administration (NNSA), the DOE Office of Science (SC), and the DOE Office of Nuclear Energy (NE).[50] The total budgets of these entities grew by approximately 2.4% in 2019.[51]

Daily operations of the USDA rely on remotely sensed data and derived information for applications spanning robotic systems for mass harvesting fruit to satellite environmental monitoring.[52, 53] The USDA budget increased 7.8% to $147 billion in 2019. That increase was mirrored in estimating the department's 2019 space-relevant budget.[54] Using the 2018 figure from *Aeronautics and Space Report of the President* as a baseline, the space-relevant USDA budget in 2019 reached approximately $17 million.[55]

Space technologies enable activities across the Department of the Interior (DOI), including those of the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the Bureau of Land Management, the U.S. Bureau of Reclamation, and the National Park Service.[56] Many applications include environmental monitoring through a combination of satellite imagery from the

LandSat constellation and GPS technology. The line items for these agencies collectively decreased 0.4% in 2019.[57] Using the 2018 figure from *Aeronautics and Space Report of the President* as a baseline and calculating a 0.4% decrease, the space-relevant DOI budget reached approximately $78 million in 2019.[58]

1.3.2.5 DOT

With the issuance of *Space Policy Directive-2* in May 2018, the Department of Transportation was tasked with establishing a new regulatory regime for licensing launch and reentry activities.[59] In March 2019, the Office of Commercial Space Transportation (AST) of the Federal Aviation Administration (FAA), the subagency that regulates commercial space transportation, released proposed streamlined requirements.[60, 61] Although the "breadth, significant impact, length and complexity" of the proposed framework led to the 45-day extension of the original comment period,[62] a number of final rules have been adopted, including revising operations related to the risk limit used to establish hazard areas of ships and aircraft during a space launch.[63]

According to the 2018 baseline set by the *Aeronautics and Space Report of the President,* the cost of these regulatory activities and other DOT space initiatives increased 25.9% in 2019, reaching $36.5 billion.[64, 65] The president's 2020 request for the space activities of the agency grew even more drastically, by 77%, and was 3.7 times the 2019 funding for the Space Data Integrator (SDI), a tool used to minimize the amount and length of time that airspace must be closed for safe space activities, and 2.4 times the 2019 funding for the FAA/AST's Center of Excellence, which "supports integration of launch and reentry into the NAS, advanced safety assessment methods, advanced vehicle safety methodologies, and human spaceflight safety."[66, 67]

1.4 Non-U.S. Government Space Investment

Non-U.S. nations invested $39.7 billion in space in 2019, a 7.7% increase over the previous year and a 54% increase over the preceding decade. An estimated 24% of non-U.S. government space spending was allocated to defense activities. Non-U.S. government spending constituted 9.4% of the global space economy in 2019.

EXHIBIT 1h. Government Space Budgets, 2019

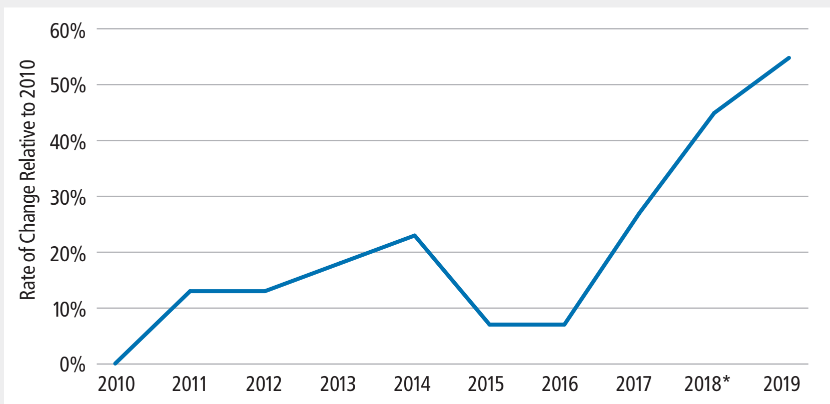
Country/Agency	Budget (U.S. Dollars)	Source	Description
United States	$47.169B	U.S. Government Public Filings	U.S. Space Spending
China	$9.596B	Space Foundation estimate	Estimated Chinese space spending
European Space Agency (ESA)	$4.733B	ESA budget	ESA budget
Japan	$3.005B	Japan Aerospace Exploration Agency (JAXA)	JAXA budget
France*	$1.044B	Centre National d'Études Spatiales (CNES)	CNES budget
Russia	$3.978B	TASS Russian News Agency	Roscosmos budget
India	$1.906B	Ministry of Finance, Government of India	Indian civil space spending
Germany*	$1.529B	Bundeshaushalt 2020	DLR space spending
South Korea	$0.476B	Allio Information (ALIO: All Public Information In-One)	KARI budget
EUMETSAT*	$0.637B	Eurospace	EUMETSAT budget
Italy*	$0.382B	Agenzia Spaziale Italiana (ASI)	ASI budget
Canada*	$0.251B	Canadian Space Agency (CSA)	CSA budget
Spain*	$0.131B	Spanish Ministry of Defense, Presupestos Generales Del Estado	Instituto Nacional de Tecnica Aeroespacial (INTA) budget
United Kingdom*	$0.200B	UK Space Agency (UKSA), Corporate Plan 2019-2020	UKSA budget
European Union*	$1.941B	Eurospace	EU space spending
Brazil	$0.026B	Brazilian Government Transparency Portal	Brazil space spending
Additional Countries	$0.398B	See Exhibit 1u	Space Budgets of Selected Additional Countries
Non-U.S. Military Space	$9.509B	Space Foundation estimate	Military Spending Outside the United States
Total	**$86.910B**		

**Excludes ESA spending*
Note: Defense spending for all non-U.S. countries is included in "Non-U.S. Military Space"
Source: Space Foundation Database

1.4.1 Non-U.S. Military Space Investment

Nations across the world invest in space for defense purposes, but these budgets are often partially, if not fully, classified. Space Foundation calculates an estimate for non-U.S. military space spending by applying the change in publicly available military space programs to the 2018 estimate for non-U.S. military space. The unclassified military space budgets of seven nations were included in this analysis—Australia, Brazil, France, Germany, Japan, Nigeria, and Spain — totaling $1.79 billion in 2019. This figure represents a 0.5% decrease over 2018 numbers, which when applied to the previous year's estimate, yielded a global 2019 non-U.S. military space spending estimate of $9.51 billion.

EXHIBIT 1i. Rate of Change in Non-U.S. Government Space Spending, 2010-2019



Revised Figure
Source: Space Foundation Database

Of documented non-U.S. military space spending, Japan recorded the most, ¥89.6 billion (USD $830 million), growing funding 3.6% over 2018.[68] France invested the next most, to the tune of €400 million, but grew investment more than any other documented nation (19.7%), in part to establish its own space command.[69, 70] Germany and Australia also increased space defense spending in 2019, growing investments to €36.5 million and AUD $6 million, respectively.[70, 71] Brazilian defense space spending decreased the most dramatically of any nation, by 23.6%,[73] but was followed by Nigeria, which reduced defense space spending by 13.9%.[74] Spanish defense space spending increased by €300,000 in 2019 but, due to changes in global currency rates between 2018 and 2019, spent approximately 2.3% less in U.S. dollars.[75]

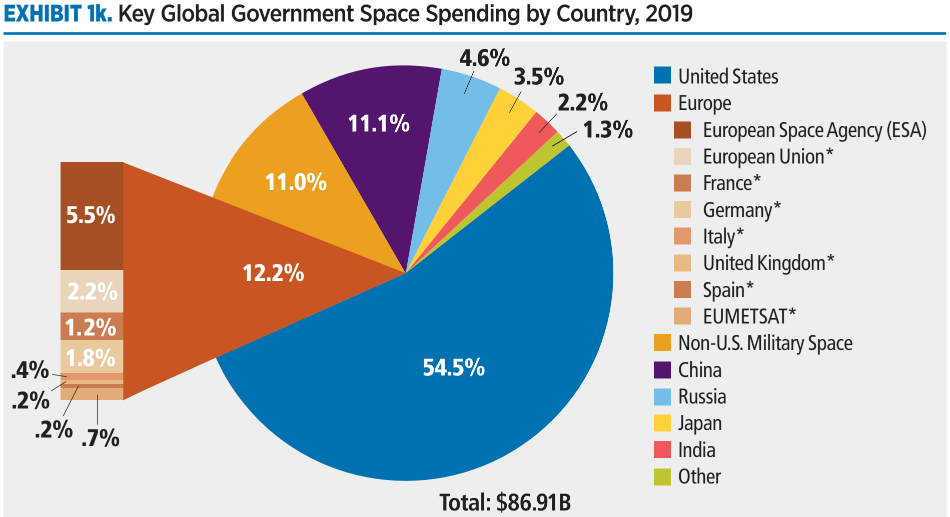
EXHIBIT 1j. Civil Government Space Budget Growth, 2017–2019

Country/Agency	Currency	2017 Funding	2018 Funding	2019 Funding	2017-2019 Change
United States	U.S. Dollar	$43.34B	$49.12B	$47.17B	8.1%
Brazil	Real	*R$0.084B*	R$0.109B	R$0.101B	16.2%
Canada*	Canadian Dollar	C$0.395B	*C$0.347B*	C$0.329B	-20.0%
European Space Agency (ESA)	Euro	*€4.620B*	€4.228B	€4.162B	-11.0%
France*	Euro	€1.09B	€0.99B	€1.04B	-4.4%
Germany*	Euro	*€0.891B*	*€1.016B*	€1.344B	33.7%
India	Rupee	₹91.555B	*₹111.884B*	₹131.3923B	30.3%
Italy*	Euro	*€0.285B*	*€0.322B*	€0.336B	15.3%
Japan	Yen	*¥342.100B*	*¥301.000B*	¥324.300B	-5.5%
Russia	Ruble	*₽181.800B*	₽182.000B	₽251.700B	27.8%
South Korea	Won	*₩660.536B*	₩692.026B	₩550.327B	-20.0%
Spain*	Euro	€0.137B	*€0.115B*	€0.115B	-19.0%
United Kingdom*	Pound	*£0.132B*	£0.179B	£0.158B	16.1%

**Excludes ESA spending*
*** Italicized numbers have been revised from previous data*
Source: Space Foundation Database

International bodies are signaling commitment to supporting and growing the global space defense domain, most notably the 30 members of the North Atlantic Treaty Organization (NATO).[76] In June 2019, NATO approved its first overarching space policy, the details of which have not been made public.[77] At the Leader's Summit in December 2019, Allies formally declared space to be a distinct "operational domain" alongside air, land, sea and cyberspace.[78] NATO leadership emphasized the need to protect western military and civilian interests but will stop short of weaponized space assets.[79]

EXHIBIT 1k. Key Global Government Space Spending by Country, 2019



*Note: *Excludes ESA spending*
Note: Defense spending for all Non-U.S. countries is included in 'Non-U.S. Military Space'
Source: Space Foundation Database

1.4.2 Non-U.S. Civil Government Space Investment

In addition to activities in the defense sector, Space Foundation tracked the civil space spending of 32 non-U.S. nations in 2019. Of non-U.S. governmental spending in 2019, 76% was allocated to activities in the civil sector, totaling $30.2 billion and representing an 10.6% increase over 2018. Collectively, non-U.S. civil space spending constituted 35% of global government space spending in 2019 and 7.1% of the 2019 global space economy.

1.4.2.1 Argentina

The budget of the Argentinian space agency, the National Space Activities Commission (CONAE), decreased 21% in 2019, from ARS$2.22 billion to ARS$1.75 billion, marking the second year in a row of decreased government space investment.[80] The setting aside of funds for future use may be responsible for this decrease: Despite a plan to launch the second satellite in the Synthetic Aperture Radar (SAR) Italian-Argentine System of Satellites for Emergency Management (SIASGE), titled SAOCOM 1-B, in September 2019,[81] the launch was moved to March 30, 2020.[82] The launch was postponed again to Q4 of 2020 due to coronavirus-related concerns.[83]

1.4.2.2 Australia

Since the establishment of the Australian Space Agency (ASA) in 2018, the Australian government has signaled ever-growing support for national and international space initiatives. The Australian government budget in 2018-2019 allocated AUD$41 million over four years for the establishment of ASA, of which approximately AUD$12.8 million was spent in 2018.[84] This allocation included AUD$15 million, or three years of funding, for the International Space Investment project (ISI), an initiative "to foster international partnerships and increase the competitiveness of Australian business within the global space economy."[85] Geoscience Australia, a government agency, also announced in 2018 that AUD$260 million would be invested in expanding geospatial satellite capabilities over the next four years.[86] The 2019-2020 budget introduced a number of other additional measures — an AUD$19.5 million Space Infrastructure Fund (SIF) to support projects in Australia's emerging domestic space industry and an AUD$6 million Australian Space Discovery Centre set to open in 2021.[87, 88]

Due to the multiyear nature of the projects described, the mid-budget cycle creation of the ASA in July 2018, and reality that the "economic baseline data" of Australian civil space spending that is needed for multiyear analysis is still in development, only estimates can be made for Australian civil space spending in 2019.[89] Given that ASA spent approximately one-fourth its four-year funding in 2019, Geoscience Australia spent approximately one-fourth of its four-year space funding in 2019, all AUD$19.5 million in SIF expenditures were distributed to the participating research projects in 2019, and the entirety of the Australian Space Discovery Center funding was paid to contractors at the onset of development, Australian civil space spending increased 29.5% in 2019, from a revised 2018 figure of AUD$77.8 million to AUD$100.8 million.

Australian military funding is detailed in *1.4.1 Non-U.S. Military Space Investment* and represented approximately 5.2% of Australian space spending in 2019.[90]

1.4.2.3 Canada

The Canadian Space Agency (CSA) has coordinated and executed Canadian space initiatives since its inception in 1989[91] and received CAD$329 million in funding for 2019.[92] This level of funding represents a modest 5% reduction over the 2018 figure of CAD$347 million. Regular programs include crewing the International Space Station (ISS) and conducting research, satellite manufacturing across sectors, and preparatory experiments for extraterrestrial exploration.[93]

Canada, a former British colony and member of the Commonwealth, is a cooperating member of the European Space Agency (ESA) and renewed its treaty in June 2019 to extend through 2030.[94] Canada contributed €11.8 million to ESA in 2019, 58% of which was mandatory and 42% of which was optional. In addition to marking a nearly 39% reduction in ESA contribution from 2018, this represents a broader shift in funding priorities, as Canada in 2018 contributed twice as much to ESA optionally as mandatorily.[95] Canada's ESA contribution change likely reflects a broad consultation survey of the space community conducted by CSA in June 2019.[96] At the Ministerial Council of the European Space Agency in November 2019, Canada committed to invest CAD$90 million in ESA to "strategically selected areas most likely to benefit Canadian industry: Earth observation, satellite communications, exploration and technology development."[97]

1.4.2.4 China

China does not release government budgetary information in the manner of other nations analyzed, making analysis of Chinese space spending difficult. As such Space Foundation builds an estimation for Chinese space spending based on the percent of Gross Domestic Product (GDP) comparable nations spend on space in the year. The countries selected in Exhibit 1l spent an average of .07% of their national GDP on space activities in 2019, a figure that, when applied to the Chinese 2019 GDP, yields an estimate of ¥65.9 billion for Chinese space spending in 2019.[98] This figure is 25% greater than Space Foundation's estimate for 2018 and comes to approximately US$9.6 billion.

EXHIBIT 1l. Domestic Space Spending as a Percentage of Gross Domestic Product (GDP), Selected Countries, 2019

Country	Currency	2019 Space Spending	2019 GDP (current prices, national currency)	% GDP Spent on Space
Russia	USD	₽251.700B	₽109.097T	0.231%
United States	EUR	$47.169B	$21.439T	0.220%
Japan	JPY	¥413.900B	¥557.716T	0.074%
France	RUB	€1.318B	€2.241T	0.055%
India	INR	₹131.392B	₹208.985T	0.063%
Germany	EUR	€1.380B	€3.440T	0.040%
Brazil	BRL	R$1.479B	R$7.197T	0.021%
Italy	EUR	€0.336B	€1.771T	0.019%
Spain	EUR	€0.189B	€1.245T	0.015%
Canada	CAD	C$0.329B	C$2.298T	0.014%
United Kingdom	GBP	£0.158B	£2.185T	0.007%
			Average % GDP Spent on Space	0.0690%

*Includes ESA spending
Source: IMF World Economic Outlook Database October 2019 edition, space spending sources as cited in this chapter

There is evidence that Chinese space spending grew in 2019, most notably due to the nation's achievements over the year. On Jan. 2, 2019, China became the first nation to land a spacecraft on the far side of the moon with its Change'4 mission,[99] the Yutu-2 rover of which beat the previous record time for a lunar rover's operation on Dec. 14, 2019.[100] China also surpassed its stated goal of launching more than 50 satellites on more than 30 government launches in 2019[101] by lofting 75 spacecraft on 31 government launches, although 32% of payloads were unidentified at the time of writing.[102] Three more launches were conducted commercially in China in 2019, each testing a new launch vehicle for the first time, with the Hyperbola-1 from iSpace and the Smart-Dragon-1 (or Jielong) from China Rocket Co. Ltd. proving successful in their attempts[103, 104] and the OS-M launch from OneSpace Technology Co., Ltd. ending in failure.[105] These commercial attempts are significant in that they are part of the rapid growth in Chinese aerospace companies that prompted the formation of the China Commercial Space Alliance on Dec. 11, 2019.[106] Operating under the Chinese National Space Agency (CNSA), the newly formed alliance will strengthen policy advocacy and carry out industry research, promote innovation and integration of the industrial chain, assist in regulation, and promote international cooperation according to the country's Belt and Road Initiative."[107] Lastly, on Dec. 27, 2019, China successfully launched the Long March-5 heavy-mass capable vehicle for the first time, ushering in a new era of possibility.[108]

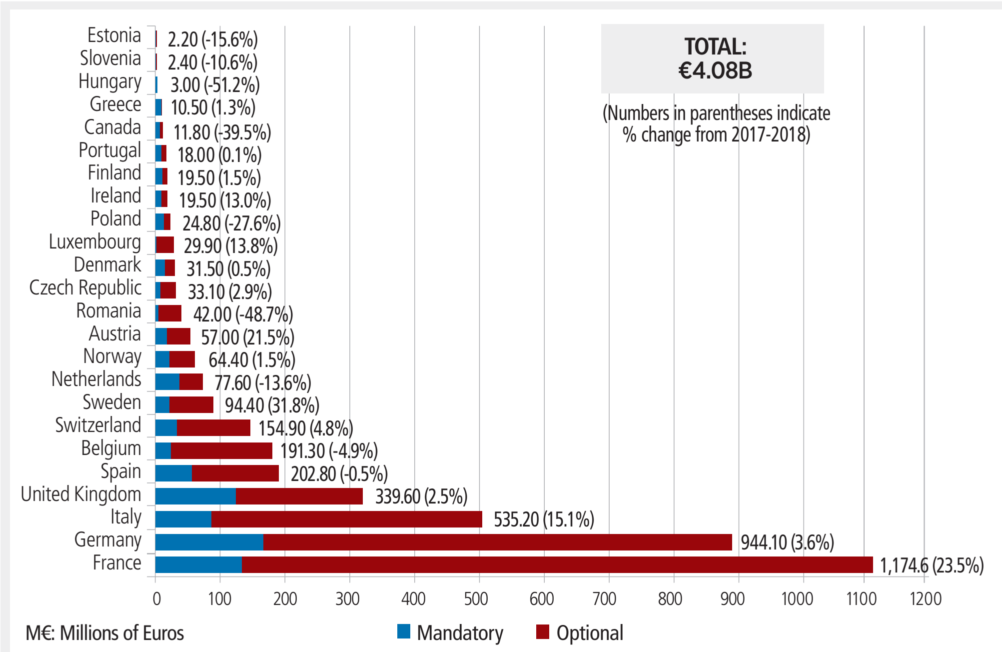
Looking forward, China has ambitious plans spanning decades. In 2020, China intends to launch Change 5, a lunar sample and return mission, and a Mars orbiter.[109, 110] Over a longer time span, the nation has a number of stated priorities: to build space capacity for cost-effective launch and access, to launch its own permanent space station, to create capacity to dominate cislunar space (the sphere between the moon and the Earth), and, once cislunar space is secured, to develop the capacity for a sustainable human presence on the moon. Further goals include deep space exploration and resource extraction from asteroids.[111, 112]

1.4.2.5 European Space Agency

The European Space Agency (ESA) is a complex, international entity comprised of 22 member states and two cooperating states and is supported by other multinational organizations.[113] ESA spending in 2019 reached €5.9 billion, an increase of 5% over 2018 and a 75% increase over a decade ago.[114]

Member states provided 70% of the ESA budget in 2019, collectively contributing €4.2 billion. Member states are obligated to mandatory contributions; however, all but one contributed additional optional funds in 2019. Luxembourg allocated 17 times the nation's mandatory contribution of €2 million and 18 nation-states followed in its footsteps, contributing at least an equal amount to optional programs as mandatory ones. The member-state-supported funding to these optional programs totaled €3.3 billion in 2019 and comprised 79% of all member state contributions to ESA.[115] Launch vehicle development, Earth ob-

EXHIBIT 1m. Member Contributions to ESA, 2019

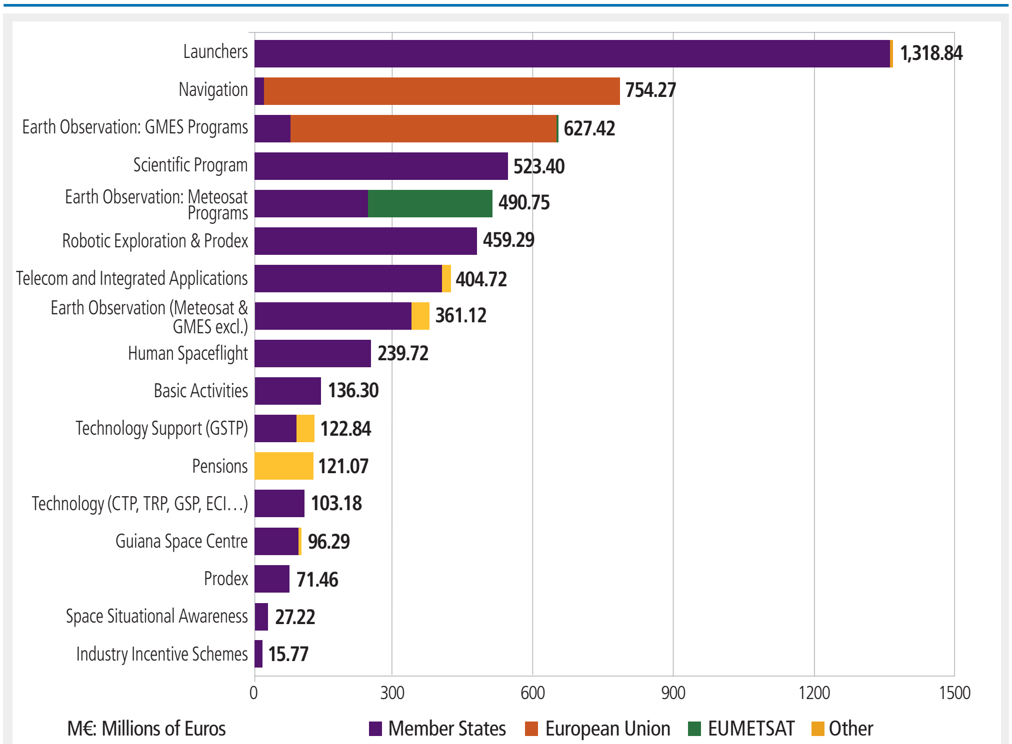


Source: Eurospace

servation, telecommunications, manned flights and the manning of the ISS are optional programs, whereas mandatory programs include basic activities, infrastructure such as the French Guiana Space Centre, and the Scientific Programme.[116]

The remaining 30% of the ESA budget is comprised of optional contributions from two other European multinational entities — the European Union (EU) and European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The EU, despite conducting independent space activities detailed in this section, contributed €1.28 billion to ESA across Earth observation and navigation programs. In the same manner, EUMETSAT invested a share of its budget in ESA's Earth observation programs in 2019, contributing €261 million.[117]

EXHIBIT 1n. ESA Budget by Program and Funding Source, 2019



Source: Eurospace

With the support of these two multinational bodies, Earth Observation (EO) programs rose to represent the largest share of the ESA budget, totaling €1.5 billion. The Global Monitoring for Environment and Security (GMES) constellation, Copernicus constellation, and a number of other EO satellites compromise ESA's Earth Observation program.[118] Launchers (€1.3 billion) and Navigation (€754 million) initiatives represented the next largest shares of the 2019 ESA budget, meaning that the three most highly funded ESA programs were all optional. The launcher program supports the use of Soyuz launchers and develops the Ariane and Vega lines of launch vehicles,[119] while the Navigation Programme encompasses the Galileo positioning, navigation, and timing satellite system.[120] The most highly funded mandatory program was the Scientific Programme (€523 million), which relies on long-term science planning and broad participation to provide

answers to "fundamental questions of astronomy, solar system science and fundamental science."[121]
France contributed the most to ESA in 2019 (€2.7 billion), followed by Germany, the United Kingdom, Italy, and Spain. For a more thorough analysis of member state contributions to ESA, see country-level sections and Exhibit 1m.

Future ESA missions are numerous and span mission areas such as solar system exploration (Aurora), Earth observation (Living Planet), and technology research and development from launchers to satellites.[122] The ESA Council committed in November 2019 to a 2020 ESA budget larger than ever before.[123]

1.4.2.6 European Union

In addition to ESA contributions, the European Union (EU) enacts its own space policy under the executive oversight of the European Commission (EC).[124] The three EU flagship space programs are of two missions: Earth observation and positioning, navigation, and timing (PNT). The Copernicus Earth Observation Programme is coordinated and managed by the EU and developed and performed by other European multinational organizations.[125] PNT is provided by the European Geostationary Navigation Overlay Service (EGNOS) and Galileo constellations, the operations and service provisions for which the EU's own space agency, the European GNSS Agency (GSA), is responsible.[126]

EU space spending decreased by 0.1% in 2019 to €1.727 billion from a 2018 outturn of €1.728 billion. A 4.1% reduction of funding to EGNOS and Galileo nearly balanced a 4.6% increase in funding for Copernicus and for growing Leadership in Space, defined as "the availability of a first-rank domestic industry, able to design, deliver and exploit state-of-the-art space systems, required by public and private customers worldwide."[127] Further changes to EU space spending include replacing a space technologies pilot program with one on space traffic and the introduction of funds to prepare the Governmental Satellite Communication (GovSatCom) program.[128]

EXHIBIT 1o. EU Space Spending by Program, 2018-2020

	Actual 2018	Appropriations 2019	Budget 2020
Line Item	Payments	Payments	Payments
Leadership in space	€161.64M	€169.02M	€204.45M
European Earth observation program	€572.96M	€599.50M	€549.00M
European satellite navigation programs (EGNOS and Galileo)	€992.88M	€952.63M	€948.23M
Pilot-project - Space trafficEuropean GNSS Agency	–	€0.35M	€0.35M
Preparing GOVSATCOM program	–	€5.00M	€5.00M
Total	**€1,727.49M**	**€1,726.50M**	**€1,707.03M**

Source: Eurospace

EU's €1.284 billion contribution to ESA constitutes over 74% of the EU space budget and is described in 1.4.2.5 *European Space Agency (ESA).*

In June 2018, the EC presented the *Multiannual Financial Framework 2021-2027*, detailing a €16 billion space program to support the Galileo, EGNOS, and Copernicus programs as well as to develop new security components for Space and Situational Awareness (SSA) and GovSatCom.[129] A revision of this economic framework was released in spring 2020 as a result of the coronavirus, and proposed reducing spending on the EU's European Space Program to €13.2 billion.[130, 131]

1.4.2.7. European Organisation for the Exploitation of Meteorological Satellites

EUMETSAT is a European agency comprised of 30 member states[132] dedicated to observing the climate and weather around the globe 24 hours a day, 365 days a year.[133] The drafted EUMETSAT contribution budget for 2019 was €560 million, a reduction of 5.8% from 2018 real figure of €595 million.

All members must contribute to the Meteosat and Polar System Programmes, both Preparatory and Transitionary. Optional contributions support collaborations with ESA and NOAA on the Copernicus and JASON Earth Observation constellations, respectively.[134] Germany, France, and the United Kingdom contributed the most to the EUMETSAT budget in 2019, as noted in EUMETSAT's €560 million contribution to ESA constitutes 47% of the total EUMETSAT budget and is described in 1.4.2.5 *European Space Agency (ESA)*.[135]

EXHIBIT 1p. EUMETSAT Contribution by Member State, 2019

Member State	Contribution Budget 2017*	Contribution Budget 2018*	Contribution Annual Report 2019**	% change 2017-2019
Austria	€11.4M	€12.5M	€14M	23%
Belgium	€13.5M	€14.5M	€0M	18%
Bulgaria	€1.4M	€1.5M	€2M	24%
Croatia	€1.6M	€1.6M	€2M	13%
Czech Republic	€5.2M	€5.4M	€6M	15%
Denmark	€9.5M	€10.3M	€11M	21%
Estonia	€0.6M	€0.7M	€1M	37%
Finland	€7.2M	€7.9M	€9M	20%
France	€78.7M	€83.5M	€92M	17%
Germany	€102.8M	€114.2M	€126M	23%
Greece	€7.5M	€6.4M	€7M	-5%
Hungary	€3.4M	€3.6M	€4M	19%
Iceland	€0.3M	€0.5M	€1M	61%
Ireland	€5.2M	€6.5M	€7M	37%
Italy	€59.4M	€60.9M	€67M	13%
Latvia	€0.7M	€0.9M	€1M	26%
Lithuania	€1.1M	€1.3M	€1M	30%
Luxembourg	€1.1M	€1.3M	€1M	24%
Netherlands	€23.1M	€25.4M	€28M	22%
Norway	€13.9M	€14.7M	€16M	17%
Poland	€12.9M	€14.2M	€16M	22%
Portugal	€6.3M	€6.5M	€7M	13%
Romania	€4.6M	€5.4M	€6M	27%
Serbia	€0.5M		€0M	-100%
Slovakia	€2.4M	€2.7M	€3M	22%
Slovenia	€1.3M	€1.3M	€1M	14%
Spain	€37.4M	€39.3M	€43M	16%
Sweden	€15.1M	€17.0M	€19M	24%
Switzerland	€18.6M	€21.4M	€24M	27%
Turkey	€22.1M	€27.3M	€30M	36%
United Kingdom	€70.5M	€86.0M	€95M	35%
Total Contributions	**€539.071M**	**€594.749M**	**€560M**	

**Real AR*
***Draft*
Source: Eurospace

EUMETSAT's current and future plans are detailed it the *EUMETSAT Strategy Challenge 2025* and involve lofting the Meteosat Third Generation (MTG) and EUMETSAT Polar System-Second Generation (EPS-SG) as well as continuing to deliver services to member states and maintaining international partnerships.[136, 137]

1.4.2.8 France

The French civil space agency, Centre National d'Etudes Spatiales (CNES), in mid-July 2020 released its *Annual Report 2019*. According to the 2020 budget, in 2019 French space spending in the civil sector totalled €2.18 billion, a 7.6% increase over 2018. The annual report details how France invested nationally — prioritizing innovation, exploration, and climate research in the domains of science, observation, telecommunications, and Ariane launch vehicle development.

France spent approximately 55% of its 2019 civil space budget, or €1.09 billion, on domestic space projects, according to the annual report.[139] Notable civil space activities of France in 2019 included ending the Ocean Surface Topography Mission (OSTM) after 11 years of collaboration with NASA,[140] awarding Airbus the CO3D (Constellation Optique 3D) contract to develop French optical Earth observation capabilities,[141] and signing agreements with the Indian Space Research Organisation (ISRO) to establish a maritime surveillance center in India[142] and share expertise in support of India's Gaganyaan human spaceflight mission.[143]

The remaining 45% was attributed to international subscriptions to EUMETSAT and ESA, 93% of which went to the latter. France is the largest contributor to ESA, the French allocation to which, approximately €1.17 billion, grew 23% in 2019 to constitute 28% of the agency's entire budget.[144] France contributed 7.3 times as much to ESA programs optionally as mandatorily, extending €694 million to the agency's Space Transportation program. Not only is France the greatest contributor to the program, this figure is 2.8 times higher than the Space Transportation contribution of the next highest member state, Germany.[145] France's EUMETSAT contribution, €79 million, was the second greatest of any member state, compromising 14% of the organization's 2019 budget.[146]

France has stated its intention expand its space program through the lens of securing "strategic autonomy" through defense space activities.[147] French military funding is detailed in *1.4.1 Non-U.S. Military Space Investment*. Defense-specific funding comprised approximately 15.5% of total French space spending.[148]

1.4.2.9 Germany

German space initiatives are enacted and coordinated by the German Aerospace Center (Deutsches Zentrum für Luft-und Raumfahrt; DLR).[149] This administration received a record amount of funding in 2019 — increasing over 30% to €1.2 billion.[150] In addition to managing Germany's international memberships to ESA and EUMETSAT, DLR conducts its own space activities, collaborating on missions such as the NASA InSight Mars Lander and conducting independent research.[151]

Germany's contributions to ESA and EUMETSAT constituted 47% of German civil space spending. Of the €1.07 billion paid to these multinational organizations, 88%, or €944 million, was allocated to ESA in 2019.[152] A 3.6% increase over 2018, Germany contributed 4.3 times more to optional programs than it paid mandatorily. The nation contributed more than any other member states to ESA's optional Earth Observation, Technology Support, and Human Spaceflight, Microgravity, and Exploration Programmes.[153]

Despite constituting only 12% of international subscriptions, Germany was the largest contributor to EUMETSAT in 2019. The €107 million budgeted for 2019 represents a 7% decrease from 2018, however, compromises over 19% of total EUMETSAT contributions.[154]

Notably, Germany has expressed the intent to continue to ramp up space investment nationally and internationally. In addition to having doubled investment on small and medium-sized German space companies, Germany committed in November 2019 to contribute €3.3 billion to European space programs over the next three to five years. This action will make Germany the largest contributor to ESA, surpassing France.[155]

German military funding is detailed in *1.4.1 Non-U.S. Military Space Investment.* Defense-specific funding comprised approximately 3% of German internal space spending.[156]

1.4.2.10 India

The year 2019 proved to be one of rising ambition for India in the space domain, and the Indian Department of Space budget proved to be no exception, growing 17.4% in 2019 to reach ₹131 billion.[157] Space technology projects constituted 68% of Department of Space spending in 2019, with space applications, such as the Space Applications Center,[158] comprising an additional 14%.[159] The Indian Department of Space oversees the Indian Space Research Organisation (ISRO) and, increasingly, collaborates with the Defence Research Development Organisation (DRDO) to undertake national projects, such as the anti-satellite test conducted in March 2019.[160, 161]

EXHIBIT 1q. ISRO Budget, FY 2018-2021

Budget Area	Actual 2018-2019		Revised 2019-2020		Estimates 2020-2021	
	Rupees	U.S. Dollars	Rupees	U.S. Dollars	Rupees	U.S. Dollars
Central Sector Schemes/ Projects	₹100,084.60M	$1,461.62M	₹121,443.40M	$1,761.34M	₹125,870.00M	$1,825.54M
Space Technology	₹63,828.20M	$932.14M	₹89,911.30M	$1,304.02M	₹97,615.00M	$1,415.75M
Space Applications	₹18,114.70M	$264.55M	₹18,627.70M	$270.16M	₹18,100.00M	$262.51M
Space Sciences	₹2,216.40M	$32.37M	₹2,818.80M	$40.88M	₹2,650.00M	$38.43M
INSAT Satellite Systems	₹15,925.30M	$232.57M	₹10,085.60M	$146.28M	₹7,505.00M	$108.85M
Other Central Sector Expenditure	₹6,782.80M	$99.06M	₹7,214.40M	$104.63M	₹6,623.00M	$96.06M
Establishment Expenditure of the Center	₹5,016.30M	$73.26M	₹2,734.80M	$39.66M	₹2,301.70M	$33.38M
Total	**₹111,883.70M**	**$1,633.94M**	**₹131,392.60M**	**$1,905.64M**	**₹134,794.70M**	**$1,954.98M**

Source: Ministry of Finance, Government of India

The DRDO does not publish space specific budgetary figures, however, the agency's total budget grew 11% to reach ₹191 billion in 2019.[162] In November 2019, the Minister of State for Defence Shripad Naik confirmed that the Defence Research and Development Board now includes a representative from Indian Space Research Organisation (ISRO), which signals continued and increasing collaboration between the two.[163]

A number of recent announcements by the Indian Government have signaled the path ahead for Indian space spending. In June 2019, IRSO Chief K Sivan announced that India will work toward lofting its own space station.[164] In July 2019, the Department of Space announced the creation of a new commercial arm of ISRO called NewSpace India Limited (NSIL) to "spearhead commercialization of various space products including production of launch vehicles, transfer to [sic] technologies and marketing of space products."[165] In September 2019, DRDO and ISRO announced a joint program to send Indian astronauts to space by 2022 called "Gaganyaan."[166] In January 2020, in response to the crash landing of the Chandrayaan-2 lunar lander, K Sivan announced the approval of a third Chandrayaan lunar lander slated to launch in 2021.[167]

1.4.2.11 Israel

Israeli civilian space activities are conducted by the Israel Space Agency (ISA) under the Ministry of Science and Technology.[168] Detailed public Israeli budget reporting is not standard, however, the Israeli government accountability and transparency organization Public Knowledge Workshop, also known as "Hasadna," released figures dating back to 2013.[169] According to its research, Israeli space spending in 2019 reached approximately ₪31.9 million, a decrease of 1.5% over 2018 and the lowest figure since 2014.[170] Israeli military space spending is not publicly available.

As for future Israeli space spending, the Ministry of Science has committed to putting ₪20 million toward a second moon shot after the lunar collision that ended the organization SpaceIL's Beresheet mission on April 11, 2019.[171]

1.4.2.12 Italy

The Italian Space Agency (ASI), operating under the Ministry of Education, University and Research, has coordinated Italy's space ambitions since 1988.[172] Funding for ASI grew by 3% in 2019, reaching €872 million from a 2018 budget of €843 million.[173] Flagship programs of the agency include the Cosmo Sky-Med Earth observation constellation and collaborations with industry on the Vega launch vehicle. Other activities of the agency include international partnerships that study cosmology, send Italian astronauts to the International Space Station, and launch probes to explore other worlds.[174] 2019 saw the launch of ASI's PRISMA Earth observation satellite[175] and first Second Generation COSMO-SkyMed satellite.[176]

ASI allocated approximately 68% of its 2019 budget to international memberships to EUMETSAT and ESA. Of the €602 million distributed between the two organizations, 89% went to ESA.[177] The third-largest contributor to ESA, Italy invested most highly in the optional Space Transportation and Human Spaceflight, Microgravity, and Exploration Programmes.

Future ambitions of Italy include "mirror programs" to the Galileo, GovSatCom, and Copernicus constellations. This initiative began with a contract in July 2019 establishing an Ital-GovSatCom as part of Italy's Space Economy initiative.[178]

EXHIBIT 1r. Japan Civil Space Spending by Agency, 2018-2020

Agency/Ministry	2018	2019	2020
Cabinet Secretariat	$682.03M	$730.13M	$728.30M
Cabinet Office	$224.03M	$392.86M	$360.90M
National Police Agency	$8.13M	$8.34M	$9.28M
Ministry of Internal Affairs and Communications	$63.23M	$68.57M	$66.80M
Ministry of Foregin Affairs	$2.71M	$1.85M	$2.78M
Ministry of Education, Culture, Sports, Science, and Technology (MEXT)	$1,633.27M	$1,687.27M	$1,730.30M
Ministry of Agriculture, Forestry, and Fisheries	$2.71M	$2.78M	$2.78M
Ministry of Economy, Trade, and Industry	$25.29M	$24.09M	$25.98M
Ministry of Land, Infrastructure, Transport, and Tourism	$50.59M	$58.37M	$89.07M
Ministry of the Enviroment	$27.10M	$30.58M	$82.57M
Total	**$2.719B**	**$3.005B**	**$3.099B**

Source: Correspondence with JAXA D.C. Office, March 2018 and July 2020.

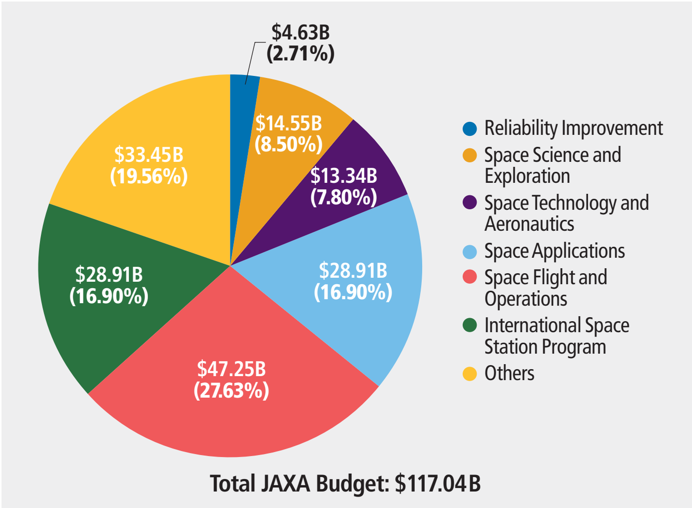
1.4.2.13 Japan

Japan enacts its civil space policy across ten different government agencies, and allocated funds to each as detailed in Exhibit 1r. In total, Japan spent ¥324 billion in civil space activities in 2019, an increase of 7.7% over a 2018 figure of ¥301 billion.

The Japan Aerospace Exploration Agency (JAXA) is at the center of the Japanese government's space ambitions, and its budget constituted approximately 56% of Japanese space spending in 2019. Founded in 2003 from the merger of the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL) and the National Space Development Agency of Japan (NASDA),[179] funding has been variable over the years.[180] The 2019 JAXA budget reached ¥184.6 billion, a 0.8% increase over 2018.[181] The agency spent most heavily on Space Flight and Operations (¥51 billion), followed by the International Space Station Program and Space Applications (¥31 billion each).[182] This 2019 investment in Space Flight and Operations is 28.5% greater than that of 2018, potentially related to costs associated with the many milestones the Hayabusa-2 mission reached throughout 2019: the first landing (February),[183] the operation of the Small Carry-on Impactor (SCI) (April),[184] the second landing and sample collection (July),[185] and the departure from Ryugu (November).[186]

JAXA has announced its intentions to expand space operations in the coming years. In September 2019, JAXA issued joint statements alongside other national and international space agencies outlining shared goals for lunar exploration[187] and the

EXHIBIT 1s. JAXA Budget by Program, 2019



Source: JAXA

Gateway project, which seeks to establish a crewed space station in lunar orbit.[188]

Japanese military funding is detailed in *1.4.1 Non-U.S. Military Space Investment.* Defense-specific funding comprised approximately 22% of total Japanese space spending. The Japanese defense sector has signaled a commitment to growing its investment in space, as in the budget for fiscal year 2020, the Defense Ministry announced the formation of a new space operation inside the Air Self-Defense Force to "detect electromagnetic interference with Japanese satellites" and "monitor space debris and unidentified objects in outer space."[189]

1.4.2.14 New Zealand

New Zealand has mobilized rapidly to enter the space domain since the 2016 formation of the New Zealand Space Agency under the Ministry of Business, Innovation and Employment (MBIE). In addition to contributing NZD$3.75 million to the New Zealand Space Agency annually (and committing to this funding level through 2023),[190] New Zealand also founded the Xerra Earth Observation Institute, formerly known on The Centre for Space Science Technology (CSST), in 2017.[191] The organization was funded at the NZD$14.7 million level in 2019,[192] consistent with the institute's allocation upon formation.[193] The New Zealand Space Agency leads New Zealand space policy, supports launches off the island, and engages internationally,[194] whereas the Xerra Earth Observation Institute maintains an Earth observation data repository specific to the nation.[195]

1.4.2.15 Russia

The Russian Government established Roscosmos in August 2015 by merging the Russian Federal Space Agency and United Rocket and Space Corporation. In addition using space advancements to provide results in the social and economic development of Russia through infrastructure development and legal regulation, the agency coordinates with international partners and, internally, the Defense Ministry of the Russian Federation on military missions.[196, 197]

Detailed Russian budget figures are not regularly released, so statements from the federally owned news agency TASS are used to determine annual Russian space spending. Initial reports signaled a ₽17 billion decrease in spending on space activities in 2019 over 2018,[198] a 9% decrease in line with a reported 16% of the Roscosmos budget that went unused in 2018.[199] Nonetheless, TASS reported in late September 2019 that Russia allocated ₽251.7 billion for the state space program in 2019 to expand the space research and diversification programs.[200] This figure marks a 38% increase in Russian space spending from a reported 2018 figure of ₽182 billion, and a 141% increase over the preceding decade.[201] Although he did not name specific programs receiving this expanded funding, Roscosmos General Director Dmitry Rogozin pointed to commercial launch vehicle projects as promising and described the agency's focus as "unifying engineering solutions."[202]

1.4.2.16 South Korea

The South Korean space agency Korea Aerospace Research Institute (KARI) operates in four primary areas of development: technology, aerospace policy, joint utilization between industry and academia, and cooperation between government and the private sector.[203] Funding for KARI dropped 20.5% in 2019 to ₩550 billion from a 2018 peak of ₩692 billion.[204]

Despite this decrease, South Korean space achievements and ambitions are growing. In supplement to the GEO-KOMPSAT-1 satellite launched in 2018, South Korea launched the Chollian 2B meteorological satellite in February 2020, billed as the world's first air-monitoring spacecraft in a geosynchronous orbit.[205] In January, the South Korean Ministry of Science and ICT, the overseeing agency of KARI, issued a press release signaling the agency's priorities from 2020 onwards. The document calls for increasing space technology investment and highlights the first launch of KSLV, the nation's first indigenous launch vehicle, planned for 2020. Also emphasized in the plans is South Korean satellite operator KT SAT, which is working toward quantum communication and intends to build the world's first 5G satellite connection.[206]

1.4.2.17 Spain

For the last 75 years, the National Institute of Aerospace Technology (INTA) has served as Spain's public space research organization.[207] Incorporated under the Spanish Ministry of Defense, Spanish national civil spending reached €115 million in 2019.[208, 209] A modest increase of €200 million over 2018, this figure represents a stark 76% increase over 2017, a reflection of growing national investment in space.[210, 211, 212] National civil space activities of the Spanish government include the continued operation of 2018's Paz Earth Observation satellite and support for the commercial Hisdesat communications constellation.[213] The Spanish government is expanding these efforts, however, starting with a planned 2020 launch of a new Spanish Earth observation satellite (SEOSAT) out of French Guiana.[214]

Spain is a member of ESA and EUMETSAT and contributed to both in 2019 — €234 million and €43 million, respectively.[215] These international memberships collectively comprised 59% of all Spanish space spending in 2019.[216, 217, 218] Spain contributed to all ESA programs in 2019, allocating 2.5 times as much for optional programs as mandatory ones.[219] Spain signaled its intention to continue to invest in ESA by raising the budget ceiling for Spanish contributions to ESA by 73% through 2026[220] and by committing to establish a national data center to distribute Copernicus data.[221]

Spanish military funding is detailed in *1.4.1 Non-U.S. Military Space Investment.* Defense-specific funding comprised approximately 16% of Spanish space spending.[222]

1.4.2.18 Switzerland

The Swiss Space Center works to implement Swiss Space Policy. Main tasks of the center include building networks between institutions and industry, facilitating access for space for research institutions and industry, providing education and training, and promoting public awareness of space.[223] Spending towards these goals on a national level decreased by nearly 26% in 2019, landing at Fr.8.4 million after a 2018 total of Fr.11.4 million.[224] Despite this decrease, Switzerland began coordination of IGLUNA in 2019, a program that poses collaborative interdisciplinary technical challenges to university students internationally.[225]

Switzerland's main instrument to implement space policy is ESA,[226] to which Switzerland contributed Fr.154 million. These funds constitute 89% of Switzerland's international subscriptions, with a Fr. 20 million contribution to EUMETSAT comprising the remainder. Switzerland contributed 3.4 times as much to optional ESA programs as to mandatory ones in 2019, investing most heavily in Space Transportation, Earth Observation, and, in keeping with its stated mission to promote access to space, the PROgramme de Développement d'Expériences scientifiques, known as PRODEX, which enables institutions and industry to work with ESA experiments.[227, 228]

1.4.2.19 United Arab Emirates

The United Arab Emirates (UAE) allocated its space agency, the UAE Space Agency, AED 171 million in 2019, a 16% reduction over 2018.[229, 230] This may correlate with the conclusion of the ISS tenure of the UAE's first astronaut in October 2019.[231] As for future activities, the UAE is on track for a July 2020 launch of its Hope Mars Mission[232] and is working to bring to fruition a vision for a scientific city on Mars by 2117.[233]

1.4.2.20 United Kingdom

The complex political reality of the United Kingdom (U.K.) in 2019 had implications on the nation's shifting space spending. Despite decreasing funding for international subscriptions by 14% in 2018, the U.K. raised funding in the same category by 37% in 2019, reaching £345 million. Funding for the National Programme spending increased 28% over the last two years, a line item that may have ballooned in part due to its inclusion of funds related to the nation's exit from the EU (Brexit) in

January 2020.[234, 235, 236] Activities of the U.K. Space Agency (UKSA), the overseeing agency of British space ambitions, include the International Partnership Programme (IPP), the National Space Technology Programme (NSTP), the General Support Programme (GSTP), and the Space for Smarter Government Programme (SSGP) as well as missions across Earth observation, space exploration, and space science.[237] The United Kingdom's next aspiration in the space domain is the development of a national spaceport with international draw, a move empowered by an agreement signed with the United States in June 2020 to give U.S. companies the ability to participate in launches from the U.K. as a customer or as contractor in the supply chain.[238]

The United Kingdom is a member of ESA and EUMETSAT, contributing €435 million in 2019. Of this total, 78%, or €340 million, was allocated to ESA. The United Kingdom contributed 1.6 times the funds to ESA optionally as mandatorily, spending more than any other member state on Navigation, Space Situational Awareness, and Telecommunications and Integrated Applications. Despite questions regarding the implications of Brexit on the U.K.'s participation in ESA, David Parker, the director of Human and Robotic Exploration at ESA, reported in January 2020 that, "Brexit doesn't affect the U.K.'s participation with ESA. Indeed, the U.K. has significantly increased its participation in ESA by about 15% of the optional programs. So we take that as a positive sign of support from the U.K."[239]

EXHIBIT 1t. Space Budgets of Selected Additional Countries, 2019

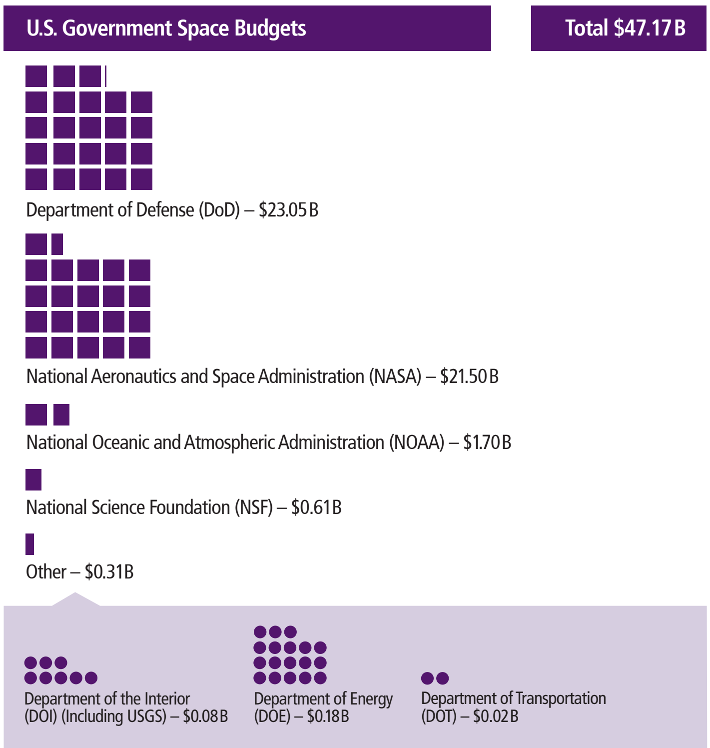
Country	Agency	2019 Budget Figure (national currency)	Currency	Budget (U.S. Dollars)	Description	Source
Argentina	National Commission of Space Activites (CONAE)	$1,751.04M	ARS	$41.22M	CONAE budget	Argentinian Government Transparency Portal
Australia	Australian Space Agency	A$100.75M	AUD	$70.76M	Australian civil space spending	Australian Budget 2019-2020
Austria	Aeronautics and Space Agency (ALR)	€7.10M	EUR	$8.08M	ALR budget	Correspondence with FFG
Belgium**	Belgian Institute for Space Aeronomy (BIRA)	€18.88M	EUR	$21.47M	Belgian space spending	Belgian Federal Budget 2019
Denmark	National Space Institute	Kr.1.90M	DKK	$.29M	Danish space spending	Danish Finance Ministry
Indonesia	National Aeronotics and Space Agency (LAPAN)	Rp792.6M	IDR	$0.06M	LAPAN budget	LAPAN
Israel	Israel Space Agency (ISA)	₪31.90M	ILS	$8.93M	Israeli space spending	Public Knowledge Workshop
Mexico	Mexican Space Agency (AEM)	Mex$62.44M	MXN	$3.24M	AEM budget	Mexico Federal Budget 2019
Netherlands	Netherlands Institute for Space Research (SRON)	ƒ20.00M	ANG	$22.74M	SRON budget	SRON
New Zealand	New Zealand Space Agency & Centre for Space Science and Technology	$18.45M	NZD	$12.40M	New Zealand space spending	New Zealand Ministry of Business, Innovation & Employment
Nigeria	National Space Research and Development Agency (NARSDA)	₦15,600.00M	NGN	$43.40M	Nigerian space spending	Nigerian Ministry of Finance
Pakistan	Pakistan Space and Upper Atmosphere Reseach Commission (SUPARCO)	Rs6,300.00M	PKR	$38.65M	SUPARCO budget	Pakistani Finance Ministry
Poland	Polish Space Agency (POLSA)	zł124.25M	PLN	$33.27M	POLSA budget	POLSA
South Africa	South African National Space Agency (SANSA)	R193.46M	ZAR	$13.73M	SANSA budget	National Treasury of the Republic of South Africa
Sweden	Swedish National Space Agency	kr226.71M	SEK	$24.41M	Swedish National Space Agency	Swedish National Space Agency
Switzerland	Swiss Space Office (SSO)	SFr8.45M	CHF	$8.65M	Swiss Confederation	Swiss Confederation
United Arab Emirates	United Arab Emirates Space Agency	د.إ171.00M	AED	$46.56M	UAE Ministry of Finance	UAE Ministry of Finance
TOTAL			Total (USD)	$397.87M		

*Space agency only (no meterology)
**Centre for Space Science and Technology founded at beginning of 2017-2018 budget cycle
Note: All ESA spending excluded
Correction, August 2020: 2019 figures for Israel and UAE have been updated

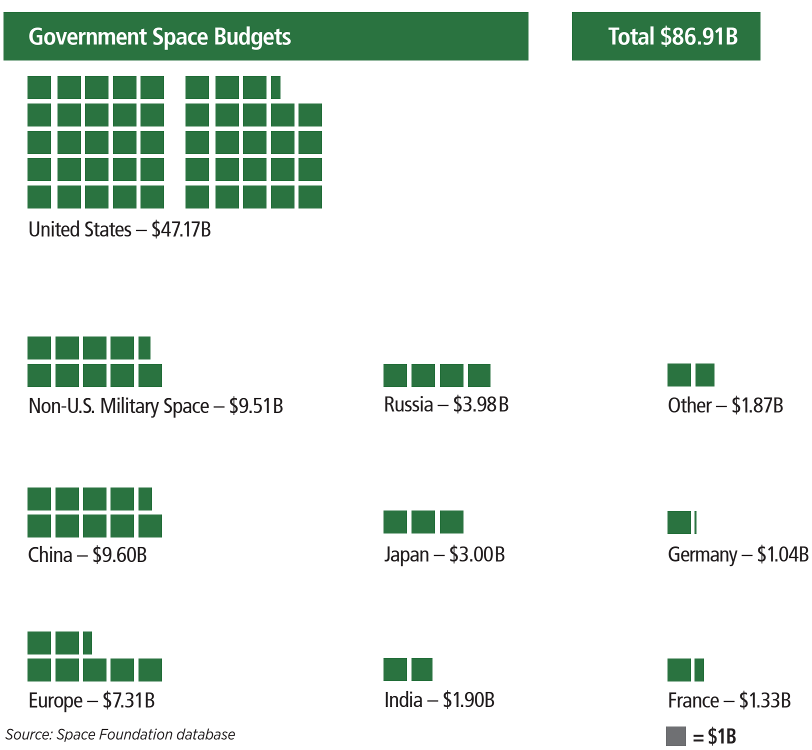
Becki Yukman is a senior data analyst for Space Foundation.

Snapshot: Government Space Spending in 2019

EXHIBIT 1u. Government Space Spending

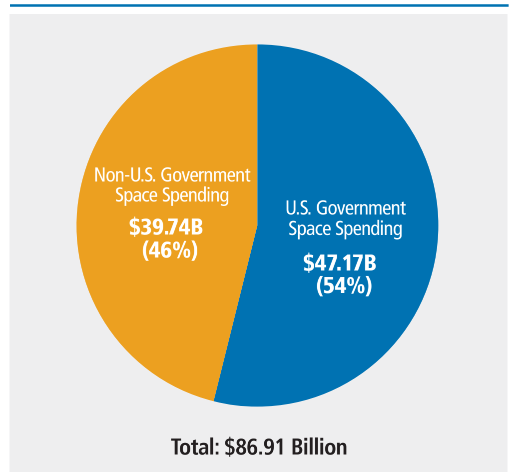


Source: Space Foundation database



Source: Space Foundation database

EXHIBIT 1v. Global Government Space Spending, 2019



1.5 Coronavirus and the Space Industry | *In the months since the world began coping with the global spread of coronavirus, the space industry has been beset by program delays, bankruptcies, and the pullback of venture capital investment. Yet there have also been signs of continuity and stabilization — on May 30, 2020, the SpaceX Crew Dragon and NASA succeeded in Launch America, an initiative to return the U.S. to human spaceflight to the International Space Station (ISS). A month later, U.S. stocks wrapped up their best quarter in more than 20 years and continued to climb into July. And in July, the United Arab Emirates and China launched probes to Mars, with the U.S. scheduled to follow. Here are a few indicators to provide a broad sense of the economy and its relationship to the space industry.*

In January, the completed Space Launch System rocket rolled out from NASA's Michoud Assembly Facility in New Orleans. Operations at Michoud and at Stennis Space Center in Mississippi were suspended in March due to coronavirus, pushing back the timeline for the Artemis launch. *Credit: NASA*

EXHIBIT 1w. Topics Covered in Coronavirus and the Space Economy

1.5 Coronavirus and the Space Economy
1.5.0 Introduction
1.5.1 Economy and Investment
1.5.2 Employment
1.6 The S-Network Space Index℠ Q1 2020 Performance
1.6.1 Index Performance
1.6.2 Index Constituents
1.6.3 Index Methodology
1.7 Insight: Quilty Analytics Q2 Mergers and Acquisitions

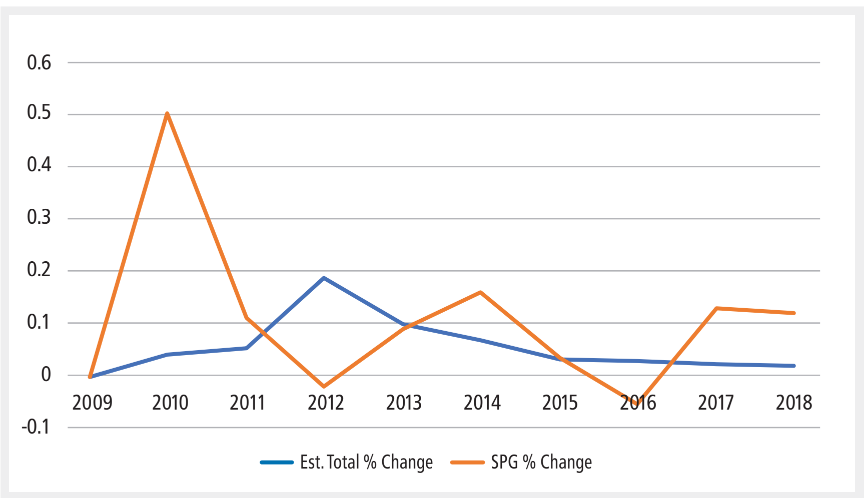
1.5.1 Economy and Investment

SpaceFund recently completed research on the correlation between the space economy and the wider global markets and found no correlation, says Meagan Crawford, managing partner of SpaceFund.

"This is good news in an economic downturn such as the one we've experienced and even during the 2008-2009 downturn," she said. "The space sector was much less affected than others."

Though the global space economy is approximately 80% commercial revenue, the presence of long-term government contracts helps provide stability, and even in the near term, companies with government contracts have the ability to borrow against them, Crawford said.

EXHIBIT 1x. Estimated Percent Change in Global Space Economy vs S&PG 1200

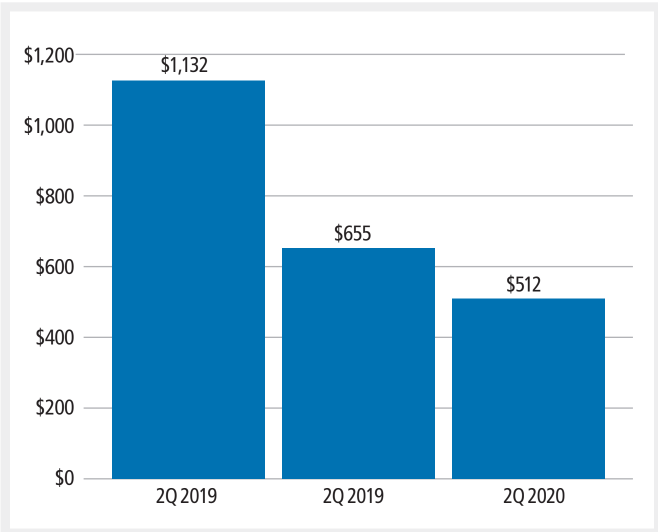


Source: SpaceFund

The space industry, like defense, is not as vulnerable, explains Henry Hertzfeld, director of The Space Policy Institute, because regardless of the overall economy, defense and cybersecurity — which are increasingly ensured through space operations — must continue to be funded. Discretionary funding, he added, could be more at risk as governments balance the economic fallout from the pandemic.

As the past months have shown, investment funding cycles can be far more volatile. Yet even that disruption is not completely unexpected; many market analysts were already observing a glut in some space sectors, and many startup companies not well-funded or lacking strong backing were likely to have collapsed regardless of the pandemic.

EXHIBIT 1y. M&A Activity, Q2 2019-Q2 2020, in Billions



Source: Quilty Analytics

Industry investment has shown a sharp decline, but Crawford and other analysts by the second quarter were seeing a return of investor interest. Quilty Analytics, which closely follows and advises on space transactions, noted the decline of global Mergers & Acquisition volumes in the wake of the pandemic, as shown in Exhibit 1y below—a drop that affected most economic sectors including space. Quilty Analytics noted, however, that acquirer interest in the space domain persists — and in many cases, is even strengthening given widely held views of long-term, secular growth in the space economy.

Seraphim Capital, in looking the total global venture capital market, finds reason for optimism, too. Their analysis determined that Q2 2020 total investment was $672 million. Compared to Q2 2019, Q2 20 investment saw an increase of 12 percent.[2]

1.5.2 Employment

In December 2019, U.S. unemployment was at 3.5% — the lowest in two decades.[3] By April, unemployment had climbed to more than 14%—the highest since World War II—only to drop by June to 11.1%, or an approximate human toll of 17.8 million jobless for the month.[4] From December 2019 to June 2020, the European Union's unemployment rate held steady at just under 7 percent. June's unemployment rate of 6.7% correlated to approximately 15 million.[5, 6] China's unemployment, which has hovered between 4 and 5% the last 20 years, climbed to 6.2% in April.[7] Some analysts of China's economy, however, place unemployment after Covid-19 closer to 10% with a jobless total of 80 million.[8]

One of the more high-profile job losses involved OneWeb. Though OneWeb has since entered into an agreement to be acquired in bankruptcy, its initial court filing in March precipitated approximately 450 layoffs.[9] Numerous other companies also laid off staff in the wake of Covid-19, from behemoths such as SES (up to 15% of its staff) and ViaSat (about 320 of its staff) to startups like Bigelow (100 of its staff) and Astra (30 of its staff).[10, 11, 12, 13]

Tying broader unemployment trends to the space industry is difficult because detailed analysis for many small job sectors is not quickly available on a monthly or even quarterly basis. The U.S. Bureau of Labor Statistics provides monthly reports that provide some broad data relating to more general job sectors that contain specific space industry jobs as identified by codes established by the North American Industry Classification System.

Based on those broader segments and two NAICS classifications more specific to space—guided missiles, space vehicles and parts, and search, detection and navigation instruments—initial data shows that 12 employment sectors that contain at least a portion of space-industry-related jobs from December 2019 to May 2020 have shown a loss of 241,600.

The more specific space sectors — guided missiles, space vehicles and parts, and search, detection and navigation instruments — were the only two to record an employment increase—of a combined 1,400 jobs from December to May.

Those gains again go to the long-term nature of space industry contracts, and more specifically, to launch activity.

Lockheed Martin has hired more than 4,700 workers since the coronavirus outbreak and anticipates hiring 12,000 by the end of the year. The company could not provide employment data specific to its space sector.

While the bulk of Lockheed Martin's portfolio is made up of defense contracts, the company also operates with civil and commercial space organizations. In April, NASA awarded a $579 million human lunar lander system contract to the Blue Origin team, with which Lockheed Martin is a partner.

EXHIBIT 1z. U.S. Employment by Sectors with a Broad Affiliation to Space Industry Jobs

Industry Sector	Dec. 2019	Jan. 2020	Feb. 2020	March 2020	April 2020	May 2020*
Aerospace products and parts	541.6	541	540.2	540.7	519.2	515.6
Guided missiles, space vehicles, and parts	87.9	88.2	88.1	88.5	88.4	88.6
Search, detection, and navigation instruments	137.4	137.9	138.2	138.6	137.8	138.1
Telecommunications	704.3	706.6	700.5	697.1	694.7	688.4
Other telecommunications	85.3	85.8	85.1	84.3	84.3	83.3
Broadcast and wireless communications equipment	49.2	49.7	49.6	49.5	48.4	48
Research and development in the physical, engineering, and life sciences	681.1	679.8	683.2	685.1	667.8	669.6
Wired telecommunications carriers	514.6	513.8	510.1	508.6	507.5	504.3
Power and communication system construction	213.6	216.5	213.1	213.5	198.7	208.2
Plate work and fabricated structural products	177.7	177.3	177.8	176.7	165.9	167.3
Residential building equipment contractors	893.4	885	884.5	883.6	776.5	843.8
Nonresidential building equipment contractors	1,400.40	1,377.50	1,385.80	1,381.3	1,206.2	1,289.70
Total (in thousands)	**5486.5**	**5459.1**	**5456.2**	**5447.5**	**5095.4**	**5244.9**

**Preliminary*
Source: US. Bureau of Labor Statistics data tables

Its operational diversity and long-term contracts have benefits down the line. Lockheed Martin is able to accelerate cash to its suppliers, explained Chris Pettigrew of Lockheed's external communications. In June, the company advanced more than

$300 million, with a focus on small businesses and at-risk suppliers due to COVID-19. That includes accelerated payments to more than 900 suppliers in its space division, Pettigrew said.

Northrop Grumman has hired thousands in its space sector this spring. Its space work includes Antares rockets and Cygnus spacecraft that resupply the ISS as well as the Artemis program to return astronauts to the moon and the James Webb Space Telescope. From March to May, Northrop Grumman hired nearly 2,000 people for space-sector jobs, and in May alone, received 16,000 applications for open positions in the space sector, Sean Elizabeth Wilson, Northrop's director of media and public relations, disclosed via email. In June, Northrop's space sector still had more than 3,200 job openings, she added.

United Launch Alliance also has had a strong 2020 with four Atlas V launches this year, including for the USSF-7 satellite launch in May with the U.S. Space Force and the launch earlier this month of NASA's Perseverance Mars rover. Additional information about ULA hiring was not available.

SpaceX did not respond to an inquiry about job openings, but in June, its company website listed more than 400 available positions. The openings show that, even in the time of a pandemic, anyone who wants to be a part of space should be able to find a place. Open positions ranged from baristas and dishwashers to space suit sewers and a senior hardware development engineer for phased array systems.

Lesley Conn is senior manager of Research & Analysis for Space Foundation.

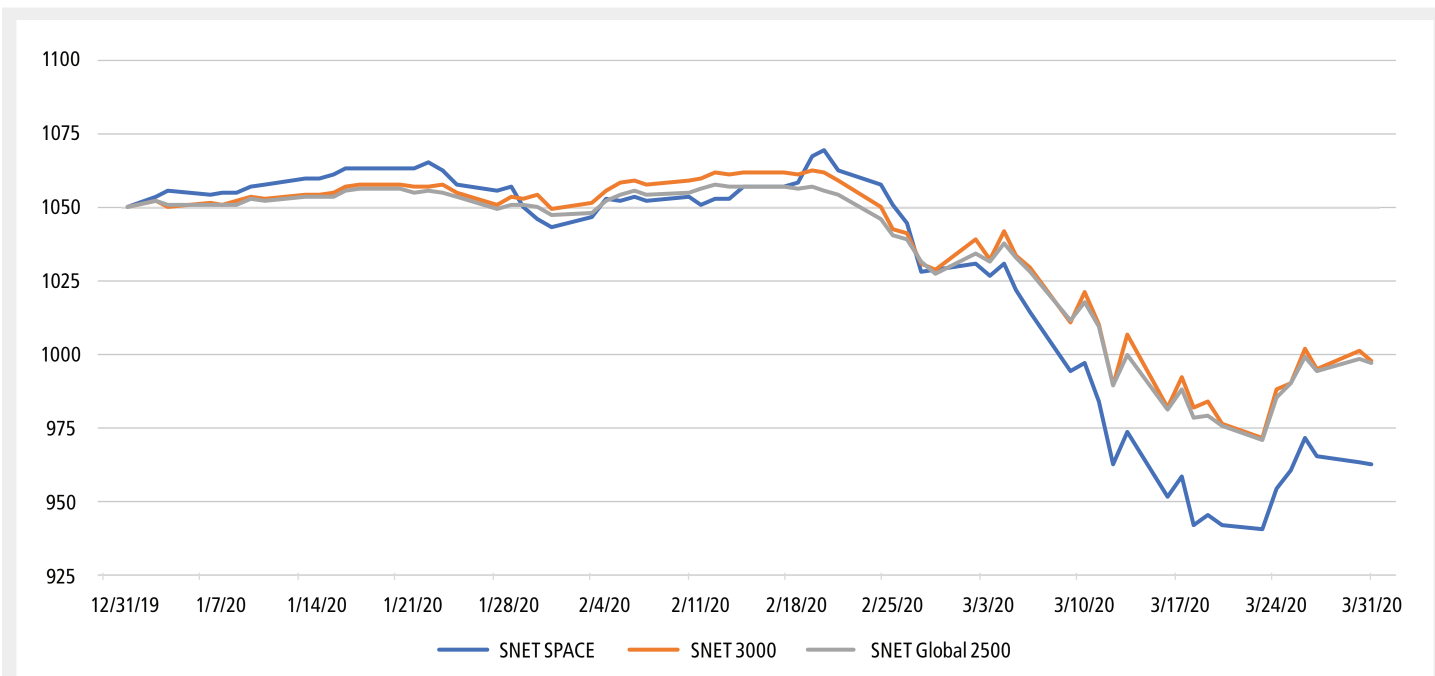
1.6 The S-Network Space Index℠ Q1 2020 Performance

The S-Network Space Index tracks a global portfolio of publicly traded companies that are active in space-related businesses such as satellite-based telecommunications; transmission of television and radio content via satellite; rocket and satellite manufacturing, deployment, operation, and maintenance; manufacturing of ground equipment that relies on satellite systems; development of space technology and hardware; and space-based imagery and intelligence services.

1.6.1 Index Performance

During the first quarter of 2020, the S-Network Space Index (SNET SPACE) started strong, gaining 7.6% as of February 20. Following this high point, SNET SPACE lost nearly half its value in a single month due to the market crash resulting from the widespread economic impact of the COVID-19 pandemic. As markets began to recover in late March, so did SNET SPACE, which closed out the quarter down 35% from its starting point as shown in Exhibit 1aa. While other indexes also fell during the market crash, the decline was not as steep. By comparison, there was only a 20.7% decline for the S-Network US Equity 3000 Index (SNET 3000), which tracks the 3,000 largest (by market capitalization) U.S. stocks. Similarly, there was a 21.2% decline for the S-Network Global 2500 Index (SNET Global 2500), which tracks a combination of the 1,000 largest U.S. stocks, 500 largest European stocks, 500 largest Pacific basin stocks (developed), and the 500 largest liquid Emerging Market stocks.

EXHIBIT 1aa. S-Network Space Index vs. Benchmark Indexes, Q1 2020



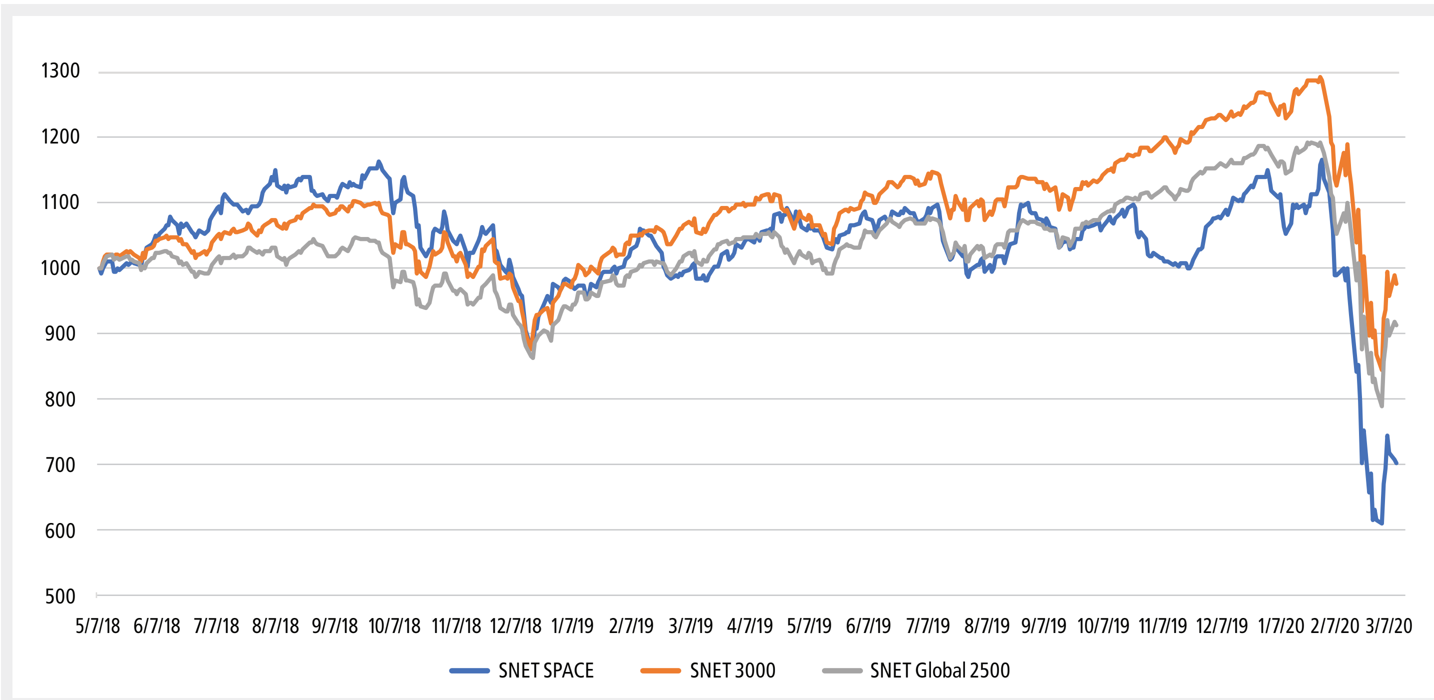
Note: Performance shown for each index is for the gross total return, assuming all dividends are reinvested.

Assessing the performance of the S-Network Space Index since live calculation began on May 7, 2018, as shown in Exhibit 1x, the index declined by 29.6%. By comparison, the SNET 3000 fell by 2.5% and the SNET Global 2500 dropped by 8.8%. The difference in performance is partly due to poor performance in Q4 2019, but the primary cause was SNET SPACE's steeper decline during the market crash in Q1 2020.

1.6.2 Index Constituents

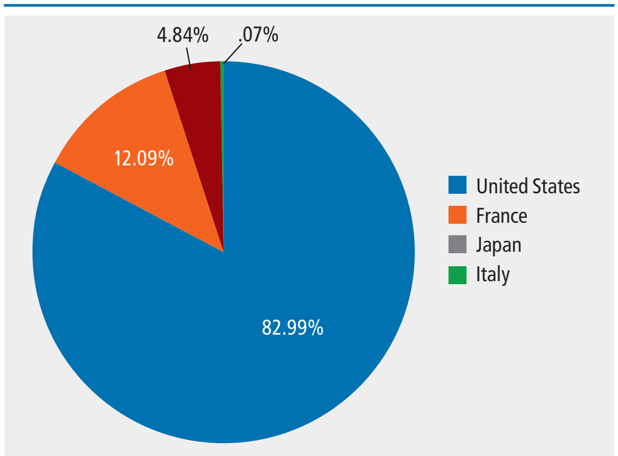
The space industry is a global one, and the composition of the S-Network Space Index reflects this diversity. Companies listed on U.S. exchanges tend to dominate due to the larger number of companies that meet the financial requirements for inclusion in the index. On March 20, the index underwent its quarterly rebalancing to maintain compliance with the index rules—adjusting the relative contributions of each of the constituent companies. One out-of-cycle change was made in February with the removal of Australia-based satellite communications provider Speedcast, which experienced financial distress that resulted in a trading halt for its stock. The company later began Chapter 11 bankruptcy proceedings in the United States. At the time of rebalancing, U.S. companies comprised 83.0% of the weight of the overall index, with France in second place at 12.1%, Japan at 4.8%, and Italy at 0.1%. Due to the removal of Speedcast, Australia is no longer represented in the index.

EXHIBIT 1bb. S-Network Space Index vs. Benchmark Indexes, May 7, 2018 – March 31, 2020



Note: Performance shown for each index is for the gross total return, assuming all dividends are reinvested.

EXHIBIT 1cc. Index Weight by Country as of March 20, 2020



Source: Space Investment Services

Performance of constituent companies in Q1 was almost uniformly negative, with all but two companies declining by 8% or more. For a quarter that witnessed unprecedented changes across the entire global economy due to the pandemic, it is often difficult to identify the specific factors that contributed to any single company's stock performance. However, several trends emerged that have implications for the space industry's future.

As many of the world's nations initiated stay-at-home orders, quarantines, and border controls to slow the spread of COVID-19, all forms of transportation declined substantially. This had a major impact on demand for mobile communications, particularly for maritime and air transportation. These two areas are predominantly served by satellite operators due to their ability to provide coverage anywhere on the planet, so there was an immediate impact on the mobile satellite communications business. As national restrictions ease and travel resumes, it is likely that some of this business will return, but the level of activity may remain depressed for an extended period depending on global health and associated economic factors.

EXHIBIT 1dd. S-Network Space Index Constituents as of March 20, 2020

Company	Ticker	Country	2020 Q1 Performance
Aerojet Rocketdyne Holdings	AJRD	United States	-8%
Airbus	AIR	France	-55%
AT&T	T	United States	-24%
Ball	BLL	United States	0%
Boeing	BA	United States	-54%
Comcast	CMCSA	United States	-23%
Dish Network	DISH	United States	-44%
Echostar Holding	SATS	United States	-26%
Eutelsat Communications	ETL	France	-34%
Garmin	GRMN	United States	-23%
Globalstar	GSAT	United States	-44%
Honeywell International	HON	United States	-24%
Intelsat	I	United States	-78%
Iridium Communications	IRDM	United States	-9%
L3Harris Technologies	LHX	United States	-9%
Leonardo	LDO	Italy	-42%
Lockheed Martin	LMT	United States	-12%
Loral Space & Communications	LORL	United States	-50%
Maxar Technologies	MAXR	United States	-32%
Northrop Grumman	NOC	United States	-12%
Orbcomm	ORBC	United States	-42%
Raytheon	RTN	United States	-37%
SES	SESG	France	-57%
Sirius XM Holdings	SIRI	United States	-31%
SKY Perfect JSAT Holdings	9412	Japan	-20%
Thales	HO	France	-17%
Trimble Navigation	TRMB	United States	-24%
Viasat	VSAT	United States	-51%
Virgin Galactic	SPCE	United States	28%

Travel restrictions have already affected space industry employment levels, as exemplified by the decision by Viasat (-51% in Q1) to lay off 300 people, or roughly 5% of its workforce.[1] In-flight connectivity accounts for approximately 10% of the company's revenue, so the reduction in air travel caused the company to look for ways to reduce costs, including furloughs and suspension of salary increases and hiring. However, the company sees opportunities for the future, as current conditions mean that additional aircraft can have Viasat equipment installed while idle, as opposed to requiring airlines to actively take them out of service during installation.

On the manufacturing side, Boeing (-54%) and Airbus (-55%) experienced the sharpest declines due to concerns about the long-term future of air travel. As airlines fell into financial difficulties and drastically reduced flight schedules, orders for new aircraft dried up and may remain low for years to come, depending on how quickly the economy recovers. Boeing and Airbus delivered less than half as many aircraft in March 2020 as in March 2019 and reduced production rates either by slowing work or suspending activity at certain facilities.[2] These effects dramatically outweighed any influence the aerospace companies' space business may have had on overall company performance, although launch delays and a slowdown in manufacturing may have contributed slightly.

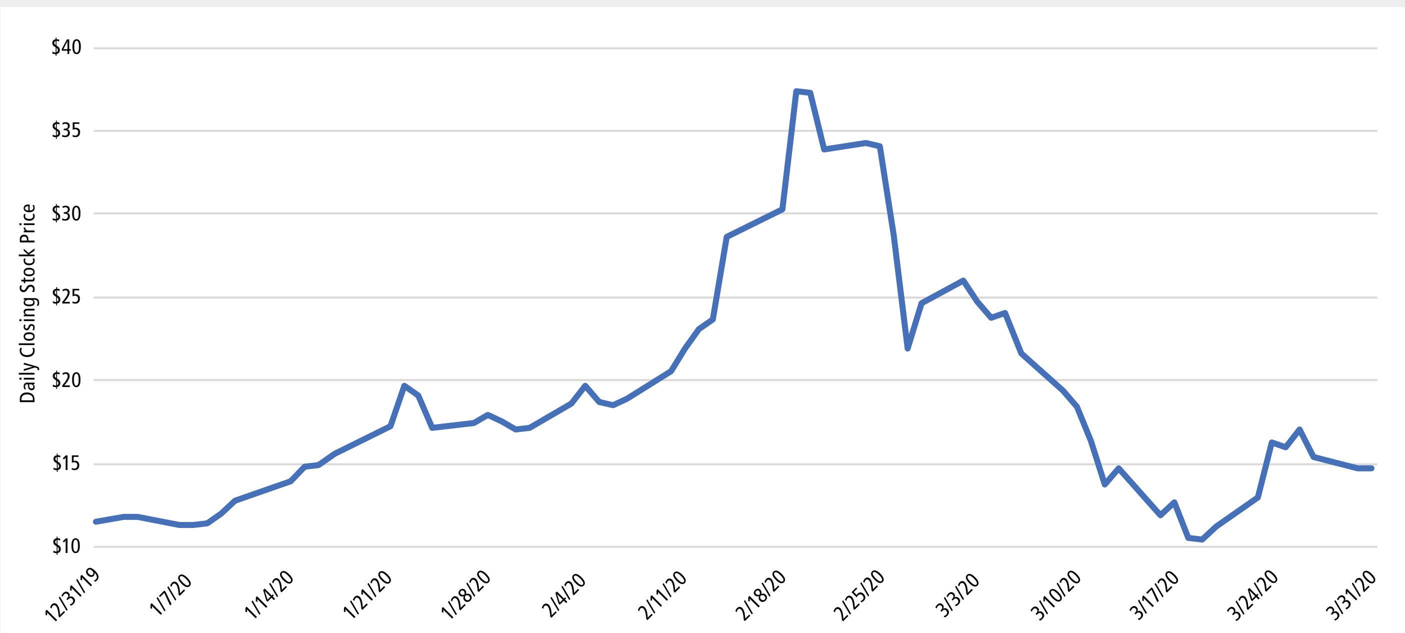
Job losses and decreased consumer confidence across the world led to concerns about consumer-oriented services. Investors weighed the potential for increased demand for at-home services such as satellite-delivered television or broadband internet against the potential for consumers to scale back spending due to economic conditions. These concerns may continue to weigh on the sector for some time as companies and investors deal with the uncertainty surrounding the easing of broad government restrictions, which may be followed by reintroduction of targeted restrictions in response to local or regional outbreaks.

While the stock performance of space companies generally trended downward along with the rest of the market, individual companies were also affected in part by their exposure to each of the trends noted above. Returning to the example of Viasat, the company benefited from widespread stay-at-home orders and reported 4,000 new residential broadband customers from January to March 2020.[3] However, this was not enough to offset the impact of the reductions in air travel and the associated in-flight connectivity business. Some companies also faced specific challenges that exerted downward pressure on their stock, as demonstrated by Intelsat (-78%) which continued to experience investor concern about its debt levels and overall financial health. These concerns later proved justified, as the company filed for Chapter 11 bankruptcy protection in May 2020.

At the other end of the performance range, the two notable companies were Ball (0%) and Virgin Galactic (+28%). Ball benefited from the fact that its space business is nested within its aerospace business segment, which constituted 16% of the company's net sales in Q1 2020. This was outweighed by the 81% of the company's Q1 sales that come from its beverage packaging business, which was viewed by investors as an area that could benefit during the pandemic and potentially in a post-pandemic world.[4]

Virgin Galactic's performance in Q1 was more directly related to space, rising by 223% from the beginning of the year to February 19. Some of this growth was due to media coverage in early February of the relocation of SpaceShipTwo, VSS Unity, to the company's commercial headquarters at Spaceport America in New Mexico.[5] The spacecraft had previously been undergoing flight tests at the Mojave Air and Space Port in California, where Virgin Galactic's manufacturing facilities are located. Investors took this as a signal that the company was getting closer to exiting its test program and beginning commercial operations. In addition, media coverage during the first half of Q1 was generally favorable, with financial analysts promoting the stock as a unique opportunity to own part of the first publicly traded company focused solely on human spaceflight.[6] This combination of existing investor interest and bullish forecasts from analysts led to rapid growth in the stock price, enticing speculative investors to get on board as the price soared, driving it up further. Ultimately, the stock crashed along with the broader market, with additional downward pressure as it reported Q4 2019 results that were below expectations,[7] prompting a drop of 35% over the course of two days in late February. Despite these challenges, the stock still ended Q1 2020 with a net gain of 28%, and the debate about how to appropriately value this first-of-its-kind company will likely continue for quite some time.

EXHIBIT 1ee. Virgin Galactic Stock Performance, Q1 2020



1.6.3 The S-Network Space Index℠ Methodology

The S-Network Space Index is considered a "pure-play" space index, unlike other indexes that combine space with other sectors such as aviation or defense. The index operates according to a clearly defined rules-based methodology overseen by an impartial Index Committee, as opposed to an actively managed index that operates at the discretion of its managers. In technical terms, it is a modified capitalization-weighted, free float-adjusted and space revenue percentage-adjusted equity index. In essence, it takes into account how much of a company's revenue comes from space-related business and combines that information with a variety of standard financial metrics to determine how influential that company's stock should be in terms of the overall index performance.

To be considered for inclusion in the S-Network Space Index, a company must generate either (1) at least 20% of its revenue or (2) at least US$500 million in revenue from space-related business. In accordance with the pure-play nature of the index, 80% of the total index weight is assigned to companies whose space-related business generates at least 50% of annual revenue (in practice, most such companies generate 100% of their revenue from space). The remaining 20% of the index weight is assigned to diversified companies that earn the majority of their revenue from non-space businesses.

To further ensure that the companies are substantially engaged in space-related activities, each company must also meet at least one of the following criteria:

- The company was the prime manufacturer (i.e., the contractor responsible for managing subcontractors and delivering the product to the customer) for a satellite in the past five years.
- The company was the prime manufacturer or operator of a launch vehicle in the past five years.
- The company currently operates or utilizes satellites.
- The company manufactures space vehicle components (for satellites, launch vehicles, or other spacecraft).
- The company manufactures ground equipment dependent upon satellite systems.

In addition to its role as an educational and informational tool for tracking the performance of the global space industry, the S-Network Space Index is also designed to serve as a benchmark upon which investment firms can base products such as exchange-traded funds (ETFs), mutual funds, or other investment instruments. As such, the index rules take into consideration financial criteria such as the average daily trading value of candidate stocks, as well as SEC regulations regarding the minimum number of constituent companies and the maximum weights permitted for constituent companies. The rule book for the index, which describes the complete methodology, is available at http://space.snetglobalindexes.com.

Contact Information and Disclaimer

The S-Network Space Index is maintained by S-Network Global Indexes Inc., supported by space industry expertise from Space Investment Services LLC. For more information, please contact index@spaceinvestmentservices.com

Micah Walter-Range is the creator and manager of the underlying stock index for the world's first exchange-traded fund (ETF) focused on the space industry. As a leading expert on the global space economy, he has authored papers on space-specific topics such as the impact of export controls on the U.S. space industrial base, and cross-sector subjects such as the role of space technology in aviation.

1.7 Insight: Mergers & Acquisitions Activity Falls and Regains Slightly in Q2

Satellite and space transactional activity experienced a notable drop in the second quarter as the COVID-19 pandemic took hold. The decline in April and May 2020 volumes was pronounced, with the principal drivers of this decrease being: (1) macroeconomic uncertainty, (2) valuation uncertainty due to extreme market volatility, (3) the need for many buyers and investors to prioritize internal issues, and (4) stay-at-home orders and travel restrictions impeding normal deal-making interactions.

Initially, in late March through May, these factors paused many M&A and financing processes that were already underway while postponing planned M&A and financing initiatives. With early steps being made toward economic reopening in May, and with COVID-19 mitigation plans underway, buyer and investor sentiment improved by mid-month, driving an uptick in activity. We expect transactional activity to improve sequentially in the third quarter versus the second, but it will not rebound to peak levels anytime soon.

During Q2, there were 12 M&A transactions announced, most with undisclosed transaction values, which compares to 17 such transactions in the prior quarter. Special situations-driven M&A was a prominent theme in the quarter, often a result of either regulatory-driven divestitures (CPI's sale of ASC Signal to Kratos Defense & Security Solutions, Raytheon's sale of its precision optics business to AMERGINT) or liquidity crisis-driven sales (sale of Phasor, Effective Space assets).

Transactions by two private equity-backed platform companies illustrate the increasing level of recent private equity interest in executing on space sector M&A consolidation strategies:

- AMERGINT Technologies, a Colorado Springs, CO, company backed by the Blackstone Tactical Opportunities private Tequity fund, in May announced the acquisitions of Tethers Unlimited and Raytheon's precision-based optics business. The latter acquisition was catalyzed by a U.S. Department of Justice-imposed requirement for Raytheon to divest its precision-based optics business as a prerequisite to closing its UTC merger.
- AE Industrial Partners' portfolio company Redwire (itself the result of its acquisition of Adcole Maryland Aerospace in March 2020) in June announced it acquired Deep Space Systems (DSS) and Made in Space.

Given the hundreds of early stage space technology companies that launched in recent years, we expect that the current macroeconomic downturn will catalyze additional stress-or-distress-driven M&A deals. In Q2, Phasor Solutions, an early stage flat panel antenna (FPA) technology company, entered administration in the U.K. as a result of insolvency, and its assets were acquired by South Korea-based defense and technology conglomerate Hanwha Systems. Also during the quarter, an affiliate of well-funded, Japan-based startup Astroscale acquired the intellectual property and certain assets of Israel/U.K.-based Effective Space Solutions (ESS), which was developing a GEO satellite mission extension platform.

What do we see on the horizon? Due in part to the space sector's overall resilience to the COVID-19 crisis, we see increasing interest by strategic and financial buyers in consolidation strategies and opportunistic M&A. Furthermore, startups and companies facing liquidity challenges will drive ongoing M&A through the balance of the year. Finally, absent a dramatic increase in investor risk appetite, we expect a steady parade of liquidity crises and bankruptcies concentrated amongst earlier-stage companies. Many of these companies will meet their final demise, while a lucky subset of those with "real" assets or opportunities will be granted a second act (OneWeb being a prime example).

Quarterly Investment Activity Review

Private investment activity in Q2 was surprisingly active in light of the macro backdrop, with nearly $400 million raised during the quarter across 31 private financing transactions. The largest rounds included another SpaceX financing of ~$125 million (helping to fund its Starlink LEO Broadband strategy) and Ligado Networks' $100 million financing on the back of the FCC's decision to license its spectrum over objections by the U.S. Department of Defense on GPS interference concerns.

There was no single overarching theme to the quarter's financing activities, but some broader sector trends were evident, with multiple early stage rounds completed for GNSS resilience / anti-jamming technologies (e.g., Xona Space, InfiniDome) and several transactions for downstream Earth observation software and analytics solutions.

Exhibit 1ff. Second Quarter Financial Actvities

Annc'd.	Target	Acquirer / Investor	Transaction EV (USD $Mil)	TEV / LTM Adj. EBITDA	Sub-Sector
Acquisitions / Buy-Outs					
06/23/20	Vricon, Inc.	Maxar Technologies	$230.0	10x	EO/Geospatial
06/16/20	ASC Signal (sub. of CPI)	Kratos Defense & Security Solutions	35.0	n.d.	Satcom
06/26/20	Nation Space and Technology Company Limited	Thaicom & CAT Telecom JV (75%/25%)	n.d.	n.d.	Satcom
06/23/20	Made In Space	Redwire (AE Industrial Partners)	n.d.	n.d.	Enablement
06/07/20	Phasor Solutions	Hanwha Systems Co. (HSC)	n.d.	n.d.	Satcom
06/03/20	Effective Space Solutions R&D Ltd. (IP & Assets)	Astroscale U.S. Inc.	n.d.	n.d.	Enablement
06/02/20	Cobham's radiation testing business	Radiation Test Solutions (RTS)	n.d.	n.d.	Enablement
06/01/20	Deep Space Systems	AE Industrial Partners, LP (AEI)	n.d.	n.d.	Enablement
05/18/20	FreeFall 5G (merger/spinoff)	ED2	n.d.	n.d.	Satcom
05/06/20	Tethers Unlimited	AMERGINT Technologies Holdings, Inc.	n.d.	n.d.	Enablement
04/20/20	Raytheon's space-based precision optics business	AMERGINT Technologies Holdings, Inc.	n.d.	n.d.	EO/Geospatial
04/06/20	Bird.i	Hanley Wood | Meyers Research	n.d.	n.d.	EO/Geospatial
Private Equity & Related Investments					
05/26/20	SpaceX	Undisclosed investors	$125.0	n.m.	Enablement
05/28/20	Ligado Networks	Undisclosed investors	100.0	n.m.	Satcom
05/06/20	Commsat	Led by Beijing Wealth Capital & AVIC Capital	38.0	n.m.	Enablement
04/06/20	Myriota	Led by Hostplus and Main Sequence Ventures	19.3	n.m.	Satcom
06/04/20	Deep Blue Aerospace	Led by China Huijin Group	14.1	n.m.	Enablement
04/14/20	Space Pioneer (Tianbing Technology)	Led by ZJU Joint Innovation Investment	14.0	n.m.	Enablement
04/06/20	IntTerra	Nikita Shashkin	10.0	n.m.	EO/Geospatial
05/06/20	VestaSpace Technology	Next Capital LLC	10.0	n.m.	Enablement
04/15/20	Kairos Aerospace	Led by OGCI Climate Inv.	9.0	n.m.	EO/Geospatial
04/07/20	Arturo	Led by Crosslink Capital	8.0	n.m.	EO/Geospatial
04/15/20	Atlas AI	Led by Airbus Ventures	7.0	n.m.	EO/Geospatial
05/20/20	Apollo Agriculture	Led by Anthemis	6.0	n.m.	EO/Geospatial
06/23/20	Satelytics	BP Ventures	5.0	n.m.	EO/Geospatial
05/18/20	Regulus Cyber	Led by SPDG	4.0	n.m.	Other
04/30/20	Infostellar	Consortium of investors	3.5	n.m.	Enablement
06/22/20	OneView	Led by TPY Capital	3.5	n.m.	EO/Geospatial
06/25/20	Leaf Space	Led by Whysol Investments	3.4	n.m.	Satcom
04/08/20	AgroScout	Led by Kibbutz Yiron	3.0	n.m.	EO/Geospatial
04/03/20	Valispace	Led by JOIN Capital	2.4	n.m.	Other
06/15/20	infiniDome	Consortium of Investors	1.6	n.m.	Other
05/14/20	Xona Space Systems	Led by 1517	1.0	n.m.	Other
05/06/20	OroraTech	Led by ConActivity KG	0.9	n.m.	EO/Geospatial
05/20/20	Space Forge	Consortium of investors	0.6	n.m.	Enablement
04/28/20	EnduroSat	Neo Ventures	0.4	n.m.	Enablement
04/04/20	Blue Skies Space	Startup Funding Club	0.1	n.m.	Other
05/26/20	Core Semiconductor	SpaceChain Foundation	n.d.	n.m.	Other
04/24/20	MinoSpace (Weina Starry Sky)	CITIC Construction Investment	n.d.	n.m.	Enablement
04/30/20	Astrocast	Consortium of private investors	n.d.	n.m.	Satcom
05/18/20	Astroscale	Led by I-NET CORP	n.d.	n.m.	Enablement
05/26/20	Enview	Led by BrightCap Ventures	n.d.	n.m.	EO/Geospatial
06/01/20	Scout Inc.	CIT GAP FUNDS	n.d.	n.m.	Other
Public Equity & Related Investments					
06/18/20	Kratos Defense & Security	Follow-on public equity offering	$209.0	n.m.	Other
04/21/20	Electro Optic Systems Holdings Ltd (EOS)	Follow-on public equity offering	84.3	n.m.	Satcom
04/29/20	Ovzon AB	PIPE & Rights Offering	50.4	n.m.	Satcom
06/10/20	AddValue Technologies	PIPE	4.2	n.m.	Satcom

Source: Quilty Analytics
TEV/LTM Adj. EBITDA = Total Enterprise Value/Last Twelve Months Adjusted Earnings Before Interest, Taxes, Depreciation and Amortization
n.d. = not disclosed
n.m. = not meaningful

On the public equity side, Kratos raised $209 million in a follow-on public equity offering for general corporate purposes and in a statement explained that would include “for potential strategic ‘tuck-in’ acquisitions to further position the company for projected growth from new and anticipated increased production and to facilitate its long-term strategy.”

Other Key Financial Developments in the Quarter

Intelsat, one of the world’s leading satellite communications operators, and Speedcast, the largest satellite communications service provider worldwide, filed for Chapter 11 bankruptcy during the second quarter. Both U.S. bankruptcy court-directed processes are proceeding forward, and both companies are continuing to operate and service their customers in the ordinary course in the meantime. We expect the Intelsat case, in particular, to take roughly a year to conclude given the complexity of the case and the timing associated with the C-band clearing and incentive payments process.

Justin Cadman is a partner with Quilty Analytics. He has more than 15 years of investment banking and capital markets experience.

Chris Quilty is the founder and partner of Quilty Analytics. Prior to establishing Quilty in 2016, he served as a sell side research analyst with Raymond James for 20 years.

This market analysis is provided by Quilty Analytics LLC and Space Foundation research.
For more information on Quilty Analytics subscription and research services, contact Info@QuiltyAnalytics.com.

Quilty Analytics Disclosures, Limitations of Use, and Disclaimer

Independent Research and Opinions Subject to Change without Notice
Quilty Analytics is an independent research and consulting company. Quilty Analytics is not a member of FINRA or the SIPC and is not a registered broker-dealer or investment advisor. All opinions, views, and analyses expressed in these Publication Services are those of Quilty Analytics at the time they were published. Quilty Analytics does not owe any fiduciary obligation to any Covered Company or Subscriber. The opinions expressed in the Publication Services may be short-term in nature and are subject to change without notice. Quilty Analytics takes no obligation to update any forward-looking statement in Publication Services to reflect events, circumstances, or changes of opinion occurring after the date on which the Publication Service is created, or to reflect the occurrence of unanticipated events.

Solely an Industry and Financial Publication for Quilty Analytics Subscribers
Quilty Analytics Publication Services, including the research or other contents hereof, have been prepared solely for distribution to Subscribers and authorized Quilty Analytics clients. The information contained herein does not constitute investment, financial, legal, tax, or any other advice. Quilty Analytics is an industry and financial research publishing company (publisher) and it does not provide investment advice to its subscribers or advocate for the purchase or sale of any investment or security.

Relationships and Potential Conflicts of Interest
Quilty Analytics and its principals provide research, consulting, advisory, and other services to a wide range of industry stakeholders, which may include Covered Companies. Consequently, while Quilty Analytics Publication Services reflect its analyst views and opinions as of the time of publication, its Subscribers should be aware that Quilty Analytics may be exposed to the risk of current or future potential conflicts of interest inherently arising from such client relationships.

Disclaimer of Liability
Subscriber agrees and acknowledges that the Publication Services are provided on an “as-is” basis, and any representations or warranties, express or implied, including without limitation any representations or warranties of non-infringement, merchantability, correctness, accuracy, or fitness for a particular purpose are specifically disclaimed. All third-party data presented herein were obtained from publicly available and third-party sources which are believed to be reliable; however, Quilty Analytics makes no warranty, express or implied, concerning the accuracy or completeness of such information. Quilty Analytics and its employees, content providers, and licensors will not be liable to Subscriber or any other persons as a result of subscriber’s use (or misuse) of the Publication Services or for any consequential, indirect, punitive, special, or exemplary damages, including without limitation, losses or lost profits, whether based on contract, tort, or other legal theory, in connection with any use of, or reliance on, Quilty Analytics research or Publication Services.

Intellectual Property, Reproduction and Distribution
These Publication Services and the contents thereof are the intellectual property of Quilty Analytics or its licensors. The Publication Services are provided solely for their internal use pursuant to the Subscriber’s subscription agreement. Subscriber shall not infringe, or enable the infringement of, the intellectual property rights of Quilty Analytics or its licensors in any way, including without limitation by making available internally or externally the Publication Services or any portion thereof except as may be permitted under its Subscription Agreement or prior written consent of Quilty Analytics.

2.0 Introduction | *The space industry relies on tens of thousands of highly skilled workers to research and design, build, and operate advanced technologies that enable space activities and increase our understanding of the space environment. These highly skilled workers and the companies they work for have an important impact on their communities, supporting thriving local economies and enabling innovative science and technology clusters. Understanding the trends in this workforce, including its size and composition, provides insight into the scale of these benefits and the overall health of the industry. Understanding these trends allows national and local decision-makers to make informed choices about how to support and grow this important resource.*

Workers closely observe as the upper composite containing the EUTELSAT KONNECT is lowered over GSAT-30 on Jan. 14, 2020, two days before its successful Ariane 5 launch and orbit. The all-electric satellite was the first to use Thales Alenia Space's new Spacebus Neo platform.
Credit: Arianespace

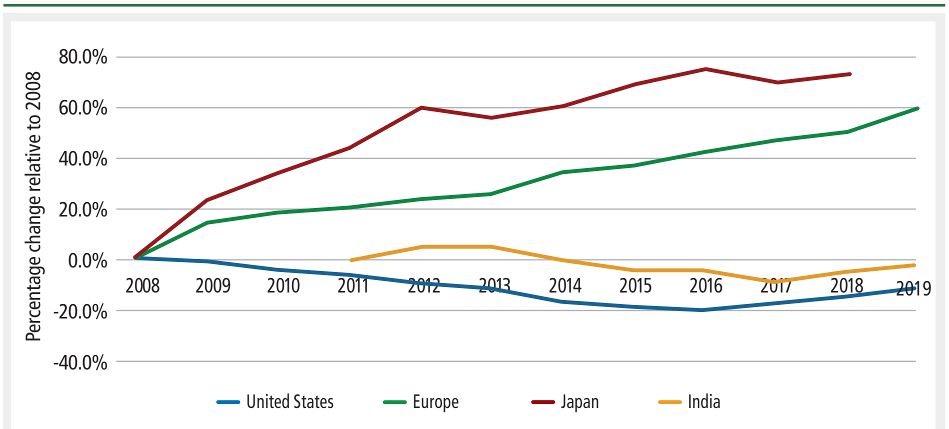
EXHIBIT 2a. Topics Covered in Workforce

2.0 Introduction
2.1 U.S. Space Workforce
2.2 European Space Workforce
2.3 Japanese Space Workforce
2.4 Indian Space Employment
2.5 Other Space Employment

2.1 U.S. Space Workforce

In 2019, there were more than 183,000 workers in the U.S. space workforce. This is an increase of about 2% over the total U.S. workforce in 2018. The vast majority of space professionals, 141,520, are employed in the private sector in companies that develop and manufacture space systems or in companies that provide services, such as telecommunications. The U.S. government employs more than 41,700 professionals, 42% of which work at NASA and 58% in the national security space workforce. Further analysis of the U.S. space workforce was included in *The Space Report 2020 Q1*.

EXHIBIT 2b. Space Workforce Trends in the United States, Europe, Japan, and India



Source: U.S. Bureau of Labor Statistics, Eurospace, Society of Japanese Aerospace Companies, India Department of Space
Note: 2019 employment data for Japan Aerospace companies was unavailable

2.2 European Space Workforce

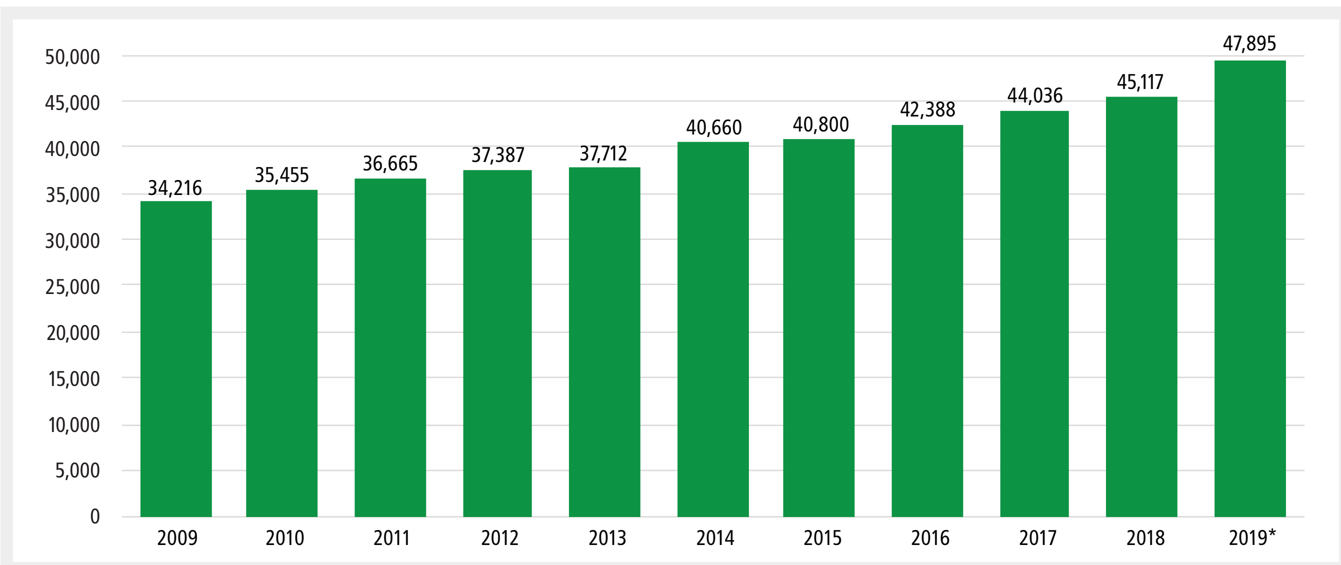
In 2019, the European space workforce included an estimated 47,895 employees working on design, development, and manufacturing of space assets. This is 6.2% larger than 2018, when the workforce included 45,117. A small portion of this increase is due to the addition of six new countries to the annual survey conducted by Eurospace, the European space industry association. These new additions — Bulgaria, Cyprus, Latvia, Lithuania, Romania, and Slovakia — accounted for 313 employees, 0.7% of the total European workforce. More than 80% of the European workforce is based in just five nations: France, Germany, Italy, Spain, and the United Kingdom. All five of these nations have experienced double-digit growth in the size of their workforce from 2014 to 2019, and all but Spain also grew from 2018 to 2019.[1]

Data on the size of the European space workforce is based on an annual survey of companies completed by Eurospace. Data collection challenges related to COVID-19 have led to delays in the finalization of 2019 employment numbers. Slight variations in total employment among exhibits below reported reflect the draft nature of this data. The survey does not include workers employed in the space services sector, including well-known companies such as Arianespace, SES, Eutelsat, and Inmarsat. These four companies alone employ an additional 5,000 employees.[2]

Although the workforce has grown steadily over the last five years, it has faced some challenges. European companies, along with those in other parts of the world, have faced a reduction in satellite manufacturing demand, which has led to layoff announcements. Thales Alenia Space, which designs, manufactures, and operates satellites, in September 2019 planned to lay off about 500 of its 8,000 workers.[3] Eutelsat anticipated laying off 100 of its 1,000 employees in October.[4] Airbus Defense and Space in February 2020 announced it would cut 2,362 positions, 7% of its workforce, due to weak sales.[5] There are some indications that the slowdown may be ending. New spacecraft orders increased in 2019 and were expected to remain high in 2020.[6]

Some of these effects also may be lessened by efforts on the part of the European Union, which announced in January it would provide 200 million euros to support Europe's space industry. About half of this will be provided as a loan to ArianeGroup as it completes the Ariane 6 rocket. The other half will be used to invest in European venture funds that support startups in the space sector.[7]

EXHIBIT 2c. European Space Industry Employment, 2009-2019



**Preliminary data*
Average Employment 2009-2019: 38,577
Source: Eurospace Facts and Figures, 2019
Copyright by Eurospace, reproduction forbidden

Although most major European space companies have policies emphasizing the importance of diversity and inclusion, most do not publicly release statistics on their composition. Data from those that do show that European space companies seem to follow similar trends to other tech companies in the United States and Europe. At SES, for example, women make up 24% of employees and 8% of top executives. 42% of employees are below age 40.[8] At Thales Alenia Space, the workforce is 24.5% female.[9] Both companies are higher than the European space industry average for number of women employed. Overall, according to Eurospace data, in 2019, women made up about one-fifth of the European space workforce. Individuals under 35 made up 23.7% of the workforce, and 21.8% of the workforce was over 54.[10]

EXHIBIT 2d. . European Space Workforce Demographics, 2019

	Number of Employees	% of Employees
Female	10,473	21.9%
Under 35 Years Old	11,366	23.7%
Over 54 Years Old	10,318	21.8%

Note: Total European Space Workforce in 2019 was 47,895 (Preliminary Estimate) Source: Eurospace Facts and Figures, 2019 Copyright by Eurospace, reproduction forbidden

EXHIBIT 2e. ESA Workforce Demographics, 2019

	Number of Employees	% of Employees
S&E Employees*	1,505	64.3%
Female	662	28.3%
Under 35 Years Old	102	4.4%
Over 54 Years Old	745	31.8%

**Science and Engineering*
Note: Total ESA workforce was 2,341 in 2019
Source: European Space Agency

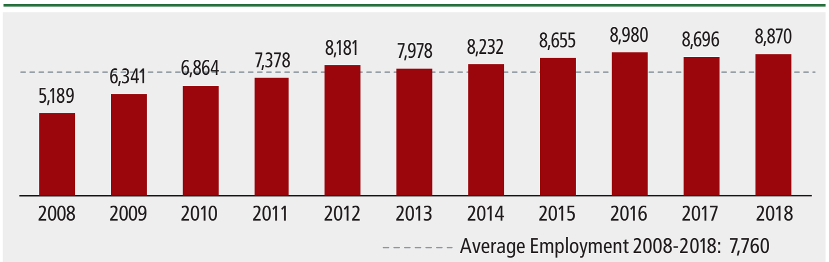
The European Space Agency (ESA) employed 2,341 people in 2019, remaining constant from employment in 2018. With respect to gender, the agency is a bit higher than the European industry as a whole, with females making up 28.3% of the workforce in 2019. The proportion of workers under 35 is particularly low, just 4.4%.

EXHIBIT 2f. European Space Industry Employment by Country, 2014-2019

National Workforce	2014	2015	2016	2017	2018	2019	5-Year Change	1-Year Change
France	15,560	15,689	16,237	16,994	17,128	18,186	16.9%	6.2%
Germany	7,269	7,288	7,825	7,901	8,526	9,071	24.8%	6.4%
Italy	4,608	5,019	4,963	5,140	5,076	5,215	13.2%	2.7%
United Kingdom	3,785	3,717	3,937	3,969	3,973	4,263	12.6%	7.3%
Spain	3,044	3,143	3,329	3,551	3,811	3,803	24.9%	-0.2%
Belgium	1,679	1,767	1,752	1,533	1,554	1,576	-6.1%	1.4%
Netherlands	1,028	968	965	1,155	1,166	1,240	20.6%	6.3%
Sweden	776	852	900	995	1,057	996	28.4%	-5.8%
Switzerland	874	878	831	805	806	842	-3.7%	4.5%
Norway	383	334	364	405	412	418	9.1%	1.5%
Austria	371	387	385	420	420	416	12.1%	-1.0%
Czech Republic	172	176	187	187	187	292	-	56.1%
Poland	40	98	193	250	266	290	-	9.0%
Denmark	223	228	238	258	257	257	15.2%	0.0%
Portugal	168	173	175	161	165	239	42.3%	44.8%
Finland	139	173	186	160	168	227	63.3%	35.1%
Hungary	97	97	97	97	97	130	-	34.0%
Lithuania	-	-	-	-	-	99	-	-
Bulgaria	-	-	-	-	-	76	-	-
Estonia	39	39	39	39	39	51	-	30.8%
Ireland	61	61	61	61	61	46	-24.6%	-24.6%
Latvia	-	-	-	-	-	41	-	-
Romania	-	-	-	-	-	41	-	-
Slovakia	-	-	-	-	-	31	-	-
Cyprus	-	-	-	-	-	25	-	-
Luxembourg	26	26	30	34	36	24	-7.7%	-33.3%
Total Workforce	**40,342**	**41,113**	**42,694**	**44,115**	**45,205**	**47,895**	**18.7%**	**6.0%**

Note: Data for Czech Republic, Hungary, and Poland was added in 2014, and is not available for previous years. An additional 28 Polish companies were added to the model in 2016.
Source: Eurospace Facts and Figures, 2018

EXHIBIT 2g. Japanese Space Industry Employment, 2008-2018



Source: Society of Japanese Aerospace Companies

EXHIBIT 2h. Japanese Space Industry Employment by Sector, 2013-2018

Employment Sector	2013	2014	2015	2016	2017	2018	5-Year Change	5-Year Change
Space Vehicles	5,365	5,676	6,018	6,349	6,186	6,318	17.8%	2.1%
Ground Facilities	1,529	1,386	1,532	1,424	1,421	1,454	-4.9%	2.3%
Software	1,084	1,170	1,105	1,207	1,089	1,098	1.3%	0.8%
Total Workforce	**7,978**	**8,232**	**8,655**	**8,980**	**8,696**	**8,870**	**11.2%**	**2.0%**

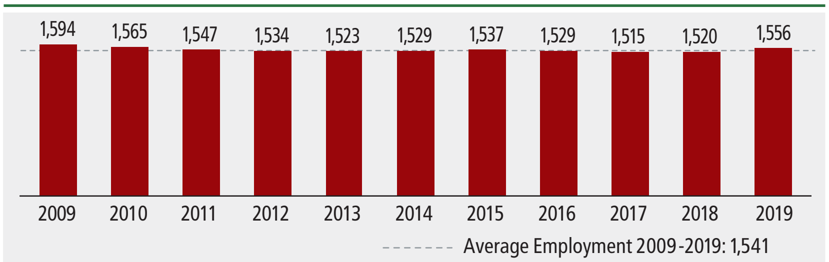
Source: Society of Japanese Aerospace Companies

2.3 Japanese Space Workforce

The Japanese space workforce included 8,870 workers in 2018, a 2.0% increase from 2017. This growth was spread across the space vehicles, ground equipment, and software sectors, all of which saw increases from 2017 to 2018. The space vehicle sector has grown 17.8% over the past five years, reflecting Japan's investments in new launch capabilities.[11]

The Japan Aerospace Exploration Agency (JAXA) employed 1,552 people in 2019, an increase of 2.4% from 2018. The majority of the JAXA workforce, 70% is made up of engineers and researchers. About 22.4% of its employees are under 35 years old, while 16.2% are 55 or older.

EXHIBIT 2i. JAXA Workforce, 2009-2019



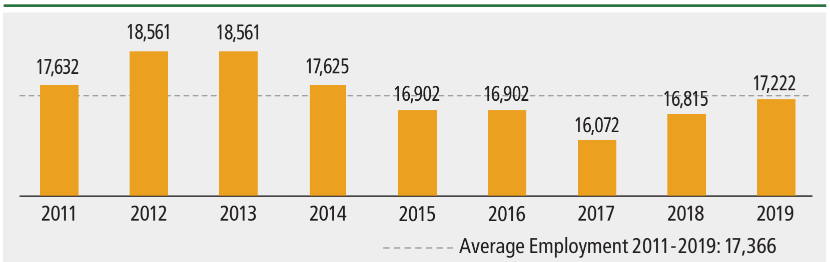
Average Employment 2009-2019: 1,541
Source: Japan Aerospace Exploration Agency

EXHIBIT 2j. JAXA Workforce Demographics, 2019

	Number of Employees	% of Employees
Engineering and Research Employees	1,089	70.0%
Under 35 Years Old	348	22.4%
Over 54 Years Old	252	16.2%

Note: Total JAXA Workforce in 2019 was 1,556
Source: Japan Aerospace Exploration Agency

EXHIBIT 2k. Indian Department of Space Employment, 2011-2019



Source: India Department of Space Annual Reports

2.4 Indian Space Workforce

The Indian Department of Space employed 17,222 people in 2019, an increase of 2.4% from 2018. Women made up 19.5% of the workforce, with about two-thirds of those working as scientific and technical staff while the remainder were administrative staff.[12] The Chandrayaan-2 Moon lander mission, launched in 2019, was the Indian Space Research Organisation's first project to be directed by a female.[13] Although the mission suffered a glitch in its final approach to the Moon that resulted in a failed landing, the ISRO chairman noted that it was the most complex mission ever attempted by the agency and classified it as "98% successful."[14]

EXHIBIT 2l. Space Agency Employment for Selected Countries, 2019

Country	Agency	Number of Employees
Australia	Australian Space Agency	19
Canada	Canadian Space Agency (CSA)	692
Czech Republic	Czech Space Office	6
Denmark	Danish National Space Center	209
Europe	European Space Agency (ESA)	2,341
France	Centre National d'Etudes Spatiales (CNES)	2,400
Germany	Deutschen Zentrums für Luft- und Raumfahrt (DLR)	8,444
Hungary	Hungarian Space Office (HSO)	250
India	Indian Space Research Organization (ISRO)	17,222
Japan	Japan Aerospace Exploration Agency (JAXA)	1,556
Poland	Space Research Center	206
South Africa	South African National Space Agency (SANSA)	204
United Kingdom	United Kingdom Space Agency (UKSA)	200
United States	National Aeronautics and Space Administration (NASA)	17,396

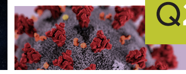
Note: Some workforce numbers were rounded off by the source.
Source: Space Foundation Database

2.5 Other Space Employment

Most nations and regions do not provide annual reports on the size of the space workforce in their nation. However, many do make public the number of individuals employed by the national space agency. A selection of this data is shown in exhibit 2k below. Note that space agencies differ significantly in their structure. In some nations, such as India, almost all space activity in the nation takes place under the auspices of the government. In others, such as Russia, the government space agency primarily plays an oversight role, and thus directly employees significantly fewer people. The United States and Europe have systems that include a mix of in-house development by government agencies and private sector space activity. Due to these differences, any direct comparisons among agency sizes must be conducted with care.

Mariel Borowitz is an assistant professor at the Sam Nunn School of International Affairs at Georgia Tech. Her research deals with international space policy issues, including international cooperation in Earth observing satellites, satellite data sharing policies, and space security issues.



3.0 Introduction | *Spacecraft deployment numbers rose by five from 2018 to 2019, increasing slightly to 466 spacecraft deployments last year. While deployments moved up, space vehicle launch attempts decreased from 114 in 2018 to 103 in 2019. The difference between deployment and launch attempt numbers is due partly to the success of two launches deploying 60 satellites per launch. As launch vehicles continue to deliver more spacecraft per launch, the industry will likely continue to see fewer launches, but more spacecraft are delivered per year.*

Artist impression of network data exchange over planet Earth
Credit: Shutterstock

EXHIBIT 3a. Topics Covered in Space Infrastructure

3.1 Spacecraft/Satellites

The primary source used to identify spacecraft for this report is the U.S. Air Force's (USAF) online spacecraft data repository, Space-Track.org. All numbers reported in the Spacecraft/Satellite portion of this analysis are based on data from Space-Track.org as of June 15, 2020. More than 10% (48) of the 466 spacecraft deployed last year have not yet been identified.

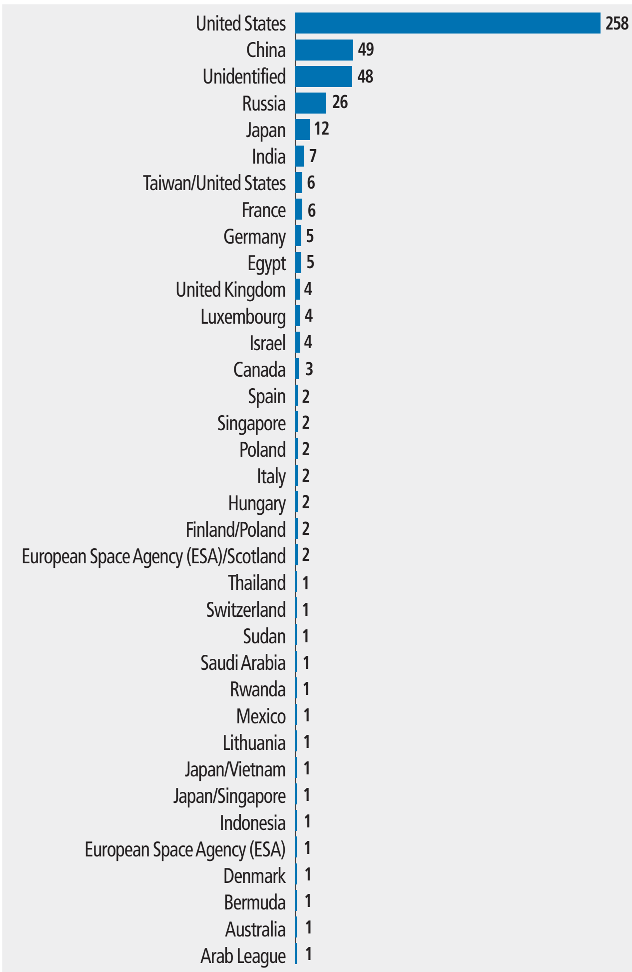
These numbers will change as the USAF continues to identify the remaining spacecraft launched.

It is also important to note that many of the spacecraft have multiple functions. In charting spacecraft purposes, the count will be significantly higher than the number of annual spacecraft deployments.

As this report is a snapshot of 2019 activities and not intended as a comprehensive list, not all nations are covered in the infrastructure section. Data regarding those countries is available to subscribers of *The Space Report Online*.

The analysis within the following sections will, more often than not, focus on the three countries, organizations, and companies with the largest share of spacecraft activities within each section.

EXHIBIT 3b. Spacecraft by Country Breakdown, 2019



Source: Space Foundation Database

3.1.1.1 Spacecraft Country Breakdown

Spacecraft operators from three nations deployed 71% (333) of the 466 spacecraft in 2019: The U.S., China, and Russia.

U.S. spacecraft operators deployed 258, or 55%, of the 466 spacecraft. This percentage is an increase for the U.S. compared to 2018 when the U.S. accounted for 39% (180 spacecraft) of that year's total number of deployed spacecraft.

China's spacecraft operators followed with 49 spacecraft, 11% of all spacecraft deployed in 2019, a decrease from 2018 when China took a 16% share of deployed spacecraft (73).

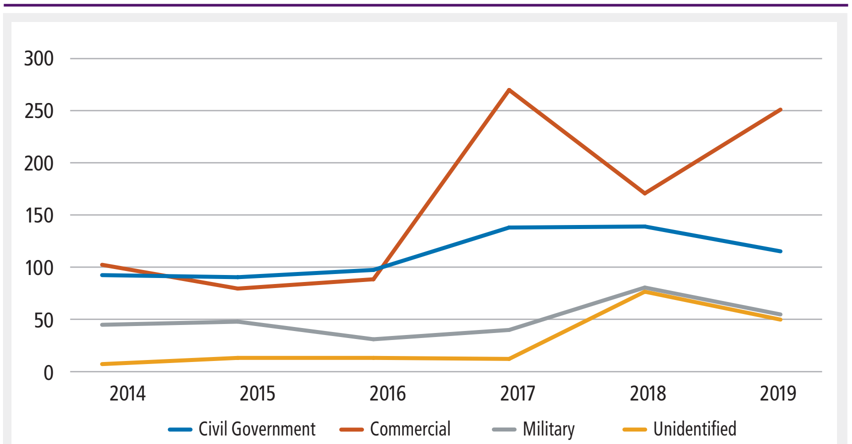
Russian spacecraft operators accounted for the remaining 26 spacecraft (6% of 2019's spacecraft deployments). Those deployments are an increase for Russia from 2018 when that nation deployed 21 spacecraft and accounted for a 4.5% share.

3.1.1.2 Spacecraft Mission Segment Breakdown

The 466 spacecraft were deployed from 97 successful launches, including deployments from the International Space Station (ISS) in 2019. Manufacturers design spacecraft to carry more than one payload onboard in many instances; mission segments counted reflect the primary payload.

Commercial missions saw the largest share of deployments, accounting for 54% of launched spacecraft (251). Commercial missions increased 48% from the 170 spacecraft launched in 2018.

EXHIBIT 3c. Spacecraft by Sector, 2014-2019



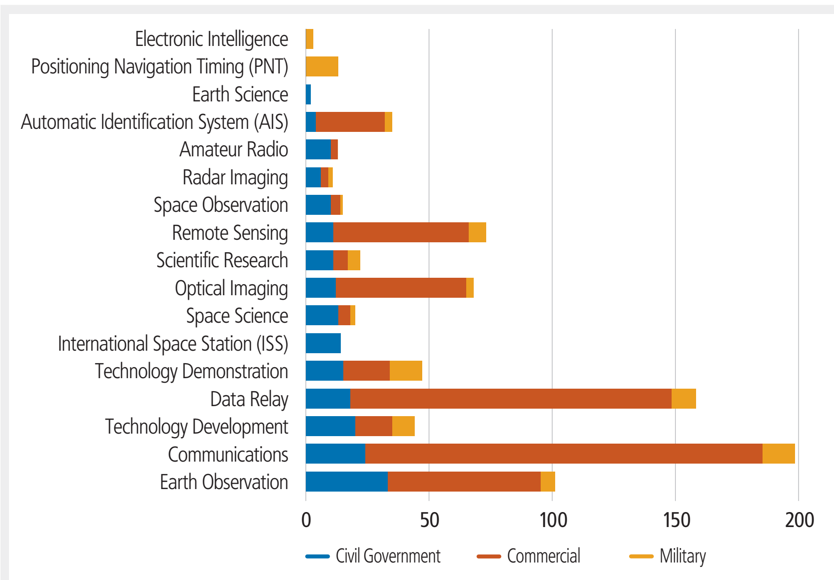
Source: Space Foundation Database

The next-highest share went to civil government, with 25% (114) of spacecraft deployed for that mission segment in 2019. That is a 5% decrease from 2018's 30% share, or 138 missions out of the 461 that launched in 2018.

The military mission segment accounted for only 11% (53) of all spacecraft deployed in 2019, which is down when compared to 2018's 17% share with 78 deployed.

The remaining spacecraft deployed in 2019 had not yet been identified as of June 15, 2020. Adjustments are frequently made to the spacecraft data repository. Totals for 2018, which had been at 465, were recently adjusted to 461 after SpaceTrack retroactively reclassified four payloads as space debris.

EXHIBIT 3d. Spacecraft by Purpose and User Segment, 2019



Source: Space Foundation Database

3.1.1.2.1 Commercial Operators

The four satellite operators with the highest share of the commercial spacecraft deployments in 2019 made up 73% of the total commercial satellites deployed. The 124 satellites SpaceX deployed in 2019 netted a 49% share of the 251 commercial spacecraft. Planet's 32 satellites accounted for a 13% share of the commercial spacecraft deployed in 2019. Spire Global, Inc. sent up 18 satellites, taking a 7% share, while Iridium Communications Inc.'s 10 satellites brought home a 4% share of all commercial spacecraft deployed in 2019.

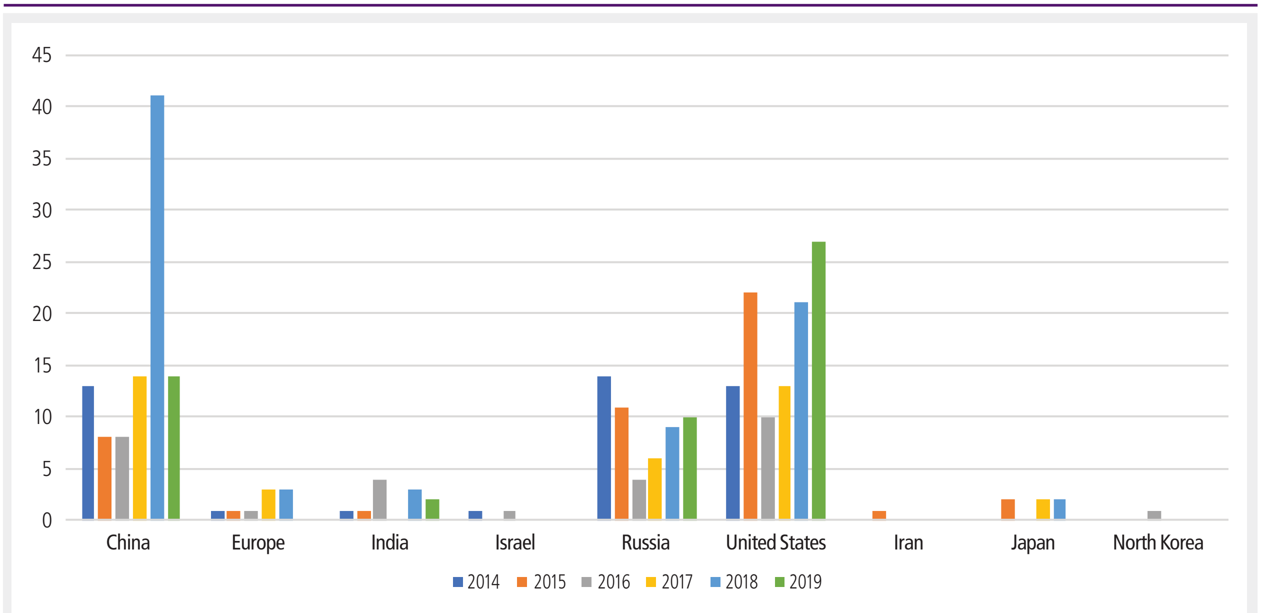
3.1.1.2.2 Civilian Operators

Three civil government operators, the U.S, China, and Russia, had the largest share (64%) of 2019's 114 civil government spacecraft deployments. This is relatively consistent with previous years; those three nations invest more in civil government operations than any other nation or multinational entity. In 2018, the U.S., China, and Russia accounted for 60% of the total share of civil government deployments, deploying a combined 83 spacecraft.

The U.S. deployed 37, or 32%, of the civil government spacecraft in 2019, a decrease from 2018's 45 spacecraft deployments. China deployed 20, an 18% share, but a decrease from 2018 when China deployed 25. Russia deployed 16 spacecraft, or 14%, of civil government spacecraft deployed last year. Russia increased its civil government payload deployments by three from 2018's 13 spacecraft deployed.

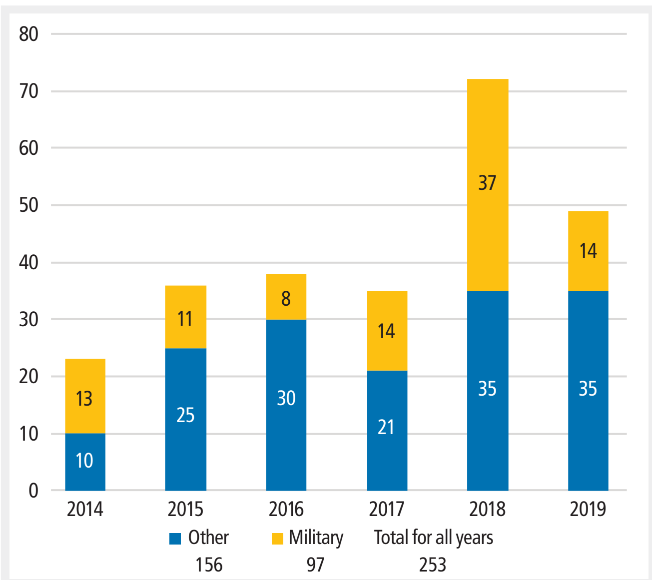
Earth observation payloads accounted for the highest share 29% (33) of civil government supported missions in 2019, followed by communications payloads at 21% (24), and data relay with an 18% share (20).

EXHIBIT 3e. Military Spacecraft by Deployment, 2014-2019



Source: Space Foundation Database

EXHIBIT 3f. Chinese Military Spacecraft Deployment, 2014-2019



Source: Space Foundation Database

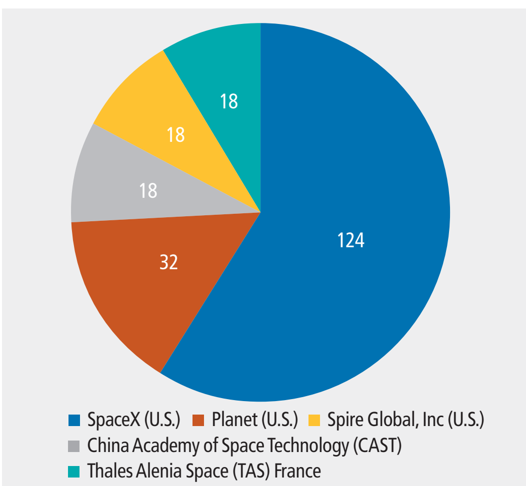
3.1.1.2.3 Military Deployments

Six nations deployed 60 military satellites in 2019: the U.S., China, Russia, India, Japan, and Mexico. Of those, the largest shares of military satellites deployed came from the U.S., China, and Russia.

The United States deployed 47% (28) of military satellites last year. The U.S. Air Force represented the largest share, 12, or 20% of all military spacecraft deployed.

China deployed 14 military satellites in 2019 (23%). The Beidou Satellite Navigation System Office deployed 10 of those and held the next-largest share of all military spacecraft deployed at 17%. The third-largest share went to Russia. Of the 10 Russian spacecraft deployed in 2019, the Ministry of Defense of the Russian Federation deployed seven, a 12% share of all military spacecraft.

EXHIBIT 3g. Top Five Spacecraft Manufacturers, 2019



Source: Space Foundation Database

3.1.1.3 Spacecraft by Operator and Manufacturer

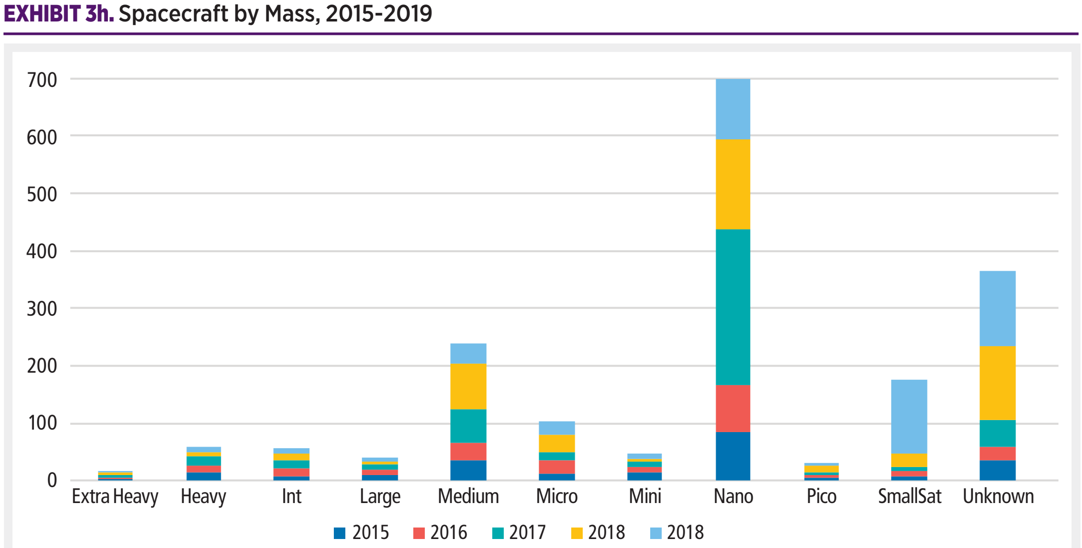
The three spacecraft operators with the largest share of 2019's deployed spacecraft are based in the U.S.: SpaceX, Planet, and Spire Global, Inc. These three commercial operators accounted for 37% (174) of all spacecraft deployed that year. The majority of SpaceX's deployments (120) were communications and data satellites. The other four were Dragon resupply missions to the ISS.

3.1.1.4 Spacecraft Masses

Of the 466 spacecraft deployed last year, 58% (272) had a mass of less than 500 kg (1102 lb). The combined masses of those satellites totaled 37,208.64 kg (82,031 lb). Of those (272) satellites, 130 fell into the SmallSat category weighing 181kg – 500 kg.

Even though only 10 heavy satellites (mass > 7,000 kg) deployed in 2019, they took the largest share of the total mass delivered to orbit, accounting for 25% (61,745 kg, 136,124 lb) of the mass of all spacecraft deployed. The heaviest spacecraft, the Japanese HTV- 8 operated by Mitsubishi Heavy Industries, launched in 2019 with a combined mass of 16,500 kg (36,400 lb). The HTV-8 is an unmanned cargo transport spacecraft that delivers supplies to the ISS.

EXHIBIT 3h. Spacecraft by Mass, 2015-2019



Source: Space Foundation Database

3.1.2 Data Insights – Starlink Overview

Starlink is a quickly expanding constellation of low Earth orbit satellites designed and manufactured by SpaceX. Starlink is the largest constellation in space, with more than 480 satellites. The company plans to deploy 42,000 satellites with the first 12,000 to deploy over eight years.[1]

SpaceX's goal is to increase its deployment rate to as many as 2,000 satellites per year.[2]

Starlink. *Credit: ESSTI*

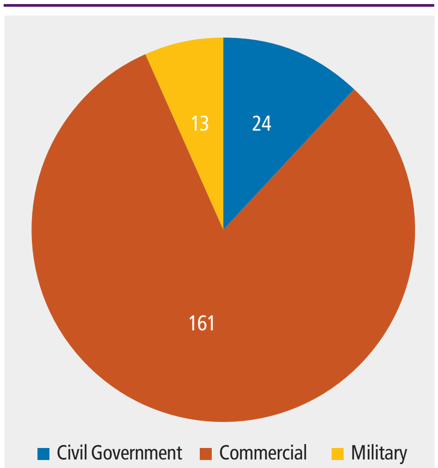
SpaceX is building satellites at a rate of six per day, four times faster than its closest competitor. It deployed 75% (120) of all communications satellites in 2019.[3] The company's flat-panel SmallSats, weigh 260 kg each and relay communications and internet of things (IoT) data and form one of the largest LEO broadband constellations ever conceived. Federal Communications Commission (FCC) approvals currently allow SpaceX to launch up to 12,000 satellites to support Starlink. That's just the beginning; in late 2019, SpaceX requested approval for up to 30,000 additional satellites.[4]

What will Starlink do?

Starlink is using phased array antennas for Ka-band uplinks, and Ku-band downlinks offer low-latency, global, high-speed broadband internet with direct-to-consumer wireless capability.[5][6] The company has said that its space-based internet service is expected to play a significant role in servicing less populated areas of the globe. Once complete, and combined with existing broadband networks, Starlink will offer fully connected internet access anywhere on Earth. SpaceX expects to reach global coverage next year.[7]

SpaceX will require a massive ground network of fixed Earth receivers to receive the thousands of Starlink signals beaming towards Earth. In a study conducted by MIT, researchers found "SpaceX's limiting factor will be the ground segment, as they need to deploy a very large number of ground stations and gateways to operate at full power".[8] In preparation, the company has secured approval from the FCC to deploy up to 1 million ground antennas. Each ground receiving station measures about 19 inches (.48 m) across.[9]

EXHIBIT 3i. Communications Satellites Deployed by Sector, 2019



Source: Space Foundation Database

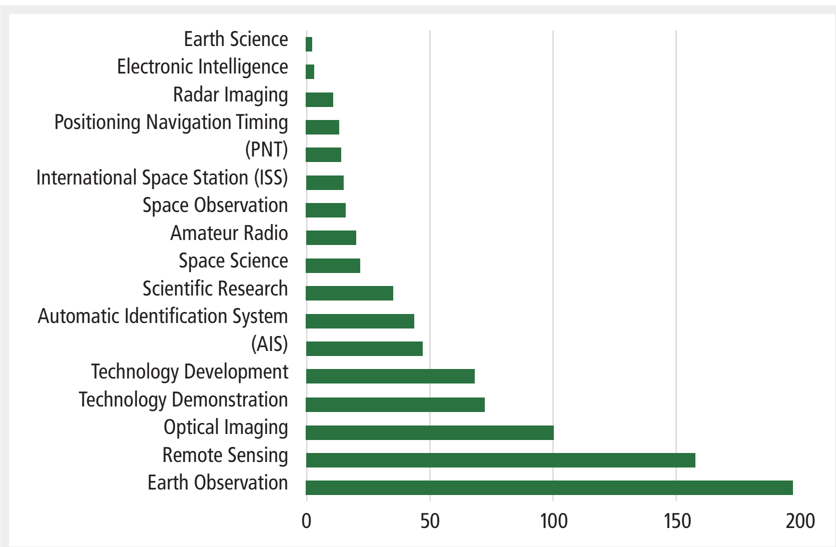
3.1.3 Communications Satellites Overview

Last year, 198 communications satellites were deployed, a 42% share of the satellites deployed in 2019. That was a 55% increase from 2018's 128 communications satellite deployments. The 198 satellites varied in physical size, mass, and payload function, from small CubeSats relaying amateur radio signals to heavy satellites with full communications capabilities. Swarm Technologies, a company working to advance the Internet of things (IoT), deployed communications and data relay picosats with a mass of just 1 kg (2.2 lbs).

At the other end of the 2019 spectrum was a Sky Perfect (JCSAT/Kacific) communications satellite with a mass of 6,800 kg (equivalent to the launch weight of 14,991 lbs). It was the heaviest communications satellite of 2019.

Communication, data relay and IoT satellites dominated the communications satellites deployed in 2019. SpaceX's Starlink missions began bulk deployments of 60 low Earth orbit communications and IoT satellites in May 2019, totaling 120 satellites.

EXHIBIT 3j. Spacecraft by Purpose, 2019



Source: Space Foundation Database

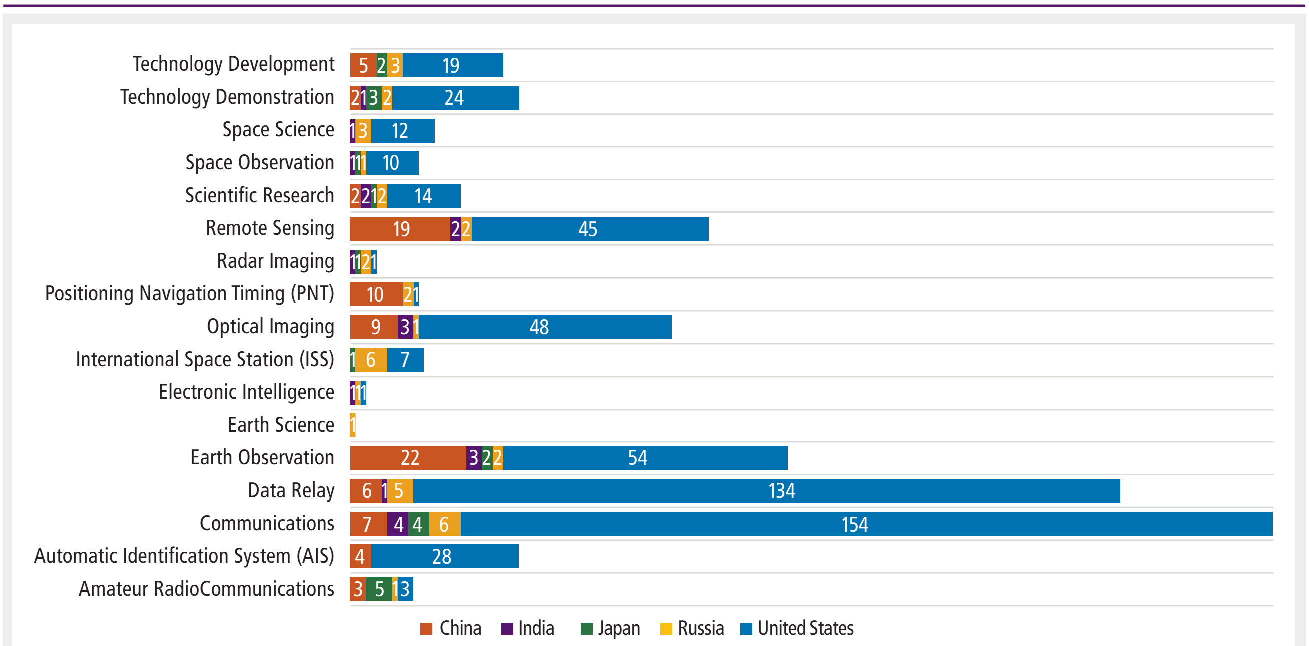
The following breakdown will cover only the three entities with the largest portions in each subsection.

3.1.3.1 Communications Satellites Mission Segment Breakdown

The vast majority of communications satellites deployed in 2019, 81% (161), were for commercial missions, increasing over 200% from 2018's 53 satellites deployed for commercial communications missions.

Civil government spacecraft ranked second with a 12% share (24), a 27% decrease from 2018's 33 satellites deployed.

EXHIBIT 3k. Spacecraft by Purpose for Top 5 Countries, 2019



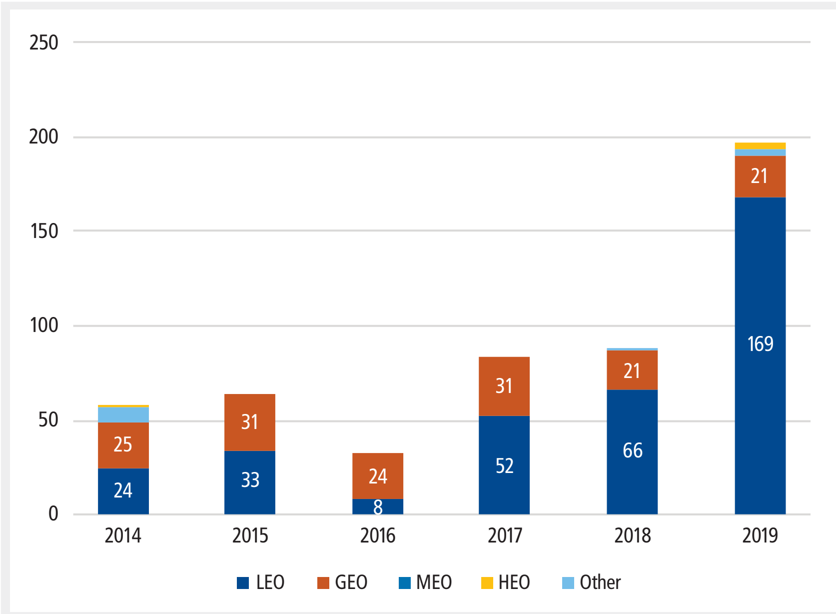
Source: Space Foundation Database

The 13 satellites deployed for military communications missions took a 7% share of communications satellites deployed in 2019, an increase of 63% from 2018's eight military communications satellites deployed.

SpaceX, Iridium, and OneWeb were the top three operators of the 161 commercial communications satellites deployed last year.

The top two commercial communications operators, SpaceX and Iridium, are headquartered in the U.S. The third, OneWeb, is a UK company. The three operated 134 of the commercial communications satellites deployed in 2019. SpaceX, with a 75% share (120), deployed the bulk of commercial communications satellites in 2019.

EXHIBIT 3l. Communications Satellites Deployed by Orbit, 2014-2019



Source: Space Foundation Database

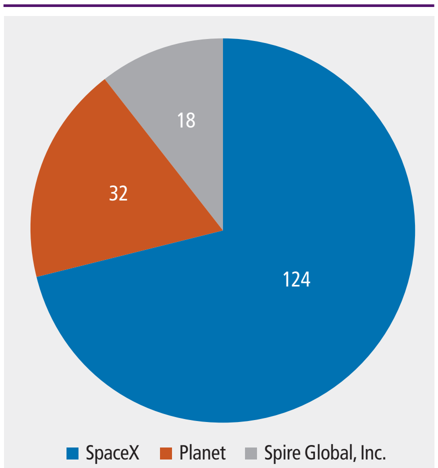
The top four operators of the 24 civil government-focused communications satellites deployed in 2019 were China Satellite Communications Co. (China Satcom), Indian Space Research Organisation (ISRO), Russian Space Agency (Roscosmos), and Japan's Kyushu Institute of Technology (KIT). The communications satellites of those four organizations accounted for a 50% share of the civil government spacecraft (12). All four organizations each deployed three satellites.

Three nations deployed 13 military communications satellites in 2019: China, Russia, and the U.S. China's Academy of Space Technology (CAST) operates a TJS-4 satellite to geostationary orbit (GEO) for signals intelligence technology development, communications, and data relay.

The Russian Ministry of Defense operates a Cosmos 2539 communications satellite to geostationary orbit (GEO), and the Russian Space Agency (Roscosmos) deployed a Cosmos 2541 communications satellite into a highly elliptical (HEO) Molniya orbit.

The U.S. deployed the 10 remaining military satellites. Only two U.S. organizations deployed to geostationary orbit: the U.S. Air Force deployed a WGS-10 global wideband communications satellite, and the U.S. Air Force Space and Missile Systems Center deployed an AEHF 5 communications satellite. The eight remaining U.S. satellites deployed to low Earth orbit (LEO). The U.S. Naval Academy (USNA) deployed both the PSAT 2 and the BRICSAT 2 communications satellites. The Department of Defense (DoD) deployed two communications and technology development satellites, CATSAT 1 and CATSAT 2. The U.S. Air Force Space Command deployed Pearl 1 and Pearl 2, both communications test satellites. U.S. Army Space and Missile Defense Command deployed Harbinger, a communications demonstration prototype satellite, and the Defense Advanced Research Project Agency (DARPA) deployed Orca 1, a communications technology demonstration satellite.

EXHIBIT 3m. Top Three Communications Operators, 2019



Source: Space Foundation Database

3.1.3.2 Communications Satellites Company Breakdown

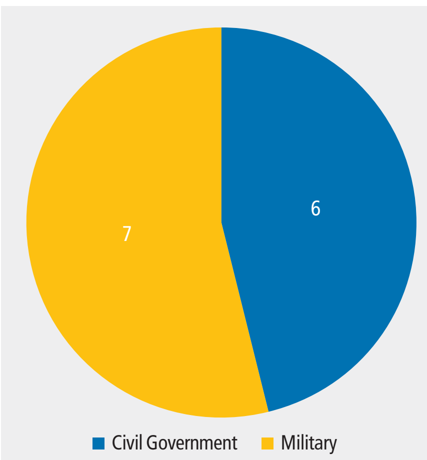
Iridium was SpaceX's closest competitor for total communications satellites deployed in 2019, deploying 10 spacecraft for a 6% share. Those deployments bring Iridium's constellation size to 66 interlinked communications satellites for point-to-point communications. Along with Iridium's primary payload, its spacecraft also has a secondary positioning, timing, and navigation (PNT) payload. Iridium is the first commercial company operating a PNT constellation.[10]

OneWeb deployed just 4% (6) of all communications satellites in 2019. OneWeb has since voluntarily filed for Chapter 11 of the Bankruptcy Code in the U.S. Bankruptcy Court.[11] Due to the high demand for LEO broadband coupled with the OneWeb ecosystem already in place, OneWeb is pressing forward with major plans. The global communications network company is now requesting an increase in constellation size from the FCC to 48,000 total satellites in orbit, 6,000 more than SpaceX is planning.

OneWeb, SpaceX's nearest competitor, plans to launch 650 satellites for its global broadband constellation. To date, OneWeb has launched 74 satellites. OneWeb has discussed publicly the desire to add up to 48,000 spacecraft. SpaceX has launched 65% of OneWeb's planned constellation.[12]

In 2019, SpaceX took a commanding lead in commercial satellite manufacturing. All of the company's Starlink satellites are designed and manufactured in-house. SpaceX manufactured 61%, or 120, of communications satellites deployed in 2019, four times as many satellites deployed by the largest share in 2018. Airbus Space and Defense came next with a 4% share, manufacturing seven spacecraft. Airbus was followed closely by Thales Alenia Space with six satellites, a 3% share of all communications satellites deployed in 2019.

EXHIBIT 3n. Positioning, Navigation, and Timing Satellites Deployed by Sector, 2019



Source: *Space Foundation Database*

3.1.4 Positioning, Navigation, and Timing (PNT) Satellites Overview

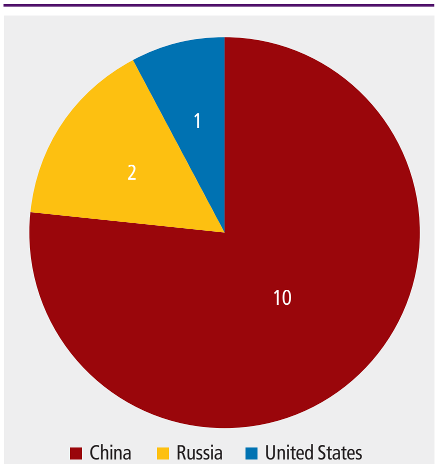
Of the 466 spacecraft deployed during 2019, 3% (13) were for Positioning, Navigation, and Timing (PNT) missions. PNT satellite deployments in 2019 increased the overall number of dedicated PNT satellites by 33% from 2018. At the end of 2019, 195 PNT satellites were orbiting the Earth in six constellations.

The Space Report's data on PNT satellites highlights major shifts with respect to the buildout of crucial PNT infrastructure. For example, 13 PNT satellites were deployed in 2019. Ten, or 77%, were for China's Beidou constellation. That share is 8% more than China's 2018 Beidou share, 69% of the total PNT satellites deployed. With China's constellation nearing full capacity, it's likely the country will slow down its PNT deployments in the years to come.

Military operations have been the driver for launching PNT constellations, but the public has been the benefactor of these launches. Commercial benefits derived therefrom, such as location services on a smartphone, or shipping logistics, far outweigh the military's investment in PNT systems.

The following breakdowns will cover the three entities with the largest portions in each subsection.

EXHIBIT 3o. Positioning, Navigation, and Timing Satellites Deployed by Country, 2019



Source: *Space Foundation Database*

3.1.4.1 PNT Satellites Mission Segment Breakdown

Much like previous years, all of the 13 PNT deployments in 2019 were for military missions. China, Russia, and the U. S. accounted for all 13 military PNT satellites. China's share was the largest, with 77% (10). Russia deployed two PNT satellites or 15% of the overall share. The U.S. deployed one PNT satellite for an 8% share.

3.1.4.2 PNT Satellites Country Breakdown

Of the 143 PNT satellites in Earth orbit during 2019, 132 were operational, up 31% from 2018's total of 101 operational satellites. Nonoperational status is due in most cases to satellites undergoing maintenance or testing.

China took the lead for the highest share of operational PNT satellites in 2019, 30% (43), with its Beidou Navigation constellation (BDS). The U.S. Global Positioning System (GPS) took second with 22% (31) of the operational satellites. Russia's Glonass PNT system moved to third with a 17% (24) share. The EU Galileo ranked fourth in 2019, with a 15% (22) share of the operational PNT satellites. India and Japan had less than a 6% share each.

3.1.4.2.1 Beidou

In 2019, the Beidou constellation grew by 30%. China deployed 11 PNT satellites in 2019, bringing the new total of its satellites deployed to 53, far more than the 35 satellites required to operate the global navigation system. Although 53 satellites have been deployed, only 48 are in the constellation (43 operational, and 5 spares in orbit).[13] The overall number of Beidou satellites exceeds the numbers in each of its U.S., Russia, and EU/ESA constellation counterparts.

The five test/spare satellites that support the constellation are not counted as part of the total operational count due to the fact that they operate on different signals systems and are considered to be purely test satellites.[14]

The constellation is comprised of spacecraft and systems operating in three main segments: space, ground, and user. The space segment utilizes three main orbits, geostationary Earth orbit (GEO), inclined geosynchronous orbit (IGSO), and medium Earth orbit (MEO).[15]

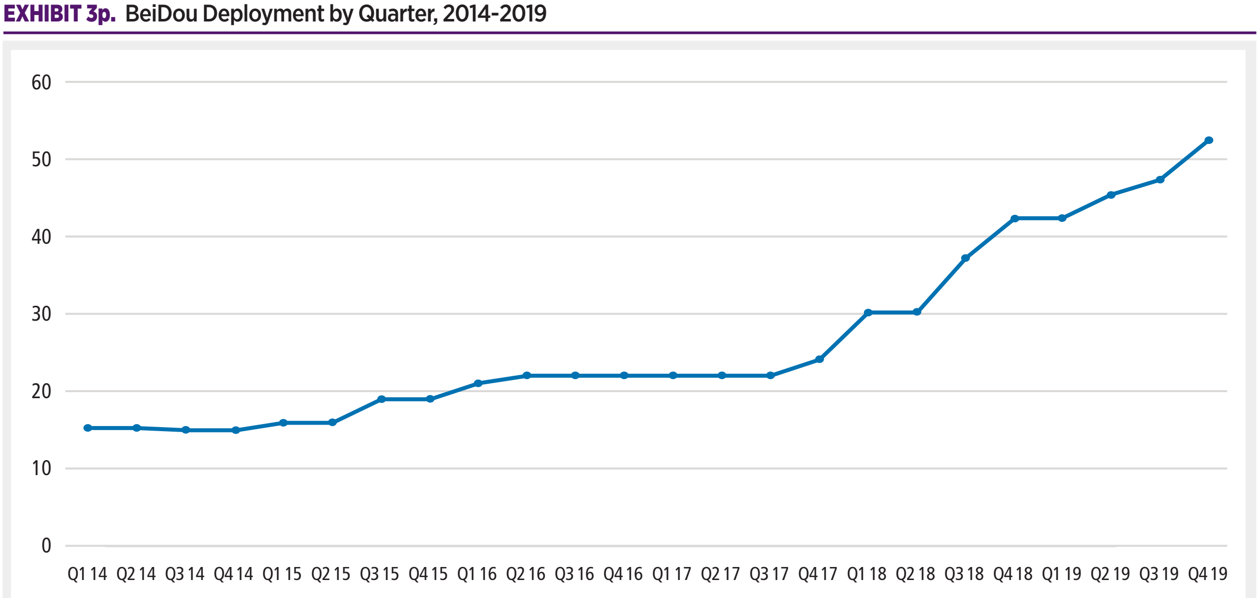
In China, 2019 marks the year of completion for the core support of the overall constellation orbiting in MEO. China launched the final two satellites to operate in MEO in December 2019, bringing the core support constellation size to 24 satellites — satisfying requirements needed to support the full constellation of 48 satellites, which is intended to be finalized by the end of 2020. The two remaining satellites will launch in 2020. As of March 2020, 54 satellites in the Beidou constellation were launched and operational. Although 54 satellites have launched, only 48 satellites remain in orbit. Six of the satellites have become in-operational since China began launching Beidou missions.

The Beidou constellation supports five major functions: real-time navigation, rapid positioning, precise timing, location reporting, and short message communication.

China Academy of Space Technology, a subsidiary of the China Aerospace Science and Technology Co., Ltd., manufactured 64% (35) of the Beidou satellites. The remaining satellites are manufactured by the Innovation Academy for Microsatellites of Chinese Academy of Science.

China's share of the global operational PNT satellites is 33%; this equates to a ranking of No. 1 for the second year in a row.

EXHIBIT 3p. BeiDou Deployment by Quarter, 2014-2019



Source: Space Foundation Database

3.1.4.2.2 Galileo

Europe's global satellite navigation system (GNSS), also known as Galileo, is funded and owned by the European Union (EU).[16] Constellation and ground segment operations and management are conducted jointly by the EU and European Space Agency (ESA). In 2019, the EU focused primarily on testing the space and ground segments. No GNSS satellites were deployed in 2019 by Europe in support of the Galileo program, leaving the constellation size at 26 spacecraft in orbit.

Once complete in 2020, the constellation will consist of 30 satellites deployed to MEO.[17] The constellation is interoperable with the U.S.'s GPS and Russia's Glonass.[18] European nations have been expanding on the success of Russia and the U.S. and are close to finalizing efforts to gain independence among the global navigation system community. Unlike the U.S. and Russia, where GPS and Glonass operations are maintained by the military, Galileo is a civilian-controlled program.

The FCC granted a waiver in 2018 for devices in the U.S. to receive signals from the Galileo system, providing more accuracy for positioning and navigation purposes.

EU's share of the global operational PNT satellites in 2019 is 15%; this equates to a ranking of No. 4.

3.1.4.2.3 NavIC

India's PNT satellites make up the Navigation with Indian Constellation (NavIC), the nation's Regional Navigation Satellite System (RNSS). The constellation grew to its current operational size in 2018 with the deployment of an eighth PNT satellite.[19] One of the previously deployed satellites is no longer operational and does not support the larger constellation, leaving the constellation size at seven.[20]

India did not launch any PNT satellites in 2019. To operate the seven satellites in the constellation, the Indian Regional Navigation Satellite System (IRNSS) receives operational support from the Indian Space Research Organisation's (ISRO) Navigation Centre (INC). NavIC provides regional location and timing services to India and its neighboring countries and provides restricted use to the Indian government and military. India's share of the global operational PNT satellites is 6%; this equates to a ranking of No. 5.

3.1.4.2.4 QZSS

Japan's Quasi-Zenith Satellite System (QZSS), also known as Michibiki, is the nation's PNT constellation. Japan's Cabinet Office maintains and operates the navigation system.[21] The constellation consists of four fully operational positioning, navigation, and timing spacecraft.[22]

Japan's four operational PNT satellites bring the nations share of global operational PNT satellites to 3%; this equates to a ranking of No. 6.

Along with positioning, navigation, and timing, the satellites are used for emergency services. Emergency information is broadcast directly to the Southeast Asia and Oceania regions.

3.1.4.2.5 Glonass

Russia's Glonass system remained steady for the second year in a row with the number of operational satellites in its constellation (24). Russia deployed two additional PNT satellites in 2019, increasing its constellation size to 27. Two of those are spares, one is in testing, and 24 are in operational orbit.[23]

Glonass-M, or Uragan-M, is Russia's second-generation PNT satellite. All 24 operational satellites are Glonass-M. These satellites are manufactured by the Russian-based company ISS Reshetnev. Russia's share of the global operational PNT satellites is 17%; this equates to a ranking of No. 3.

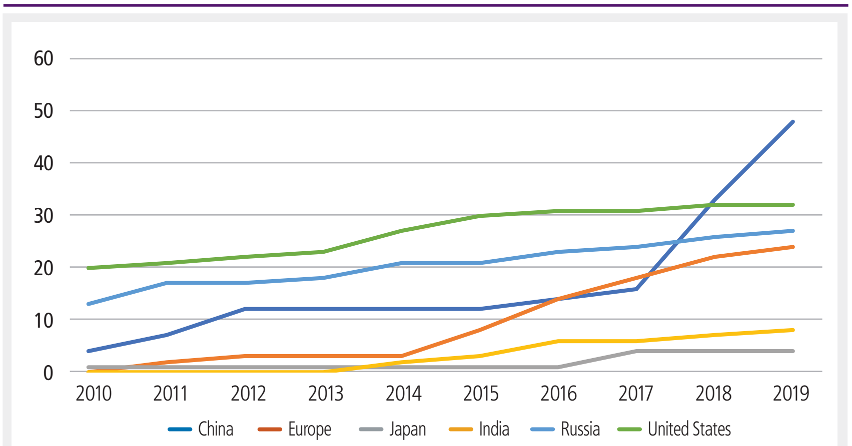
3.1.4.2.6 GPS

The U.S. GPS is operated and maintained by the U.S. Air Force. GPS has been the world's preeminent navigational system since operations began in 1988. The constellation has undergone various changes throughout those 32 years to achieve success. Technological developments leading to increasing satellite functionality have created a constant demand for upgrades, replacements satellites, and constellation security.

A combination of legacy and modernized satellites operates in sync to form the full operational constellation of 31 PNT satellites. There are 11 legacy GPS satellites type Block IIR supporting the system, and 20 modernized satellites; 19 are GPS II satellites. Seven of the GPS II's are type Block IIR-M, which are a modernized type Block IIR, and 12 are type Block IIF.[24] Only one GPS III satellite has been deployed, the GPS III/IIIF.

In September 2018, the U.S. Air Force awarded Lockheed Martin a "fixed-price" contract worth $7.2 billion to build 22 GPS lll-F (follow-on) satellites.[25] Lockheed expects to deliver the first satellite under this new contract by 2026. In an announcement from the office of the Secretary of the Air Force, Chief of Staff Gen. David L. Goldfein stated, "This investment in GPS lll continues to advance our capabilities into the future".[26]

EXHIBIT 3q. Positioning, Navigation, and Timing Constellation Size, 2010–2019



Source: Space Foundation Database

The U.S. share of the global operational PNT satellites is 22%; this equates to a ranking of No. 2.

3.1.5 Earth Observation/Remote Sensing (EO/RS) Satellites Overview

Of the 466 deployed spacecraft in 2019, 22% (101) were deployed for Earth observation/ remote sensing (EO/RS) missions. That is a 57% decrease from 2018's 38% share (176).

The following breakdowns will cover the three entities with the largest portions in each subsection.

3.1.5.1 EO/RS Satellites Mission Segment Breakdown

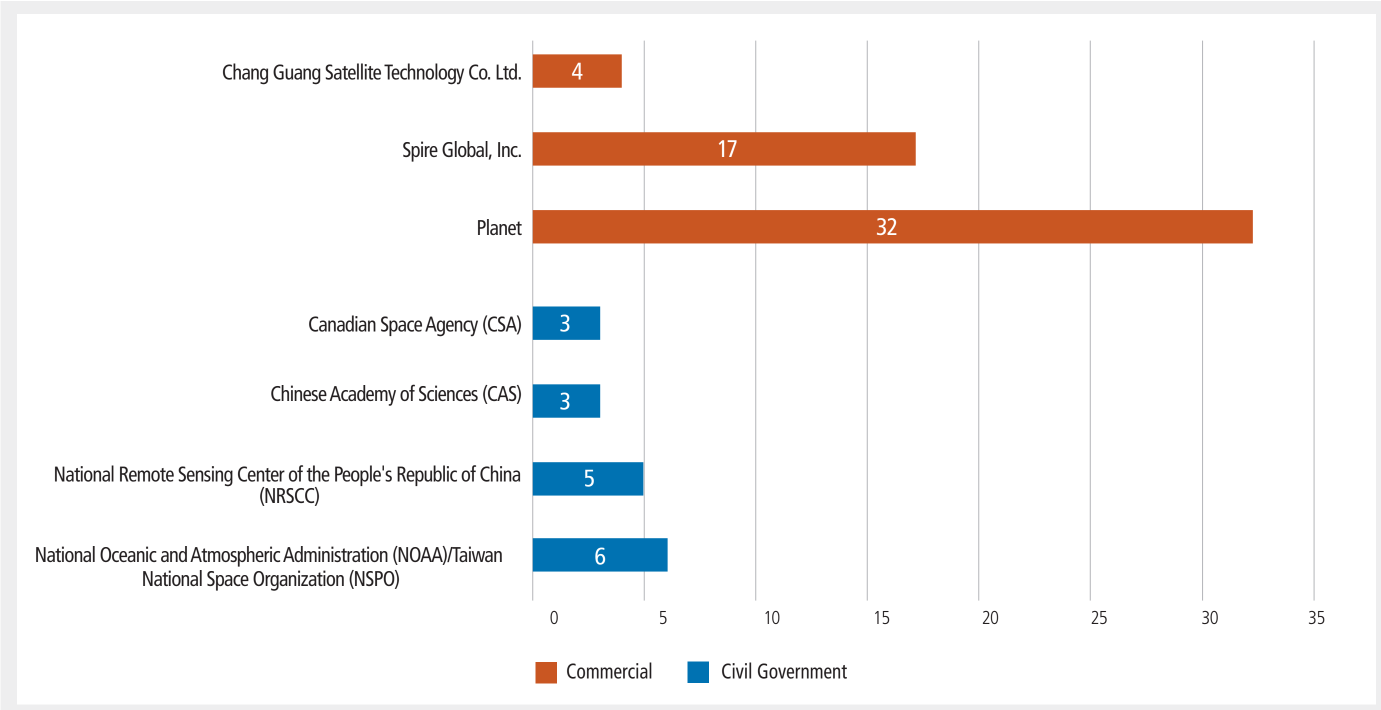
Of the 101 EO/RS satellites deployed in 2019, a majority, 61% (62), were deployed for commercial purposes. The 62 commercial satellites are a decline from the number of commercial EO/RS satellites deployed in 2018 (98). Civil government EO/RS satellites accounted for a 33% share with 33 deployments. The military segment deployed the least amount of EO/RS satellites in 2019 with a 6% share.

The three satellite operators with the largest share of commercial EO/RS were Planet, Spire Global, Inc., and Chang Guang Satellite Technology Co. Those 62 satellites made up a 52% share of the commercial EO/RS satellites deployed in 2019. Planet had the largest share of 2019 EO/RS satellite deployments, with 32. Spire Global's 17 deployments represent the second-largest share. Chang Guang Satellite Technology's four commercial EO/RS satellites took a 4% share.

During 2019, the four civil government operators with the largest shares of EO/RS satellites deployed 17 of the 33 civil government satellites launched for the year.

The National Oceanic and Atmospheric Administration (NOAA), working with the Taiwan National Space Organization (NSPO), deployed six out of the 33 EO/RS civil satellites deployed, an 18% share of that mission segment.

EXHIBIT 3r. Top 3 Earth Observation/Remote Sensing (EO/RS) Satellites Deployed by Operator and User, 2019



Source: Space Foundation Database

The National Remote Sensing Center of the People's Republic of China (NRSCC) accounted for 15% (5) of the civil government EO/RS spacecraft deployed. The third-largest share was a tie between the Chinese Academy of Sciences (CAS) and the Canadian Space Agency (CSA). Both organizations deployed three civil government EO/RS satellites, each with a 9% share of that mission segment.

Four nations deployed six EO/RS spacecraft for military purposes in 2019. This number is a dramatic decrease from 2018's 27 EO/RS spacecraft deployed for military use. China deployed three spacecraft, and the remaining nations, India, the U.S., and Mexico each deployed just one EO/RS satellite in 2019.

3.1.5.2 EO/RS Satellites Country Breakdown

Earth observation and remote sensing satellite operations are conducted from various countries around the globe. In 2019, the bulk of EO/RS operators were located in the U.S. and China. The two nations deployed a combined 82 satellites, 81% of all EO/RS spacecraft deployed during 2019.

Two U.S. companies, Planet and Spire Global, had 49 satellites deployed last year, accounting for nearly 49% of all EO/RS satellites deployed globally and 91% of the 54 U.S. EO/RS deployments in 2019. Planet's 32 satellite deployments gave the company the largest share of all organizations deploying EO/RS spacecraft in 2019, a decrease from 2018's 38 satellites deployed. Those efforts netted the company a 32% share of all EO/RS satellites deployed, while Spire's 17 satellites deployed gave that company a 17% share. Spire's total spacecraft deployed also decreased from 2018's 28 EO/RS satellites deployed.

The National Remote Sensing Center of the People's Republic of China (NRSCC) deployed five of the 22 Chinese EO/RS satellites. The NRSCC had the largest share at 23% of the EO/RS spacecraft deployed by China. Tied closely behind were the Chang Guang Satellite Technology Co., and the China Aerospace Science and Technology Corporation (CASC), each with an 18% (4) share of spacecraft deployed by China in 2019.

2018's top three EO/RS manufacturers remained in the same positions in 2019. Planet, Spire, and China Academy of Space Technology (CAST) accounted for 55% (56) of all EO/RS satellites deployed in 2019. While Planet and Spire operate their satellites, CAST is primarily a manufacturer.

3.1.5.3 EO/RS Meteorological Focus

Meteorology satellite deployments decreased by nearly half, from 49 in 2018 to 25 in 2019. Two civil government organizations, one civil government company, and one commercial company deployed 25 satellites, earning them a combined 25% share of all EO/RS satellites deployed with a meteorological focus. There were no military missions deploying EO/RS meteorology satellites in 2019.

Seventeen satellites were commercial EO/RS payloads with a meteorological focus last year, accounting for 68% of that mission segment. All 17 were manufactured and deployed by Spire Global.

Civil government meteorology satellites made up 32% (8) of deployed EO/RS meteorology spacecraft. A collaboration between the U.S. and Taiwan deployed six of those satellites, while the Russian Space Agency and the Russian company, Russian Space Systems (RSS), deployed one satellite each.

3.2 Exploration and Research Spacecraft, Landers, and Rovers—Overview

Of the 466 spacecraft deployed in 2019, less than 1% (3) were used for space exploration and research. Two of those deployments were lunar mission with one from Israel and one from India. The third exploration craft, a Russian and German international collaboration, was sent to a selenocentric (sun) orbit.

All three of the exploration deployments came from the civil government segment. SpaceIL and the Israeli Space Agency, the Russian Space Agency (Roscosmos) and the German Center for Aviation and Avionics (DLR), and the Indian Space Research Organisation (ISRO) operated the three spacecraft.

Israel deployed the Beresheets lander, Russia and Germany deployed the SPEKTR RG, and India deployed the Chandrayaan 2 spacecraft.

There were no commercial exploration and research deployments in 2019.

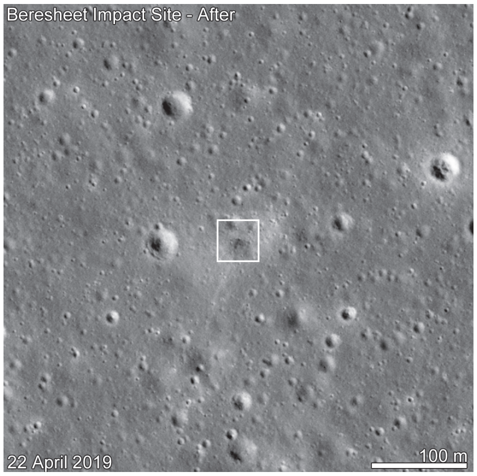
Beresheet lander. *Credit: ESSTI*

3.2.1 Exploration and Research Spacecraft, Landers, and Rovers—A Mission Sampling

3.2.1.1 Exploring the Moon: Beresheet

The space industry's first privately funded lunar lander launched from Florida's Cape Canaveral Air Force Station on February 22, 2019. The lander, with a mass of 585kg (1,290 lbs) and measuring about 1.5m (5 ft) high and 2.3m (7.5 ft) wide, was a collaboration between the Israeli Space Agency and the Israeli nonprofit organization SpaceIL. The Beresheet mission gave Israel the fourth spot in the number of nations that have touched down on the lunar surface, followed by Russia (USSR at the time), the U.S., and China.

The mission was not a complete success. After 6.5 million kilometers and two months of travel time, the spacecraft reached lunar orbit and completed the lunar orbit insertion maneuver. That was the last successful task Beresheet completed. Shortly after lunar orbital insertion, on April 11, 2019, the spacecraft crash landed on the moon's surface.[27] SpaceIL reports a malfunction caused a series of problems resulting in an engine shutdown and crash on the moon at 32.5956°N, 19.3496°E.[28 29]



Beresheet crash site. *Credit: NASA*

Beresheet had many firsts in its mission: The first non-governmental mission to the moon, the first rideshare to the moon, and the smallest spacecraft to aim and reach the moon.[30]

3.2.1.2 Exploring Lunar Orbit: Chandrayaan 2

Chandrayaan 2, comprised of a lunar orbiter, a lunar lander, and a small lunar rover, launched on July 22, 2019, from the Satish Dawan Space Center in India. The spacecraft reached lunar orbit on August 19, 2019, and set down on the unexplored south pole of the lunar surface less than a month later on September 6, 2019. Chandrayaan 2's attempts at a soft landing failed, although none of the on-board equipment was damaged.

Some of the missions include lunar topographic mapping from lunar orbit, lunar exospheric research, and lunar surface sampling. Scientists and engineers at the ISRO planned for an extensive research mission with Chandrayaan 2. Thirteen payloads operate on three lunar explorers: the Chandrayaan 2 lunar orbiter, the Vikram lunar lander, and Pragyan lunar rover.

Chandrayaan 2 . *Credit: ISRO*

The lunar orbiter weighs 2,379 kg (5,245 lbs). It carries a terrain-mapping camera, an orbital high-resolution camera, a soft X-ray spectrometer, an IR spectrometer, a solar X-ray monitor, a synthetic aperture radar, an atmospheric compositional explorer, and dual frequency radio experiment.[31 32]

The Vikram lander carries three scientific payloads: The radio anatomy of Moon bound hypersensitive ionosphere and atmosphere (RAMBHA), which is used to measure electron density and temperatures on the Moon's surface, the Chandrayaan's surface thermo-physical experiment (ChaSTE) which will measure the temperature gradient of thermal activity of the lunar surface, and an instrument for lunar seismic activity (ILSA), a lunar seismometer.[33]

Chandrayaan 2 . *Credit: ISRO*

The six-wheeled Pragyan Rover weighs just 27 kilograms (60 lbs) and comes equipped with two payloads. An alpha particle X-ray spectrometer (APXS), and a laser induced breakdown spectroscope. Both are used for inspecting the elemental composition of the Moon's surface.[34]

India's Chandrayaan 2 spacecraft mission is intended to focus on the search for water, study lunar surface composition, and measure seismic activity to gain a better understanding of the origin and the evolution of the Moon.[35]

3.2.1.3 Exploring the Universe from L2: Spektr-RG

In 2019, Russia, in collaboration with Germany, deployed a space observatory referred to formally as the Spectrum Roentgen Gamma Space Observatory (Spektr-RG). The launch occurred on July 13, 2019, from the Russian-leased Baikonur cosmodrome located in Kazakhstan.[36]

The Spektr-RG is the second satellite in a series of three.[37] Onboard payloads include two X-ray mirror telescopes: a German eROSITA telescope and the Russian ART-XC telescope. Each nation receives data from its respective telescope.[38]

Spektr-RG's mission is to rotate in an elliptical orbit around an area known as the Lagrange point L2, which will provide the best celestial viewing area. The spacecraft will be perfectly positioned to communicate with operators on Earth, and it will also have a clear view of the Sun, the Earth, and deep space. The spacecraft successfully reached orbit in October 2019. Its main goal is to map the entire visible universe in the X-ray spectrum, conducting six-month surveys over a 6.5-years.[39 40]

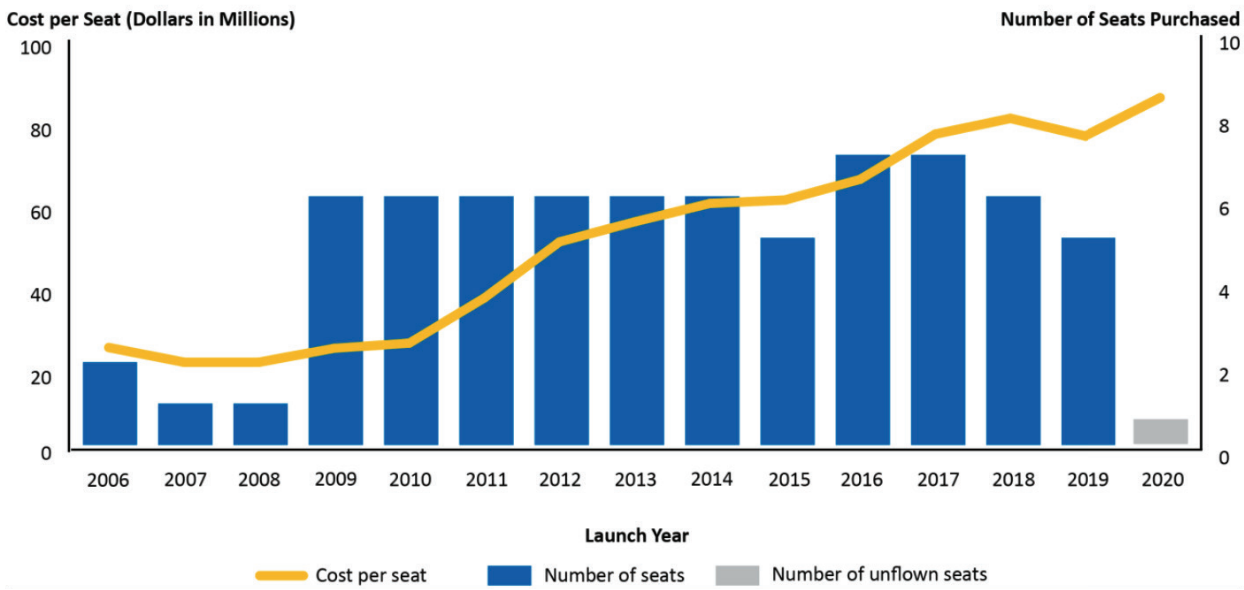
Scientists anticipate using the data received from eROSITA and ART-XC to gain a better understanding of massive black holes at the center of forming superclusters — stars in various stages of their lifecycles — and the different forms of dark matter, dark energy, and their effects.

Matt Christine is a data analyst for Space Foundation.
Senior Data Analyst Becki Yukman contributed to this report.

3.3 SNAPSHOT: Russian and U.S. Human Spaceflight Cooperation

Since 2006, NASA has paid the Russian government approximately $3.9 billion to purchase Soyuz seats for astronauts from the United States and the International Space Station's other international partners, according to a 2019 report by NASA's Office of Inspector General. As a contingency to U.S. human spacecraft launches, NASA in May announced it would pay more than $90 million for a seat on the Soyuz this fall. A look at some related numbers:

EXHIBIT 3s. Cost per Soyuz Seat by Launch Date



Source: NASA Office of Inspector General (OIG) analysis of Agency-provided contract information.

EXHIBIT 3t. Tentative ISS Crew Vehicle Flights and Crewmember Allocation

	2019					2020												2021												
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Flight Schedule																													
Soyuz-1	58S		61S												63S												65S		
Soyuz-2	59S								62S												64S								
Boeing						Test Flight											Crew-2						Crew-3						
SpaceX											Crew-1						Crew-2						Crew-3						
Crewmember Allocation																													
USOS	4	4	4	4	4	7	5	5	4	4	8[a]	5[a]	5[a]	5[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]	4[a]
Roscosmos	2	2	2	2	2	2	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total crew on ISS	6	6	6	6	6	9	6	6	6	6	10	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Source: NASA OIG summary of ISS Flight Plan from September 24, 2019. Per management officials, this schedule is under Agency review and subject to change.
Note: The Soyuz lines indicate expedition designations. Red cells indicate crewed scenarios that pose a risk to ISS operations because of reduced crew, yellow cells indicate nominal operations, and green cells indicate optimal conditions based on the current capacity of the ISS.
[a] Current space agency discussion will allocate a fourth seat aboard U.S. commercial vehicle flights to a USOS or Roscosmos crew member. Russian seats would be by barter system.

3.4 SNAPSHOT: 2020 Launch Activity

Despite a global pandemic, launches for the first half of 2020 were on par with previous years. The 41 successful launches just slightly below the average number of successful launches over the past five years, at 43.2.

EXHIBIT 3u. Launches in First Half of 2020

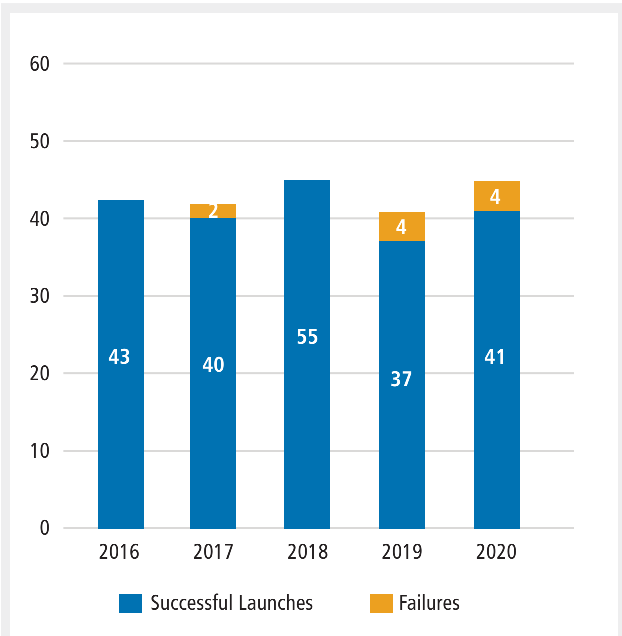
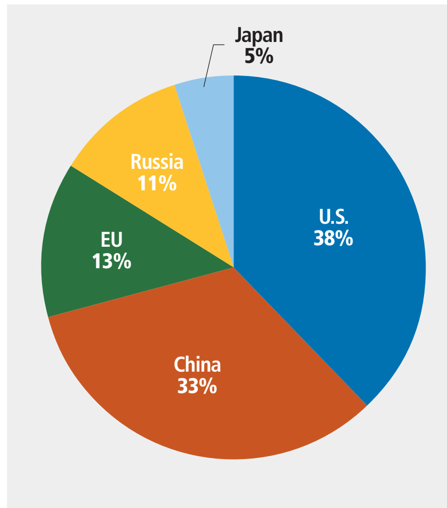
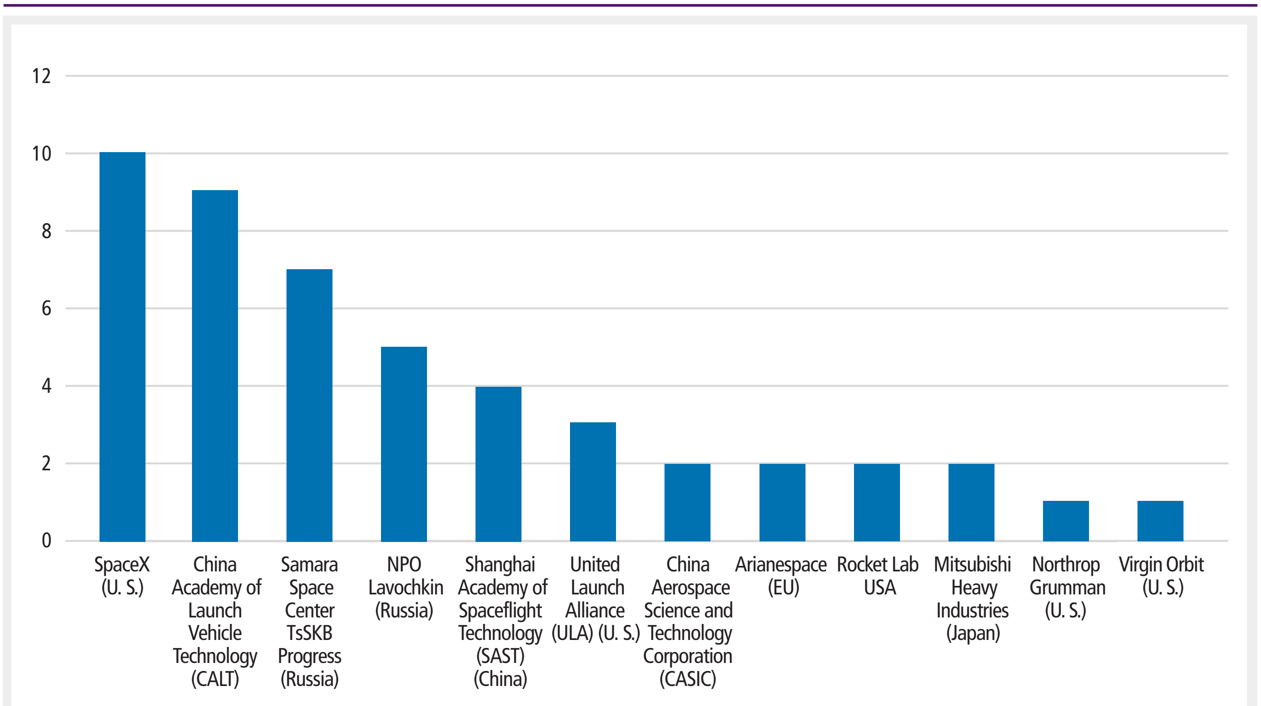


EXHIBIT 3v. 2020 1H Launches by Country

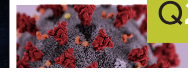


Source: JAXA

EXHIBIT 3w. 2020 1H Launches by Manufacturer



All exhibits from Space Foundation Database



3.5 Q&A: Anti-Satellite Tests and the Global, Commercial Ramifications

On April 15, Russia conducted a non-contact anti-satellite test, joining India, China, and the United States in developing and testing such a capability. To gain better insight about this emerging global issue, *The Space Report* reached out to the Colorado Springs-based Space ISAC, the only all-threats security information source for the public and private space sectors.

Two Space ISAC members, Dr. Michael P. Gleason and Dr. Michael Ryschkewitsch, shared thoughts on what the April test means for the larger space community, the steps nations should take, and the options manufacturers and operators have in hardening and protecting satellites.

Dr. Gleason is the national security senior project engineer with Aerospace Corporation's Center Space for Policy and Strategy and has 30+ years in space operations and policy.

Dr. Ryschkewitsch is the space exploration sector head at the The Applied Physics Laboratory. He formerly served as the Chief Engineer NASA.

From the recent Russian ASAT Test and others what can we consider "lessons learned" about the threat to the space sector?

Michael Gleason: The Russian test highlights yet again that space is an increasingly contested domain, a warfighting domain per se, and we should not be surprised if conflict extends into space. Whether directly targeted or not, the threat to all space actors comes from the space debris generated by kinetic kill ASATS like the Russian Nudol ASAT.

Michael Ryschkewitsch: The Chinese test of 2007 was a wake-up call. Many people first became aware of the possibility of hostilities in space against space assets, and they also quickly understood the universal hazard and expense to all operators from the resultant long-lasting debris and avoidance maneuvers. The good news was that the international outcry was intense, and since that time all nations with this capability have used them in a way to not create debris. The lesson learned: The voice of the community can have a positive effect.

What is the future of ASAT technology and the implications for space warfare? Do you think the commercial sector needs to anticipate ASATs as commonly available weapons?

MG: Trends point to more, increasingly capable terrestrially based ASATs such as the Nudol, and ever more threats from co-orbital weapons including space-based kinetic weapons, jammers, high-powered microwaves, and perhaps lasers someday. In the last dozen years, China, Russia, India, and the United States have demonstrated the ability to destroy satellites kinetically with ASATs. The commercial space sector should not assume conflict will not extend into space. Commercial satellite owners could help reduce the threat by helping to establish norms of responsible behavior in space. Intelsat set the example in 2015 when the president of Intelsat General publicly called out Russian behavior as "irresponsible" regarding the close approach of Russia's Luch satellite to an Intelsat commercial satellite. Commercial satellite owners could also help the government attribute malicious behavior by sharing data they may possess on any interference they encounter.

Do you think any new policies/modified policies need to be in place to protect satellite owners from ASATs or reduce the threat?

MR: While more nations may choose to develop this capability, it is not clear what the real potential use is beyond a last-ditch effort in dire straits. While it is possible to destroy an adversary's satellite and perhaps "level" some playing field, the aftermath threatens everyone's space assets, including those of the user of the weapon. This is a classic case where the capability is more valuable as a deterrent than in actual use. There are international agreements codifying measures to avoid creating more

debris and in a perfect world would serve as a starting point for agreements to limit the use of ASAT capabilities.
From your perspective, what options do satellite owners have in preventing these types of attacks on their systems?

MG: Satellite owners should make their satellites difficult to attack and, in that way, deter attacks from the start. Satellite owners should use encrypted command and control uplinks/downlinks as a first level of defense against malicious attacks. Have counters to jamming. Harden against high-powered microwaves. Maneuverability helps. The more satellites are hardened, the better they will prevent an attack in the first place. Soft targets will attract more attacks.

MR: Nation-state operators are likely to have ready information and capability to protect their systems against the initial attack, and warnings may be extensible to others via entities such as the Space ISAC. Beyond the initial event however, everyone will be adversely affected by the risk of loss and the need to analyze more and maneuver more often. Understanding best practices and better tools and techniques may reduce the impact, but the only way to stop it is by international agreement. There are similarities to the maritime laws and agreements that may serve as examples for the space community. A real question will be how and by whom will these be enforced. Again, there are examples in the maritime domain, but the extension to space won't be easy.

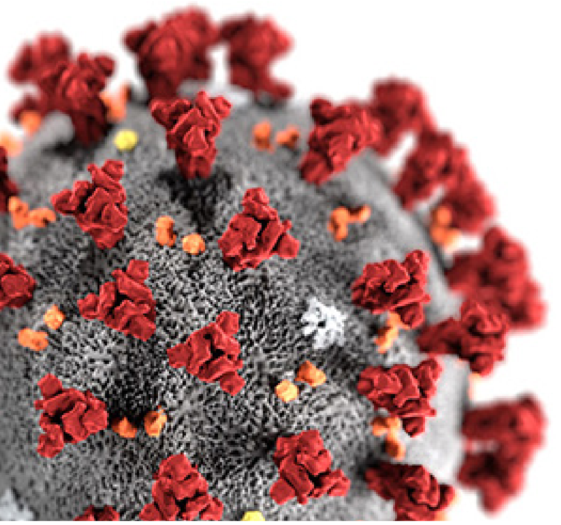
What else should satellite owners contemplate regarding cyber or non-cyber security threats while promoting a culture of security?

MG: Good communication among stakeholders is a prerequisite because it facilitates trust and increases cooperation. Complete, accurate, and timely information sharing among stakeholders is crucial for identifying and countering threats. Establishing means to communicate rapidly among stakeholders and share information is a priority.

How does the Space ISAC help with information sharing to promote awareness within the space sector of these non-cyberattacks?

MG: Space ISAC conferences, seminars, and other events and mechanisms facilitate cooperation and the development of trust among stakeholders, which is a prerequisite for effectively preparing to counter emerging threats. Sharing information on sensitive, proprietary information such as satellite anomalies (which could be caused by an attack), and/or satellite maneuvers (to avoid a threat), and so forth requires trust and confidence in each other.

MR: The Space ISAC can help in several ways. Timely sharing of information can help tactically in adapting operations and sharing useful practices and experiences. It may be even more important to facilitate community discussion and the combining of voices to speak out against dangerous actions and seek constructive change. As an organization with members from multiple nations and with global equities, Space ISAC is a natural forum for beginning these discussions.



4.0 Introduction | *Alongside the monumental achievements in space history have also come great crises. Indeed, with the risks inherent in space travel, it could be said that things not always going as planned is part and parcel of the industry. The silver lining is that space workers are also well known for quick and decisive actions when things do go off course. Perhaps it's no surprise then, that the companies mentioned here have been swift and deliberate in their response to the coronavirus.*

This illustration, created at the Centers for Disease Control and Prevention (CDC), reveals ultrastructural morphology exhibited by coronaviruses.
Credit: CDC/Alissa Eckert, MS; Dan Higgins, MAMS

EXHIBIT 4a. Topics Covered in Space Products & Innovation

4.0 Introduction
4.1 Space Companies Tap Innovation, Resourcefulness to Support Coronavirus Relief Efforts
4.1.1 Testing and Diagnostics
4.1.2 Ventilators
4.1.3 Satellites and Geospatial Data
4.1.4 Personal Protective Equipment (PPE)
4.1.5 Internet Connectivity and Data Services
4.1.6 Community and Business Support
4.2 Hurricane Tracking and Earth Observation Data
4.2.0 Introduction
4.2.1 Earth Observation at NASA
4.2.1.1 Global Precipitation Measurement
4.2.1.2 Future Applications
4.2.2 Earth Observation at NOAA
4.2.2.1 National Weather Service
4.2.2.2 Future Applications
4.2.3 Conclusion

4.1 Space Companies Tap Innovation, Resourcefulness to Support Coronavirus Relief Efforts

4.1.1 Testing and Diagnostics

Immediate concerns when the pandemic began centered on shortages of testing kits and limited information about how the virus spreads. On March 26, Jeff Bezos, founder of aerospace company Blue Origin, spoke with the World Health Organization (WHO) director-general to exchange thoughts on how to help control the pandemic.[1] Bezos' Amazon Web Services pledged $20 million to support the development of new tools to diagnose the virus, and Bezos' Amazon Care also assisted by leveraging its infrastructure to provide logistics, deliveries, and pickups of at-home coronavirus test kits in the hard-hit Seattle area.[2]

Cobham Advanced Electronic Solutions shared that it has responded to an increased demand for its application-specific integrated circuits. These circuits aid in the rapid sequencing of coronavirus samples, which help diagnose patients. They also are used in medical devices to deliver the genomic sequence of the virus that causes the COVID-19 disease.[3]

Diazyme Laboratories, Inc., an affiliate of aerospace company General Atomics, announced that with guidance from the U.S. Food and Drug Administration (FDA) it has increased the availability of two proprietary test kits used to study the novel coronavirus.[4]

4.1.2 Ventilators

Nightmarish stories from frontline healthcare workers have recounted heartrending choices as to who receives a ventilator and who does not in situations where both patients are in critical need.[5] In response to that, SpaceX founder Elon Musk directed efforts to produce more ventilators to combat the shortage. On March 21, medical supply company Medtronic shared that it had partnered with SpaceX to discuss solutions,[6] and in an April 4 follow up, Medtronic confirmed SpaceX would ramp up production of solenoid valves for Medtronic's ventilators.[7]

Richard Branson's Virgin Orbit launch firm partnered with the Bridge Ventilator Consortium.[8] On April 6, the company announced the two were aspiring to hit a production rate of 100 units per week. Bridge projected at that time that production would double within a week, and then double again in subsequent weeks.[9]

VITAL (Ventilator Intervention Technology Accessible Locally) is a new high-pressure ventilator developed by NASA and tailored to treat coronavirus (COVID-19) patients. *Credit: NASA/JPL-Caltech*

NASA also joined the effort to produce more ventilators, with its Jet Propulsion Laboratory (JPL) producing a prototype from initial design to field test within 37 days.[10] The device passed a critical test on April 21 at the Icahn School of Medicine at Mount Sinai, New York, and FDA approval followed on April 30. An update from NASA on May 29 disclosed that after receiving more than 100 applications, JPL had selected eight U.S. manufacturers to produce the ventilator.[11]

The United Kingdom also assembled a consortium of manufacturers under the name VentilatorChallengeUK.[12] Among the 27 participating companies are British aerospace company BAE Systems and multinational European aerospace company Airbus. A March 30 media release stated the combined support of this collaboration would allow for a rapid increase in production from hundreds of units per month to thousands per month, toward ultimately fulfilling its 10,000-unit goal.[13] Also in March, with the launch of rockets on hold, the Indian Space Research Organisation (ISRO) reportedly began developing its own simple-to-operate ventilator to meet the country's urgent demand in treating COVID-19 patients.[14]

An April 4, 2020 satellite image from remote sensing company Planet shows the sudden appearance of a coronavirus testing facility in New York City's Central Park, indicative of the medical response there.
Credit: Photo courtesy of Planet

4.1.3 Satellites and Geospatial Data

It may seem paradoxical that beyond closely analyzing the coronavirus microbe in labs, its effects on humanity are being observed from much farther away — specifically, from low Earth orbit. Discussion in an April 29 webinar hosted by Space Foundation and CompTIA Space Enterprise Council largely revolved around the use of geospatial data provided by satellites in monitoring the effects of the pandemic.[15] Remote sensing company Planet, which is providing satellite imagery to the United Nations, gave several examples of how these pictures can show geographical changes indicative of the progression of a disease.

Maxar Technologies is also providing satellite imagery to support the Centers for Disease Control (CDC), the Federal Emergency Management Agency (FEMA), and the Department of Homeland Security (DHS) in the U.S., as well as the WHO's global efforts. About 1 billion of Earth's citizens live in unmapped areas, complicating the delivery of aid to people in those regions. To assist in this dilemma, Maxar also donates imagery to the nonprofit organization Humanitarian OpenStreetMap, staffed by volunteers who map these areas, allowing responders to identify routes for transporting food and medicine, and facilitating the delivery of aid.[16]

The pandemic has raised concerns about the strength of the world's food supplies, triggering an immediate interest in monitoring the threat that various lockdowns and restrictions pose to food supply chains and logistics. Representatives of the Microsoft Azure Space service are taking images and data from various partners and converting them into actionable models that allow users to perform predictive analytics. In Azure's collaboration with the U.S. National Guard (Project SALUS), its querying systems can be used to overlay a map of the U.S. with data linked to regional supplies of beef, bread, milk, or eggs. These maps then identify areas where there may be shortages — or surpluses that could remedy shortages elsewhere.[17]

NASA's Earth Sciences division reached out to its employees for suggestions on how the agency could redirect its existing products and efforts to address the advancing pandemic,[18] offering a one-time allocation of roughly $2 million to fund such efforts. In a similar move, the European Space Agency (ESA) announced it was seeking proposals for its "Space in Response to COVID-19 Outbreak in Italy" by asking how affiliates could use communications, navigation, and Earth observation assets to support healthcare and research efforts in the hard-hit country. ESA offered the selected companies access to €2.5 million in funding.[19]

The TROPOMI (Tropospheric Monitoring Instrument) aboard the Sentinel-5P Copernicus satellite has observed such atmospheric changes for ESA. The instrument is the most accurate in capturing measurements of nitrogen dioxide as well as other particulates and industrial gases from space, and it has recorded decreases of up to 30% in fine particulate pollution over China[20] and Italy[21] during pandemic lockdown phases.

4.1.4 Personal Protective Equipment (PPE)

Another ongoing struggle in the global battle against coronavirus has been the shortage of PPE available to protect frontline workers from infection. In January, before the pandemic had even reached the U.S., Boeing announced a donation of 250,000 medical-grade respiratory masks to address shortages in China, which were provided to health officials in Wuhan City, Hubei Province, and Zhoushan, Zhejiang Province.[22]

On April 14, after the virus arrived in the U.S., it was reported that Boeing had produced the first reusable 3D-printed face shields with the intention of donating them to healthcare professionals.[23] The company stated it was set to produce thousands more units per week and planned to gradually increase future output. By that time, the company had already donated tens of thousands of units of PPE, including face masks, goggles, gloves, safety glasses, and protective bodysuits to support healthcare workers in the hardest-hit locations in the U.S.[24] Additionally, Boeing offered the use of its airlift capabilities, including one of its largest cargo carriers — the Boeing Dreamlifter — to help transport needed supplies. On April 26, the aircraft flew its first mission to deliver 1.5 million medical facemasks from Hong Kong to Charleston, South Carolina.[25]

SpaceX also produced face shields and hand sanitizer to donate to hospitals.[26] Additionally, SpaceX founder Elon Musk donated 50,000 N95 surgical masks and various protective items to an undisclosed hospital in the U.S. and had promised to donate 250,000 masks of a similar protection level from his companies to other hospitals.[27]

On March 30, United Technologies CEO Gregory Hayes announced the company had delivered 90,000 pieces of PPE to FEMA that week, and in the following week planned to deliver another million pieces. United was also beginning to produce face shields with the expected output of 10,000 units within the following month.[28]

United Launch Alliance (ULA) also supported pandemic relief efforts.[29] Company President and CEO Tory Bruno tweeted a video of his home 3D printers producing ventilator manifolds and face shields using files generated by Makers Unite, a group assembled to encourage people with 3D printers to use them to supply critically needed medical equipment.[30]

Blue Origin has also been credited with manufacturing 3D-printed face shield components to help combat the crisis.[31] Meanwhile, Lockheed Martin began limited production of personal protective equipment and face shields and offered engineering support for initiatives to accelerate outside PPE production.[32] A May 29 update from Lockheed Martin stated that, to date, across the U.S., it had produced more than 59,000 protective gowns and 29,000 face shields, and had also donated the PPE to more than 125 locations where frontline medical workers were caring for COVID-19 patients and other at-risk individuals.[33]

4.1.5 Internet Connectivity and Data Services

The rising use of online services for telehealth, teleconferencing, working from home, education, financial transactions, and myriad other purposes amidst the pandemic underscored the need for uninterrupted and widespread access to high-speed internet service. Global satellite communications company Viasat announced March 16 it was participating in the FCC's "Keep Americans Connected Initiative," pledging that for the following 60 days it would: not terminate service to any customers due to an inability to pay bills because of pandemic-related disruptions, waive any late fees customers incurred because of economic circumstances related to the pandemic, and would open its Wi-Fi hotspots to all Americans to keep people connected during the crisis.[34]

In the April 29 Space Foundation webinar, Mike Lubin, Viasat vice president for corporate development, also outlined the company's efforts to expand affordable internet connectivity to nations and regions that have very little, thereby granting more widespread access to the suddenly critical aforementioned services.[35]

On March 23, The White House Office of Science and Technology Policy announced the COVID-19 High Performance Computing Consortium to study the coronavirus and develop treatments and vaccines.[36] This collaboration includes NASA as well as the National Science Foundation, Department of Energy, and other companies and universities. To assist in these efforts, NASA is providing access to its supercomputers at the Ames Research Center.

In May, NASA also announced a hackathon to focus global programming ingenuity on combating the pandemic.[37] This special edition of the annual Space Apps Challenge is a global collaboration focused on mitigating the spread of the virus. Unlike previous years, this year's campaign is being rolled out as a NASA-led partnership with space agencies from around the globe, including the Canadian Space Agency (CSA), French Space Agency (CNES), Japanese Space Agency (JAXA), and ESA. The projects cover a variety of pertinent topics, including air purification, monitoring the environmental effects of the pandemic, identifying environmental factors responsible for outbreaks, and developing solutions to address social isolation.

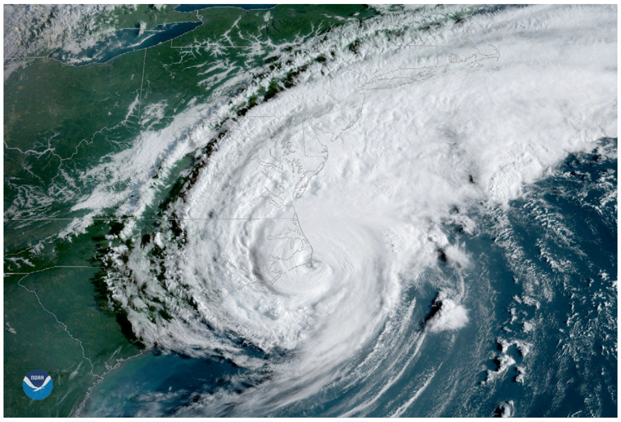
4.1.6 Community and Business Support

Another adverse effect of the pandemic has been the severe blow it has dealt to the global economy. In a May 29 statement, Lockheed Martin disclosed it had accelerated more than $300 million in funds that week, with a focus on small businesses and suppliers at risk due to the pandemic. Lockheed also mentioned it had awarded a $400,000 grant to the Parkland Hospital Foundation in Dallas that week, part of its ongoing charitable contributions of $5 million to state and local organizations that support communities in which Lockheed Martin operates.[38]

Likewise, on April 21, the Aerojet Rocketdyne Foundation announced a campaign to provide up to $750,000 to support COVID-19 relief efforts in communities where company facilities are located. The campaign included direct donations totaling $250,000 to COVID-19 relief efforts in communities across the nation, and an employee matching program that pledged to match up to $250,000 in employee donations to nonprofits supporting COVID-19 relief efforts as directed by contributing employees.[39]

Since its inception, the space industry has surprised mankind time and time again by achieving what was once considered the impossible, demonstrating that perseverance and logistics can conquer almost any seemingly insurmountable challenge. The examples highlighted here prove how companies vital to today's space exploration are also vital to the survival of Earth's citizens — and provide more reminders of how often space technologies and applications find their way back to benefit our collective well-being here on Earth.

Andrew de Naray is a multimedia content writer and editor for Space Foundation.



Hurricane Dorian as seen from the International Space Station.
Credit: NASA

4.2 Hurricane Tracking and Earth Observation Data

4.2.0 Introduction

The United States was impacted by 14 natural disasters that each caused over a billion dollars in damage in 2019.[1] Fortunately, scientists are using a multitude of resources to learn more about severe weather, including remote sensing satellites that monitor the Earth from space.[2] Information from these satellites becomes especially important during hurricane season when wind, rain, and the potential for flooding endanger life and property.[1] Last year, satellite imagery taken before and after Hurricane Dorian made its U.S. landfall at Cape Hatteras, North Carolina, allowed the Federal Emergency Management Agency (FEMA) to identify the areas most affected by the storm and to coordinate a rapid response with state and local officials. Evacuation orders were issued for counties across the Southeast.[3] Assistance-based organizations such as the American Red Cross assembled nearly 200 emergency shelters for residents in those areas to wait out the storm in safety.[4] Florida Gov. Ron DeSantis mobilized 4,500 members of the National Guard as meteorologists predicted the storm would be particularly destructive in that state.[5] The remote sensing satellite programs that aided these responsive actions are often collaborative efforts between government agencies and countries.[6] These instruments collect a range of data that help scientists evaluate Earth's weather systems and prepare for natural disasters in real time.[7]

4.2.1 Earth Observation at NASA

NASA's Earth Observing System (EOS) is made up of a series of remote sensing satellites that have been monitoring Earth's environmental systems for decades.[8] As part of the Earth Science Division of NASA's Science Mission Directorate, EOS gathers information on different aspects of the planet's weather and climate systems. Multiple current and completed satellite missions have collected data on precipitation, water vapor, clouds, radiation, the oceans, and more.

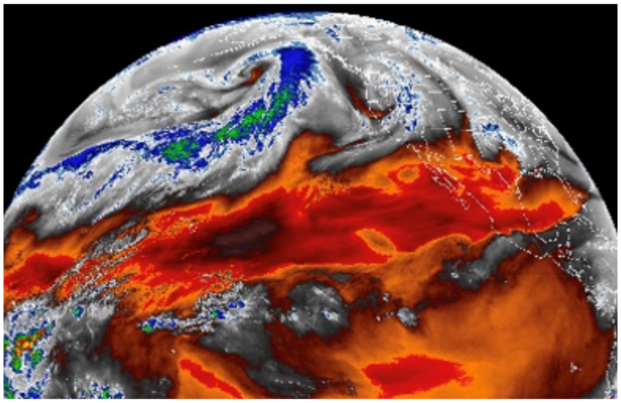
GPM Core Observatory produced the first nearly global observations of rainfall and snowfall. *Credit: NASA*

4.2.1.1 Global Precipitation Measurement

One program that monitors the Earth's weather systems is the Global Precipitation Measurement (GPM) mission. This is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) that launched in 2014.[6] The GPM program encompasses a constellation of satellites led by the GPM Core Observatory, which obtains information on the state, distribution, and movement of water throughout the Earth's atmosphere.[9] According to Dr. Dalia Kirschbaum, GPM's Deputy Project Scientist for Applications and Disaster Coordinator, the information gathered from these satellites provide an unprecedented measure of global rain and snowfall.[6]

These measurements can be used for weather forecasting and the prediction and analysis of natural disasters. Satellites offer a considerable advantage over Earth-based equipment as they can provide more frequent and reliable measurements that cover more of the planet's surface area.[9] Ground-based methods are limited and have a difficult time obtaining information from bodies of water. The GPM mission, however, is able to remotely gather data on the type and amount of precipitation, the movement of weather systems, and can even generate three-dimensional structures of storms.[6] Information collected on precipitation and wind structure, ocean surface temperature, and land surface moisture can be assimilated into models to improve forecasting. Results generated from these models help community leaders and emergency management coordinators make decisions on evacuation orders and resource mobilization before a storm even makes landfall.[9] Environmental data can be acquired and sent to weather forecasters in as little as 15 minutes.[6]

While the number of applications for Earth observation data is growing, there are potential issues regarding usage. Managing large amounts of data and obtaining results from models can be difficult due to the use of different formats.[10] This process can be time-consuming, costly, and often requires special training.[11] NASA has made an effort to expand the use of its observational data in several ways, Kirschbaum said.[6] Much of this information is considered open source data and is available to the public at no charge. The agency also offers training programs on data usage, such as Applied Remote Sensing Training (ARSET). This program teaches participants how to acquire and use remote sensing data for decision-making.[12]



GPM Core Observatory produced the first nearly global observations of rainfall and snowfall. *Credit: NASA*

4.2.1.2 Future Applications

The increased use of environmental data shows the importance and benefits of Earth observation science. The potential for future applications in this field seems almost limitless. Kirschbaum and others at NASA are working on an upcoming remote sensing program called Aerosol and Cloud, Convection and Precipitation (ACCP).[6] These next-generation satellites will measure climate variability and change as well as weather and air quality.[13] Information gathered will be added to the long-running record of Earth observation data and will be used to further improve forecasting and environmental modeling.

4.2.2 Earth Observation at NOAA

Monitoring our home planet is also important to the National Oceanic and Atmospheric Administration (NOAA) as the agency seeks to understand and predict changes in the Earth's systems and share that knowledge with others.[14] NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) gathers data on environmental systems from satellites and other resources.[15] That information is used to analyze weather systems around the world and evaluate the scale of natural disasters after they occur.

4.2.2.1 National Weather Service

The National Weather Service (NWS) operates as part of NOAA[16] and uses satellite information to directly deliver data on environmental systems to the public and community decision makers and to issue forecasts and warnings about severe weather.[17] Dr. Jordan Gerth, a meteorologist at the NWS Office of Observations, specified that information from remote sensing satellites improves the accuracy of weather prediction worldwide.[18] Measurements from NOAA satellite imagery offer insights into land and sea conditions, cloud distribution, moisture levels, temperature, and wind and speed direction. This data can be entered into models and used to evaluate the development, movement, and intensity of storms.

The greatest strength of these satellite observations, Gerth said, is that they provide widespread coverage of the planet's systems, which allows for frequent imaging.[18] While it is difficult to take measurements of oceans and remote lands from Earth, satellites are able to deliver important information about changes in conditions from across the globe. These images, which are taken frequently over the course of 24 hours, improve weather forecasting and predictions. Some geostationary satellites, which continuously monitor the same section of the planet, are capable of taking images of storms every 30 seconds. Geostationary Operational Environmental Satellites (GOES) are part of a joint program between NOAA and NASA that continually monitors the Western Hemisphere.[19] This group of satellites is responsible for monitoring and tracking storms, providing more lead time to prepare for a storm's landfall.

4.2.2.2 Future Applications

While the latest series of geostationary satellites, GOES-R, is operational through the year 2036,[20] Gerth and others at NOAA are evaluating options for future satellites that will allow them to continue their observations for the next 20 years.[18] They are assessing new instruments and considering the use of smaller constellation satellites. This presents a possible opportunity to obtain weather data from commercial satellite partners. As part of this evaluation, NOAA is also connecting with people on the front lines. The agency is researching and discovering ways to improve the acquisition and use of satellite imagery to deliver the information needed by meteorologists, emergency responders, and industry officials.

4.2.3 Conclusion

While many people may never consider the source of their local weather forecast, data obtained from remote sensing satellites provide vital information used to track and analyze Earth's environmental systems. The importance and value of Earth observation data prove that activities in space are not only about exploring other worlds. They also help us to safeguard life on our planet.

Tara Larson is a graduate of the University of Colorado with a master's degree in public administration with emphasis on the space industry. She is a research consultant for Space Foundation.

SPACE FOUNDATION

Thomas Dorame
Vice President,
Washington Strategic Operations

RESEARCH & ANALYSIS

Lesley Conn
Senior Manager

Becki Yukman
Senior Data Analyst

Matt Christine
Data Analyst

CONTRIBUTORS

SPACE INVESTMENT SERVICES

Micah Walter-Range
Director of Research
Space Investment Services LLC

Dr. Mariel Borowitz
Assistant Professor
Sam Nunn School of
International Affairs,
Georgia Institute of Technology

Andrew de Naray
Multimedia content writer
and editor
Space Foundation

Phuong Tengco
Researcher

Tara Larson
Research consultant

Steve Edelman
Editor

QUILTY analytics

Chris Quilty
Founder and Partner
Quilty Analytics

Justin Cadman
Partner
Quilty Analytics

SPACE ISAC

Design Development Team

ROMIE LUCAS
graphic design & illustration

Section 1 | The Space Economy

1.0 The 2019 Global Space Economy

1 "NASA Statement on National Space Council Policy for Future American Leadership in Space." NASA Oct. 5, 2017. https://www.nasa.gov/press-release/nasa-statement-on-national-space-council-policy-for-future-american-leadership-in. Accessed June 25, 2020.

2 "New Space Policy Directive Calls for Human Expansion Across Solar System." NASA. Dec. 11, 2017. https://www.nasa.gov/press-release/new-space-policy-directive-calls-for-human-expansion-across-solar-system. Accessed June 25, 2020.

3 "President Donald J. Trump is Unveiling an America First National Space Strategy". The White House. March 23, 2018. https://www.whitehouse.gov/briefings-statements/president-donald-j-trump-unveiling-america-first-national-space-strategy/. Accessed June 25, 2020.

4 "Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space." The White House. May 24, 2018. https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/. Accessed June 25, 2020.

5 "Space Policy Directive-3, National Space Traffic Management Policy." The White House. June 18, 2018. https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/. Accessed June 25, 2020.

6 "Text of Space Policy Directive-4: Establishment of the United States Space Force." The White House. Feb. 19, 2019. https://www.whitehouse.gov/presidential-actions/text-space-policy-directive-4-establishment-united-states-space-force/. Accessed June 25, 2020.

7 "Office of The Under Secretary of Defense (Comptroller)/Chief Financial Officer." Department of Defense. Feb. 2020. https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/fy2021_Budget_Request_Overview_Book.pdf. Accessed July 15, 2020

8 "Aeronautics and Space Report of the President Fiscal Year 2018 Activities." The United States Government. https://history.nasa.gov/presrep2018.pdf, page 224. Accessed July 14, 2020.

9 "Defense Budget Materials - FY2021." Under Secretary of Defense. Feb. 2020. https://comptroller.defense.gov/Budget-Materials/. Accessed June 8, 2020.

10 "Defense Budget Materials - FY2021." Under Secretary of Defense. Feb. 2020. https://comptroller.defense.gov/Budget-Materials/. Accessed June 8, 2020.

11 Insinna, Valerie. "Here's how much money the Defense Department wants for its trio of new space organizations." March 12, 2019. https://www.defensenews.com/smr/federal-budget/2019/03/12/heres-how-much-money-the-defense-department-wants-for-its-trio-of-new-space-organizations/. Accessed July 15, 2020.

12 "FY2020 National Security Space Budget Request: An Overview." Congressional Research Service. June 7, 2019. https://www.hsdl.org/?view&did=826128. Accessed July 15, 2020.

13 "DOD Releases Fiscal Year 2021 Budget Proposal." Department of Defense. Feb. 10, 2020. https://www.defense.gov/Newsroom/Releases/Release/Article/2079489/dod-releases-fiscal-year-2021-budget-proposal/. Accessed July 15, 2020.

14 "FY 2021 Budget Estimates." National Aeronautics and Space Administration. Feb. 10, 2020. https://www.nasa.gov/sites/default/files/atoms/files/fy2021_summary_budget_brief.pdf, page 12. Accessed June 4, 2020.

15 "Aeronautics and Space Report of the President Fiscal Year 2018 Activities." The United States Government. https://history.nasa.gov/presrep2018.pdf, page 224. Accessed June 5, 2020.

16 Dreier, Casey. "NASA just got its best budget in a decade." Feb. 15, 2020. https://www.planetary.org/blogs/casey-dreier/2019/0215-fy2019-nasa-gets-its-best-budget-in-decades.html. Accessed June 25, 20203

17 "Science Programs." NASA Science. https://science.nasa.gov/technology/science-programs. Accessed June 25, 2020.

18 "Explore FY2020 Budget Estimates Briefing Book." NASA. https://www.nasa.gov/sites/default/files/atoms/files/fy2020_summary_budget_brief.pdf. Accessed June 25, 2020.

19 "FY 2021 Budget Estimates." NASA. Feb. 10, 2020. https://www.nasa.gov/sites/default/files/atoms/files/fy2021_summary_budget_brief.pdf, page 12. Accessed June 4, 2020.

20 "FY 2021 Budget Estimates." NASA. Feb. 10, 2020. https://www.nasa.gov/sites/default/files/atoms/files/fy2021_summary_budget_brief.pdf, page 12. Accessed June 4, 2020.

21 "Explore FY2020 Budget Estimates Briefing Book." NASA. https://www.nasa.gov/sites/default/files/atoms/files/fy2020_summary_budget_brief.pdf. Accessed June 25, 2020.

22 "Explore FY2020 Budget Estimates Briefing Book." NASA. https://www.nasa.gov/sites/default/files/atoms/files/fy2020_summary_budget_brief.pdf. Accessed June 25, 2020.

23 "What's Next for NASA?" NASA. January 2, 2020. https://www.nasa.gov/about/whats_next.html. Accessed June 25, 2020.

24 "SpaceX successfully launches Nasa astronauts into orbit." The Guardian. May 30, 2020. https://www.theguardian.com/science/2020/may/30/spacex-nasa-crewed-spaceflight-launch-dragon-capsule-elon-musk-trump. Accessed June 25, 2020.

25 Cawley, James. "Mars Perseverance Rover Targeted to Launch July 20." NASA. June 10, 2020. https://blogs.nasa.gov/mars2020/2020/06/10/mars-perseverance-rover-targeted-to-launch-july-20/. Accessed June 25, 2020.

26 Clark, Stephen. "Launch of NASA's Perseverance Mars rover delayed to July 22." Spaceflight Now. June 24, 2020. https://spaceflightnow.com/2020/06/24/launch-of-nasas-perseverance-mars-rover-delayed-to-july-22/. Accessed June 25, 2020.

27 "OSIRIS-REx Swoops Over Sample Site Osprey." NASA. June 3, 2020. https://www.nasa.gov/feature/goddard/2020/osiris-rex-swoops-over-sample-site-osprey. Accessed June 25, 2020.

28 "NASA's OSIRIS-REx Ready for Touchdown on Asteroid Bennu." NASA. May 20, 2020. https://www.nasa.gov/feature/goddard/2020/nasa-s-osiris-rex-ready-for-touchdown-on-asteroid-bennu. Accessed June 25, 2020.

29 "Moon to Mars Overview." NASA. https://www.nasa.gov/topics/moon-to-mars/overview. Accessed June 25, 2020.

30 "'Green Run' Test Will Pave the Way for Successful NASA Moon Missions." NASA. July 25, 2019. https://www.nasa.gov/exploration/systems/sls/green-run-test-paves-way-for-nasa-moon-missions.html. Accessed June 25, 2020.

31 Foust, Jeff. "NASA offers mixed messages on future budgets." Space News. June 4, 2019. https://spacenews.com/nasa-offers-mixed-messages-on-future-budgets/. Accessed June 25, 2020.

32 "FY 2021 President's Budget Request Summary". NASA. March 11, 2020. https://www.nasa.gov/sites/default/files/atoms/files/fy2021_congressional_justification.pdf. Accessed June 25, 2020.

33 "NOAA 2020 Budget Summary." NOAA. https://www.noaa.gov/sites/default/files/atoms/files/FY2020-BlueBook.pdf, p.98. Accessed June 1, 2020.

34 "Mission Overview." NOAA. https://www.goes-r.gov/mission/mission.html. Accessed June 26, 2020.

35 "GOES-R: NOAA's most advanced geostationary environmental satellites." NESDIS. https://www.goes-r.gov/downloads/resources/documents/tri-brochure.pdf. Accessed June 26, 2020.

36 "What is Jason-3?" NOAA. September 17, 2018. https://www.nesdis.noaa.gov/jason-3/mission.html. Accessed June 26, 2020.

37 Leslie, John. "DSCOVR: Deep Space Climate Observatory." https://www.nesdis.noaa.gov/content/dscovr-deep-space-climate-observatory. Accessed June 26, 2020.

38 "Mission." Office of Space Commerce. https://www.space.commerce.gov/about/mission/. Accessed June 26, 2020.

39 "NOAA 2020 Budget Summary." NOAA. https://www.noaa.gov/sites/default/files/atoms/files/FY2020-BlueBook.pdf, p.98. Accessed June 1, 2020.

40 "About." NCEI. https://www.ncei.noaa.gov/about. Accessed June 26, 2020.

41 "Final FY19 Appropriations: National Oceanic and Atmospheric Administration." American Institute of Physics. February 27, 2019. https://www.aip.org/fyi/2019/final-fy19-appropriations-national-oceanic-and-atmospheric-administration. Accessed June 26, 2020.

42 "After 14 Years, COSMIC/FORMOSAT-3 Ends Service." NOAA. May 1, 2020. https://www.nesdis.noaa.gov/content/after-14-years-cosmicformosat-3-ends-service. Accessed June 26, 2020.

43 "COSMIC-2 soars into orbit aboard SpaceX Falcon Heavy rocket." NOAA. June 25, 2019. https://www.noaa.gov/media-release/cosmic-2-soars-into-orbit-aboard-spacex-falcon-heavy-rocket. Accessed June 16, 2020.

44 "FY2021 BUDGET REQUEST TO CONGRESS." United States National Science Foundation. https://www.nsf.gov/pubs/2020/nsf20005/nsf20005.pdf. Accessed June 1, 2020.

45 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. December 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

46 "Statement on NSF and SpaceX Radio Spectrum Coordination Agreement." NSF. June 4, 2019. https://www.nsf.gov/news/news_summ.jsp?cntn_id=298678. Accessed June 30, 2020.

47 "Faculty Development in the Space Sciences: Program Solicitation NSF 19-558." NSF. https://www.nsf.gov/pubs/2019/nsf19558/nsf19558.htm. Accessed June 30, 2020.

48 "Next Generation Software for Data-driven Models of Space Weather with Quantified Uncertainties (SWQU)." NSF. https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505758. November 21, 2019. Accessed June 30, 2020.

49 "National Space Weather Strategy and Action Plan." The White House. March 2019. https://www.whitehouse.gov/wp-content/uploads/2019/03/National-Space-Weather-Strategy-and-Action-Plan-2019.pdf. Accessed June 30, 2020.

50 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

51 "Department of Energy FY 2021 Congressional Budget Request." Department of Energy Office of Chief Financial Officer. Feb. 2020. https://www.energy.gov/sites/prod/files/2020/02/f72/doe-fy2021-budget-in-brief_0.pdf. Accessed June 3, 2020.

52 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

53 "USDA and NASA Explore the Frontier of Agriculture." USDA New Farmers. https://newfarmers.usda.gov/usda-and-nasa-explore-frontier-agriculture. Accessed June 28, 2020.

54 "FY 2021 Budget Summary". United States Department of Agriculture. https://www.usda.gov/sites/default/files/documents/usda-fy2021-budget-summary.pdf, page 93. Accessed June 4, 2020.

55 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

56 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

57 "Fiscal Year 2021 The Interior Budget in Brief." U.S. Department of the Interior. February 2020. https://www.doi.gov/sites/doi.gov/files/uploads/2021-highlights-book.pdf, page BH-4. Accessed June 5, 2020.

58 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 28, 2020.

59 "Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space." The White House. May 24, 2018. https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/. Accessed June 29, 2020.

60 "Commercial Space Transportation Regulations." FAA. June 11, 2020. https://www.faa.gov/space/licensing_process/regulations/. Accessed June 29, 2020.

61 "FAA Rule Would Streamline Commercial Space Launch and Reentry Requirements." FAA. March 26, 2019. https://www.faa.gov/news/updates/?newsId=93306. Accessed June 29, 2020.

62 "FAA Extends Comment Period on Rulemaking to Streamline Commercial Space Activities". FAA May 31, 2019. https://www.faa.gov/news/updates/?newsId=93828&omniRss=news_updatesAoc&cid=101_N_U. Accessed June 29, 2020.

63 "Commercial Space Transportation Regulations." FAA. June 11, 2020. https://www.faa.gov/space/licensing_process/regulations/. Accessed June 29, 2020.

64 "Aeronautics and Space Report of the President: Fiscal Year 2018 Activities". NASA. Dec. 20, 2019. https://history.nasa.gov/presrep2018.pdf. Accessed June 29, 2020.

65 Smith, Marcia. "DOT Requests Big Boost for Commercial Space Transportation in FY2020." Space Policy Online. March 11, 2019. https://spacepolicyonline.com/news/dot-requests-big-boost-for-commercial-space-transportation-in-fy2020/. Accessed June 30, 2020.

66 "Budget Highlights 2020." U.S. Department of Transportation. https://www.fhwa.dot.gov/cfo/dot_bh2020_030719final.pdf. Accessed June 30, 2020.

67 Smith, Marcia. "FAA Space Office Gets Budgets Boost in House Appropriations Bill." Space Policy Online. June 24, 2019. https://spacepolicyonline.com/news/faa-space-office-gets-budget-boost-in-house-appropriations-bill/. Accessed June 30, 2020.

68 "我が国の防衛と予算: 平成３１年度予算の概要 Defense Programs and Budget of Japan." Ministry of Defense. December 2018. https://www.mod.go.jp/j/yosan/yosan_gaiyo/2019/yosan.pdf. Accessed July 9, 2020.

69 Defence Attaché Mentz, Nicolai. "French implementation of the Military Planning Law 2019-2025." Feb. 6, 2019. Orientation at DDAC 2019. https://censec.dk/wp-content/uploads/2019/02/Foredrag-om-Frankrigs-implementering-af-forsvarsliget-2019-pr%C3%A6sentation.pdf. Accessed May 12, 2020.

70 Weitering, Hanneke. "France Is Launching a 'Space Force' with Weaponized Satellites." Aug. 2, 2019. https://www.space.com/france-military-space-force.html. Accessed June 30, 2020.

71 "Bundeshaushalt 2020." Bundesministerium der Finanzen. Dec. 2019. https://www.bundeshaushalt.de/fileadmin/de.bundeshaushalt/content_de/dokumente/2020/soll/Nachtrags-HH_2020_geschuetzt.pdf, pages 32, 34, 47. Accessed May 18, 2020.

72 Budget 2019-2020: Portfolio Budget Statements 2019-20 Budget Related Paper No. 1.4A Defence Portfolio. Commonwealth of Australia. 2019. https://www.defence.gov.au/Budget/19-20/2019-20_Defence_PBS_00_Complete.pdf. Accessed June 16, 2020.

73 Portal da Transparência. Orçamento da Despesa Pública. May 8, 2020. http://www.portaltransparencia.gov.br/orcamento/despesas?paginacaoSimples=false&tamanhoPagina=&offset=&direcaoOrdenacao=asc&palavraChave=espacial&de=2019&ate=2019&colunasSelecionadas=ano%2Cfuncao%2CsubFuncao%2Cprograma%2Cacao%2CgrupoDespesa%2CelementoDespesa%2CorcamentoInicial%2CorcamentoAtualizado%2CorcamentoRealizado%2CpercentualRealizado%2CorgaoVinculado&ordenarPor=grupoDespesa&direcao=asc. Accessed May 12, 2019.

74 Ibeh, Joseph. "Nigerian president approves budget for space and Nigeria Air project." Space in Africa. May 20, 2019. https://africanews.space/nigerian-president-approves-budget-for-space-and-nigeria-air-project/. Accessed May 20, 2020.

75 "Presupuesto por programas y memoria de objetivos. Tomo IV (Sección 14)." https://www.sepg.pap.hacienda.gob.es/Presup/PGE2019Prorroga/MaestroTomos/PGE-ROM/doc/L_19P_E_G4.PDF, page 55.

76 "What is NATO?" NATO. https://www.nato.int/nato-welcome/. Accessed July 3, 2020.

77 "NATO Defence Ministers to address key security challenges." NATO. June 25, 2019. https://www.nato.int/cps/en/natohq/news_167096.htm. Accessed July 3, 2020.

78 Banks, Martin. "NATO names space as an 'operational domain,' but without plans to weaponize it." Defense News. Nov. 20, 2019. https://www.defensenews.com/smr/nato-2020-defined/2019/11/20/nato-names-space-as-an-operational-domain-but-without-plans-to-weaponize-it/. Accessed July 3, 2020.

79 Boffey, Daniel. "NATO leader identifies space as the next 'operational domain'." The Guardian. Nov. 20, 2019. https://www.theguardian.com/world/2019/nov/20/nato-identifies-space-as-next-operational-domain. Accessed July 3, 2020.

80 "Presupuesto de gastos y su ejecución detallada - agrupación anual 2019." Ministerio de Economia Argentina. May 1, 2019. https://www.presupuestoabierto.gob.ar/sici/datos-abiertos#. Accessed Feb. 4, 2020.

81 "Launch of Argentina's SAOCOM 1A satellite. The Foreign Ministry and its role in promoting the space industry." Ministry of Foreign Affairs, International Trade, and Worship Argentina. https://www.cancilleria.gob.ar/en/news/newsletter/launch-argentinas-saocom-1a-satellite-foreign-ministry-and-its-role-promoting-space. Accessed June 16, 2020.

82 Ingrassia, Victor. "New Argentine satellite: Tomorrow the Saocom 1B leaves for the US to be launched by SpaceX." Infobae. Feb. 20, 2020. https://www.infobae.com/salud/ciencia/2020/02/20/nuevo-satelite-argentino-manana-parte-a-eeuu-el-saocom-1b-para-ser-lanzado-por-spacex/. Accessed June 16, 2020.

83 Clark, Stephen. "Coronavirus concerns force postponement of SpaceX launch with Argentine satellite." Spaceflight Now. March 24, 2020. https://spaceflightnow.com/2020/03/24/coronavirus-concerns-force-postponement-of-spacex-launch-with-argentine-satellite/. Accessed June 16, 2020.

84 "Annual Report 2017-18." Innovation and Science Australia. Oct. 25, 2018. https://www.industry.gov.au/sites/default/files/2018-11/innovation-and-science-australia-annual-report-2017-18.pdf. Accessed on June 16, 2020.

85 "State of Space Report: A report by the Australian Government Space Coordination Committee, 1 January 2018 –30 June 2019." Australian Government and Australian Space Agency. May 2020. https://www.industry.gov.au/sites/default/files/2020-05/state-of-space-report-2018-19.pdf Accessed June 16, 2020.

86 "CEO statement on Budget 2018-19." Geoscience Australia. May 9, 2018. https://www.ga.gov.au/news-events/news/latest-news/ceo-statement-on-budget-2018-19. Accessed July 15, 2020.

87 "State of Space Report: A report by the Australian Government Space Coordination Committee, 1 January 2018 –30 June 2019." Australian Government and Australian Space Agency. May 2020. https://www.industry.gov.au/sites/default/files/2020-05/state-of-space-report-2018-19.pdf. Accessed June 16, 2020.

88 "Australian Space Discovery Centre." Australian Space Agency. June 11, 2020. https://www.industry.gov.au/strategies-for-the-future/australian-space-agency/australian-space-discovery-centre. Accessed June 16, 2020.

89 "State of Space Report: A report by the Australian Government Space Coordination Committee, 1 January 2018 –30 June 2019." Australian Government and Australian Space Agency. May 2020. https://www.industry.gov.au/sites/default/files/2020-05/state-of-space-report-2018-19.pdf. Accessed June 16, 2020.

90 "Budget 2019-2020: Portfolio Budget Statements 2019-20 Budget Related Paper No. 1.4A Defence Portfolio." Commonwealth of Australia. 2019. https://www.defence.gov.au/Budget/19-20/2019-20_Defence_PBS_00_Complete.pdf. Accessed June 16, 2020.

91 "Canadian space milestones." Canadian Space Agency. https://www.asc-csa.gc.ca/eng/about/milestones.asp. Accessed June 16, 2020.

92 "Canadian Space Agency 2019-20 Departmental Plan." Canadian Space Agency. 2019. https://www.asc-csa.gc.ca/eng/publications/dp-2019-2020.asp#plans. Accessed May 12, 2020.

93 "About the rovers." Canadian Space Agency. http://www.asc-csa.gc.ca/eng/rovers/about.asp. Accessed on June 16, 2020.

94 "Canada-European Space Agency Cooperation Agreement." Canadian Space Agency. Oct. 23, 2019. https://www.asc-csa.gc.ca/eng/funding-programs/canada-esa/about-cooperation-agreement.asp. Accessed June 16, 2020.

95 Eurospace. Correspondence with author. June 2020.

96 “Canada Faces Decision Point in European Space Agency Program Participation.” SpaceQ.ca. June 2020. https://spaceq.ca/canada-faces-decision-point-in-european-space-agency-program-participation/. Accessed June 16, 2020.

97 “News from the Canadian Space Industry.” Canadian Space Agency. November 28, 2019. https://www.asc-csa.gc.ca/eng/industry/news.asp. Accessed June 16, 2020.

98 “Download the entire World Economic Outlook database: October 2019.” International Monetary Fund. Oct. 2019. https://www.imf.org/external/pubs/ft/weo/2019/02/weodata/download.aspx. Accessed June 10, 2020.

99 Myers and Mou, Steven Lee and Zoe. “‘New Chapter’ in Space Exploration as China Reaches Far Side of the Moon.” The New York Times. Jan. 2, 2019. https://www.nytimes.com/2019/01/02/world/asia/china-change-4-moon.html. Accessed July 15, 2020.

100 Leonard, David. “China's Farside Moon Rover Breaks Lunar Longevity Record.” Space.com. Dec. 18, 2019. https://www.space.com/china-change-4-rover-moon-record.html. Accessed July 15, 2020.

101 Jones, Andrew. “China will attempt 30-plus launches in 2019, including crucial Long March 5 missions.” Space News. Jan. 29, 2019. https://spacenews.com/china-will-attempt-30-plus-launches-in-2019-including-crucial-long-march-5-missions/. Accessed July 15, 2020.

102 Space Foundation database.

103 Jones, Andrew. “Chinese iSpace achieves orbit with historic private sector launch.” Space News. July 25, 2019. https://spacenews.com/chinese-ispace-achieves-orbit-with-historic-private-sector-launch/. Accessed July 15, 2020.

104 Jones, Andrew. “Chinese commercial rocket Smart Dragon-1 reaches orbit with first launch.” Space News. Aug. 19, 2019. https://spacenews.com/chinese-commercial-rocket-smart-dragon-1-reaches-orbit-with-first-launch/. Accessed July 15, 2020.

105 Barbosa, Rui. C. “Maiden launch of OneSpace OS-M rocket fails.” Spaceflight Now. March 27, 2019. https://www.nasaspaceflight.com/2019/03/maiden-launch-of-onespace-os-m-rocket-fails/. Accessed July 15, 2020.

106 Jones, Andrew. “China creates commercial space alliance, expands launch complex.” Space News. Dec. 20, 2019. https://spacenews.com/china-creates-commercial-space-alliance-expands-launch-complex/. Accessed July 15, 2020.

107 “商业航天产业联盟在北京成立 打造商业航天资源聚合平台. Commercial Aerospace Industry Alliance was Established in Beijing to Build a Commercial Resource Aggregation Platform” China News Network. Dec. 11, 2019. http://www.chinanews.com/cj/2019/12-11/9031242.shtml. Accessed July 15, 2020.

108 Fei and Xiaoshu, Yu and Quan. “China's largest carrier rocket Long March-5 makes new flight.” Xinhua. Dec. 27, 2019. http://www.xinhuanet.com/english/2019-12/27/c_138662139.htm. Accessed July 15, 2020.

109 “China's Chang'e-5 will bring back lunar samples.” Asia Times. Oct. 28, 2019. https://asiatimes.com/2019/10/chinas-change-5-will-bring-back-lunar-samples/. Accessed July 16, 2020.

110 Jones, Andrew. “Here's where China is looking to land its 2020 Mars rover.” Planetary Society. Nov. 21, 2018. https://www.planetary.org/blogs/guest-blogs/china-2020-rover-sites.html. Accessed July 16, 2020.

111 “Section 3: China's Ambitions in Space: Contesting The Final Frontier” U.S.-China Economic and. Security Review Commission. https://www.uscc.gov/sites/default/files/2019-11/Chapter%204%20Section%203%20-%20China%E2%80%99s%20Ambitions%20in%20Space%20-%20Contesting%20the%20Final%20Frontier.pdf. Accessed July 16, 2020.

112 Goswami, Namrata. “China's Future Space Ambitions: What's Ahead?” The Diplomat. Nov. 4, 2019. https://thediplomat.com/2019/11/chinas-future-space-ambitions-whats-ahead/. Accessed July 16, 2020.

113 “ESA Member States, Canada and Slovenia” https://m.esa.int/Education/ESA_Member_States_Canada_and_Slovenia. Accessed on June 8, 2020.

114 Eurospace. Correspondence with author. June 2020.

115 Eurospace. Correspondence with author. June 2020.

116 “ESA, an intergovernmental customer.” ESA. Sept. 26, 2014. https://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/ESA_an_intergovernmental_customer. Accessed June 17, 2020.

117 Eurospace. Correspondence with author. June 2020.

118 “Earth observing missions: Mission navigator.” ESA. https://www.esa.int/Applications/Observing_the_Earth/Earth_observing_missions. Accessed June 17, 2020.

119 “Europe's Launchers.” ESA. https://m.esa.int/Our_Activities/Space_Transportation/Launch_vehicles/Europe_s_launchers. May 10, 2017. Accessed on June 17, 2020.

120 “What Is Galileo?” ESA. https://m.esa.int/Our_Activities/Navigation/Galileo/What_is_Galileo. Nov. 2, 2017. Accessed on June 17, 2020.

121 “Science Programme.” ESA. Nov. 11, 2014. https://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/Science_Programme. Accessed June 18, 2020.

122 “Future activities of the European Space Agency.” ESA. https://www.esa.int/About_Us/Corporate_news/Future_activities_of_the_European_Space_Agency. Accessed June 24, 2020.

123 “ESA ministers commit to biggest ever budget.” ESA. Nov. 11, 2019. https://www.esa.int/About_Us/Corporate_news/ESA_ministers_commit_to_biggest_ever_budget. Accessed June 24, 20203

124 “EU space policy.” European Council, Council of the European Union. June 16, 2020. https://www.consilium.europa.eu/en/policies/eu-space-programmes/. Accessed June 21, 2020.

125 “Copernicus In Brief.” Copernicus. https://www.copernicus.eu/en/about-copernicus/copernicus-brief. Accessed June 18, 2020.

126 “What we do.” European Global Navigation Satellite Systems Agency. https://www.gsa.europa.eu/about/what-we-do. May 13, 2020. Accessed on June 18, 2020.

127 “Strengthening the European Space Sector Through An Ambitious Industrial Policy.” Eurospace. May 2019. https://eurospace.org/wp-content/uploads/2019/05/strengthening-the-european-space-sector-through-an-ambitious-industrial-policy.pdf. Accessed July 13, 2020.

128 “Statement of Estimates of the European Commission for the financial year 2019.” European Union. June 2019. https://ec.europa.eu/info/sites/info/files/about_the_european_commission/eu_budget/draft-budget-2020-wd-13-web-1.4_soe.pdf. Accessed June 18, 2020.

129 “EU budget: A €16 billion Space Programme to boost EU space leadership beyond 2020.” European Commission. June 6, 2018. https://ec.europa.eu/commission/presscorner/detail/en/IP_18_4022. Accessed June 18, 2020.

130 “Europe's moment: Repair and prepare for the next generation.” European Commission. May 27, 2020. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_940. Accessed June 18, 2020.

131 “COVID-19: List of the measures taken in relation to the ITRE remit: May-June 2020.” European Parliament. July 13, 2020. https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/652726/IPOL_BRI(2020)652726_EN.pdf. Accessed July 15, 2020.

132 “Member States.” EUMETSAT. https://www.eumetsat.int/website/home/AboutUs/WhoWeAre/MemberStates/index.html. Accessed June 19, 2020.

133 “What We Do.” EUMETSAT. https://www.eumetsat.int/website/home/AboutUs/WhatWeDo/index.html. Accessed June 19, 2020.

134 “EUMETSAT PROGRAMMES.” EUMETSAT. Jan. 13, 2020. Accessed on June 19, 2020.

135 Eurospace. Correspondence with author. June 2020.

136 “Science Plans for the Future Missions.” EUMETSAT. https://www.eumetsat.int/website/home/Data/ScienceActivities/ScienceStudies/SciencePlansforfuturemissions/index.html. Accessed June 24, 2020.

137 “EUMETSAT Strategy Challenge 2025.” EUMETSAT. 2016. https://www.eumetsat.int/website/home/Data/ScienceActivities/ScienceStudies/SciencePlansforfuturemissions/index.html. Accessed June 24, 2020.

138 “Un budget exceptionnel.” Centre National d'Etudes Spatiales (CNES). March 6, 2020. https://cnes.fr/fr/web/CNES-fr/11507-le-2eme-budget-au-monde.php. Accessed July 16, 2020.

139 “Un budget exceptionnel.” Centre National d'Etudes Spatiales (CNES). March 6, 2020. https://cnes.fr/fr/web/CNES-fr/11507-le-2eme-budget-au-monde.php. Accessed July 16, 2020.

140 “Ocean-Monitoring Satellite Mission Ends After 11 Successful Years.” NASA. Oct. 4, 2019. https://www.nasa.gov/press-release/ocean-monitoring-satellite-mission-ends-after-11-successful-years. Accessed July 16, 2020.

141 “Airbus to develop CO3D Earth Observation programme for CNES.” Airbus. July 8, 2019. https://www.airbus.com/newsroom/press-releases/en/2019/07/airbus-to-develop-co3d-earth-observation-programme-for-cnes.html. Accessed July 16, 2020.

142 “Agreement to establish maritime surveillance centre in India.” Ministère de l'Europe et des Affaires Étrangères. Feb. 14, 2019. https://in.ambafrance.org/France-India-space-cooperation-in-human-spaceflight-mission. Accessed July 16, 2020.

143 “Gaganyaan: Russian space suits, French medicine for Indian astronauts?” The Hindu. Aug. 24, 2019. https://www.thehindu.com/sci-tech/science/gaganyaan-russian-space-suits-french-medicine-for-indian-astronauts/article29236527.ece. Accessed July 16, 2020.

144 Eurospace. Correspondence with author. June 2020.

145 Eurospace. Correspondence with author. June 2020.

146 Eurospace. Correspondence with author. June 2020.

147 Laudrain, Arthur. “France's ‘strategic autonomy’ takes to space.” International Institute for Strategic Studies. Aug. 14, 2019. https://www.iiss.org/blogs/military-balance/2019/08/france-space-strategy. Accessed July 16, 2020.

148 "Bundeshaushalt 2020." Bundesministerium der Finanzen. Dec. 2019. https://www.bundeshaushalt.de/fileadmin/de.bundeshaushalt/content_de/dokumente/2020/soll/Nachtrags-HH_2020_geschuetzt.pdf, pages 32, 34, 47. Accessed May 18, 2020.

149 "DLR Space Administration." DLR. https://www.dlr.de/rd/en/desktopdefault.aspx/tabid-2099/3053_read-4706/. Accessed June 19, 2020.

150 "Bundeshaushalt 2020." Bundesministerium der Finanzen. Dec. 2019. https://www.bundeshaushalt.de/fileadmin/de.bundeshaushalt/content_de/dokumente/2020/soll/Nachtrags-HH_2020_geschuetzt.pdf, pages 32, 34, 47. Accessed May 18, 2020.

151 "Space." DLR. https://www.dlr.de/EN/research/space_node.html. Accessed June 19, 2020.

152 Eurospace. Correspondence with author. June 2020.

153 Eurospace. Correspondence with author. June 2020.

154 Eurospace. Correspondence with author. June 2020.

155 "Germany invests 3.3 billion euro in European space exploration and becomes ESA's largest contributor." DLR. Nov. 28, 2019. https://www.dlr.de/content/en/articles/news/2019/04/20191128_esa-ministerial-2019.html. Accessed June 19, 2020.

156 "Bundeshaushalt 2020." Bundesministerium der Finanzen. December 2019. https://www.bundeshaushalt.de/fileadmin/de.bundeshaushalt/content_de/dokumente/2020/soll/Nachtrags-HH_2020_geschuetzt.pdf, pages 32, 34, 47. Accessed May 18, 2020.

157 "Expenditure Profile 2020-2021." Ministry of Finance, Government of India. https://www.indiabudget.gov.in/doc/eb/vol1.pdf, page 17, 48. Accessed May 19, 2020.

158 "Space Applications Centre (SAC)." Department of Space, Indian Space Research Organisation. https://www.isro.gov.in/about-isro/space-applications-centre-sac. Accessed June 19, 2020.

159 "Expenditure Profile 2020-2021." Ministry of Finance, Government of India. https://www.indiabudget.gov.in/doc/eb/vol1.pdf, page 17, 48. Accessed May 19, 2020.

160 Pubby, Manu. "India test first anti-satellite missile system, codenamed Mission Shakti." The Economic Times: India Times. https://economictimes.indiatimes.com/news/politics-and-nation/pm-modis-big-announcement-india-successfully-tests-anti-satellite-weapon/articleshow/68592702.cms. Accessed June 19, 2020.

161 Goswami, Namrata and Peter Garretson. "Critical Shifts in India's Outer Space Policy." The Diplomat. April 16, 2019. https://thediplomat.com/2019/04/critical-shifts-in-indias-outer-space-policy/. Accessed June 19, 2020.

162 "Steady rise in budget allocation for DRDO." DRDO. Nov. 28, 2019. https://drdo.gov.in/sites/default/files/drdo-news-documents/DRDO_News_28_Nov_2019.pdf. Accessed July 15, 2020.

163 "Steady rise in budget allocation for DRDO." DRDO. Nov. 28, 2019. https://drdo.gov.in/sites/default/files/drdo-news-documents/DRDO_News_28_Nov_2019.pdf. Accessed July 15, 2020.

164 "India will have its own space station. says ISRO chief K Sivan." India Today. June 13, 2019. https://www.indiatoday.in/india/story/india-will-have-its-own-space-station-isro-k-sivan-1548112-2019-06-13. Accessed June 19, 2020.

165 "New Space India Ltd. incorporated as a new commercial arm of D/o Space: Finance Minister." Government of India, Department of Space. July 5, 2019. https://pib.gov.in/Pressreleaseshare.aspx?PRID=1577403. Accessed June 19, 2020.

166 Somasekhar, M. "IRSO, DRO join hands for Gaganyaan project." The Hindu Business Line. Sept. 18, 2019. https://www.thehindubusinessline.com/news/science/isro-drdo-join-hands-for-gaganyaan-project/article29442238.ece. Accessed June 19, 2020.

167 Pinto, Nolan. "Chandrayaan-3 on: ISRO announces plans for another Moon mission." https://www.indiatoday.in/science/story/isro-k-sivan-chandrayaan-3-mission-1633025-2020-01-01. Accessed June 19, 2020.

168 "About the Israel Space Agency." ISA. https://www.space.gov.il/en/About. Accessed June 20, 2020.

169 "The Public Knowledge Workshop ("Hasadna")." Public Knowledge Workshop. https://www.hasadna.org.il/en/. Accessed June 20, 2020.

170 "19.40.02.11. ללחה תינכת." Public Knowledge Workshop. https://next.obudget.org/i/budget/0019400211/2019. Accessed May 18, 2020.

171 "Israel Space Agency gives $5.6 million to help launch 2nd shot at moon." Jewish Telegraphic Agency. May 7, 2019. https://www.jta.org/quick-reads/israel-space-agency-gives-5-6-million-to-help-launch-beresheet-2-project. Accessed June 20, 2020.

172 "The Italian Space Agency in short: profile and activities." ASI. https://www.asi.it/en/the-agency/the-italian-space-agency-in-short-profile-and-activities/. Accessed June 20, 2020.

173 "DELIBERAZIONE N. 71/2020." Agenzia Spaziale Italiana. April 15, 2020. https://trasparenza.strategicpa.it/asi/archivio/23945-anno-2019/doc/2331, pages 20-21. Accessed June 20, 2020.

174 "The Italian Space Agency in short: profile and activities." ASI. https://www.asi.it/en/the-agency/the-italian-space-agency-in-short-profile-and-activities/. Accessed June 20, 2020.

175 "Launch Kit: March 2019 VV14 PRISMA." Arianespace. March 2019. https://www.arianespace.com/wp-content/uploads/2019/03/DDP-VV14-GB.pdf. Accessed June 20, 2020.

176 "Soyouz [sic] VS23 launch: a quadruple success for Thales Alenia Space." Thales Alenia Space. Dec. 18, 2019. https://www.thalesgroup.com/en/worldwide/space/press_release/soyouz-vs23-launch-quadruple-success-thales-alenia-space. Accessed June 20, 2020.

177 Eurospace. Correspondence with author. June 2020.

178 Henry, Caleb. "Italy to increase space projects with 'mirror programs' of European agencies." July 20, 2019. https://spacenews.com/italy-to-increase-space-projects-with-mirror-programs-of-european-agencies/. Accessed June 20, 2020.

179 "JAXA History." JAXA. https://global.jaxa.jp/about/history/index.html. Accessed June 20, 2020.

180 "Transition and Number of Staff and Budget." JAXA. https://global.jaxa.jp/about/transition/index.html. Accessed June 21, 2020.

181 Toukaku, Yoshio. "JAXA Space Science Program and International Collaboration." Institute of Space and Astronautical Science (ISAS)/ JAXA. May 2019. https://www.essc.esf.org/fileadmin/user_upload/essc/Toukaku_JAXA_Space_Science_Program_and_International_Collaboration.pdf, page 4. Accessed May 26, 2020.

182 Toukaku, Yoshio. "JAXA Space Science Program and International Collaboration." Institute of Space and Astronautical Science (ISAS)/ JAXA. May 2019. https://www.essc.esf.org/fileadmin/user_upload/essc/Toukaku_JAXA_Space_Science_Program_and_International_Collaboration.pdf, page 4. Accessed May 26, 2020.

183 "Hayabusa2 Latest Status, the Successful First Touchdown." JAXA. Feb. 22, 2019. https://global.jaxa.jp/press/2019/02/20190222a.html. Accessed June 21, 2020.

184 "Successful Operation of Asteroid Explorer Hayabusa2's SCI." JAXA. April 25, 2019. https://global.jaxa.jp/press/2019/04/20190425a.html. Accessed June 21, 2020.

185 "Success of the Second Touchdown of Asteroid Explorer "Hayabusa 2"." JAXA. July 11, 2019. https://global.jaxa.jp/press/2019/07/20190711a.html. Accessed June 21, 2020.

186 "Hayabusa2 departs from Ryugu." JAXA. Nov. 13, 2019. https://global.jaxa.jp/press/2019/11/20191113a.html. Accessed June 21, 20203

187 "Joint Statement on Cooperation in Lunar Exploration." JAXA/NASA. Sept. 24, 2019. https://global.jaxa.jp/press/2019/09/20190924a.html. Accessed June 21, 2020.

188 "Multilateral Coordination Board Joint Statement toward the development of the Gateway." Sept. 10, 2019. https://global.jaxa.jp/press/2019/09/20190910a.html. Accessed June 21, 2020.

189 "Japan seeks record ¥5.32 trillion defense budget with new focus on space and cyberspace". The Japan Times. Aug. 30, 2019. https://www.japantimes.co.jp/news/2019/08/30/national/japan-record-defense-budget-space-cyberspace/. Accessed June 21, 2020.

190 "Vote Business, Science and Innovation - Economic Development and Infrastructure Sector - Estimates 2019/20." Government of New Zealand. May 17, 2018. https://treasury.govt.nz/publications/estimates/vote-business-science-and-innovation-economic-development-and-infrastructure-sector-estimates-2019-20-html. Accessed May 20, 2020.

191 Jones, Pam. "Alexandra Space Science Centre Gets Rebrand." https://www.odt.co.nz/regions/central-otago/alexandra-space-science-centre-gets-rebrand. April 4, 2019. Accessed on June 21, 2020.

192 "Xerra Earth Observation Institute." Ministry of Business, Innovation & Employment. https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/regional-research-institutes/xerra-earth-observation-institute/. Accessed May 20, 2020.

193 Jones, Pam. "Alexandra Space Science Centre Gets Rebrand." https://www.odt.co.nz/regions/central-otago/alexandra-space-science-centre-gets-rebrand. April 4, 2019. Accessed on June 21, 2020.

194 "About us." Ministry of Business, Innovation & Employment: New Zealand Space Agency. https://www.mbie.govt.nz/science-and-technology/space/about-us/. Accessed June 21, 2020.

195 "Xerra Earth Observation Institute." Ministry of Business, Innovation & Employment. https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/regional-research-institutes/xerra-earth-observation-institute/. Accessed on June 21, 2020.

196 "ROSCOSMOS General Information." ROSCOSMOS. http://en.roscosmos.ru/119/. Accessed on June 22, 2020.

197 Howell, Elizabeth. "Roscosmos: Russia's Space Agency." Space.com. Jan. 30, 2018. https://www.space.com/22724-roscosmos.html. Accessed on June 22, 2020.

198 "Россия потратит на космическую деятельность в 2018 году почти 182 млрд рублей. Russia Will Spend Almost 182 Billion Rubles on Space Activities in 2018" TASS. Sept. 29, 2017. https://tass.ru/kosmos/4604334. Accessed June 22, 2020.

199 Горки, Московская область. “ О финансово-экономическом состоянии госкорпорации «Роскосмос» и её подведомственных организаций. On the financial and economic condition of the state corporation Roscosmos and its subordinate organizations” Правительство России. Jan. 23, 2019. http://government.ru/news/35460/. Accessed May 29, 2020.

200 “Funding for Russian space industry to be expanded.” TASS. Oct. 15, 2019. https://tass.com/science/1080735. Accessed June 22, 2020.

201 “Россия потратит на” Russian will spend (See 200).

202 “Funding for Russian space industry to be expanded.” TASS. Oct. 15, 2019. https://tass.com/science/1080735. Accessed June 22, 2020.

203 “Major Functions.” KARI. https://www.kari.re.kr/eng/sub01_02.do. Accessed June 22, 2020.

204 “18. 수입 및 지출 현황. Korea Aerospace Research Institute Income and Expenditure" All Public Information In-One. April 9, 2020. www.alio.go.kr/popReport.do?seq=20200 41102006347&disclosureNo=2020041102006347 attachment 알리오 18번_2019년 수지결산표.pdf. Accessed May 21, 2020.

205 “S. Korea’s Chollian-2B Environmental Satellite Makes Contact After Successful Launch.” Seoul Traffic Broadcasting. Feb. 19, 2020. http://tbs.seoul.kr/eFm/newsView.do?typ_800=N&idx_800=2385275&seq_800=. Accessed June 22, 2019.

206 “Space tech a key focus for South Korea in 2020.” Spacetech Asia. https://www.spacetechasia.com/space-tech-a-key-focus-for-south-korea-in-2020/. Accessed June 22, 2020.

207 “About us.” INTA. https://www.inta.es/INTA/en/quienes-somos/. Accessed June 23, 2020.

208 “Presupuesto por programas y memoria de objetivos. Tomo IV (Sección 14).” Ministerio de Hacienda. https://www.sepg.pap.hacienda.gob.es/Presup/PGE2019Prorroga/MaestroTomos/PGE-ROM/doc/L_19P_E_G4.PDF, page 55. Accessed June 23, 2020.

209 “Presupuesto por programas y memoria de objetivos. Tomo IV (Sección 14).” Ministerio de Hacienda. https://www.sepg.pap.hacienda.gob.es/Presup/PGE2019Prorroga/MaestroTomos/PGE-ROM/doc/L_19P_E_G4.PDF, page 47-48. Accessed June 23, 2020.

210 “El INTA contará con un presupuesto de 188 millones, un 36% más.” Info Espacial. April 7, 2018. http://www.infoespacial.com/es/2018/04/07/noticia-contara-presupuesto-millones. html. Accessed June 23, 2020.

211 “El INTA contará con un presupesto do 190 millones en 2019.” Info Espacial. Jan. 16, 2019. http://www.infoespacial.com/es/2019/01/16/noticia-contara-presupuesto-millones.html. Accessed June 23, 2020.

212 “Presupuesto por programas ymemoria de objetivos. Tomo XIV (Sección 27).” Ministerio de Hacienda. https://www.sepg.pap.hacienda.gob.es/Presup/PGE2017Proyecto/MaestroTomos/PGE-ROM/doc/L_17_A_G27.PDF. Accessed June 23, 2020.

213 “El INTA contará con un presupesto do 190 millones en 2019.” Info Espacial. Jan. 16, 2019. http://www.infoespacial.com/es/2019/01/16/noticia-contara-presupuesto-millones.html. Accessed June 23, 2020.

214 “Vega to take Spain’s SEOSAT-Ingenio into orbit.” ESA. May 20, 2019. https://www.esa.int/Applications/Observing_the_Earth/Vega_to_take_Spain_s_SEOSAT_Ingenio_into_orbit. Accessed June 23, 2020.

215 Eurospace. Correspondence with author. June 2020.

216 “Presupuesto por programas y memoria de objetivos. Tomo IV (Sección 14).” Ministerio de Hacienda. https://www.sepg.pap.hacienda.gob.es/Presup/PGE2019Prorroga/MaestroTomos/PGE-ROM/doc/L_19P_E_G4.PDF, page 55. Accessed June 23, 2020.

217 “Presupuesto por programas y memoria de objetivos. Tomo IV (Sección 14).” Ministerio de Hacienda. https://www.sepg.pap.hacienda.gob.es/Presup/PGE2019Prorroga/MaestroTomos/PGE-ROM/doc/L_19P_E_G4.PDF, page 47-48. Accessed June 23, 2020.

218 Eurospace. Correspondence with author. June 2020.

219 Eurospace. Correspondence with author. June 2020.

220 “Spain raises the ceiling for its contribution to the European Space Agency by 73 percent.” GTD System and Software Engineering. May 3, 2019. https://www.gtd.es/en/news-and-events/spain-raises-ceiling-its-contribution-european-space-agency-73-cent. Accessed June 23, 2020.

221 “Spain joins Copernicus Sentinel Collaborative Ground Segment.” ESA. Nov. 26, 2019. https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Spain_joins_Copernicus_Sentinel_Collaborative_Ground_Segment. Accessed June 23, 2020.

222 “我が国の防衛と予算: 平成３１年度予算の概要. Defense Programs and Budget of Japan” Ministry of Defense. December 2018. https://www.mod.go.jp/j/yosan/yosan_gaiyo/2019/yosan.pdf. Accessed July 9, 2020.

223 “Our Mission.” Swiss Space Center. https://www.spacecenter.ch/aboutus/mission/. Accessed June 23, 2020.

224 “Band 2B: Teil II.” Schweizerische Eidgenossenschaft. March 26, 2020. https://www.efv.admin.ch/dam/efv/de/dokumente/Finanzberichte/finanzberichte/rechnung/2019/rg2b-2019.pdf.download.pdf/RG2B-6-8-d.pdf, p. 248. Accessed May 26, 2020.

225 “IGLUNA: About.” Swiss Space Center. https://www.spacecenter.ch/igluna/. Accessed June 23, 2020.

226 “A Report on Space Science in Switzerland.” Swiss Academy of Sciences. 2019. https://sciencesnaturelles.ch/uuid/9ad9c99d-559d-5e62-b3fe-772f41aefe48?r=20190807115818_1587129077_bb0744f2-2d2c-5a83-ab93-1a4cd48f3ba1. Accessed June 23, 2020.

227 Eurospace. Correspondence with author. June 2020.

228 “Prodex.” ESA. https://sci.esa.int/web/prodex. Accessed June 23, 2020.

229 “UAE Federal Budget 2019 - Highest in the Country’s History.” United Arab Emirates Ministry of Finance. https://www.mof.gov.ae/en/resourcesAndBudget/fedralBudget/Pages/budget2019.aspx. Accessed May 26, 2020.

230 “Federal Budget 2018.” UAE Ministry of Finance. https://www.mof.gov.ae/en/resourcesAndBudget/fedralBudget/Pages/budget2018.aspx. Accessed June 24, 2020.

231 Urrutia, Doris Elin. “The 1st Emirati Astronaut Has Had a Blast in Space, But It’s Time to Come Home.” Space.com. https://www.space.com/first-uae-astronaut-space-reactions-returning-home.html. Accessed June 24, 2020.

232 Bailey, Stephanie. “UAE’s Hope Probe prepares for launch to Mars.” CNN. May 29, 2020. https://edition.cnn.com/2020/05/19/middleeast/space-mars-hope-probe-uae-spc-scn-intl/index.html. Accessed June 24, 2020.

233 “National Space Programme.” UAE. January 16, 2020. https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/national-space-programme. Accessed June 24, 2020.

234 “UK Space Agency Corporate Plan 2019-20.” UK Space Agency. July 23, 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819881/Corporate_report.pdf. Accessed May 26, 2020.

235 “U.K. Space Agency Corporate Plan 2018-19.” UK Space Agency. Dec. 6, 2018. https://www.gov.uk/government/publications/uk-space-agency-corporate-plan-2018-19. Accessed June 5, 2019.

236 “Britain’s exit from the EU (Brexit).” Dover District Council. https://www.dover.gov.uk/Corporate-Information/Brexit/Brexit-Home-Page-Brexit-Britains-exit-from-the-EU.aspx. Accessed June 24, 2020.

237 “UK space missions: case studies and programmes.” UK Space Agency. Dec. 19, 2018. https://www.gov.uk/government/collections/uk-space-missions-case-studies-and-programmes#launchuk-and-spaceports. Accessed June 24, 2020.

238 “New UK-US agreement allows boost UK’s spaceport plans.” UK Space Agency. June 17, 2020. https://www.gov.uk/government/news/new-us-uk-agreement-boosts-uks-spaceport-plans. Accessed June 24, 2020.

239 Pearson, Ezzy. “How will Brexit affect Britain’s role in the European Space Agency?” Jan. 31, 2020. https://www.skyatnightmagazine.com/space-missions/how-will-brexit-affect-britain-role-in-european-space-agency/. Accessed June 24, 2020.

1.5 Coronavirus and the Space Industry

1 “U.S. Stocks Finish Best Quarter in More Than 20 Years.” Wall Street Journal. June 30, 2020. https://www.wsj.com/articles/global-stock-markets-dow-update-6-30-2020-11593508397. Accessed July 3, 2020.

2 “There Are Rays of Light — In Spite Of COVID — For The Space Tech Sector... So States Seraphim Capital.” Satnews. July 16, 2020. https://news.satnews.com/2020/07/16/there-are-rays-of-light-in-spite-of-covid-for-the-space-tech-sector-so-states-seraphim-capital/. Accessed July 20, 2020.

3 Civilian Unemployment June 2000 to June 2020, U.S. Bureau of Labor Statistics. https://www.bls.gov/charts/employment-situation/civilian-unemployment-rate.htm. Accessed July 10, 2020.

4 The Employment Situation, U.S. Bureau of Labor Statistics. June 6, 2020. https://www.bls.gov/news.release/pdf/empsit.pdf. Accessed July 8, 2020.

5 Eurostat, Unemployment Statistics. June 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php/Unemployment_statistics#Unemployment_in_the_EU_and_the_euro_area. Accessed July 14, 2020.

6 Europe — EU27 Unemployment Rate Falls to Lowest Rate Since 2000. Staffing Industry Analysis. March 4, 2020. https://www2.staffingindustry.com/eng/Editorial/Daily-News/Europe-EU27-unemployment-rate-falls-to-lowest-rate-since-2000-53004. Accessed July 10, 2020.

7 Unemployment ticks higher in China as coronavirus shock to economy persists. CNBC. May 15, 2020. https://www.cnbc.com/2020/05/15/unemployment-rises-in-china-as-coronavirus-shock-to-economy-persists.html. Accessed July 13, 2020.

8 80 million Chinese may already be out of work. 9 million more will soon be competing for jobs, too. CNN Business. May 8, 2020. https://www.cnn.com/2020/05/08/economy/china-unemployment-intl-hnk/index.html. Accessed July 13, 2020.

9 "OneWeb goes bankrupt, lays off staff, will sell satellite-broadband business." Ars Technica. March 30, 2020. https://arstechnica.com/information-technology/2020/03/oneweb-goes-bankrupt-wont-challenge-spacex-in-satellite-broadband-race/. Accessed June 8, 2020.

10 "Viasat cuts workforce by 6% due to coronavirus." Via Satellite. April 24, 2020. https://www.satellitetoday.com/business/2020/04/24/report-viasat-cuts-workforce-by-6-due-to-coronavirus/. Accessed June 8, 2020.

11 "SES to Restructure and Consolidate Part of European Operations into Luxembourg Headquarters." SES. May 29, 2020. SES. https://www.ses.com/press-release/ses-restructure-and-consolidate-part-european-operations-luxembourg-headquarters. Accessed June 8, 2020.

12 "Bigelow Aerospace lays off entire workforce." Space News. March 23, 2020. https://spacenews.com/bigelow-aerospace-lays-off-entire-workforce/. Accessed June 8, 2020.

13 "Rocket Startup Astra Trims Staff to Survive Pandemic Until Next Year." CNBC. April 5, 2020. https://www.cnbc.com/2020/04/05/rocket-startup-astra-trims-staff-to-survive-pandemic-until-next-year.html. Accessed June 8, 2020.

14 United Launch Alliance. Mission updates. https://www.ulalaunch.com/missions. Accessed July 10, 2020.

15 SpaceX. https://www.spacex.com/careers/. Accessed June 8, 2020.

1.6 The S-Network Space Index℠ Q1 2020 Performance

1 Caleb Henry, "Viasat laid off 300 amid steep drop in air travel," Space News, May 28, 2020, https://spacenews.com/viasat-laid-off-300-amid-steep-drop-in-air-travel/

2 J. Kasper Oestergaard, "Airbus and Boeing Report March 2020 Commercial Aircraft Orders and Deliveries," Forecast International, April 17, 2020, https://dsm.forecastinternational.com/wordpress/2020/04/17/airbus-and-boeing-report-march-2020-commercial-aircraft-orders-and-deliveries/

3 Caleb Henry, "Viasat laid off 300 amid steep drop in air travel," Space News, May 28, 2020, https://spacenews.com/viasat-laid-off-300-amid-steep-drop-in-air-travel/

4 Lee Samaha, "2 Stocks to Buy During the COVID-19 Crisis," The Motley Fool, March 23, 2020, https://www.fool.com/investing/2020/03/23/2-stocks-to-buy-during-the-covid-19-crisis.aspx

5 Virgin Galactic, "Virgin Galactic Welcomes SpaceShipTwo Unity to Spaceport America, New Mexico," Feb. 13, 2020, https://www.virgingalactic.com/articles/virgin-galactic-welcomes-spaceshiptwo-unity-to-spaceport-america-new-mexico/

6 Michael Sheetz, "Speculative space stock Virgin Galactic is up 170% in just two months," CNBC, Jan. 23, 2020, https://www.cnbc.com/2020/01/23/virgin-galactic-stock-up-170percent-in-two-months-on-space-investor-interest.html

7 Michael Sheetz, "Virgin Galactic reports greater-than-expected quarterly loss, shares slide," CNBC, Feb. 25, 2020, https://www.cnbc.com/2020/02/25/virgin-galactic-earnings-q4-2019.html

Section 2 | Space Workforce

2.0 U.S. Space Workforce

1 Eurospace. Eurospace Facts and Figures 2019.

2 Arianespace. Company Profile. https://www.arianespace.com/service-and-solutions-old/. Accessed March 23, 2020. SES. Annual Report 2018. https://www.ses.com/sites/default/files/SES_AR_2018_A4_0319_web_0.pdf. Accessed March 23, 2020. Eutelsat. Careers. https://www.eutelsat.com/en/group/careers.html. Accessed March 23, 2020. Inmarsat. Annual Report and Financial Statements 2018. https://www.inmarsat.com/wp-content/uploads/2019/12/Inmarsat-Group-Limited-Annual-Report-2018.pdf. Accessed March 23, 2020.

3 Thierry Dubois. "Thales Alenia Space Unveils New Sat Amid Job Cuts." Aviation Week. 12 September 2019. https://aviationweek.com/defense-space/thales-alenia-space-unveils-new-sat-amid-job-cuts. Accessed March 23, 2020.

4 Caleb Henry. "Eutelsat planning layoffs, hiring freeze to rein in spending." Space News. 31 October 2019. https://spacenews.com/eutelsat-planning-layoffs-hiring-freeze-to-rein-in-spending/. Accessed March 23, 2020.

5 Caleb Henry. "Airbus, citing weak space market, to cut more than 2,300 jobs." Space News. 20 February 2020. https://spacenews.com/airbus-citing-weak-space-market-to-cut-more-than-2300-jobs/. Accessed March 23, 2020.

6 Caleb Henry. "Geostationary satellite orders bouncing back." Space News. February 21, 2020. https://spacenews.com/geostationary-satellite-orders-bouncing-back/ (accessed June 30, 2020)

7 Jeff Foust. "EU to invest 200 million euros into space industry." Space News. 22 January 2020. https://spacenews.com/eu-to-invest-200-million-euros-into-space-industry/. Accessed March 23, 2020.

8 SES. "Diversity and Inclusion." https://www.ses.com/about-us/environmental-social-and-governance-esg/diversity-inclusion. Accessed March 23, 2020.

9 Thales. "International Women's Day: A Male Perspective." 6 March 2020. https://www.thalesgroup.com/en/worldwide/space/news/international-womens-day-male-perspective. Accessed March 23, 2020.

10 Eurospace. Eurospace Facts and Figures 2019.

11 Society of Japanese Aerospace Companies. Japanese Space Industry Annual Survey Report. 2019.

12 India Department of Space. Annual Report 2019-2020.

13 T E Narasimhan. "Women make up 30% of Chandrayaan-2 workforce, two lead the mission." Business Standard. 13 July 2019. https://www.business-standard.com/article/current-affairs/women-make-up-30-of-chandrayaan-2-workforce-two-lead-the-mission-119071300559_1.html. Accessed March 23, 2020.

14 "Chandrayaan-2: Was India's Moon mission actually a success?" BBC News. 30 September 2019. https://www.bbc.com/news/world-asia-india-49875897. Accessed March 23, 2020.

Section 3 | Space Infrastructure

3.1 Spacecraft/Satellites

1 Dave Mosher. "SpaceX may want to launch 42,000 internet satellites — about 5 times more spacecraft than humanity has ever flown." Business Insider. Oct. 17, 2019. https://www.businessinsider.com/spacex-starlink-internet-satellites-itc-filing-30000-additional-42000- total-2019-10 (accessed on May 20, 2020)

2 Michael Sheetz. "Elon Musk says SpaceX Starlink internet satellites are key to funding his Mars vision." CNBC. May 15, 2019. https://www.cnbc.com/2019/05/15/musk-on-starlink-internet-satellites-spacex-has-sufficient-capital.html (accessed on May 6, 2020)

3 Eric Ralph. "SpaceX Starlink factory building satellites four times faster than closest competitor." Teslarati. March 12, 2020. https://www.teslarati.com/spacex-starlink-satellite-production-faster-than-competitors/ (accessed on May 4, 2020)

4 Caleb Henry. "SpaceX submits paperwork for 30,000 more Starlink satellites." SpaceNews. October 15, 2019. https://spacenews.com/spacex-submits-paperwork-for-30000-more-starlink-satellites/ (accessed on May 4, 2020)

5 Mark Handley. "Simulating Starlink." UCL Department of Computer Science. 2020. http://nrg.cs.ucl.ac.uk/mjh/starlink/ (accessed on May 6, 2020)

6 Caleb Henry. "SpaceX seeks FCC permission for operating all first-gen Starlink in lower orbit." SpaceNews. April 21, 2020. https://spacenews.com/spacex-seeks-fcc-permission-for-operating-all-first-gen-starlink-in-lower-orbit/ (accessed on May 15, 2020)

7 Starlink. 2020. https://www.starlink.com/ (accessed on May 6, 2020)

8 Inigo del Portillo, Bruce G. Cameron, and Edward F. Crawley. "A Technical Comparison of Three Low Earth Orbit Satellite Constellation Systems to Provide Global Broadband." Massachusetts Institute of Technology. Oct. 1, 2018. http://www.mit.edu/~portillo/files/Comparison-LEO-IAC-2018-slides.pdf (accessed on May 10, 2020)

9 "SpaceX Receives FCC Approval To Deploy One Million Starlink 'UFO' User Terminals In US." Spacewatch Global. 2020. https://spacewatch.global/2020/03/spacex-receives-fcc-approval-to-deploy-one-million-starlink-ufo-user-terminals-in-us/ (accessed on May 6, 2020)

10 Hamza Benzerrouk. "Iridium Next LEO Satellites as an Alternative PNT in GNSS Denied Environments – Part 1." Inside GNSS. June 17, 2019. https://insidegnss.com/iridium-next-leo-satellites-as-an-alternative-pnt-in-gnss-denied-environments-part-1/ (accessed on May 20, 2020)

11 "OneWeb files for chapter 11 restructuring to execute sale process." OneWeb. March 27, 2020. https://www.oneweb.world/media-center/oneweb-files-for-chapter-11-restructuring-to-execute-sale-process (accessed on May 4, 2020)

12 Chris Gebhardt, Danny Lentz. "Falcon 9 becomes U.S. rocket leader; Starlink 'where are they now' edition." Nasa Spaceflight. April 21, 2020. https://www.nasaspaceflight.com/2020/04/falcon-9-us-leader-starlink/ (accessed on May 6, 2020)

13 "Beidou Constellation Status." Information and analysis center for positioning, navigation and timing. June 22, 2020. https://www.glonass-iac.ru/en/BEIDOU/ (accessed on June 22, 2020)

14 "Constellation Status." Test Assessment Research Center of China Satellite Navigation Office. 2020. http://www.csno-tarc.cn/system/constellation&ce=english (accessed on May 2, 2020)

15 "System." Beidou Navigation Satellite System. 2020. http://en.beidou.gov.cn/SYSTEMS/System/ (accessed on May 4, 2020)

16 "Galileo." European Commission. 2020. https://ec.europa.eu/growth/sectors/space/galileo (accessed on May 3, 2020)

17 "Constellation Information." European GNSS Service Centre. 2020. https://www.gsc-europa.eu/system-service-status/constellation-information (accessed on May 10, 2020)

18 "What is Galileo?" European GNSS Service Center. 2020. https://www.gsc-europa.eu/galileo/what-is-galileo (accessed on May 3, 2020)

19 "IRNSS-1I." Department of Space, Indian Space Research organization. April 12, 2018. https://www.isro.gov.in/Spacecraft/irnss-1i (accessed on May 3, 2020)

20 "List of Navigation Satellites." Department of Space, Indian Space Research Organisation. 2020. https://www.isro.gov.in/spacecraft/list-of-navigation-satellites (accessed on May 10, 2020)

21 "QZSS Satellite Information." Quasi-Zenith Satellite System. June 5, 2020. https://qzss.go.jp/en/technical/qzssinfo/index.html (accessed on May 4, 2020)

22 "QZSS Satellite Information." Quasi-Zenith Satellite System. June 5, 2020. https://qzss.go.jp/en/technical/qzssinfo/index.html (accessed on May 10, 2020)

23 "Glonass Constellation Status." Information and analysis center for positioning, navigation and timing. June 22, 2020. https://www.glonass-iac.ru/en/GLONASS/ (accessed on June 22, 2020)

24 "GPS Constellation Status." Information and analysis center for positioning, navigation and timing. June 22, 2020. https://www.glonass-iac.ru/en/GPS/ (accessed on June 22, 2020)

25 "AF announces selection of GPS III follow-on contract." Secretary of the Air Force Public Affairs. Sept. 14, 2018. https://www.af.mil/News/Article-Display/Article/1633793/af-announces-selection-of-gps-iii-follow-on-contract/ (accessed on May 20, 2020)

26 "AF announces selection of GPS III follow-on contract." Secretary of the Air Force Public Affairs. Sept. 14, 2018. https://www.af.mil/News/Article-Display/Article/1633793/af-announces-selection-of-gps-iii-follow-on-contract/ (accessed on May 20, 2020)

27 "Beresheet." NASA Science Solar System Exploration. May 15, 2019. https://solarsystem.nasa.gov/missions/beresheet/in-depth/ (accessed on May 10, 2020)

28 SpaceIL. 2020. http://www.visit.spaceil.com/ (accessed on May 10, 2020)

29 "Beresheet." The Planetary Society. 2019. https://www.planetary.org/explore/space-topics/space-missions/beresheet.html (accessed on May 12, 2020)

30 "Moon Lander." IAI. 2020. https://www.iai.co.il/p/moon-lander (accessed on May 16, 2020)

31 "Chandraayan 2 complete project payload." Department of Space, Indian Research Organisation. 2020. https://www.isro.gov.in/chandrayaan2-payloads (accessed on May 15, 2020)

32 "Chandraayan 2 engineering the future of lunar exploration." Department of Space, Indian Research Organisation. 2020. https://www.isro.gov.in/chandrayaan2-spacecraft (accessed on May 15, 2020)

33 "Chandraayan 2 complete project payload." Department of Space, Indian Research Organisation. 2020. https://www.isro.gov.in/chandrayaan2-payloads (accessed on May 15, 2020)

34 "Chandraayan 2 complete project payload." Department of Space, Indian Research Organisation. 2020. https://www.isro.gov.in/chandrayaan2-payloads (accessed on May 15, 2020)

35 "Chandraayan 2 Indian ambitions, universal aspirations. Department of Space, Indian Research Organisation. 2020. https://www.isro.gov.in/chandrayaan2-mission (accessed on May 15, 2020)

36 "Spectrum Roentgen Gamma." 2020. http://srg.iki.rssi.ru/?page_id=2&lang=ru (accessed on May 12, 2020)

37 William Graham. "Russian Proton-M launches Spektr-RG observatory. NASA Spaceflight.com. July 13, 2019. https://www.nasaspaceflight.com/2019/07/russian-proton-m-spektr-rg-observatory/ (accessed on May 12, 2020)

38 "Spectrum Roentgen Gamma." 2020. http://srg.iki.rssi.ru/?page_id=2&lang=ru (accessed on May 13, 2020)

39 "Spectrum-RG: around the Lagrange point in 177 days." Space Research Institute. April 16, 2020. http://press.cosmos.ru/spektr-rg-vokrug-tochki-lagranzha-za-177-dney (accessed on May 13, 2020)

40 William Graham. "Russian Proton-M launches Spektr-RG observatory. NASA Spaceflight.com. July 13, 2019. https://www.nasaspaceflight.com/2019/07/russian-proton-m-spektr-rg-observatory/ (accessed on May 13, 2020)

Section 4 | Space Infrastructure

4.1 Coronavirus Relief Efforts

1 Instagram Post. Bezos, Jeff. https://www.instagram.com/p/B-NbzviHy5B/?utm_source=ig_embed. March 26, 2020. (Accessed April 14, 2020.)

2 "Amazon will deliver and pick up at-home test kits provided by new coronavirus program in Seattle." CNBC. Farr, Christina. https://www.cnbc.com/2020/03/23/amazon-delivers-coronavirus-test-kits-for-scan-a-gates-backed-effort.html. March 23, 2020. (Accessed April 14, 2020.)

3 "Cobham Advanced Electronic Solutions Space Pedigree Aids in Coronavirus Fight." Business Wire. https://www.businesswire.com/news/home/20200330005084/en/. March 30, 2020. (Accessed April 14, 2020.)

4 "Diazyme Laboratories, Inc. Announces Availability of COVID-19 Antibody Tests." https://www.diazyme.com/diazyme-laboratories-inc-announces-availability-of-covid-19-antibody-tests. March 23, 2020. (Accessed April 14, 2020.)

5 "Which coronavirus patients will get life-saving ventilators? Guidelines show how hospitals in NYC, U.S. will decide." USA Today. McCoy, Kevin and Wagner, Dennis. https://www.usatoday.com/story/news/2020/04/04/coronavirus-ventilator-shortages-may-force-tough-ethical-questions-nyc-hospitals/5108498002/. April 4, 2020. (Accessed April 21, 2020.)

6 Twitter tweet. Medtronic. https://twitter.com/Medtronic/status/1241459765047222272. March 21, 2020. (Accessed April 21, 2020.)

7 Twitter tweet. Medtronic. https://twitter.com/Medtronic/status/1246449963304914945. April 4, 2020. (Accessed April 21, 2020.)

8 "Coronavirus: Richard Branson latest business mogul 'stepping up' in state's COVID-19 response." The Mercury News. Crowley, Kerry. March 25, 2020. (Accessed April 21, 2020.)

9 "Update on Virgin Orbit Ventilators." Virgin Orbit. https://virginorbit.com/update-on-virgin-orbit-ventilators/. April 6, 2020. (Accessed April 21, 2020.)

10 "NASA Develops COVID-19 Prototype Ventilator in 37 Days." NASA. Good, Andrew. https://www.nasa.gov/feature/jpl/nasa-develops-covid-19-prototype-ventilator-in-37-days. April 23, 2020. (Accessed June 5, 2020.)

11 "Eight US Manufacturers Selected to Make NASA COVID-19 Ventilator." NASA. Good, Andrew. https://www.nasa.gov/press-release/eight-us-manufacturers-selected-to-make-nasa-covid-19-ventilator. May 29, 2020. (Accessed June 5, 2020.)

12 "Britain orders 10,000 ventilators from F1, aerospace consortium." Reuters UK. Holton, Kate. https://uk.reuters.com/article/uk-health-coronavirus-britain-ventilator/britain-orders-10000-ventilators-from-f1-aerospace-consortium-idUKKBN21H0JF. March 30, 2020. (Accessed April 21, 2020.)

13 "Smiths Group to Produce 10,000 Ventilators for the UK Government." Smiths.com. https://www.smiths.com/news-and-media/2020/03/smiths-group-to-produce-10000-ventilators-for-the-uk-government. March 30, 2020. (Accessed April 21, 2020.)

14 "With launches on hold, Isro designing ventilators, making hand sanitizers." Times of India. Singh, Surendra. https://timesofindia.indiatimes.com/india/with-launches-on-hold-isro-designing-ventilators-making-hand-sanitisers/articleshow/74878097.cms. March 29, 2020. (Accessed June 5, 2020.)

15 "Ready to Fight: How the Space Industry is Leading the Charge to Combat COVID-19." Space Foundation and CompTIA. https://comptia.zoom.us/webinar/register/WN_tnH-KlKyRN2rBtrq7aHU7A. April 29, 2020. (Accessed May 15, 2020.)

16 "Satellite Data Reveals the Pandemic's Effects From Above." Wired. Scoles, Sarah. https://www.wired.com/story/satellite-data-reveals-the-pandemics-effects-from-above/. April 9, 2020. (Accessed May 15, 2020.)

17 "Ready to Fight: How the Space Industry is Leading the Charge to Combat COVID-19." Space Foundation and CompTIA.

18 "NASA Taps Workforce for Innovative Ideas for Coronavirus Response Efforts." NASA. https://www.nasa.gov/directorates/spacetech/nasa-taps-workforce-for-innovative-ideas-for-coronavirus-response-efforts. April 1, 2020. (Accessed June 8, 2020.)

19 "Space in Response to COVID-19 Outbreak in Italy." ESA. https://business.esa.int/funding/invitation-to-tender/space-response-to-covid-19-outbreak. March 31, 2020. (Accessed May 15, 2020.)

20 "COVID-19: nitrogen dioxide over China." ESA. https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/COVID-19_nitrogen_dioxide_over_China. March 13, 2020. (Accessed May 15, 2020.)

21 "Satellite track emissions drop over China, Italy during coronavirus outbreak." Space.com. Gohd, Chelsea. https://www.space.com/coronavirus-pollution-emissions-drop-china-italy-satellite-views.html. March 20, 2020. (Accessed May 15, 2020.)

22 “Boeing Donates 250,000 Medical Masks to Battle Coronavirus in China.” Boeing/PRNewswire. https://boeing.mediaroom.com/2020-01-29-Boeing-Donates-250-000-Medical-Masks-to-Battle-Coronavirus-in-China. January 29, 2020. (Accessed June 5, 2020.)

23 “Boeing delivers first reusable 3D-printed face shields.” Aerospace Manufacturing and Design. Brothers, Eric. https://www.aerospacemanufacturinganddesign.com/article/boeing-delivers-first-reusable-3d-printed-face-shields/. April 14, 2020. (Accessed June 5, 2020.)

24 “Boeing fights coronavirus, will produce face shields for health care workers.” Fox Business. Barrabi, Thomas. https://www.foxbusiness.com/lifestyle/boeing-coronavirus-face-shieds. March 27, 2020. (Accessed June 5, 2020.)

25 “Boeing's massive oversized cargo plane just flew its first COVID-19 mission from Hong Kong to South Carolina. Take a look at the 'Dreamlifter.'“ Business Insider. Pallini, Thomas. https://www.businessinsider.com/coronavirus-boeing-donating-three-747-dreamlifters-to-aid-distribution-2020-3. April 27, 2020. (Accessed June 8, 2020.)

26 “SpaceX is making and donating hand sanitizer and face shields for the coronavirus effort, says internal email.” CNBC. Kolodny, Laura. https://www.cnbc.com/2020/03/25/spacex-makes-and-donates-hand-sanitizer-face-shields-to-stop-covid-19.html. March 25, 2020. (Accessed June 5, 2020.)

27 “Coronavirus Pandemic: Tesla CEO Elon Musk Donates 50,000 N95 Masks to US Hospital.” News18. https://www.news18.com/news/tech/coronavirus-pandemic-tesla-ceo-elon-musk-donates-50000-n95-masks-to-us-hospital-2548749.html. April 9, 2020. (Accessed June 5, 2020.)

29 “United Technologies to begin manufacturing face shields.” Fox Business Videos. https://video.foxbusiness.com/v/6145868710001/#sp=show-clips. March 30, 2020. (Accessed June 5, 2020.)

29 “Space companies rally to supply medical equipment amid pandemic.” Spaceflight Now. Clark, Stephen. https://spaceflightnow.com/2020/04/07/space-companies-rally-to-supply-medical-equipment-amid-pandemic/. April 7, 2020. (Accessed June 5, 2020.)

30 Twitter tweet. Bruno, Tory. https://twitter.com/torybruno/status/1245753921361997824. April 2, 2020. (Accessed June 8, 2020.)

31 “Space companies rally to supply medical equipment amid pandemic.” Spaceflight Now. Clark, Stephen.

32 “Space companies rally to supply medical equipment amid pandemic.” Spaceflight Now. Clark, Stephen.

33 “Lockheed Martin Accelerates $300 Million This Week to Suppliers.” Lockheed Martin. https://www.lockheedmartin.com/en-us/news/statements-speeches/2020/lockheed-martin-accelerates--300-million-this-week-suppliers.html. May 29, 2020. (Accessed June 5, 2020.)

34 “Viasat to Participate in FCC’s ‘Keep Americans Connected’ Initiative; Pledges to Keep Customers and Small Businesses Connected During Coronavirus Outbreak.” Viasat. https://www.viasat.com/news/viasat-participate-fcc’s-‘keep-americans-connected’-initiative-pledges-keep-customers-and-small. March 16, 2020. (Accessed June 5, 2020.)

35 “Ready to Fight: How the Space Industry is Leading the Charge to Combat COVID-19.” Space Foundation and CompTIA.

36 “NASA looking to play greater role in coronavirus pandemic response.” SpaceNews. Foust, Jeff. https://spacenews.com/nasa-looking-to-play-greater-role-in-coronavirus-pandemic-response/. March 25, 2020. (Accessed June 5, 2020.)

37 “NASA hackathon leverages global ingenuity to combat the coronavirus pandemic.” TechRepublic. Adams, R. Dallon. https://www.techrepublic.com/article/nasa-hackathon-leverages-global-ingenuity-to-combat-the-coronavirus-pandemic/. May 26, 2020. (Accessed June 5, 2020.)

38 “Lockheed Martin Accelerates $300 Million This Week to Suppliers.” Lockheed Martin.

39 “Aerojet Rocketdyne Foundation Supporting COVID-19 Relief Efforts.” Aerojet Rocketdyne. https://www.rocket.com/article/aerojet-rocketdyne-foundation-supporting-covid-19-relief-efforts. April 21, 2020. (Accessed June 5, 2020.)

4.2 Hurricane Tracking and Earth Observation Data

1 “Last Year’s Billion-Dollar Disasters Show Crucial Link Between NOAA Satellites and Emergency Managers.” NESDIS News and Articles, 7 Feb. 2020, www.nesdis.noaa.gov/content/last-year’s-billion-dollar-disasters-show-crucial-link-between-noaa-satellites-and-emergency. Accessed 28 May 2020.

2 Tan, Zhenyu, Yue, Peng, and Gong, Jianya. “An Array Database Approach for Earth Observation Data Management and Processing.” International Journal of Geo-Information, vol. 6, 2017. doi:10.3390/ijgi6070220.

3 Roache, Madeline. “At Least 1 Million People in These Counties Are Under Evacuation Orders As Hurricane Dorian Approaches.” Time, 2 Sept. 2019, https://time.com/5666941/hurrican-dorian-evacuation-orders-counties/. Accessed 8 June 2020.

4 “12,000 People in Evacuation Shelters as Red Cross Prepares for Hurricane Dorian.” American Red Cross, 3 Sept. 2019, www.redcross.org/about-us/news-and-events/press-release/2019/12-000-people-in-evacuation-shelters-as-red-cross-prepares-for-hurricane-dorian.html. Accessed 8 June 2020.

5 Wagner, Meg. “Hurricane Dorian Descends on U.S.” CNN, 1 Sept. 2019, https://web.archive.org/web/20190901232615/https://www.cnn.com/us/live-news/hurricane-dorian-september-2019/h_a393d6ba4448c763863f90244b565567. Accessed 8 June 2020.

6 Kirschbaum, Dalia. Personal interview. 1 June 2020.

7 Jiang, Yunfeng, Sun, Min, and Yang, Chaowei. “A Generic Framework for Using Multi-Dimensional Earth Observation Data in GIS.” Remote Sensing, no. 8, 2016. doi:10.3390/rs8050382.

8 “NASA’s Earth Observing System Project Science Office.” National Aeronautics and Space Administration, 19 Oct. 2019, https://eospso.nasa.gov/. Accessed 2 June 2020.

9 “Global Precipitation Measurement Mission Brochure.” National Oceanic and Atmospheric Administration, NP-2012-10-346-GSFC, 2012, www.nasa.gov/sites/default/files/files/GPM_Mission_Brochure.pdf.

10 Chen, Nengcheng, Zhou, Lianjie, and Chen, Zeqiang. “A Sharable and Efficient Metadata Model for Heterogeneous Earth Observation Data Retrieval in Multi-Scale Flood Mapping.” Remote Sensing, vol. 7, 2015. doi:10.3390/rs70809610

11 Sun, Ziheng, Di, Liping, Hao, Haosheng, Wu, Xiaoqing, Tong, Daniel, Zhang, Chen, Virgei, Cora, Fang, Hui, Yu, Eugene, Tan, Xicheng, Yue, Peng, and Lin, Li. “CyberConnector: a service-oriented system for automatically tailoring multisource Earth observation data to feed Earth science models.” Earth Science Information, vol. 11, no. 1, 2018, pp. 1-17. doi:10.1007/s12145-017-0308-4.

12 “Applied Remote Sensing Training.” National Aeronautics and Space Administration, 1 June 2020, https://arset.gsfc.nasa.gov/. Accessed 2 June 2020.

13 “Decadal Designated Observable Study: Aerosol and Cloud, Convection and Precipitation.” National Aeronautics and Space Administration, 2 June 2020, https://science.nasa.gov/earth-science/decadal-accp. Accessed 2 June 2020.

14 “About Our Agency.” National Oceanic and Atmospheric Administration, www.noaa.gov/about-our-agency. Accessed 28 May 2020.

15 “About NESDIS.” National Oceanic and Atmospheric Administration, www.nesdis.noaa.gov/content/about. Accessed 28 May 2020.

16 “About the National Weather Service.” National Oceanic and Atmospheric Administration, www.weather.gov/about/. Accessed 28 May 2020.

17 “Forecasts and Service.” National Oceanic and Atmospheric Administration, www.weather.gov/about/forecastsandservice. Accessed 28 May 2020.

18 Gerth, Jordan. “Re: Satellite Data Usage.” Received by Tara Larson, 3 June 2010.

19 “Currently Flying.” National Oceanic and Atmospheric Administration, www.nesdis.noaa.gov/content/currently-flying. Accessed 28 May 2020.

20 “Satellite and Information Service: Satellite Missions.” National Oceanic and Atmospheric Administration, www.nesdis.noaa.gov/content/satellite-missions. Accessed 29 May 2020.

As a 501(c)(3) nonprofit organization, philanthropic support is vital in fueling the Space Foundation's important programs and services. Every gift is significant in funding our work to **inspire**, **educate**, **connect**, and **advocate** for the global space community.

Discover the impact of giving at www.SpaceFoundation.org/Donate

SPACE FOUNDATION HQ

4425 Arrowswest Drive
Colorado Springs, CO 80907
+1.719.576.8000

WASHINGTON, D.C.

1700 North Moore Street, Suite 1105
Arlington, VA 22209

www.SpaceFoundation.org