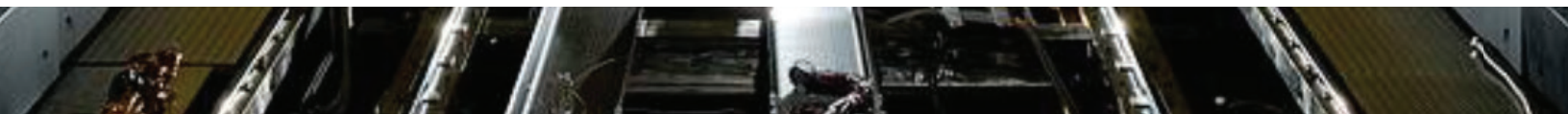
SPACE FOUNDATION

THE SPACE REPORT

THE AUTHORITATIVE GUIDE TO GLOBAL SPACE ACTIVITY

2021 Q3

NEW SPACE TELESCOPES | U.S. SPACE JOBS RECOVERY | COMMERCIAL REVENUE



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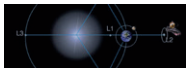
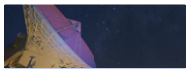

Small Satellite Mass Categories

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.).

Q3

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SPACE FOUNDATION

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

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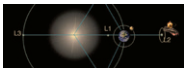
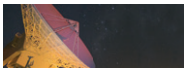
ABOUT THE COVER IMAGE:
The first six flight-ready James Webb Space Telescope's primary mirror segments are prepped to begin final cryogenic testing at NASA's Marshall Space Flight Center. This represents the first six of 18 segments that will form NASA's James Webb Space Telescope's primary mirror for space observations.

Credit: NASA/MSFC/David Higginbotham

Introduction to *The Space Report* | Quarter 3

The idea of "Space for all" was further validated with the flights of Space X Inspiration4 in September and Blue Origin's second mission in October. Eight civilians, ranging in age from 29 to 90, climbed into capsules, departed Earth, and for at least a few minutes, experienced weightlessness and the off-world perspective of seeing the planet from space.

William Shatner appeared the most profoundly affected. Decades earlier, as "Star Trek" Capt. Kirk, he fueled the imaginations and scientific careers of fans when space programs were in their infancy. After landing, he wept with emotion and said he hoped "to never recover" from seeing the beauty and vulnerability of Earth and its thin, fragile atmosphere.

William Shatner and his Blue Origin crewmates.
Credit: Blue Origin

Space tourism will not be the final frontier, as NASA reminded on Oct. 21 in announcing that the unpiloted Artemis 1 lunar orbit mission might be a go as early as February.

The exhilaration of civilian flights and the progress in returning to the Moon, however, comes amid more muted awareness of political and military unease in space. In mid-October came the first reports that China in August is believed to have tested a nuclear-capable hypersonic missile, which U.S. officials fear could cripple its defense systems.[1] The United States, Russia, and North Korea have tested hypersonic missiles as well,[2] but reports soon followed that China has also developed an anti-satellite weapon that would damage a satellite and present as an engine malfunction long after a small explosive was locked onto the satellite's thruster.[3]

Te Space Report seeks to provide information and insight on all aspects of the global space industry by examining developing issues and offering long-term data analysis. Here are highlights from this edition:

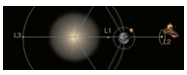
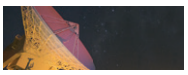
1 | Space Infrastructure

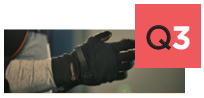
Te James Webb Space Telescope, set to launch in December, will be the first of a new generation of space telescopes, but it will be joined by others within the decade. To obtain next-generation observations, engineers have designed a range of new technologies, including novel cooling systems, foldable mirrors, and high-tech pointing gear. Future telescopes also have greater onboard storage and downlink capabilities, increasing the amount of data scientists can collect.

2 | The Space Economy

Equity financing activity in the space sector posted another near-record high in Q3 21 following the prior quarter's all-time high. Third-quarter equity financings nearly doubled to 55 from 28 in the same period of last year (Q3 20), according to Quilty Analytics analysis. In dollar value of those disclosed transactions, Q3 21 recorded $9.8 billion in investment activity, up from $6.6 billion in Q3 20.

Since 2018, the higher volume has been matched by greater investment per transaction, resulting in a 200% increase in the average value of the 10 largest transactions examined in the last four years. The maximum transaction value has jumped more than 300%.



3 | Space Workforce

Space employment in the United States has continued to be resilient to the global pandemic. The initial drop in the workforce due to COVID-19 in April 2020 was only 2.9% compared to the total U.S. private sector drop of 15.4%. The industry had a slow initial recovery but has been maintaining growth at a near constant rate since July 2020. By late 2020, the space industry workforce had surpassed pre-pandemic levels while the U.S. private sector was still 3.5% below pre-pandemic employment.

One particular sector in the U.S. space industry – Guided missiles, space vehicles, and parts – saw almost no initial employment drop due to the pandemic in April 2020 and continued to steadily grow over the past year. Compared to U.S. total private employment, which has only increased 4.1% from July 2015 to July 2021, this sector has grown by 33.3% over the same period, according to monthly statistics from the U.S. Bureau of Labor Statistics.

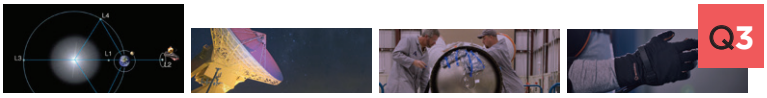
4 | Space Products & Innovation

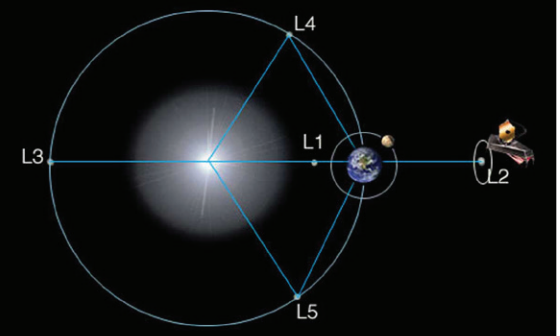
Exoskeletons that optimize human movements have been a staple of science fiction for decades, but the needs of astronauts aboard the International Space Station (ISS) have brought one such tool to life. Developed by NASA researchers and patented for commercial development, the RoboGlove ergonomically assists the wearer by reducing the hand force needed to use tools during repetitive, exhaustive tasks in challenging environments. Now marketed as the Ironhand, the product is available for workers on Earth.

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





Introduction | *Barring schedule slips, a half dozen of the most powerful telescopes ever imagined will launch this decade. The most notable, NASA's James Webb Space Telescope, is set to launch Dec. 18, 2021, kicking off a new era of cosmology for scientists around the world. James Webb and five other telescopes are slotted to fly at Lagrange Point 2 some 1.5 million kilometers (932, 056 miles) from Earth, using this remote vantage point to study deep-space targets.*

This NASA illustration shows the position of the James Webb Space Telescope near Lagrange Point 2. *Credit: NASA*

Six Telescope Launches to Watch this Decade

NASA and other space agencies have launched roughly a dozen telescopes since 1990 with the purpose of studying deep space beyond our solar system. In-space observatories can collect infrared, X-ray, and other radiation types absorbed by Earth's atmosphere, enabling more scientific research than their terrestrial counterparts. Astronomers are increasingly using unique vantage points available in space to expand understanding of the cosmos beyond what can be learned from Earth's surface.

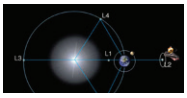
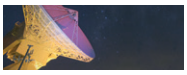
While space has its advantages, the harsh environment and demanding, high-fidelity data sought off world make for extreme engineering challenges. Further complicating these missions, scientists are increasingly seeking telescopes launched to the gravitationally stable region of Lagrange Point 2. There the planet's reflection won't disturb sensitive detections, but any hardware failures will be fatal (L2 currently is too remote for repairs).

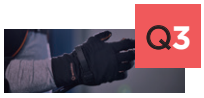
The L2 location will allow the world's largest space agencies to conduct deep-space missions with as little interference from solar radiation or Earth's backscatter of radiation and particles as possible. To obtain next-generation observations, engineers have designed a range of new technologies, including novel cooling systems, foldable mirrors and high-tech pointing gear. Future telescopes also have greater onboard storage and downlink capabilities, increasing the amount of data scientists can collect.

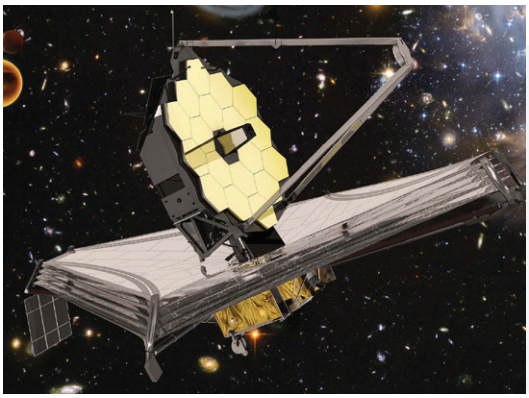
Many of these telescopes are dedicated to understanding the early universe shortly after the Big Bang, and/or to the study of exoplanets, including their discovery, characteristics, and categorization. Some missions will overlap with other telescopes, but with the intent of being complementary as opposed to duplicative.

Here are the six biggest observatories launching to L2 this decade, what they aim to accomplish, and the technology needed for each to succeed*.

*Excludes orbiters and probes launched on science missions to specifically visit other worlds or to study the sun alone. Also excludes Chinese and Russian telescopes for which little information is available.





James Webb Space Telescope

- Launch date: Dec. 18, 2021
- Type: Optical and Infrared/near infrared
- Mission life: Five years
- Mass: 6,500 kg
- Owner: NASA (ESA and the Canadian Space Agency are partners)
- Primary industrial partners: Northrop Grumman, Ball Aerospace, Space Telescope Science Institute

Credit: ESA

When astronomers produced the iconic Hubble Deep Field in 1995, it taught them that the universe had far more galaxies than previously thought. Th at realization became the inspiration for the James Webb Space Telescope, an observatory 100 times more powerful than the Hubble Space Telescope that will peer back to the beginning of the universe.[1]

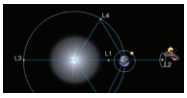
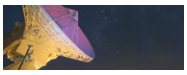
James Webb will pick up where Hubble left off , collecting imagery of galaxies too distant for Hubble's optical sensor. Light from the oldest galaxies is so stretched by the expansion of the universe (a change called redshift) that the wavelengths became elongated past the visible spectrum and are now only detectable as infrared radiation (i.e., heat). James Webb's massive 6.5-meter mirror (just over six times larger than Hubble's) is coated with gold, a thermally sensitive material, to detect those infrared beams. An intricate, multilayer sunshield will block heat from our own sun, protecting faint, deep-space measurements from thermal interference.

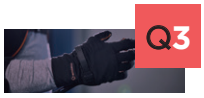
Along with galaxies, James Webb's advanced sensors will enable astronomers to see a wide range of cosmic phenomenon, including proto-planets forming inside dusty nebulae, distant supernovae from the universe's fi rst stars, and supermassive black holes generating violent interstellar winds.[2, 3] NASA plans to use James Webb for a host of studies too challenging or time-intensive for Hubble.

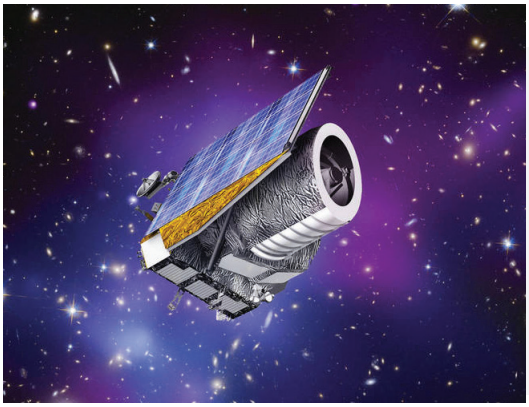
Building James Webb involved overcoming several engineering diffi culties. The telescope's sunshield, measuring the size of a tennis court, uses fi ve membranes of Kapton, a thermal-resistant plastic, to block the sun's rays.[4] Remanufacturing of the sunshield's primary support structure in the early 2010s — coupled with fi xing tears in the sunshield in 2018 and in January 2021— required extra time, but NASA is now confi dent the system will passively cool James Webb's mirror and three of its four instruments down to only 36 Kelvin (-237 degrees Celsius).[5, 6]

James Webb also requires an intricate active cooling system called a cryocooler to chill one sensor, the Mid-Infrared Instrument, even further down to 6 Kevin. Valve leaks, underperformance and other issues plagued the device from 2006 to early 2021, when the last technical risks were retired.[7, 8] Th e cryocooler circulates ultra-cold Helium through 20 meters of thin tubing, chilling the telescope so it can detect faint thermal signals from celestial objects.[9]

James Webb's aperture consists of 18 hexagonal mirrors, each equipped with its own actuators to independently tweak angles, curvature, and positioning.[10] Th e mirrors unfold in a honeycomb pattern, overcoming a major limitation of past telescopes — launch vehicle volume constraints. Th e origami-style approach could pave the way for future large telescope ideas previously considered too big to launch.





Credit: NASA

Euclid

- Launch date: H2 2022
- Type: Optical and near-infrared
- Mission life: Six years
- Mass: 2,200 kilograms
- Owner: ESA
- Primary industrial partners: Thales Alenia Space Italia (prime) and Airbus Defence and Space France (payload)

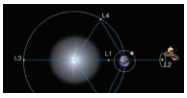
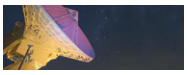
An estimated 27% of the mass in the universe is believed to be dark matter — a so-far undetected, but gravitationally influential type of matter that dominates the universe. Another 68% of the universe is believed to be dark energy, thought to be a leading cause of the expansion of the universe.[11]

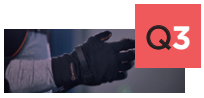
ESA's Euclid telescope aims to put a spotlight on dark matter and dark energy, metaphorically speaking. The orbital observatory will image more than a third of the night sky in an effort to map the geometry of the "dark universe."[12] And while accurate pointing is important for any telescope, it is extremely critical for Euclid.

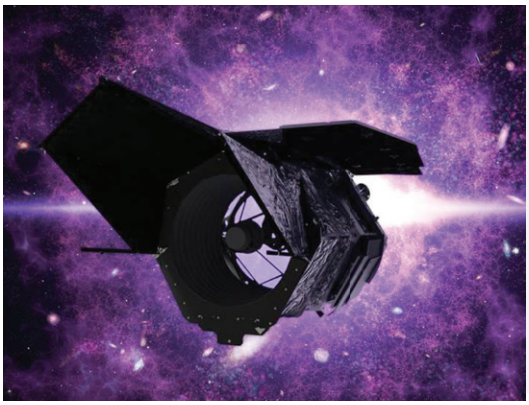
While Euclid and NASA's James Webb will complement each other, Euclid is purpose-built specifically for deep-space galactic observations. ESA anticipates Euclid will image billions of galaxies as far as 10 billion light years away, collecting enough data about the large-scale distribution of galaxies to gauge the influence of dark energy and dark matter (neither of which can be seen).[13]

Manufacturers built Euclid's payload module out of silicon carbide, a material that holds its shape well even when changing temperature. Metal, in contrast, expands and contracts in response to heat, which can degrade the focus of optical sensors. ESA used silicon carbide on its Herschel telescope in 2009 and Gaia in 2013, but not to the extent seen on Euclid.[14]

Euclid will also need more stability than what's obtainable with reaction wheels alone, since such commonly used components can introduce micro-vibrations that would affect observations. Spanish supplier Sener developed a "fine guidance sensor" to hone Euclid's movements after the telescope slews from one target to another. The fine guidance sensor helps Euclid aim at targets with extremely high precision for up to 700 seconds.[15]





Credit: NASA

Nancy Grace Roman Space Telescope

- Launch date: mid-2020s
- Type: Optical and Infrared
- Mission life: Five years
- Mass: 4,200 kg
- Owner: NASA
- Primary industrial partners: TBA

After James Webb, NASA's next big telescope aims to make deep-space observations on a scale never before seen. Current designs call for a telescope with Hubble-class resolution, but with a field of view equal to 100 Hubbles, plus infrared imaging.[16]

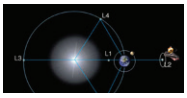
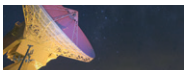
The Nancy Grace Roman Space Telescope, named after NASA's first chief astronomer,[17] will leverage new technologies to make it lighter, sharper, and faster than previous orbital telescopes. It will also carry an experimental coronagraph — devices used to block starlight — to pave the way for future exoplanet finders.[18]

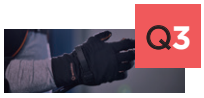
NASA plans to use Roman to conduct large-scale surveys of the universe without sacrificing image quality. What takes Hubble 21 days to image, Roman will complete in under 30 minutes, according to the Space Telescope Science Institute.[19] And, by working in concert with other observatories, Roman will help provide a "big picture" understanding of the universe while finding interesting targets for others like James Webb to do more concentrated studies.

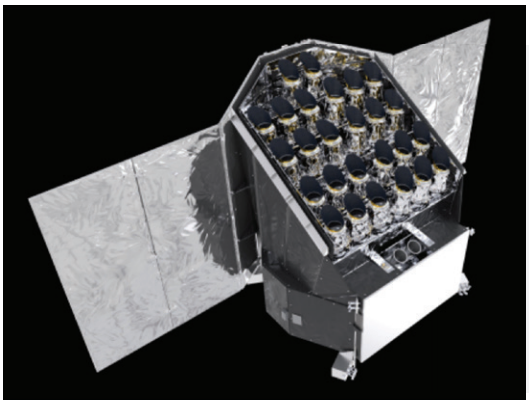
At 2.4 meters across, Roman's primary mirror will be the same size as Hubble's. The difference is Roman will direct observations onto 18 detectors with a collective 300 million pixels, giving the telescope its wide field of view.[20] NASA expects Roman's mirror will weigh one fourth that of Hubble's thanks to newer, lightweight building materials. Additionally, the mirror will get a boost in image quality thanks to a network of around 2,000 tiny piston-like actuators that can change its shape to correct imperfections.[21]

Roman's demonstrator coronagraph will use the telescope's mirrors and a set of masks to isolate starlight from distant exoplanets. Once a planet is found, the coronagraph will also enable spectroscopic measurements of exoplanet atmospheres, helping scientists search for Earth-like worlds.[22]

NASA anticipates Roman will collect 20,000 terabytes of data, a large jump from the 172 terabytes Hubble produced over 30 years and the 1,000 terabytes projected to come from James Webb.[23] All Roman observations are expected to be available in days, avoiding long wait times so astronomers can conduct more research faster than previously possible.





PLATO

- Launch date: 2026
- Type: Optical
- Mission life: Four years
- Mass: 2,150 kg
- Owner: ESA
- Primary industrial partners: OHB, Thales Alenia Space, Ruag Space, DLR

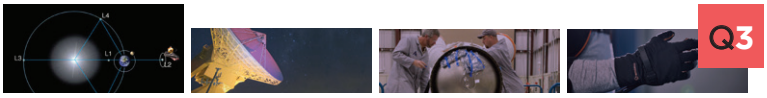
Credit: ESA

Europe's next planet-hunter, the PLAnetary Transits and Oscillations of stars telescope (PLATO), will continue the search for Earth-like worlds but with more detail than earlier purpose-built planet hunters. PLATO will carry an array of 26 cameras, each equipped with four highly sensitive light detectors called Charged Coupled Devices. Once launched, PLATO will carry a collective 2.12 gigapixels — more than twice that of the current record holder, ESA's star-mapper telescope Gaia, launched in 2013.[24]

PLATO's mission is to find planets as they transit in front of their host stars, causing tiny but detectable dips in brightness. Large, fast-moving exoplanets are easiest to spot because they block the most light and require the shortest observations. PLATO will search for difficult to spot planets that are smaller and have longer orbits.

PLATO will monitor hundreds of thousands of stars continuously for up to two years, with an emphasis on finding planets orbiting in their star's habitable zones (where liquid water can exist on a planet's surface).[25] The majority of PLATO's 24 cameras will take pictures every 25 seconds, while the last two cameras will target the brightest stars with shorter exposures of 2.5 seconds each.

For planets that orbit their stars within 90-500 days, PLATO is simulated to outperform other exoplanet hunter telescopes Kepler by a factor of 10 and TESS by a factor of 1000.[26] Additionally, the observatory will study stellar seismic activity (asteroseismology) to further scientific understanding of stellar internal structures and their evolution.[27] The German space agency, Deutsches Zentrum für Luft- und Raumfahrt (DLR), is leading a consortium of European research centers and institutes in providing the scientific instrument.[28] Once complete, PLATO will sport the largest digital combined camera ever flown in space, according to ESA.[29]



Credit: ESA/JAXA

LiteBIRD

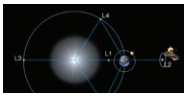
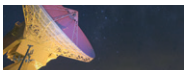
- Launch date: 2028-2029
- Type: 40 to +400 GHz
- Mission life: Three years
- Mass: 2,600 kg
- Owner: JAXA
- Primary industrial partners: JAXA

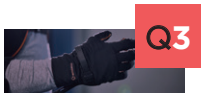
In 2016, scientists observed gravitational waves for the first time, proving that major cosmic explosions can send ripples through the fabric of space-time.[30] The Japan Aerospace Exploration Agency (JAXA) aims to make the first-ever observations of quantum-induced gravitational waves with LiteBIRD, the "Lite" satellite for the study of B-mode polarization and Inflation from cosmic background Radiation Detection.[31]

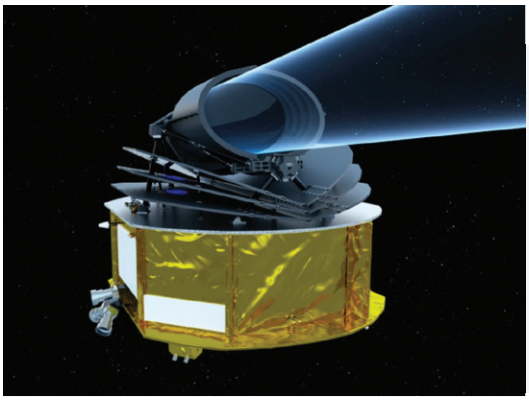
LiteBIRD's focus is on "primordial cosmology," studying the origins of the universe by mapping the cosmic microwave background radiation left over from the Big Bang (called CMB). Specifically, LiteBIRD will look for polarization in the cosmic background radiation, which should have imprints left by gravitational waves from the beginning of the universe.[32] Those imprints are called B-modes, and if found, will sharpen understanding of inflation — an exponentially quick expansion of the universe that occurred for a fraction of a second after the Big Bang.

To detect B-modes, LiteBIRD will use a trio of telescopes covering a wide range of spectrum (from 34 to 448 gigahertz) in search of extremely faint CMB readings. All three LiteBIRD telescopes need to be cooled down to 5 degrees Kelvin to detect those signals. The observatory will use three protective conical structures called "V-grooves" to reduce heat down to 30 Kelvin, complemented by mechanical cryocoolers that drop temperatures to 5 Kelvin.[33]

LiteBIRD is the spiritual successor to ESA's Planck observatory, which operated from 2009 to 2013. The future observatory will be the first to use a rotating half wave plate for polarization splitting, a technology that reduces noise, resulting in cleaner signals.[34] JAXA plans to launch the observatory on an H3 rocket from Mitsubishi Heavy Industries.





ARIEL

- Launch date: 2029
- Type: Optical and Infrared
- Mission life: Four to six years
- Mass: 1,500 kg
- Owner: ESA
- Primary industrial partners: TBD (U.K. is leading the science and the coordination of payload development)

Credit: ESA

Assuming ESA's Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL) telescope launches on schedule in 2029, it will mark the agency's third exoplanet observatory launched in 10 years (following PLATO and CHEOPS). The difference with ARIEL is that its purpose is not exoplanet discovery, but to conduct detailed studies of worlds found by earlier missions.[35]

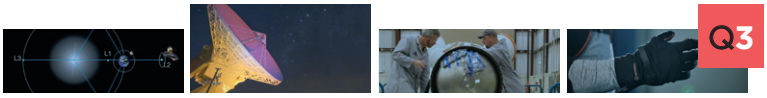
Astronomers plan to study up to 1,000 exoplanets, analyzing light as it passes through their atmospheres to glean details about their temperatures and chemical compositions. That information will fill knowledge gaps about the relationship between planetary chemistry and stellar environments.[36]

ARIEL is designed to detect water vapor, carbon dioxide, methane and other molecules in exoplanet atmospheres. Some planets will get closer studies, looking into seasonal patterns, including atmospheric variations and weather.

ESA has yet to announce a manufacturer for ARIEL, but much of the telescope's design is based on heritage components from other observatories. The telescope's infrared spectrometer will adapt hardware from the NEOCam mission, a fine guidance system from Euclid, and cryogenic technology from James Webb.[37]

ESA plans to launch ARIEL on an Ariane 62 rocket.

Caleb Henry is a senior analyst for Quilty Analytics and a former staff writer for Space News.



Introduction | *Commercial space activity, undertaken by private industry with little or no government investment, accounts for more than 79.8% of the global space economy. Despite the global pandemic, commercial space revenues continue to grow, increasing 6.6% from $334.75 billion in 2019 to $356.68 billion in 2020.[1] Nearly two-thirds of commercial revenue comes from Space Products and Services such as direct-to-home television and applications that use positioning, navigation, and timing satellite signals. The remainder is generated from Commercial Infrastructure and Support Industries, including satellite manufacturing and launch.*

ESA's 35 meter-diameter dish antenna at New Norcia, Western Australia. Ground stations and equipment, the largest segment of Commercial Space Infrastructure and Support Services, grew 6.4% last year.
Credit: Dylan O'Donnell/Flickr

Despite Pandemic, Double-digit Growth in 2020 in Some Commercial Sectors

Commercial Infrastructure and Support Industries

Commercial Infrastructure and Support Industries revenue totaled $137.23 billion in 2020, an increase of 16.4% from $117.94 billion in 2019. This category includes the products and services provided by the private sector that enable the development, launch, and successful operation of commercial space assets. This includes satellite manufacturing and launch services, as well as space insurance. It also includes revenue generated from ground stations and equipment needed to send and receive satellite signals, and data from commercial space situational awareness firms used to ensure safe operation of space assets in orbit. Commercial human spaceflight revenues also contribute to this total.

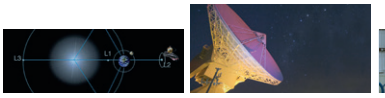
Revenues for Commercial Space Infrastructure and Support Industries, 2020

Agency	Budget	Source
Ground Stations and Equipment	$118.45B	Satellite Industry Association, European GNSS Agency (GSA)
Satellite Manufacturing (Commercial)	$16.17B	Eurospace
Launch Industry (Commercial)	$2.07B	Eurospace
Insurance Premiums	$0.45B	AXA XL, a division of AXA
Space Situational Awareness and On-Orbit Servicing	$0.04B	Northern Sky Research
Commercial Human Spaceflight (Deposits)	$0.06B	News Reports; Public Filings
Total	**$137.24B**	

Launch

There were 114 launch attempts in 2020, 104 of which were successful. The number of launch attempts was 17.5% greater than in 2019. Commercial launches — those carried out for a non-government customer — accounted for 38 attempts and five failures in 2020. This was also an increase from the previous year, up 40.7% from 27 attempts in 2019.[2] This growth is an impressive feat given the impact of the global pandemic during which launches were affected by staffing issues at spaceports, government-mandated shutdowns, challenges of international travel, and delays in payload development and delivery.[3]

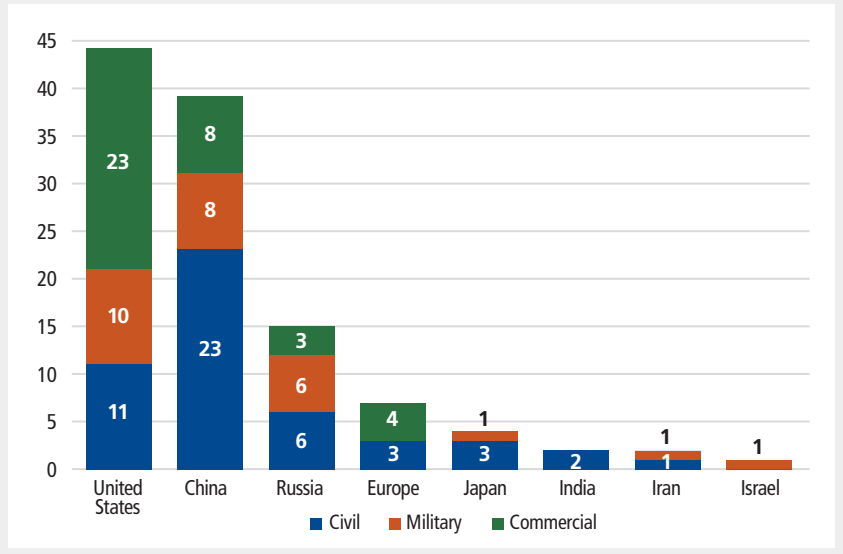
The total market value of launches in 2020 increased 14.2%, to $9.25 billion in 2020 from $8.10 billion in 2019. Much of this growth was due to increases in commercial revenues, which were up 78.5% — growing from $1.16 billion in 2019 to $2.07 billion in 2020. Commercial revenue accounted for 22.4% of the total market value of launches in 2020. The remaining 77.6%, or $7.18 billion, is in government investment and is detailed in the 2021 Q1 and Q2 editions of *The Space Report*. Launch market values are based on estimates provided by Eurospace, the trade association of the European space industry. The model used to estimate these values was updated in 2021, leading to changes in previous year totals, compared to those published in previous editions of *The Space Report*.[4]



The majority of commercial launches that took place in 2020 occurred in the United States, which had 44 launch attempts and four failures. Among the 40 successful launches were 25 SpaceX launches, many of which lofted SpaceX's own Starlink satellites. There were seven successful launches of RocketLab's Electron rocket, but the company suffered one launch failure in July 2020 due to faulty electrical connections that caused the second stage engine to cut out too early.[5] The remaining failures included the maiden flight of Virgin Galactic's Launcher One, and the first two launch attempts of the California-based space start-up Astra.[6]

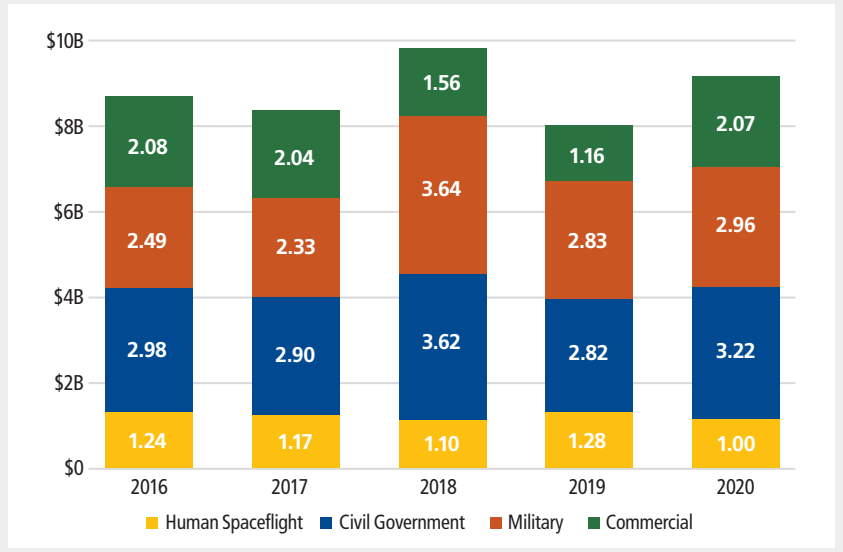
China was home to eight commercial launches in 2020, seven of which were successful. Four of the successes used Long March rockets and two used Kuaizhou rockets operated by ExSpace, a commercial subsidiary of the China Aerospace Science and Industry Corporation (CASIC).[7] ExSpace also experienced a failure, with the maiden flight of its Kuaizhou-11 rocket. The Chinese start-up Galactic Energy successfully launched its Ceres-1 launcher for the first time in November 2020. In Europe, Arianespace had three successful launches of its Ariane-V vehicle and one successful Vega launch. Russia conducted three successful Soyuz launches for commercial customers.[8]

Orbital Launch Attempts, 2020



Source: Space Foundation Database

Launch Services Value by Market, 2016-2020



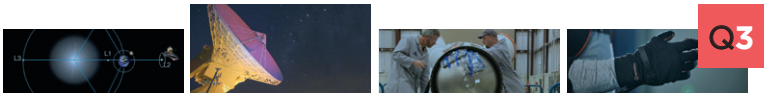
Source: Space Foundation Database

Satellite Manufacturing

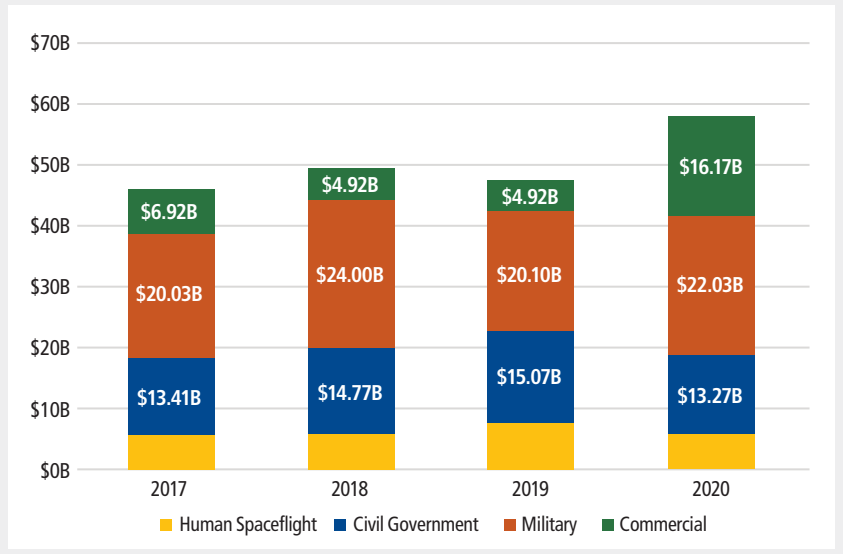
In 2020, 1,230 spacecraft launched for the year, an increase of 163% from the 467 launched in 2019. Of these, 1,098 spacecraft, or 89.3%, were commercial payloads. U.S. companies launching large constellations account for much of this volume. In 2020, SpaceX launched 832 Starlink satellites.[9]

Manufacturing revenue associated with commercial payloads launched in 2020 totaled $16.17 billion in 2020, more than three times higher than the $4.92 billion associated with payloads launched in 2019. This increase mirrors the dramatic increase in the number of commercial payloads launched in 2020 compared to 2019. Estimates are based on analysis carried out by Eurospace and reflect a new methodology implemented in 2021, leading to updates in previous year totals compared to past editions of *The Space Report*.[10]

The revenue associated with commercial payloads accounted for 28.1% of total payload revenue in 2020, which was estimated at $57.56 billion.[11] The remaining $41.4 billion, or 71.9%, was associated with government spacecraft, including cargo launched to the International Space Station as part of NASA's commercial resupply services program.

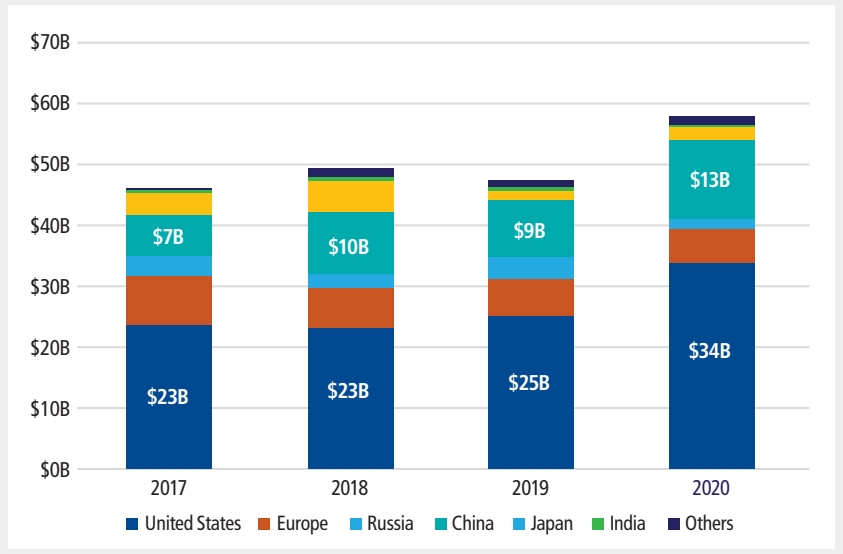


Spacecraft Value by Market, 2017-2020



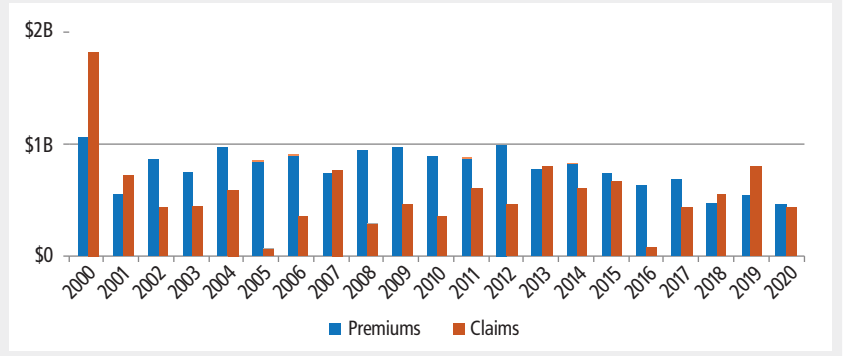
Source: Space Foundation Database

Spacecraft Value by Manufacturing Country, 2017-2020



Source: Space Foundation Database

Space Insurance Industry Estimates, 2000-2020



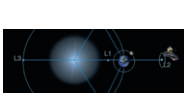
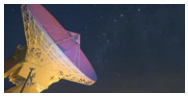
Source: AXA XL, a division of AXA

Insurance

With their dependence on cutting-edge technologies and need to operate in the remote and inhospitable space environment, space projects always involve some risk. Many companies rely on insurance to help manage these risks. It's possible to purchase insurance for almost all phases of the life of a spacecraft, from launch through operations, but not all operators choose to purchase this insurance. In 2020, 46.5% of launches carried insured satellites. Of the approximately 4,100 active satellites in orbit in early 2021, only 276 are insured. Most of these are in geosynchronous orbit (GEO), where nearly half of all active satellites are insured. In low Earth orbit (LEO), less than 2% of satellites are insured.[12]

The increase in new launch companies and the proliferation of constellations of small satellites create new types of risks and increase volatility in the market. While the number of small insured launches has been increasing in recent years, many of these new actors do not purchase insurance. For example, SpaceX does not purchase insurance for its Starlink satellites.[13] The increase in risk posed by the increase in objects has led some companies to stop offering collision insurance for satellites in LEO.[14]

After two years in which claims exceeded premiums, space insurers saw net gains in 2020. Premiums amounted to $452.5 million while claims were $427.9 million.[15] Still, insurance rates have increased significantly since 2019, and insurers do not believe they are likely to go down in the near future as the industry continues to adjust to new technologies and methods of operation.[16]

Ground Stations and Equipment

Spacecraft operators use control stations on the ground to send commands to spacecraft and receive information on spacecraft health. Ground-based receivers, including satellite phones, terminals, dishes, and chipsets, allow end users to access data and signals from satellites. In 2020, the revenue associated with these ground stations and equipment was estimated at $118.4 billion, an increase of 6.4% from the $111.3 billion in 2019. Much of the revenue — 71.3% — in this category comes from the sale of global navigation satellite system devices, such as the GPS chips in cell phones. Revenues from GNSS equipment were estimated at $84.4 billion in 2020, an increase of 7.7% over estimated revenue for 2019.[17]

Space Situational Awareness and On-Orbit Servicing

Space is becoming increasingly congested, and satellite operators rely on Space Situational Awareness (SSA) data — information about where objects in space are and predictions of where they will be in the future — to avoid potential collisions. While much of this data comes from government space surveillance programs, particularly U.S. Space Command, commercial providers of SSA data and products have increased significantly in recent years. These companies provide additional data as well as tailored observation and analysis services.

While SSA providers help satellite operators avoid collisions and diagnose the cause of anomalies on orbit, the on-orbit servicing sector provides services to repair satellites that are damaged or refuel those that are nearing the end of their design life. Since 2000, 77 satellites in GEO have suffered anomalies that could potentially have been addressed with on-orbit servicing and many others could have benefited from life extension services, such as refueling.[18]

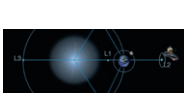
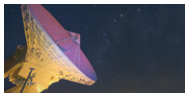
The first commercial on-orbit servicing mission — Northrop Grumman's Mission Extension Vehicle 1 (MEV-1) successfully docked with the Intelsat 901 spacecraft in February 2020 and will provide five years of life extension services before moving on to provide similar services to a new client spacecraft.[19] MEV-2 launched in August 2020 and docked with its client satellite in April 2021.[20] Numerous other companies hope to enter this market in the near future. Northern Sky Research estimated global revenues in the SSA and on-orbit servicing sector at nearly $40 million in 2020, more than double the $18 million in estimated revenue in 2019.[21]

Commercial Human Spaceflight

Commercial human spaceflight efforts continue to develop, inching nearer to operational flights. Virgin Galactic sold about 600 tickets at $250,000 per ticket before halting sales following the failure of a test flight. In 2020, the company allowed potential customers to put down a $1,000 refundable deposit toward the purchase of a future ticket. The company ended the campaign after receiving approximately 1,000 deposits. The company hoped to make its first operational flight, carrying founder Richard Branson in 2020, but it was accomplished on July 11, 2021, due to delays related to the pandemic. The company expects to reopen ticket sales after this flight, with higher prices than those offered to early purchasers.[22] Commercial flights are expected to begin in 2022.[23]

Virgin Galactic has also been making efforts to diversify its income streams. In October 2019, the company Virgin Galactic signed a contract with the Italian Air Force for a research and training flight that will produce $2 million in revenue. In 2020, the company signed an agreement with the Institute of Astronautical Sciences to fly a private researcher who will conduct experiments and technology demonstrations during a suborbital flight. NASA has a similar agreement and has selected a researcher that will test a camera and biomedical sensors. Virgin Galactic officials have stated that new agreements have been priced at about $600,000 per seat.[24] In 2019, the company went public via a special purpose acquisition company, raising additional funds.[25] Revenues for 2020 were reported at $0.2 million, significantly lower than the $3.8 million reported in 2019.[26]

Unlike Virgin Galactic, historically, Blue Origin did not open ticket sales or allow deposits to be made, a situation that continued through 2020. However, in May 2021, the company announced it would hold an auction for a seat on New Shepard's first crewed flight, which launched July 20, 2021. The winning bid was $28 million, but days before the flight,

the passenger declined.[27] Jeff Bezos and his brother Mark were on the July flight, as was aviation icon Wally Funk.[28] This flight was quickly followed by Blue Origin's second crewed flight in October, which included William Shatner on board.

The third major player in commercial human spaceflight is SpaceX. The company successfully launched humans for the first time in May 2020, in a demonstration flight for NASA's Commercial Crew Program. The first operational flight followed in November 2020 and the second in April 2021.[29] SpaceX launched its first fully commercial flight in September 2021. The flight, called Inspiration4, was funded by billionaire Jared Isaacman and included three other civilians who orbited the Earth in the Dragon capsule. Another commercial flight, organized by Axiom space and planned for January, will take three billionaires to the International Space Station, with each paying $55 million for the trip. They will be escorted by Axiom Vice President Michael López-Alegría, a former NASA astronaut.[30]

Commercial Space Products and Services

Commercial space products and services include direct-to-home television, satellite radio, Earth observation, and other businesses that rely directly on space assets. Value-added services built on satellite signals, such as the numerous GPS-enabled apps available on smartphones, also fall within this category. These commercial space products and services account for 61.5% of all global commercial space revenue. The total increased by 1.2% from $216.81 in 2019 to $219.44 in 2020.

Revenues for Commercial Space Products and Services, 2020

Category	Revenue	Source
Position, Navigation, and Timing	$97.11B	European GNSS Agency (GSA)
Direct-to-Home Television	$89.85B	Satellite Industry Association, Public Filings
Satellite Communications	$20.75B	Satellite Industry Association, Public Filings
Satellite Radio	$8.04B	Sirius XM Public Filings
Earth Observation	$3.70B	Northern Sky Research
Total	**$219.45B**	

Broadcasting

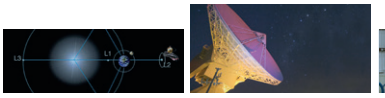
Satellites placed in geostationary orbit circle the Earth at a speed that allows them to appear stationary above one area of the Earth. This attribute makes them particularly useful in broadcasting television and radio signals, which can be received using a dish antenna or satellite receiver on the ground. Satellite television revenue totaled approximately $89.85 billion in 2020, a decrease of 2.3% from 2019.[31]

In the United States, the satellite TV market is dominated by DISH Network and DirecTV. DISH Network generated $12.9 billion in revenue in 2020, an increase of 0.7% from $12.81 billion in 2019.[32] AT&T, which acquired DirecTV in 2015, does not report revenue for its satellite activities separately.[33] However, both companies have reported decreasing subscribers as they face intense competition from other media companies, particularly those like Netflix, Hulu, and others that provide on-demand streaming services online.

DISH TV has responded by expanding its offerings, so that along with access to live TV channels, subscribers also get "DISH On Demand" streaming services and "DISH Anywhere" mobile applications that provide mobile access to content.[34] AT&T announced in February 2021 that it was spinning off DirecTV, along with AT&T TV and U-Verse. The value for the new company is estimated at $16.25 billion, significantly less than the $48.5 billion AT&T paid to acquire DirecTV in 2015.[35]

Satellite TV companies faced multiple challenges from the pandemic. Lockdowns and concern about virus spread reduced the ability of companies to perform in-house service operations. High unemployment and economic uncertainty also decreased the number of new subscribers. Many commercial subscribers, such as sports bars and restaurants were closed or operating at much lower capacity. The companies' own workforces, as well as their supply chains, were also affected by the pandemic, causing delays in service.[36]

Revenue from satellite radio operator Sirius XM totaled $8.04 billion in 2020, an increase of 3.2% from 2019. The company largely acquires customers when the customers purchase new cars. Sirius XM has agreements with every major automaker in the United States to offer satellite radios in their cars, with many including a subscription in the sale or lease of new vehicles. Shifts in the volume of auto sales due to the pandemic have created challenges and uncertainties for the business.[37]



Position, Navigation, and Timing

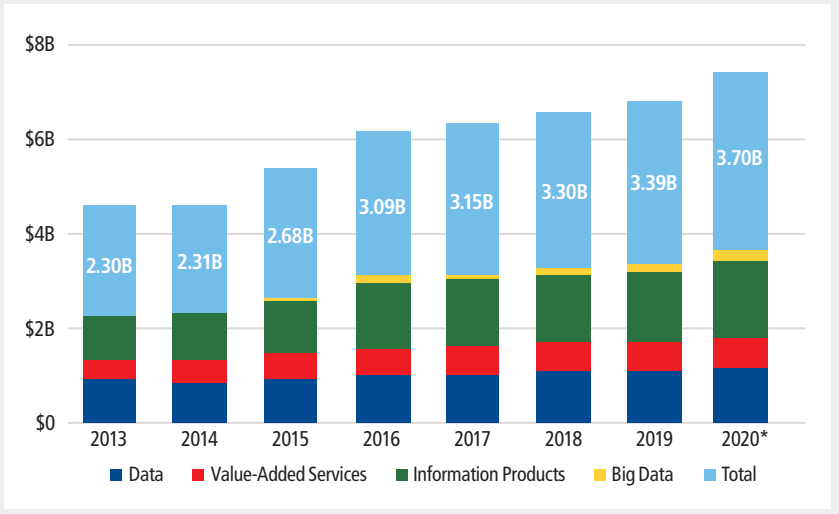
Multiple governments operate global satellite navigation systems, which rely on a constellation of satellites to provide position, navigation, and timing services around the globe. These systems, such as the U.S. Global Positioning System (GPS), are fully funded by governments, and provide these signals free of charge to end users. Many commercial entities have taken advantage of this, generating a vast market of value-added services built on positioning, navigation, and timing satellite signals. The European Global Navigation Satellite Systems Agency (GSA) estimates that the revenue from these value-added services totaled $97.11 billion in 2020, an increase of 6.6% from 2019.[38]

Communications

Communications satellites provide two-way data, voice, and video applications for users around the world with satellite phone and internet services. Traditionally split into fixed satellite services — relying on geostationary satellites and receivers in a fixed location on the ground — and mobile satellite services — using satellites in low earth orbit to serve customers moving around the Earth — this industry has become increasingly diverse in recent years. Companies have invested in a broad range of satellite assets and are targeting a wide array of potential customers, particularly those that operate in remote areas not well served by traditional phone and internet services. Estimated revenue was $20.75 billion in 2020, down 7.8% from 2019.[39]

New to this sector is a wave of companies aiming to use large constellations of small satellites to provide satellite internet. SpaceX's Starlink constellation is the furthest along, with nearly 1,000 satellites launched by the end of 2020.[40] The company began its first public beta test in October 2020. In January 2021, it expanded the beta test to include more areas within the United States, as well as Canada and the United Kingdom.[41] By May 2020, more than 500,000 people had placed an order or a deposit for the service.[42] Competitors OneWeb and Amazon's Project Kuiper have continued development but have not yet begun offering services.

Earth Observation Revenue, 2013-2020

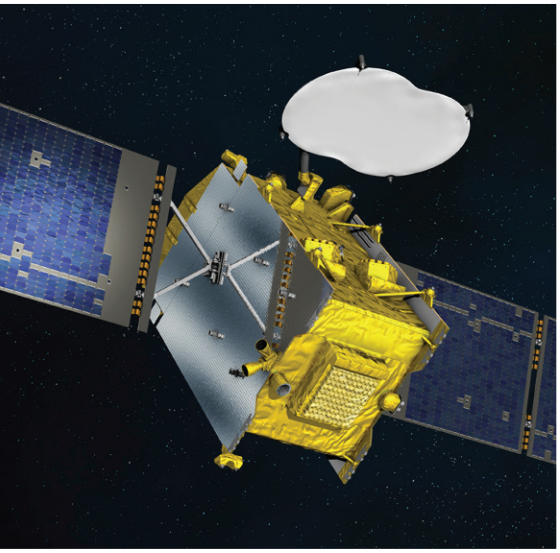


**Estimated Revenue*
Source: Northern Sky Research, Public Filings

Earth Observation

Earth observation satellites monitor the Earth from space, collecting a variety of types of data and imagery. Sometimes commercial entities sell the raw data collected by their satellites, but increasingly, companies are finding that value-added services and information products — created by processing the data or adding additional information, are of greater interest to customers. According to estimates by Northern Sky Research, total Earth observation revenues increased 9.1% from 2019 to 2020, from $3.39 billion to $3.70 billion.[43]

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.



Introduction | *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; launch vehicle 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.*

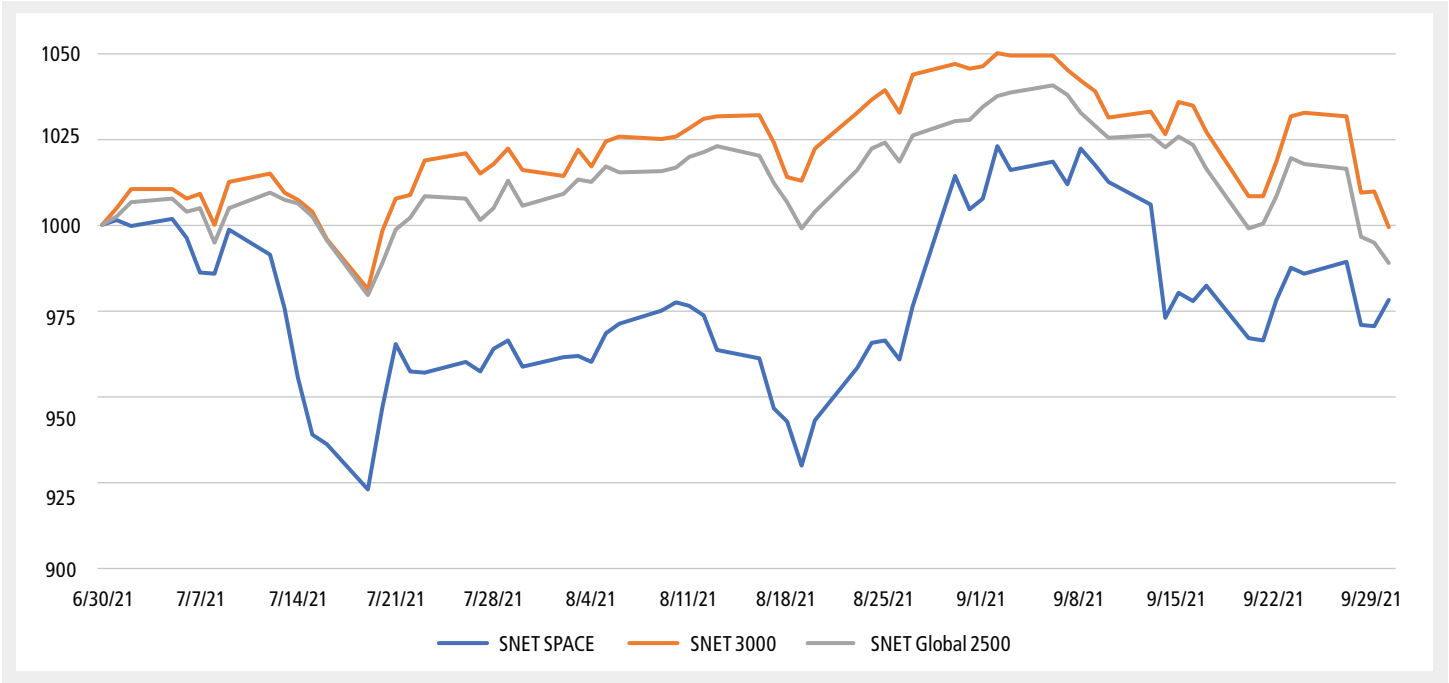
The Eutelsat Quantum, launched in July, is the world's first fully reprogrammable satellite. Eutelsat posted the highest Q3 earnings among space companies tracked by the S-Network Space Index.
Illustration: ESA

The S-Network Space Index℠ Q2 2021 Performance

Index Performance

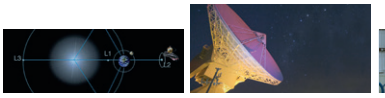
In the third quarter of 2021, the S-Network Space Index (SNET SPACE) underperformed other benchmark indexes, declining 2.2%. This compares to a 0.1% decrease for the S-Network U.S. Equity 3000 Index (SNET 3000), which tracks the 3,000 largest (by market capitalization) U.S. stocks. Similarly, there was a 1.1% decrease 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.

S-Network Space Index vs. Benchmark Indexes, Q3 2021

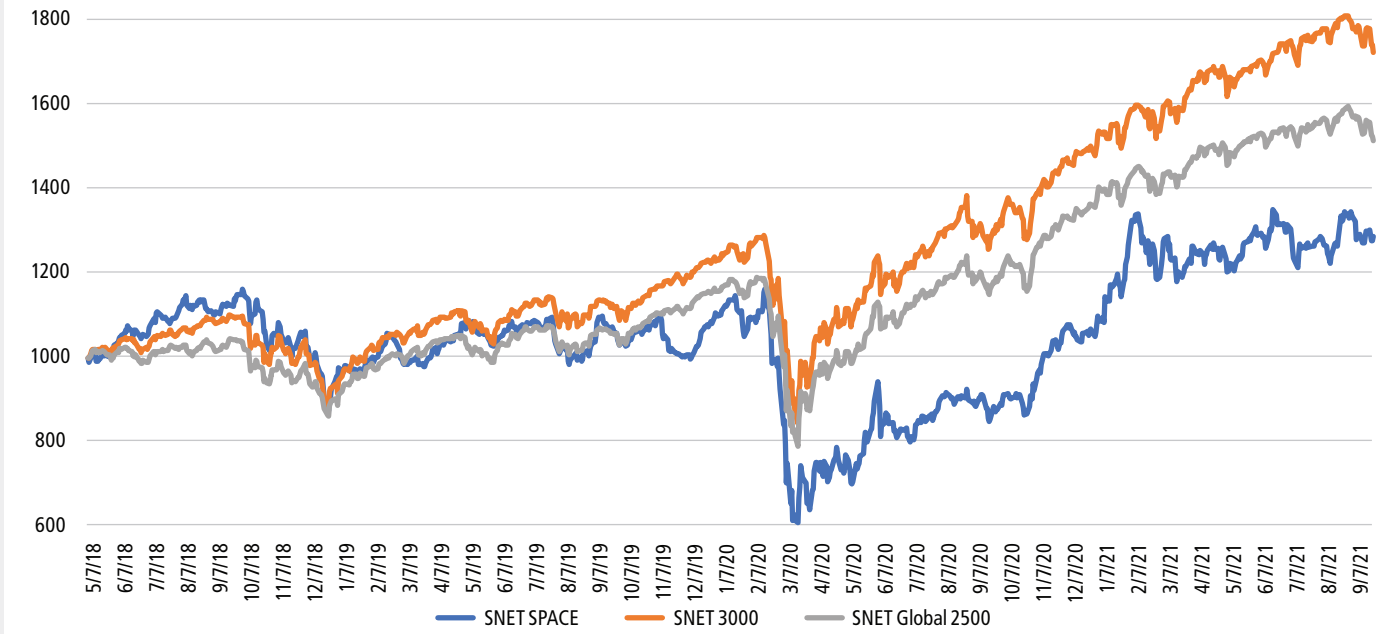


Note: Performance shown for each index is for the gross total return, assuming all dividends are reinvested.

Assessing the multi-year performance of the S-Network Space Index since live calculation began in May 2018, there remains a substantial gap that opened up in late 2019 and early 2020 between SNET SPACE and the other indexes. Over the lifetime of the index, SNET SPACE is up 30.0% as compared to growth of 72.7% for the SNET 3000 and 51.8% for the SNET Global 2500.



S-Network Space Index vs. Benchmark Indexes, May 7, 2018 – Sept. 30, 2021



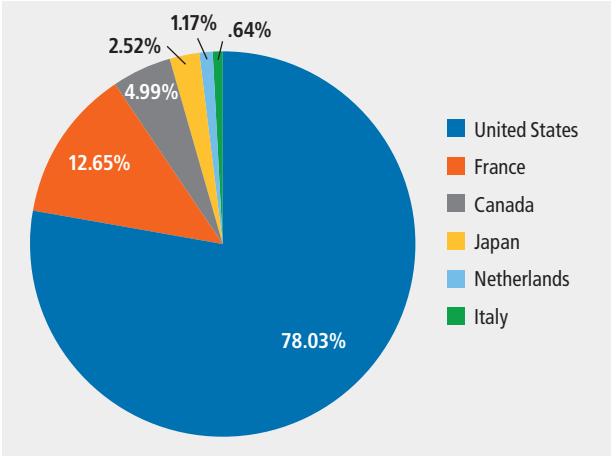
Note: Performance shown for each index is for the gross total return, assuming all dividends are reinvested.

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 Sept. 17, 2021, 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 to the index constituents on September 1, as satellite communications provider Orbcomm completed its acquisition by private investment management firm GI Partners. As a privately held company, Orbcomm is no longer listed on the Nasdaq Stock Market and has been removed from the index.

At the end of Q3, U.S.-listed companies comprised 78.03% of the weight of the overall index, with France in second place at 12.65%, Canada at 4.99%, Japan at 2.52%, the Netherlands at 1.17%, and Italy at 0.64%. Israel is not formally included because Gilat (0.81% of the index weight) is listed on both Israeli and U.S. exchanges, and the U.S. listing is used for the index due to higher trading activity.

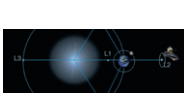
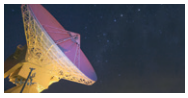
Index Weight by Listing Country as of Sept. 30, 2021



Q3 2021 Highlights

Performance of constituent companies in Q3 was evenly split, with 17 companies advancing while 17 declined. Individual results ranged from a decrease of 45% to an increase of 21%.

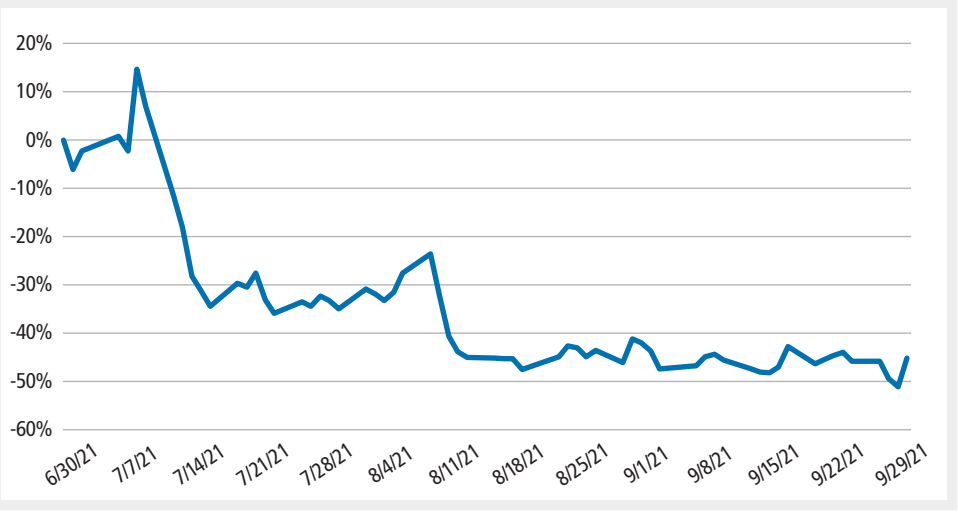
Stock performance for certain companies was driven by media stories, some of which involved real events while others were based on rumors. In the former category, Virgin Galactic (-45%) had been trending upward in Q2 in anticipation of founder Richard Branson's suborbital spaceflight as part of the first passenger flight by the company, which occurred near the beginning of Q3 on July 11. The momentary stock price peak following the successful

S-Network Space Index Constituents as of June 30, 2021

Company	Ticker	Country	2021 Q2 Performance
Aerojet Rocketdyne Holdings	AJRD	United States	-10%
Airbus	AIR	France	6%
AST SpaceMobile	ASTS	United States	-16%
AT&T	T	United States	-6%
Avio	AVIO	Italy	-13%
Ball	BLL	United States	11%
Boeing	BA	United States	-8%
Comcast	CMCSA	United States	-2%
Dish Network	DISH	United States	4%
Echostar Holding	SATS	United States	5%
Eutelsat Communications	ETL	France	21%
Garmin	GRMN	United States	7%
Gilat Satellite Networks	GILT	United States	-12%
Globalstar	GSAT	United States	-6%
Honeywell International	HON	United States	-3%
IHI	7013	Japan	9%
Iridium Communications	IRDM	United States	0%
L3Harris Technologies	LHX	United States	2%
Leonardo	LDO	Italy	4%
Lockheed Martin	LMT	United States	-9%
Loral Space & Communications	LORL	United States	11%
Maxar Technologies	MAXR	United States	-29%
MDA	MDA	Canada	0%
Northrop Grumman	NOC	United States	-1%
Raytheon Technologies	RTX	United States	1%
SES	SESG	France	20%
Sirius XM Holdings	SIRI	United States	-7%
SKY Perfect JSAT Holdings	9412	Japan	6%
Thales	HO	France	-2%
TomTom	TOM2	Netherlands	-3%
Trimble Navigation	TRMB	United States	1%
Viasat	VSAT	United States	10%
Virgin Galactic	SPCE	United States	-45%
Weathernews	4825	Japan	13%

Virgin Galactic Stock Performance, Q3 2021

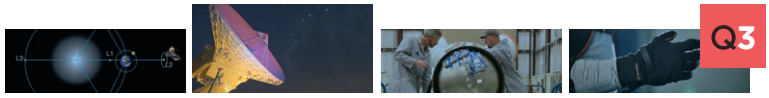


Source: Space Foundation database

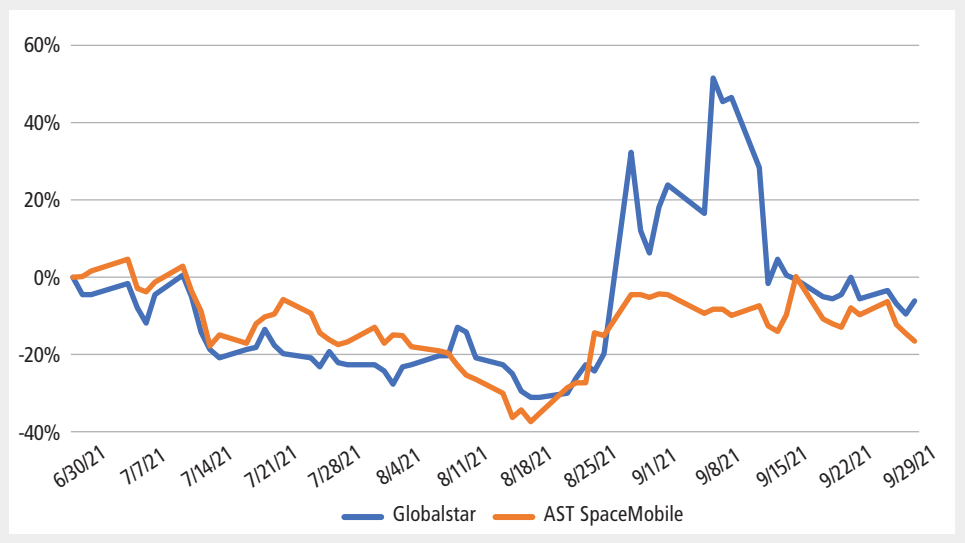
flight, and its accompanying media fanfare, quickly disappeared as the company announced the issuance of $500 million in additional shares the following day. This concerned investors who were expecting the company to begin revenue-generating operations with the cash and vehicles it currently has, rather than continuing to raise and spend substantial amounts of money to establish operations. In early August, the stock also declined as Branson sold off approximately $300 million of his shares in the company. Although he still retained a substantial ownership share of Virgin Galactic, investors reacted negatively to the sale as a possible indicator of the company's prospects.

In an example of rumor-driven market shifts, on Aug. 29 a report by TFI International Securities analyst Ming-Chi Kuo suggested that Apple would announce that the next-generation iPhone would include some degree of direct satellite connectivity. He also identified Globalstar as the satellite company most likely to partner with Apple on this effort.[1] As a long-standing source of rumors about Apple (with a mixed record), his report set off a flurry of pseudo-technical analysis that drove a significant spike in shares of Globalstar. When Apple held its annual iPhone event two weeks later, with no mention of satellite connectivity, Globalstar's stock promptly gave up its gains. Other satellite operators experienced a halo effect from the rumor, including index constituent AST SpaceMobile — a company that exists primarily to meet the expected market demand for direct-to-cellphone satellite connectivity, unlike Globalstar. Although AST SpaceMobile experienced a ramp-up in share price along with Globalstar, it did not suffer the same drop after Apple's iPhone event, presumably because it had attracted investors who were more interested in the long-term potential of its technology as highlighted by the media coverage surrounding Globalstar.

The entire Globalstar/Apple episode underscored several observations regarding investor interest and understanding of the space industry. First, as with Virgin Galactic's flight, key events can drive up sudden interest in space companies (whether based in reality or not).



Globalstar and AST SpaceMobile Stock Performance, Q3 2021



Source: Space Foundation database

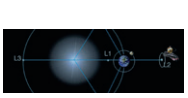
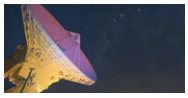
Second, financial analysts and investors are not necessarily equipped to evaluate the accuracy of rumors, but they can still be swayed to take a chance on a stock if the rumors involve major non-space companies with high name recognition. Third, space companies such as AST SpaceMobile that are recent entrants to the public market will likely rely on collaboration with their non-space partners (such as terrestrial network operators or major consumer brands) to build out their business and increase investor awareness.

Multiple space companies began to trade on exchanges across the world throughout Q3, and several will be added to the index in the December 2021 semi-annual reconstitution, provided they meet the index criteria. The cash raised by these companies during the process of going public is also having a ripple effect on the broader industry, regardless of whether the companies went through a traditional IPO or a transaction with a special purpose acquisition company (SPAC). In one example, U.S.-based remote sensing and analytics company Spire announced its acquisition of exactEarth, a Canadian company that uses satellites to monitor Automatic Identification System beacons aboard maritime vessels.[2] Assuming the transaction closes as expected in late 2021, exactEarth will become a fully owned subsidiary of Spire instead of an independent publicly traded company that has been listed on the Toronto Stock Exchange since 2016. From the perspective of the S-Network Space Index team, the deal takes a public space company that was too small to include in the index and adds its value to a new public company that has a much larger market capitalization and trading volume. Other recent market entrants may also seek acquisitions as a way to demonstrate to shareholders that they are delivering the growth that was promised as they went public. It will be interesting to see how the markets react to these efforts and how that affects the behavior of the companies going forward.

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 USD $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:

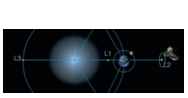
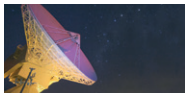
- The company was the prime manufacturer (i.e., the contractor responsible for managing subcontractors and delivering the product to the customer) for a satellite in the past five years.
- The company was the prime manufacturer or operator of a launch vehicle in the past five years.
- The company currently 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.

Quilty Analytics: Q3 21 Equity Financing Maintains Record Yearly Trend

The third quarter of 2021 represented the fifth consecutive quarter of elevated transaction activity across the satellite and space markets. In Q3 21, there were 16 space-related acquisitions/buyouts, 55 private placements and venture equity financings totaling $1.7 billion in funds raised, and nine public offerings (inclusive of three pending de-SPAC transactions) totaling $2.9 billion in gross proceeds.

Q3 21 M&A Review

The year-ago comparable period (Q3 20) included a "bounce-back effect" following the COVID freeze. M&A activity was slightly down year-over-year from 18 deals in Q3 20 to 16 deals in Q3 21, but also up sharply on a sequential basis over the last quarter from 11 to 16. While financial sponsor-driven activity remains a key theme (particularly in the enablement category for space segment businesses that support rapidly growing government and defense programs), Q3 21 was more well-rounded as strategic buyers upped their participations.

BAE Systems acquired UK-based In-Space Missions for its range of SmallSat domain expertise, including its Faraday-hosted payload offerings. BAE is now the fifth major aerospace and defense contractor to acquire or invest in a SmallSat company in recent years, the other four being: Lockheed Martin Ventures' investment in Terran Orbital, Boeing's acquisition of Millennium Space, Raytheon's acquisition of Blue Canyon Technologies, and General Atomics' acquisitions of Tiger Innovations and Surrey Satellite Technology U.S. These transactions enable defense prime contractors to internalize a range of low-Earth orbit (LEO) capabilities previously dominated by startups. Additionally, Airbus and Thales Alenia Space have U.S. joint ventures for high-rate production of smaller spacecraft platforms (Airbus-OneWeb Satellites and LeoStella, respectively).

We anticipate further activity in small spacecraft production as contractors seek to add foundational capability and critical systems/payload expertise to support what is arguably the fastest-growing arena in space: mission-critical government programs in LEO. Raytheon Technologies' September acquisition of SEAKR Engineering, a key supplier of satellite avionics and data management, is consistent with this theme.

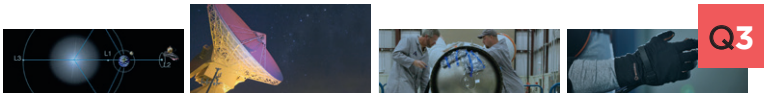
Private Equity (PE) once again played a major role in space industry consolidation, with multiple private-equity firms continuing to seek footholds in space. In Q3 21, there were four PE sponsor-backed transactions, the largest being Providence Equity Partners' acquisition of satcom maritime business Marlink for $1.4 billion. On the Enablement side, there were three sponsor-backed transactions: ATL Partners' acquisition of GEOST (Quilty Analytics advised GEOST in this transaction), Arlington Capital Partners' acquisition of L3Harris' Electron Devices Narda Microwave-West divisions, and Arcline Investment Management's add-on of BEI Precision System & Space to its Quantic Electronics platform.

Finally, we expect satcom ecosystem M&A to resume its consolidation over the next several quarters. Stimulated by operators' need to reach downstream, increasing clarity on LEO broadband strategies, a still-fragmented market, and cash injections from U.S. C-band spectrum proceeds, the satcom industry will continue to evolve markedly. On a related note, in Q3 21, SpaceX acquired Swarm Technologies for its spectrum assets related to Starlink — a surprising move for the usually-insular SpaceX (financial details were not disclosed).

Q3 21 Equity Financing Activity Review

Equity financing activity in the space sector posted another near-record high in Q3 21 following the prior quarter's all-time high. Third-quarter equity financings nearly doubled to 55 from 28 in the same period of last year (Q3 20).

LEO broadband led the way with three equity financings in Q3 21, including OneWeb's $300 million investment from Hanwha and Telesat's two financing announcements: $519 million from the government of Canada and $109 million from the government of Ontario.

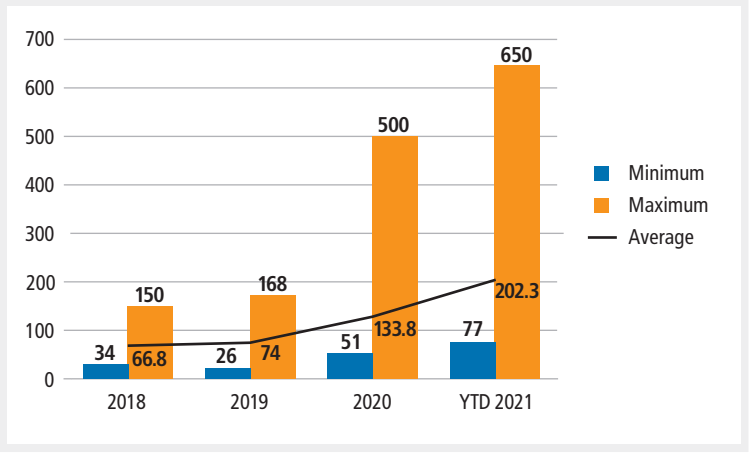


We broadly see two key themes at play regarding equity financings in space:

- Increasing average financing round sizes, demonstrating a growing appetite by larger funds and later-stage funds to invest in space (breaking down previous barriers that existed just two years ago before space became a "hot" sector), and
- A greater volume of seed and early stage investments as entrepreneurs capitalize on new ideas, disruption, and increased financing available for space companies.

A summary of equity financing size for the top 10 space financings by year for 2018 to 2021 (year to date) tracks recent growth:

Top 10 Equity Financings, 2018-YTD 2021

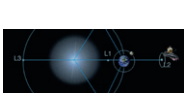
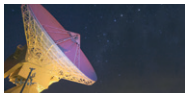


Note: Table includes only satellite and space companies that announced venture-like financings.
Source: Quilty Analytics

With still-high (though falling) cost of market entry for many space companies, large financing rounds are often necessary to operationalize systems or technologies. In years past, companies would often attain Series A, and sometimes Series B, rounds before struggling to raise the requisite later-stage expansion capital. Today, this dynamic has shifted, making larger rounds possible and creating a critical mass of new innovation for the industry at large. We are optimistic that these changing financing dynamics will lead to a more resilient and robust space sector in the long term, provided that new investors are jumping into the sector with "eyes wide open" regarding the particular risks of space (launch failure, on-orbit anomalies, the heavy role of government, etc.).

Second, a growing volume of seed and pre-venture financings is occurring. New entrants are establishing space businesses against a ripe backdrop of insatiable investor demand and a conducive macro and sector environment. Not coincidentally, increasing later-stage fundraising success begets increased early-stage financing activity. It is not clear within the current industry cycle what percentage of the newer entrants will reach success (or perhaps survive at all, in the case of many "me-too" issuers), but it is a trend to watch closely.

Public equity financing activity increased sharply in Q3 21 with nine public financings raising a collective $2.9 billion. Following a vibrant late-2020 to early 2021 Special Purpose Acquisition Company (SPAC) environment for space, public offering activity was more subdued in Q2 21 but rocketed higher in Q3 21, including transactions for Planet, Satellogic, and Virgin Orbit. Additionally, Yahsat is the first operator to complete a traditional Initial Public Offering (IPO) in recent memory, raising $731 million. Virgin Galactic had the only follow-on offering shortly after its successful demonstration flight, raising $500 million. Two other unique public offerings were Astrocast's direct listing on Euronext Growth Oslo and Seraphim Capital's IPO of a collection of its space investment assets into Seraphim Space Investment Trust Plc, raising $250 million.

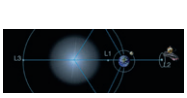
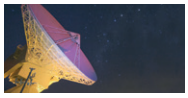



Announced	Target	Acquirer / Investor	Transaction (US$ Mil)	TEV / LTM Adj. EBITDA	Sub-Sector
Acquisitions / Buyouts			**Ent. Value**	**Valuation**	**Type**
07/23/21	Ultra Electronics Holdings plc	Cobham Limited	$3,592	17.3X	Other
09/13/21	Marlink (majority stake)	Providence Equity Partners	1,400	n.d.	Satcom
09/14/21	exactEarth Ltd.	Spire Global Inc.	161	n.m.	EO/Geospatial
07/06/21	Design and Development Engineering Services Corporation ("DDES")	BlueHalo	n.d.	n.d.	Enablement
07/13/21	Alpha Space Test & Research Alliance (merger)	MEI Technologies, Inc.	n.d.	n.d.	Other
07/14/21	Facebook's satellite team	Amazon	n.d.	n.d.	Satcom
08/03/21	L3Harris Technologies' Electron Devices & Narda Microwave-West divisions	Arlington Capital Partners	n.d.	n.d.	Satcom
08/09/21	Swarm Technologies	SpaceX	n.d.	n.d.	Satcom
08/12/21	Stellatus Solutions LLC	Slingshot Aerospace, Inc.	n.d.	n.d.	EO/Geospatial
08/17/21	Micro Aerospace Solutions	Phantom Space Corporation	n.d.	n.d.	Enablement
08/17/21	BEI Precision Systems & Space Company, Inc.	Quantic Electronics (Arcline Investment Management)	n.d.	n.d.	Enablement
08/19/21	GEOST, LLC	ATL Partners	n.d.	n.d.	Enablement
08/19/21	Intelligent Automation, Inc.	BlueHalo	n.d.	n.d.	Other
09/14/21	In-Space Missions	BAE Systems	n.d.	n.d.	Enablement
09/14/21	SEAKR Engineering, Inc.	Raytheon Technologies	n.d.	n.d.	Enablement
09/23/21	Systima Technologies	Karman Missle & Space Systems	n.d.	n.d.	Other
Private Placements (Equity) & Related			**Investment**	**Valuation**	**Type**
08/12/21	Telesat Lightspeed	Government of Canada	$519	n.m.	Satcom
08/11/21	OneWeb	Hanwha Systems	300	3,400	Satcom
08/06/21	Telesat Lightspeed	Government of Ontario	109	n.m.	Satcom
08/19/21	Beijing MinoSpace Technology Co.,Ltd.	Consortium of investors	77	n.m.	Enablement
07/28/21	Isar Aerospace	Led by HV Capital, Porsche SE, and Lombard Odier	75	n.m.	Enablement
07/11/21	SpaceIL	Consortium of investors	70	n.m.	Other
08/04/21	Sceye	Led by KittyHawk Ventures	50	n.m.	EO/Geospatial
08/09/21	Space Transportation	Led by Matrix Partners China	46	n.m.	Enablement
08/04/21	ispace	Led by Incubate Fund	46	n.m.	Enablement
07/14/21	Cape Analytics	Led by Pivot Investment Partners	44	n.m.	EO/Geospatial
07/22/21	Accion Systems	Tracker Capital	42	n.m.	Enablement
07/29/21	Varda Space Industries	Led by Khosla Ventures & Caffeinated Capital	42	n.m.	Enablement
09/27/21	Isotropic Systems	Led by Serpahim Space Investment Trust Plc	37	n.m.	Satcom
08/09/21	Istar Space Technology Co., Ltd.	Consortium of investors	31	n.m.	Enablement
07/27/21	Space Pioneer (Beijing Tianbing Technology Co., Ltd.)	Consortium of investors	30	n.m.	Enablement
08/17/21	Kairos Aerospace	Led by DCVC	26	n.m.	EO/Geospatial
09/16/21	HySpecIQ	Peter Thiel	20	n.m.	EO/Geospatial
07/15/21	Kolmostar	CTC Capital	16	n.m.	Other
07/15/21	GHGSat	Led by the Government of Québec's Investissement Québec	15	n.m.	EO/Geospatial
09/20/21	Near Space Labs	Led by Crosslink Capital	13	n.m.	EO/Geospatial
08/26/21	EnduroSat	EIB's European Guarantee Fund	12	n.m.	Enablement
09/13/21	Earth Observant	Undisclosed	11	n.m.	EO/Geospatial
09/07/21	Orbit Fab Inc.	Led by Asymmetry Ventures	10	n.m.	Enablement
09/01/21	BlackSky Holdings, Inc.	Palantir Technologies Inc.	8.0	n.m.	EO/Geospatial
09/14/21	Cambium Biomaterials, Inc.	Undisclosed	8.0	n.m.	Enablement
09/22/21	Xona Space Systems	Co-led by Seraphim Space Investment Trust (LSE:SSIT) and MaC Venture Capital	8.0	n.m.	Other
09/28/21	Starfish Space	Co-led by NFX and MaC Venture Capital	7.0	n.m.	Enablement
07/27/21	R3-IoT	Led by Space Capital	4.3	n.m.	Satcom
08/19/21	Urban Sky	Led by Catapult Ventures and Union Labs	4.1	n.m.	EO/Geospatial
09/28/21	Astrome Technologies	Led by IAN Fund, Urania Ventures, & Lakshmi Narayanan (founder of Cognizan	3.4	n.m.	Satcom
08/09/21	SpeQtral	Led by Xora Innovation	3.3	n.m.	Other
07/15/21	Digantara	Kalaari Capital	2.5	n.m.	Enablement
08/03/21	Alpine Advanced Materials	Undisclosed	2.5	n.m.	Enablement
07/18/21	Agile Space Industries	Led by Greenline Ventures LLC	2.1	n.m.	Enablement
08/16/21	Turion Space Corp.	Undisclosed	2.0	n.m.	Enablement
09/17/21	Aurora Propulsion Technologies	Led by Practica Capital	2.0	n.m.	Enablement
08/23/21	Bright Ascension	Consortium of investors	1.4	n.m.	Other
08/10/21	Spaceit	Led by Icebreaker.vc	1.2	n.m.	Other
09/08/21	Launchspace Technologies Corporation	Crowd-funding platform NetCapital Funding Portal Inc.	1.1	n.m.	Enablement
07/05/21	3D Planeta	Led by Concrete Ventures	1.0	n.m.	EO/Geospatial
09/01/21	Payload Aerospace	Consortium of investors	0.7	n.m.	Enablement
09/15/21	Payload	Led by Winklevoss Capital	0.7	n.m.	Other
07/13/21	ElevationSpace Inc.	Consortium of investors	0.3	n.m.	Enablement
08/04/21	Epsilon3	Y Combinator	0.1	n.m.	Other
08/04/21	Latitudo40	Undisclosed	0.1	n.m.	EO/Geospatial
07/08/21	Isotropic Systems	Seraphim Capital	n.d.	n.m.	Satcom
07/08/21	Commodities AI ("CdAI")	Seraphim Capital	n.d.	n.m.	EO/Geospatial
07/09/21	Space Forge	Led by Type One Ventures and Space Fund	n.d.	n.m.	Enablement
07/15/21	SCOUT	CIT GAP Funds	n.d.	n.m.	Other
07/20/21	CILAS	Led by Lumibird	n.d.	n.m.	Other
08/05/21	Hermeus	Led by USAF	n.d.	n.m.	Other
08/11/21	Cemvita Factory Inc.	Led by 8090 Partners	n.d.	n.m.	Other
08/25/21	High Earth Orbit Robotics	Led by David Harding (founder of Winton Group)	n.d.	n.m.	Enablement
08/25/21	Vyoma	Atlantic Labs	n.d.	n.m.	Other
08/30/21	Inversion Space	Undisclosed	n.d.	n.m.	Other
Public Equity and Related			**Gross Proceeds**	**TEV**	**Type**
07/09/21	Al Yah Satellite Communications Co. (Yahsat)	IPO	$731	$1,874	Satcom
07/07/21	Planet	dMY Technology IV	545	2,250	EO/Geospatial
07/12/21	Virgin Galactic	ATM offering	500	8,222	Other
08/23/21	Virgin Orbit	NextGen Acquisition Corp. II	483	3,218	Enablement
07/06/21	Satellogic	CF Acquisition Corp. V (SPAC)	350	850	EO/Geospatial
07/07/21	Seraphim Space Investment Trust Plc	IPO	250	n.a.	Other
08/25/21	Astrocast	Direct listing on Euronext Growth Oslo	52	n.m.	Satcom
09/06/21	Kleos Space S.A.	PIPE	9	103	EO/Geospatial
07/22/21	FLYHT Aerospace Solutions Ltd.	PIPE	5	n.a.	Other

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

Our Expectations

Q3 21 transaction activity continued near peak levels due to a confluence of favorable capital markets conditions, an increasingly "investable" range of space-related companies, and highly bullish buyer and investor sentiment.

What do we see on the horizon? Strategics and financial sponsors will remain highly active in M&A, particularly focused on mission-critical assets and businesses supporting rapidly growing government space programs. Traditional aerospace and defense companies are seeking to establish or expand their space activities. On the equity financing side, large rounds are growing in amount and frequency, while small rounds are also becoming more numerous, capitalizing on current attractive macro and industry trends.

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.

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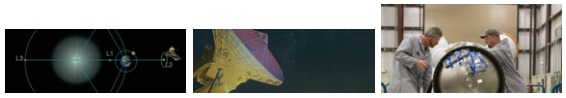


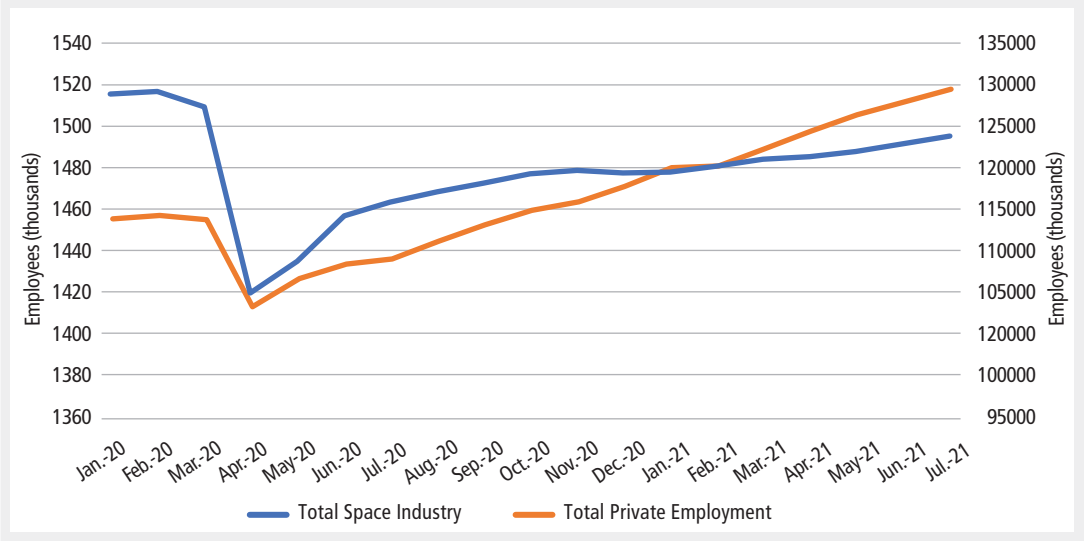
Introduction | *The latest employment data from the U.S. Bureau of Labor Statistics shows that the U.S. space industry has recovered from the initial pandemic shutdown drop and has surpassed January 2020 employment, while total private employment is still below pre-pandemic levels by 3.5%.*

Employment in the guided missile and space vehicle sector has grown nearly 5% since January 2020. Seen here, technicians assemble Orion's abort motor at the U.S. Army's White Sands Missile Range. *Source: NASA*

Space Industry Workforce Recovers to Pre-Pandemic Levels; Guided Missiles and Space Vehicles Saw Continued Growth Throughout Pandemic

New employment data through July 2021 indicates that while a few space-related job sectors have seen continued loss, the overall private space industry has recovered and grown since January 2020.

U.S. Employment and Space-Related Employment, Jan. 2020 – July 2021



Note: Both functions are graphing total employment in thousands for their respective industries; however, they are graphed on separate scales to illustrate the similar trends. Total space industry employment is scaled on the left while total private employment is scaled on the right
Source: Space Foundation, U.S. Bureau of Labor Statistics

Looking at the larger space industry by using a combination of relevant job codes under the North American Industry Classification System (NAICS), the space employment trend is similar to the total private industry pandemic trend but slightly less elastic. Space industry employment fell 2.9% during the initial employment cuts in April 2020 compared to the total private employment drop of 15.4%, according to data from the U.S. Bureau of Labor Statistics (BLS). However, the space industry also had a slower initial recovery than total employment (0.96% compared to 3.1% in May 2020) before maintaining growth at a near constant rate since July 2020. The latest employment data from July 2021 shows that the space industry has recovered from the initial drop and has surpassed January 2020 employment, while total private employment is still below pre-pandemic levels by 3.5%.

It should be noted that these are broader NAICS codes available for monthly analysis and are not as specific by industry as more detailed NAICS codes available for quarterly BLS analysis. There are non-space activities in some of the NAICS categories involved in this space industry estimate, but it is an indicator of overall space-related activity. The three industries most closely related to the private space industry are: Guided missiles, space vehicles, and parts (336414,5,9); Broadcast and wireless communications equipment (33422); and Other telecommunications (5174,9).

Industry Title	NAICS Code	July YOY Employment Growth
Guided missiles, space vehicles, and parts	336414,5,9	3.22%
Search, detection, and navigation instruments	334511	-0.29%
Power and communications system construction	23713	3.00%
Broadcast and wireless communications equipment	33422	4.48%
Other telecommunications	5174,9	-0.67%
Plate work and fabricated structural products	33231	3.85%
Research and development in physical, engineering, and life sciences	54171	9.25%

Source: U.S. Bureau of Labor Statistics

In a breakdown by industry, five out of seven NAICS codes saw year-over-year (YOY) growth in July 2021. This trend represents recovery from the initial pandemic employment cuts as well as continued growth in the case of industries that did not have a large drop in employment in Q2 2020. The two industries that had negative YOY employment growth had a loss of less than 1%. Both industries did not see a large drop in employment during the start of the pandemic, which indicates other factors may be the cause of their employment decline.

Guided missiles, space vehicles, and parts (NAICS codes 336414, 336415 and 336419)

Month	Employment (thousands)
Jan-20	88.7
Feb-20	88.7
Mar-20	89.2
Apr-20	**89.1**
May-20	89.3
Jun-20	89.4
Jul-20	90
Aug-20	90.2
Sep-20	**90**
Oct-20	**89.8**
Nov-20	90.4
Dec-20	90.6
Jan-21	91.6
Feb-21	91.9
Mar-21	92.4
Apr-21	92.8
May-21	92.9
Jun-21	93.2
Jul-21	**92.9**
Total Change	**+4.735%**

Source: U.S. Bureau of Labor Statistics

The performance of one sector in the space industry stands out over the period of employment data. Guided missiles, space vehicles, and parts saw almost no initial employment drop in April 2020, and the industry has even maintained its steady growth throughout the pandemic. Compared to total private employment in July 2021, which recovered to only 4.1% higher than employment levels in July 2015, Guided missiles, space vehicles, and parts employment has increased by 33.3% over five years, according to BLS monthly data.

Industry performance during the pandemic did not slow down, as the number of space launches increased from 2019 to 2020. Launches in the first half of 2021 also hit a five-year record high. The U.S. industry is partially supported by U.S. military and NASA contracts, which were not affected heavily by the pandemic. As the U.S. Space Force has been established and reorganized, it increased the number of contracts signed through the Space Enterprise Consortium. It expects to reach a total contract value of $1 billion in its first year after the expansion announcement.[1]

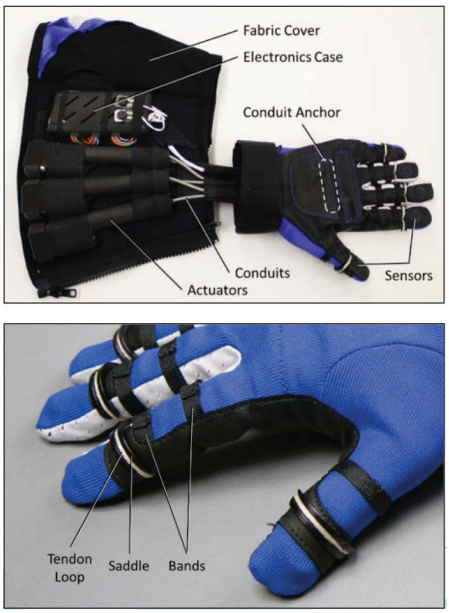
Zoe Hobbs is an economist and research analyst at Space Foundation.

Introduction | *Exoskeletons that optimize human movements have been a staple of science fiction for decades, but the needs of astronauts aboard the International Space Station (ISS) have brought one such tool to life. Developed by NASA researchers and patented for commercial development, the RoboGlove ergonomically assists the wearer with by reducing the hand force needed to use tools during repetitive, exhaustive tasks in challenging environments.*

Bioservo developed the Ironhand, an exosekeleton for optimizing hand gesture ergonomics, using NASA's patented RoboGlove technology.
Source: Bioservo

Getting Torqued: NASA, GM Glove Technology Adds Power, Ease to Manual Tasks

General Motors and NASA began to work together in 2009 after noticing how much of a problem hand fatigue is, especially when working in bulky, pressurized spacesuit gloves.[1] They conceived the Human Grasp Assist while developing the Robonaut 2 (R2), the first humanoid robot in space.



The features that comprise the RoboGlove, from wrist to fingertips.
Source: National Institute of Standards and Technology

Johnson Space Center adapted the Human Grasp Assist into the RoboGlove, a lightweight, tech-boosted glove that enables users to grip tools and perform repetitive movements painlessly for extended lengths of time.

Integrating RoboGlove technology into gloves provides about 10 lbs. of continuous grip strength augmentation.[2] The RoboGlove implements a hybrid rigid and soft solution to optimize force transmission, such as in its palm bar, which uses material embedded with rigid 3D-printed components.[3] Pressure sensors in the glove's fingertips, akin to the ones that provide R2 with its sense of touch, detect when a user is grasping something, and the synthetic tendons then automatically pull the wearer's fingers into a gripping position where they are held until released.[4] The Roboglove also uses rigid saddles around the fingers to distribute the force from the glove's tendon loop evenly and to prevent cinching of the cable loop around the finger.[5] A battery pack worn on the belt or as a backpack provides power.

Internal trials on the RoboGlove starting in 2012 put the technology's possible applications across industries on display. The success of early trials was limited due to poor glove fit; researchers nonetheless accomplished numerous jobs, including installing door glass, crimping, installing weather strips, grasping power tools in a variety of applications, stamping/die pulls where tongs are used, and using a mallet in general assembly. Further tests measured grip strength, assessed dexterity with timed tasks, and examined subjective fatigue and neuromuscular effort.[6]

RoboGlove has potential beyond space applications to assist manual laborers, such as construction workers, hazardous material workers, or assembly line operators, whose jobs require continuous grasping and ungrasping motion. It also has potential applications in prosthetic devices and rehabilitation aids and may be leveraged to serve people with impaired or limited arm and hand muscle strength. NASA has made the technology available to companies to license or commercialize.[7]

The IronHand being utilized on a construction site.
Source: Bioservo

Ironhand: From the Research Lab to the Factory Floor

A study by the Chalmers University of Technology in Gothenburg, Sweden, determined that 48% of all injuries reported in a factory involved hand and wrist injuries.[8] Hand injuries are the second-most common type of workplace injury according to the U.S. Bureau of Labor Statistics[9] and can be expensive to treat — anywhere from $540 to $26,000 per incident, according to the National Safety Council.[10]

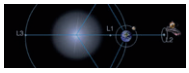
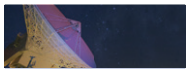
Recognizing these risks, Bioservo licensed the RoboGlove design from NASA in 2016 and partnered with GM to develop the glove for its workers. GM helped Bioservo test and improve the Ironhand by piloting it in a variety of jobs at its manufacturing plants.[11] Bioservo Technologies released an updated version of the Ironhand, deemed Ironhand 2.0, in June 2021, complete with improved activation, better grip, and advanced data collection. The company simultaneously launched the IronConnect Pro application, which collects analytical information from the glove when it is in use and summarizes the data into ergonomic risk assessment reports to track the risk of injury and prevent it.[12]

Conclusion

The RoboGlove concept and the subsequent development of the Ironhand are one of the more recent examples of the NASA Technology Transfer Program providing space technology to commercial developers for on-Earth use. The success of this collaboration between government researchers and industry hints at the future such joint work can achieve, and the actualization of exoskeleton technology provides a glimpse of the possibilities space technology yields here on Earth. ABI Research estimated in 2020 that the exoskeleton market, then valued at US$392 million, will grow to US$6.8 billion in global revenue by 2030.[13]

The IronConnect Pro app in use.
Source: Bioservo

Becki Yukman is a senior data analyst for Space Foundation.

SPACE FOUNDATION

Thomas Dorame
Senior Vice President
Space Foundation

RESEARCH & ANALYSIS

Lesley Conn
Senior Manager

Becki Yukman
Senior Data Analyst

Zoe Hobbs
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

Steve Edelman
Editor

Shawn Huff
Wendy Perelstein
Web Support

Dennis Thompkins
Researcher

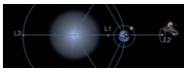
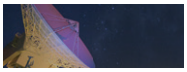
Design Development Team
ROMIE LUCAS
graphic design & illustration

QUILTY analytics

Chris Quilty
Founder and Partner
Quilty Analytics

Justin Cadman
Partner
Quilty Analytics

Caleb Henry
Senior Analyst Quilty Analytics

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Section 1 | Space Infrastructure

Six Telescope Launches to Watch this Decade

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Despite Pandemic, Double-digit Growth in 2020 in Some Commercial Sectors

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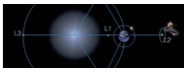
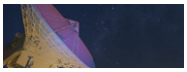

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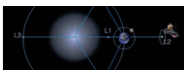
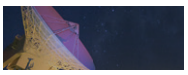

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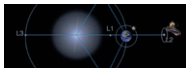
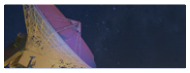

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