

**Written Testimony of Tom Stroup
President, Satellite Industry Association
Before the
United States Senate Committee on Commerce, Science, and Transportation
Subcommittee on Communications, Technology, Innovation, and the Internet

Hearing on
Launching Into The State of the Satellite Marketplace**

Chair Latta and Ranking Member Matsui and distinguished Members of the Subcommittee, thank you for inviting me to testify before you today. I am Tom Stroup, President of the Satellite Industry Association (SIA).¹ SIA is a U.S.-based trade association that represents the leading satellite operators, service providers, manufacturers, launch services providers, space situational awareness companies, and ground equipment suppliers.

Satellites are the backbone of modern society. We rely on them for communications, position, navigation and timing, and remote sensing across the globe. In addition to the vast range of services offered by the industry today, the companies represented by SIA are poised to lead the U.S. into an interconnected and data-driven future.

We are at a time of explosive innovation in the space industry, with over 7,000 active satellites on orbit today² and plans for tens of thousands more through the end of the decade.

¹SIA Executive Members include: Amazon; The Boeing Company; DIRECTV; EchoStar Corporation; HawkEye 360; Intelsat S.A.; Iridium Communications Inc.; Kratos Defense & Security Solutions; Ligado Networks; Lockheed Martin Corporation; Northrop Grumman; OneWeb; Planet Labs PBC; SES Americom, Inc.; Spire Global Inc.; and Viasat Inc. SIA Associate Members include: ABS US Corp.; The Aerospace Corporation; Artel, LLC; AST & Science; Astranis Space Technologies Corp.; Aurora Insight; Blue Origin; Comtech; Eutelsat America Corp.; ExoAnalytic Solutions; Hughes; Inmarsat, Inc.; Kymeta Corporation; Leonardo DRS; Lynk; Omnispace; OneWeb Technologies; Ovzon; Panasonic Avionics Corporation; Peraton; SpaceLink; Skyloom; Telesat; ULA and XTAR, LLC. SIA Affiliate Members include: ARA; ATG; Davis Wright Tremaine; EVONA; Genus Group; Hogan Lovells; Integrasys LLC; Kencast; Keysight Technologies, Inc.; Media Broadcast Satellite; Orange Business Services; Orbital Research; Plexus Corp; SD Government; Sheppard Mullin; Skylo Technologies and Wiley

² “NORAD GP Element Sets Current Data”, CelesTrak, 30 January 2023 <https://celestrak.org/NORAD/elements/>

Before more fully exploring the innovation in the industry, it is important to understand the breadth of service provided by satellite companies.

Americans have long relied upon satellites to provide direct to home TV, satellite radio, and distribution of programming to cable companies as well as to TV and radio broadcasters. The satellite industry provides FCC-defined broadband service today across the globe and is prepared to bring the furthest corners of America into the 21st Century by serving as the most viable technology capable of bridging the digital divide in rural areas as well as working to bring the nation into an interconnected future as a backbone for 5G, IoT, and Artificial Intelligence (AI) technologies. Satellite technology will not only enable U.S. leadership domestically, but will be an essential foundation as we set up a permanent lunar space station.

Satellites today provide anytime, anywhere global connectivity to consumers, utilities, supply chain logistics providers, the IoT community, cruise and other ships, airlines, and unmanned aerial vehicles. Soon, we will be living in a world where an autonomous car can update its operating system while driving anywhere in the world via a satellite link, spectators at a football game will be able to connect to satellite and use augmented reality to revisit plays on smart glasses in real-time, and connected sensors on infrastructure will be able to determine potential failures as well as directly deploy satellite-connected UAVs to inspect even the most remote sites. Geospatial satellite data has not only transformed environmental monitoring, but also provides essential business analytics from monitoring remote infrastructure to analyzing supply chain performance. When integrated with geolocation data provided by Global Positioning System (GPS), AI can be used in real time to redirect resources and optimize output.

In addition, satellites play a critical role in preparation, response, and recovery from national disasters, electrical outages and terrorist attacks. Unlike terrestrial communications

counterparts, satellite networks are not susceptible to damage from such disasters because the primary repeaters are onboard the spacecraft and not part of the ground infrastructure. Hand-held terminals, portable Very Small Aperture Terminal (VSAT) antennas, and temporary fixed installations can all be introduced into a post-disaster environment to provide support to relief and recovery efforts. In addition, the deployment of direct to mobile satellite connectivity will greatly expand the range of communications available in emergencies. Remote sensing satellites are used to provide better weather forecasting through both optical sensors and by measuring the refraction of GPS signals in the Earth's atmosphere to achieve better weather profiles. Remote sensing data and analytics can also help pinpoint where damage has occurred and what routes to the location are still accessible. Furthermore, synthetic aperture radar satellites can see through clouds and allow the mapping of damaged regions when storms are still overhead.

Satellite technology is transforming agriculture across America. Satellite broadband, for instance, enables remote farms with livestock sensors, soil monitors, and autonomous farming equipment in rural America, far beyond where terrestrial wireless and wireline can reach or make economic sense to deploy. Precision GPS technologies allow farmers to increase crop yield by optimizing use of fertilizer, pesticides, herbicides, and applying site-specific treatments to fields. Earth imaging satellites provide regular high-resolution imagery that allows farmers to determine when to plant, water, or fertilize crops and can be used to provide crop yield estimates and monitor global food security. Satellite advances in weather forecasting help farmers prepare for drought, floods, and other adverse weather conditions.

Satellites are not only a core technology for our domestic future but also play a crucial role today for advancing our national security priorities and partnerships abroad. Satellite

communications have been a lifeline in Ukraine, where terrestrial infrastructure has been destroyed. Earth imaging satellites allow for unprecedented monitoring and analysis of areas of concern. This commercial imagery is often shareable with partner nations and the general public and has been a game changer in providing near-real time transparency into the Russian invasion of Ukraine. These images have enabled the world to more effectively respond to the humanitarian crisis in Ukraine and better understand the ever-changing situation on the ground. Synthetic aperture radar satellites can see through clouds, and thus, for instance, can provide insight into North Korea's military operations during the 50% of the time the country is cloud-covered. Remote sensing satellites are also capable of mapping radiofrequency transmissions, at the level of a handheld radio in space, and have been critical in monitoring the movement of Russian troops in Ukraine and detecting sources of GPS interference. From troops on the ground to the largest remotely piloted aircraft, our military relies on space and will need to utilize the most advanced technologies to lead it in the IoT and AI battlefield applications of the future.

The satellite industry today is investing constantly to ensure it can address the challenges of the future and to make its technologies available to every American. Satellite companies are working to optimize the use of spectrum, by investing in high-throughput satellites and flexible, software defined payloads that allow for instantaneous reallocation of spectrum resources and the mitigation of harmful interference. Costs are dropping for both space and ground systems through the use of modular satellites, digital engineering, intersatellite links and cloud-integrated ground stations, which minimize the need for expensive ground architecture. Flat panel and phased-array antennas lower consumer costs and enable better connectivity that has been essential to the deployment of non-geostationary satellite constellations. Launch costs have also declined dramatically, a result of reusable rockets, enhanced in-space transportation and

improved separation technologies that provide opportunities for ridesharing through the launch of over 100 satellites on a single launch.

The U.S. satellite industry is continuously gaining momentum, with estimated revenue of \$179 billion in 2021.³ However, this figure does not reflect revenues generated from businesses which rely on satellite services behind the scenes. Satellites remain a pillar of U.S. infrastructure, enabling the American economy in ways consumers might not be aware, such as supporting smartphone app transactions, to use just one example. We are submitting for the record SIA's State of the Satellite Industry Report, which includes detailed economic analysis, and SIA's Satellite 101 briefing, which provides further information on satellite technologies.

While the U.S. has long led the space sector, China trails close behind, with similar investments in space technologies that not only will be transformative in times of conflict, but also undermine international democracy. China is investing in navigation, communications, and remote sensing systems to rival the U.S.; it has already launched its BeiDou Global Navigation Satellite System to rival GPS and provides free military-grade service to some of its allies. It has planned a constellation of 13,000 communications satellites, as well as remote sensing constellations from optical to radar. As these services are offered below market rate or free of charge globally, with them will come backdoor security risks for the China to exploit as exist with Huawei. It is critical for Congress to support continued domestic innovation and avoid regulations that put U.S. providers on an unequal playing field internationally.

The U.S. satellite industry is set to revolutionize daily life as we move into a more interconnected world where change on Earth is more visible than ever. In order to ensure the success of the U.S. satellite industry both domestically and globally, the industry needs:

³ Satellite Industry Association, State of the Satellite Industry Report 2022

1. Assured access to the spectrum that enables these technologies, from communications frequencies to remote sensing data downlinks. As we approach the World Radiocommunications conference, strong interagency coordination is needed to preserve the spectrum needed for satellite operations and enable the use of future satellite technologies.
2. Technology inclusive policies, allowing for innovative solutions across domains to address America's most challenging needs including the provision of broadband services at the most affordable rates.
3. Adequate funding for government agencies responsible for oversight and licensing of the industry to enable them to keep up with the rapid pace of growth in the sector.
4. A level playing field with international competitors, including the removal of satellite technologies from restrictive export-control regulation when international commercial alternatives exist.

I appreciate the opportunity to appear before you and I am happy to answer any questions.



INTRODUCTION TO THE SATELLITE INDUSTRY

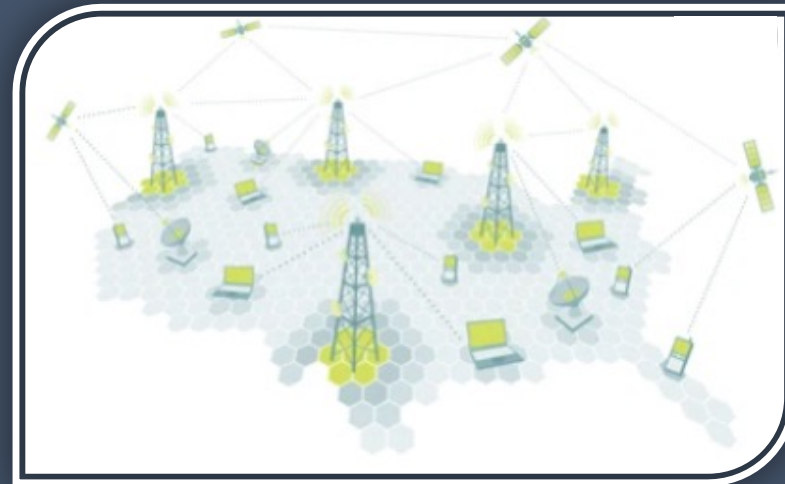
SATELLITE INDUSTRY ASSOCIATION

Satellites Are The Backbone of Modern Society

Remote Sensing



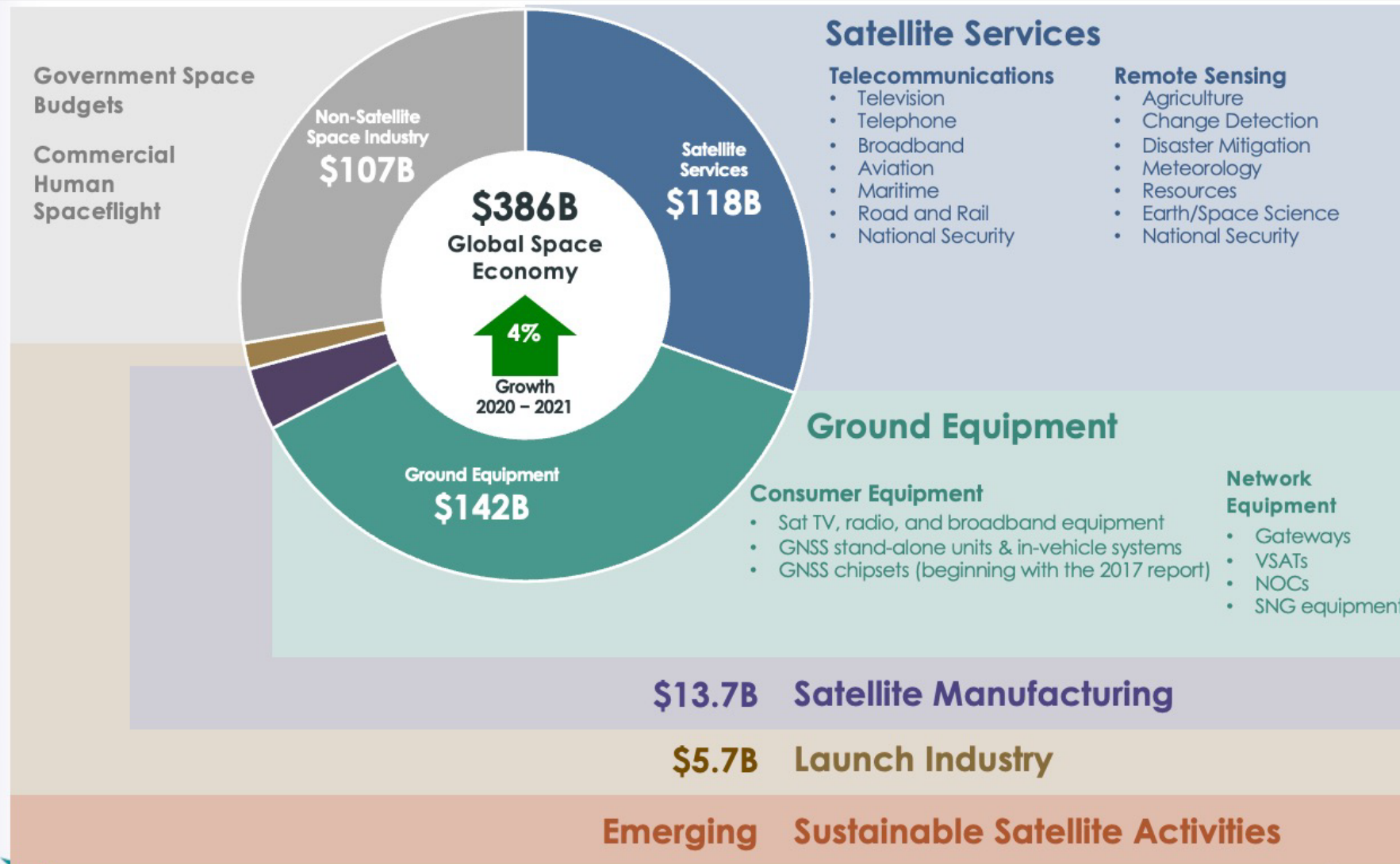
Satellite Communications



GPS



The Satellite Industry in Context



Satellite Services

Telecommunications

- Television
- Telephone
- Broadband
- Aviation
- Maritime
- Road and Rail
- National Security

Remote Sensing

- Agriculture
- Change Detection
- Disaster Mitigation
- Meteorology
- Resources
- Earth/Space Science
- National Security

Ground Equipment

Consumer Equipment

- Sat TV, radio, and broadband equipment
- GNSS stand-alone units & in-vehicle systems
- GNSS chipsets (beginning with the 2017 report)

Network Equipment

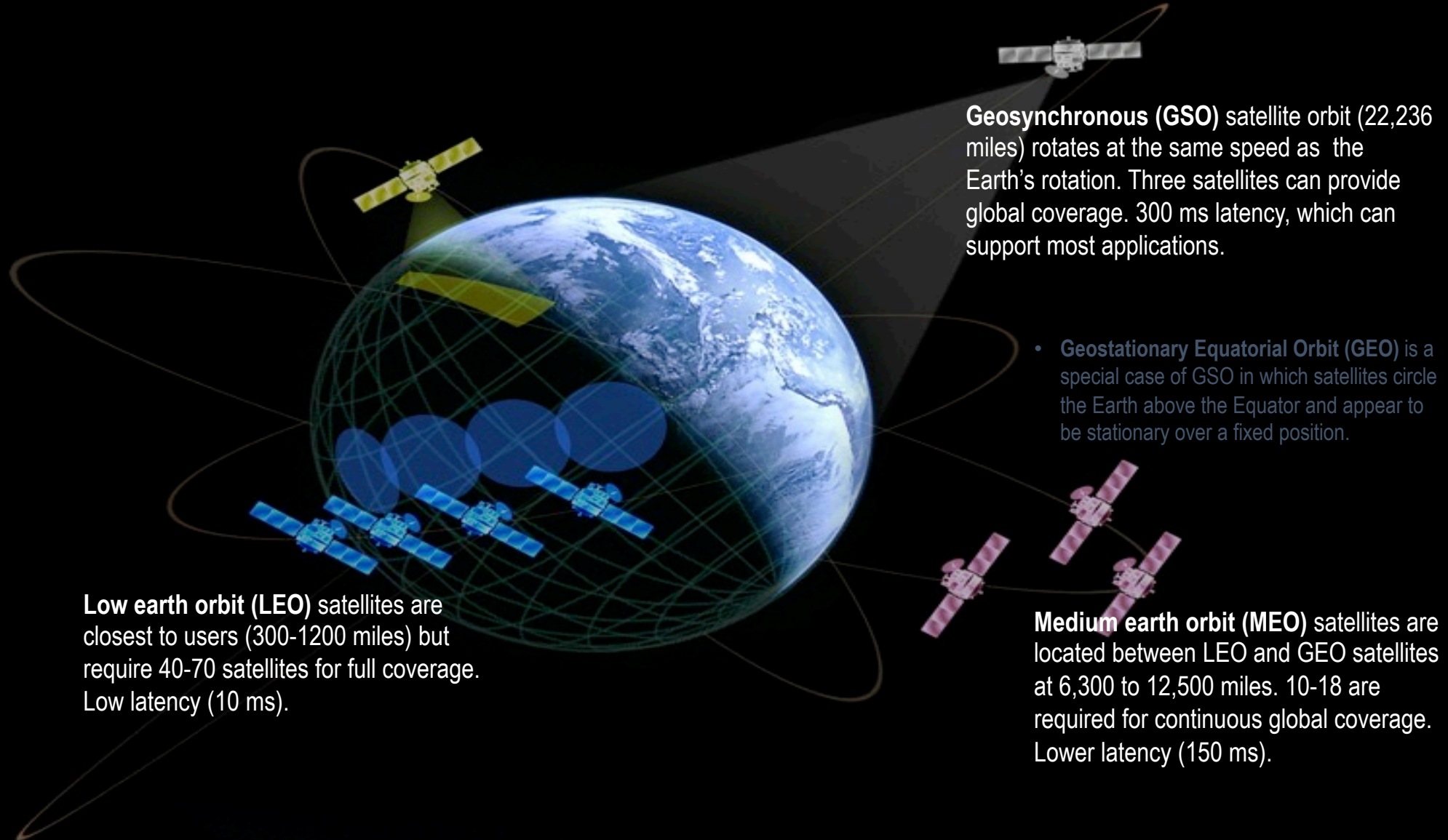
- Gateways
- VSATs
- NOCs
- SNG equipment

\$279B
Satellite Industry
(72% of Space Economy)

Government space budgets include civil and military spending by 70 countries, ESA. Commercial human spaceflight includes commercial missions to ISS, suborbital and orbital flights.

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Satellites Provide Services at a Range of Altitudes



Low earth orbit (LEO) satellites are closest to users (300-1200 miles) but require 40-70 satellites for full coverage. Low latency (10 ms).

Geosynchronous (GSO) satellite orbit (22,236 miles) rotates at the same speed as the Earth's rotation. Three satellites can provide global coverage. 300 ms latency, which can support most applications.

- **Geostationary Equatorial Orbit (GEO)** is a special case of GSO in which satellites circle the Earth above the Equator and appear to be stationary over a fixed position.

Medium earth orbit (MEO) satellites are located between LEO and GEO satellites at 6,300 to 12,500 miles. 10-18 are required for continuous global coverage. Lower latency (150 ms).

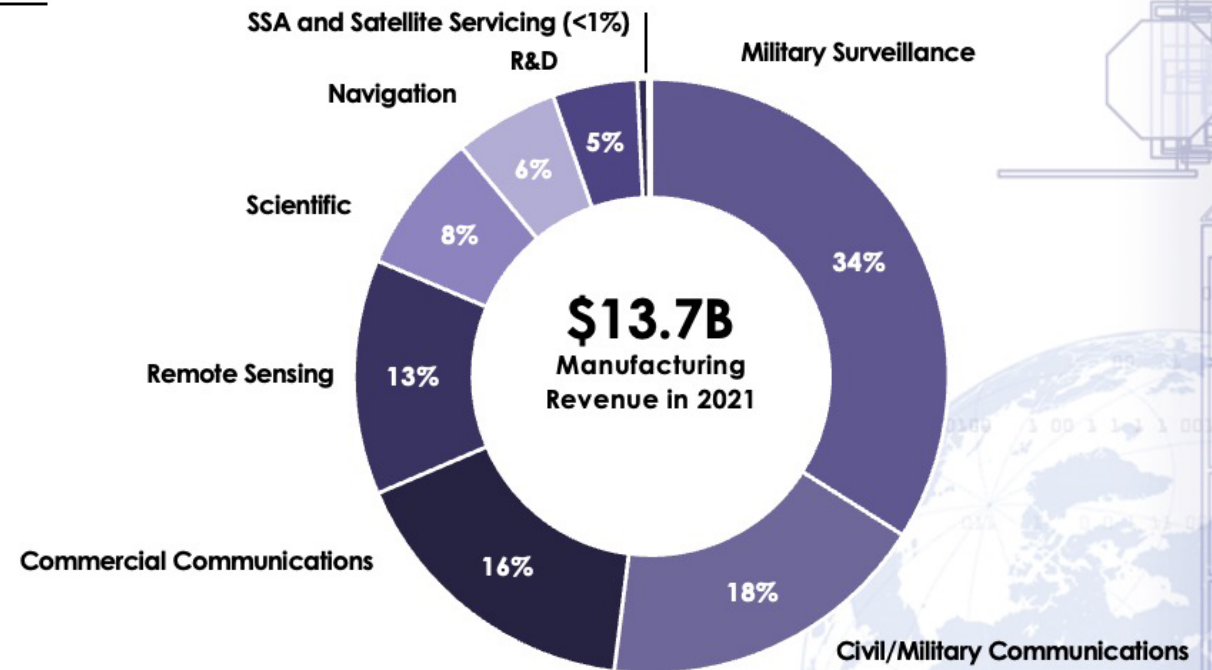
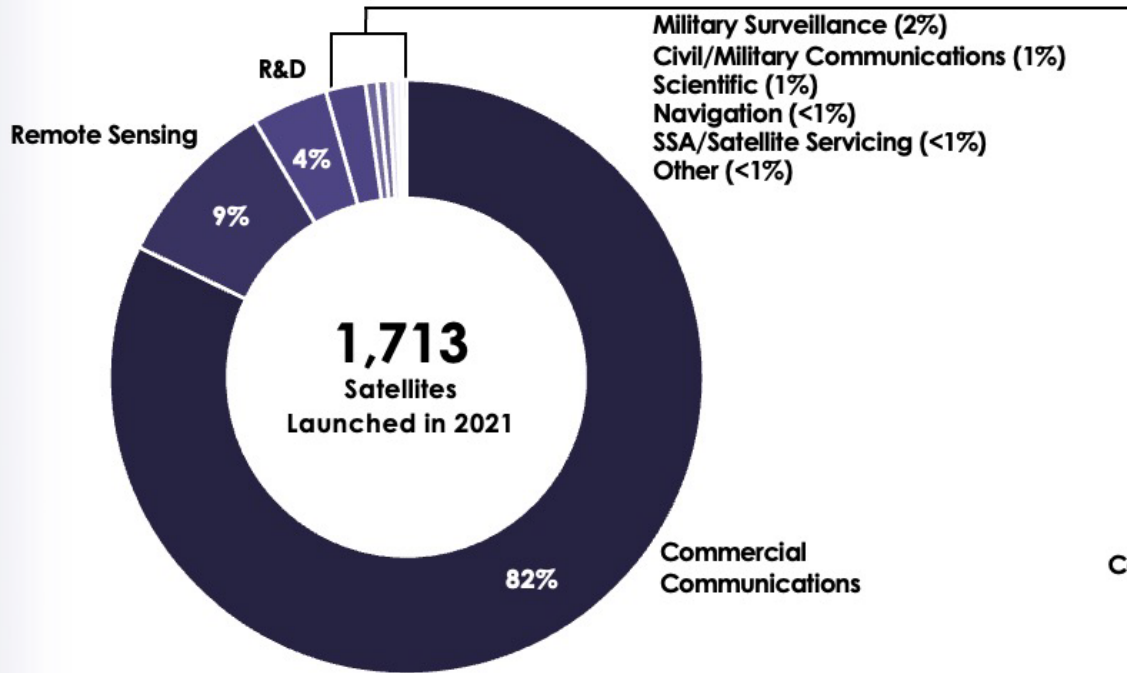


Satellite Manufacturing Findings



- Worldwide 2021 revenues totaled \$13.7B; increase 12.2%
- 1,713 commercially-procured satellites launched in 2021; 519 more than in 2020
- 1,635 commercially-procured smallsats ($\leq 600\text{kg}$) launched (1,140 in 2020)

- Communications satellites represented 16% of total revenues, compared to 15% in 2020
- Military surveillance satellites accounted for 34% of revenues, compared to 41% in 2020



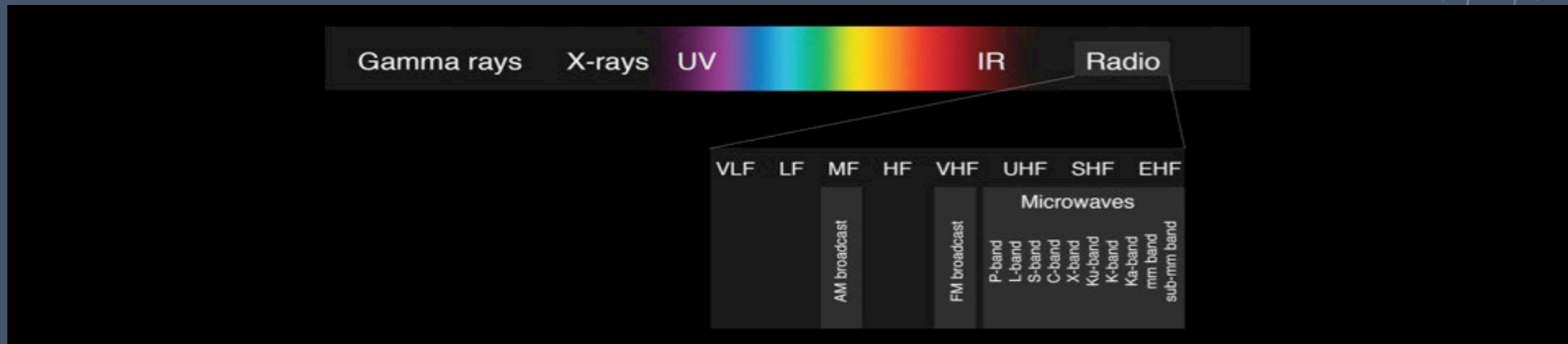
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Number of Satellites Launched, by Mission Type

Value of Satellites Launched, Estimated by Mission Type



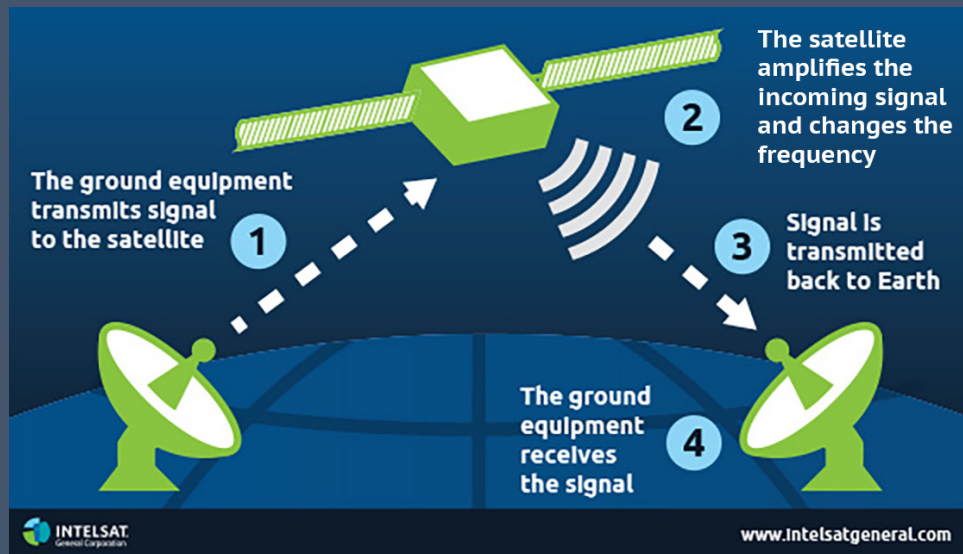
Satellites Operate In A Wide Range of Frequency Bands



The International Telecommunication Union (ITU) allocates international commercial satellite spectrum (via companies' governments):

VHF/UHF	30 MHz- 1 GHz	Telemetry, Tracking, and Command (TT&C), Internet of Things applications, Earth Exploration Satellite Service (EESS)
L-band	1-2 GHz	Mobile services (MSS), Radionavigation Satellite Services (RNSS)
S-band	2 – 2.9 GHz	MSS, EESS, satellite radio (DARS), TT&C
C-band	3.4 – 6.7 GHz	Fixed satellite services (FSS), RNSS, TT&C
X-band	8 – 12 GHz	EESS, Military/satellite imagery and communications
Ku-band	10.7 – 18.1 GHz	FAA, satellite TV/broadcast, FSS “broadband” , TT&C
Ka-band	17.3 – 21.2 GHz and 24.25 – 31 GHz	FSS “broadband” and inter-satellite links, EESS, TT&C
Q/V-band	33-75 GHz	FSS, inter-satellite links, EESS
W-band	75-100 GHz	FSS, MSS, EESS

Satellite Networks Include a Variety of Space and Ground Systems



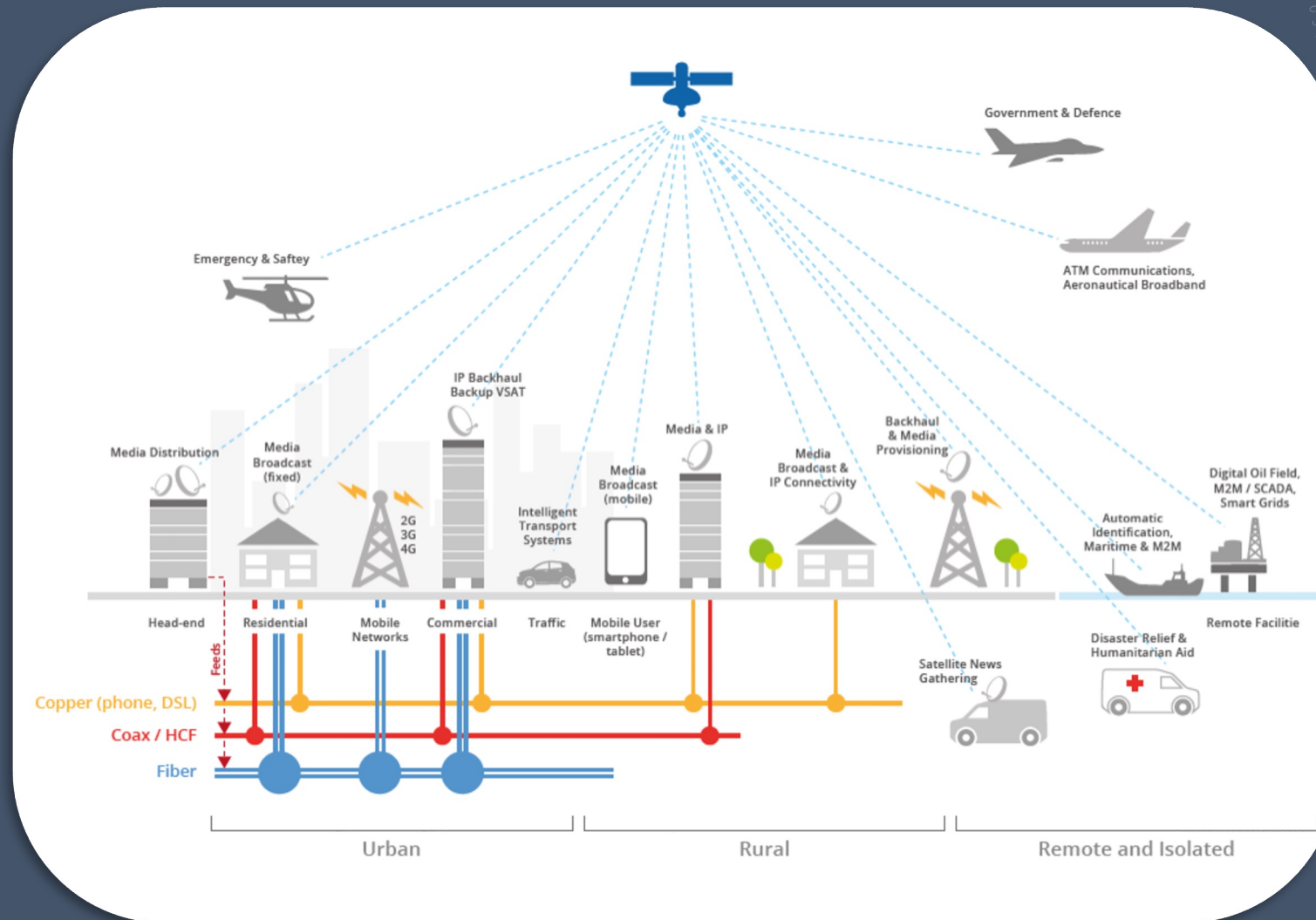
Space Segment

- Satellites in Geostationary Orbit or Non-Geostationary Orbit (Medium Earth Orbit, Low Earth Orbit, Highly Elliptical Orbit)

Ground Segment

- Telemetry, Tracking, and Control (TT&C): used to “fly” the satellite
- Gateway/Hub: used to manage communications
- User Terminals: devices used to connect the customer to the satellite network
 - Can be receive-only or transmit; mobile or fixed; a dish, a laptop, or a handheld, depending on the application, site, etc.

Satellites Provide a Variety of Fixed and Mobile Communications Services



Communications Satellite Ground Equipment Provides Solutions for a Wide Range of Needs



Teleport with many
earth stations



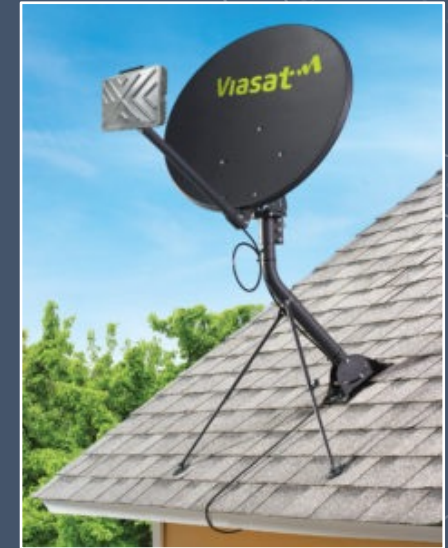
VSAT dishes for private
networks and credit
cards



Mobile platforms
on ships, planes



Receivers for laptops,
cell phones with
converter sleeve;
direct to phone
services demonstrated



Satellite Innovation is Improving Capacity and Reach

- High-Throughput Satellites utilize spot beam technology and frequency reuse to increase capacity more than 20x
- Dynamic spectrum use allows for reallocation of spectrum to most-needed areas
- Flat panel antennas are being developed to enhance communications on the move
- Constellations of tens to thousands of smaller NGSO satellites beginning to provide low-latency broadband worldwide

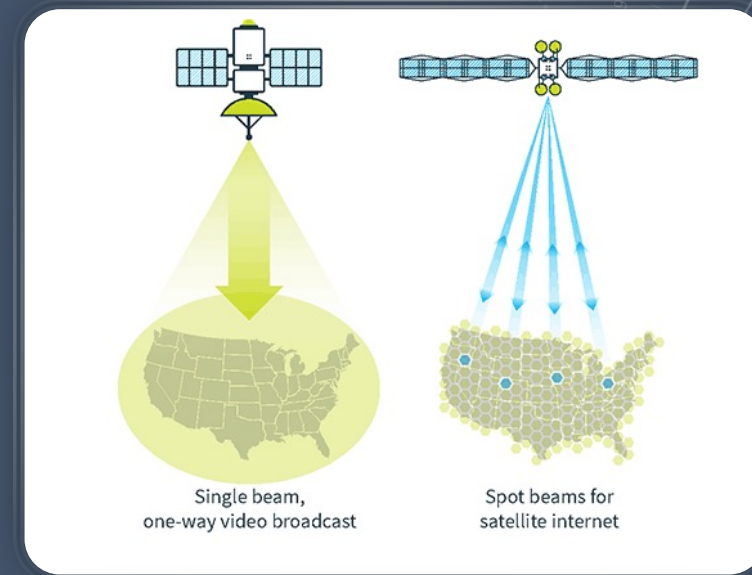


Image credit: Viasat (top), Hughes (bottom)

Satellite Imagery Monitors the Entire Earth Daily, Provides High-Resolution Detail

Satellites can image the Earth in many different ways:

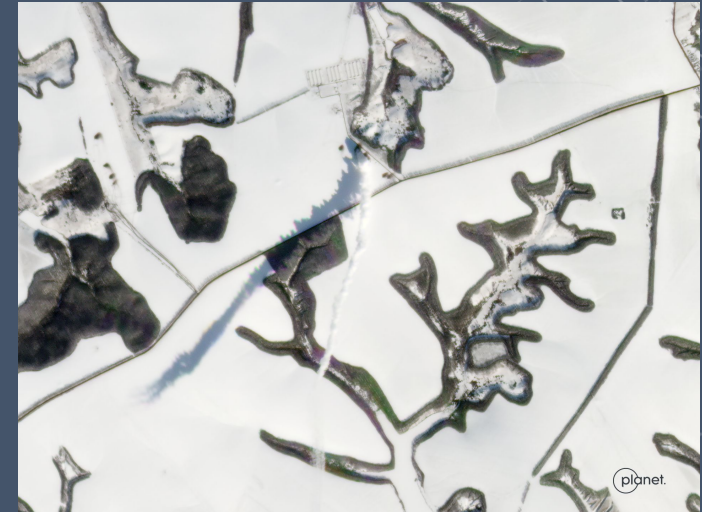
- Visible: natural color or black & white images
- Infrared: capturing wavelengths the human eye can't see; this can see through smoke, determine vegetation health, identify materials, etc.
- Radar: active satellite sensors send radar signals to Earth and measure how long it takes to come back, creating the image; these satellites work in all weather conditions and during the day and night.

Applications:

- Defense and intelligence: mission planning, situational awareness
- Humanitarian Aid and Disaster Response (HADR)
- Commercial: Maps for autonomous vehicles and infrastructure planning and monitoring

Technological advances:

- Resolution: U.S. satellites collect imagery as sharp as 30 cm, leading the world's capabilities
- Revisit: U.S. satellites can increasingly monitor the world by imaging a single location multiple times within a single day.
- Access: Imagery is now more easily obtained. Combining cloud storage with cloud computing allows users to leverage AI and machine learning to extract insights from imagery at scale.



Planet satellite captures Russian Rocket Attack on Ukraine in Belgorod Oblast, 3/4/22

Remote Sensing Is Expanding into Non-Imaging Analytics

Types of sensors:

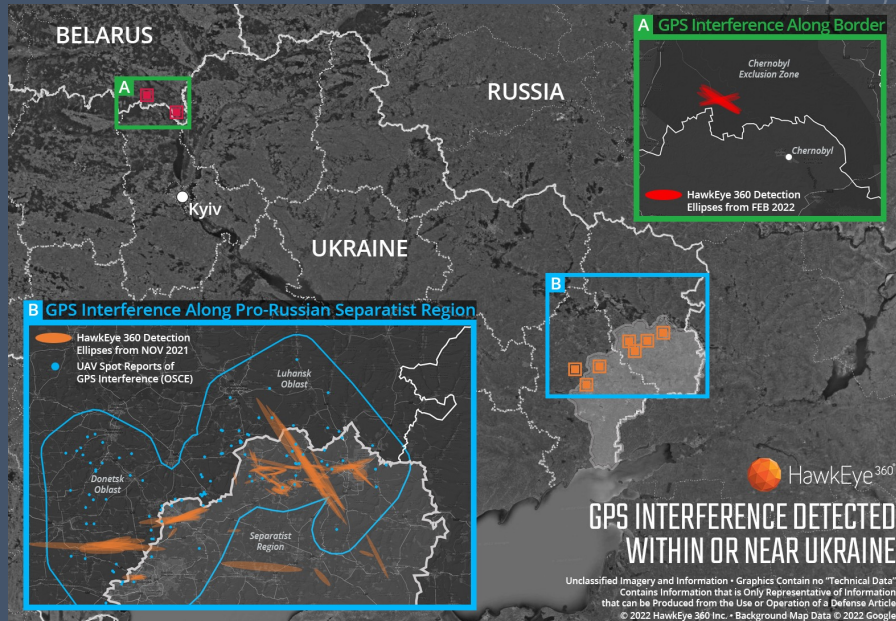
- Signal occultation / reflectometry / altimetry
- Radio frequency detection

Applications:

- Accurate commercial weather forecasts
- Tracking illegal ship activity on the ocean
- Aviation safety
- M2M/IoT communications

Technological Advances:

- Advanced data analytics
- Geolocation of RF signals
- Dramatic cost and latency reduction



Spire Maritime AIS and Spire Aviation ADS-B data.



Case Study: Remote Sensing Services

Commercial Remote Sensing Satellite Systems

As of June 21, 2022



Systems with at least two operational satellites, by relative size of constellation, percentage of satellites on orbit, and sensor type

U.S. Systems

Optical

Maxar

10 sats
(4 launched)
750 – 2,500kg / MS

Planet (Pelican)

32 sats
(0 launched)
200kg / MS

Planet (Dove)

~150sats (~150 on orbit)
5kg / MS

Planet (Skysat)

21 sats
(21 launched)
120kg / MS, V

Blacksky

23 sats
(20 launched)
55kg / MS

Synthetic Aperture Radar (SAR)

Capella

36 sats (8 launched)
100kg / SAR

Umbra Lab

12 sats (2 launched)
50kg / SAR

Other Systems

Spire

~150sats (~150 on orbit)
5kg / RO

Hawkeye 360

21sats (12 launched)
30kg / RF

PlanetIQ

20 sats (4 launched)
30kg / RO

GHGSat

10 sats (3 launched)
15kg / HS

Geooptics

24 sats (8 launched)
10kg / RO

Non-U.S. Systems

Canon (Japan)

100 sats (3 launched)
10kg / MS

Imagesat (Israel)

2 sats (2 launched)
300kg / MS

DMCii (UK)

3 sats (3 launched)
450kg / MS

Chang Guana (China)

196 sats
(94 launched)
40 – 95kg / MS, V

ZeroG Lab (China)

132 sats
(4 launched)
6-50kg / MS

21AT (China)

3 sats (3 launched)
440kg / MS

Sat Revolution (Poland)

66 sats (3 launched)
4kg / MS

Zhuhai Orbita (China)

34 sats (12 launched)
100kg / MS, HS, V

Axelspace (Japan)

10 sats (5 launched)
80kg / MS

HK Aerospace Tech (Hong Kong)

3 sats (3 launched)
50kg (est) / MS

Satelloic (Argentina)

202 sats
(32 launched)
41kg / MS, HS

ADA Space (China)

192 sats
(2 launched)
10kg / MS

ICEYE (Finland)

18 sats (14 launched)
85kg / SAR

IQPS (Japan)

36 sats (2 launched)
100kg / SAR

Synspective (Japan)

30 sats (2 launched)
150kg / SAR

MDA (Canada)

1 sat (1 launched)
2,195kg / SAR

Airbus (France)

12 sats (10 launched)
Mass varies / MS, SAR

UnseenLabs (France)

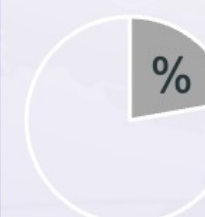
50 sats (7 launched)
6kg / RF

Ningxia Jinqui IT (China)

10 sats (10 launched)
250kg (est) / RF

Kleos Space (Luxembourg)

40 sats (16 launched)
9kg / RF



Size of pie chart represents relative size of constellation

Shaded area represents share of satellites launched

Satellite Technologies Are Aiming to Create a More Sustainable Space Future

- Commercial tracking providing more accurate data
- Automated collision avoidance allows real-time maneuvering
- First satellite servicing missions have occurred
- Active debris removal demonstration successful



Mission Extension Vehicle
(Northrop Grumman)

SIA[★]

State of the Satellite Industry Report

2022


BRYCE
TECH



SIA: Voice of the U.S. Satellite Industry

Member Companies



Prepared by:



Study Overview



- ✦ SIA's 25th annual study of satellite industry data
- ✦ Performed by BryceTech
- ✦ Reports on 2021 activity derived from unique data sets, including proprietary surveys, in-depth public information, and independent analysis
- ✦ All data are global, unless otherwise noted
- ✦ Prior year revenues are not adjusted for inflation
- ✦ Satellite manufacturing and launch revenues recorded in year of launch

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2021 satellite industry revenue \$279B



Satellite manufacturing: \$13.7B revenue

More commercially procured satellites deployed (40% increase over 2020), mainly smaller, lower cost satellites in LEO broadband constellations. More affordable GEO satellites. Small number of exquisite national security satellites



Satellite services: \$118B revenue

Despite ongoing changes in TV viewership, greater revenues per user + growth in burgeoning markets. Continued increased demand for broadband. Remote sensing growing with mature operators and new companies contributing to growth



Launch industry: \$5.7B revenue

Growth in revenue of 8%. Historic high number of launches in 2021. U.S. maintained the largest launch revenue share of any country. Increased launch rate driven by launches of LEO broadband constellations



Ground equipment: \$141.7B revenue

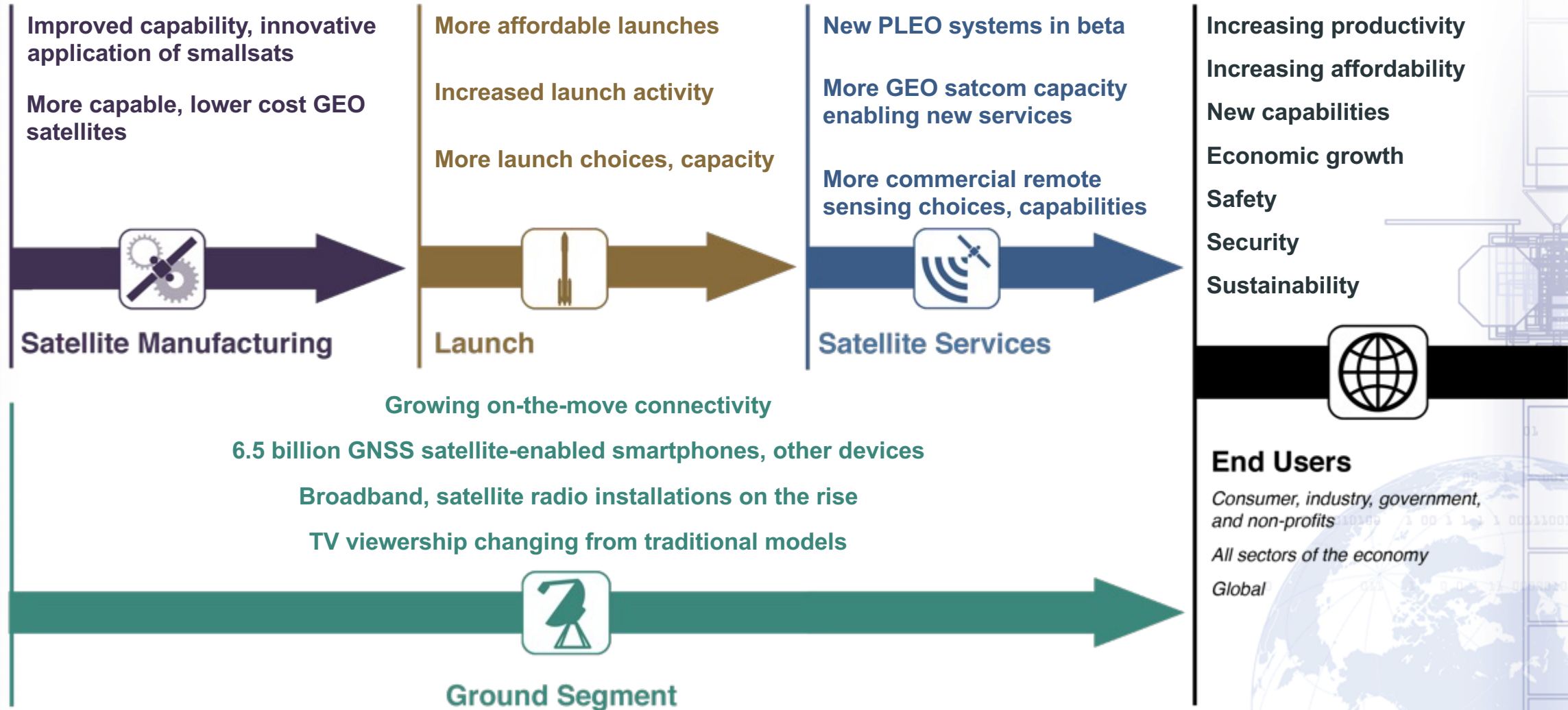
Continued growth in GNSS, network equipment revenues. Television viewership changing from traditional models

Global satellite industry revenue increased 3% in 2021, driven by growth across all segments

Increasing Affordability and Productivity, New Capabilities



Changing Industry Dynamics



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Increasing Affordability and Productivity, New Capabilities

Transformative Technology Innovation



Satellite Manufacturing

Flexible, software-defined payloads: deliver speed, flexibility through reconfigurability; additional power

Miniaturization, modular satellites: smaller and more sophisticated; standardization for multiple missions, responsive production

Digital engineering: shifting design and development into virtual environment to reduce costs and accelerate timelines

Satellite servicing: life extension, repair, upgrade, deorbit



Launch

Launch reusability/techniques for vehicle return: enables reduced prices and higher launch rate

In-space transportation: enables delivery to custom, specific orbits with advantage of lower cost rideshare missions

Improved deployment/separation technologies: enable launch of 100+ satellites on a single launch (record 143 satellites as of January 2021)



Satellite Services

Progress in spot-beam technologies: enables high-throughput (HTS) and very high-throughput (VHTS) satellites

Inter-satellite links (ISL) and optical communications: mitigate dependence on ground stations and expand coverage

Improved sensors: radar, hyperspectral, RF mapping, radio occultation enhancements enable new remote sensing services



Ground Segment

Flat panel/phased-array antennas: enable better on the move connectivity as antenna steers to maintain signal; significant for connecting to satellites in NGSO

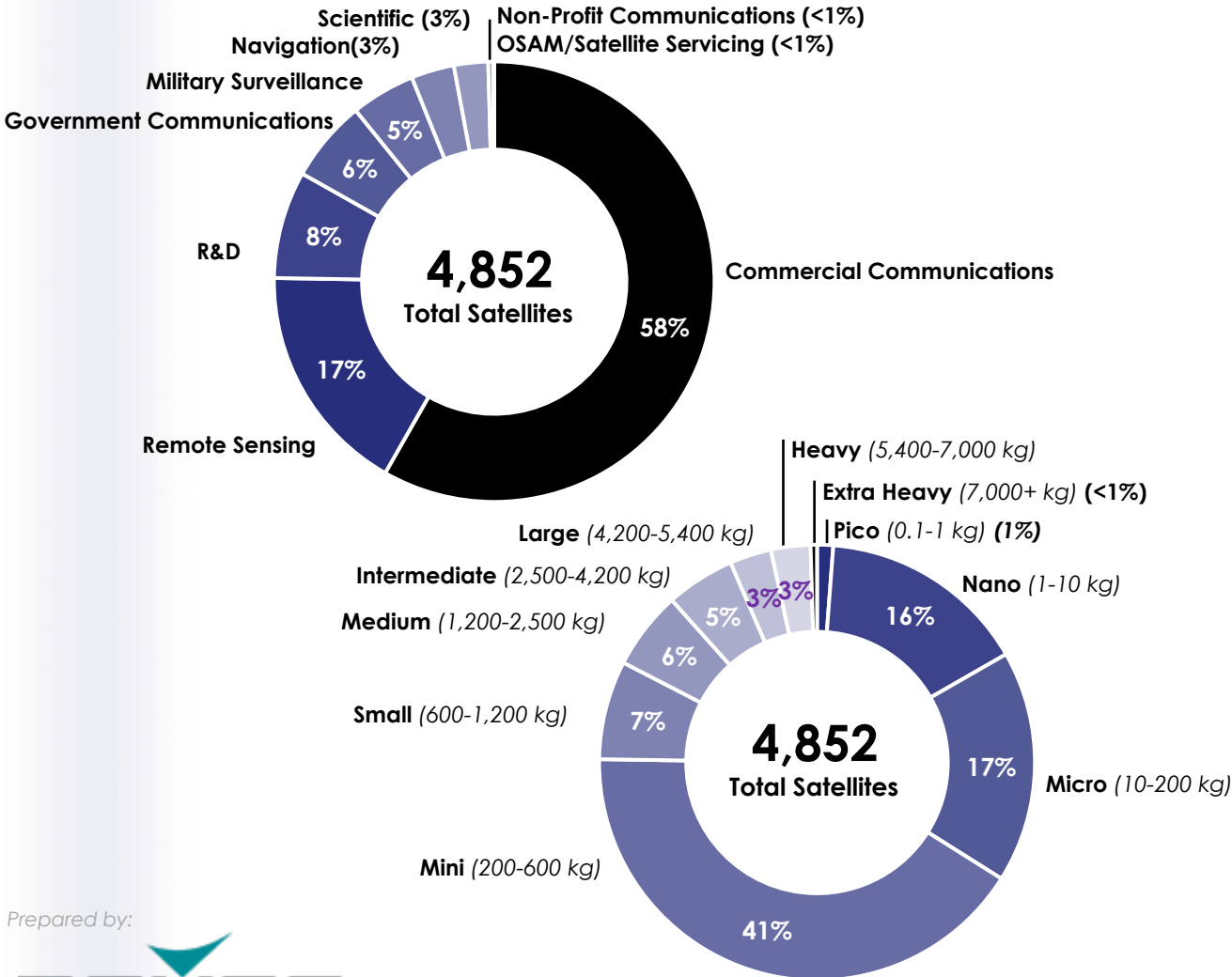
Cloud-integrated ground stations as a service: enable operators to command and control satellites, and downlink, process, and store data in cloud architectures without need for dedicated ground infrastructure

Satellite industry investment in technology delivers continual improvement in affordability and productivity, enabling new capabilities and creating new markets

Prepared

The Satellite Network in Context

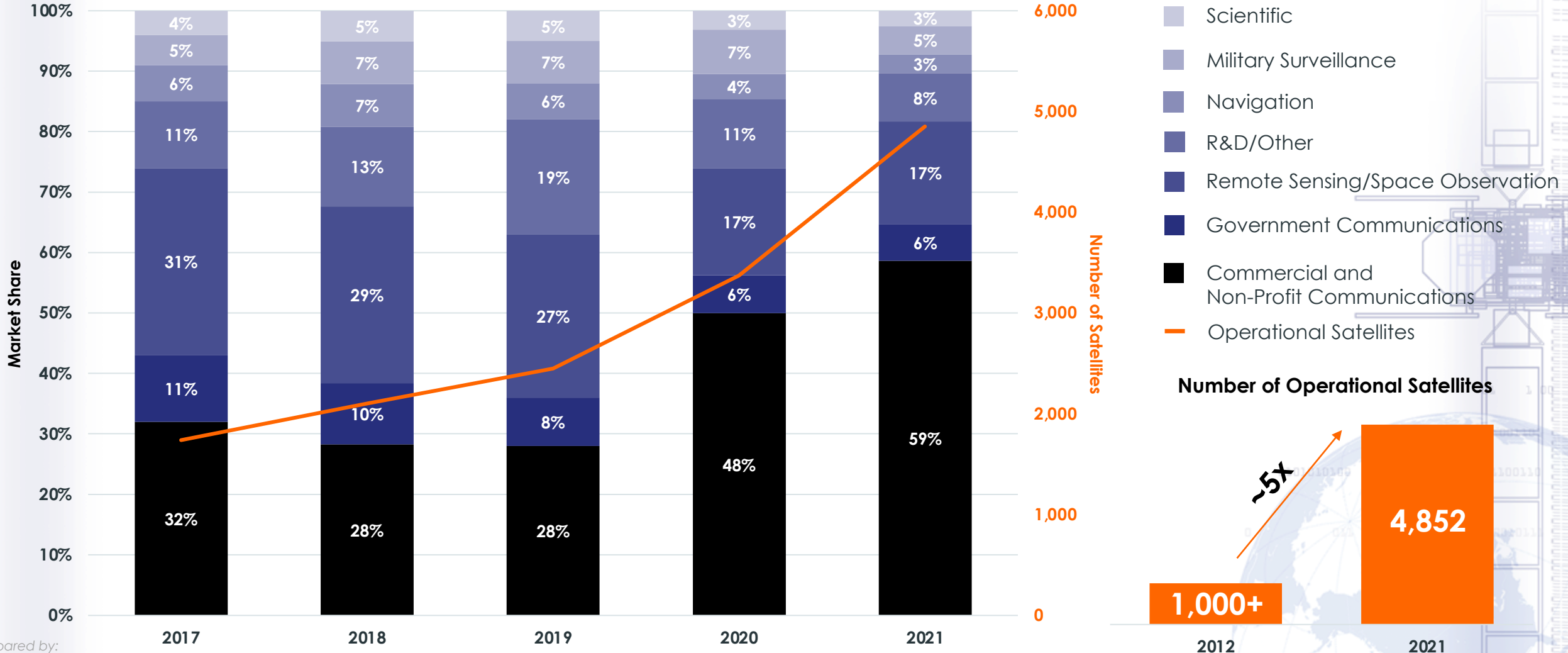
Operational Satellites by Function and Mass Class



- ✘ Active satellites have increased 233% over 5 years (from 1,459 on December 31, 2016)
 - Record breaking # of smallsats deployed 2020, 2021 (satellites ≤600kg)
 - Total satellite mass on orbit about 4,100 metric tons
 - 204 active satellites launched before 2005
 - 574 active satellites in GEO (12 more than in 2020, mostly providing communications services)
- ✘ 4,852 satellites operated by entities from 79 countries (some in regional consortia) Cumulatively, 97 countries have deployed at least one satellite since 1957
- ✘ U.S. entities operate 2,800+ satellites, some in partnership with other nations
- ✘ Estimated as of December 31, 2021

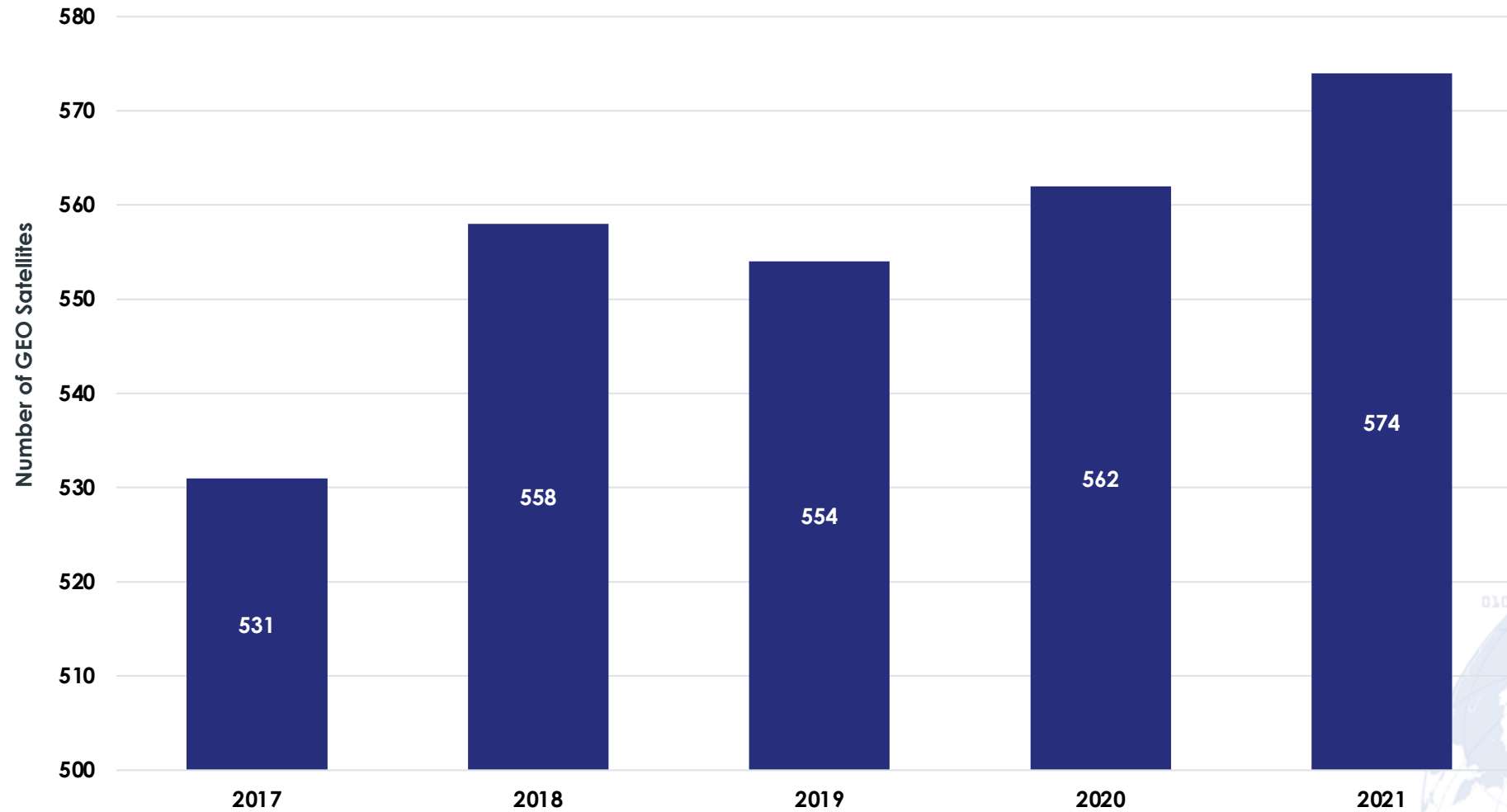
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Operational Satellites, by Year



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Operational GEO Satellites, by Year



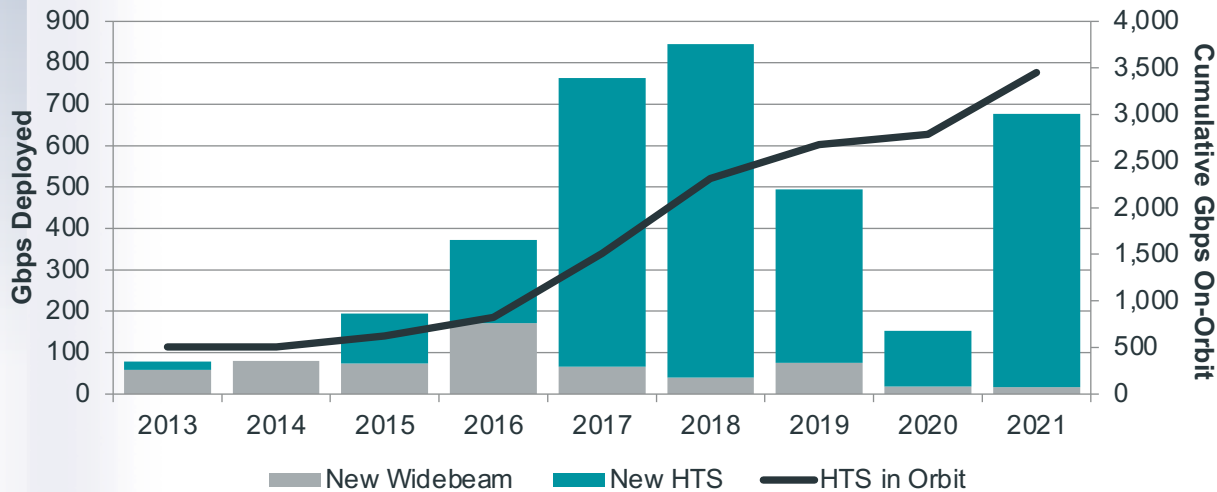
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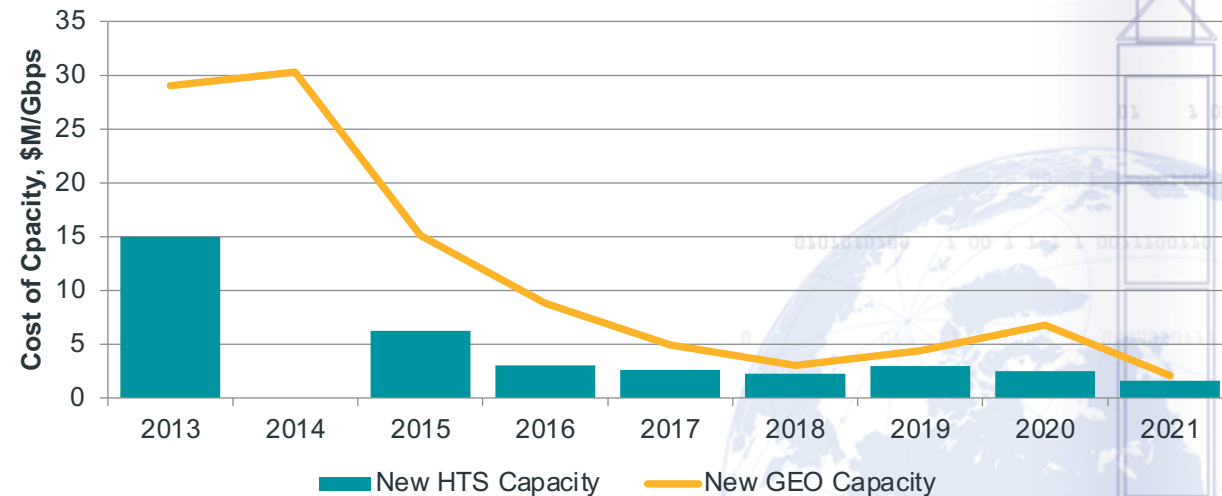
New Satcom Capacity Deployment and Cost Trends

- ✦ Significant new HTS capacity deployed in 2021
- ✦ Growth in HTS capacity results in lower overall manufacturing cost per Gbps
- ✦ Continued deployment of less expensive satcom capacity leads to more affordable satellite broadband connectivity, improved affordability, greater data volumes and speed offered to multiple markets
- ✦ Operators plan to deploy near 200 Tbps through 2026
 - Over 6 Tbps total capacity on planned GEO satellites under contract and in development
 - Potential capacity exceeding 180 Tbps planned by NGSO constellations in development

New Capacity, Widebeam and HTS, Gbps



Cost of New GEO Capacity, \$M/Gbps



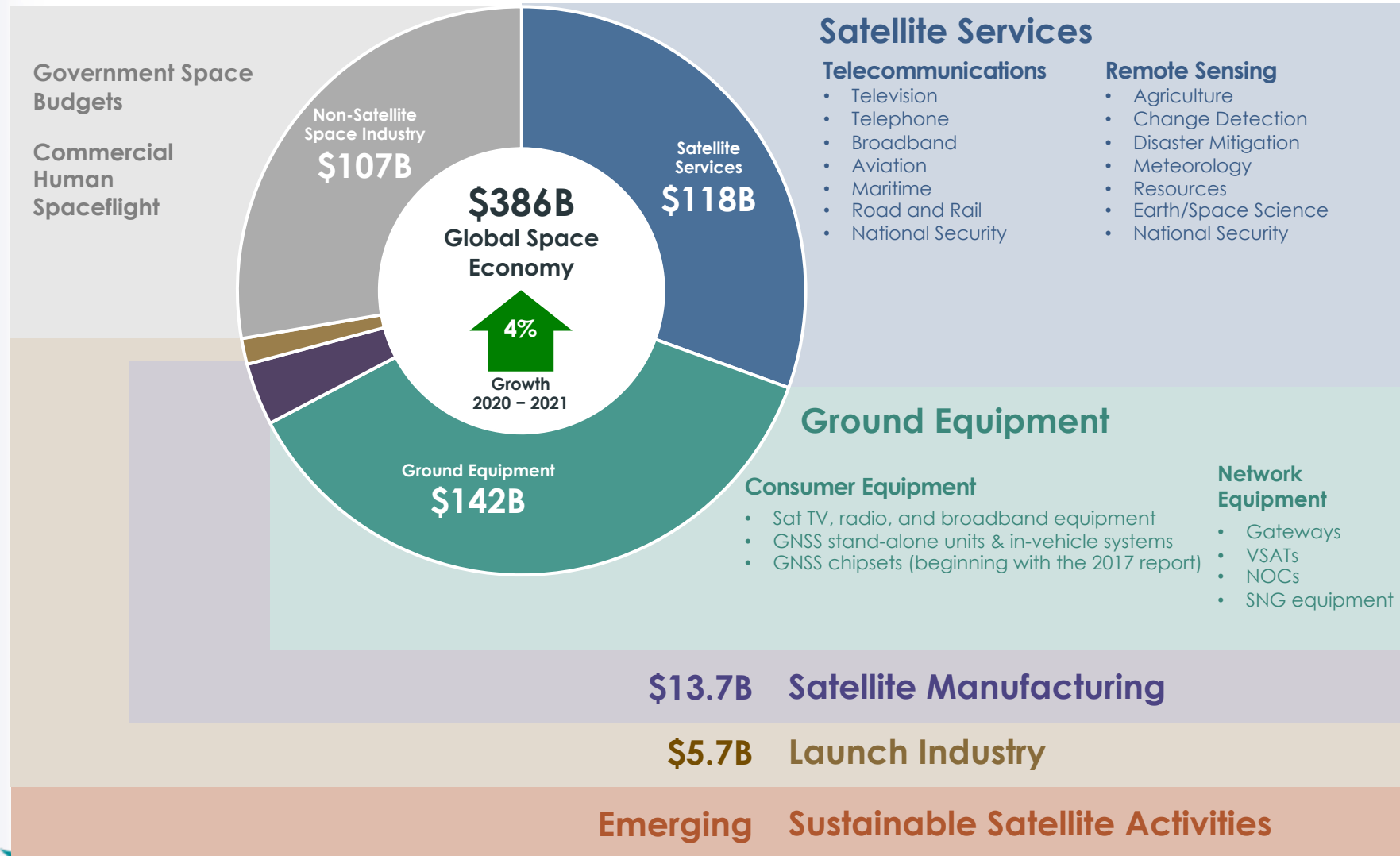
Prepared by:



Satellite capacity cost estimated based on satellite manufacturing prices.

Future capacity estimates reflect publicly announced plans and manufacturing contracts; some systems may not deploy.

The Satellite Industry in Context



\$279B
Satellite Industry
 (72% of Space Economy)

*Government space budgets include civil and military spending by 70 countries, ESA.
 Commercial human spaceflight includes commercial missions to ISS, suborbital and orbital flights.*

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Emerging Industry Segment – Sustainable Satellite Activities **SIA**

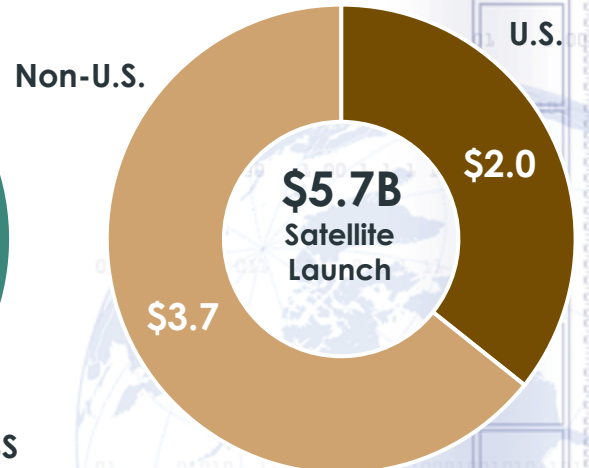
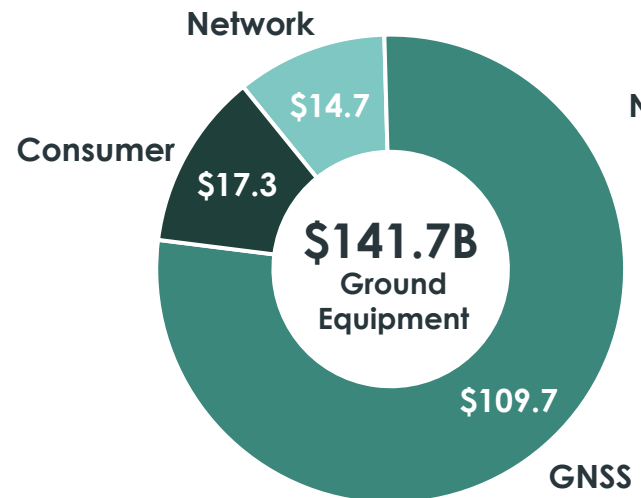
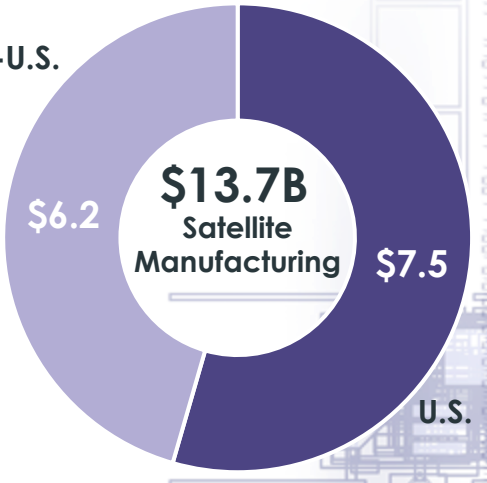
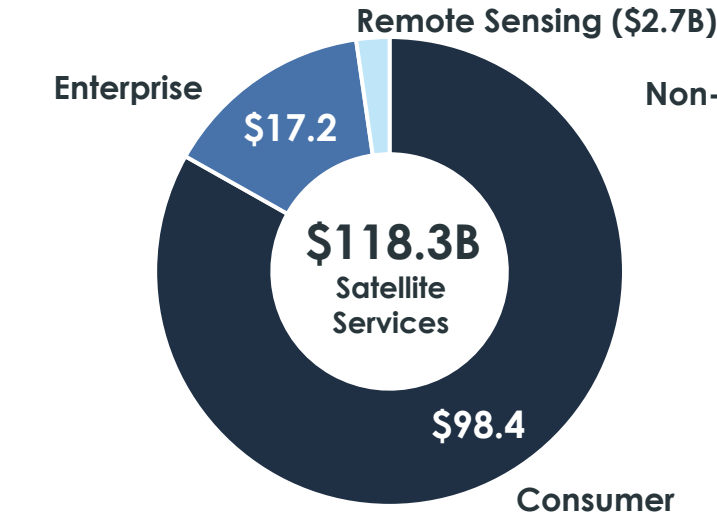
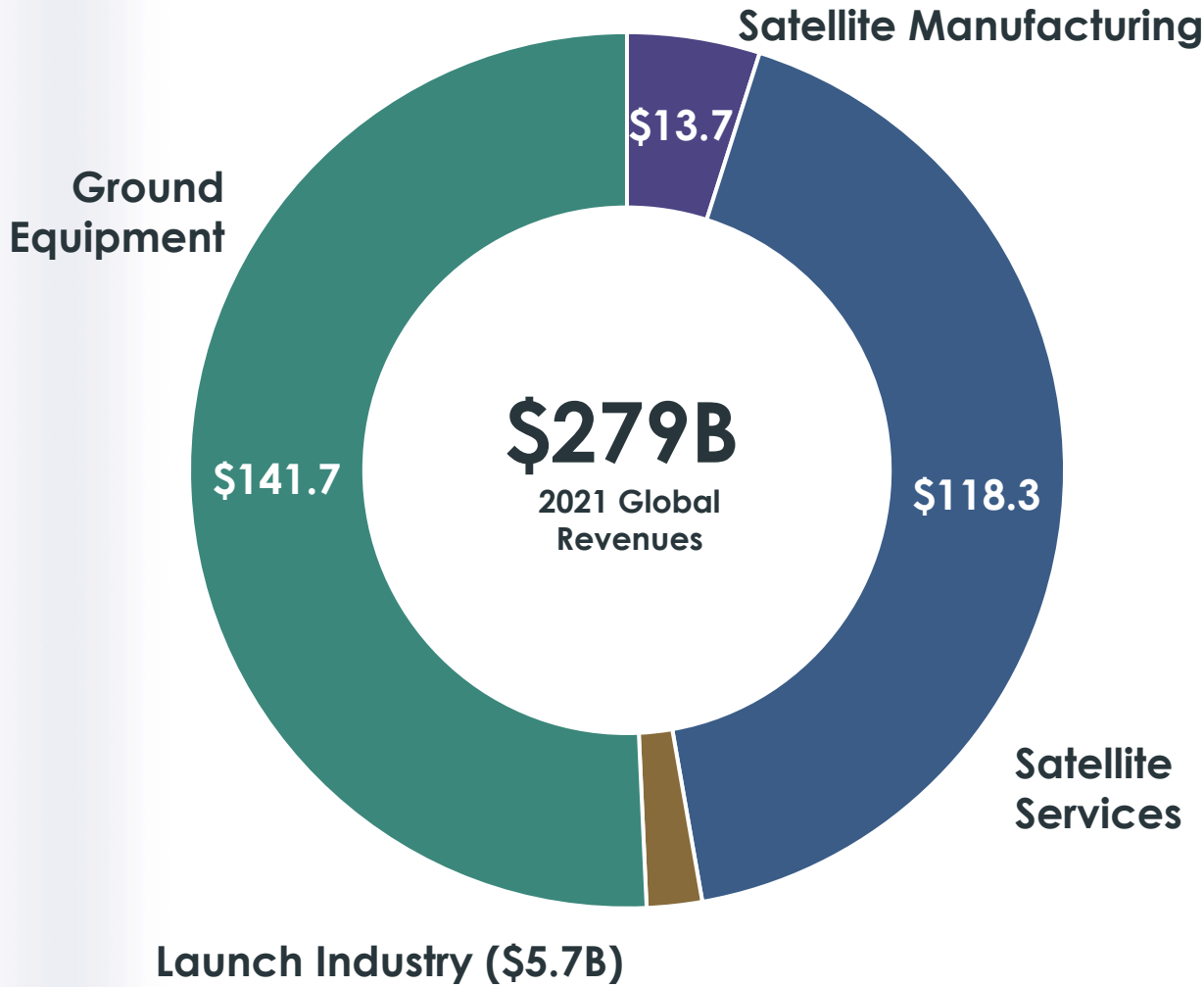
- ✦ Emerging satellite industry segment encompasses new business areas generally related to sustainable satellite activities
 - Globally, companies ranging from early-stage to established
 - Current revenues modest, expected to increase
- ✦ Satellite servicing
 - Life extension
 - Moving satellites
 - Maintenance + modification
- ✦ Active debris removal
- ✦ Space domain awareness, space traffic management
- ✦ Delivery to custom orbits post-launch
- ✦ In-space satellite manufacturing and assembly

Recent Developments

- 1st commercially operational satellite servicing system (MEV)
- 1st commercial active debris removal demonstration
- 1st propellant tanker deployed (+ close-range inspection)
- Commercial space tracking company has 4 ground-based radars in operation
- Future missions announced include commercially operational ADR vehicle and GEO propellant tanker
- Companies incorporating cooperative features into spacecraft design

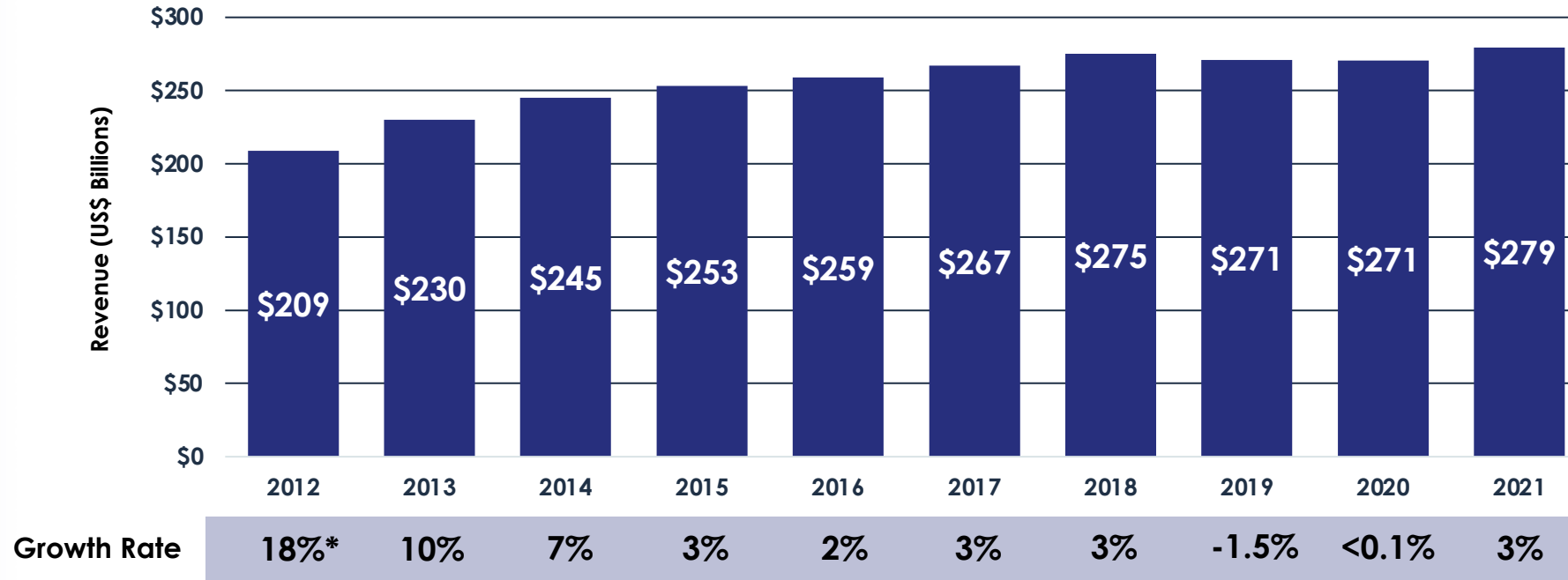
Prepared by:

2021 Satellite Industry Indicators Summary



Global Satellite Industry Revenues

Global Satellite Industry Revenues (\$ Billions)

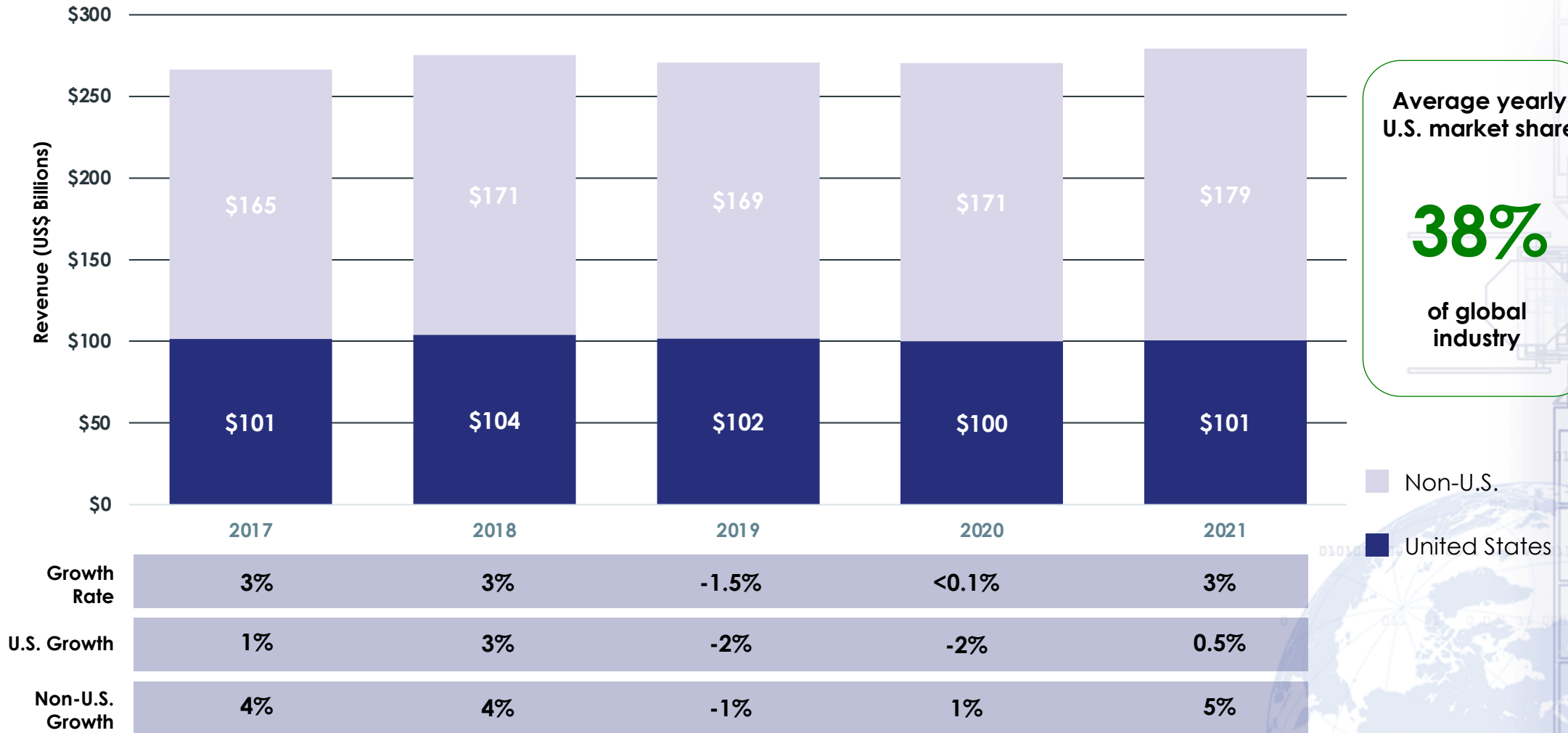


1.3x
Ten-Year
Global Industry
Growth

Global satellite industry revenue increased 3% in 2021, driven by growth across all segments. GNSS products and services saw highest growth

*Reported since 2017 and including years beginning with 2012, ground equipment revenues include entire GNSS segment: stand-alone navigation devices and GNSS chipsets supporting location-based services in mobile devices, traffic information systems, aircraft avionics, maritime, surveying, and rail.

Global Satellite Industry Revenues U.S. Share



Average yearly U.S. market share

38%

of global industry

Notes: Previously reported U.S. share of revenues adjusted to reflect updated GNSS estimate.

Prepared by:





Satellite Manufacturing

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Satellite Manufacturing

Changing Industry Dynamics

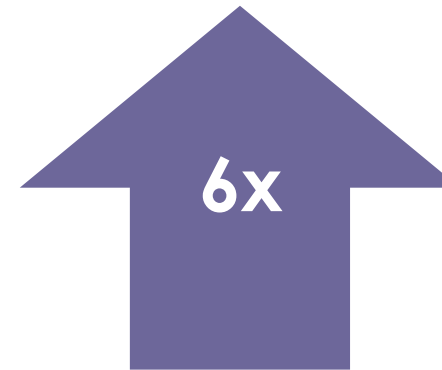


Improved capability, innovative application of smallsats ($\leq 600\text{kg}$)

- ✕ IoT/M2M, new types of remote sensing, sustainable space activities
- ✕ Faster development, demonstration, and iteration
- ✕ New manufacturing facilities in the U.S. and internationally
- ✕ Proliferated LEO broadband deployments under way, driving increase in sats launched

More capable, lower cost large satellites

- ✕ Increase in throughput per kg launched (x6)
- ✕ High-throughput satellites (HTS)
- ✕ Dramatic decrease in manufacturing cost/throughput (-90%)
- ✕ Flexible/software-defined payloads for efficient on-orbit use
- ✕ Modularity for responsive build
- ✕ Electric propulsion



Throughput/kg
(2013 – 2021)



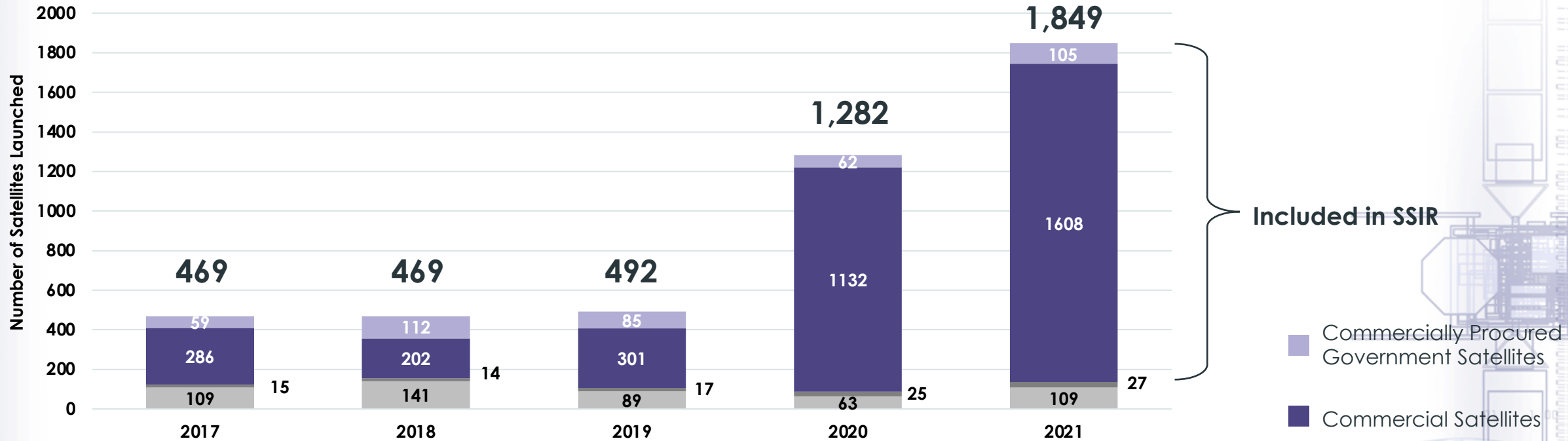
Cost/Gbps
(2013 – 2021)

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Satellite Manufacturing: Methodology



✘ Included in SSIR: commercially procured satellites

- Commercial satellites: satellites manufactured under internationally-competed contracts or produced in-house by privately-funded organizations. Revenues include estimates of in-house transfers
- Commercially-procured government satellites: manufacturing contracts typically captive or competed among national manufacturers

✘ Not included in SSIR

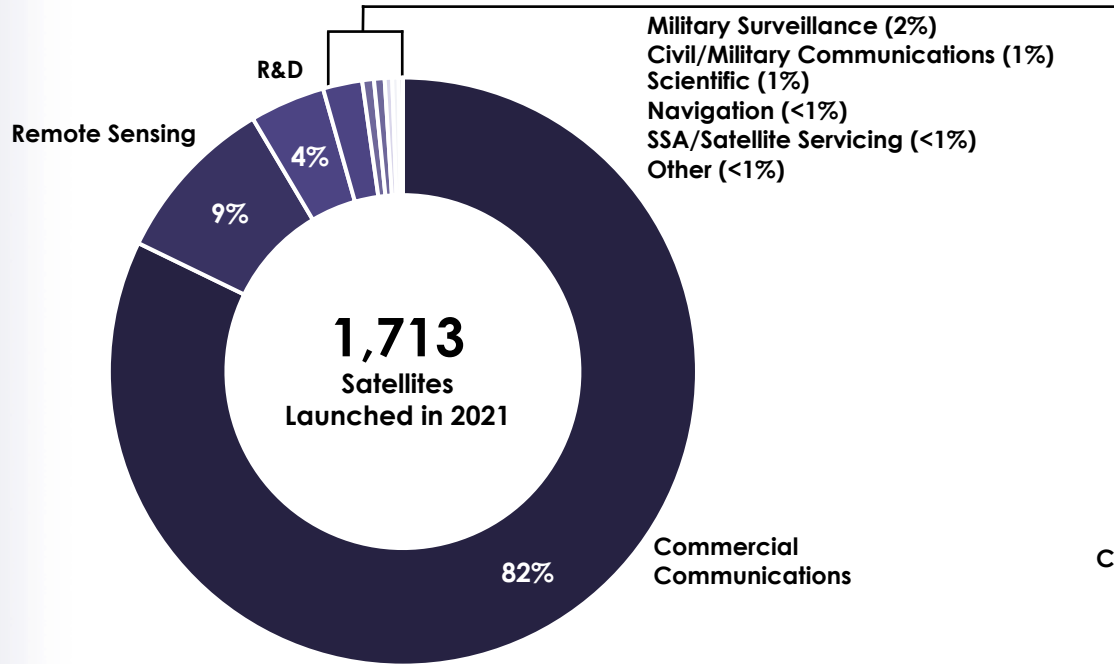
- Spacecraft other than satellites: crew and cargo vehicles and some other spacecraft
- Satellites not procured commercially: satellites produced in-house by a government agency or a university



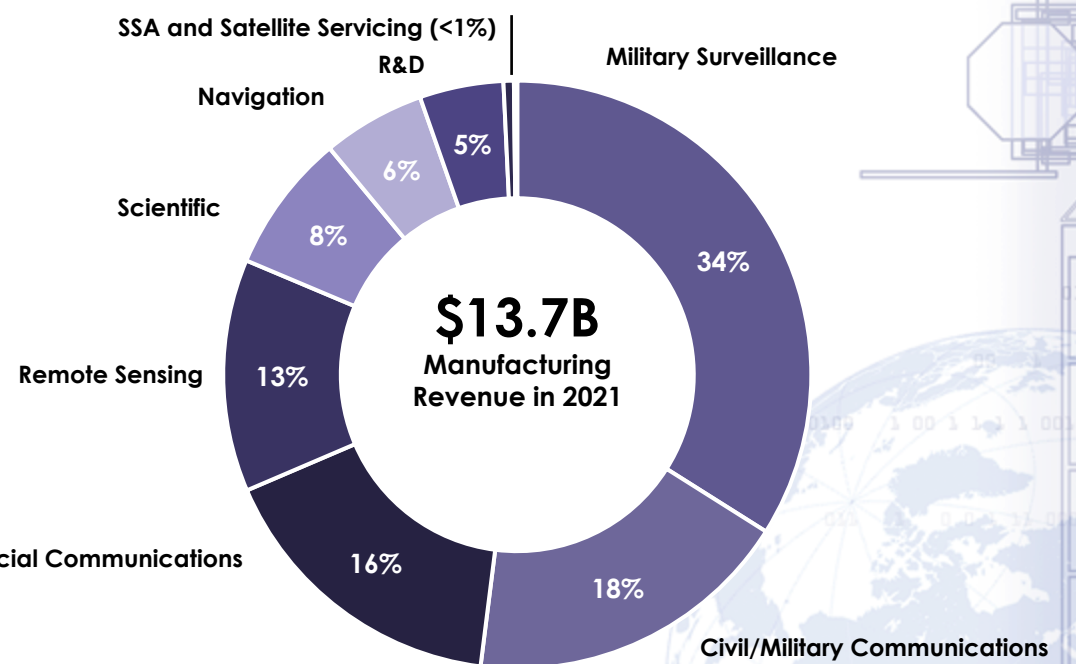
Satellite Manufacturing Findings



- Worldwide 2021 revenues totaled \$13.7B; increase 12.2%
- 1,713 commercially-procured satellites launched in 2021; 519 more than in 2020
- 1,635 commercially-procured smallsats ($\leq 600\text{kg}$) launched (1,140 in 2020)
- Communications satellites represented 16% of total revenues, compared to 15% in 2020
- Military surveillance satellites accounted for 34% of revenues, compared to 41% in 2020



Number of Satellites Launched, by Mission Type



Value of Satellites Launched, Estimated by Mission Type

Prepared by:



Special Topic: James Webb Space Telescope (JWST)

- ✦ NASA JWST launched in 2021 with a cost of \$8.8B
- ✦ Nearly 20 years from development to launch
- ✦ Largest, most powerful space telescope constructed
 - Designed to fundamentally alter understanding of universe
 - Infrared telescope observes space/ time previously unobservable with unprecedented resolution/ sensitivity
- ✦ Telescopes typically included in SSIR because of commonality in telescope and sat technologies
- ✦ Manufacturing revenues counted in year of launch. \$8.8B JWST excluded from 2021 manufacturing revenues
- ✦ International partners
 - European Space Agency – near infrared spectrograph, mid-Infrared instrument optics assembly, launch on Ariane 5
 - Canadian Space Agency – fine guidance sensor/near infrared imager and slitless spectrograph
 - Over 300 other contributors globally

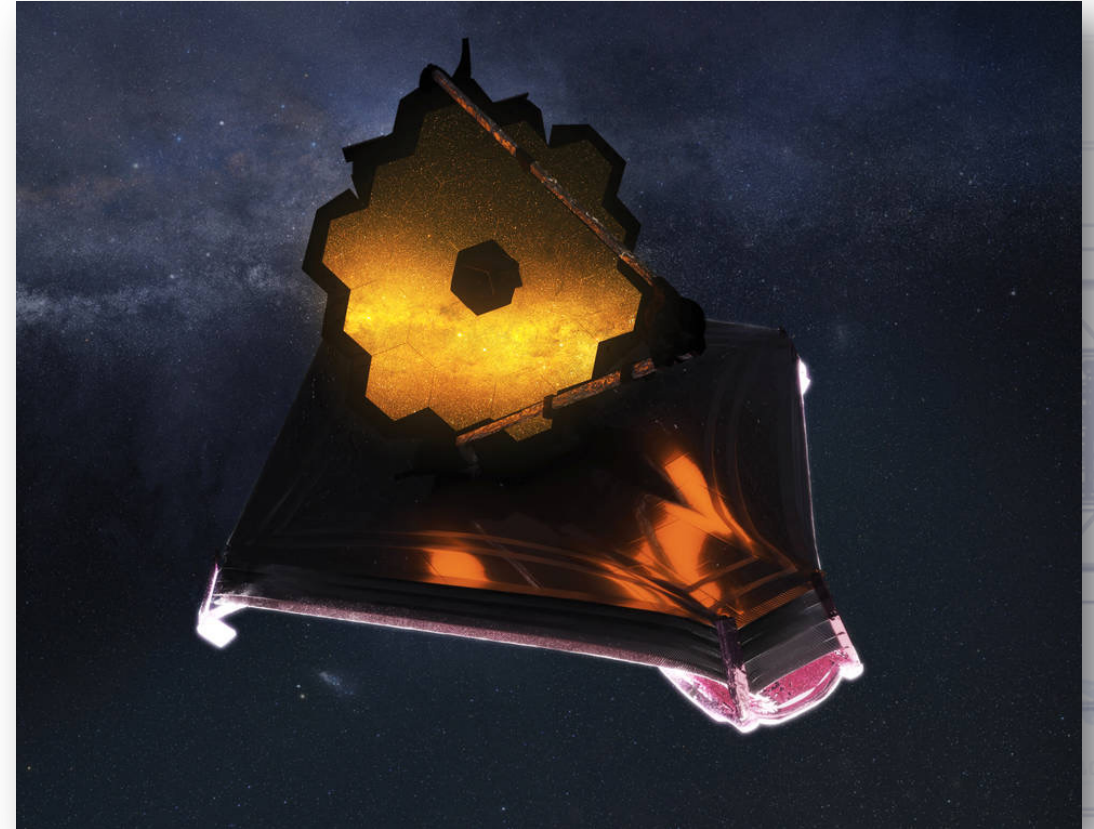
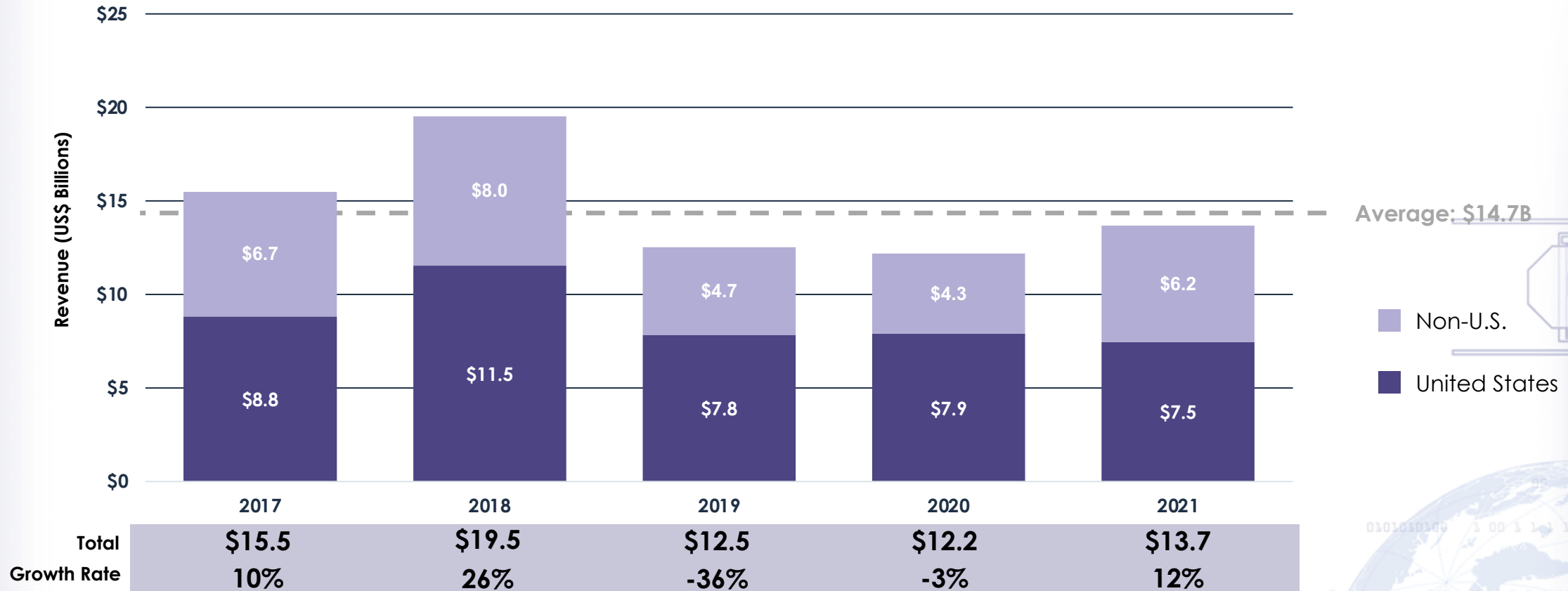


Image: NASA



Satellite Manufacturing Revenues



- ✦ Worldwide 2021 revenues totaled \$13.7B
- ✦ In 2021, U.S. share of global revenues was 54%, from 65% in 2020

Prepared by:



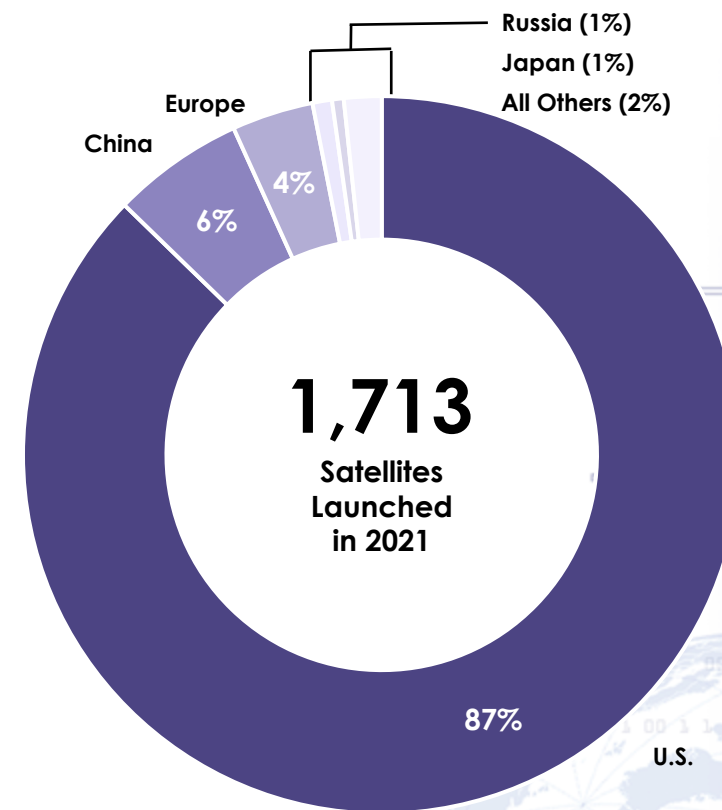
Satellite manufacturing revenues are recorded in the year of satellite launch. Do not include satellites built by governments or universities. Data based on unclassified sources.



Satellite Manufacturing: Industry Findings and U.S. Highlights



- ✦ More medium-to-heavy class satellites launched: 57 (13 U.S.-made) vs. 42 (10 U.S.) 2020
- ✦ U.S. satellite manufacturing revenues 6% lower
 - Commercial sector 9% lower, government sector 5% lower
 - 80% of U.S. revenues from U.S. government contracts
- ✦ Massive rollout of LEO broadband constellations continued in 2021, dominated by US manufacturing
 - 989 Starlink satellites launched in 2021
 - 284 OneWeb satellites launched in 2021
- ✦ U.S. firms built about 87% of commercially procured satellites launched in 2021 and earned 54% of manufacturing revenues



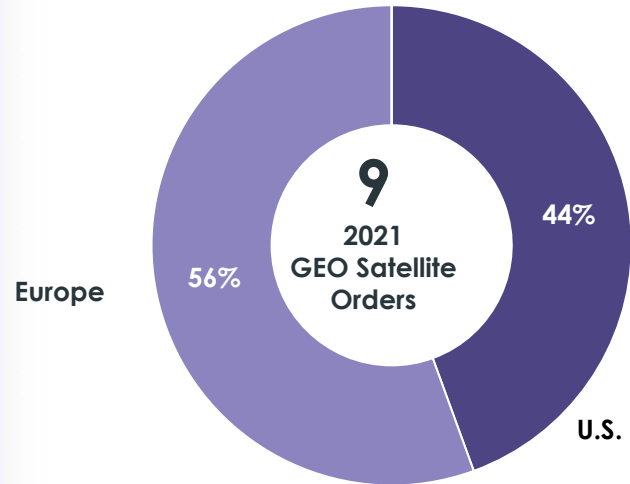
Number of Satellites Launched by Country/Region of Manufacturer

Prepared by:

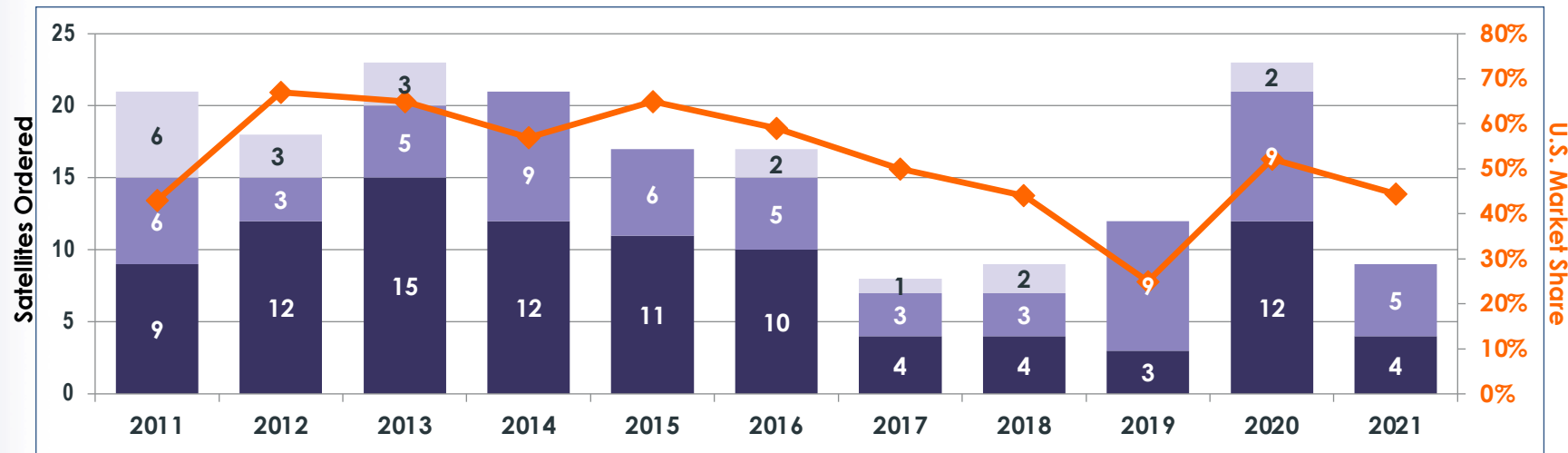




Future Indicator: GEO Satellite Commercial Manufacturing Orders



- ✦ Commercial orders for 9 GEO satellites announced
- ✦ 4 orders won by U.S. manufacturers; 12 in 2020
- ✦ 5 orders won by European manufacturers; 9 in 2020
- ✦ Large # of orders in 2020 driven by FCC C-band decisions (13 sats)
- ✦ GEO sat orders affect GEO launches, manufacturing revenue in subsequent years



- U.S. GEO Orders
- Europe GEO Orders
- All Other GEO Orders
- U.S. Satellite Orders (%)

Prepared by:





Satellite Services

- ✦ Consumer Services
 - Satellite Television
 - Satellite Radio
 - Satellite Broadband
- ✦ Enterprise Services
 - Transponder Agreements
 - Managed Network Services
 - Mobile Voice and Data
- ✦ Remote Sensing Services



New PLEO systems in beta

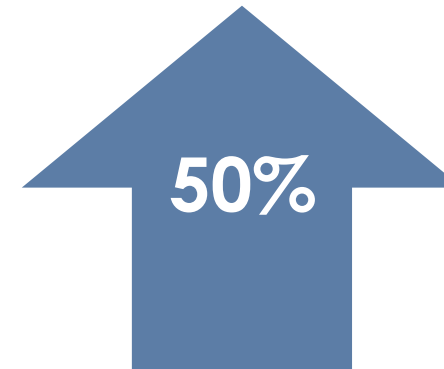
More GEO satcom capacity on orbit (+3x) enabling new services

- ✦ Increase in total HTS capacity on orbit
- ✦ Cost of new capacity deployed in 2021 less than 1/10 of that in 2013
- ✦ Decrease in cost of HTS
- ✦ Mobility: in-flight, cruise ships connectivity
- ✦ IoT connectivity
- ✦ Faster broadband, +50% subs since 2017

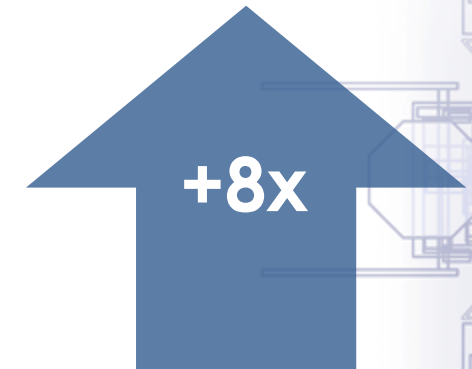
More new commercial remote sensing choices and capabilities

- ✦ 8x+ times more active remote sensing satellites
- ✦ Commercial imagery resolution increasing across sensor types (multispectral, hyperspectral, SAR, RF mapping, RO, etc.)

Prepared by: ✦ Increased fusion of data analytics with imagery



**New Broadband
Subscribers
(2017 – 2021)**



**Commercial Remote
Sensing Satellites
(2012 – 2021)**



Satellite Services Overview



- ✦ Consumer satellite service revenues
 - Broadband grew 1.5%
 - Satellite radio grew 5%
 - Satellite TV grew 1%
- ✦ Enterprise service revenues
 - Mobile voice and data service revenues stayed flat
 - Managed network services grew 1%
 - Transponder agreements decreased 4%
- ✦ Remote sensing service revenues grew 4%
- ✦ Trends
 - Markets for value-added satellite services grew across multiple segments, including broadband and satellite radio
 - Remote sensing grew 4%; mature operators and new companies contributing to growth
 - More mature DTH posted 1% growth, with slight increase in revenue per user, FX benefits
 - COVID-19 negative impact on enterprise (air travel, maritime demand) still present, less severe

Prepared by:





Satellite Services Findings: Consumer Services



- ✘ Satellite radio and broadband revenues grew 5% and 1.5%, respectively. Satellite radio subscribers decreased by 2%, while broadband subscribers grew 11%
- ✘ Slight increase in satellite TV revenues; continuing trends in TV viewership, customer preferences

Satellite Radio

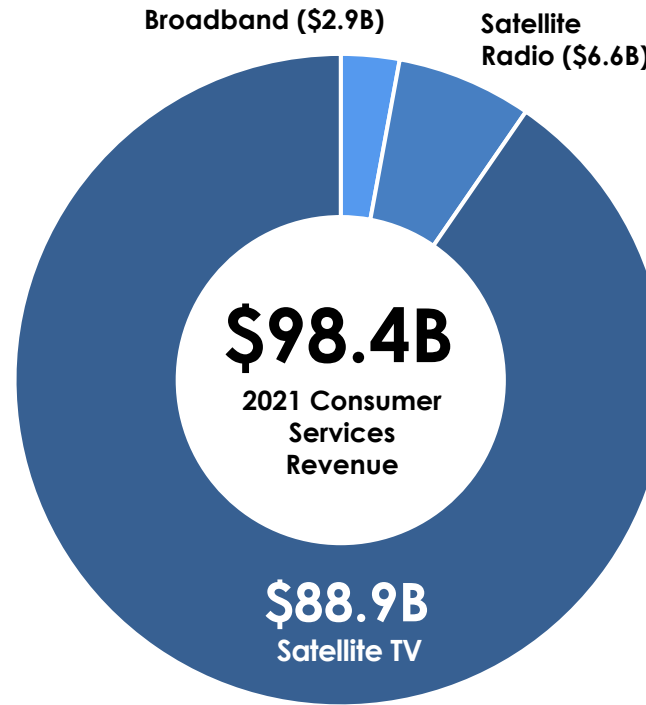
- Satellite radio (DARS) revenues grew 5%
- DARS subscribers decreased 2% to ~34M
- Mostly North American customer base

Satellite End-User Broadband

- Revenue grew ~1.5%
- Subscribers grew 11%, to over 3M, mainly outside U.S.
- Higher revenue per user in the U.S.
- Driven by GEO broadband. Additional capacity over U.S. allowed operators to add subscribers, offer more bandwidth, resulting in growth: 12% in 2018, 19% in 2019, 8% in 2020
- New LEO constellations deploying, at least one signing up subscribers in beta mode
- Dominated by U.S. providers, adding both U.S. and non-U.S. subscribers

Satellite TV Services

- Satellite TV revenue (DBS/DTH) increased 1%, mainly driven by one major non-U.S. provider; accounted for 75% of all satellite services revenues, 91% of consumer revenues
- Global satellite TV subscriber base is estimated at 210M+ commercial subscribers (plus a similar number of free-to-air satellite TV homes)
- Subscribers and revenue declining in the U.S.
- Lower per-user revenues outside U.S, trends in number of subscribers vary by provider
- 34% of global revenues attributed to U.S., not counting a major European provider now owned by a U.S. cable company, potentially increasing this share to 57%
- Slow growth of Ultra-HD channels, slightly over 1% of total TV channels worldwide
- HD channels 30+ percent of all TV channels
- Contributing to slower demand for satellite capacity: improving compression technologies; consumers continue to "cut the cord," opt for online on-demand services



■ Broadband ■ Satellite Radio ■ Satellite TV

Prepared by:





Satellite Service Findings: Enterprise Services



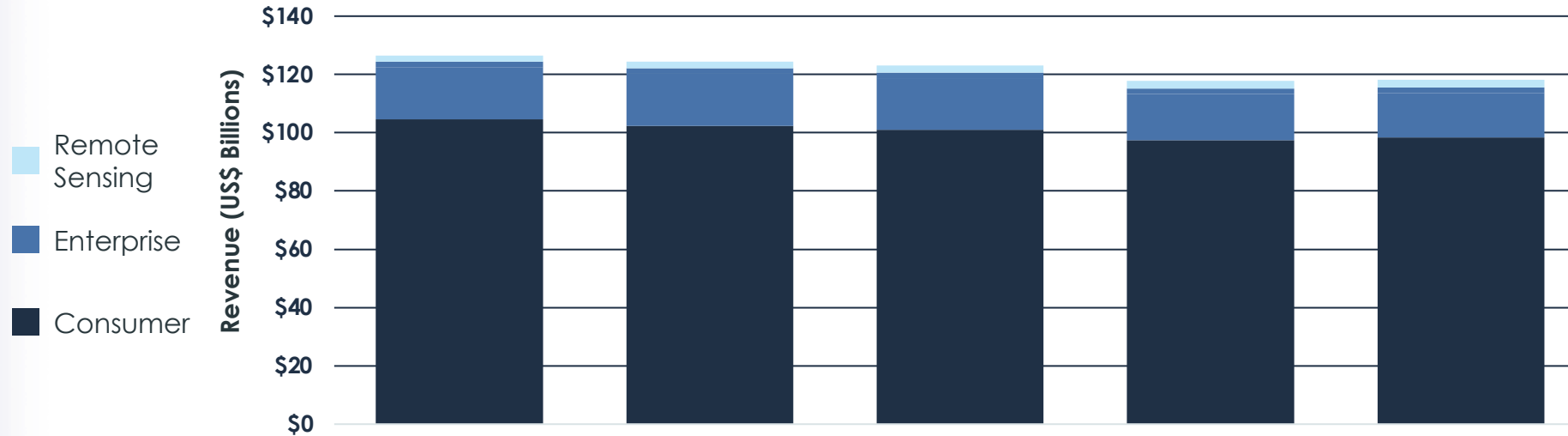
- ✦ Mobile Voice and Data revenue flat, \$2B
 - Includes end-to-end mobile voice and data (including IoT) services over MSS frequency bands as defined by regulators
 - Multiple startup satellite IoT companies generated commercial service revenue
- ✦ Managed network services revenue increased 1%
 - Includes fixed and mobility VSAT/private network services, maritime and in-flight broadband connectivity services over FSS bands
 - Reflects continued COVID-19 negative impact on demand for air travel, maritime industries
 - Increasing availability of HTS capacity
- ✦ Transponder agreements revenue decreased 4%
 - Leasing transponder capacity to industry verticals including media & broadcasting, telecom, governments
 - Continued effects of COVID-19
 - Abundance of capacity, competition in transponder market
 - More affordable capacity leading to lower revenues

Mobile Voice and Data Vs. Managed Services

- Mobile Voice and Data
 - Services provided using MSS frequencies (L, S-band) as defined by regulators. Some M2M and IoT operators use VHF band
 - Provided by GEO and LEO satellite operators
- Managed Services
 - Provided to fixed and transportable/mobile VSATs, terminals on vehicles, vessels, and aircraft
 - Use FSS frequencies (C, Ku, Ka-band) to primarily provide broadband connectivity
 - Increased HTS capacity and new antenna technology has made service over FSS bands to mobility/on-the-move customers more attractive
 - Provided by existing GEO and MEO satellite operators. New LEO broadband constellations roll out beta service as they continue massive satellite deployments
 - Fixed (FSS), mobile (MSS) satellite service defined by frequency, not by whether customer equipment is fixed or mobile



Satellite Services: Global Revenue



The U.S. share of global satellite services revenue in 2021 was **38%**

Growth Rate	2017	2018	2019	2020	2021
	0.5%	-1.8%	-1.1%	-4.2%	0.4%

	2017	2018	2019	2020	2021
Total	\$126.6	\$124.3	\$123.0	\$117.8	\$118.3
Consumer	\$104.6	\$102.4	\$101.0	\$97.5	\$98.4
Satellite TV (DBS/DTH)	\$97.1	\$94.2	\$92.0	\$88.4	\$88.9
Satellite Radio (DARS)	\$5.4	\$5.8	\$6.2	\$6.3	\$6.6
Satellite End-User Broadband	\$2.1	\$2.4	\$2.6	\$2.8	\$2.9
Enterprise	\$19.7	\$19.8	\$19.7	\$17.7	\$17.2
Transponder Agreements (1)	\$11.1	\$10.6	\$10.0	\$9.2	\$8.6
Managed Services over FSS bands (2)	\$6.8	\$7.3	\$7.7	\$6.5	\$6.6
Mobile Voice and Data over MSS bands (3)	\$1.8	\$1.9	\$2.0	\$2.0	\$2.0
Remote Sensing	\$2.2	\$2.1	\$2.3	\$2.6	\$2.7

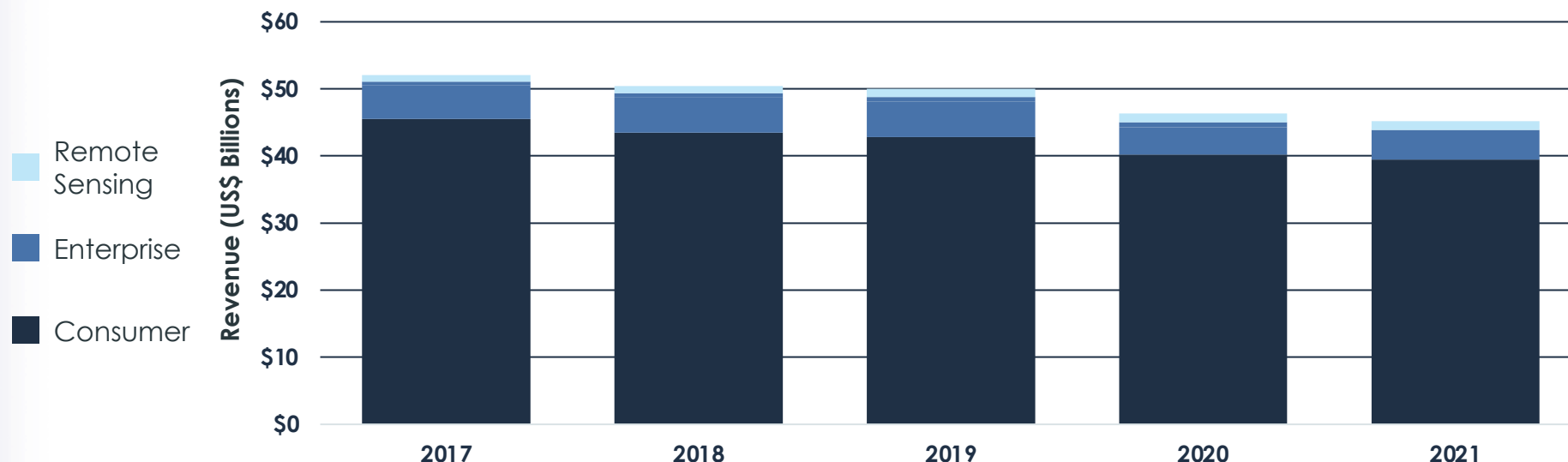
Prepared by:



Notes: Numbers may not sum due to rounding. (1) Leasing transponder capacity to industry verticals including media & broadcasting, telecom, governments. (2) Includes fixed and mobility VSAT/private network services, maritime and in-flight broadband connectivity services over FSS bands. (3) Includes end-to-end mobile voice and data (including IoT) services over MSS frequency bands as defined by regulators



Satellite Services: U.S. Revenue



The U.S. share of global satellite services revenue in 2021 was **38%**

Growth Rate	2017	2018	2019	2020	2021
	0%	-3.5%	-1%	-7%	-2%

	2017	2018	2019	2020	2021
Total	\$52.1	\$50.3	\$49.7	\$46.3	\$45.2
Consumer	\$45.5	\$43.5	\$42.8	\$40.2	\$39.5
Satellite TV (DBS/DTH)	\$38.3	\$35.5	\$34.0	\$31.4	\$30.1
Satellite Radio (DARS)	\$5.4	\$5.8	\$6.2	\$6.3	\$6.6
Satellite End-User Broadband	\$1.8	\$2.2	\$2.4	\$2.5	\$2.8
Enterprise	\$5.6	\$5.9	\$6.0	\$4.8	\$4.4
Transponder Agreements (1)	\$0.3	\$0.3	\$0.2	\$0.0	\$0
Managed Services over FSS bands (2)	\$4.7	\$4.9	\$5.1	\$4.1	\$3.6
Mobile Voice and Data over MSS bands (3)	\$0.6	\$0.7	\$0.7	\$0.7	\$0.8
Remote Sensing	\$1.0	\$1.0	\$1.2	\$1.3	\$1.3

Prepared by:



Notes: Numbers may not sum due to rounding. (1) Leasing transponder capacity to industry verticals including media & broadcasting, telecom, governments. (2) Includes fixed and mobility VSAT/private network services, maritime and in-flight broadband connectivity services over FSS bands. (3) Includes end-to-end mobile voice and data (including IoT) services over MSS frequency bands as defined by regulators



Case Study: Remote Sensing Services

Commercial Remote Sensing Satellite Systems

As of June 21, 2022



Systems with at least two operational satellites, by relative size of constellation, percentage of satellites on orbit, and sensor type

U.S. Systems

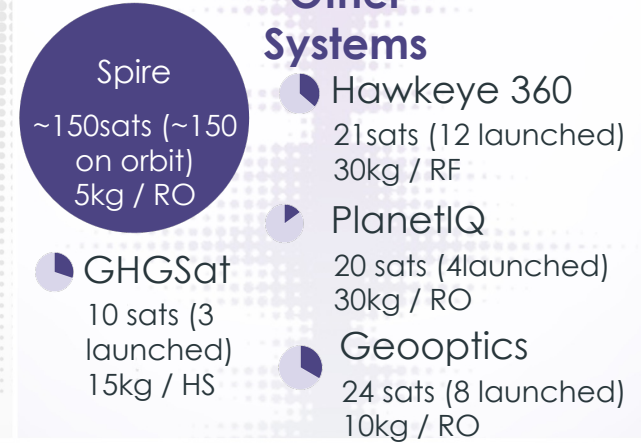
Optical



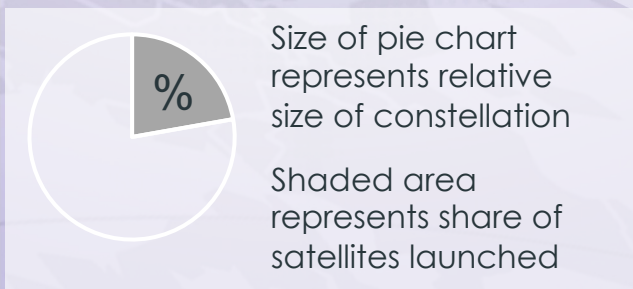
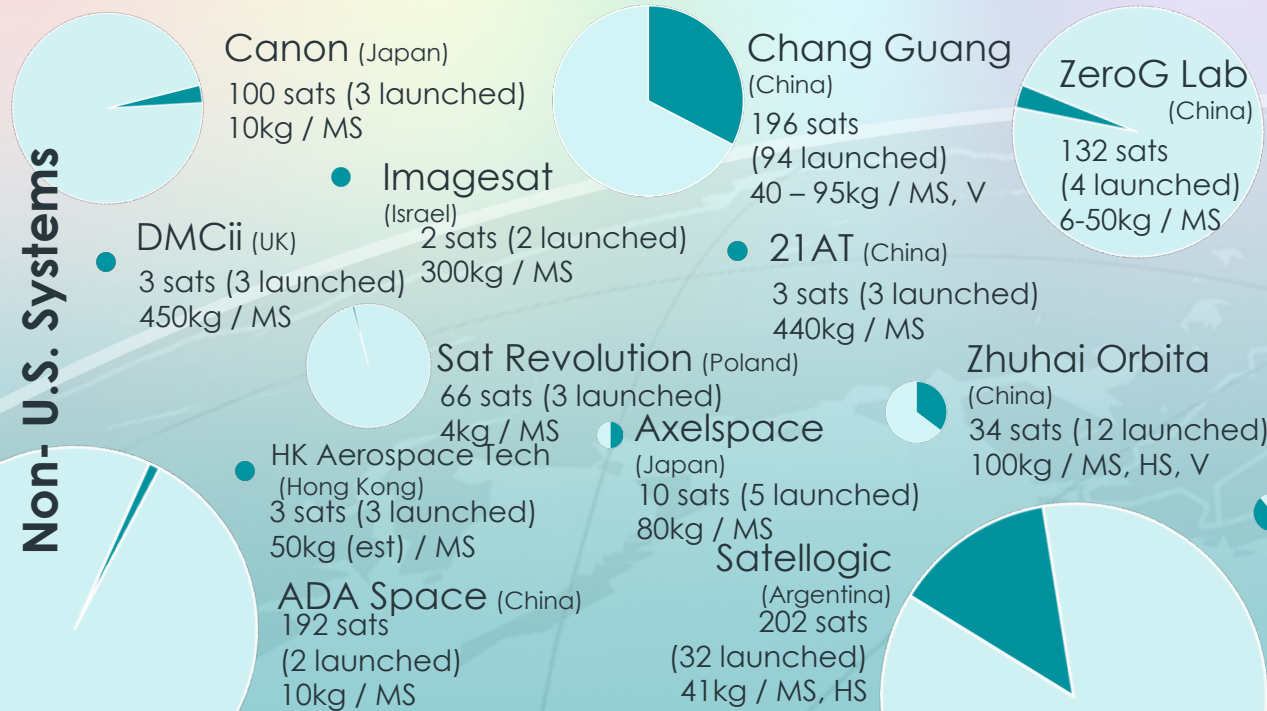
Synthetic Aperture Radar (SAR)

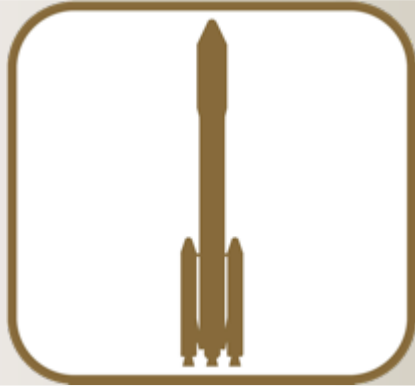


Other Systems



Non-U.S. Systems





Launch

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Launch

Changing Industry Dynamics

More affordable launches

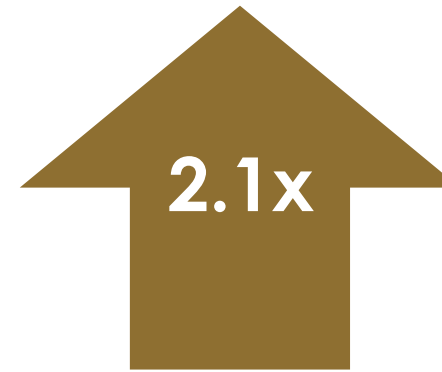
- ✦ \$/kg down 34%
- ✦ U.S. market share of internationally competed launches increased from zero in 2011 to 40%+, 2017 – 2021

Increased launch activity

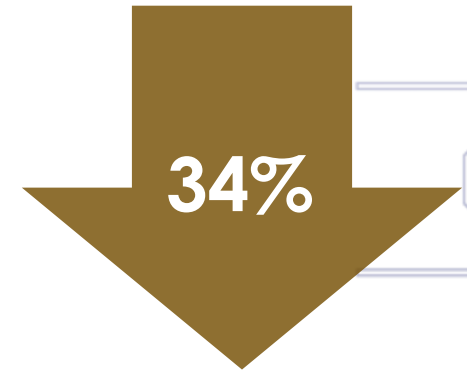
- ✦ More satellites launched per year, driven by smallsats (+12x more sats launched in 2021 vs 2012)
- ✦ More satellite upmass launched per year (2.1x)

More launch choices, capacity becoming available

- ✦ Routine use of reusable launch vehicles
- ✦ Increased rideshare opportunities
- ✦ New small vehicles (operational and planned)
- ✦ Next-generation medium-to-heavy launch vehicles expected to become operational soon



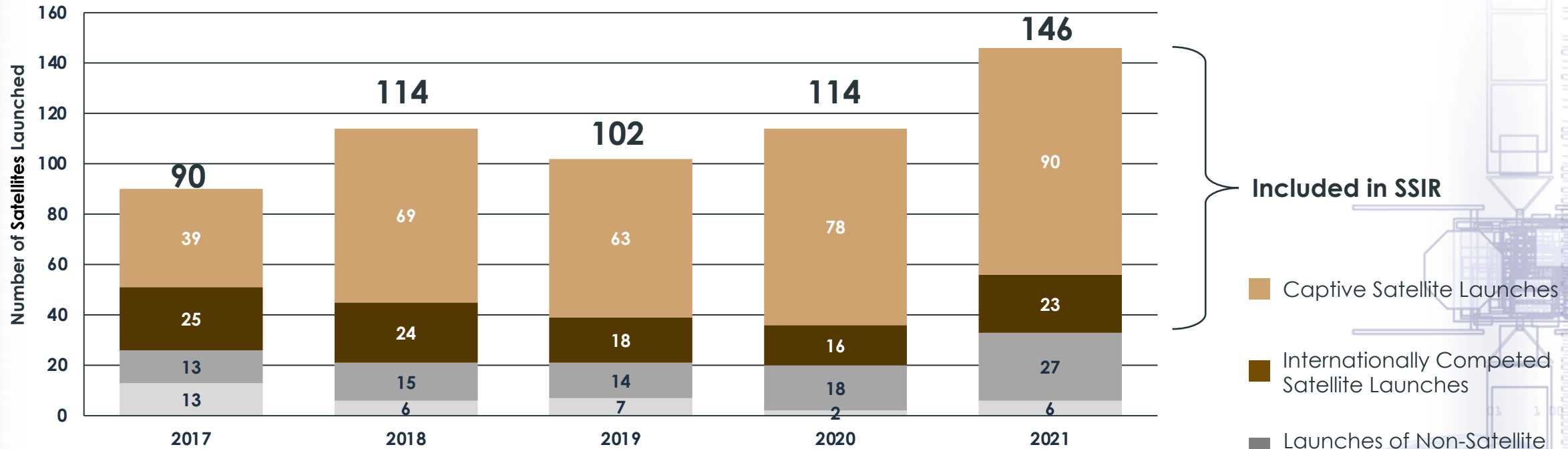
**Upmass
(2012 – 2021)**



**Price/kg
(2012 – 2021)**



Satellite Launch: Methodology



Included in SSIR

- Captive Satellite Launches
- Internationally Competed Satellite Launches
- Launches of Non-Satellite Missions
- Launches Not Procured Commercially

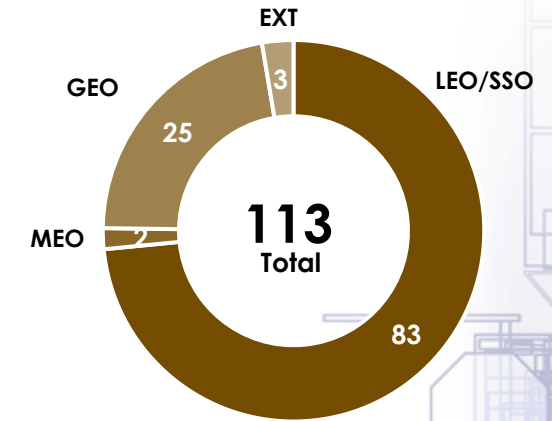
- ✘ Included in SSIR: commercially-procured satellite launches
 - Internationally-competed launches of satellites
 - Captive satellite launches procured from launch providers on contractual basis or privately-funded launches. Revenues include estimates for self-provided commercial launches
- ✘ Not included in SSIR
 - Launches of non-satellite missions (crew and cargo to ISS, other space vehicles)
 - Launches not procured commercially – a government agency providing a launch of a satellite owned by the same agency (e.g., ISRO)



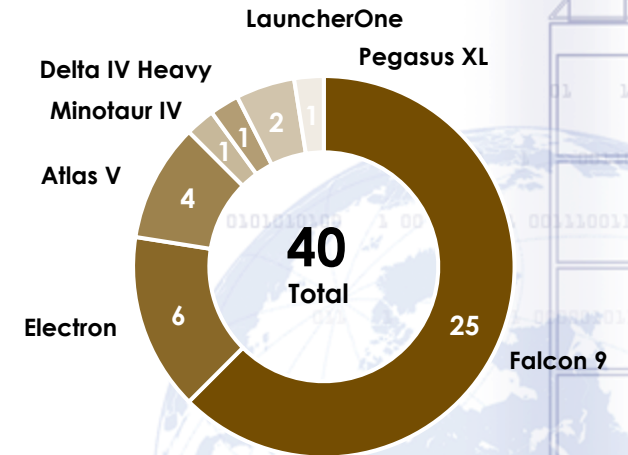
Launch: Industry Findings and U.S. Highlights



- ✦ \$5.7B revenues from commercially-procured satellite launches worldwide; 8% increase from 2020
- ✦ At 113, an increase of 20% in commercially-procured launches from 2020 (94)
 - Reflects commercial LEO broadband constellation launches in 2021 (27 launches)
 - Including all launches (non-satellite missions), 146 launches is most ever
- ✦ U.S. captured 36% of commercially-procured launch revenues
 - Increasingly competitive U.S. commercial launch prices
 - Increasing number of providers (e.g., Virgin Orbit, Astra)
 - 40 launches by U.S. providers (34 in 2020), 19 SpaceX Starlink launches
- ✦ Continuing trends
 - Launches of U.S. government satellites generated 25% of global revenues
 - Government customers worldwide remained the revenue driver (65%, from 67% in 2020), reflecting increased launch activity in China
 - European industry maintaining launch cadence
 - Russian internationally-competed launches remain low: one in 2021 (zero in 2020)



2021 Commercially Procured Satellite Launches by Orbit



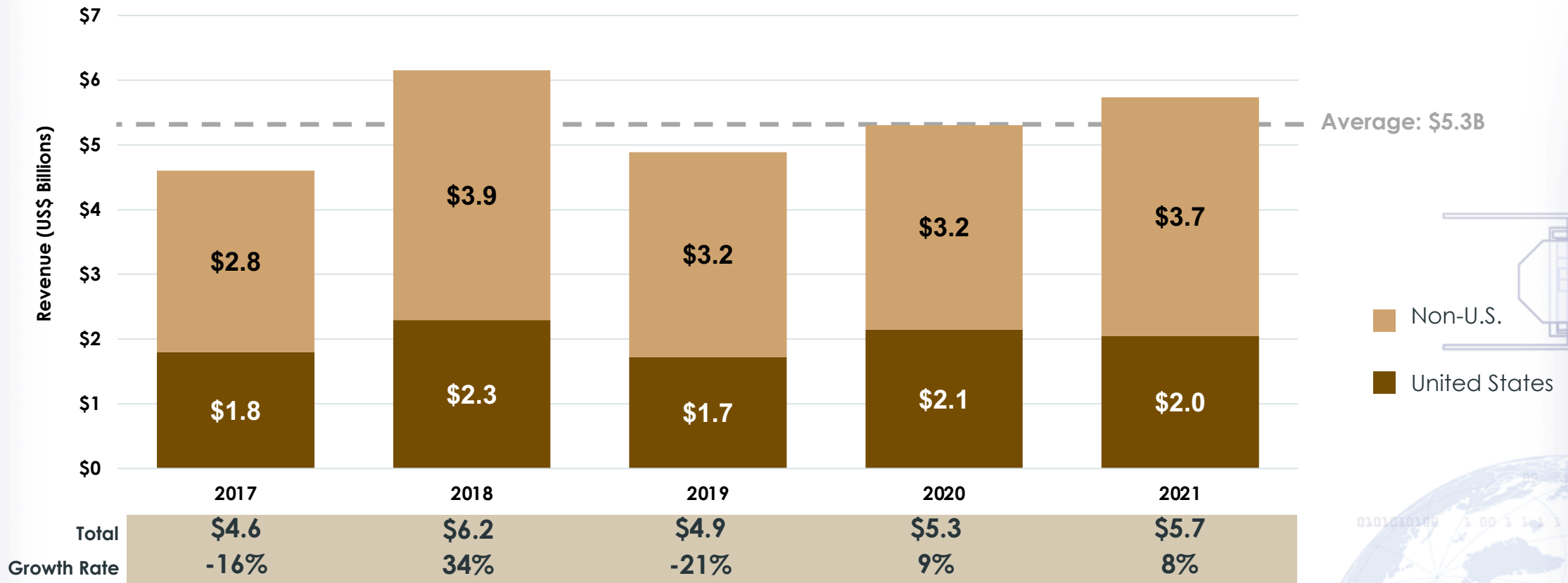
2021 Commercially Procured U.S. Satellite Launches by Vehicle

Prepared by:





Launch Industry Revenues



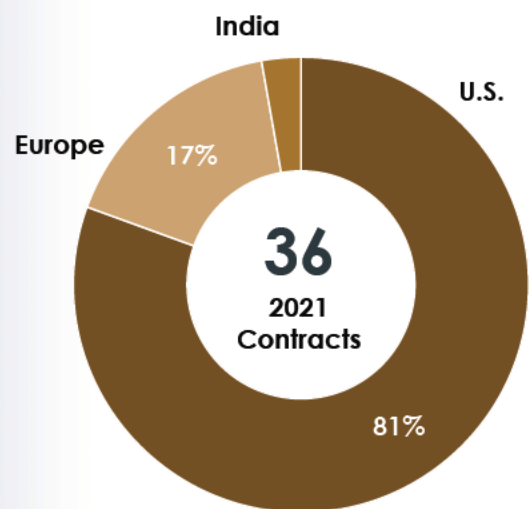
- ✕ \$5.7B global revenues in 2021 from commercially procured satellite launches
- ✕ U.S. share of global launch revenues in 2021 was 36% (41% in 2020)

Prepared by:

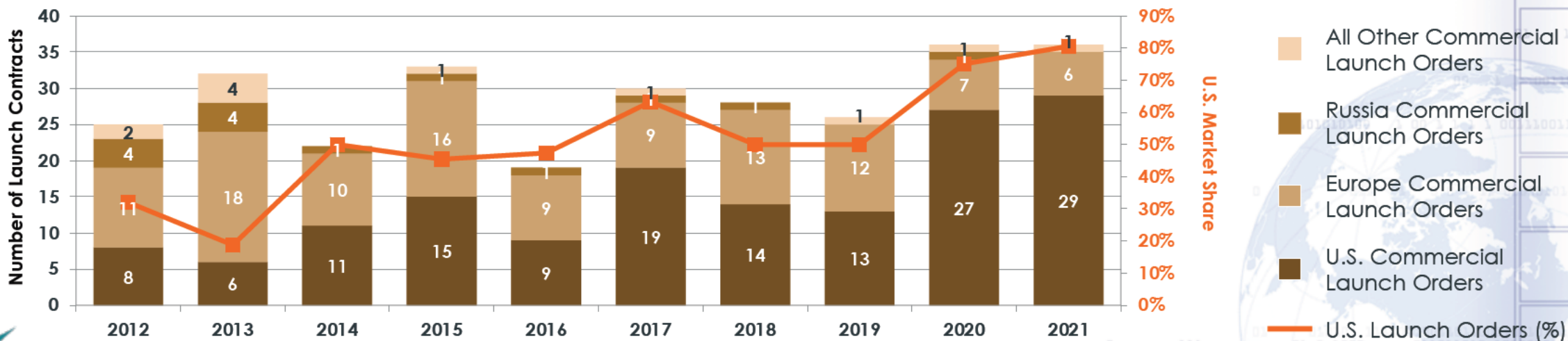




Future Indicator: Commercial Satellite Launch Contracts



- ✦ 36 competed orbital launch contracts announced in 2020 (36 in 2019)
 - U.S. providers awarded 29 contracts for a total of 107 launches, plus options
 - U.S. medium/large launch providers captured 12 contracts, 14 launches
 - U.S. small launch providers captured 17 contracts, 107 launches, plus options (includes 58 ABL launches from Lockheed)
 - European providers captured 6 contracts for a total of 8 multi-manifest launches
 - India captured 1 contract for 6 launches
- ✦ Many more contracts announced for small satellite rideshare
- ✦ Excludes Starlink launches on Falcon 9 (19 in 2021)
- ✦ Announced in 2022: 83 launches for Amazon Kuiper (ULA, Arianespace, Blue Origin)



Prepared by:



Ground Equipment

- ✦ Network Equipment
 - Gateways
 - Control stations
 - Very small aperture terminals (VSATs)
- ✦ Consumer Equipment
 - Satellite TV dishes
 - Satellite radio equipment
 - Satellite broadband dishes
 - Satellite phones and mobile satellite terminals
- ✦ Satellite navigation stand-alone hardware



Growing on-the-move connectivity

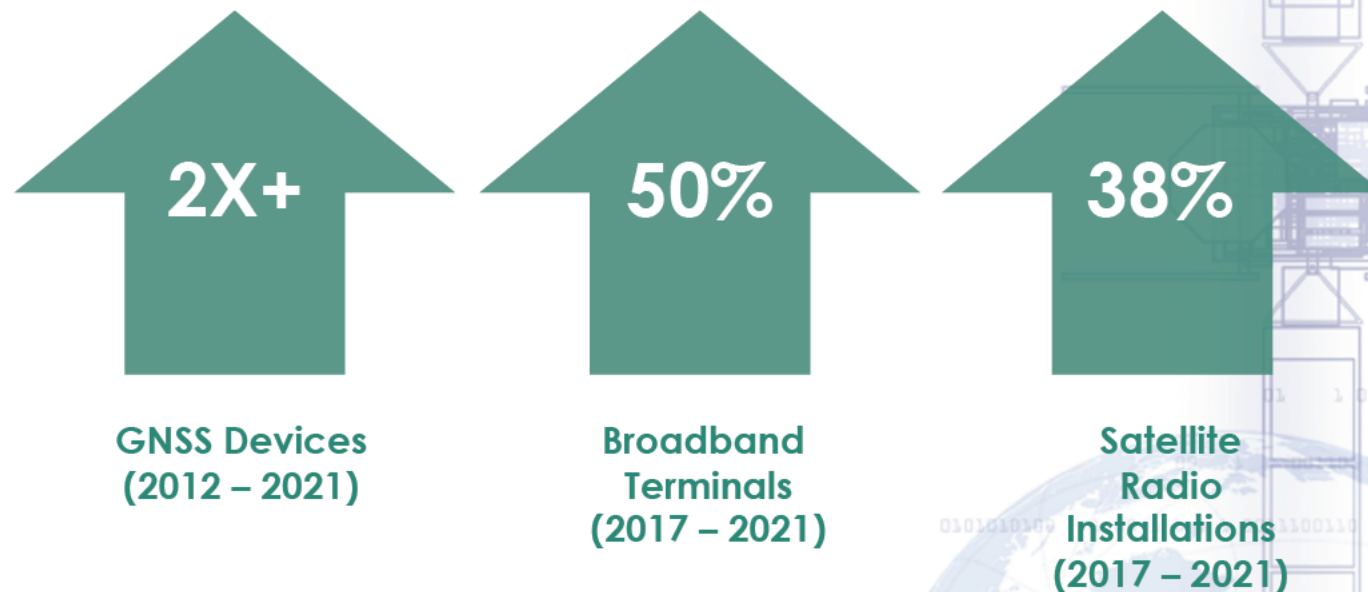
6.5 billion GNSS satellite-enabled smartphones, other devices in use

- ✘ Millions of unique location-based services, apps
- ✘ Mass-produced chipsets resulting in lower costs
- ✘ More than doubled over the past decade

Broadband, satellite radio installations on the rise

- ✘ Broadband terminals up 50% over 5 years
- ✘ Installed satellite radios up 38% over 5 years

Television viewership changing from traditional models



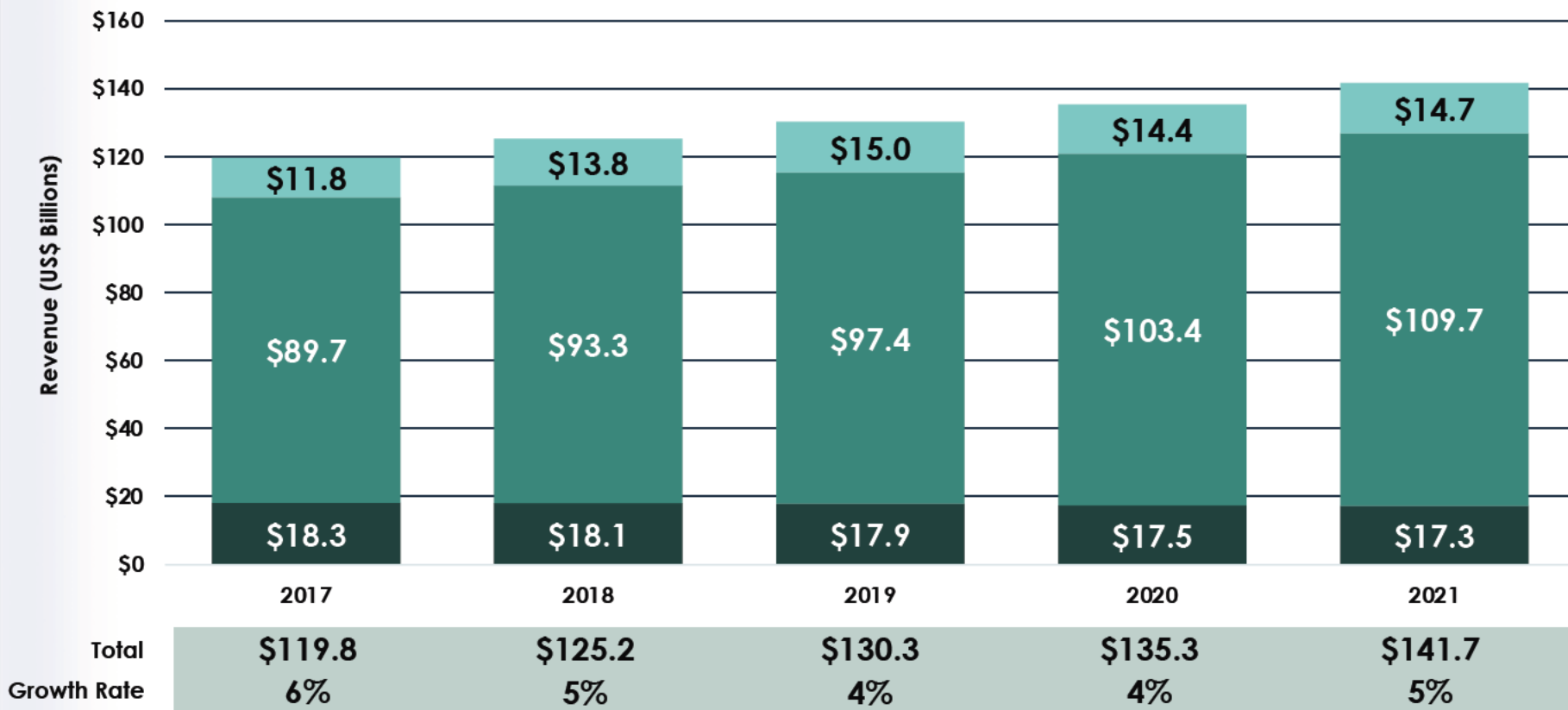


Ground Equipment Findings

- ✦ Total satellite ground equipment revenues increased 5% in 2021
- ✦ Satellite navigation (global navigation satellite systems, GNSS) revenues increased 6%
 - Includes equipment (including software updates), excludes downstream applications
 - Stand-alone and in-vehicle units
 - Components (mainly chipsets) directly enabling location-based capabilities in mobile devices, traffic information systems, aircraft avionics, and in maritime, surveying, rail, and other equipment
 - Increase in sales of connected and automated driving systems with GNSS components
- ✦ Network equipment revenues increased 2%. Revenues are returning to growth albeit slowly, reflecting some continuing COVID-19 related limitations
- ✦ Revenue from consumer equipment for satellite TV, radio, and broadband, and mobile satellite terminals (non-GNSS) revenues decreased 1%, with satellite TV receiver revenues decreasing in most markets, partially offset by growth in broadband



Global Satellite Ground Equipment Revenues



The U.S. share of ground equipment revenue in 2021 was **32%**

- Network Equipment
- GNSS Equipment
- Consumer Equipment
Satellite TV, Radio, Broadband, and mobile (Non-GNSS)

Network Equipment — gateways, network operations centers (NOCs), satellite news gathering (SNG) equipment, flyaway antennas, very small aperture terminal (VSAT) equipment.
Consumer Equipment — non-GNSS: satellite TV, radio, and broadband equipment, mobile satellite terminals.
GNSS — includes the entire GNSS segment: stand-alone navigation devices and GNSS chipsets supporting location-based services in mobile devices, traffic information systems, aircraft avionics, maritime, surveying, and rail.
Estimates based on GSA GNSS Market Report Issue 4, 5, and 6; EUSPA EO and GNSS Market Report 2022; other data.

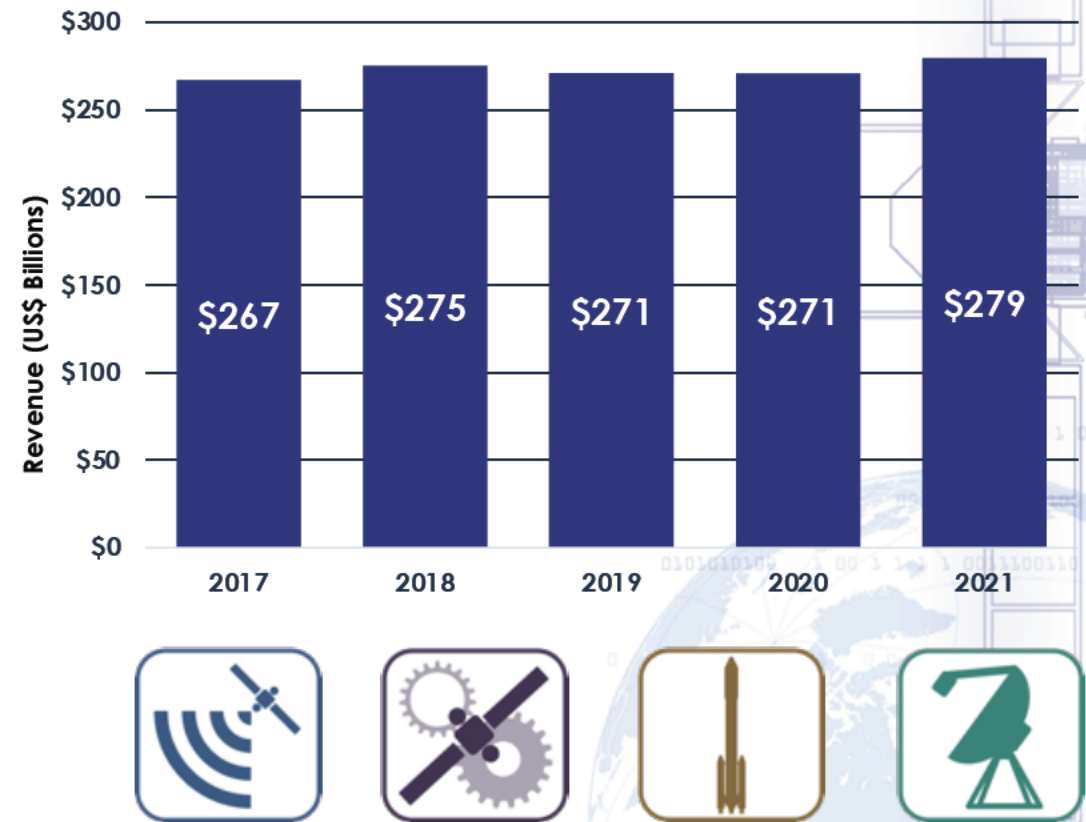
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Summary: Top-Level Global Satellite Industry Findings

- ✦ Record numbers of satellite deployments and launches
 - 1,849 spacecraft launched 2021 (vs 1,282 in 2020)
 - 146 launches (vs 136 in 1967)
- ✦ Satellite industry driving increased affordability and productivity, new capabilities
 - PLEO broadband systems in beta (1,273 launched 2021)
 - Growth in HTS capacity, lower overall cost per Gbps
 - Less expensive satcom capacity leads to more affordable satellite broadband connectivity
 - Increase in resolution, revisit of commercially satellite imagery across sensor types
 - More affordable launches
- ✦ Growth across all segments
 - Manufacturing +12%
 - Satellite services +0.4%
 - Launch +8%
 - Ground equipment +5%

2021 Satellite Industry Revenue \$279B



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**The voice of the
satellite industry**

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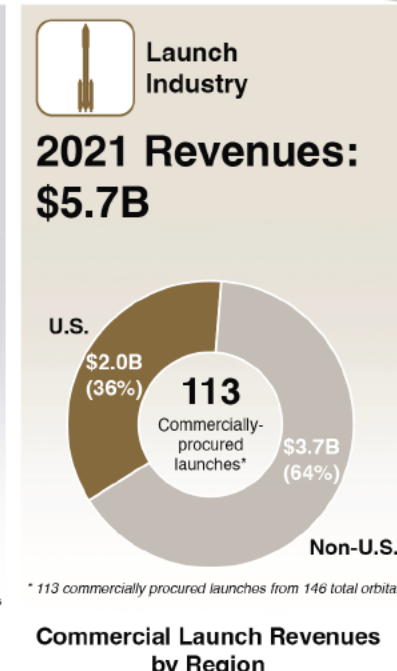
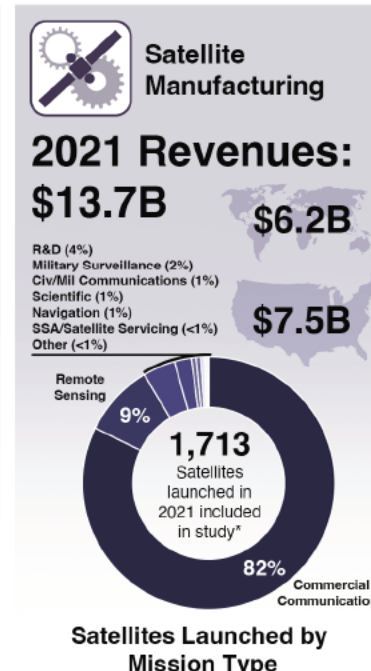
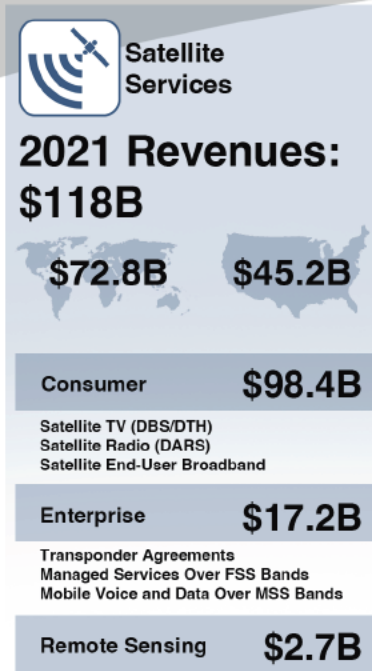
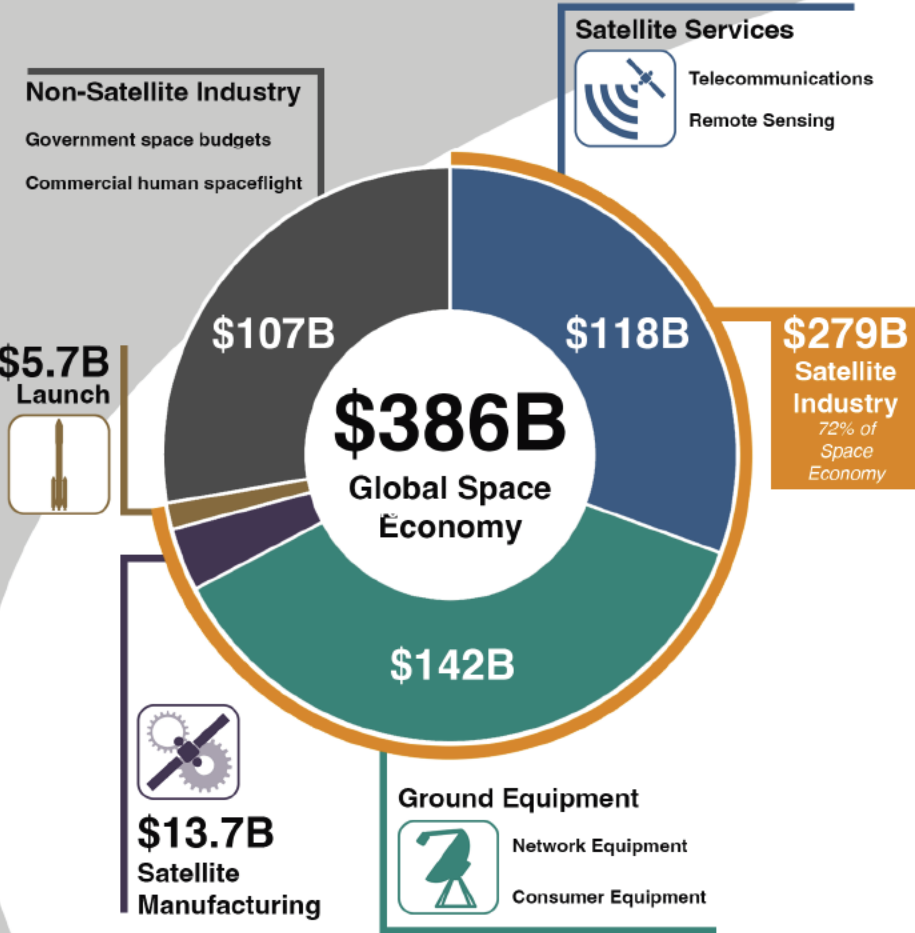
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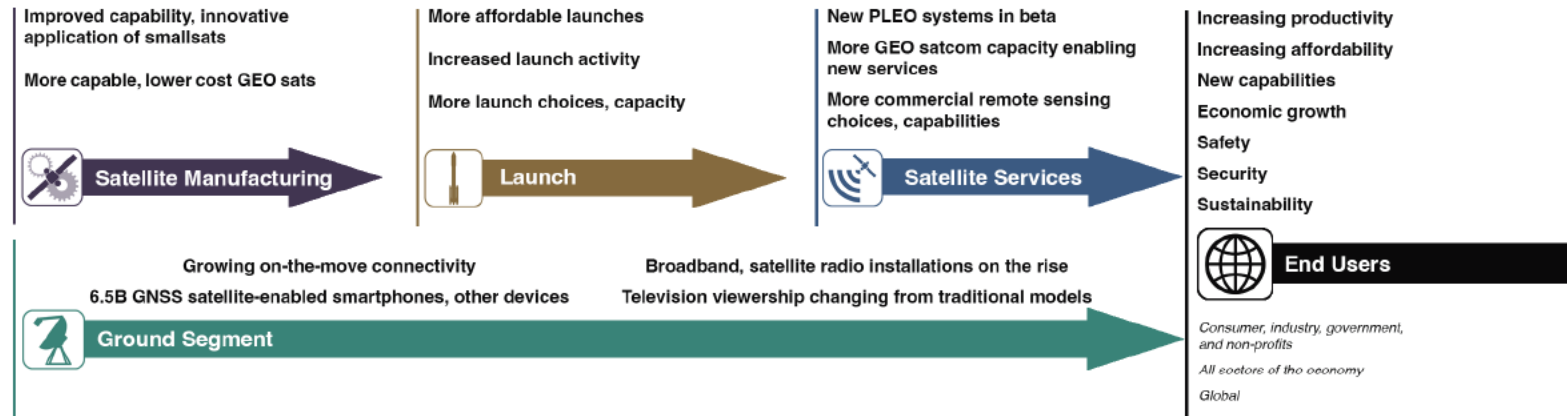
2021 Global Satellite Industry Revenues

The Satellite Industry in Context

(2021 revenues worldwide in billions of U.S. dollars)



Changing Industry Dynamics: Increasing Affordability and Productivity, New Capabilities



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