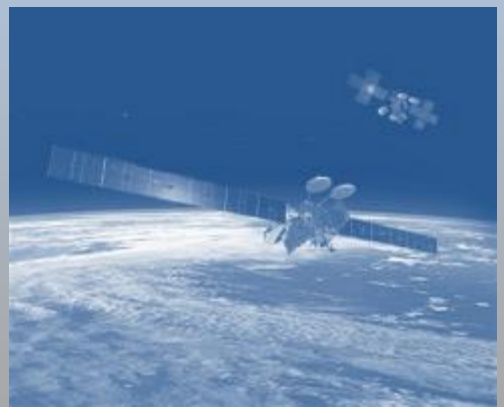
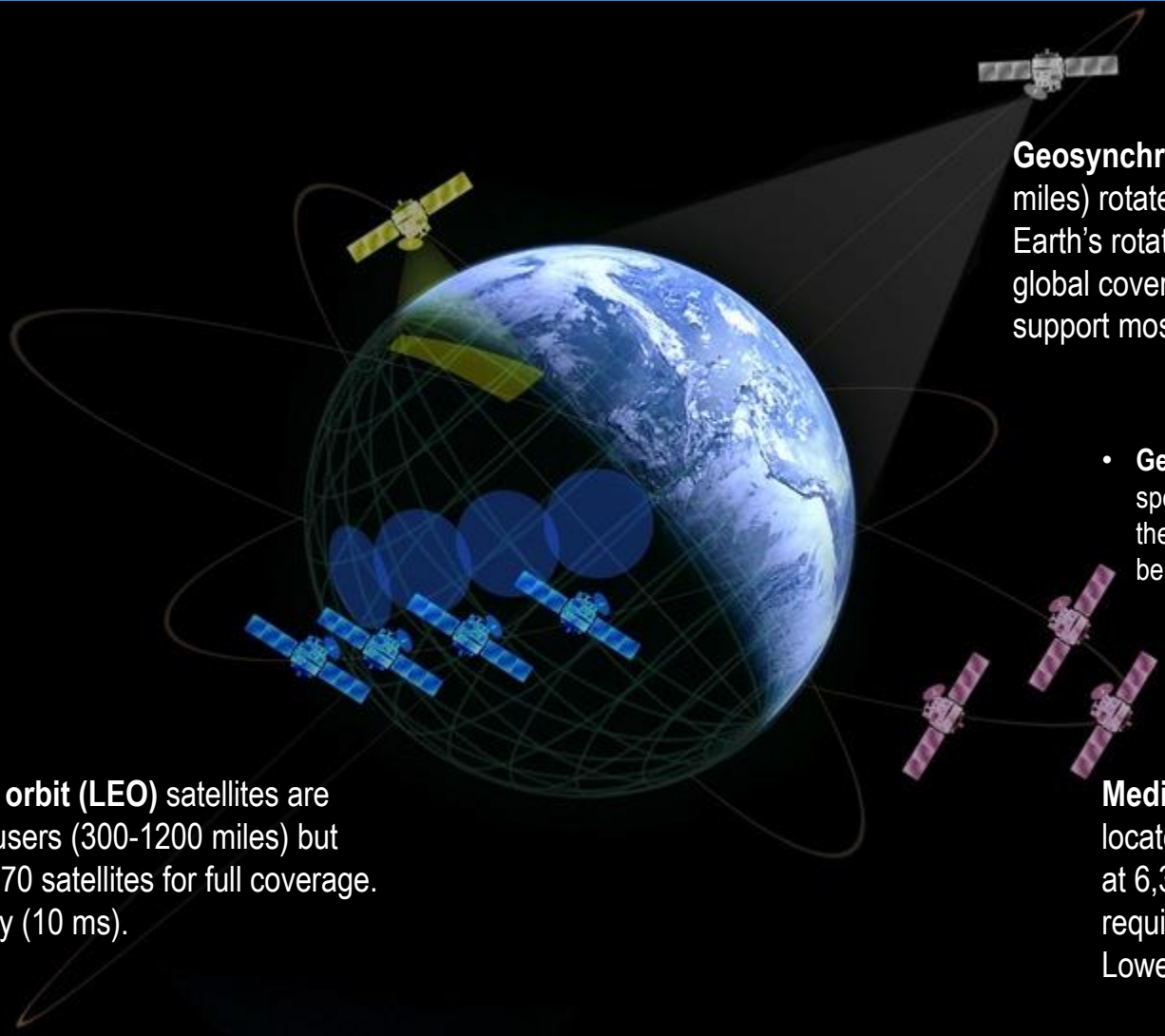
Introduction to the Satellite Industry

Introduction:
Satellites are Essential to our Modern Society

- Continuously delivering Earth Observation; Position, Navigation, Timing; and Communications to all
- Establishing global leadership in space network innovations
- Assuring lynchpin services to protect our nation
- Serving as an Incubator for Next-Gen Technology
- Providing ubiquitous connectivity and information services, daily and in time of disaster
- Broadband, Media, and Entertainment in every format



Basics: Satellite Segment



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.

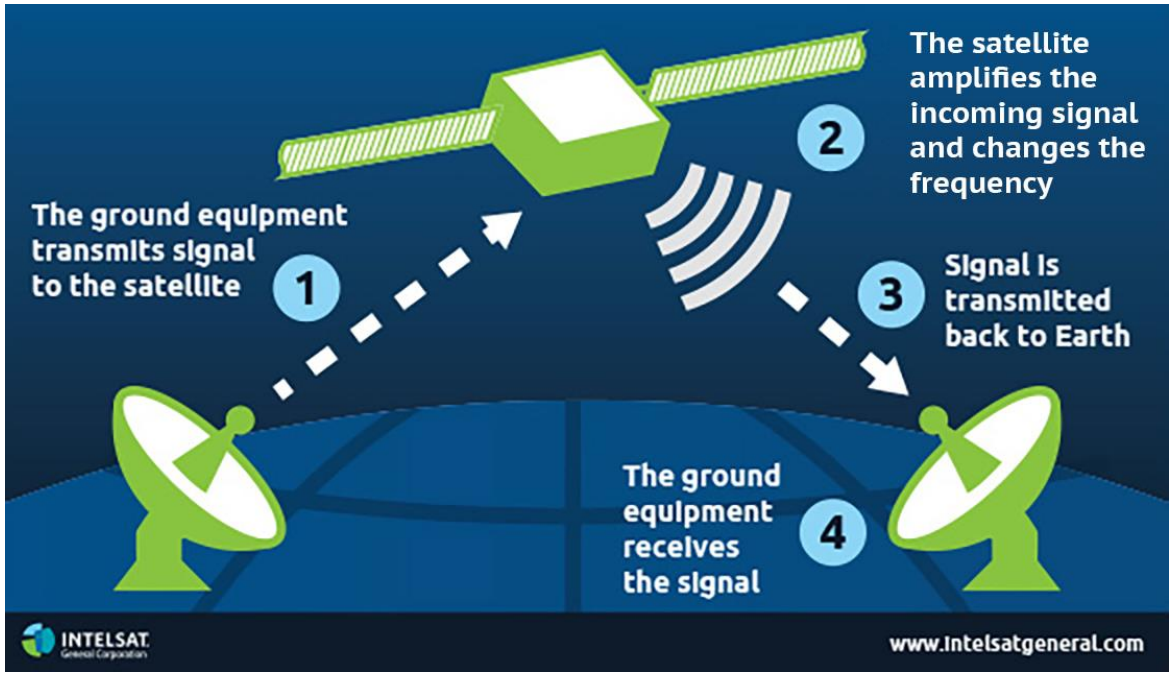
- **Geostationary Equatorial Orbit (GEO)** is a special case of GSO in which satellites circle the Earth above the Equator and appear to be stationary over a fixed position.

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

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).

Basics: Key Satellite Network Elements

- Space Segment
  - Satellites in geostationary orbit or non-geostationary orbit (medium earth orbit, or low earth 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.



Basics: Unique Attributes of Satellites

- **Large geographic coverage**
  - interconnecting widely distributed networks
  - providing broadcasting services over a country, region, or entire hemisphere
  - providing “last mile” connectivity for telecom services, broadband and video services
- **Instant infrastructure**
  - always-on network redundancy
  - emergency connectivity
- **Supporting Mobility**
  - voice, data, broadband, or mobile video
  - air, land, or sea
- **Wide Area Observation**
  - Collecting data or large swaths over land and ocean
  - Diverse sensor information for varying types of information

Satellites provide a variety of mobile and fixed communications services

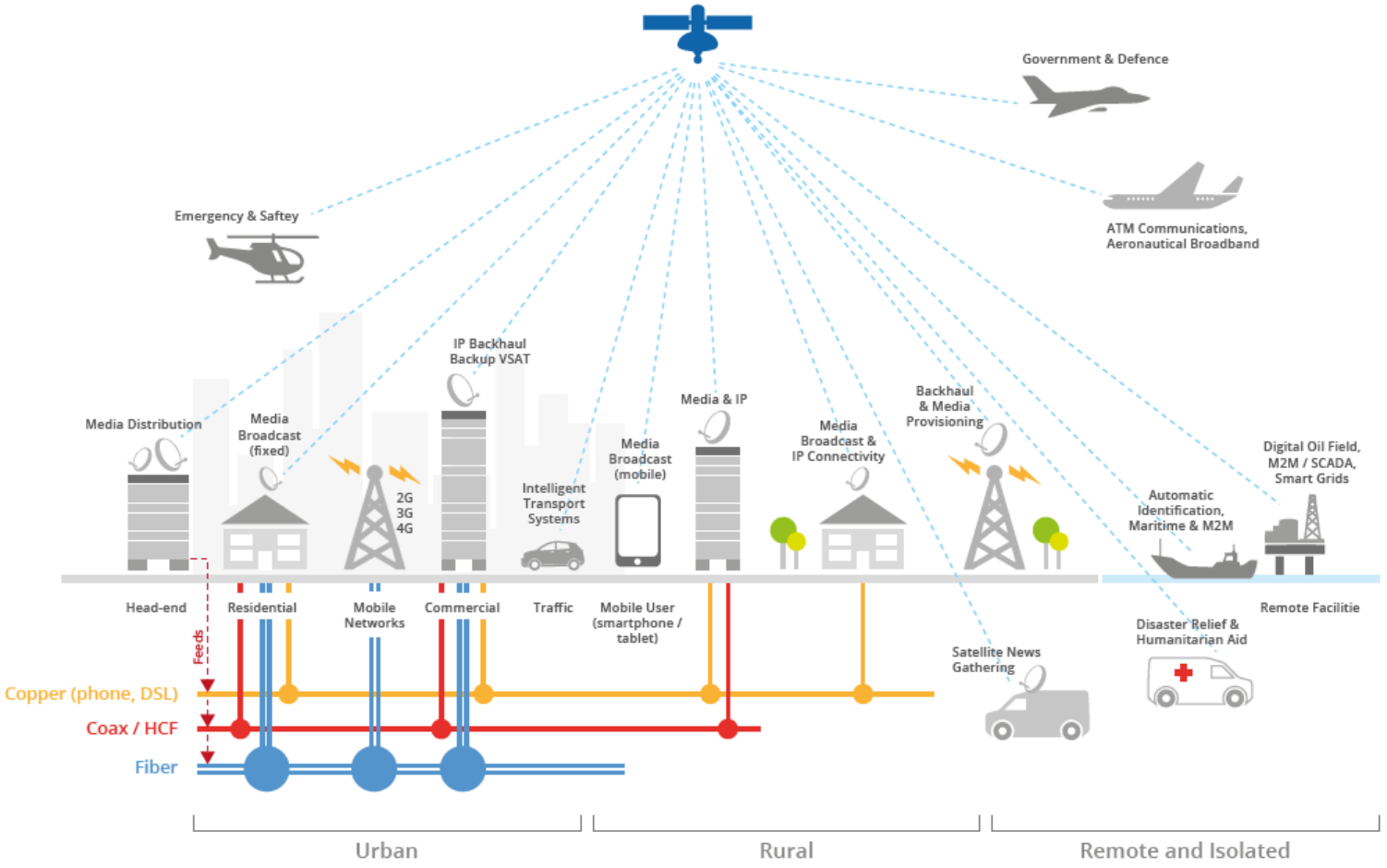
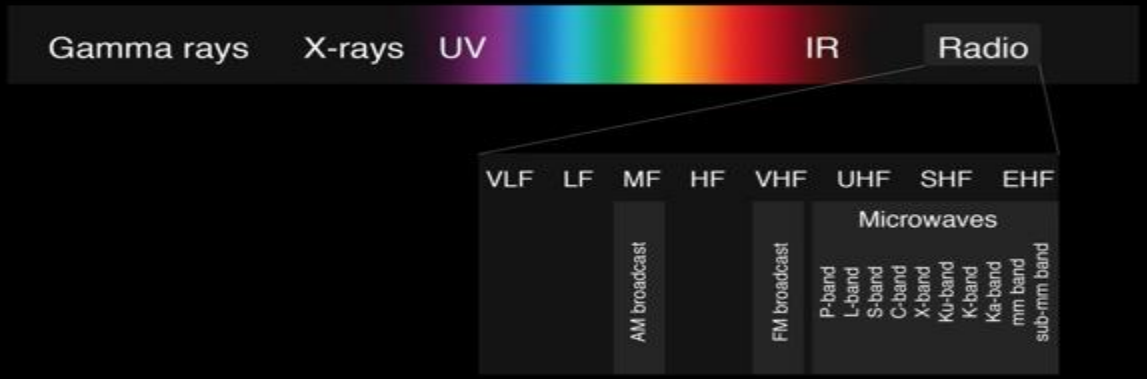


Image credit: ESOA

Basics:
Frequency Assignment



The International Telecommunication Union (ITU) is the venue for registering GEO orbital slots (via companies' governments) and has allocated specific frequency ranges used by commercial satellites globally:

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 Ground Equipment

- **Fixed Satellite Services (FSS)* network equipment and consumer terminals**
  - Wide range of sizes and costs
    - Teleports with many Earth Stations
    - VSAT dishes for private corporate networks and credit card
    - Consumer terminals for high-speed broadband at lower cost and easier install
  - May be stationary, transportable or in motion/on a mobile platform (aircraft, ship, vehicle)
- **Mobile Satellite Services (MSS)* terminals**
  - Provide voice or data services
  - Form factors vary from business card-size modems to laptop-size receivers and sleeves to convert mobile phones
- **GNSS equipment and chipsets**
  - Provide Position, Navigation, and Timing information to either standalone devices (e.g., Garmin) or integrated into other devices (e.g., cell phones)

May be stationary, transportable (newsgathering), or in motion/on a mobile platform (vehicle, aircraft, vessel)

*FSS and MSS defined by frequency, and no longer defined by whether or not the services are mobile

Satellite Communications Innovation Trends

- 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 will provide low-latency broadband worldwide

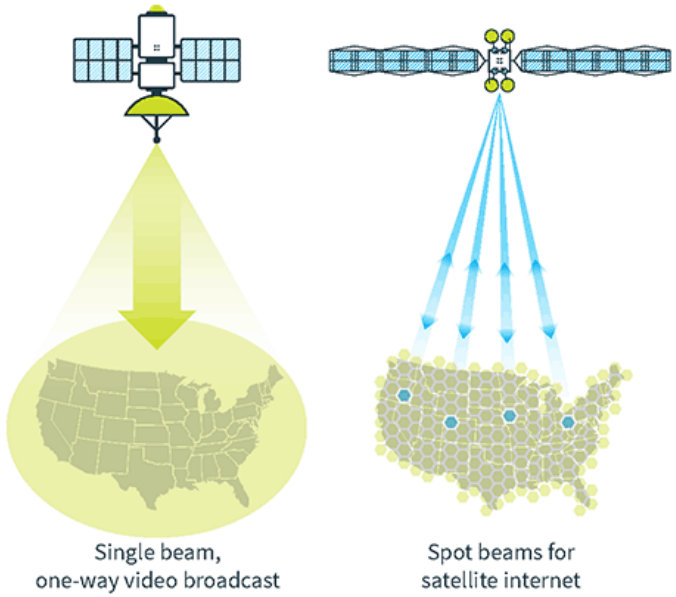
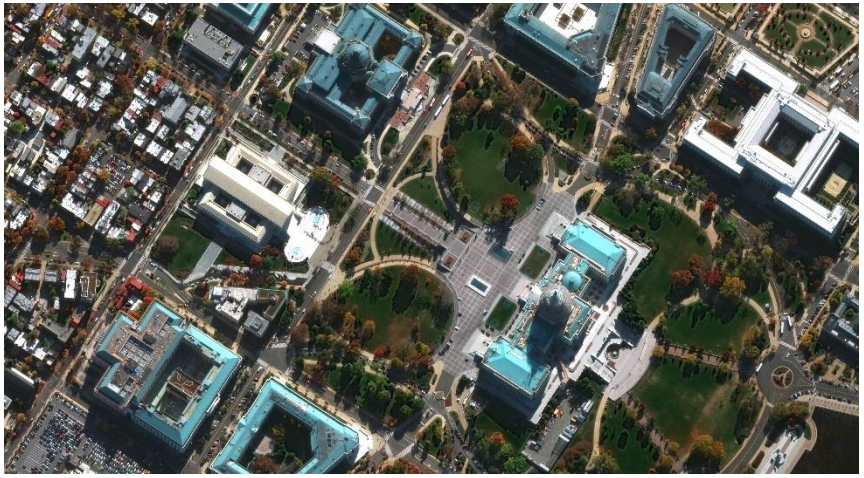


Image credit: Viasat

Satellite Imagery Innovation Trends

- 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.



Maxar's WorldView-3 satellite images in 30 cm resolution.

Planet satellite captures North Korean missile launch, 5/4/19

Non-imaging Remote Sensing Trends

- 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

HawkEye 360's geolocation of VHF-16 maritime distress signals near the Auckland Islands.

Spire Maritime AIS and Spire Aviation ADS-B data.

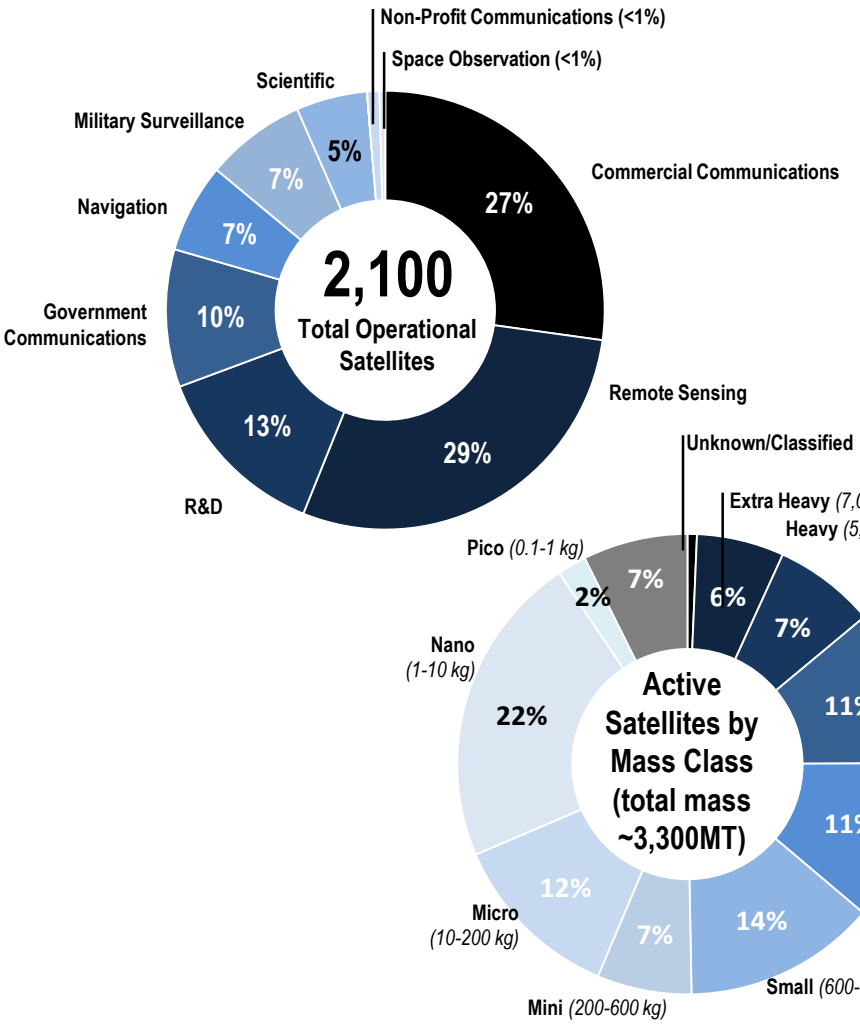
Satellite Services Findings: Fixed and Mobile Services

- Mobile Satellite Services grew 3% from 2017-2018
  - MSS operators continued increasing penetration into the IoT markets
  - LEO MSS operators fully deployed new generation satellites
  - GEO MSS operators bundle MSS with managed FSS and broadband services
- Fixed Satellite Services: managed network service 7% revenue growth from 2017-2018, offset decline in transponder leasing
  - Continued expansion in in-flight connectivity and other mobility applications
  - Operators providing consumer broadband also drive the mobility application expansion
  - Deployment of additional high-throughput satellite (HTS) capacity

The Satellite Network in Context

- Estimated as of December 31, 2018
- Number of satellites increased 67% over 5 years (from 1,261 in 2014)
  - Satellites launched 2014—2018 increased 243% over previous 5 years
    - Average 210/year
    - Due mostly to small/very small satellites in LEO (<1,200 kg)
  - Total satellite mass in orbit about 3,300 metric tons
  - Average operational lives of larger (mostly communications) satellites becoming longer, exceeding 15 years; 272 active satellites launched before 2003
  - 558 active satellites in GEO (27 more than in 2017, mostly providing communications services)
- 2,100 satellites operated by entities from 68 countries (some in regional consortia)
  - Cumulatively, organizations from 86 countries have deployed at least one satellite since 1957
- U.S. entities operate 849 satellites, some in partnership with other nations

Operational Satellites by Function and Mass Class

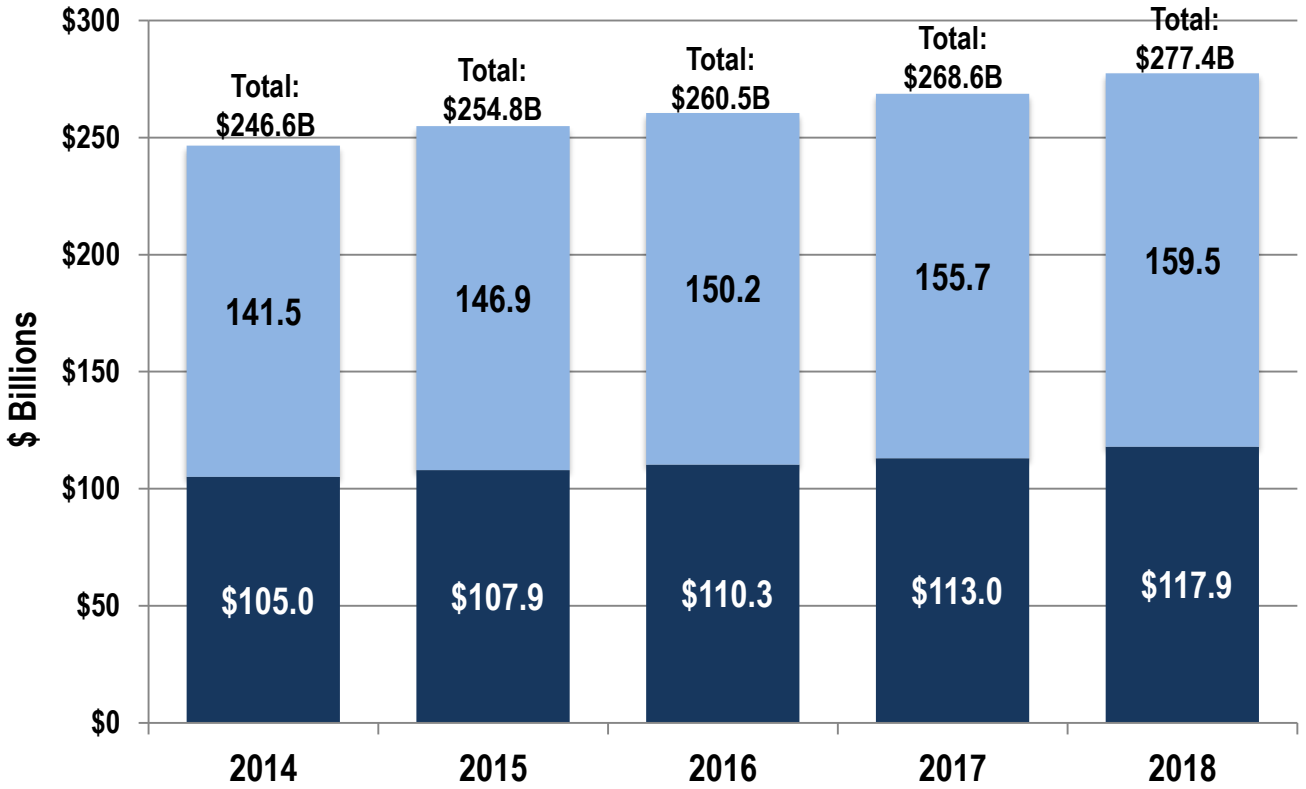


Global Satellite Industry Revenues: U.S. Portion

Average yearly U.S. market share

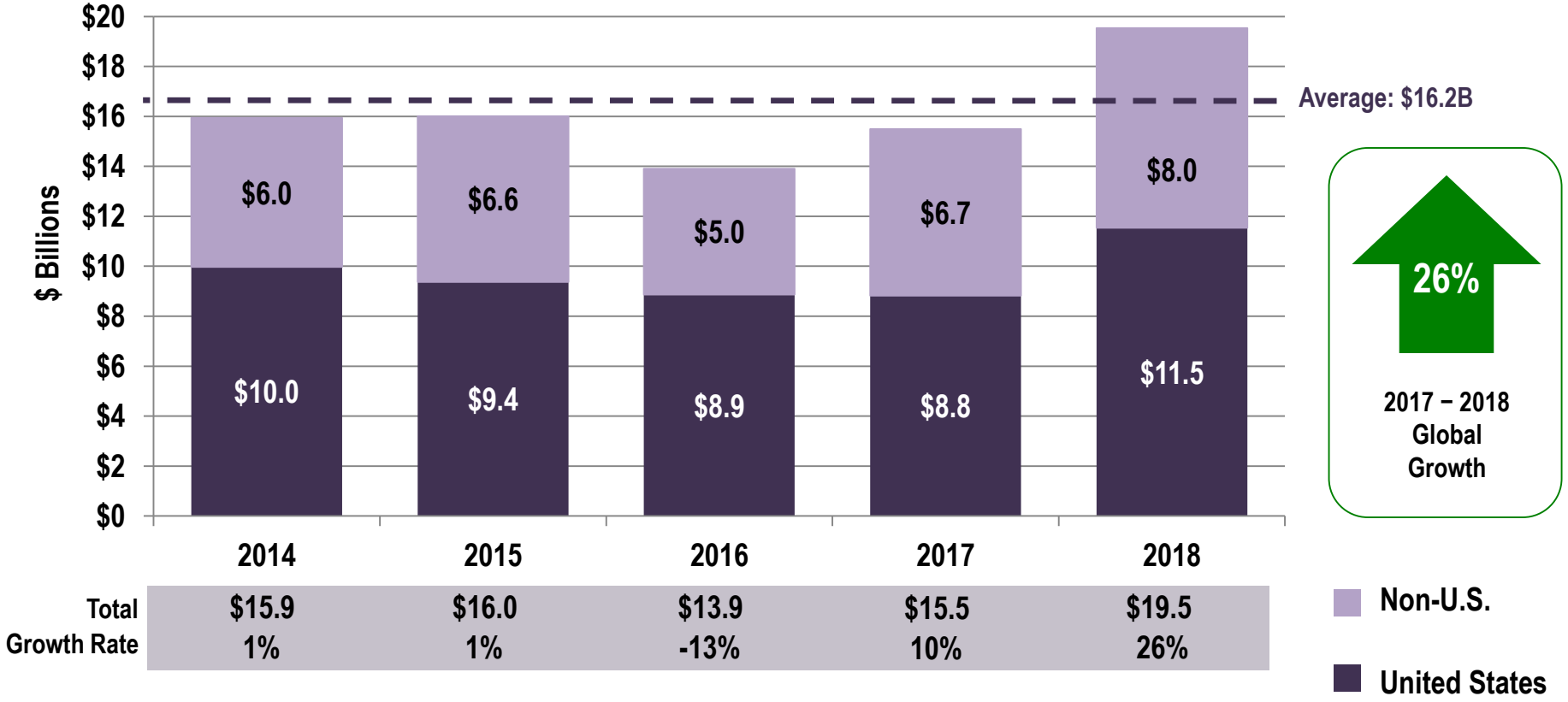
43%

of global industry



	2014	2015	2016	2017	2018
Growth Rate	7%	3%	2%	3%	3%
U.S. Growth	4%	3%	2%	2%	4%
Non-U.S. Growth	9%	4%	2%	4%	2%

Satellite Manufacturing Revenues

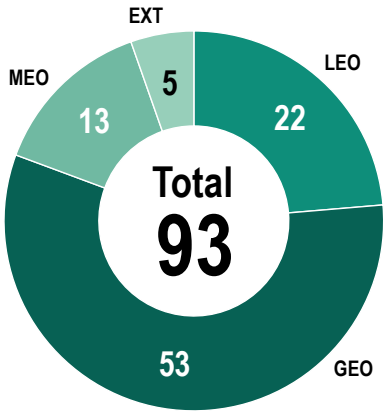


- Worldwide 2018 revenues totaled $19.5B
- In 2018, U.S. share of global revenues was 59%, in line with 57% in 2017

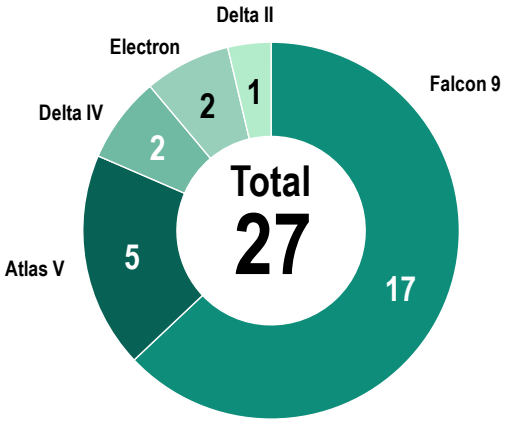
NOTE: Satellite manufacturing revenues are recorded in the year of satellite launch. Do not include satellites built by governments or universities. Data based on unclassified sources.

U.S. Satellite Launch Industry Findings

- $6.2B revenues from commercially procured satellite launches worldwide; 34% growth
- Record number of commercially procured satellite launches worldwide (93 – higher than in any previous years; 64 in 2017)
- U.S. had largest share (37%) of commercially procured launch revenues; 27 launches by U.S. providers (23 in 2017)
- Record year for Chinese launch providers – 39, all captive except 1 internationally competed launch (previous maximum – 22 launches in 2016)
- Continuing trends
  - Launches of U.S. Government satellites generated 23% of global launch revenues
  - Government customers worldwide remained the revenue driver (growing to 71%, from 55% in 2017), reflecting increased launch activity in China
  - European provider Arianespace maintaining launch cadence
  - No commercial launches from Russian providers, continuing decline



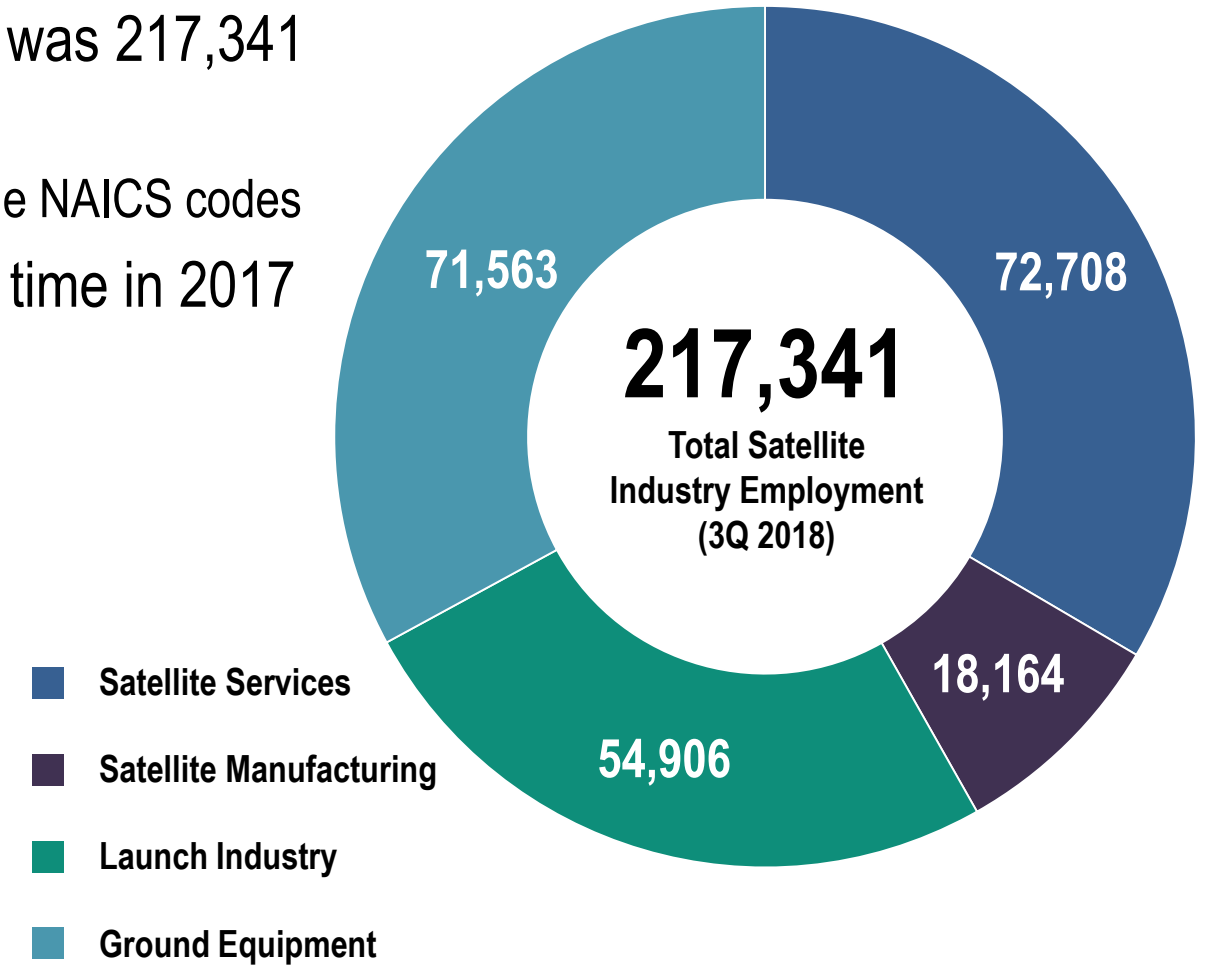
2018 Commercially Procured Satellite Launches by Orbit



2018 Commercially Procured U.S. Satellite Launches by Vehicle

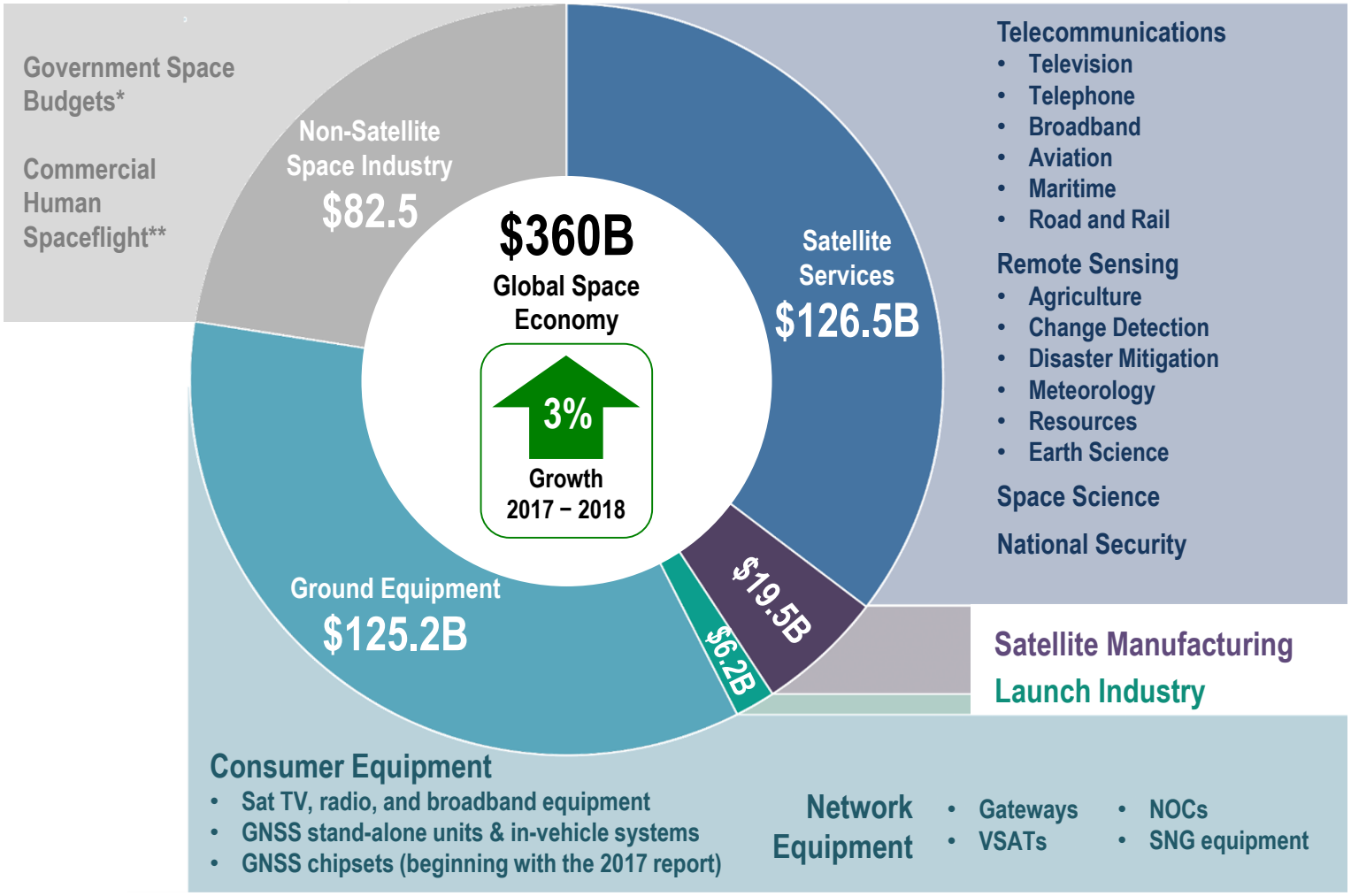
U.S. Employment Impact

- In 3Q 2018, satellite industry employment in the U.S. was 217,341
  - Private sector only
  - Estimated across multiple NAICS codes
- 2% increase over same time in 2017



Source: analysis of data from U.S. Bureau of Labor Statistics (BLS).

The Satellite Industry in Context



** Includes government civil and military space spending by 70 countries and international organizations (ESA) using published data.*

*** Includes commercial cargo missions to ISS and other human spaceflight projects, about $2B*

Acronyms: Network operations centers (NOCs), satellite news gathering (SNG), very small aperture terminal (VSAT) equipment, global navigation satellite systems (GNSS)

Satellite Services Findings: Consumer Services

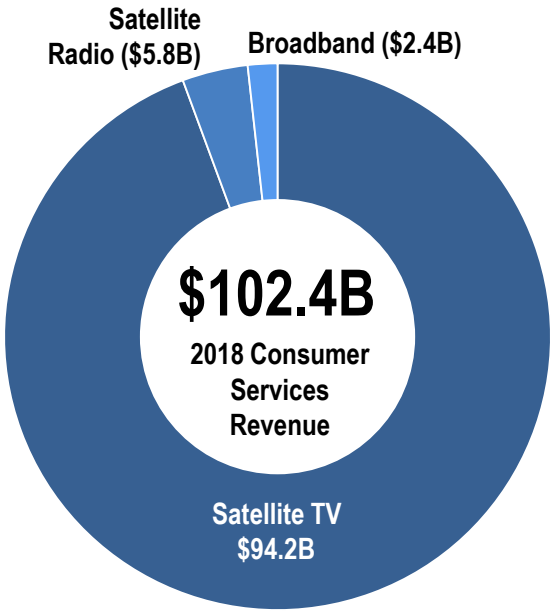
- Satellite radio and broadband revenues grew 7% and 12% from 2017-2018, respectively
- Satellite radio and broadband subscribers grew 4% and 6% from 2017-2018, respectively

Satellite Radio

- Satellite radio (DARS) revenues grew 7%
- DARS subscribers grew 4%, to 34 million
- Mostly North American customer base

Satellite Consumer Broadband

- Revenue grew 12%
- Subscribers grew 6%, to slightly over 2M
- Higher revenue per user in the U.S.
- Capacity available on newly launched GEO satellites over the U.S. allows operators to add subscribers, offer more bandwidth; new LEO constellations will add more capacity
- Majority of subscribers in the U.S., growing numbers outside the U.S



Satellite TV Services

- Satellite TV services (DBS/DTH) declined 3%, accounted for 74% of all satellite services revenues; 92% of consumer revenues
- 220M+ satellite pay-TV subscribers worldwide (plus 190M+ free-to-air satellite TV homes) in 2018
- Subscribers and revenue declining in the U.S.
- Lower per-user revenues combined with growing or flat subscriber numbers outside U.S.
- 38% of global revenues attributed to U.S.
- Number of Ultra-HD channels growing slowly, around 1% of total global TV channels
- HD channels about 30% of all TV channels
- Contributing to slower demand for satellite capacity: improving compression technologies; growing numbers of consumers continue to opt for IP-based video services

Global Competitiveness of the Satellite Industry Depends On

- Spectrum access that enables growth
- A predictable while adaptive regulatory environment
- Continuous improvement of export regulation
- A level playing field internationally
- Public-Private Partnerships that invest in satellite services and technologies, encouraging growth
- A sustainable orbital environment with which to operate in and provide services from

Satellites play a key role in the U.S. economy, for infrastructure, and national security.
Now is the time to create the regulatory conditions for the industry's continued success.

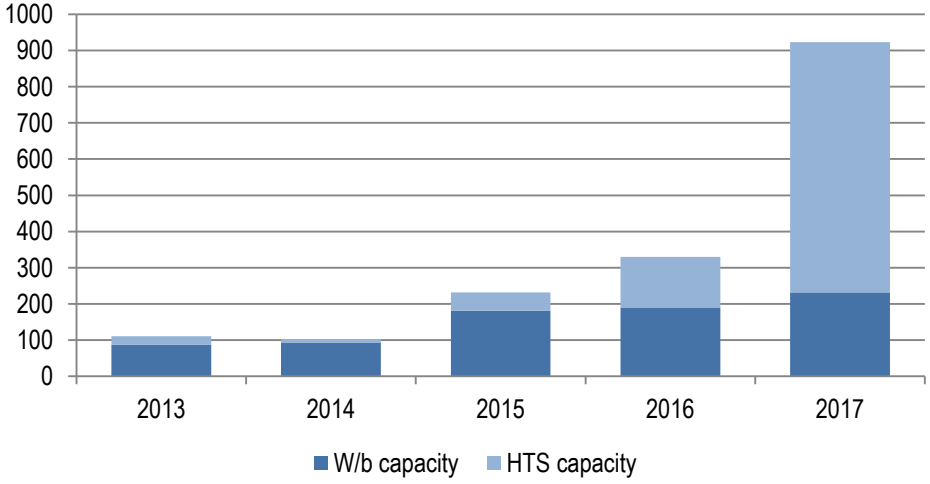
Satellite Industry Association: 24 Years as the Voice of the U.S. Satellite Industry

SIA Member Companies

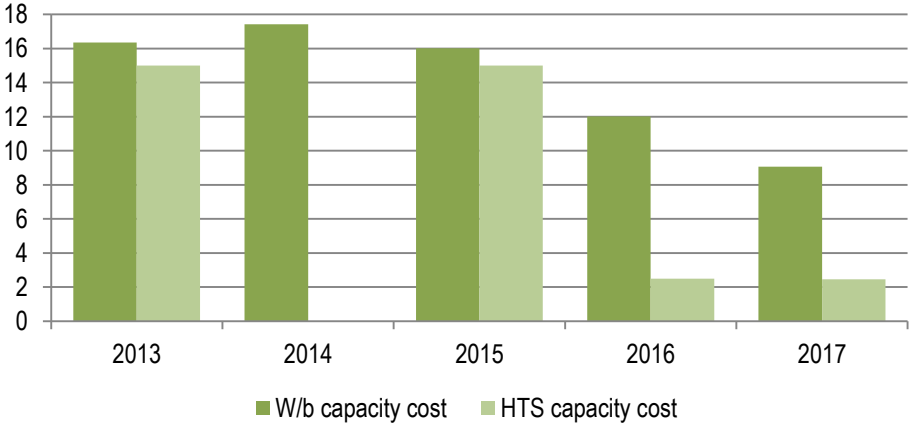
Case Study: New Satellite Capacity Deployment and Cost Trends

- Significant new capacity deployed in 2016 – 2017, driven by high-throughput satellites (HTS)
- Growth in HTS capacity results in lower overall cost per Gbps
- More capacity and decreasing cost leads to more affordable satellite broadband connectivity; improved affordability; greater data volumes and speed offered to multiple markets
- Companies plan to deploy up to 30 Tbps of capacity through 2022 (estimated at about 3 Tbps today)
  - Total capacity of planned GEO satellites under contract and in development: over 5 Tbps
  - New LEO/MEO constellations under contract and in development: up to 25 Tbps

New Capacity Launched by Year, Gbps



New W/b vs. HTS Capacity Cost, $M/Gbps



Notes: Satellite capacity cost estimated based on satellite manufacturing prices
Future capacity estimates reflect publicly announced plans and manufacturing contracts; some systems may not deploy

Case Study: Remote Sensing Services

- For many years, global remote sensing services were offered by small number of operators
- New competitors and new partnerships have recently emerged
- Tremendous investment and innovation driven by interest in business intelligence products using satellite imagery and powered by advances in data analytics and artificial intelligence (AI)
- Industry maturation
  - New systems continue to be announced
  - Certain industry consolidation through mergers and acquisitions in 2013 – 2017
    - *Operational includes initial deployment through full capacity*
    - *UrtheCast operates cameras aboard ISS and acquired assets from Elecnor Deimos, but is also planning to deploy optical and radar satellites*
    - *exactEarth/Harris features hosted payloads, rather than dedicated satellites*
    - *Criteria for inclusion are satellites on orbit, announced funding, signed launch contract/agreement, or NOAA license*
    - *Acronyms: MS – multispectral, HS – hyperspectral, RO – radio occultation, RF – radio frequency, AIS – Automatic Identification System; ADS-B – automatic dependent surveillance—broadcast*

Operational
Planned

		Country	High Res (<1m)	High revisit (≤1 day)	Sensor Description	Number of Satellites	Typical Sat Mass (kg)	Generating Revenue (GR), Start-up no/some revenue (SU)	Added in 2018 SSIR
Large Sats	***Maxar***	CAN	●	●	Optical (MS), radar	15	150-2,200	GR	
	Airbus Intelligence	FR	●	●	Optical (MS), radar	9	430-3,085	GR	
	ImageSat	IL	●		Optical (MS)	3	280-370	GR	
	21AT/TripleSat	UK/CN	●		Optical (MS)	3	350	GR	
	UrtheCast	CAN	●	●	Optical, radar	26	300-1,400	GR	
Small Satellites (<200 kg)	***Astro Digital***	USA	●	●	Optical (MS)	30	10-20	SU	
	Axelspace	JP	●	●	Optical (MS)	50	95	SU	
	BlackSky Global	USA	●	●	Optical (MS)	60	55	SU	
	Capella Space	USA			Radar	30	TBD	SU	
	Chuang. Sat. Tech. Co.	CN		●	Optical (MS)	60+	420	SU	
	Earth-i	UK	●	●	Optical (MS), video	TBD	80	SU	
	GeoOptics	USA		●	RO	24	TBD	SU	
	HawkEye 360	USA		●	RF mapping	3+	13	SU	
	Hera Systems	USA		●	Optical (MS)	48	12	SU	
	ICEYE	FIN	●	●	Radar	18	150	SU	
	Kleos	LUX		●	RF mapping	20	TBD	SU	
	Orbital Micro Systems	UK		●	Optical (MS)	39	10	SU	
	Planet	USA	●	●	Optical (MS), video	100+	4-150	GR	
	PlanetiQ	USA		●	RO	18	20	SU	
	SatByul	KR			Optical	8	10	SU	●
	Satellogic	ARG	●	●	Optical (HS)	25+	37	SU	
	Spire Global	USA		●	RO, AIS, ADS-B	75+	4.5-6	GR	
	Siwei Star Company	CN			Optical (MS)	24+	TBD	SU	
	SpaceVR	USA	●		Optical (MS)	2	4	SU	●
	Umbra Lab	USA		●	Radar	12	TBD	SU	●

Space Sustainability

- Satellite operators and launch providers are committed to a safe and sustainable space environment
- **SIA Principles for Satellite Operators**
  - Be Trackable - Know where your satellite is;
  - Be Transparent - Communicate and share;
  - Prevent Radio Frequency Interference (RFI)
- **Space Data Association's Latest Recommendations**
  - "All responsible operators should, at a minimum, ensure:
    - Development of and adherence to space standards, best practices and established norms of behavior;
    - Reliance on STM systems that always seek the best, most actionable and timely collision avoidance data, techniques, and mitigation strategies;
    - Collaborative, mutual and transparent sharing of key satellite operations information elements, including planned maneuvers, spacecraft characteristics and RF information;
    - Adherence to station keeping boxes, authorized RF levels and national, international and organizational space debris and RFI mitigation policies and practices."