INTRODUCTION TO THE SATELLITE INDUSTRY

SATELLITE INDUSTRY ASSOCIATION

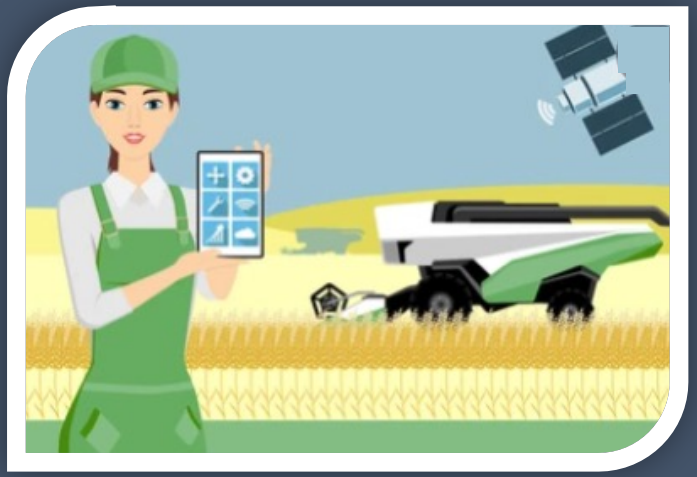
SIA The voice of the satellite industry

Satellites Are The Backbone of Modern Society

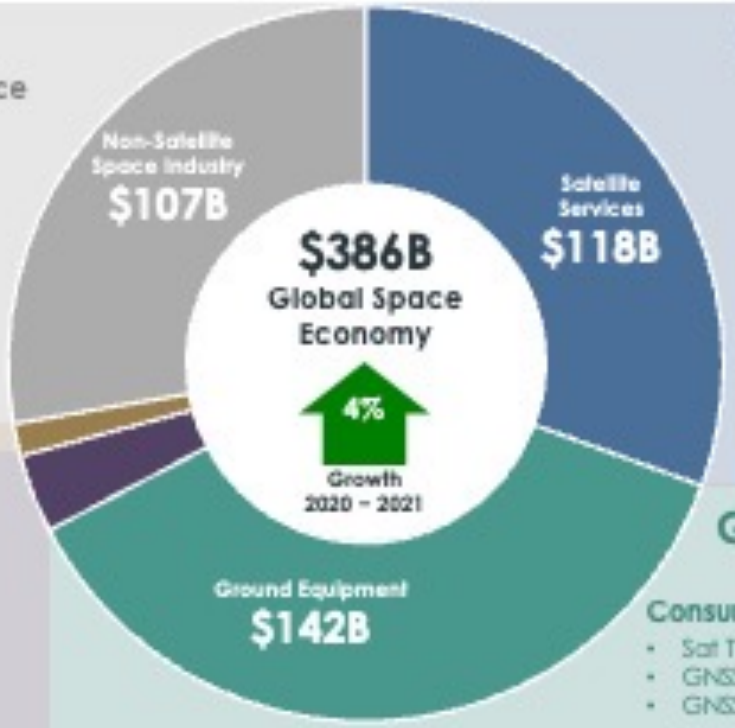
Remote Sensing

Satellite Communications

GPS



The Satellite Industry in Context



Government Space Budgets

Commercial Human Spaceflight

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

$13.7B Satellite Manufacturing

$5.7B Launch Industry

Emerging Sustainable Satellite Activities

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

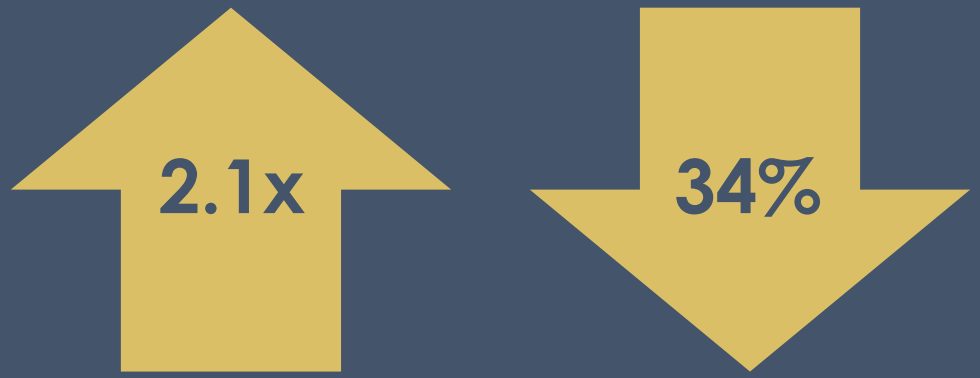
Government space budgets include civil and military spending by 70 countries, ESA.
Commercial human spaceflight includes commercial missions to ISS, suborbital and orbital flights.

The Launch Industry is Providing More Frequent And Affordable Access to Space

- **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)

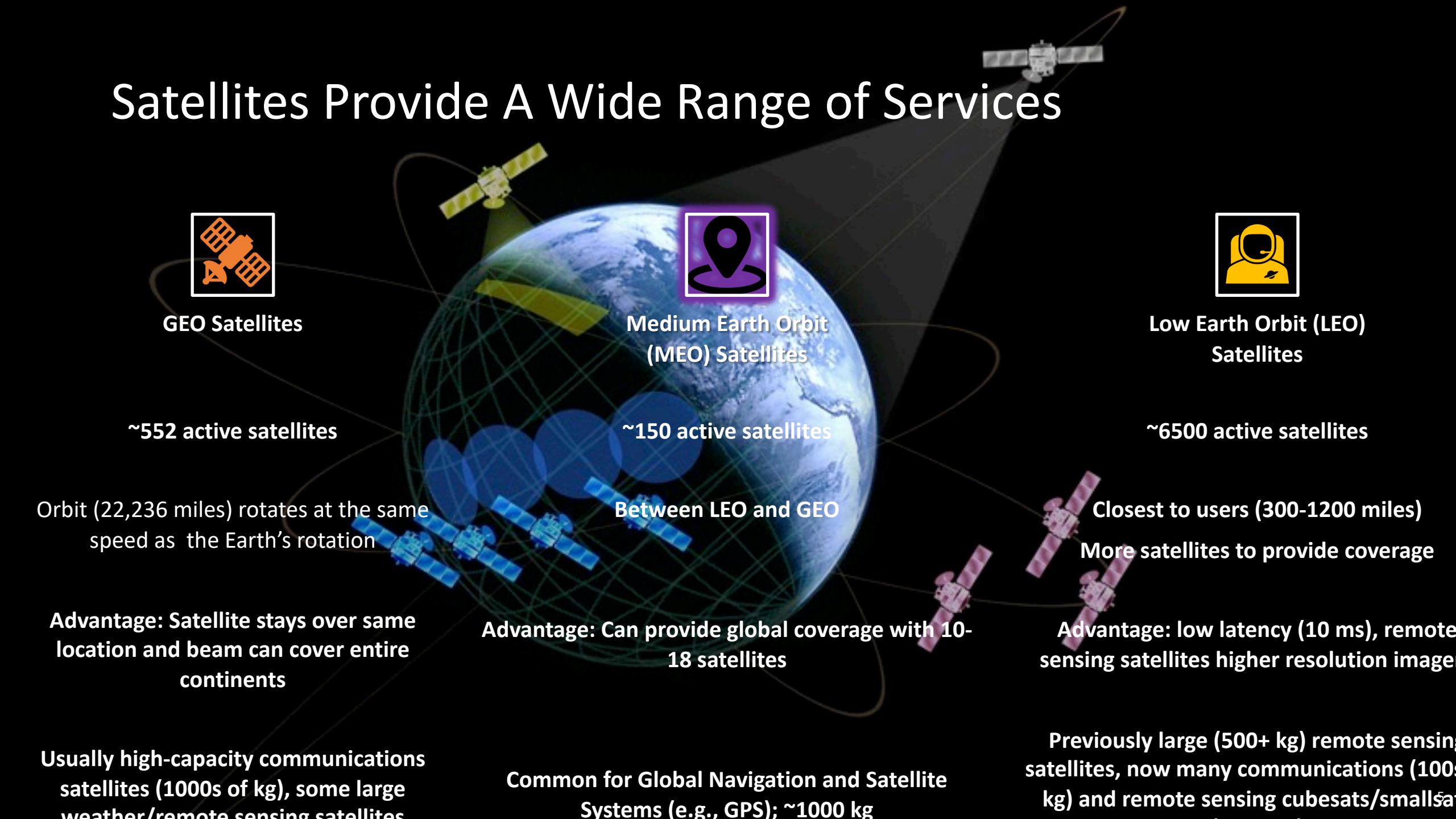
- **More launch choices, capacity becoming available**
- Routine use of reusable launch vehicles
- Increased rideshare opportunities
- New small vehicles (operational and planned)
- Next-generation medium-to-heavy launch vehicles expected to become operational soon



Upmass (2012 – 2021)

Price/kg (2012 – 2021)

Satellites Provide A Wide Range of Services



GEO Satellites

~552 active satellites

Orbit (22,236 miles) rotates at the same speed as the Earth's rotation

Advantage: Satellite stays over same location and beam can cover entire continents

Usually high-capacity communications satellites (1000s of kg), some large weather/remote sensing satellites

Medium Earth Orbit (MEO) Satellites

~150 active satellites

Between LEO and GEO

Advantage: Can provide global coverage with 10-18 satellites

Common for Global Navigation and Satellite Systems (e.g., GPS); ~1000 kg

Low Earth Orbit (LEO) Satellites

~6500 active satellites

Closest to users (300-1200 miles)

More satellites to provide coverage

Advantage: low latency (10 ms), remote sensing satellites higher resolution image

Previously large (500+ kg) remote sensing satellites, now many communications (100s kg) and remote sensing cubesats/smallsat

Satellite Networks Include a Variety of Space and Ground Systems

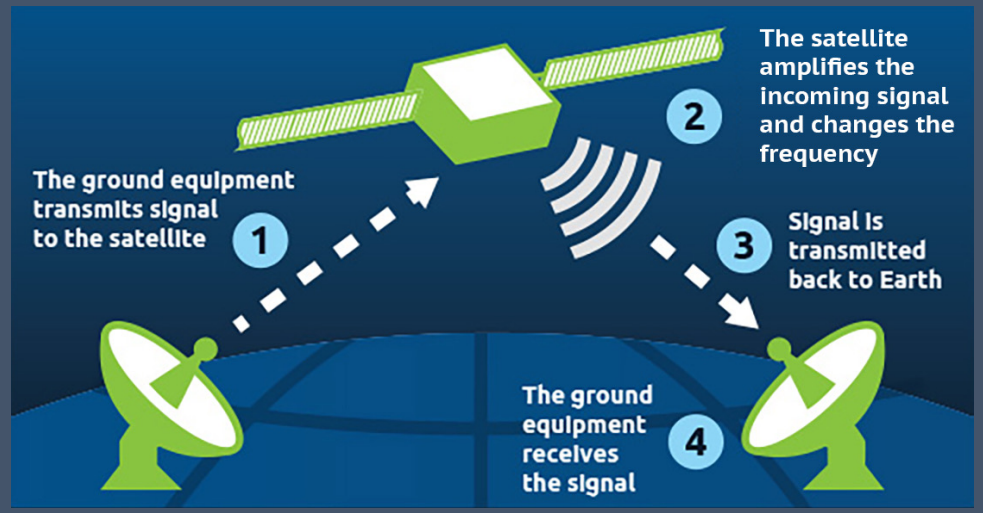


Image Source: Intelsat

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.

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

Image Source: Viasat

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
- Satellites enable Mobile Network Operators to provide continuous uninterrupted service to users
- 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

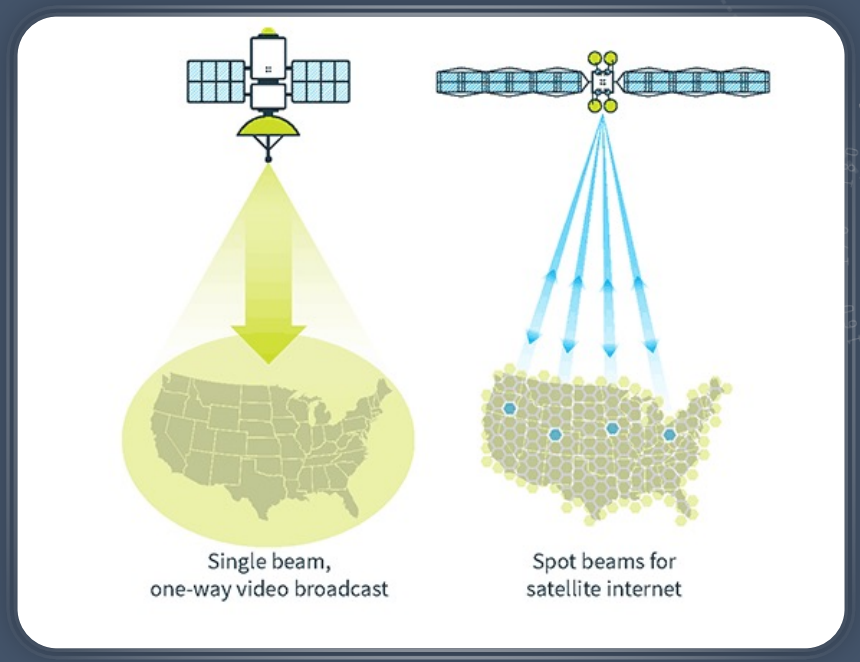


Image Source: Viasat (top), Hughes (bottom left), Amazon (bottom right)

DIRECT TO DEVICE / HANDSET

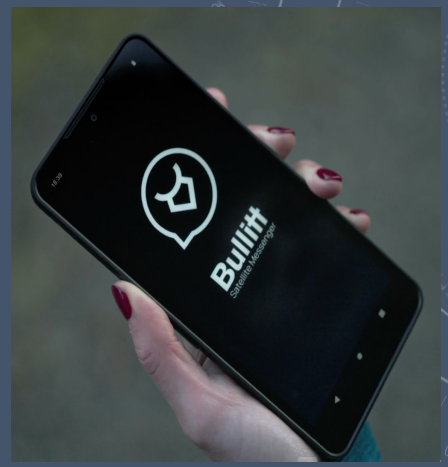


Image Source: EchoStar

- Historically, the satellite industry has used proprietary technology and developed satellite-specific hardware user terminals.
- While great strides in cost and performance have been achieved, penetration of satellite-based communication technologies has remained relatively limited compared to terrestrial (cellular) technologies.
- Implementation of hybrid satellite-terrestrial communication standards are enabling the satellite industry to target larger mass-market opportunities.
- Use of 3GPP & LoRa standards-based technologies is leading to integration of satellite communications capabilities into smartphones and IoT devices.
    - 3GPP is “Third Generation Partnership Project” which provides the standards for the technology underlying most cellular networks and User Equipment worldwide
    - LoRa is a de facto standard for IoT networks managed by the LoRa Alliance and Semtech
- Early adopter phase for Direct to Handset has started with multiple companies announcing basic messaging capabilities using proprietary implementations.
- Longer term, 3GPP standards-based designs will offer more advanced capabilities and higher bandwidth services that will enable widely available compatible devices such as Smartphones, Tablets and IoT devices to communicate natively with both satellite and terrestrial networks enabling a range of applications from text messaging, email, safety alerts and internet connectivity.
- This is the opportunity to provide satellite-enabled devices and services to a mass market given cost reductions that deliver price points that will be the foundation for the long-held vision of a mass market for satellite connected devices.

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.

Satellite captures Russian Rocket Attack on Ukraine in Belgorod Oblast, 3/4/22, Image Source: Planet

Remote Sensing Is Expanding into Non-Imaging Analytics

Types of sensors:

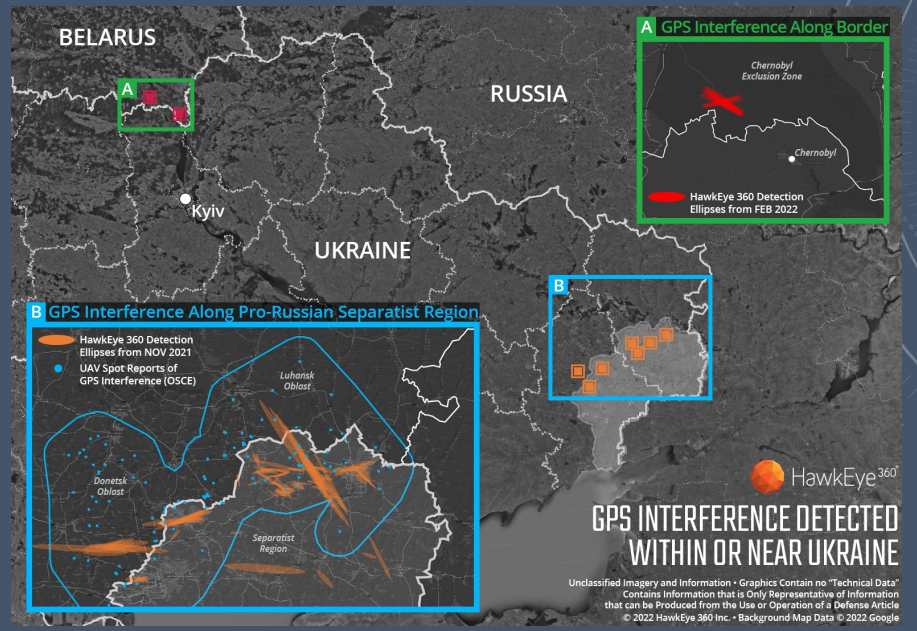
- Signal occultation / reflectometry / altimetry
- Radio frequency detection

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



Maritime AIS and Spire Aviation ADS-B data Image Source: Spire.

Case Study: Remote Sensing Services

Commercial Remote Sensing Satellite Systems

As of June 21, 2022

SIA

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

Optical

U.S. Systems

- **Maxar**
  10 sats
  (4 launched)
  750 – 2,500kg / MS
- **Blacksky**
  23 sats
  (20 launched)
  55kg / MS
- **Planet (Dove)**
  ~150sats (~150 on orbit)
  5kg / MS
- **Planet (Skysat)**
  21 sats
  (21 launched)
  120kg / MS, V
- **Planet (Pelican)**
  32 sats
  (0 launched)
  200kg / MS

Non- U.S. Systems

- **Canon** (Japan)
  100 sats (3 launched)
  10kg / MS
- **Chang Guang** (China)
  196 sats
  (94 launched)
  40 – 95kg / MS, V
- **ZeroG Lab** (China)
  132 sats
  (4 launched)
  6-50kg / MS
- **Imagesat** (Israel)
  2 sats (2 launched)
  300kg / MS
- **DMCii** (UK)
  3 sats (3 launched)
  450kg / 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
- **Satellogic** (Argentina)
  202 sats
  (32 launched)
  41kg / MS, HS
- **ADA Space** (China)
  192 sats
  (2 launched)
  10kg / MS

Synthetic Aperture Radar (SAR)

- **Capella**
  36 sats (8 launched)
  100kg / SAR
- **Umbra Lab**
  12 sats (2 launched)
  50kg / SAR
- **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

Other Systems

- **Spire**
  ~150sats (~150 on orbit)
  5kg / RO
- **GHGSat**
  10 sats (3 launched)
  15kg / HS
- **Hawkeye 360**
  21sats (12 launched)
  30kg / RF
- **PlanetIQ**
  20 sats (4launched)
  30kg / RO
- **Geooptics**
  24 sats (8 launched)
  10kg / RO
- **UnseenLabs** (France)
  50 sats (7 launched)
  6kg / RF
- **Ningxia Jingui 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

Satellites are the Future of Agriculture

- Ability to optimize fertilizer usage and water usage through precision agriculture and planning
  - 30% of US farmers use satellite data[2]
    - Remote sensing data allows for improved allocation of water, fertilizer, detection of crop health issues, and better weather prediction
    - NOAA Adapt-N program reduces nitrogen fertilizer loss, saving farmers $30/acre, could save US farmers $2.7B if used for all corn in the US[3]
    - Data is very affordable ($99 for 1000 hectares), but need internet service to use
  - Satellite communications enables the use of sensors in fields and on farm animals– IoT is the future of Ag
  - GPS allows for precise planting of crops and use of fertilizer
- Famine Early Warning Systems Network tracks famines in South Sudan using satellite data, allowing early warning of potential food shortages and identify areas that need help [1]
  - Crowdsourced analysis of satellite imagery is helping

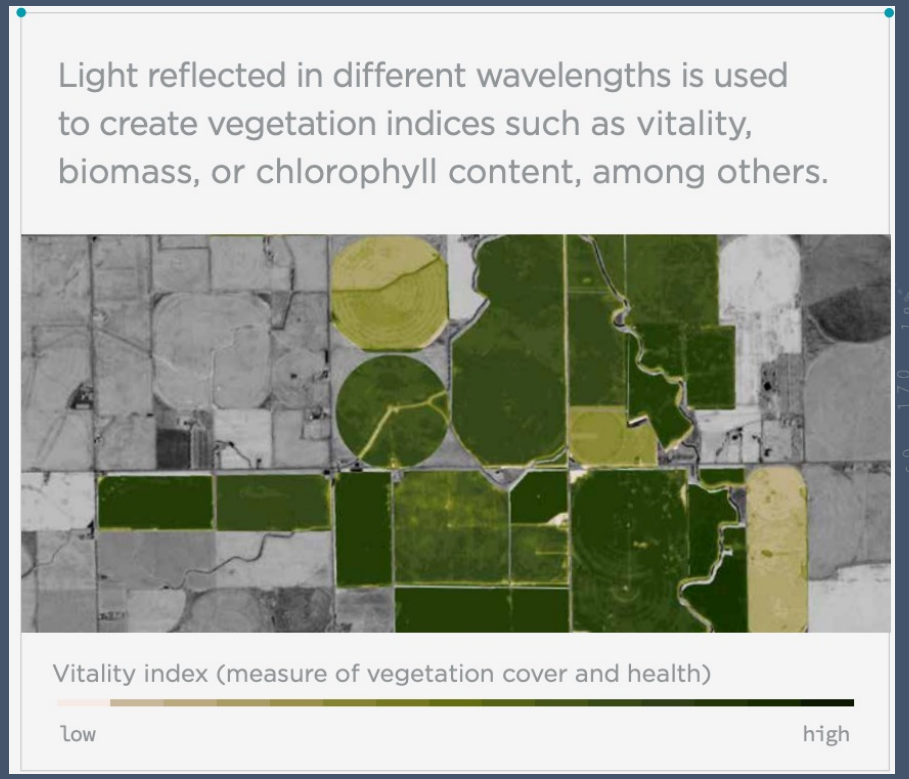
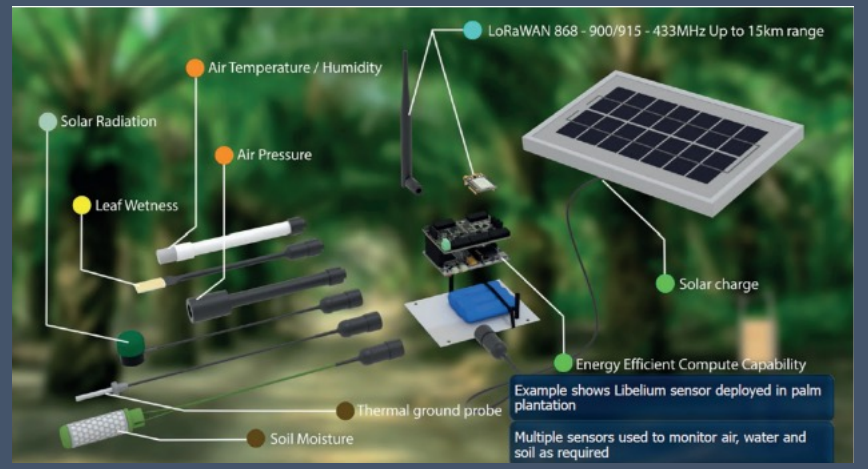


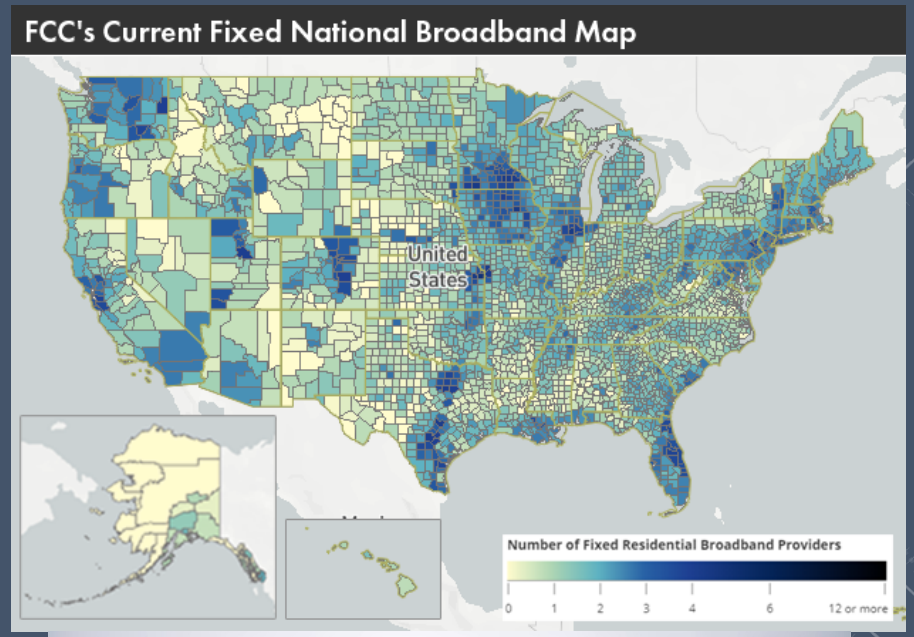
Image Credit: Planet (2018)



Wireless sensor node, Image Source: Inmarsat (2017)

Satellites Can Bridge the Digital Divide

- Satellite operators provide FCC-defined broadband coverage to the entire continental US
- Satellite operators working with Tribal leadership to provide access to remote tribal lands
  - Hoh Tribe, Pikangikum First Nation, Nooksack Tribe among those working directly with satellite operators
  - “The last 8 years, I feel like we’ve been paddling up river with a spoon and almost getting nowhere with getting internet to the Reservation…It seemed like out of nowhere it [satellite internet] just came up and catapulted us into the 21st century. Our youth are able to do education online. Telehealth is no longer going to be an issue.”
  - “I can only think of the difference it can make at the school for the students. Right now, because of COVID-19, all of our instruction is online” -- Kurt Macrae (Eenchokay Birchstick School)
- Community wifi hotspots a viable business model for many international customers
  - Service provided to e.g., rural Mexican villages[1]



Internet provided to Pikangikum First Nation. Image Source: SpaceX

Satellites are Critical to Disaster Mitigation and Relief[1]

- Satellite services critical to forecasting; new commercial satellite services such as GPS radio occultation greatly improve forecasting
- Optical data integral to disaster planning; change detection algorithms can help determine areas most likely to be impacted by a disaster, monitor change post-disaster
  - Data used for risk assessments
- Synthetic Aperture Radar critical in disaster response as it can see through clouds
- Satcom often the only telecommunications available post-hurricane, can be set up rapidly. Critical for emergency responders and general public
  - Can take months to get terrestrial infrastructure up again

Image Source: Inmarsat

Satellites Drive Our Interconnected Future [1,2]

- Navigation satellites improve efficiency and reduce fuel consumption for travel and supply chains
- Remote sensing can be used to monitor traffic patterns and aid in urban planning, pollution monitoring
- Satellites will be used by smart vehicles to avoid accidents due to weather, communicate with dispatch centers, receive upgrades to software while on the move
- Satcom is critical to asset tracking for shipping and logistics
    - 44% of global transportation companies have identified environmental monitoring as a key area for IoT deployment

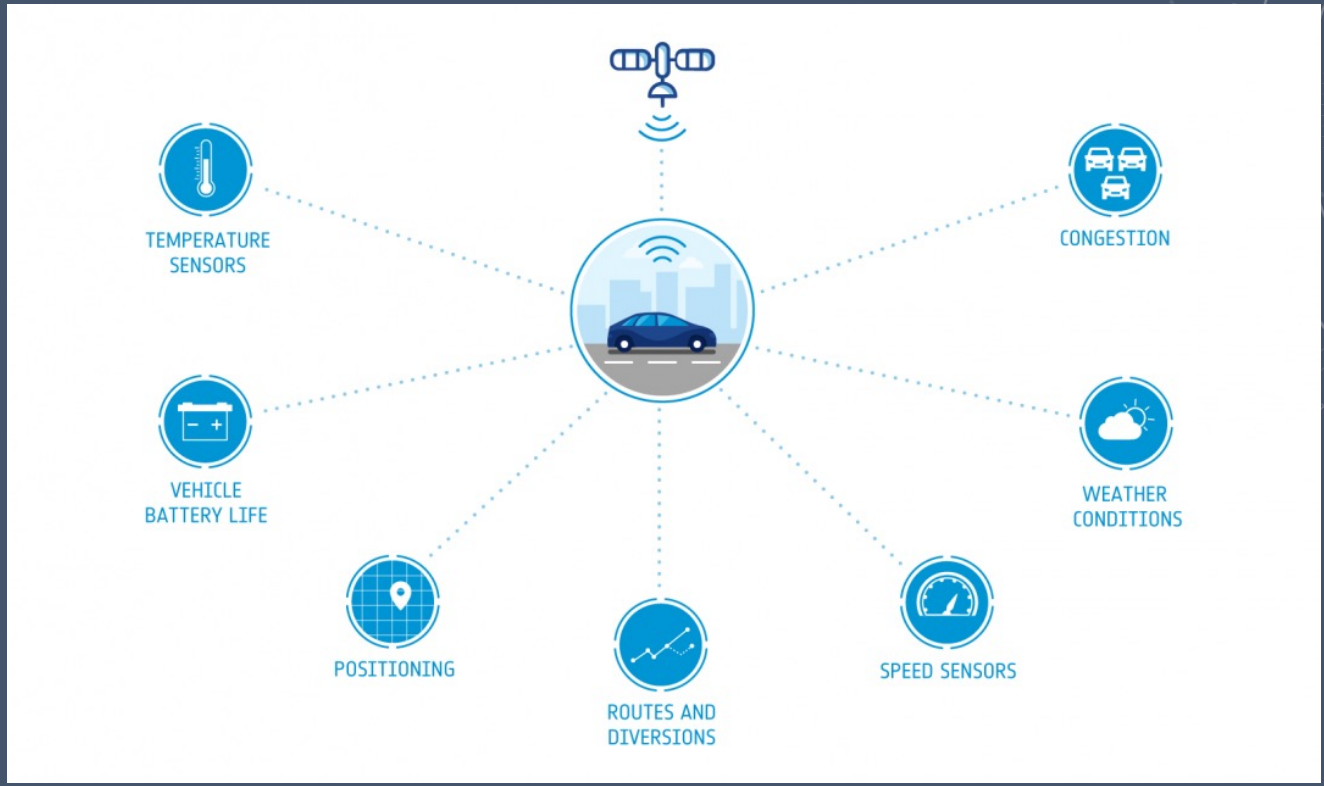
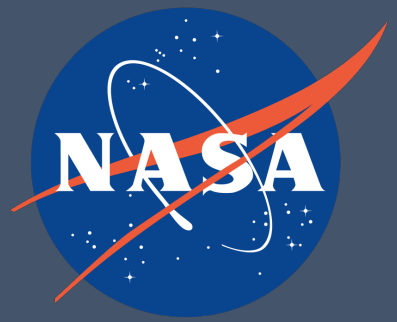


Image Source: European Space Agency, 2018

U.S. Space Policy Requires a Coordinated Whole Of Government Approach



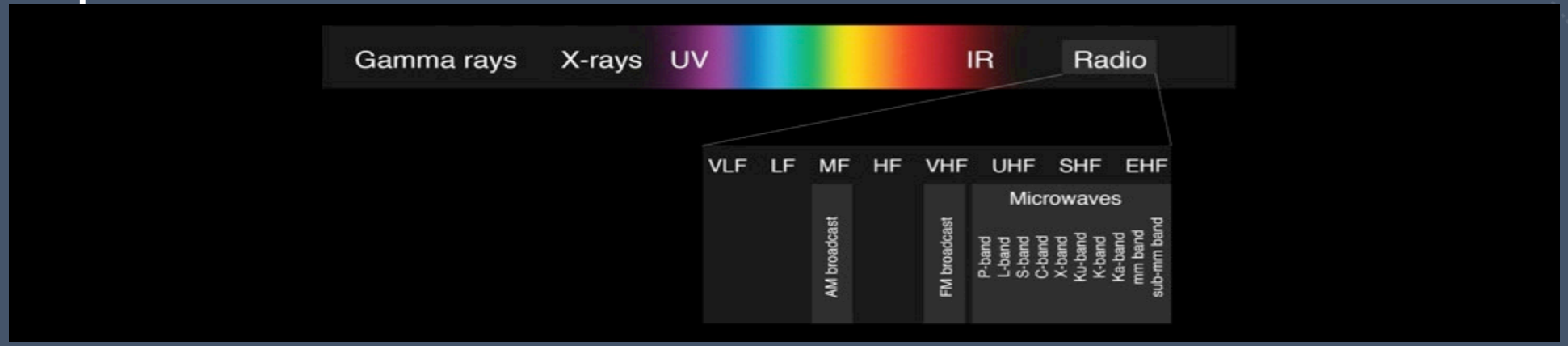
FCC Licenses Required by all Operators With U.S. Market Access

- Operators file initial application at the FCC, then transmitted to International Telecommunications Union (ITU)
  - Upon submission, GEO satellites must be brought into use in 7 years
  - NGSO first satellite launched in 7 years, 10% of constellation by 7+2 years, 50% in 7+5, 100% in 7+7 years
- Types of licenses:
  - Part 25 Regular Licensing
  - Part 25 Smallsat Licensing
    - Streamlined, up to 10 satellites <180 kg and <600 km
  - Experimental
  - Amateur Radio

FCC Licensing Process Depends on Station Type

- GSO operators are assigned orbital slots on a first-come, first-served basis
  - Fixed Satellite Systems are spaced two degrees apart
  - Application goes on public notice
- FCC holds NGSO processing rounds to allow all entrants in certain spectrum bands to be considered on equal footing
  - Systems approved after processing round must coordinate and go on public notice to ensure there is no harmful interference
  - No specific orbital plane allocation
- FCC licensing includes NGSO remote sensing systems, which need bandwidth to transmit data
- All applicants must file an orbital debris mitigation plan
- Earth stations also require submitted application and subsequently go on public notice

Satellites Need Different Spectrum Bands for Different Capabilities



The International Telecommunication Union (ITU) allocates specific bands for specific space/satellite types of use, not limited to commercial, military or civil users – *global harmonization of allocation technically essential for global footprint of satellites*

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 satellite services (MSS), Radionavigation Satellite Services (e.g., GPS)
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, 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	Used for High Density FSS “broadband” and inter-satellite links, EESS, TT&C
Q/V-band	33-75 GHz	Used for High Density FSS, inter-satellite links, EESS
W-band	75-100 GHz	Next Generationa FSS, MSS, EESS

The Satellite Industry is Regulated by a Complex Web of Government Agencies

- Department of Commerce
  - NTIA authorizes federal use of spectrum, including many military and civil satellite systems
  - NOAA licenses Earth Observation satellites (excludes non-Earth imaging systems); requires interagency approval including input from DoD and IC
    - Office of Space Commerce working to develop commercial space situational awareness capabilities and take over DoD's role with TraCCS (Traffic Coordination System for Space)
  - BIS regulates export control
  - NIST heavily involved on standards related to cybersecurity
- FAA Office of Commercial Space Transportation
  - In addition to licensing launch, authorizes payloads not covered elsewhere in the regulatory process (e.g., non-imaging remote sensing systems)
- State
  - Bureau of Oceans, Environment and Science
  - Bureau of Arms Control, Verification, And Compliance
  - Directorate of Defense Trade Controls
    - International Traffic in Arms Regulations
  - Bureau of Communications and Information Policy
- Also coordinate with DoD and DHS on a number of issues related to national security, including provision of services, cybersecurity, space sustainability

The Commercial Satellite Revolution Necessitates Modern Policies for Technological Advancement

- Access to spectrum is key for all space operations
  - The World Radiocommunications Conference is this year and requires coordination at the most senior levels of the FCC, NTIA, and State
- Regulatory certainty is needed to ensure large investments for technologies that take 5+ years to realize are able to operate
- Technologically inclusive policies that allow for innovative solutions should be utilized rather than picking winning technologies
- Funding is needed to ensure expeditious licensing; regulators have been strapped for staffing and resources to accommodate the boom of the commercial sector
- U.S. Leadership is needed both domestically and internationally to ensure access to space and assure competitiveness of the U.S. Commercial Space Sector
  - Revision of export control laws or other licensing restrictions is needed
  - U.S. Leadership in international fora such as the International Telecommunications Union and standards-setting bodies is key
- Interagency cooperation with commercial actors on space sustainability and cybersecurity issues is needed to ensure continued access to space technologies

Updates to Commercial Remote Sensing Policy and Export Controls Are Needed to Ensure U.S. Competitiveness

- U.S. Commercial Remote Sensing Policy Set in 2003, Commercial Remote Sensing Landscape has Changed Vastly in Two Decades
  - New and emerging technologies (e.g., RF, hyperspectral) should be included
  - International companies especially in China and Europe developing comparable capabilities and U.S. remote sensing regulatory/export control landscape have imposed significant restrictions on international sale of data
    - Should consider goals of U.S. economic leadership and secure supply chain
    - Should be de facto presumed exportability of data except when clear national security/foreign policy risk
    - Revisit rate or frequencies should be unrestricted except when clear national security/foreign policy risk
    - Challenging to support U.S. allies and partners with direct sales

Satellite Technologies Are Aiming to Create a More Sustainable Space Future

- Operators are facing increasing congestion on-orbit and modernizing space operations to ensure a sustainable space future
  - Commercial tracking is providing more accurate space data, and currently being integrated into the Department of Commerce's Traffic Coordination System for Space (TraCCS) and integrated with data from DoD
  - Commercial providers are investing in new technologies and designing more sustainable space architectures to mitigate collision risk including:
    - Deploying test satellites to lower altitudes for fast deorbit in the event of failure
    - Automated transponder systems that allow for the broadcast of the spacecraft's position in the event of a mission-ending failure
    - Automated collision avoidance systems

Satellite Breakup Captured
(Image Source: ExoAnalytic Solutions)

Space Sustainability is a Global Problem

- Space is inherently global; international coordination is needed to ensure all operators worldwide are helping to maintain a sustainable space environment
  - The U.N. Committee on the Peaceful Uses of Outer Space (COPUOS) has membership of over 100 countries worldwide and administers the four U.N. Space Treaties
    - Private actors subject to oversight from the "launching state"
    - Actors liable for damage caused by spacecraft either on-orbit or on Earth; this has not been legally tested
    - Actors must register the launch of their space objects
    - 21 non-binding Long-Term Sustainability Guidelines adopted, with further guidelines under discussion
  - Increasing intersection of commercial and military space
    - Anti-Satellite Tests fall under purview of U.N. First and Fourth Committees
    - Debris from recent anti-satellite tests has threatened commercial space operations daily
- FCC currently working on updating orbital debris regulations; will likely apply to all operators seeking U.S. market access

Satellite Operators Are Seeking to Actively Remove Debris and Extend On-Orbit Lifetimes Through Servicing

- First satellite servicing missions have occurred
  - Docking allowed for lifetime extension of 5 years on-orbit for GEO satellite
- Active debris removal demonstration successful
  - Successful commercial and government demonstrations to remove debris
- In-Space Servicing, Assembly, and Manufacturing (ISAM)

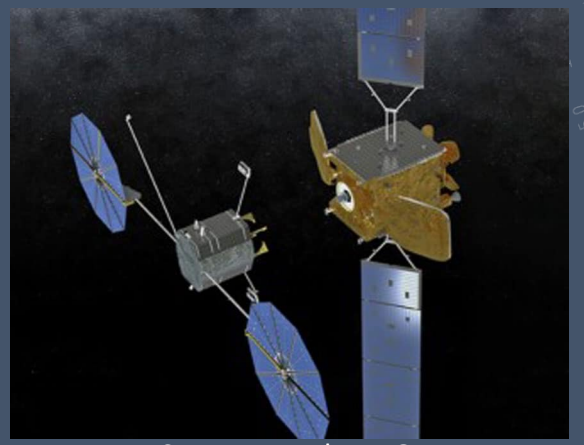


Image Source: Northrop Grumman

Looking Toward A Trillion Dollar Space Economy

- Commercial sector is continuing to look to be the backbone of America's technological future, both in space and on-Earth
  - Commercial lunar contracts
  - IoT/M2M connectivity on the ground and remote sensing data analytics will allow the integration of real-time sensor information to automate processes from farming to transportation

Image Source: Blue Origin

Image Source: Lockheed Martin

THANK YOU!

Questions?

For more information, please contact Aline McNaull,
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SIA The voice of the satellite industry