Program Executive Office
Command, Control, Communications,
Computers and Intelligence (PEO C4I)

State of Non-Geo Stationary Orbit (NGSO) Satellite Communications and SATCOM Terminal (transportable) Non-Geo Stationary (STtNG)

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Satellite Orbit Types

- Geosynchronous Orbit (GEO)
  - Positioned exactly at 35,786 km from Earth's equatorial surface
  - User Terminal (UT) apertures are nominally low-cost but large fixed parabolic reflector based and may require complex terminal equipment
- Medium Earth Orbit (MEO)
  - Positioned ~2,000 km to ~35,000 km from Earth at any inclinations
  - UT apertures are nominally low cost and compact terminal with smaller parabolic reflector(s) or Active Electrically Scanned Array (AESA)
- Low Earth Orbit (LEO)
  - Positioned ~400 km to ~2,000 km from Earth's surface
  - Highly integrated AESA UTs

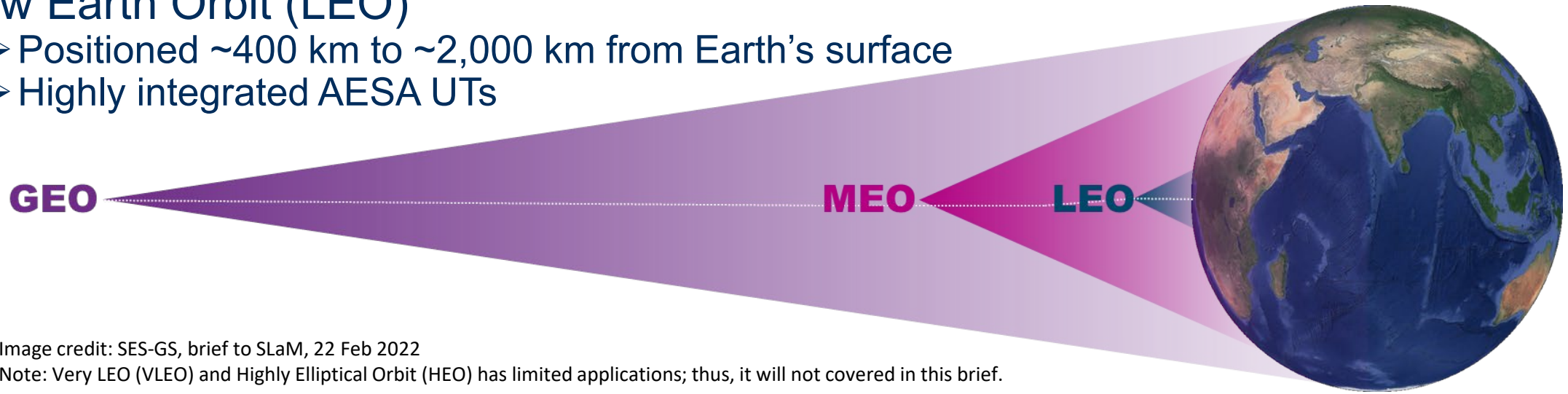
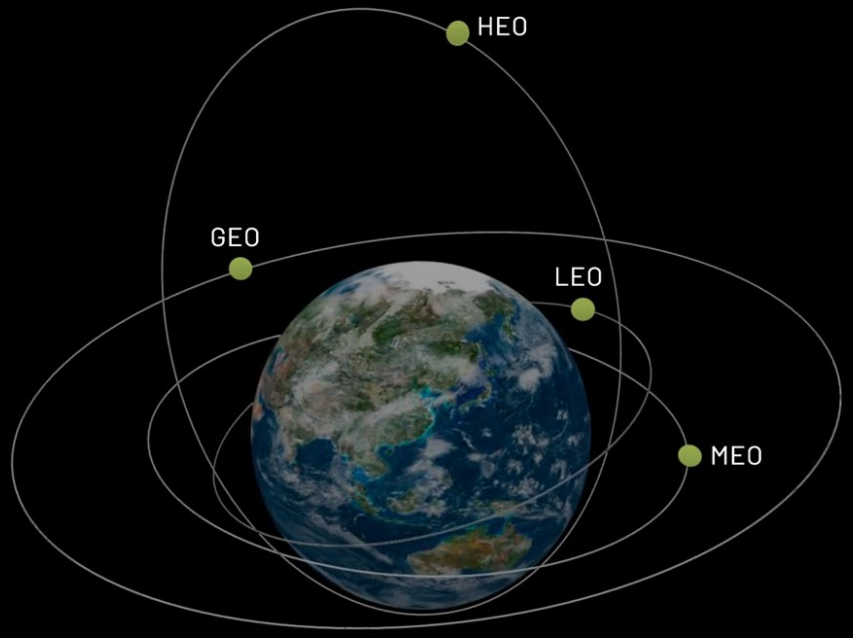


Image credit: SES-GS, brief to SLaM, 22 Feb 2022
Note: Very LEO (VLEO) and Highly Elliptical Orbit (HEO) has limited applications; thus, it will not covered in this brief.

Launch Vehicle Comparison



Satellite at 550km above MSL:

- Spherical area: ~601 km^2
- Velocity: 27,641 km/h or 7,668 m/s

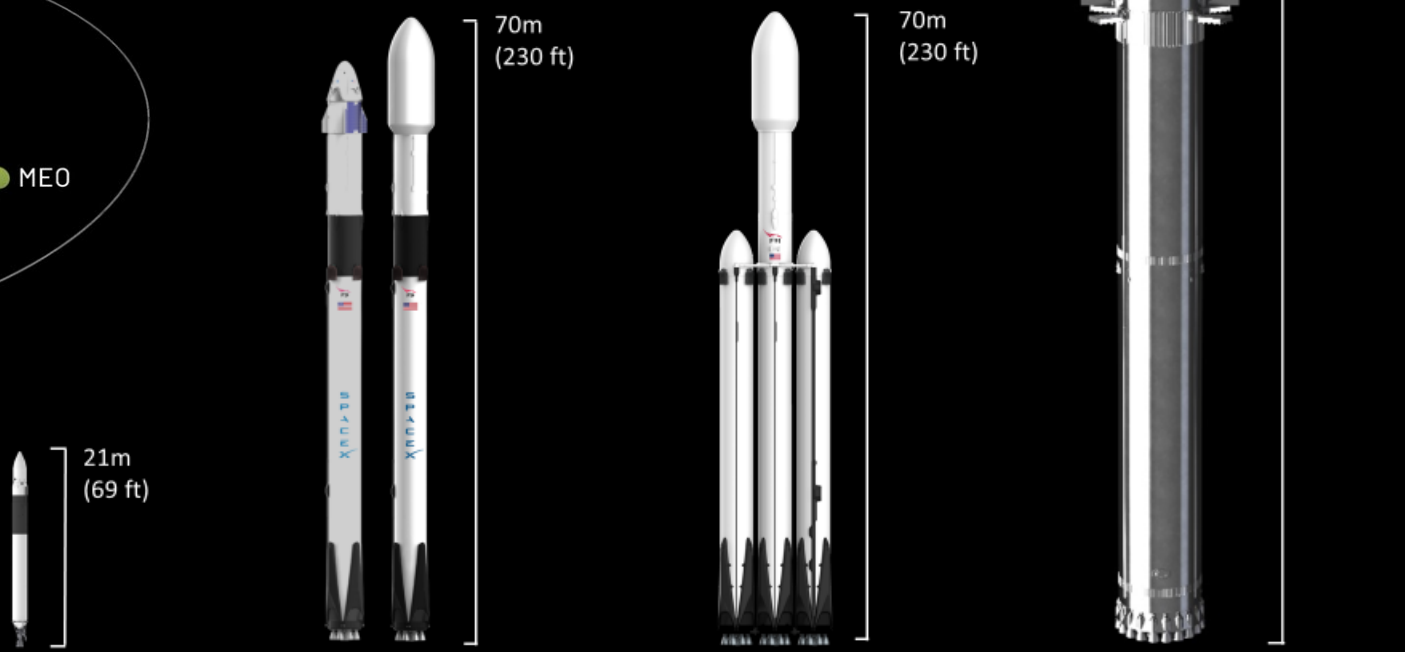
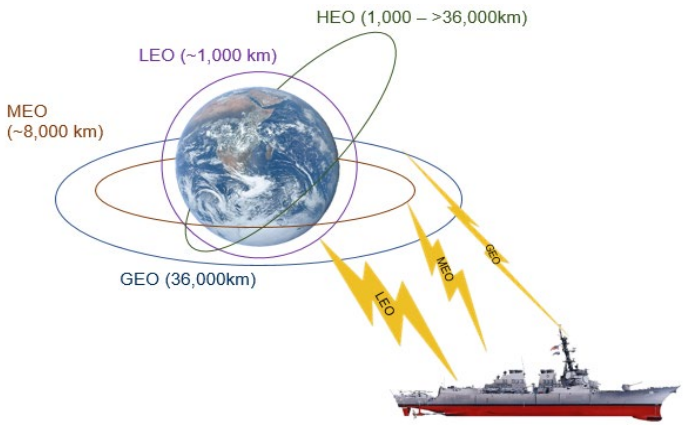


Image credits: SpaceX and ThinKom

Satellite Constellations Statistics

- Constellation Size
  - 4,987: Sum of all satellites in orbit in early 2020[1]
  - 540: Starlink satellites in orbit on 13 June 2020
  - 8,241 (7.166): Starlink satellites launched as of 06 April 2025
  - 660 (654): Eutelsat / OneWeb, 20 October 2024; Gen 1 is fully operational
  - 2 (2): Amazon Kuiper satellites launched as of 06 October 2023
  - 46k+: by 2027 Combined constellation plan size for SpaceX, OneWeb, and Amazon Kuiper
  - 60k+ by 2030: Including TeleSat, Lynk, SES mPOWER, Echostar, and many others
- LEO and MEO Performance
  - Latencies (round trip with nominal system delay)
    - Terrestrial networks: 10 ms to 150 ms
    - Geosynchronous Satellites: 300 ms or higher
    - MEO: 50 ms to 150 ms
    - LEO: 15 ms to 100 ms
  - User Data Throughput Rates
    - 25 Mb/s to 10+ Gb/s down
    - 10 Mb/s to 1+ Gb/s up
  - Global coverage with RF and optical Inter-satellite links



[1] "United Nations Register of Objects Launched into Outer Space", UNOOSA; includes Sputnik. http://www.unoosa.org/oosa/en/spaceobjectregister/index.html. Retrieved on 11 June 2020

Proliferation Continues At A Rapid Pace!

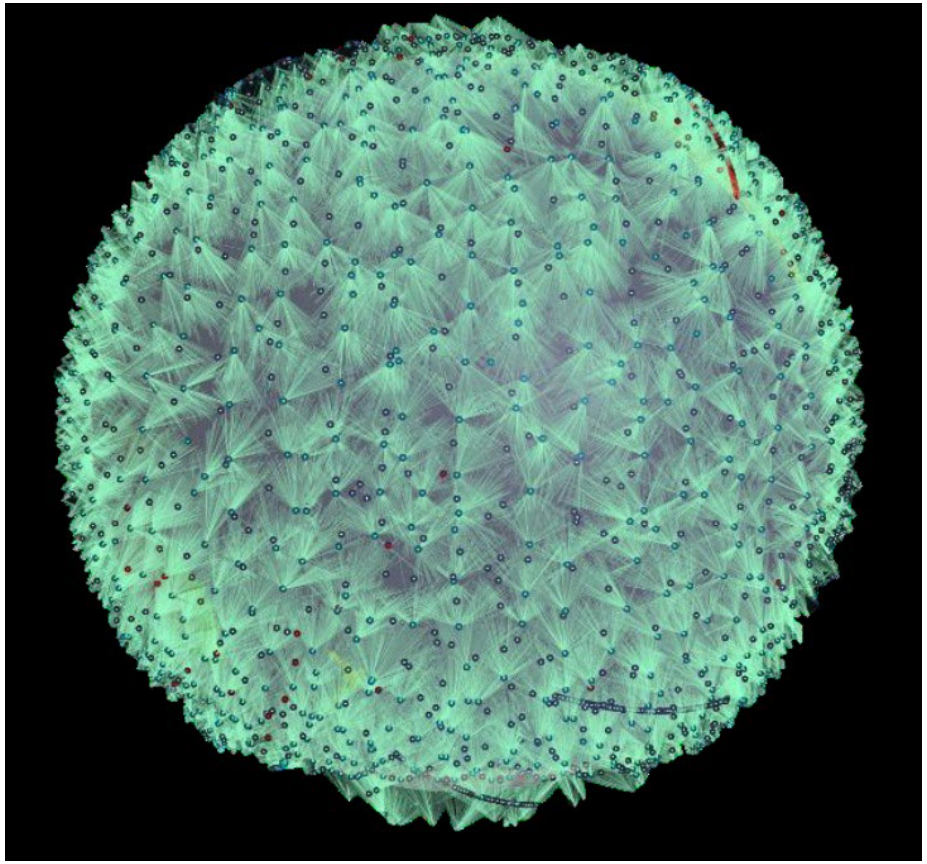
Sample Constellation – Starlink

- Satellite Types and Quantities
  - Tin Tin 1 & 2 (22 Feb 2018)
  - v 0.9, 60 (15 May 2019)
  - v 1.0, 1,665 (Gen 1.0)
  - v 1.5, 2,987 (Gen 1.5); 2,181 (Gen 2)
  - v 2.0 “mini”, 3,370[1]
  - v 2.x, Starship Launch
- Starshield
  - Details are classified U.S. S//TK
- Frequencies
  - User Terminal: Ku
  - Gateway: Ka
  - Limited S on some

[1]As of 08 06 April 2025

48 Beams per Phased Array Aperture

3 or 4 arrays per satellite + 5G NTN on some



Starshield Will Rapidly Increase Starlink Satellite Count

Starlink's Optical Inter-Satellite Links (OISLs)

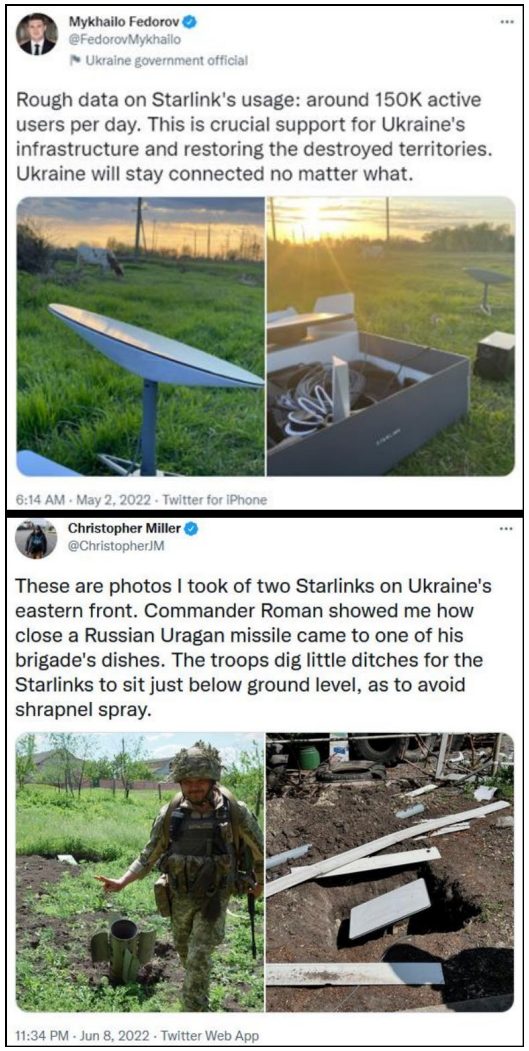
- Optical Inter-Satellite Links (OISL)
  - Available on v 1.5 + satellites
  - λ: 1,550 nm to 1,684 nm
  - OpenZR+
- Number of OISLs per satellite
  - 3 on v 1.5
  - 4 on v 2.0 mini
- Throughputs and Distances
  - 100 Gb/s over 3,200 km
  - 400 Gb/s over 2,000 km
  - Longest link[1]: 5,400 km

[1] "Starlink's Laser System Is Beaming 42 Million GB of Data Per Day", PCMag. https://www.pcmag.com/news/starlinks-laser-system-is-beaming-42-million-gb-of-data-per-day. Retrieved on 31 January 2024

OpenZR+ Will Likely Dominate as the OISL Standard

Starlink In Ukraine

- Timeline
  - Russia Invades: 0 Starlink service
  - +48 hours: 400 kits plus service
  - 2025: 75,000+ kits in service
- Adaptations to Issues
  - GPS jamming: Overcome by entering local position
  - Power consumption: Reduce performance to operate on vehicle cigarette lighter port
  - Lack of mobility: Enabled early roaming protocols and waveforms
- Current Status
  - Starlink utilization for humanitarian missions
  - Military use => constellation is a fair target



Ukraine Offered A Glimpse Of PLEO's Tremendous Capabilities In Wartime Settings

Summary of Navy NGSO Priorities

- High availability resilient, reliable, diverse, and affordable global communications
- EMCON Receive Only
- Global Extended Band
  - (CUI) X, Mil-Ka, Q, and S bands
  - Include polar region
- Hybrid Space Architecture
  - Seamless hybrid constellation handovers
  - Support direct platform-to-platform connections
- Operate in moderate to high sea states and weather conditions
- Vendor offers spare terminals with Move/Add/Change provisioning from shore and platform
- Ability to utilize Navy's certified aperture and terminal equipment
- Provide organic Assured Positioning, Navigation, and Timing (APNT) services
- Common 3U VPX modems and ancillaries
- Symmetric or "Inverse" Asymmetric Links

Hybrid Constellation Required To Fully Realize These Priorities

SATCOM Terminal (transportable) Non-Geostationary (STtNG)

- Transit Case Based
  - Hosts wideband and protected modems
  - Meets Navy's environmental requirements
  - Control Unit (CU) to Automate all functions
  - Weight: 2 Person Lift
  - Transport and Operational within Hours
- Consolidated Multi-band/Multi-session Apertures
- Support 6+ ADNS Connections
- Below Deck or Expeditionary
  - USMC
  - SOF
  - Agencies
- Embedded Training

Any Orbit
Any Vendor
Any Time
Any Where

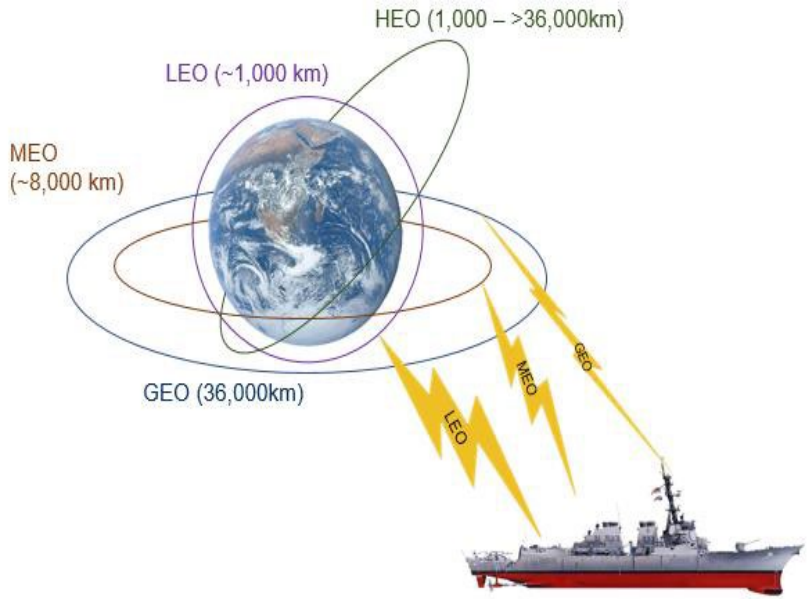
Increments	Increment 0	Increment 1	Increment 2/2W	Increment 3/4
System	Starlink Ku or O3b Ka	Starlink Ku or O3b Ka	Full STtNG LEO, MEO, GEO A2PNT	Full STtNG LEO, MEO, GEO, HEO, A2PNT
Quantity	Ad Hoc	78 => 211	126	211 to incl MSC and Natl Secty Cut
Connectivity	Wireless (No ADNS)	Ku or Ka (ADNS 1 Link)	Ku & Ka, AC2, ADNS (1-4 Links)	Ku, Ka, S, X, AC2, Future Modem, ADNS (4-6 Links)
Application(s)	ADMIN MS 365	Operational Ship's Network	Operational Ship's Network	Operational Ship/Sub Network

STtNG Delivers Common Shipboard Interface to Vendor-Agnostic NGSO Capability

U.S. Navy SATCOM Focus Areas

- Foster
  - Advancements in LEO/MEO and HEO
  - Innovative modem technology
  - Out of the box commercial bandwidth leasing
  - Zero trust solutions for data transport
  - Support ubiquitous transport investigation
  - Aid in instantiation of 5G
  - Solutions for legacy systems
  - Preplanned Product Improvement (P^3I)

- PMW/A 170 strives to enhance industry's understanding of US DoD's needs to enable expedited roll-out of the following interest areas:
  - Multi-beam arrays
  - Multi-link baseband
  - Creative leasing strategies
  - Open architectures



Government – Industry Collaboration Is Critical!

Accelerated delivery of required capability that is affordable, integrated and interoperable

Acronyms

A2PNT	Alternative and Assured Positioning, Navigation, and Timing
AC2	Assured Command Control (Modem)
APNT	Assured Positioning, Navigation, and Timing
AESA	Active Electrically Steerable Antenna
APM	Assistant Program Manager
CBSP	Commercial Broadband Satellite Program
CSaT	Commercial SATCOM as Transport
DtC	Direct to Cell (5G NTN + Future G Payloads)
EMCON	Emission Control
GEO	Geostationary Earth Orbit
GNSS	Global Navigation Satellite System
IDIQ	Indefinite Delivery Indefinite Quantity
KPP	Key Performance Parameter
LEO	Low Earth Orbit
MEO	Medium Earth Orbit

Acronyms

NGSO	Non-Geostationary Satellite Orbit
OISL	Optical Inter-Satellite Link
PIC	Photonic Integrated Circuit
POM	Program Obligation Memorandum
RFP	Request for Proposal
PNT	Positioning, Navigation, and Timing
S&T	Science & Technology
SDA	Space Development Agency
SLaM TIME	SATCOM LEO and MEO Technical Information Meeting and Exchange
STtNG	Satellite Terminal (transportable) Non-Geostationary
TRANSEC	Transmission Security
TT&C	Telemetry, Tracking, and Control
UT	User Terminal
VPX	Virtual Path Cross-Connect
WAMS	Wideband Anti-jam Modem System