

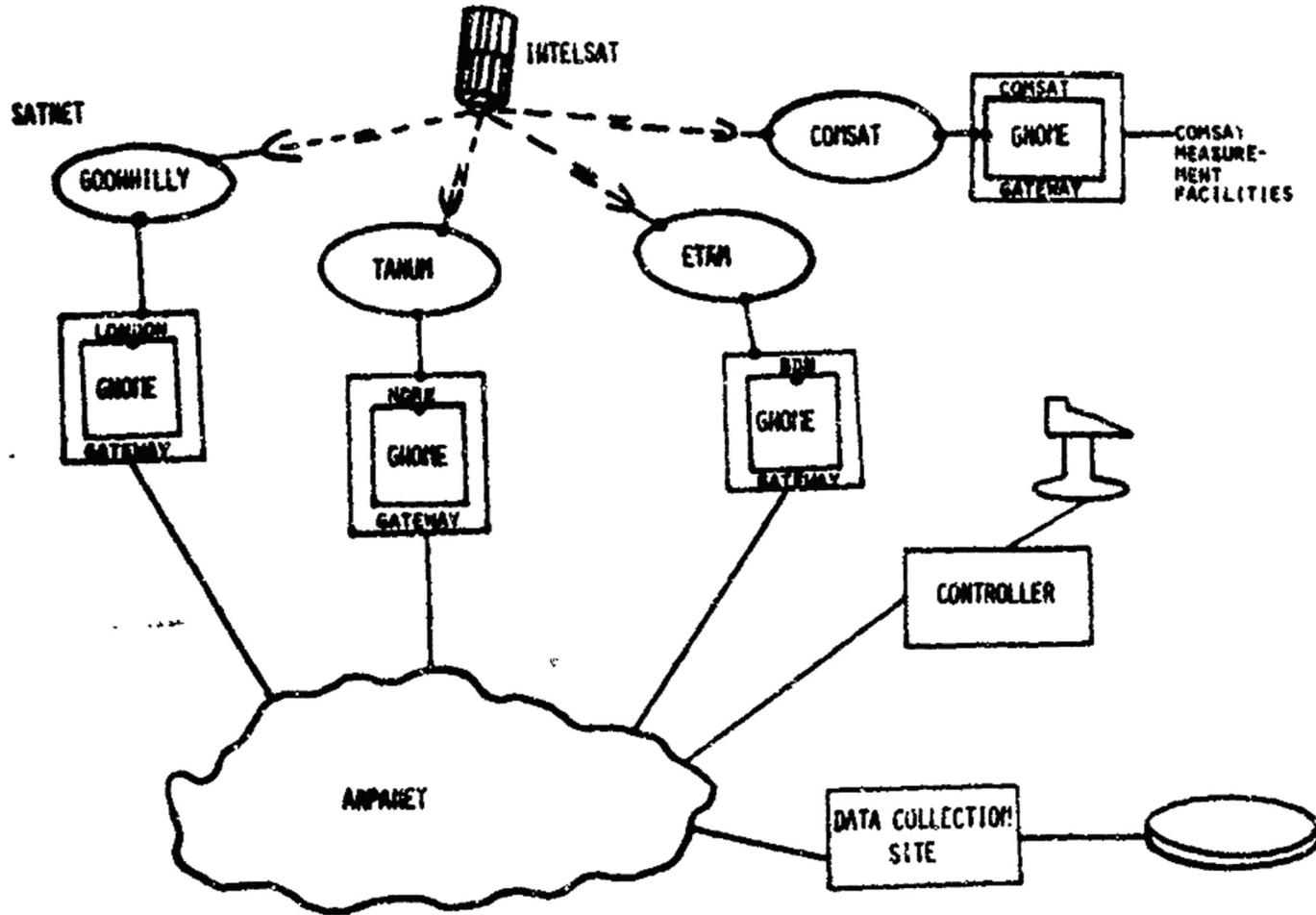
# A **LEO** Networking Primer

NISHANTH SASTRY  
UNIVERSITY OF SURREY



When NOR...  
Seismic Dat...  
capacity wa...

In 1968, the...  
the principl...  
is the prede...



SATNET: Peter Kirstein Report to DARPA, 1977

The first [Transmission Control Program](#) demonstration, linking SATNET, the ARPANET, and [PRNET](#) took place on November 22, 1977. As a result of this work, SATNET played a central role in the creation of the [Internet protocol suite](#).

[Peter Kirstein](#) chaired the International Cooperation Board (ICB), formed by Cerf in 1979, to coordinate activities to develop packet satellite research. [\[6\]\[7\]](#)

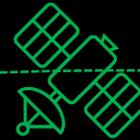
Internet.

transmitted to the  
The transmission

project based on  
named ARPANET and



GEO  
35786 KM



MEO  
2000 - 10,000 KM



LEO  
160 - 2000 KM



# SatComm – Big Picture

# LEO vs MEO vs GEO

## GEOSTATIONARY EARTH ORBIT (GEO)

**Orbit:** 35,786km

**Earth Coverage:** Very large (min. 3 satellites required)

**Beam footprint size/km:** 200-3500

**Latency:** High (~250 to 500ms)

**# Active:** ~541

**Usage:**

- Mobile Backhaul
- Weather data & Broadcast TV
- HTS technology allow basic MBB

## MEDIUM EARTH ORBIT (MEO)

**Orbit:** 2,000 to 34,000km

**Earth Coverage:** Large (min. 6 satellites required)

**Beam footprint size/km:** 100-1000

**Latency:** Medium (~180ms)

**# Active:** ~159

**Usage:**

- PNT (GNSS, GPS)
- Higher throughput (HTS) Backhaul & data connectivity

## LOW EARTH ORBIT (LEO)

**Orbit:** 500 to 2000km

**Earth Coverage:** Small (100-1000 satellites required)

**Beam footprint size/km:** 100-1000

**Latency:** Low (~40ms)

**# Active:** >3,700

**Usage:**

- Higher throughput & lower latency data services
- Direct to phone connectivity
- 3D Positioning

**Potential:**

- PNT (Relay or Satellite Time and Location [STL])



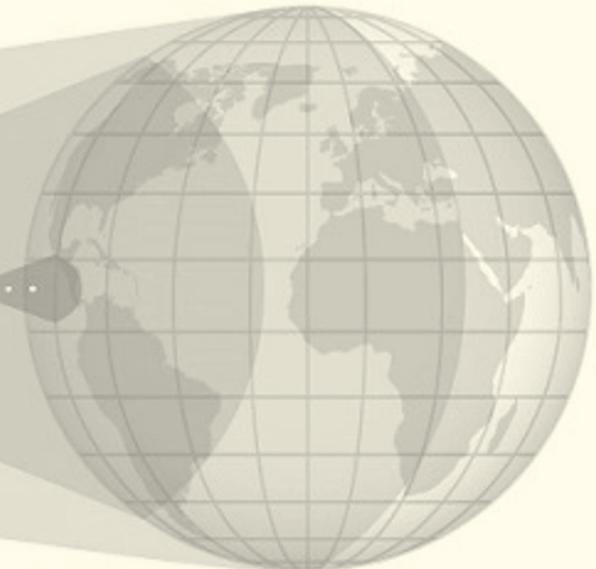
GEO



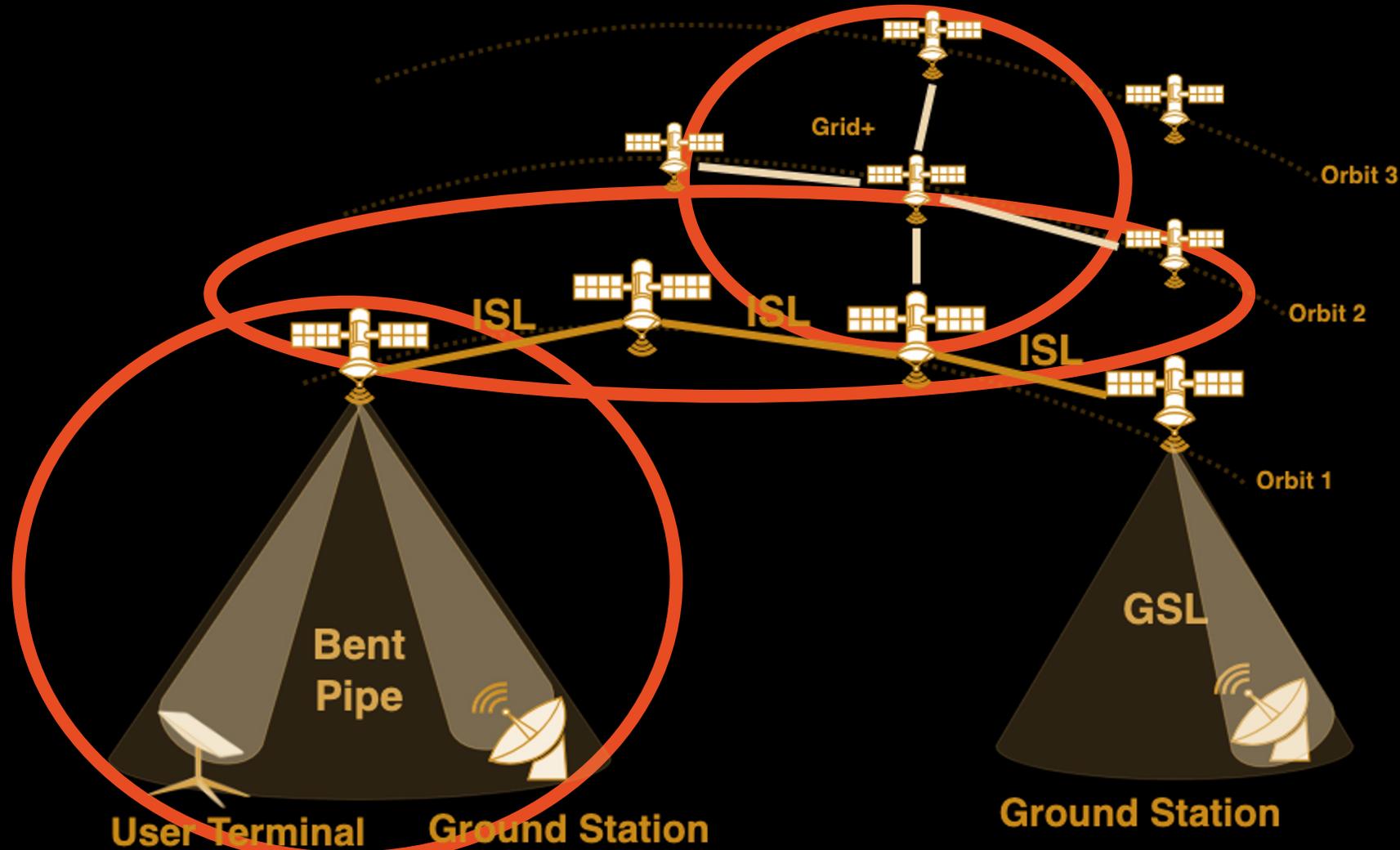
MEO



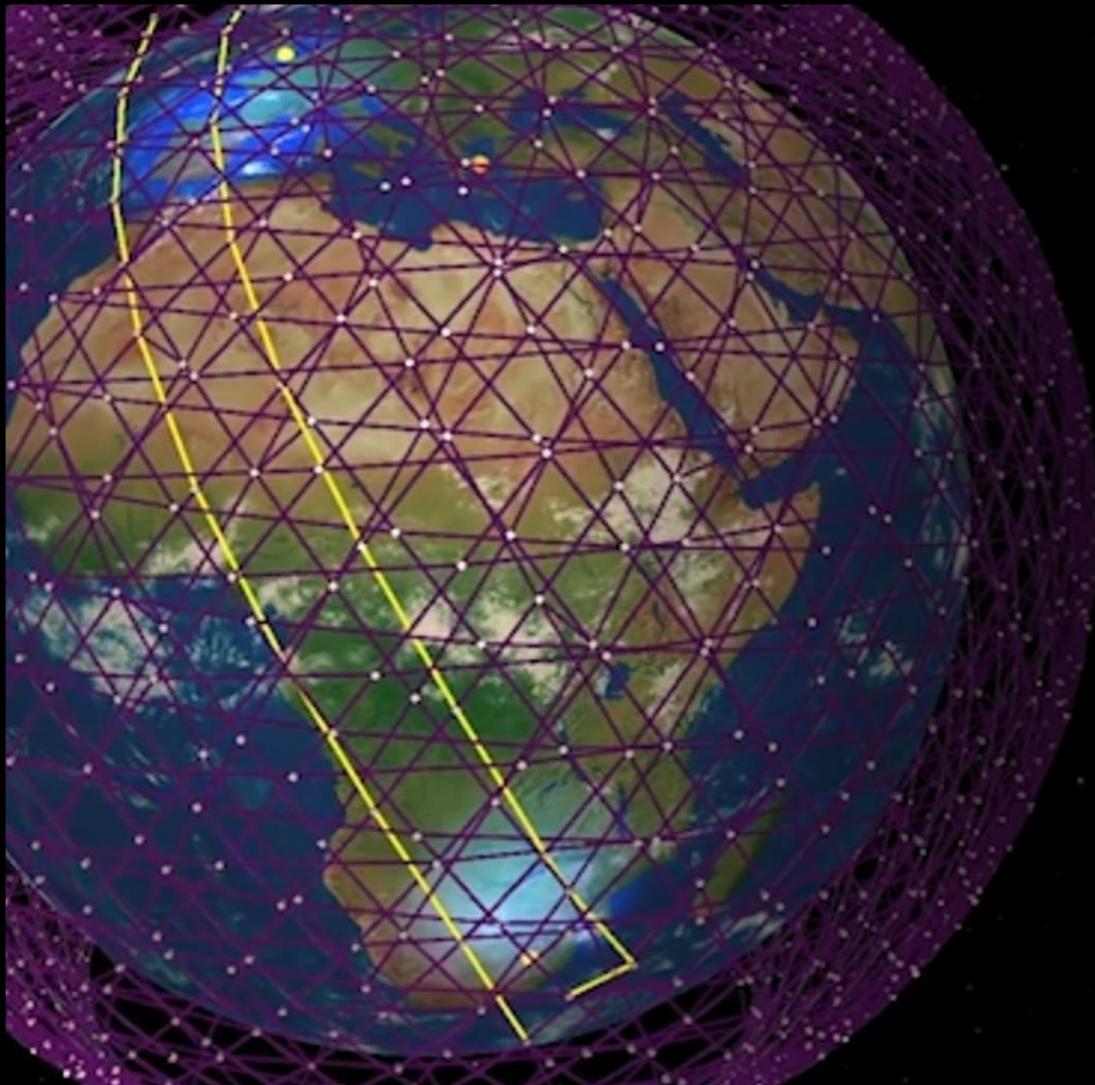
LEO



# ARCHITECTURE OF STARLINK & OTHER LEO MEGA CONSTELLATIONS



# +20,000 Satellites will be in Space by 2027



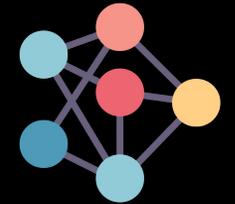
## Fast-moving Routers

Traveling at 27,000 KM/h,  
making the connection with  
the ground segment ~3-6  
mins



## Network Protocols

Challenge all our network  
management, transport and  
routing protocols

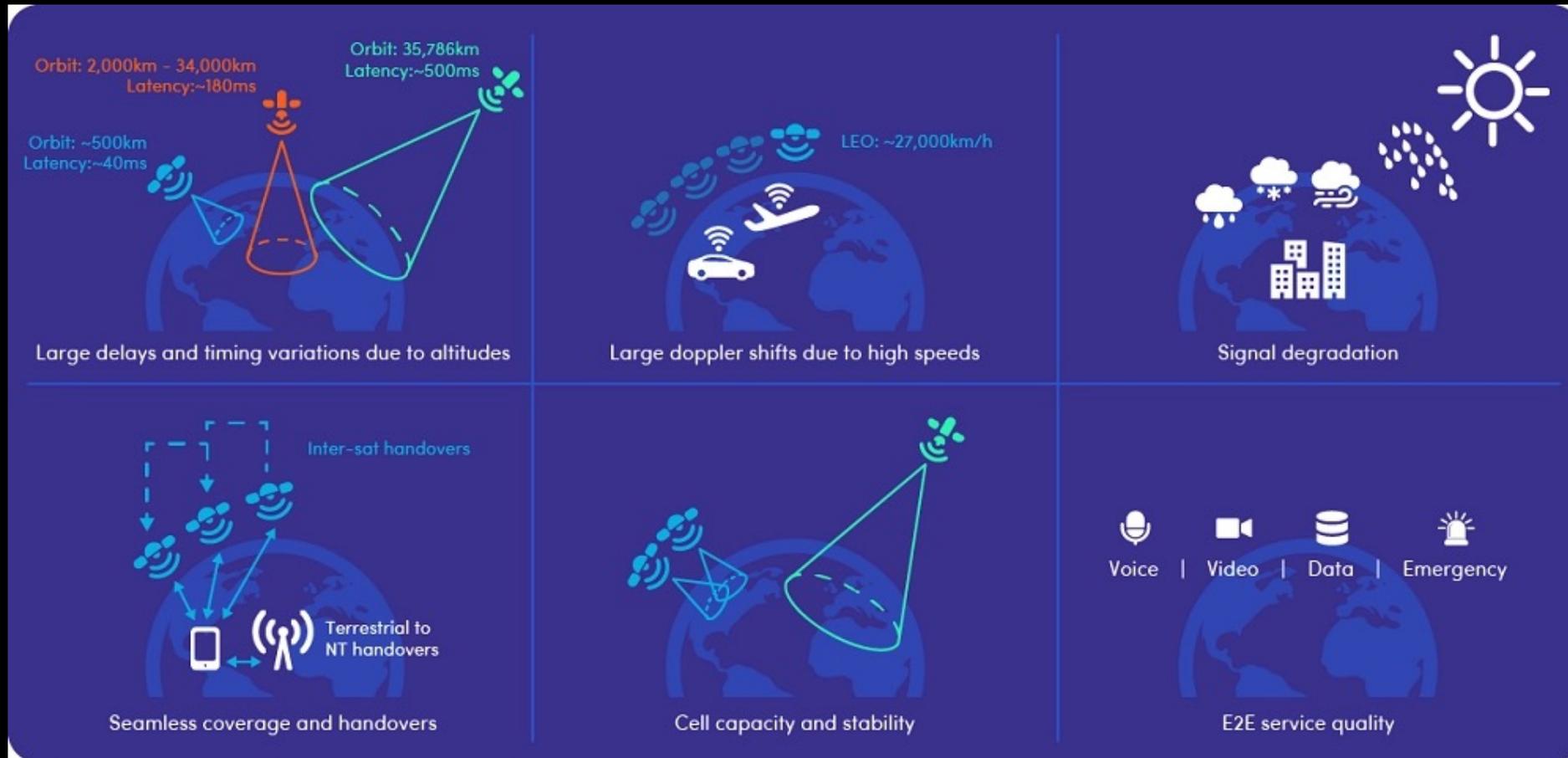


## Large Scale, Dynamic Network

High dynamic network and  
rapid changes to the  
network topology



# ADDITIONAL L2 CHALLENGES



# FURTHER POINTERS

## LEO is not just Starlink:

- Amazon Leo (Kuiper); BlueOrigin TeraWave; Eutelsat/OneWeb...

## LEO is not just broadband

- Satellite IoT
- Direct-to-Cell

## Space Networking extends beyond LEO!

- NASA Artemis (5G connectivity on the moon)
- IPNSIG
  - See Also: SPACE RG, a new IRTF group.

# LEO Measurement

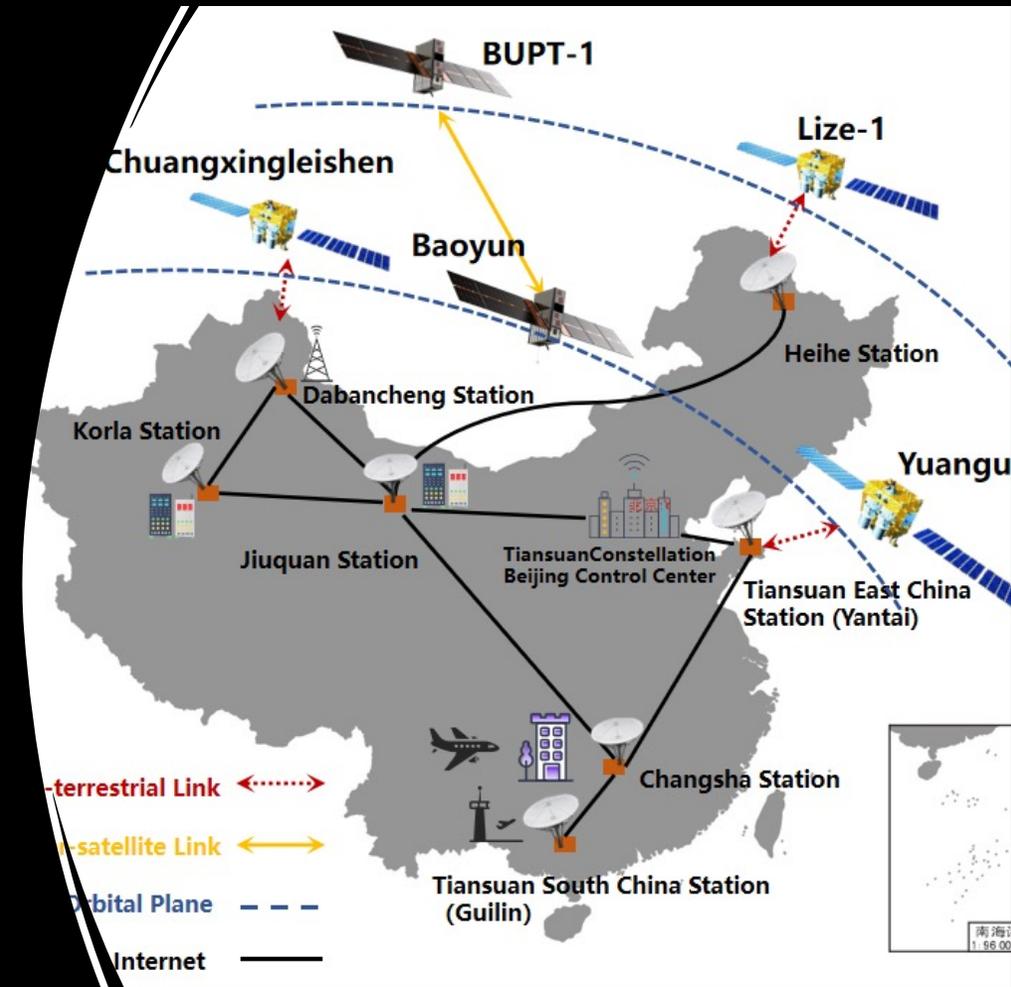
A call to arms

NISHANTH SASTRY  
UNIVERSITY OF SURREY



# HOW TO MEASURE & UNDERSTAND LEO NETWORKS?

- BYO Constellation?
- White box visibility which SpaceX won't grant!
- Complex and expensive endeavour!
  - Does not capture complexity of *megaconstellations*
    - Starlink has nearly 10K satellites with ISLs
    - May not replicate emergent behaviours
- Orbits  $\neq$  Starlink (or other constellations)
  - Cannot capture specificities of deployed or planned constellations



# A TYPOLOGY FOR LEO EVALUATIONS

Volume



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**MEASUREMENT USING PUBLIC DATASETS**

CoNEXT'23  
SIGMETRICS'26




Coverage



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**MEASUREMENT USING BROWSER PLUGINS**

IMC'22,  
CoNEXT'23,  
HotNets'24



Flexibility



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**XEOVERSE "DIGITAL TWIN" (SIMULATOR)**

IFIP Networking'24

- Scalable,
- Responsive,
- High fidelity,
- Low-footprint

Simulation of LEO/MEO/GEO (mega)constellations

Control

UNIVERSITY OF SURREY

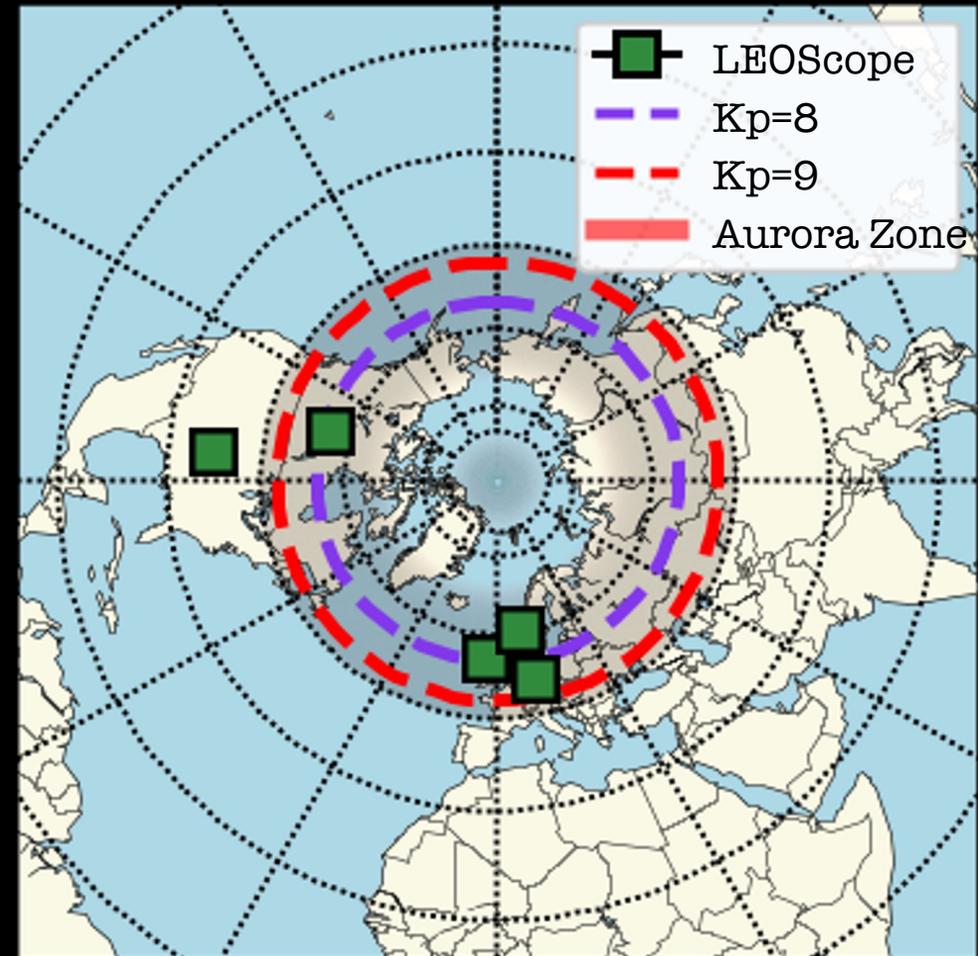
**LEOSCOPE:  
MEASUREMENT USING VOLUNTEER NODES**  
AKA "PLANETLAB FOR STARLINK"

SIGCOMM  
CCR



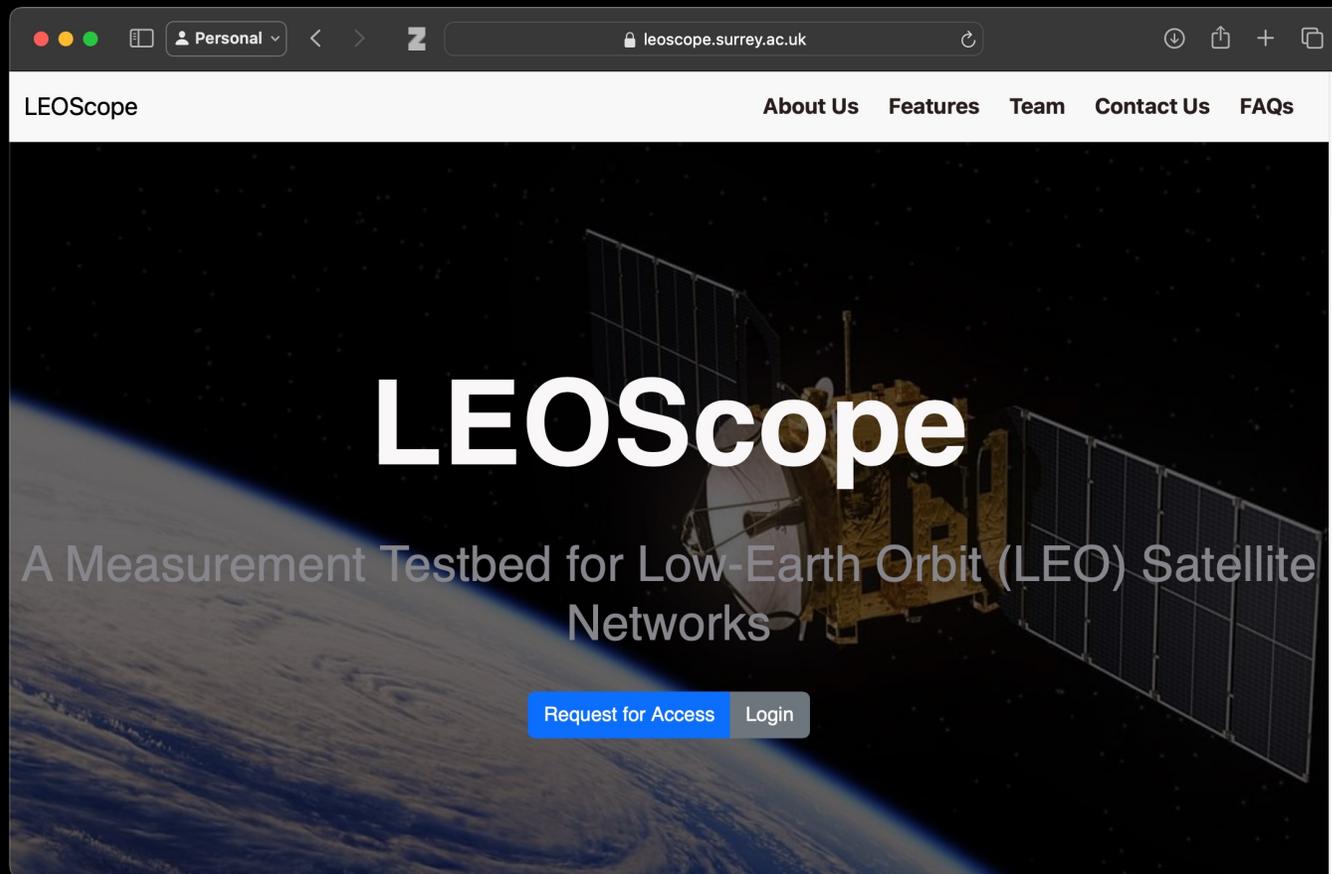

# CALL TO ARMS: EARTH-BASED RESEARCH INFRA

1. **Measurement** of *deployed* constellations (**LEOScope**)
2. **Simulation** of *deployed, planned or imagined* constellations (**xEOVerse, Hypatia, CosmicBeats**)
3. User participation via Browser plugins (**NetMet**)
4. Public data/devices (**RIPE, MLab**)



Effects of 1.5 years of Geomagnetic Storms  
SIGMETRICS'26

# LEOScope



LEOScope

About Us Features Team Contact Us FAQs

# LEOScope

A Measurement Testbed for Low-Earth Orbit (LEO) Satellite Networks

[Request for Access](#) [Login](#)

<https://leoscope.surrey.ac.uk>

# A CALL TO ARMS



	A1	A	B	C	D
1	Resources Name	Resource Type	URL	Publication	
25	FOCUS	Simulator		<a href="#">SPIE</a>	
26	Roman-HitchHiking	Data Collection	<a href="https://github.com/UCLA-SCaN/roman_hitchhiking">https://github.com/UCLA-SCaN/roman_hitchhiking</a>	<a href="https://dl.acm.org/doi/10.1145/3748749.3749">https://dl.acm.org/doi/10.1145/3748749.3749</a>	
27	LEO-HitchHiking	Data Collection	<a href="https://github.com/stanford-esrg/LEO_HitchHiking">https://github.com/stanford-esrg/LEO_HitchHiking</a>	<a href="https://lizzhikevich.github.io/assets/papers/LI">https://lizzhikevich.github.io/assets/papers/LI</a>	
28	WetLinks	Dataset	<a href="https://github.com/sys-uos/WetLinks">https://github.com/sys-uos/WetLinks</a>	<a href="https://ieeexplore.ieee.org/abstract/document/">https://ieeexplore.ieee.org/abstract/document/</a>	
29	Starlink on the Autobahn	Dataset	<a href="https://github.com/sys-uos/Starlink-on-the-Autobahn">https://github.com/sys-uos/Starlink-on-the-Autobahn</a>	<a href="https://ieeexplore.ieee.org/abstract/document/">https://ieeexplore.ieee.org/abstract/document/</a>	
30	Starlink on the road	Dataset	<a href="https://github.com/sys-uos/Starlink-on-the-Road">https://github.com/sys-uos/Starlink-on-the-Road</a>	<a href="https://ieeexplore.ieee.org/abstract/document/">https://ieeexplore.ieee.org/abstract/document/</a>	
31	phantomlink	Emulator	<a href="https://github.com/robinohs/phantomlink">https://github.com/robinohs/phantomlink</a>	<a href="https://doi.org/10.1145/3744200.3744758">https://doi.org/10.1145/3744200.3744758</a>	
32	FLoRaSat	Simulator	<a href="https://gitlab.inria.fr/jffraire/florasat">https://gitlab.inria.fr/jffraire/florasat</a>	<a href="https://hal.science/hal-05424077v1">https://hal.science/hal-05424077v1</a>	
33	IPN-v	Visualizer	<a href="https://gitlab.inria.fr/jffraire/ipn-v">https://gitlab.inria.fr/jffraire/ipn-v</a>	<a href="https://hal.science/hal-04996148v1">https://hal.science/hal-04996148v1</a>	
34	DtnSim	Simulator	<a href="https://gitlab.inria.fr/jffraire/dtnsim">https://gitlab.inria.fr/jffraire/dtnsim</a>	<a href="https://ieeexplore.ieee.org/document/822755">https://ieeexplore.ieee.org/document/822755</a>	
35	Satellite Applications Lab Testbed	Testbed	<a href="https://abdn.elsevierpure.com/en/equipments/satellite-ap">https://abdn.elsevierpure.com/en/equipments/satellite-ap</a>	<a href="https://doi.org/10.1016/j.comnet.2025.111950">https://doi.org/10.1016/j.comnet.2025.111950</a>	
36	Deepspace IP Toolkit - QUIC	Simulator	<a href="https://github.com/deepspaceip/dipt-quic-workbench">https://github.com/deepspaceip/dipt-quic-workbench</a>		
37	Deepspace IP Toolkit - HTTP	Simulator	<a href="https://github.com/deepspaceip/dipt-http">https://github.com/deepspaceip/dipt-http</a>		
38	Deepspace IP Toolkit - Network scenarios	Dataset	<a href="https://github.com/deepspaceip/dipt-space-network-scenarios">https://github.com/deepspaceip/dipt-space-network-scenarios</a>		
39	Deepspace IP Toolkit - Header Compression	Implementation	<a href="https://github.com/deepspaceip/dipt-schc-tap">https://github.com/deepspaceip/dipt-schc-tap</a>		
40	Deepspace IP Toolkit - Network management	Implementation	<a href="https://github.com/deepspaceip/dipt-netconf-over-quic-proxy">https://github.com/deepspaceip/dipt-netconf-over-quic-proxy</a>		
41	Deepspace IP Toolkit - IP store and forward	Implementation	<a href="https://github.com/deepspaceip/dipt-ip-store-forward">https://github.com/deepspaceip/dipt-ip-store-forward</a>		
42	Meteornet	Simulator	<a href="https://gitlab.com/camilo.rojas/meteornet">https://gitlab.com/camilo.rojas/meteornet</a>		
43	cote	Simulator	<a href="https://github.com/cmabstract/cote">https://github.com/cmabstract/cote</a>	<a href="https://dl.acm.org/doi/pdf/10.1145/3373376.3">https://dl.acm.org/doi/pdf/10.1145/3373376.3</a>	
44	Argus 1 constellation (Brandon Lucia)	Satellites			
45	EPASat	Satellites			
46	OPSSat	Satellites			
47	Polarlink	Satellites			<a href="https://www.uvic.ca/ecs/news/cfar-spaceteo.p">https://www.uvic.ca/ecs/news/cfar-spaceteo.p</a>
48	Tartan Artibeus	Satellites			<a href="https://par.nsf.gov/servlets/purl/10424448">https://par.nsf.gov/servlets/purl/10424448</a>

<http://tiny.cc/space-networking-tools>