U.S. DEPARTMENT OF ENERGY

BERKELEY LAB

ESnet ENERGY SCIENCES NETWORK

Exploring the use of LEOsat to expand the ESnet Wireless Edge

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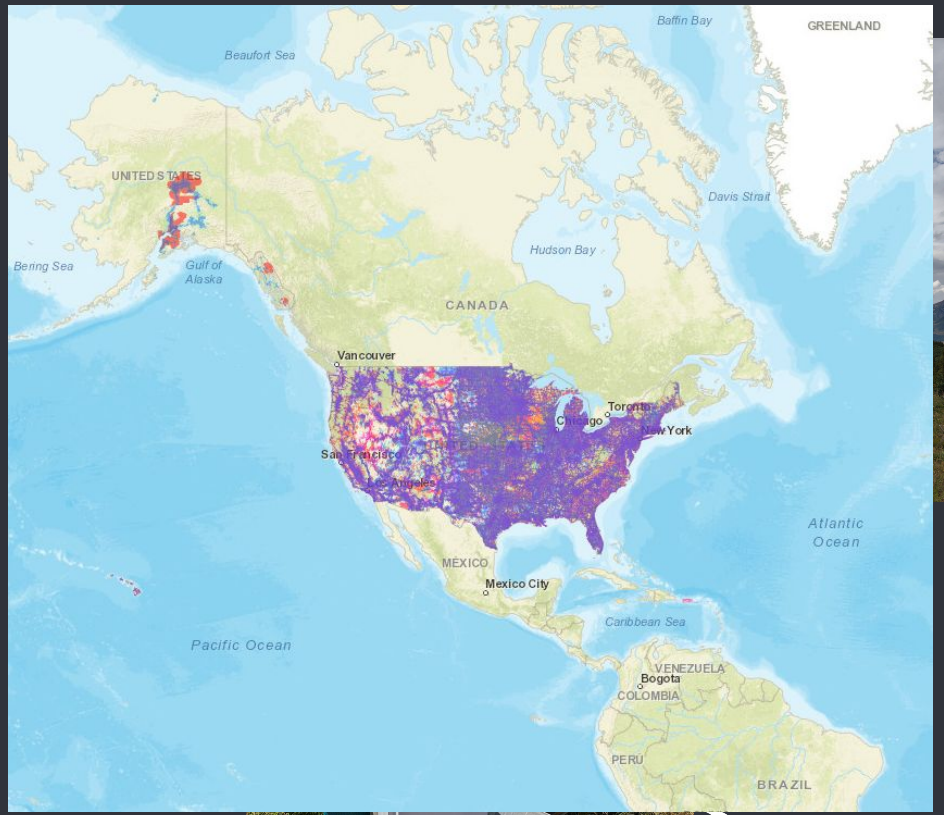
What is the wireless edge?

1) Earth and environmental science is increasingly producing data beyond where ESnet can provide fiber connectivity.

2) Sometimes commercial cellular works. Surprisingly, often it doesn't.



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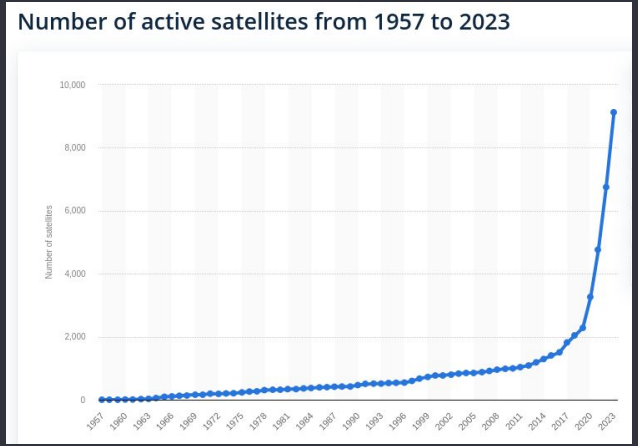
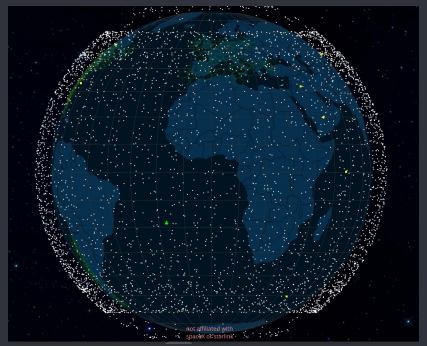
At a point of inflection for LEOsat services

- SpaceX Starlink: Has 42,000 satellites planned, approved, or under development
- OneWeb: Has 7,088 satellites planned, approved, or under development
- Amazon Kuiper: Has 3,236 satellites planned, approved, or under development
- China GW: Has 12,992 satellites planned, approved, or under development
- Telesat Lightspeed: Has 298 satellites planned, approved, or under development
- Inmarsat Orchestra: Has 150-175 satellites planned, approved, or under development
- Globalstar: A prominent LEO mega-constellation under construction
- Flock: A prominent LEO mega-constellation under construction
- The United States, the United Kingdom, China, Canada, Japan, Russia, and the European Union are all proposing LEO mega constellations. Analysts project that up to 50,000 satellites could orbit the Earth in the next decade.





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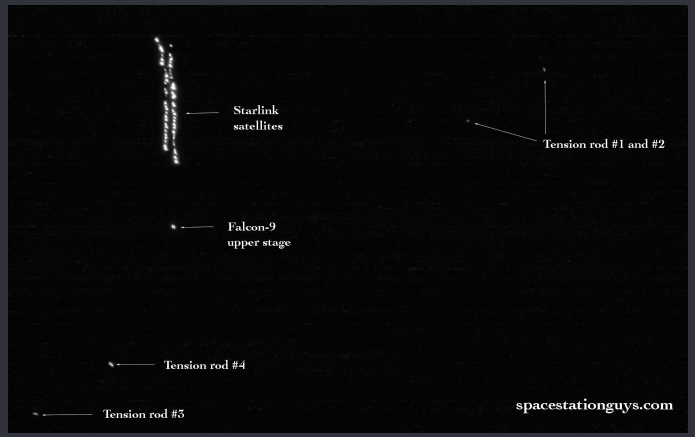
Beyond number of satellites - bandwidth on orbit also exploding

- Gen 1 Starlink satellites provide 20.2 Gbps / 16 beams / 2000 connections per beam.
  - Bent pipe —>satellite must see terminal/downlink at same time to complex on orbit mesh
- Gen 2 Starlink ~ 80+ Gbps per satellite, plus no bent pipe problem, due to inter-satellite optical links → 200 Gbps
  - Total system capacity, gen 2 ~ 1.65 Tbps - but not clear what that really means.
  - Anyway, lots more orbital bandwidth than ever before



https://spacestationguys.com/gallery/starlink-satellites/

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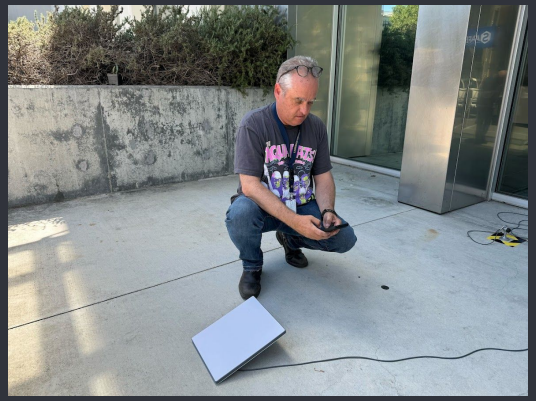
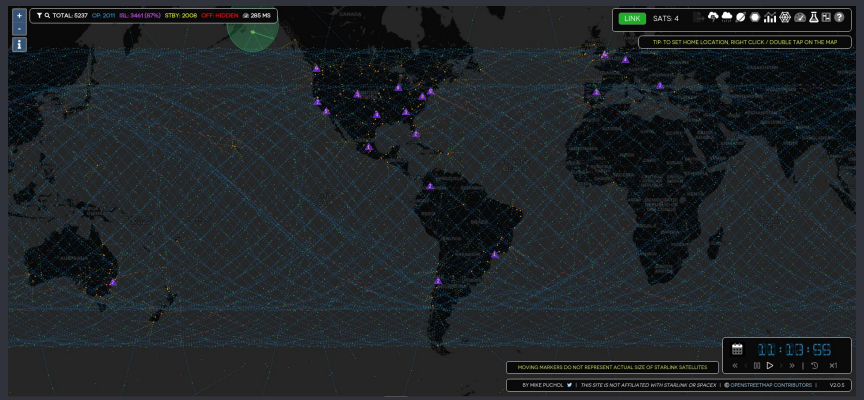
Availability and commoditization….

- Terminal and service prices decreasing
- New Starlink Mini uses ~25W, increasing off-grid usability
- Trivial to set up
- Sustained uplink speeds better than commercial cellular in most remote - US applications
  - 133 Mbps down, 14 Mpbs up from an 18 cm plate





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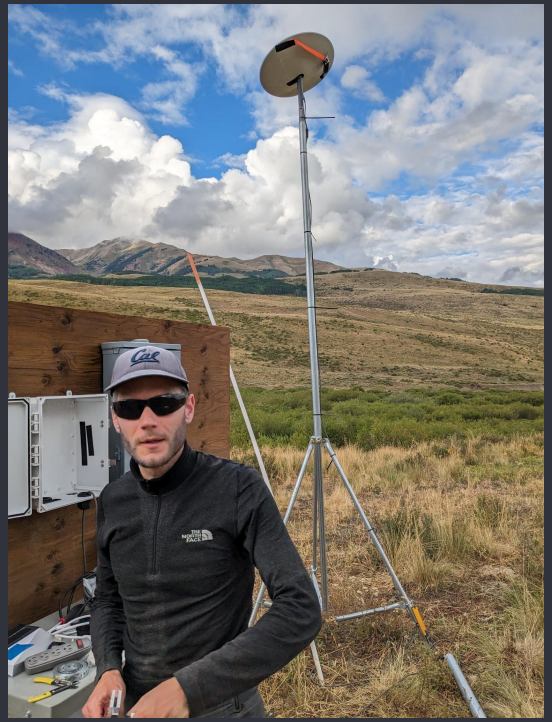
Integrating LEOsat into scientific backhaul

- Absolutely a no-brainer for single point sites, with a clear view of the sky, and electrical power.

- As these uses grow, ESnet will expand peering with Starlink, etc.



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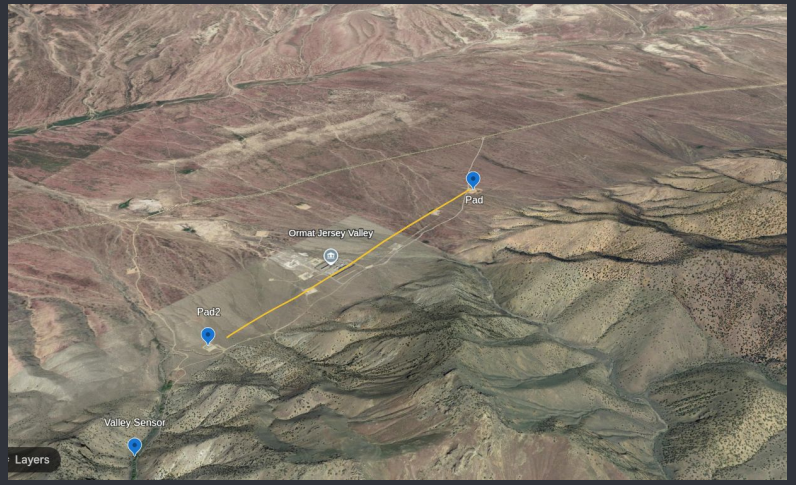
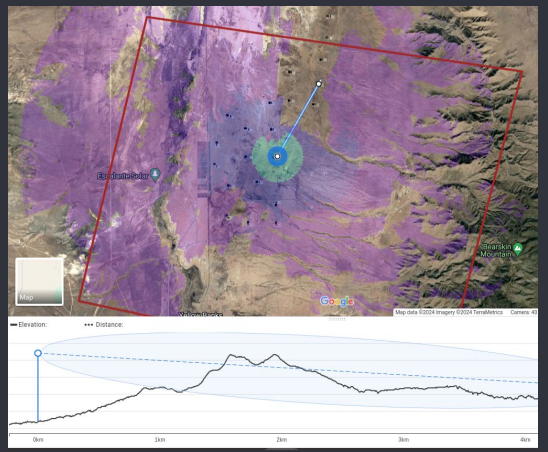
LEOsat mixed use cases

- Wider area coverage to distributed sensors may require use of other LAN wireless option
  - Too expensive, power limits to deploy multiple LEOsat terminals in an area
  - LoRA, directional wifi, private cellular (US CBRS) supported by LEOsat WAN





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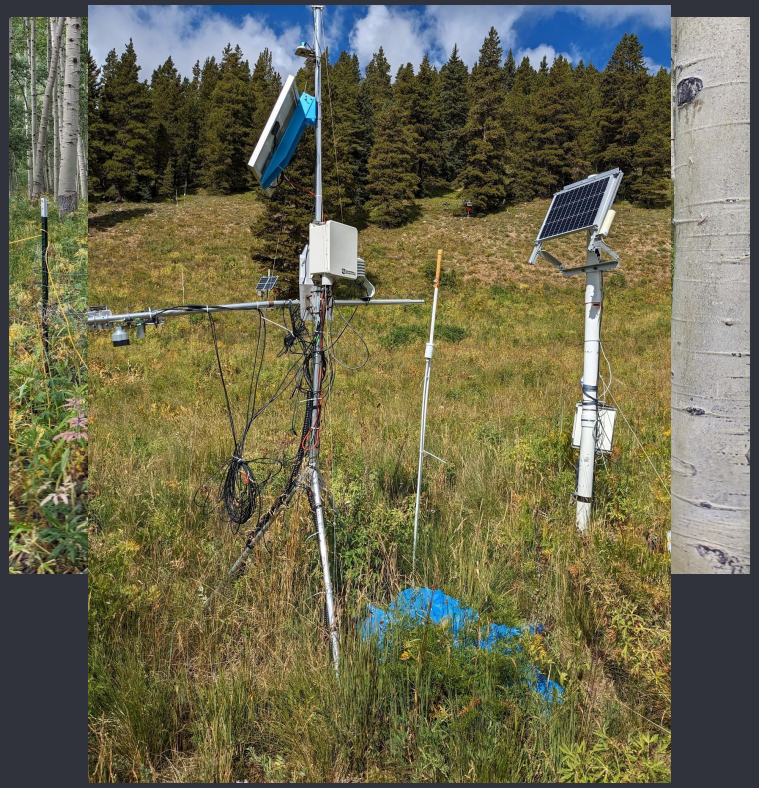
Example: Crested Butte, CO Watershed

- Effort to model a watershed area with integrated physical models from subterranean to high atmosphere.
- Bureau of Land Management constraints on solar panel use, limits on flora/fauna disruption
- Physical access limited much of the year
- Edge devices supported with Wifi, LoRA and Cellular Routers



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Provides a realistic/challenging laboratory for wireless backhaul

- Deployed a private cellular tower approx 6.5 km away, using tight beam to cover sensor area.
- Backhaul via Starlink to Seattle, then to ESnet
- Allows the possibility of dedicated connectivity for areas where there may be 10s-100s of sensors distributed in an area, and where LEOsat modems can't be deployed to cover.

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Some final thoughts

- Cellular to orbit will be especially exciting - initially for field sensor control, but for backhaul as well as bandwidth increases
- Satellite AP form factors will continue to decrease in size and power demand - but physics will conspire to make it ideal in some circumstances, and less ideal in others
- At ESnet we are trying to understand the technology tradespace (as it evolves) so that we can expand our services to support field science…the brief I give in 3 years may not be the same as I give now!