

Nov
2025

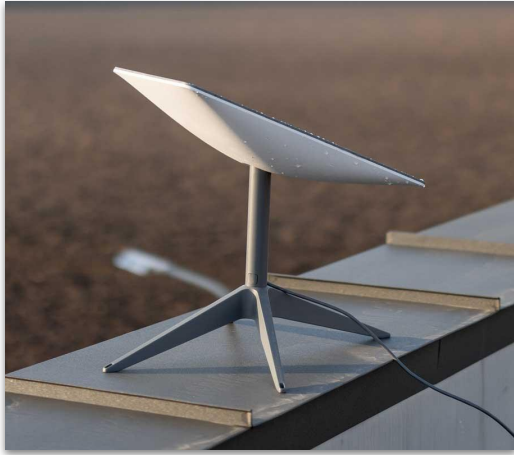
Anyone, Anywhere but not Everyone, Everywhere

Starlink doesn't close the digital
divide

IETF 124 Montreal, Canada

Presented by Wesley Woo

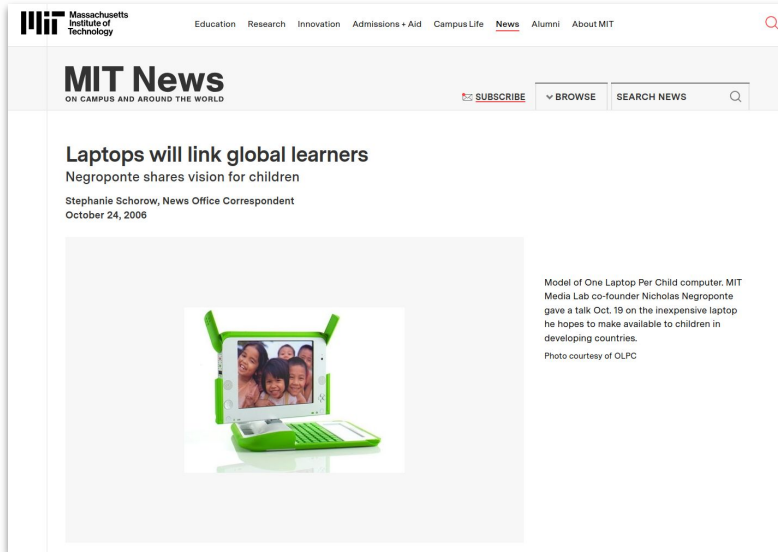




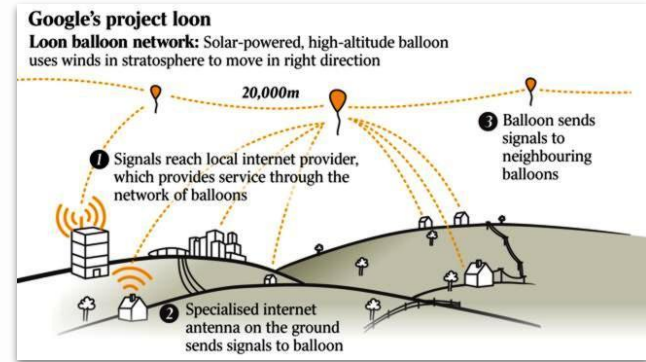
These days, researchers studying the digital divide are commonly asked: doesn't Starlink solve the digital divide?

By digital divide, I am referring to **universal, meaningful** coverage.

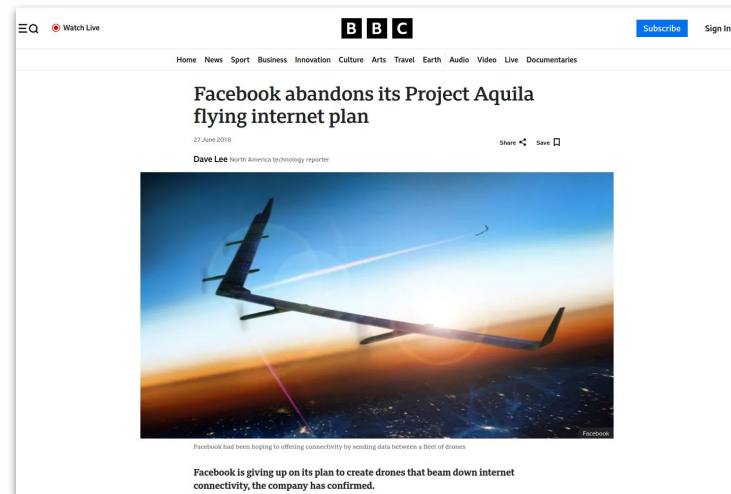
For academics in the space, this question takes a familiar shape



One Laptop Per Child



Project Loon

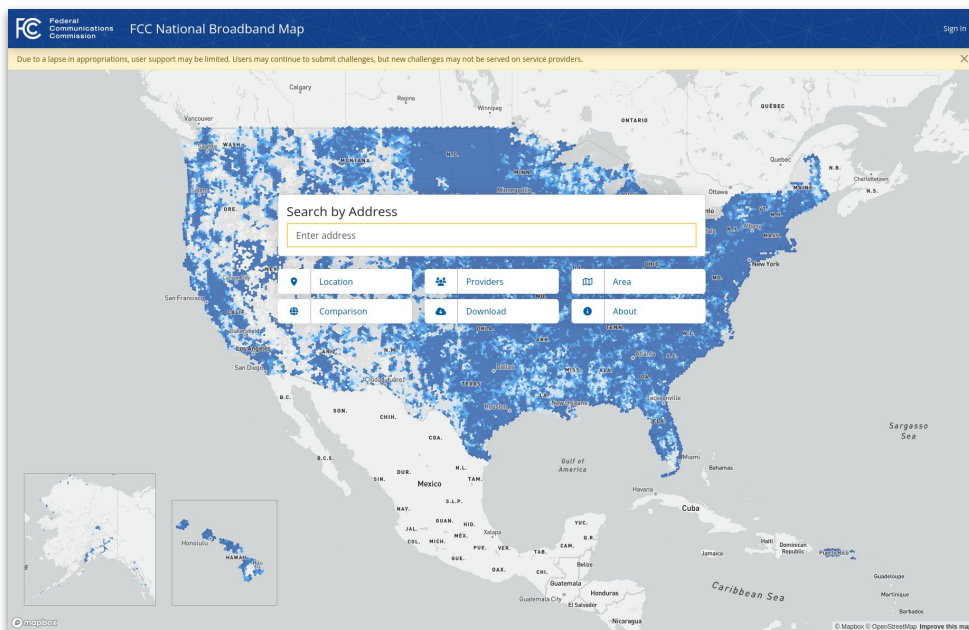


Project Aquila

In this work, we explore the limitations of Starlink to provide universal + meaningful Internet service.

- Focus on the **capacity** and **affordability** of Starlink to serve currently **un(der)served residential locations** (though other factors affect Internet adoption)
- Use the **United States** as case study due to **data availability** + **clear guidelines** for reliable Internet service
- Note that **different countries** have different connectivity **goals** + **definitions** of reliable service

We use the National Broadband Map, Schedule S filings, + US Census income datasets



Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

Application of _____
SPACE EXPLORATION HOLDINGS, LLC _____
For Approval of Orbital Deployment _____
And Operating Authority for the _____
SpaceX Gen2 NGSO Satellite System _____

Call Signs: _____
File No. _____

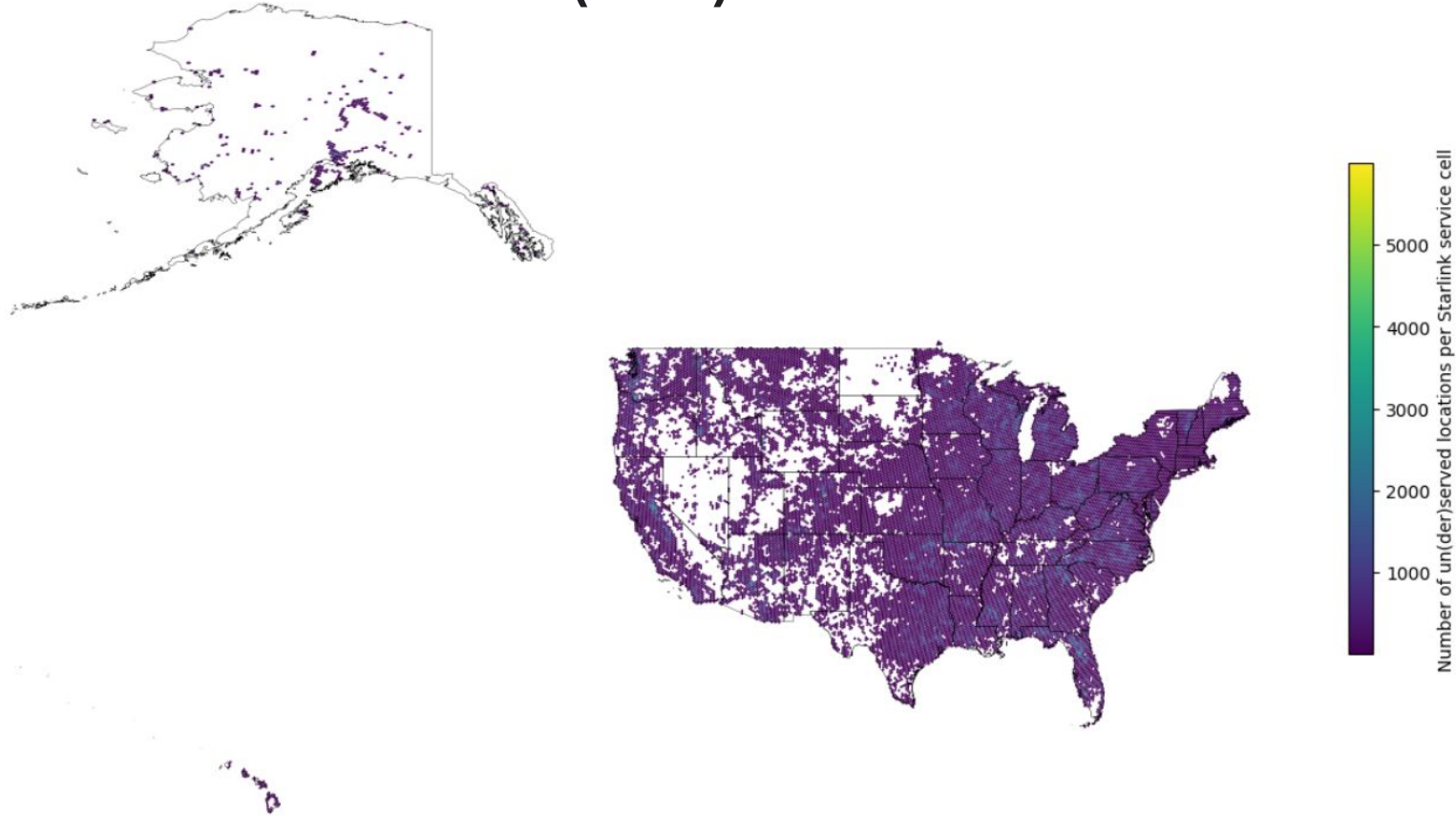
**APPLICATION FOR APPROVAL FOR ORBITAL DEPLOYMENT AND
OPERATING AUTHORITY FOR THE SPACEX GEN2 NGSO SATELLITE SYSTEM**

William M. Wiltshire
Paul Canty
HARRIS, WILTSHIRE & GRANNIS LLP
1919 M Street, N.W.
Suite 900
Washington, DC 20036
202-730-1300 tel
202-730-1301 fax

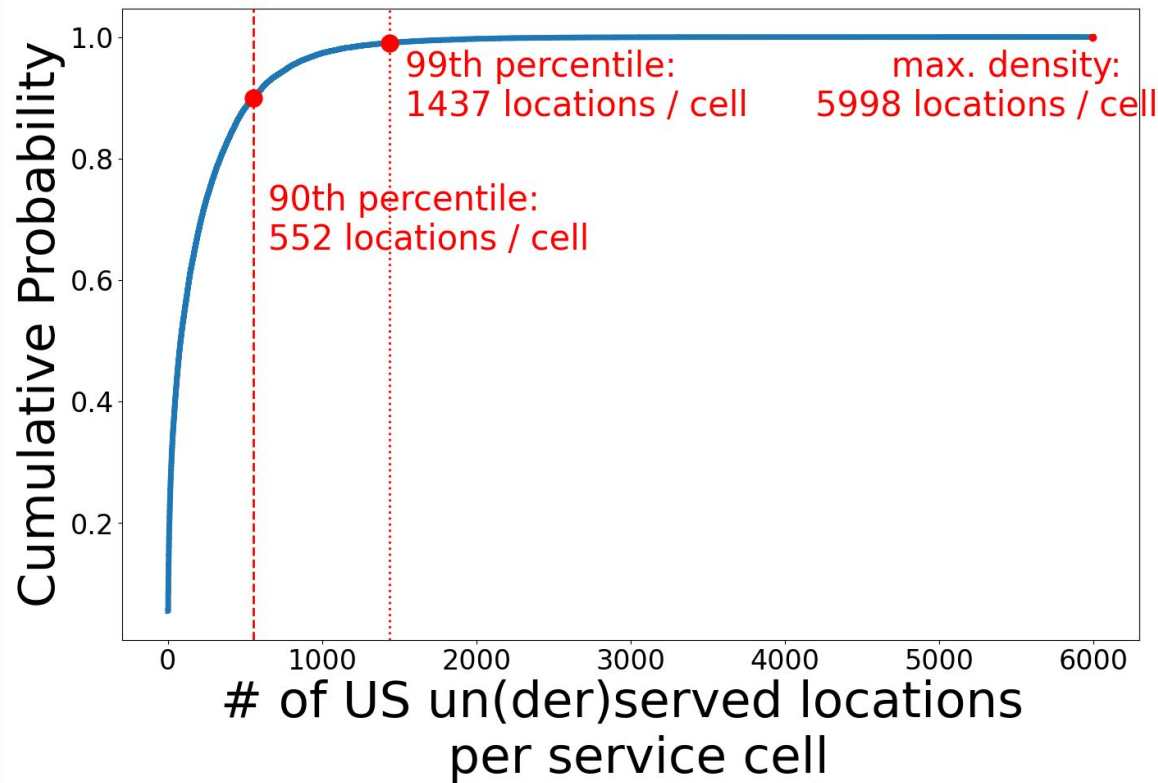
David Goldman
Director of Satellite Policy
SPACE EXPLORATION TECHNOLOGIES CORP.
1155 F Street, N.W.
Suite 475
Washington, DC 20004
202-649-2700 tel
202-649-2701 fax

Counsel to SpaceX
May 26, 2020

Distribution of un(der)served US locations



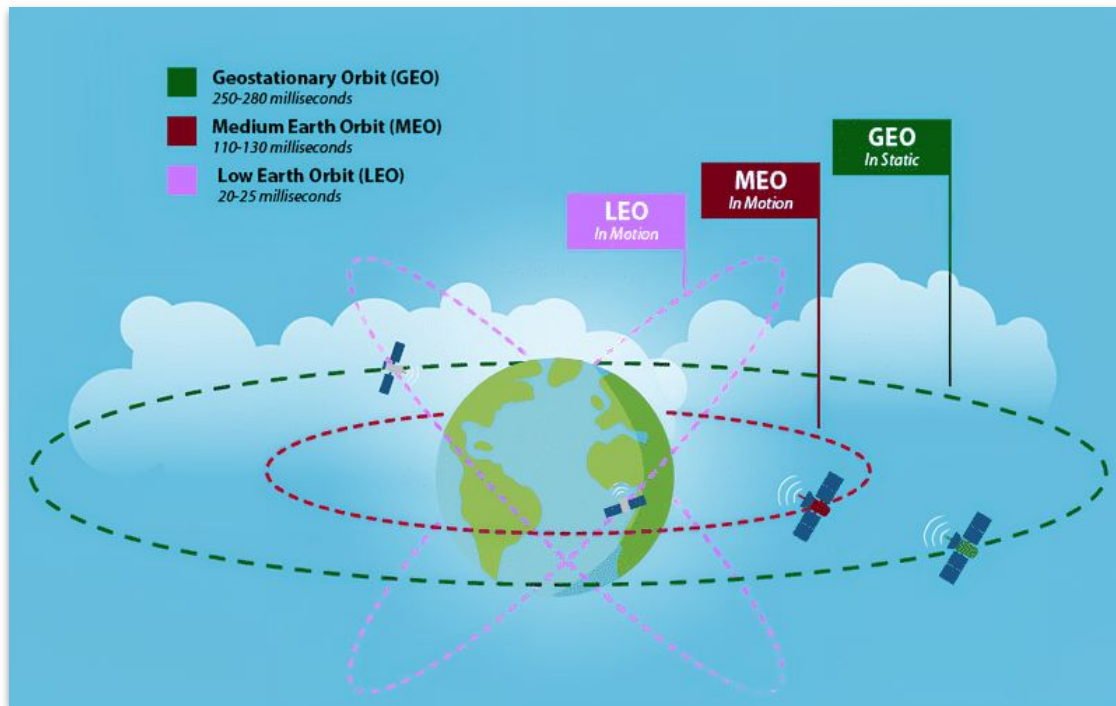
Distribution of un(der)served US locations



Evaluating Capacity

Evaluating Capacity *About LEO*

- GSO satellite technology has been around for a while, serving Internet over **wireless channels**
- Starlink takes advantage of lower launch and material costs to place satellites in **LEO orbit**
- These satellites offer lower latency service, though introduce the **mobility problem**



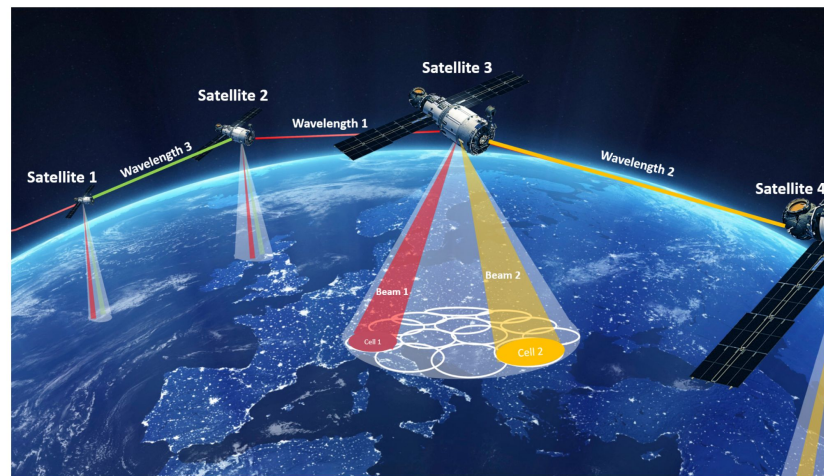
Evaluating Capacity

Is Starlink bandwidth constrained?

Band (GHz)	# Beams	Usage
10.7–12.75 (2050 MHz)	4	Downlink to UTs
19.7–20.2 (500 MHz)	8	DL to UTs
17.8–18.6 (800 MHz)	8	DL to UTs / GWs
18.8–19.3 (500 MHz)	4	DL to UTs / GWs
71–76 (5000 MHz)	4	DL to GWs
Total to UTs / Cells	24 / 28	3850 / 8850 MHz

Parameter	Value
UT downlink spectrum	3850 MHz
Spectral efficiency	~4.5 bps/Hz [33]
Max per-cell capacity	~17.3 Gbps
Peak Cell users	5998 users
FCC throughput requirement	100/20 Mbps (DL/UL)
Peak Cell DL demand	599.8 Gbps
Max DL oversubscription	~35:1

Table 1: Starlink Single Satellite Capacity Model



Evaluating Capacity

Is Starlink bandwidth constrained?

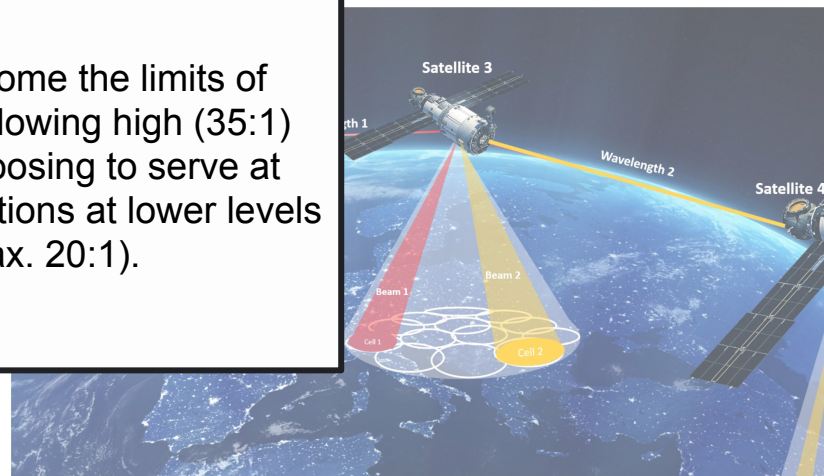
Band (GHz)
10.7–12.75 (205)
19.7–20.2 (500)
17.8–18.6 (800)
18.8–19.3 (500)
71–76 (5000 M)
Total to UTs /

Parameter
UT downlink
Spectral efficiency
Max per-cell capacity
Peak Cell users
FCC throughput requirement
Peak Cell DL demand
Max DL oversubscription

FINDING 1: Starlink can overcome the limits of spectrum availability either by allowing high (35:1) oversubscription rates or by choosing to serve at most 99.9% of un(der)served locations at lower levels of oversubscription (max. 20:1).

~4.5 bps/Hz [33]
~17.3 Gbps
5998 users
100/20 Mbps (DL/UL)
599.8 Gbps
~35:1

Table 1: Starlink Single Satellite Capacity Model



Evaluating Capacity

What size constellation would the US need?

Mobility of LEO satellites introduces 2 scaling properties:

1. **High** cost to serve the **first** customer, **low** cost to serve the **second**
2. **Demand density** determines the size of the constellation

Evaluating Capacity

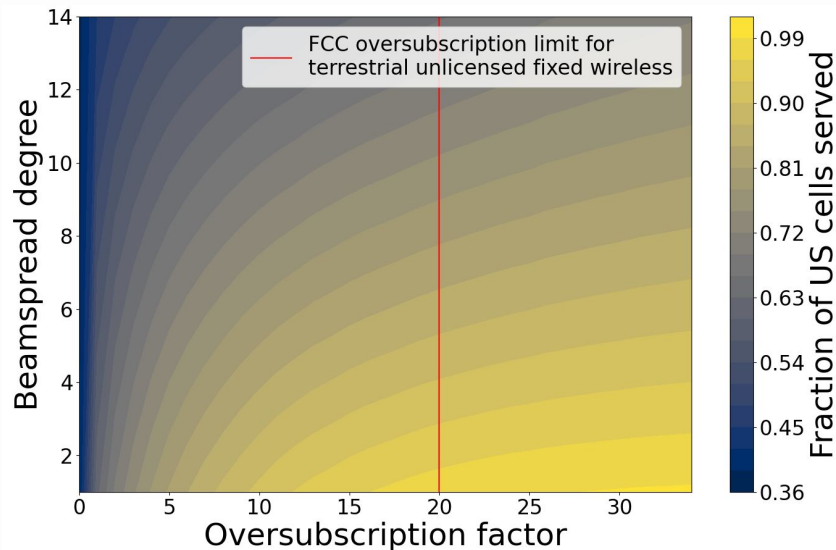
What size constellation would the US need?

- Assume the **densest cell** requires **all available spectrum** to serve (4 satellite beams)
- Also assume **surrounding cells** can be served with a **single beam** (“best case scenario” assumption)
- Given **symmetry** of satellite constellations, we can derive **total constellation size**

Evaluating Capacity

What size constellation would the US need?

Beamspread Factor	Constellation size (full service)	Constellation size (max. 20:1 oversub.)
1	79287 satellites	80567 satellites
2	40611	41261
5	16486	16750
10	8284	8417
15	5532	5621

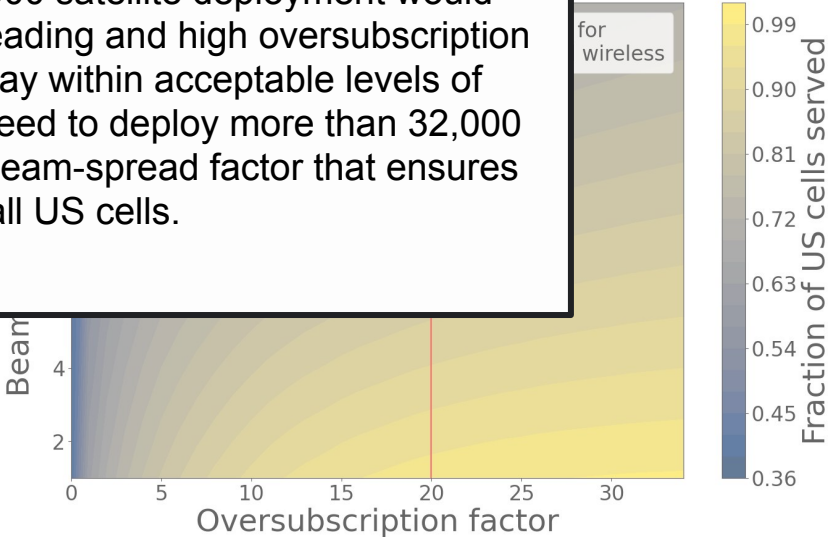


Evaluating Capacity

What size constellation would the US need?

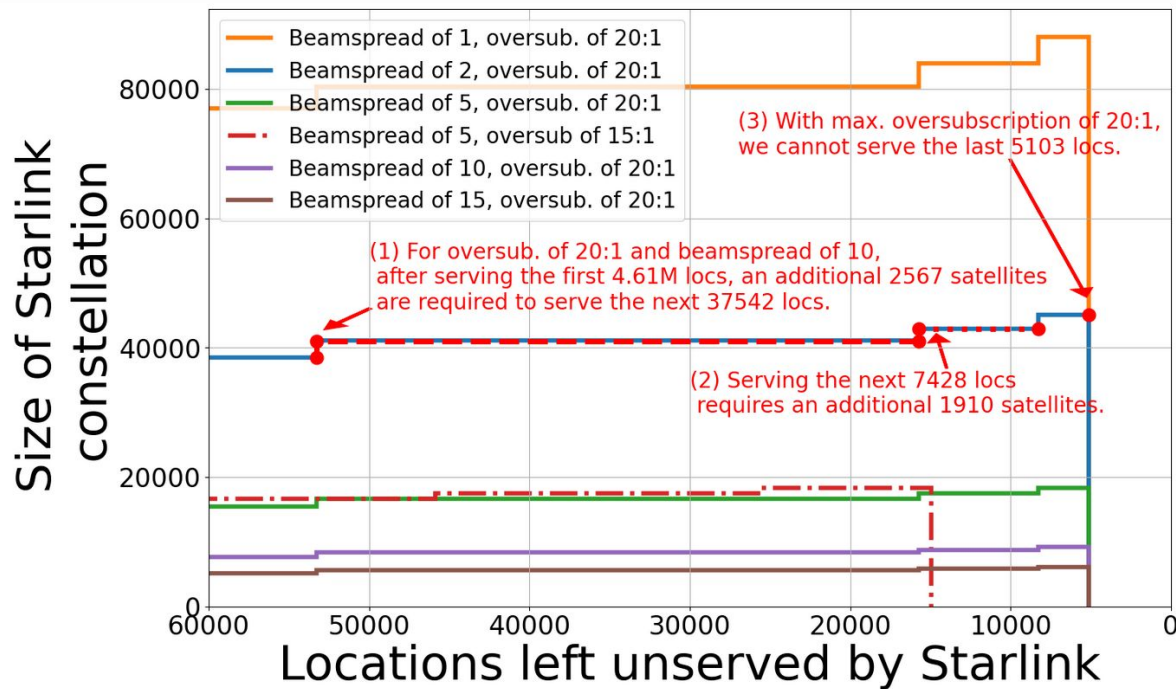
Beamspread Factor	Constellation size	Constellation size for wireless
1	79	
2	40	
5	16486	16750
10	8284	8417
15	5532	5621

FINDING 2: Starlink's current 8000 satellite deployment would require high degrees of beam-spreading and high oversubscription rates to serve all US cells. To stay within acceptable levels of oversubscription, Starlink would need to deploy more than 32,000 additional satellites to achieve a beam-spread factor that ensures coverage of all US cells.



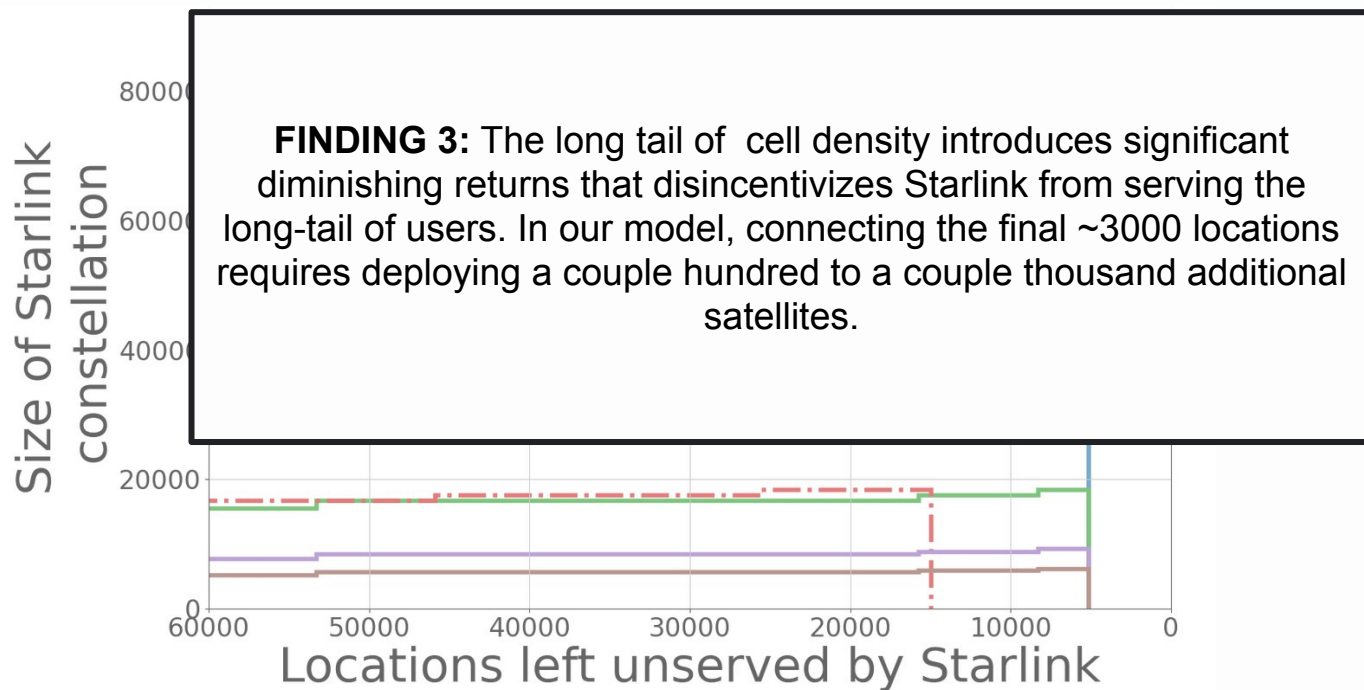
Evaluating Capacity

What size constellation would the US need?



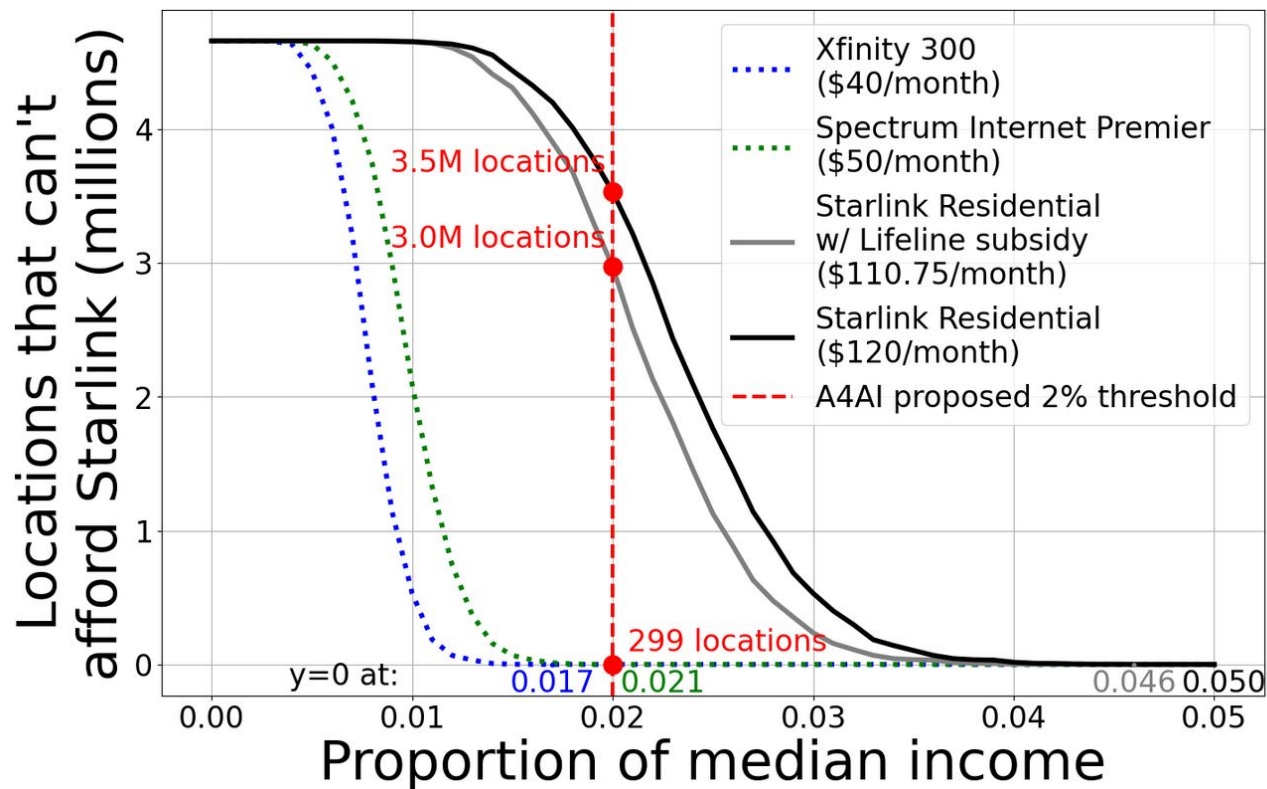
Evaluating Capacity

What size constellation would the US need?

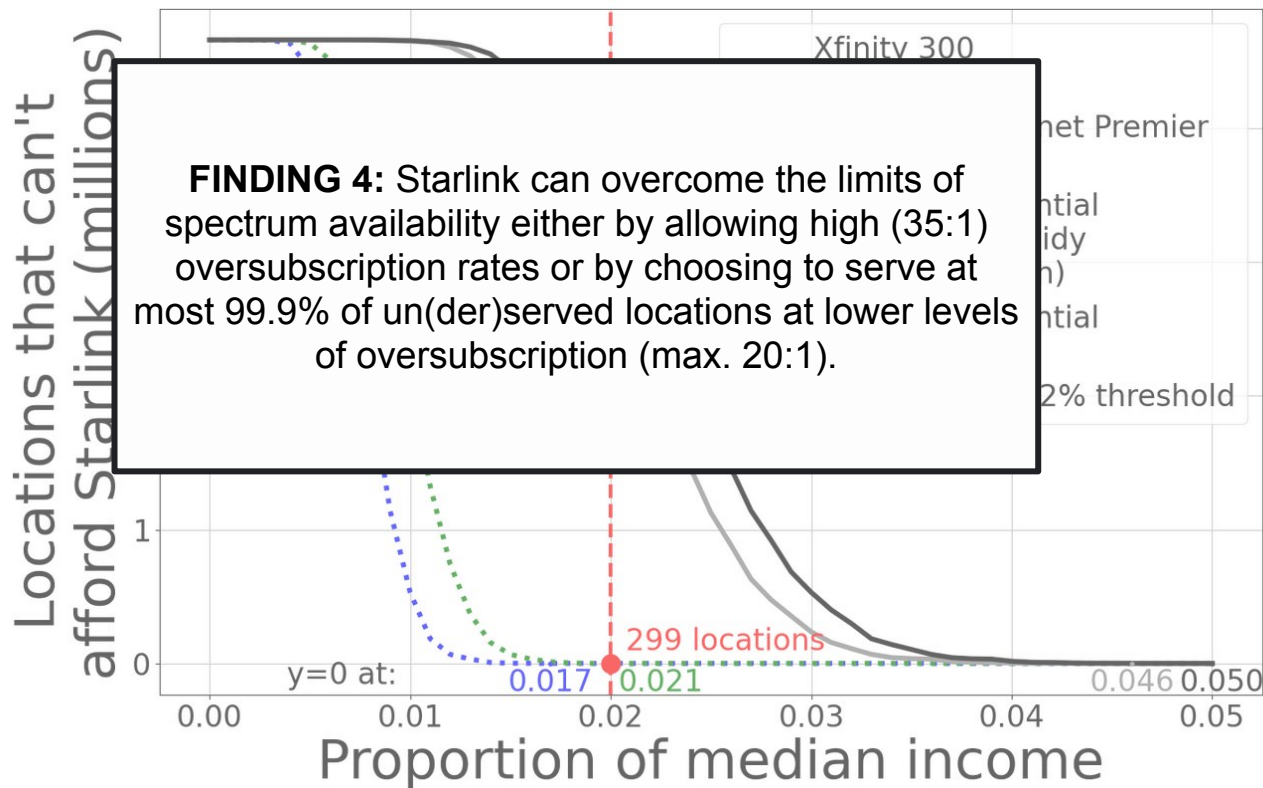


Evaluating Affordability

Evaluating Affordability



Evaluating Affordability



As per Steve Song, Starlink is “just another rock” in filling the digital divide “jar”.

Closing the digital divide requires innovation of multiple forms, including novel technologies, new models of spectrum access and infrastructure sharing, and community or municipal-based approaches to connectivity



Summary of Results + Future Directions

**High rates of
oversubscription
required given
current spectrum
allocations**



What are current rates of oversubscription in Starlink's network? In practice, what is an appropriate maximum oversubscription rate?

**Even with beam-
spreading and over-
subscription, SL
requires ~40k sats.**



Can Starlink afford to host a constellation of 40,000 satellites?

**Highly diminishing
returns to serving
long-tail of users**



How to best serve unconnected rural areas with high demand for Internet?

**3.5M locations are
unable to afford
Starlink service**



What are barriers to Internet adoption, even when it is affordable?