TEXAS
The University of Texas at Austin

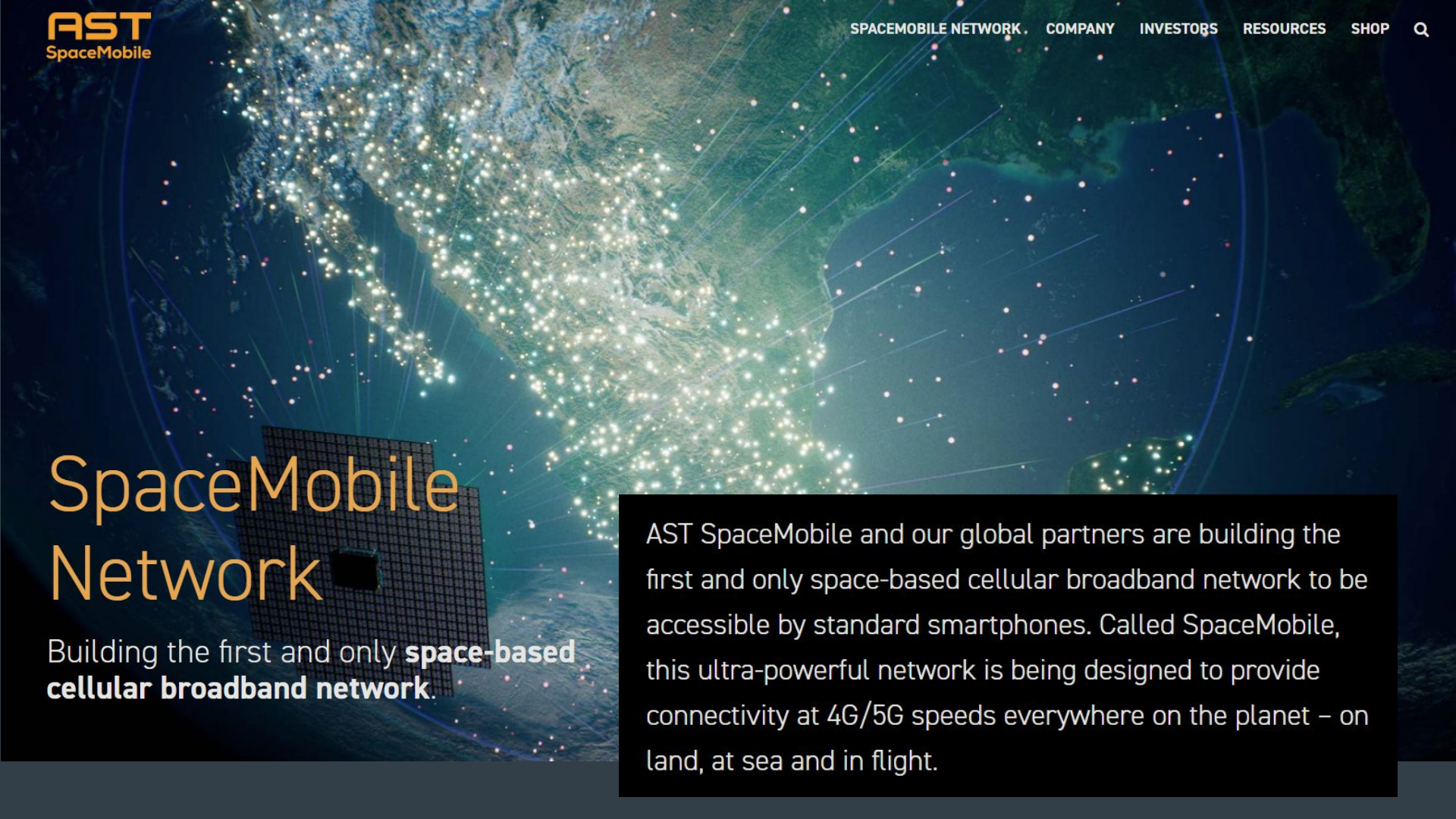
6G @ UT

The Science and Strategy Behind D2C

Todd Humphreys
The University of Texas at Austin

6G@UT Forum | April 3, 2025

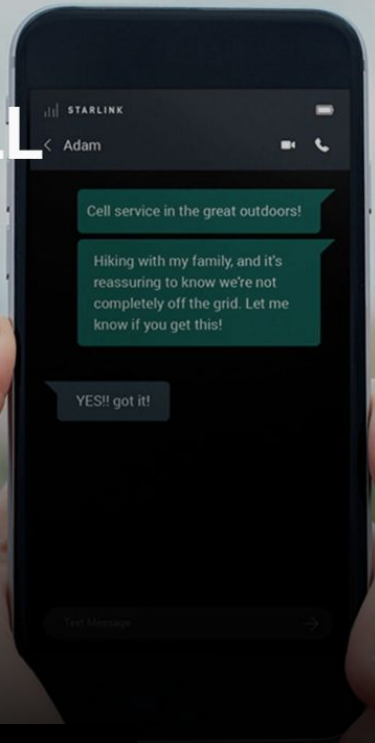
Contenders


AST
SpaceMobile
SPACEMOBILE NETWORK
COMPANY
INVESTORS
RESOURCES
SHOP
SpaceMobile Network
Building the first and only **space-based cellular broadband network**.
AST SpaceMobile and our global partners are building the first and only space-based cellular broadband network to be accessible by standard smartphones. Called SpaceMobile, this ultra-powerful network is being designed to provide connectivity at 4G/5G speeds everywhere on the planet – on land, at sea and in flight.

STARLINK DIRECT TO CELL

Engineered to eliminate mobile dead zones around the world.
Service now available.

LEARN MORE



UBIQUITOUS COVERAGE

Starlink satellites with Direct to Cell capabilities enable ubiquitous access to texting, calling, and browsing wherever you may be on land, lakes, or coastal waters. Direct to Cell will also connect IoT devices with common LTE standards.

LEO Broadband

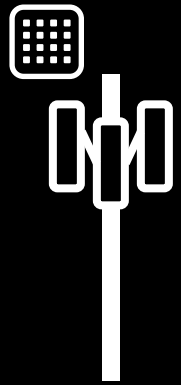
Optical Inter-Satellite Link
2+ Gbps

Satellite-to-User-Terminal Links
100+ Mbps

Point of Presence

Satellite-to-Gateway Link
20+ Gbps

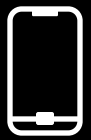
6G Backhaul Link
400+ Mbps

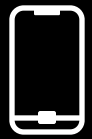


Terrestrial
5G/6G Link

POP-to-Gateway Link (Fiber)

Direct-to-Handset Link
0.1-20 Mbps



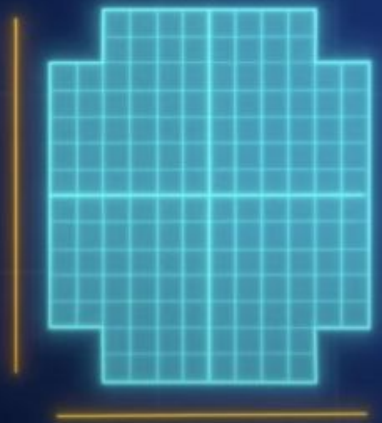


UT-to-Handset Link

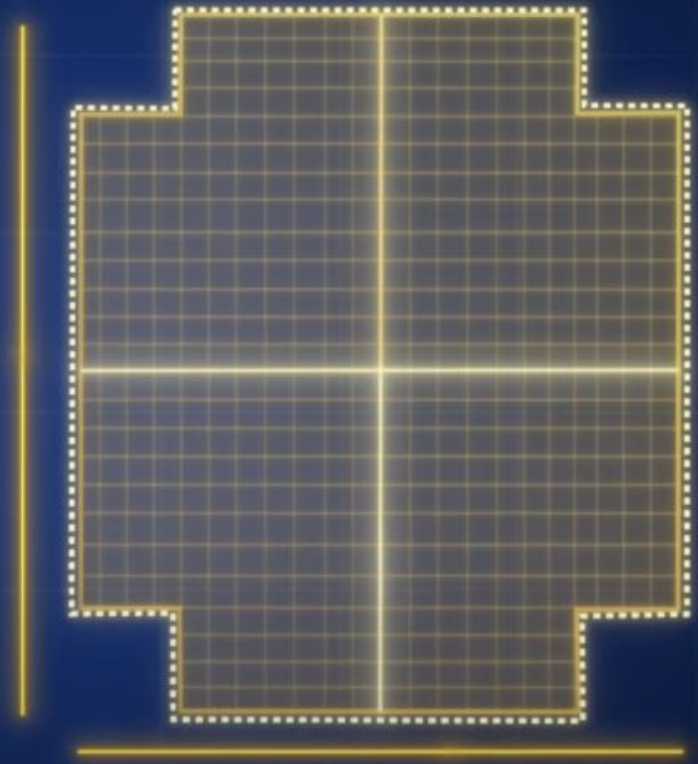
AST SpaceMobile

Starlink

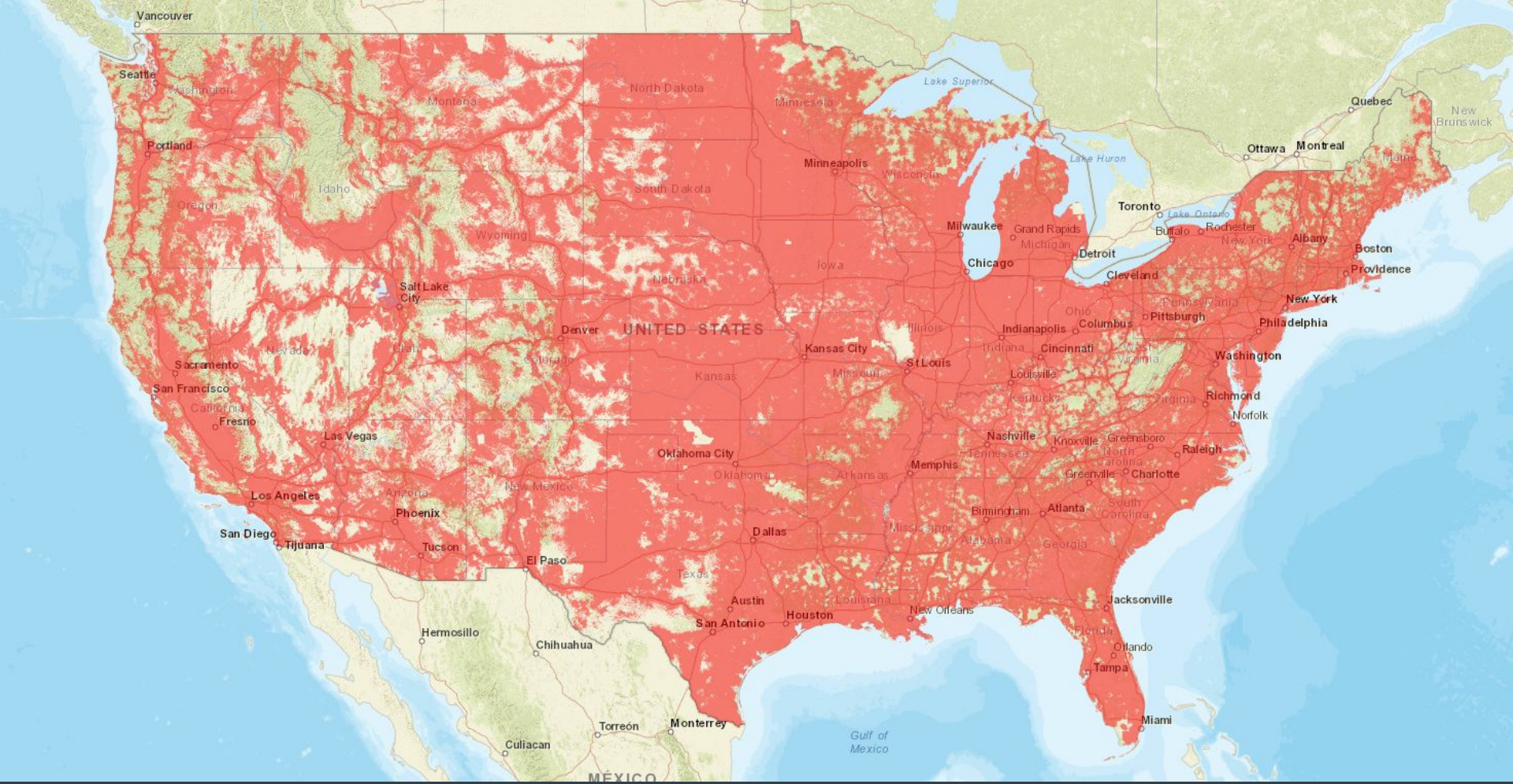
Space deployment allows for enormous arrays even at sub-GHz frequencies. Bluewalker 3 satellite focuses dozens of ~ 3-deg. beams on surface to support direct-to-handset comms.



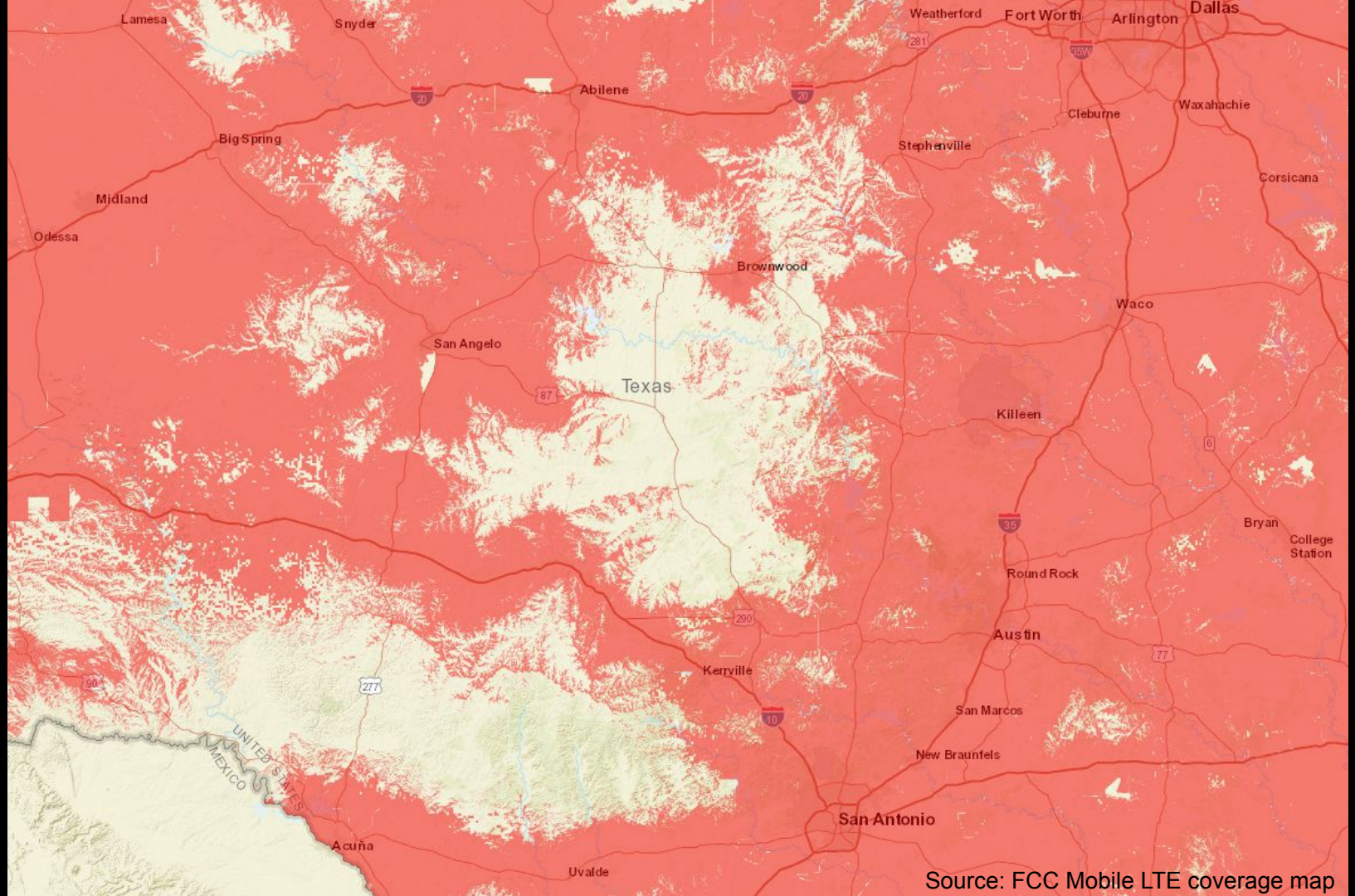
FIRST-GEN
BLUEBIRD



NEXT-GENERATION
BLUEBIRD

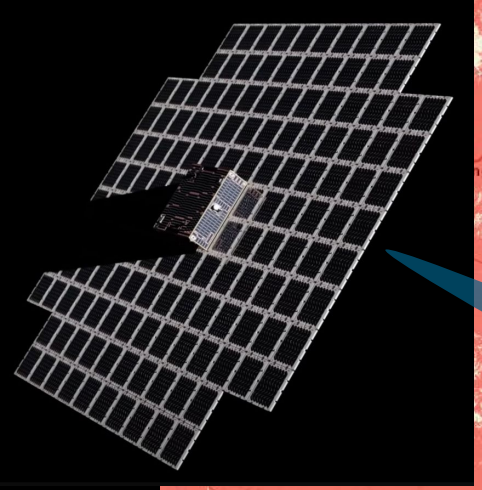


Source: FCC Mobile LTE coverage map



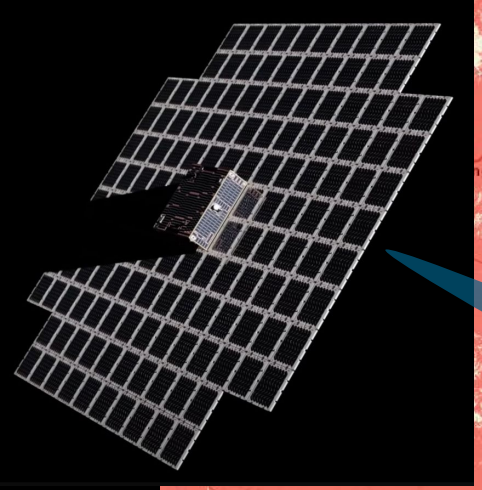
Source: FCC Mobile LTE coverage map

Case Study



20-km beam footprint
Rural: 30 people/km^2
50% smartphone ownership
~4000 smartphones in footprint
5% peak concurrency
200 peak active users
600 kbps/user

Bluebird Block II
220 m^2 phased array
2500 independent beams
40-MHz bandwidth
3 bps/Hz spectral efficiency
120 Mbps total rate (max)



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Bluebird Block II
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Starlink's D2C footprint is *larger* and its bandwidth (from T-Mobile) is only 10 MHz, so *even lower* potential data rate per user.

Starlink's and AST's D2C offerings as planned will not be "broadband" except in special cases where the whole available bandwidth is devoted to a few customers.

Q: What could we change to get true broadband D2C to many simultaneous customers?

Design Space & Constraints

Power

Directivity

Spectral Efficiency
(bps/Hz)

Bandwidth

MIMO

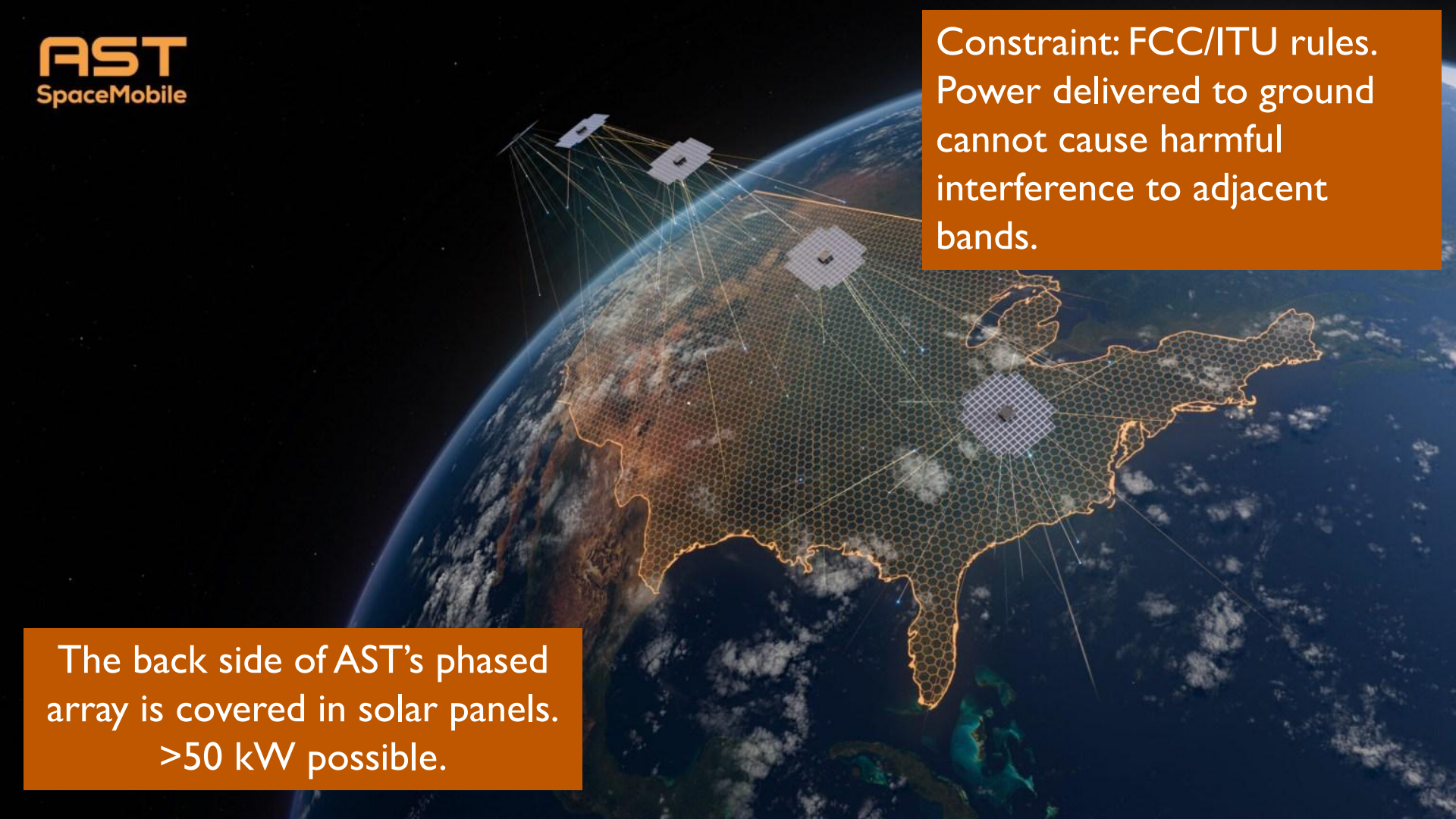
Power

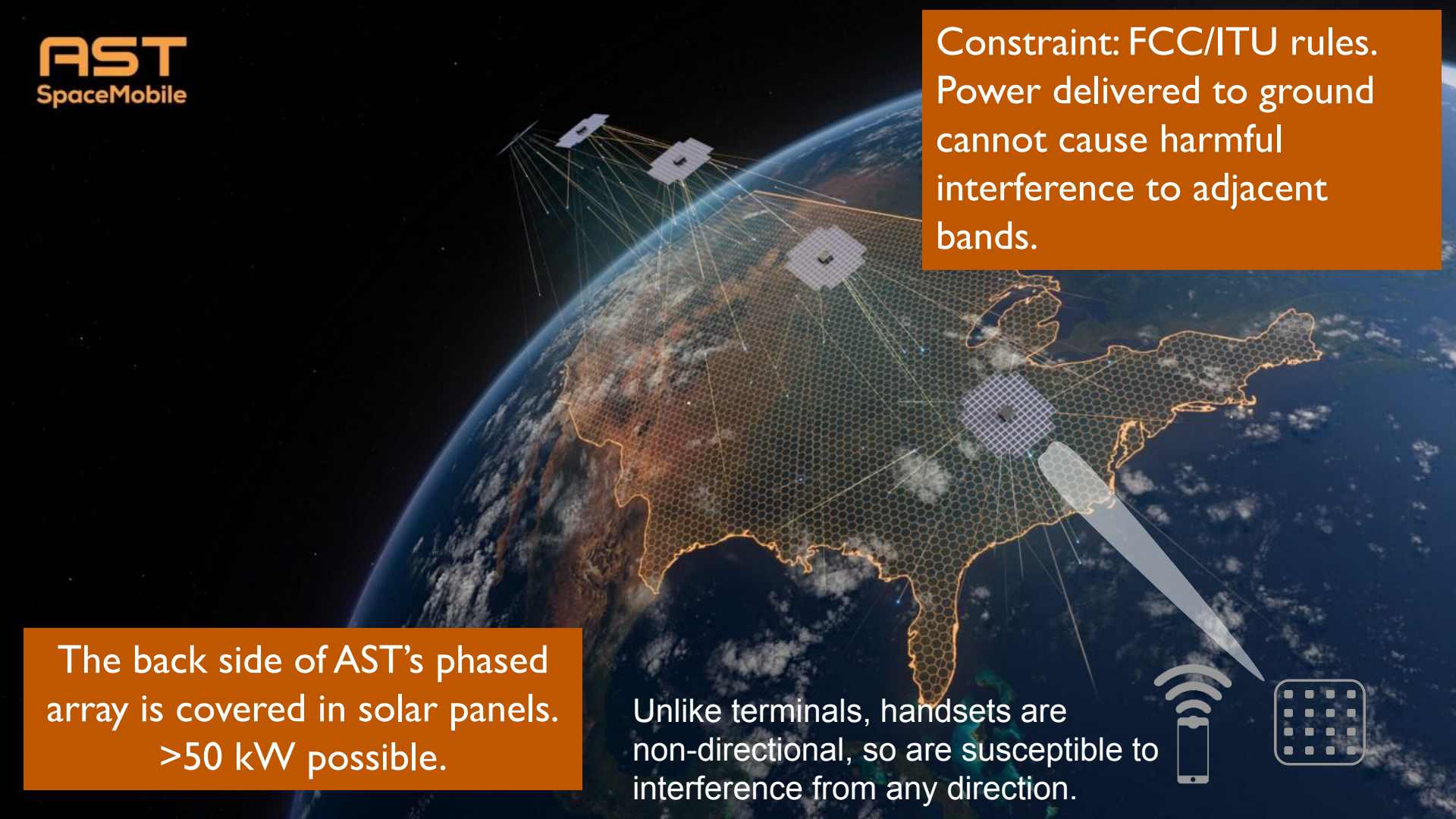
Directivity

Spectral Efficiency
(bps/Hz)

Bandwidth

MIMO


AST
SpaceMobile
Constraint: FCC/ITU rules. Power delivered to ground cannot cause harmful interference to adjacent bands.
The back side of AST's phased array is covered in solar panels. >50 kW possible.


AST
SpaceMobile
Constraint: FCC/ITU rules. Power delivered to ground cannot cause harmful interference to adjacent bands.
The back side of AST's phased array is covered in solar panels. >50 kW possible.
Unlike terminals, handsets are non-directional, so are susceptible to interference from any direction.

In 2024, SpaceX requested a waiver to transmit at 9.4 dB higher power than the SCS framework allows.

AT&T and Verizon fought back, citing harmful interference.

In March 2025, the FCC granted SpaceX's waiver request.

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Space Bureau and Wireless Telecommunications Bureau Seek Comment on Filings of SpaceX and T-Mobile Requesting to Establish Supplemental Coverage from Space	)	GN Docket No. 23-135; ICFS File Nos. SAT-MOD-20230207-00021, SAT-AMD-20240322-00061
	)	
Application for Authority for Modification of the SpaceX NGSO Satellite System to Add a Direct to Cellular System	)	Call Sign: S3069

ORDER

Adopted: March 7, 2025 **Released: March 7, 2025**

By the Chief, Space Bureau, and the Acting Chief, Wireless Telecommunications Bureau:

I. INTRODUCTION

1. By this Order, the Space Bureau and Wireless Telecommunications Bureau conditionally grant the request of Space Exploration Technologies Corp. (SpaceX) for waiver of section 25.202(k)(1) of the Commission's rules, thereby permitting aggregate out-of-band emissions (OOBE) in the United States at a power flux density (PFD) level up to -110.6 dBW/m^2/MHz.[1] SpaceX asserts that the public interest is supported by allowing a waiver of the established PFD to this level, which "will protect adjacent band networks from harmful interference while ensuring that consumers and first responders can use an increasingly robust set of features even in the most challenging circumstances," and will avoid placing artificial caps on the number of satellites used to provide supplemental coverage from space for terrestrial networks.[2] For the reasons discussed below, we find that there is good cause to grant SpaceX's waiver request, subject to the conditions outlined herein, including requiring that SpaceX address any harmful interference to adjacent band terrestrial wireless networks or else cease operations under the waiver.

II. BACKGROUND

2. In March 2024, the Commission issued the *Single Network Future: Supplemental*

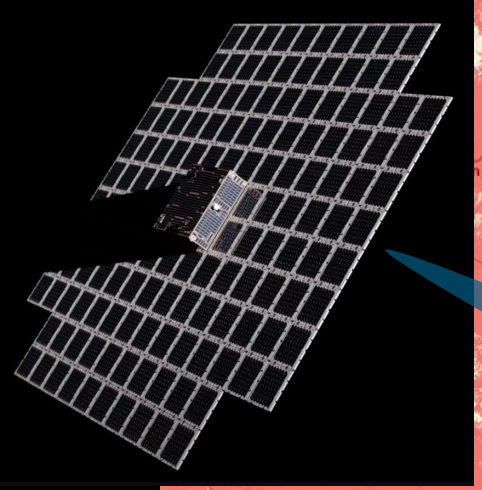
Power

Directivity

Spectral Efficiency
(bps/Hz)

Bandwidth

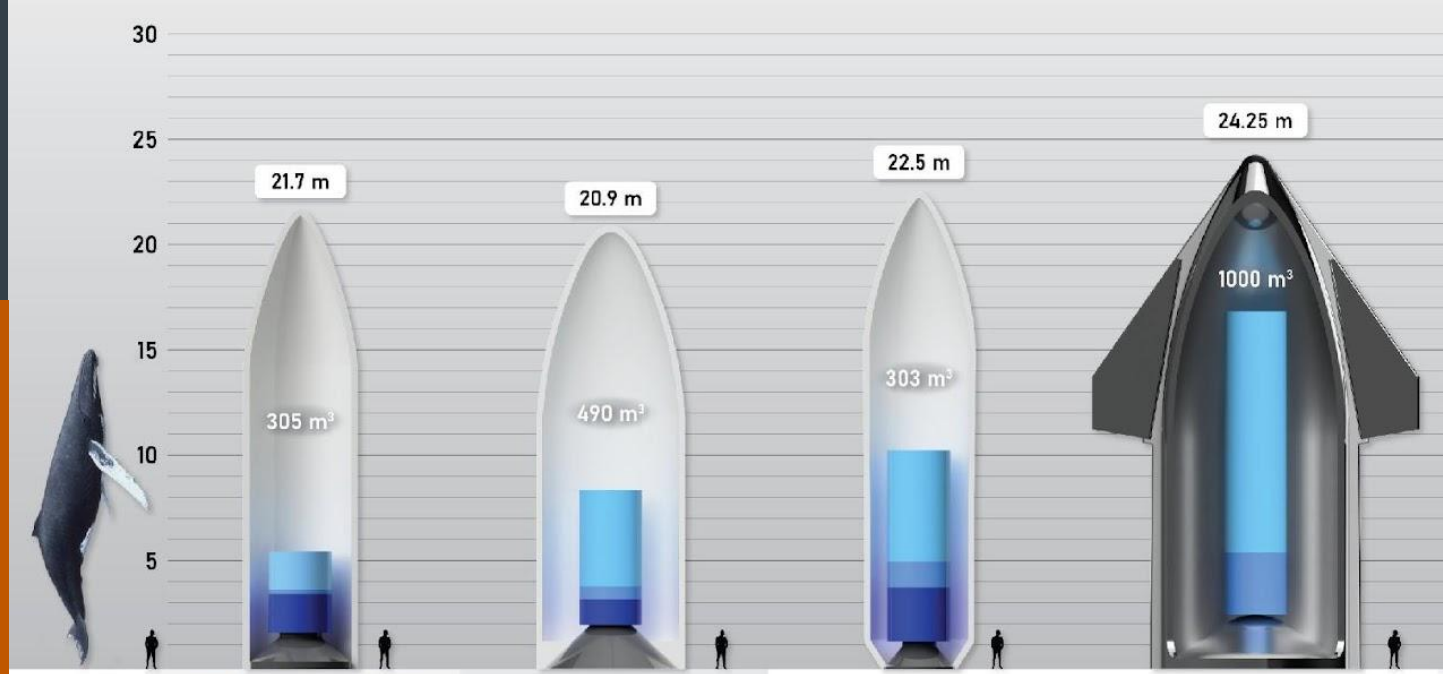
MIMO



Area of beam footprint scales inversely as the antenna area.

Space deployment allows for enormous arrays even at sub-GHz frequencies. Bluewalker 3 satellite focuses dozens of ~ 3-deg. beams on surface to support direct-to-handset comms.

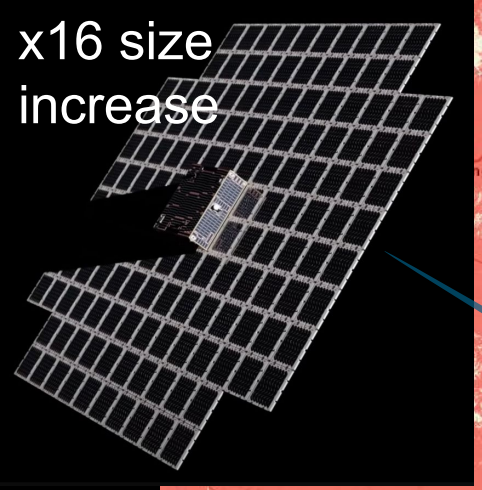
Constraint: Launch fairing volume. The largest conceivable phased array over next ~10 years could only be ~16x the area of the Bluebird Block II.



	Vulcan Centaur Heavy Expended	New Glenn 1st Stage Reuse	Falcon Heavy Expended	Starship Full Reuse, No Refuel
LEO	27,200 kg	45,000 kg	63,800 kg	100,000+ kg
GTO	14,400 kg	13,000 kg	26,700 kg	21,000 kg
TLI	13,000 kg	8,500 kg	18,000 kg	N/A
🍌	2,775,454	4,454,545	2,754,545	9,090,909

ULA BLUE ORIGIN SPACEX

Source: Ken Kirtland



x16 size increase

5-km beam footprint
Rural: 30 people/km^2
50% smartphone ownership
5% peak concurrency
9.2 Mbps/user

Area of beam footprint scales inversely as the antenna area.

Power

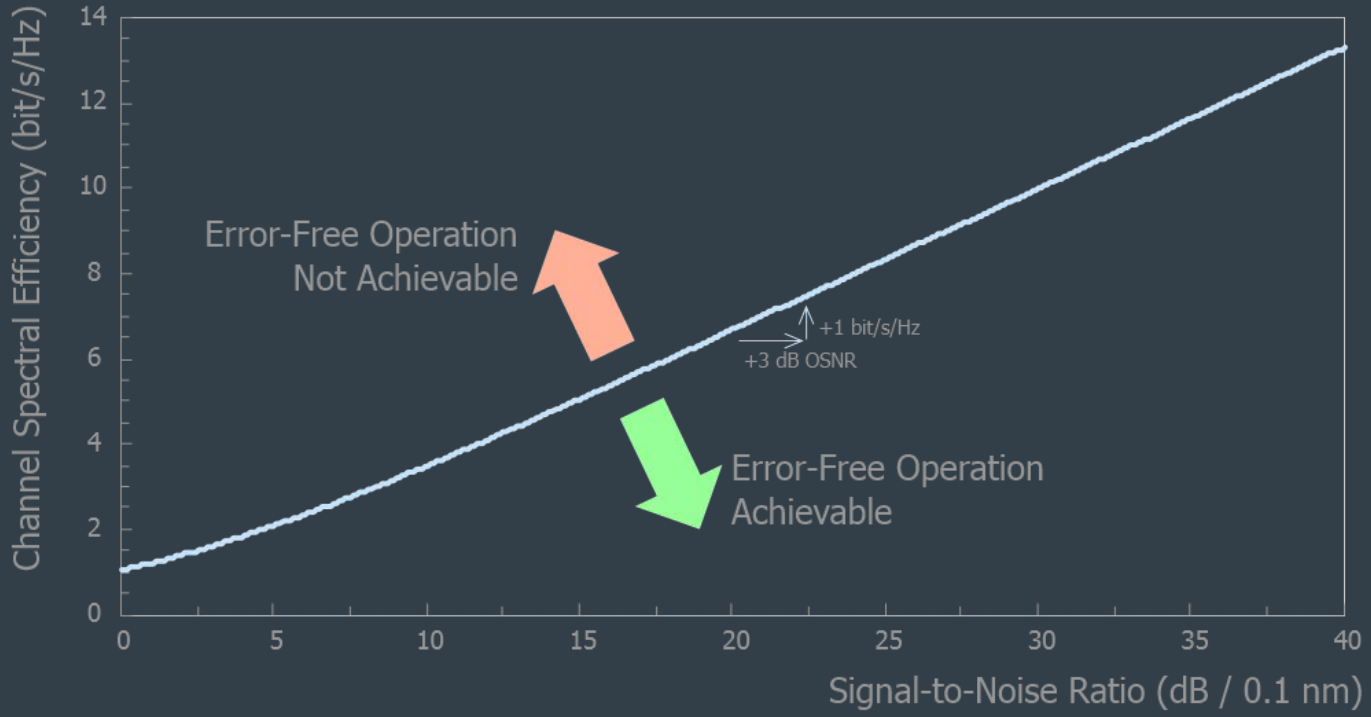
Directivity

Spectral Efficiency
(bps/Hz)

Bandwidth

MIMO

Constraint: Shannon limit. For a given power flux density on ground, there is a maximum channel capacity in bps/Hz. AST is already near this limit.



Gain of phone antenna limited by size/wavelength.

Power

Directivity

Spectral Efficiency
(bps/Hz)

Bandwidth

MIMO

Mobile Satellite Services (MSS) spectrum

Fixed Satellite Services (FSS) spectrum

Terrestrial cellular spectrum (under SCS)

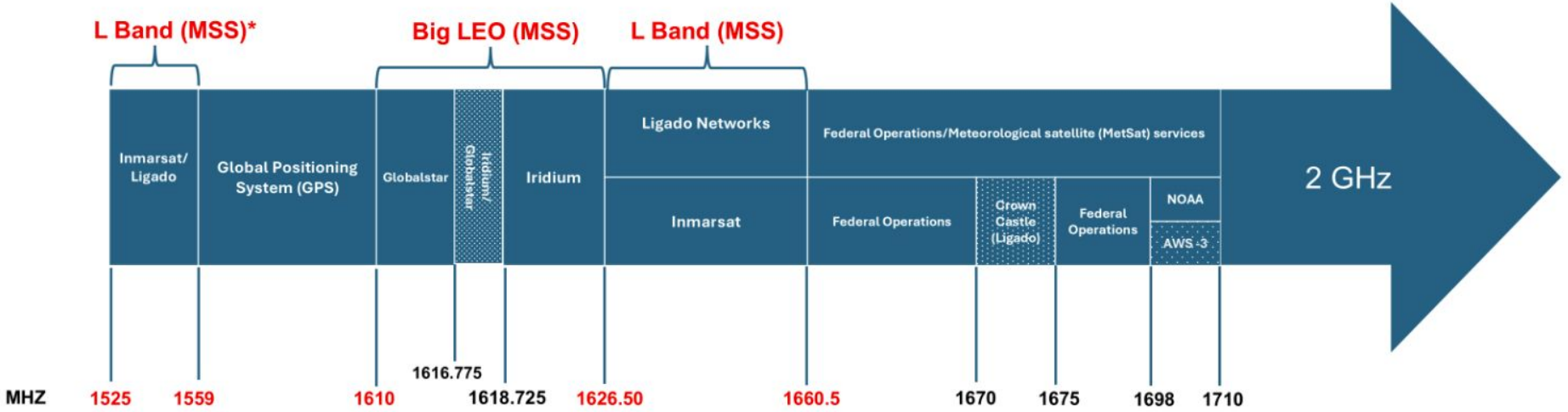
Mobile Satellite Services (MSS) spectrum

Fixed Satellite Services (FSS) spectrum

Terrestrial cellular spectrum (under SCS)

L Band Allocations – U.S.

Constraint: Most already allocated to credible users.



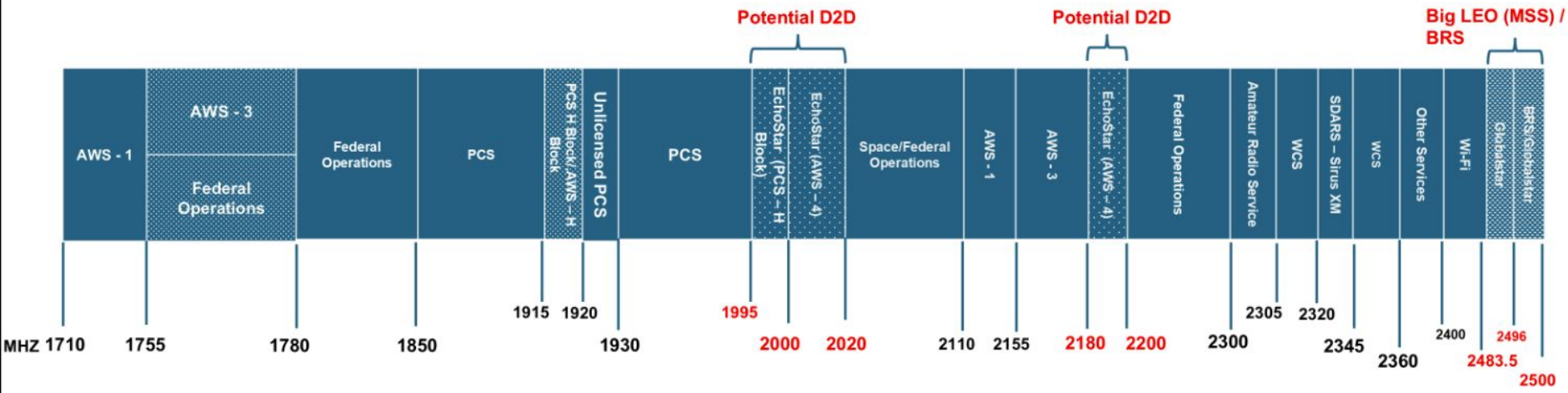
* Currently under regulatory and legal scrutiny.

-- Represents shared spectrum

-- Represents terrestrial use spectrum

Source: Company Filings, Press Release, Summit Ridge Group, LLC and TMF Associates, Inc. analysis

Upper L Band, 2 GHz and S- Band Allocations – U.S.



-- Represents shared spectrum

-- Represents potential D2D spectrum

Constraint: Most already allocated to credible users.

Source: Company Filings, Press Release, Summit Ridge Group, LLC and TMF Associates, Inc. analysis

Mobile Satellite Services (MSS) spectrum

Fixed Satellite Services (FSS) spectrum

Terrestrial cellular spectrum (under SCS)

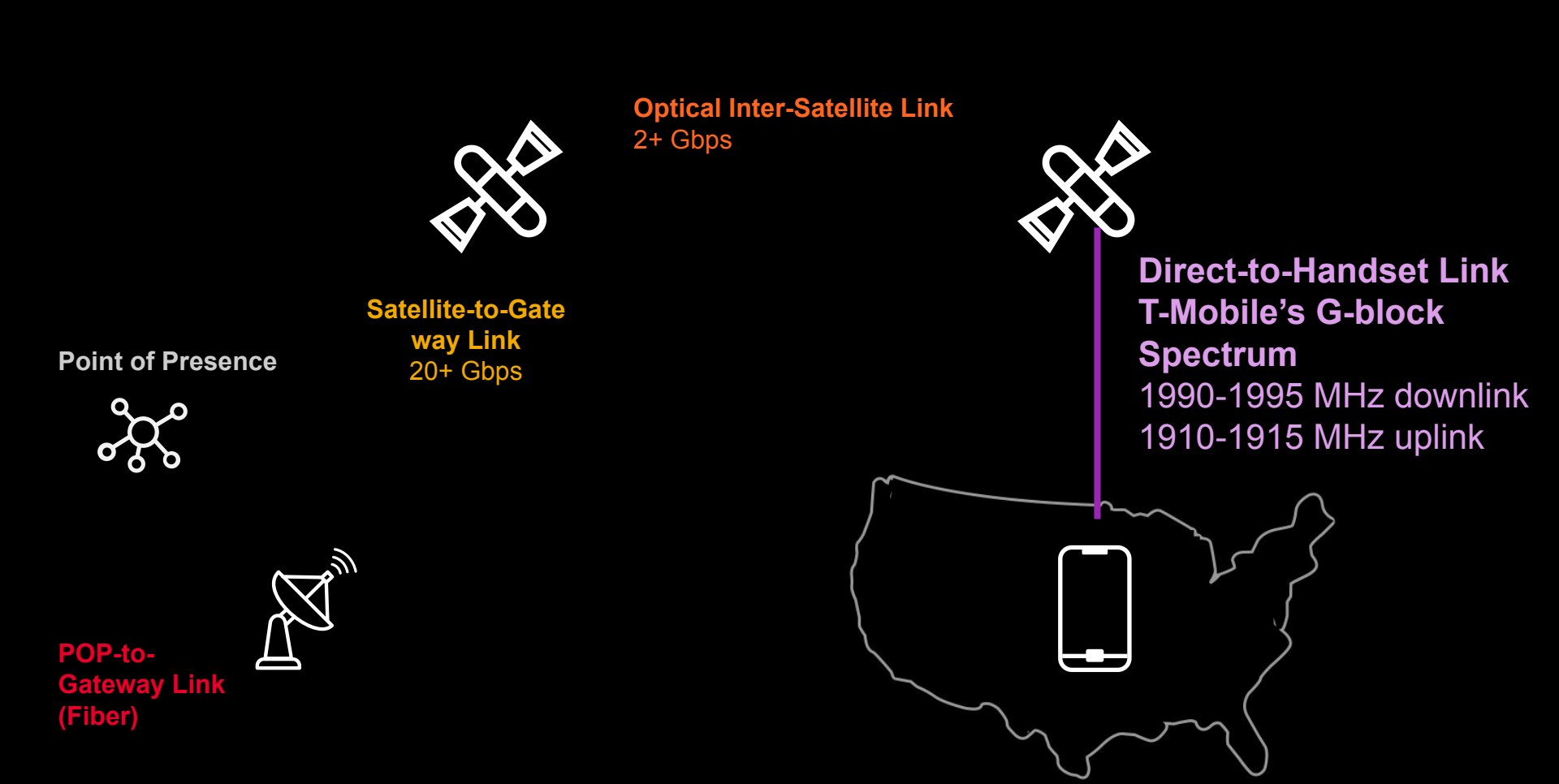
Constraint: Ku and Ka band spectrum sharing depends on user equipment directivity; otherwise not workable.

Mobile Satellite Services (MSS) spectrum

Fixed Satellite Services (FSS) spectrum

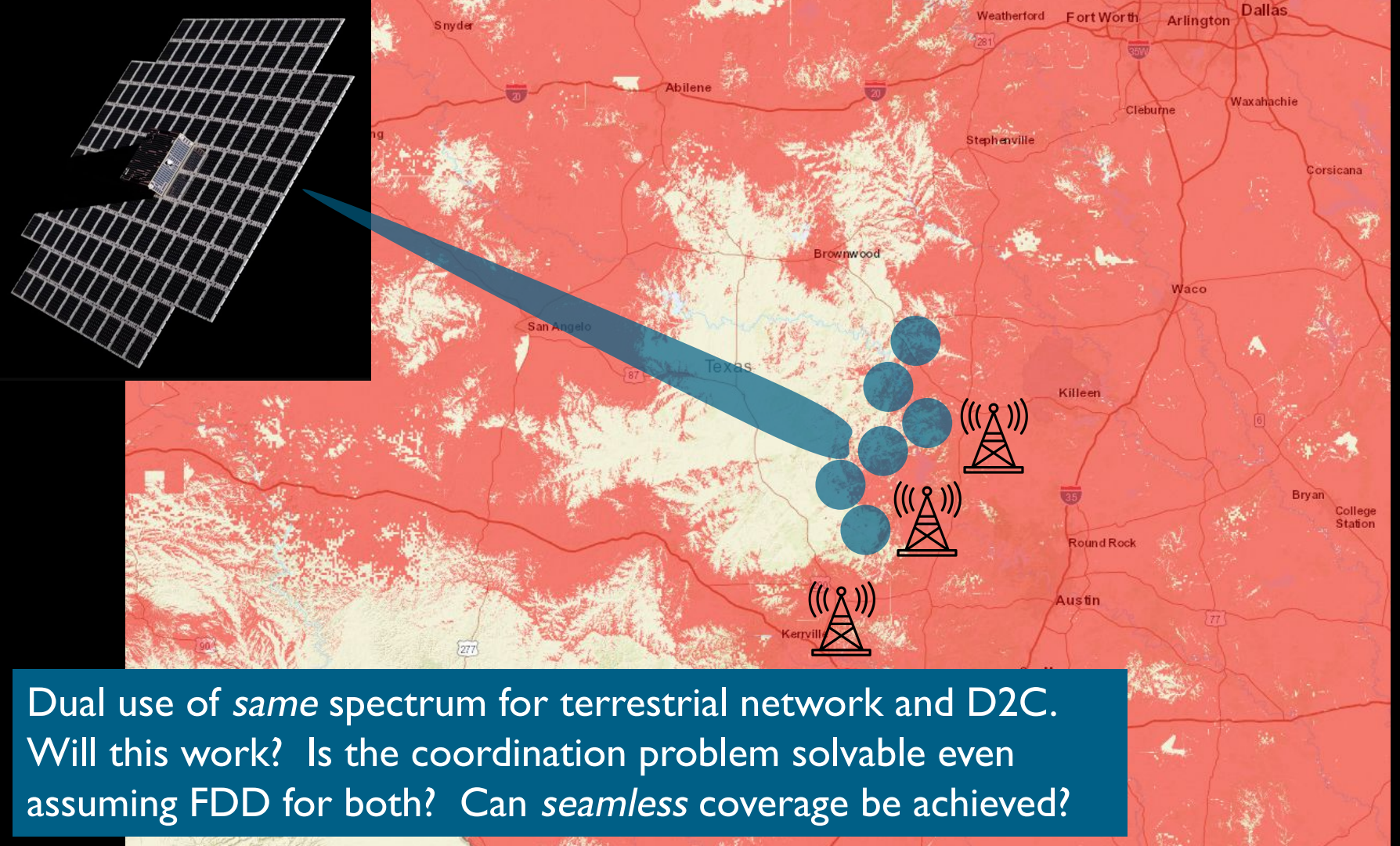
Terrestrial cellular spectrum (under SCS)

Q: Set aside terrestrial spectrum exclusively for D2C, or dual-purpose it for both terrestrial network and D2C?



T-Mobile + SpaceX approach: exclusive set-aside

But other mobile network operators are *extremely reluctant* to follow T-Mobile in setting aside their precious terrestrial spectrum for exclusive D2C use.



Dual use of *same* spectrum for terrestrial network and D2C. Will this work? Is the coordination problem solvable even assuming FDD for both? Can *seamless* coverage be achieved?

Power

Directivity

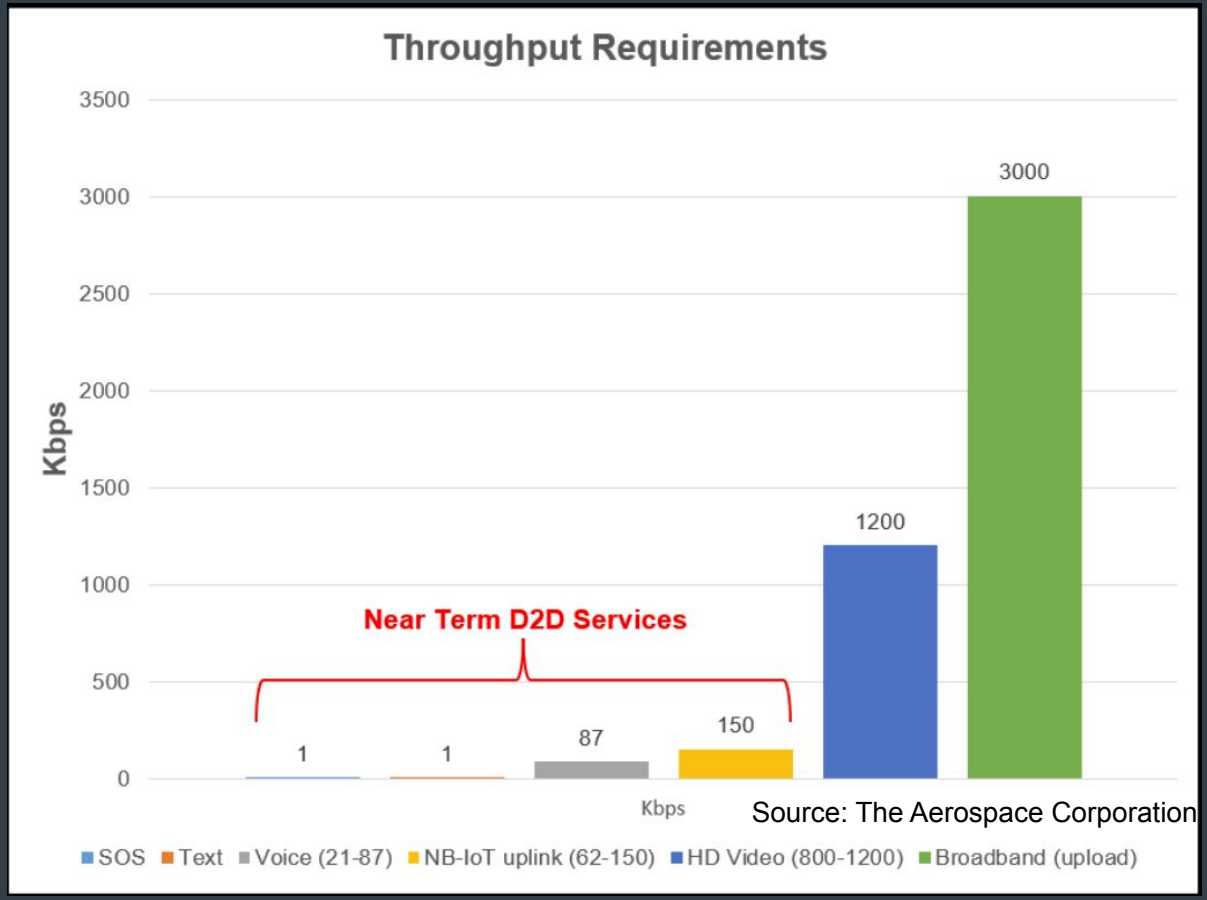
Spectral Efficiency
(bps/Hz)

Bandwidth

Constraint: Multi-satellite MIMO into an omni-directional antenna would require carrier-phase-level alignment between the satellites. *Is this possible*?

Conclusions

D2C will only exceed 3G rates (~3 Mbps) under special circumstances, but will nonetheless be revolutionary.



Source: The Aerospace Corporation

Much can be done with 3 Mbps!


6G
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UT