A Technical Comparison of Three Low Earth Orbit Satellite Constellation Systems to Provide Global Broadband

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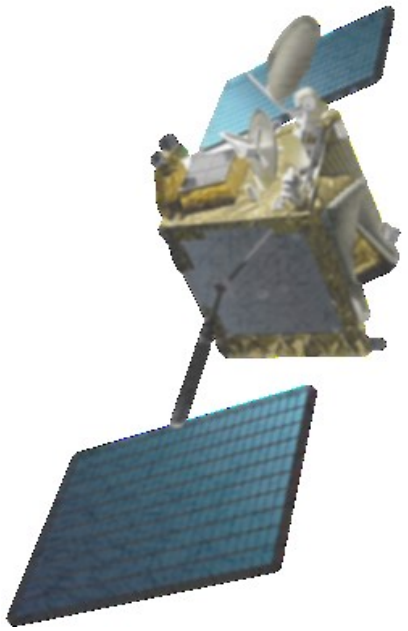
October 1st 2018

69th International Astronautical Congress 2018
Bremen, Germany

IAC-18-B2.1.7



Motivation

- In the last 3 years there has been a new wave of proposals of **LEO mega-constellations to provide broadband**. (11 proposals)
- This paper compares the **technical aspects** of three of these systems as described in their FCC application filings:
  - **OneWeb**, **SpaceX**, and **Telesat**
- Moreover, we analyze **ground segment requirements** and estimate the **total system forward capacity** (sellable capacity) for each of the systems.

Description: OneWeb's Ku&Ka-band System

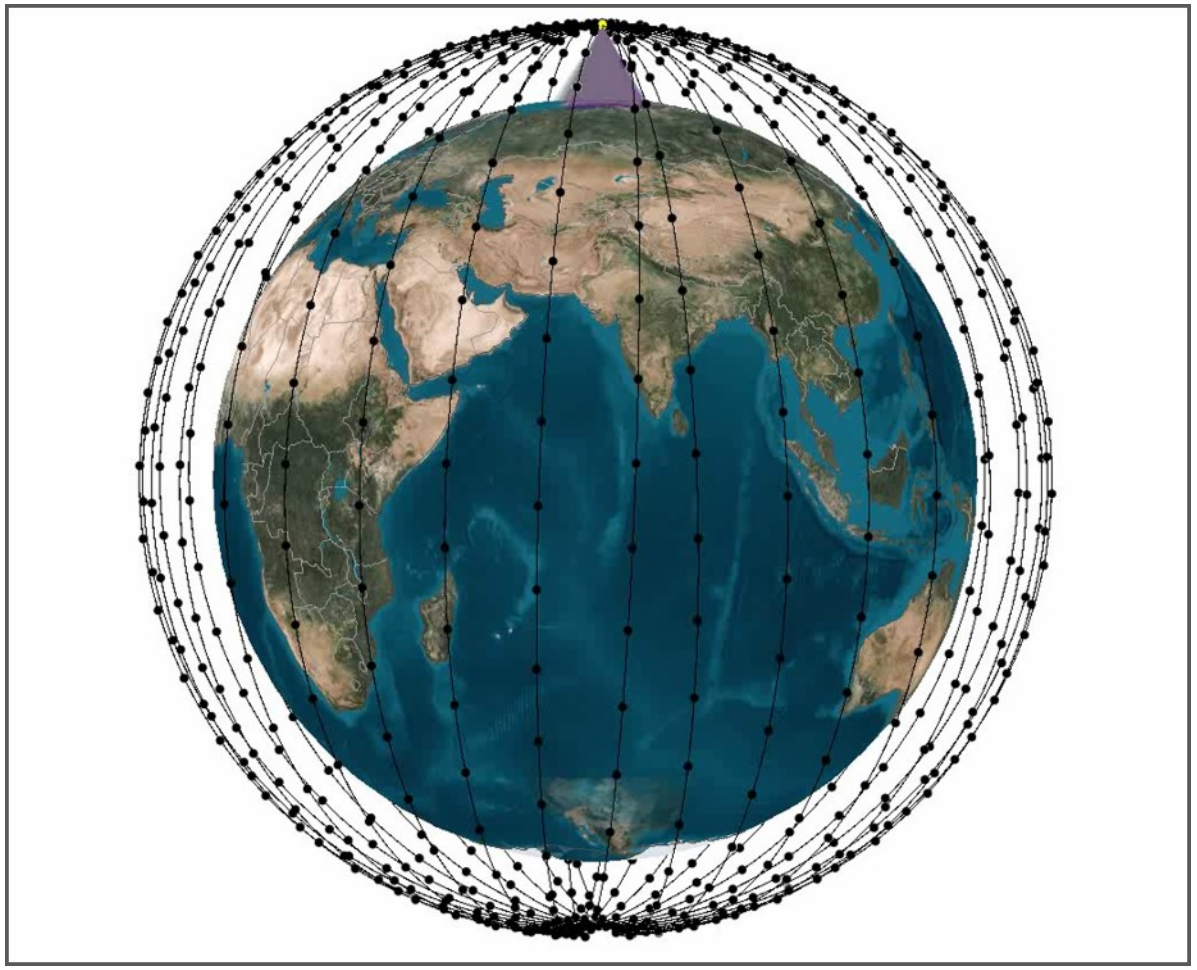


Figure 1.- OneWeb 720 satellites constellation

System characteristics

- 720 satellites in 18 polar planes at 1,200 km @ 86.4º (40 satellites per plane)
- User links @ Ku-band, gateway links @Ka-band
- Bent pipe architecture
- No crosslinks
- Compact satellites 145 kg.
- Target first launch Q4'18, Q1'19 (21 Soyuz rockets)
- Beginning of service 2019

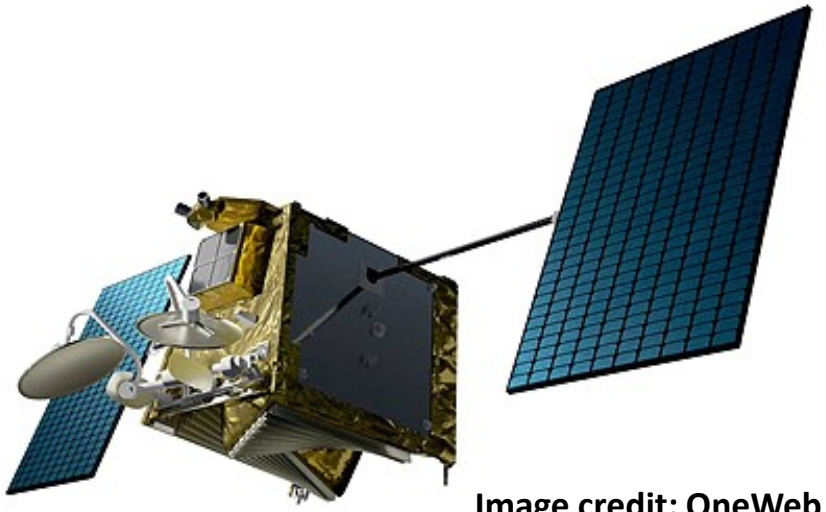


Image credit: OneWeb

Description: SpaceX's Ku&Ka-band System

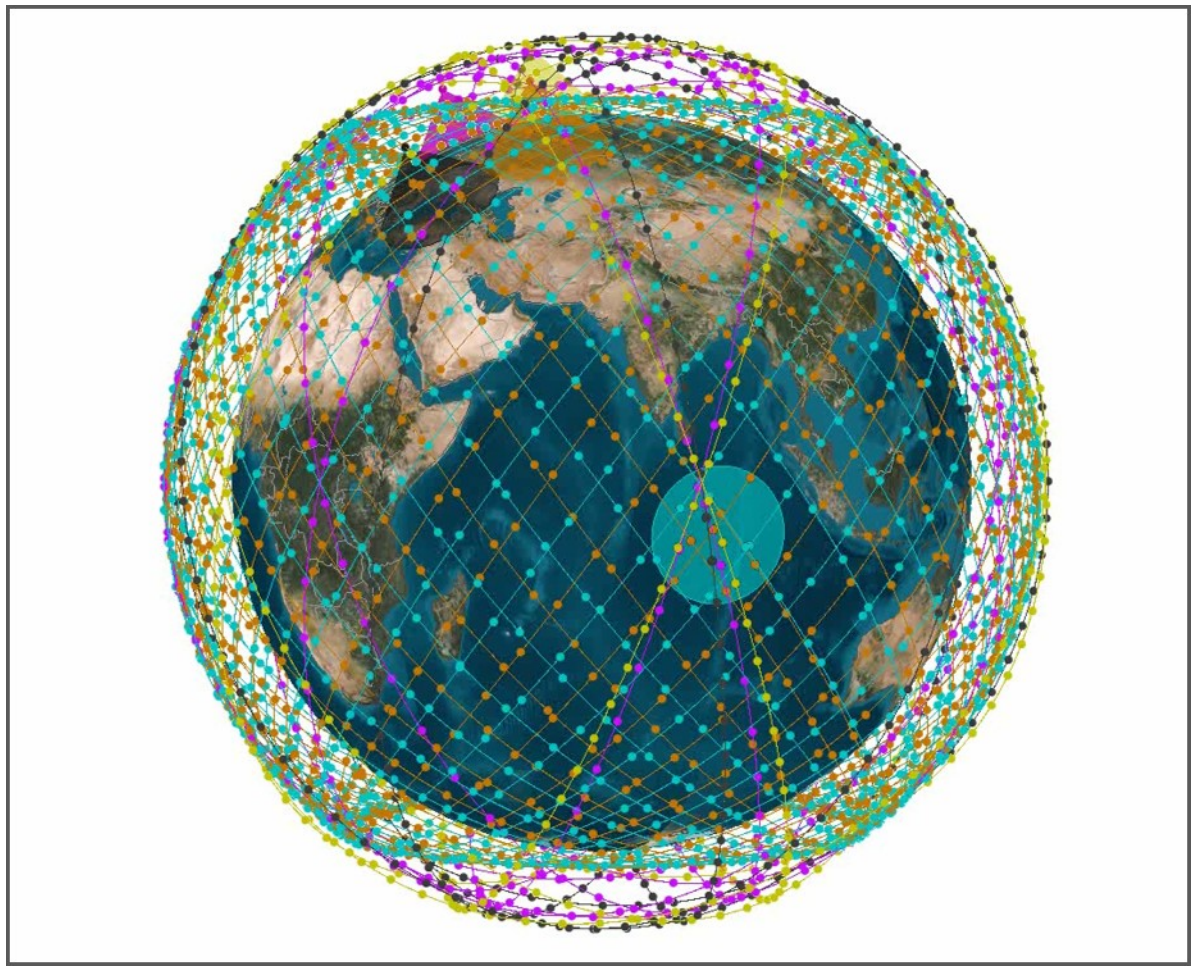


Figure 2.- SpaceX 4,425 satellites constellation

System characteristics

- 4,425 Satellites in 83 planes. Inclined orbits + polar orbits.

- User links @ Ku-band, gateway links @Ka-band
- Optical crosslinks between satellites
- Digital payload with beam steering and shaping capabilities

- Medium size satellites 386 kg, in house designed.
- Target first launch 2019 (~170 Falcon 9 launches for full constellation deployment)
- Beginning of service 2020

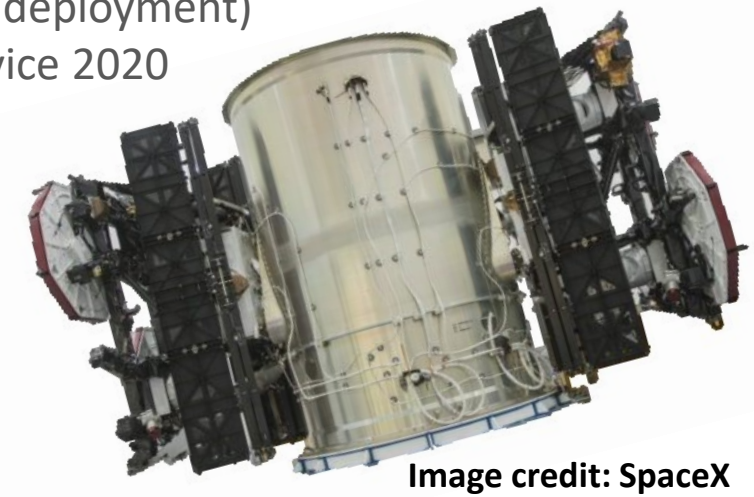


Image credit: SpaceX

Description: Telesat's Ka-band System

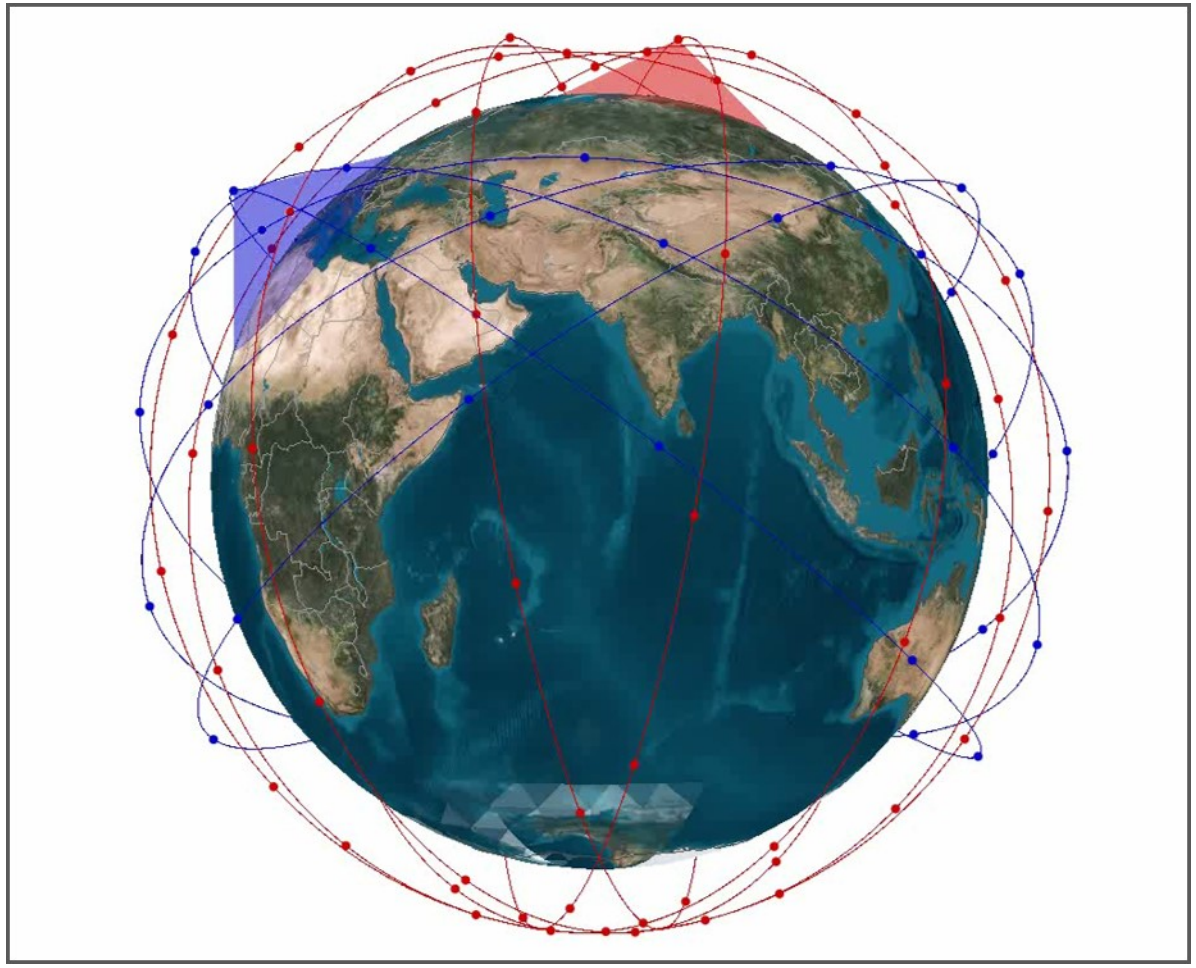
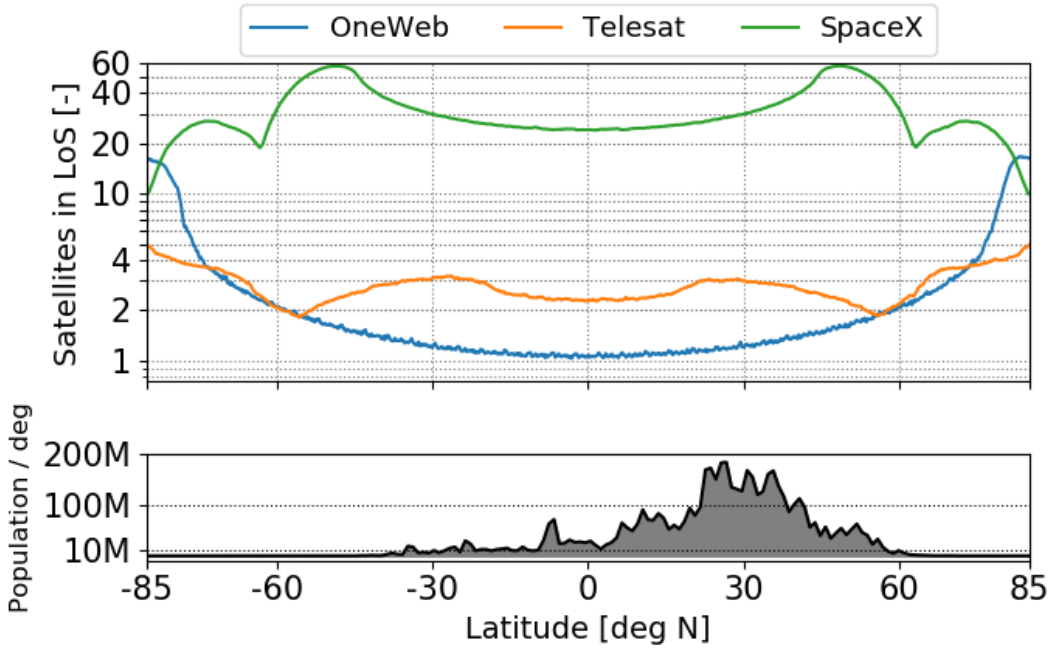


Figure 3.- Telesat 117 satellites constellation

System characteristics

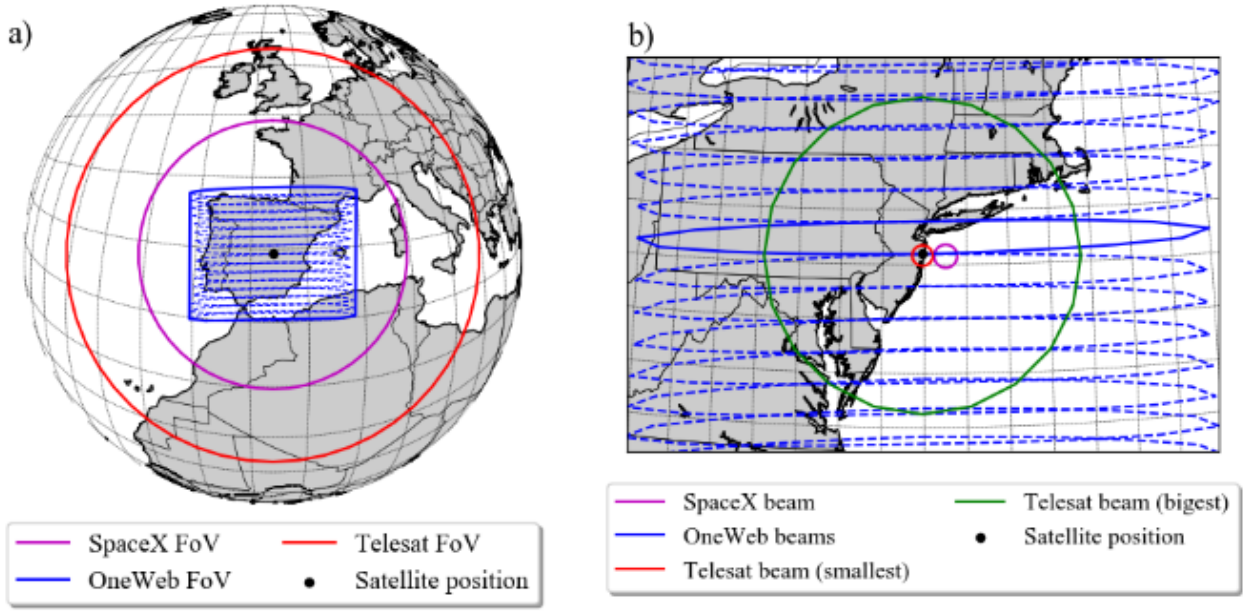
- 117 Satellites in 11 planes:
  - Polar: 6 planes x 12 satellites at 1,000 km @ 99.5º
  - Inclined: 5 planes x 9 satellites at 1,200 km @ 37.4
- User and gateway links @Ka-band
- Optical crosslinks between satellites
- Digital payload:
  - Beamforming: steering and shaping capabilities for at least 16 beams.
  - Demodulation + modulation + IP-Routing
- Launch 2021
- Beginning of service 2022
- External design and manufacturing.

Satellites in line of sight and beam characteristics



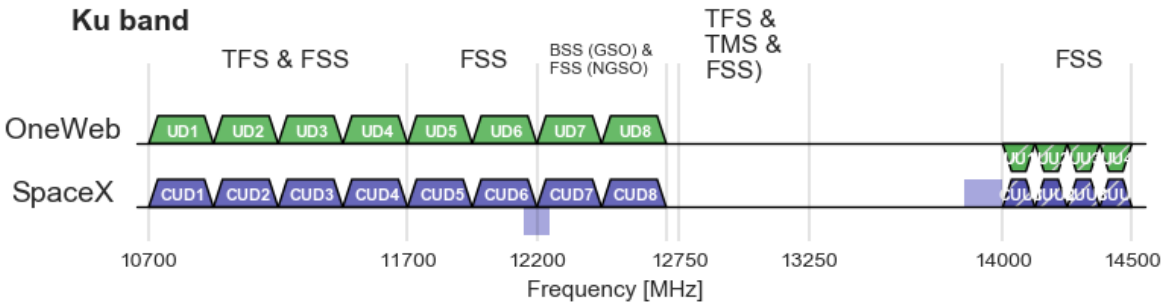
- Great differences in the number of satellites within line of sight for different latitudes between constellations.
- Telesat and SpaceX concentrate their satellites within the ±60 latitude band by using inclined and polar orbits.

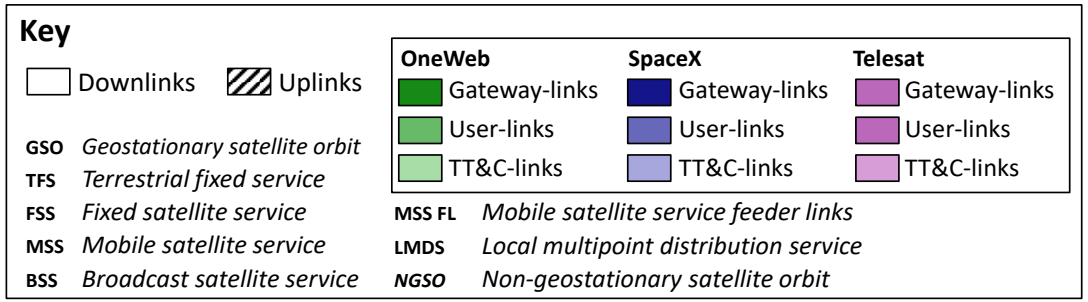
- Significant differences in beam footprint and field-of-view areas.
- SpaceX and Telesat have steerable and shapeable user beams. One web has fixed beams.

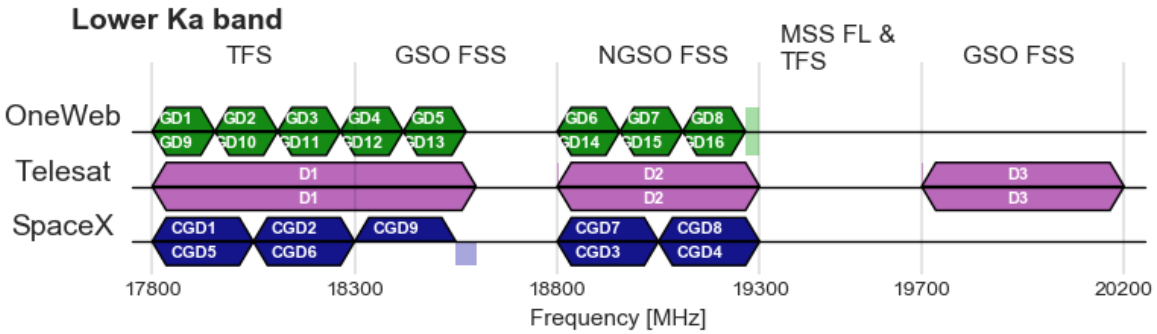


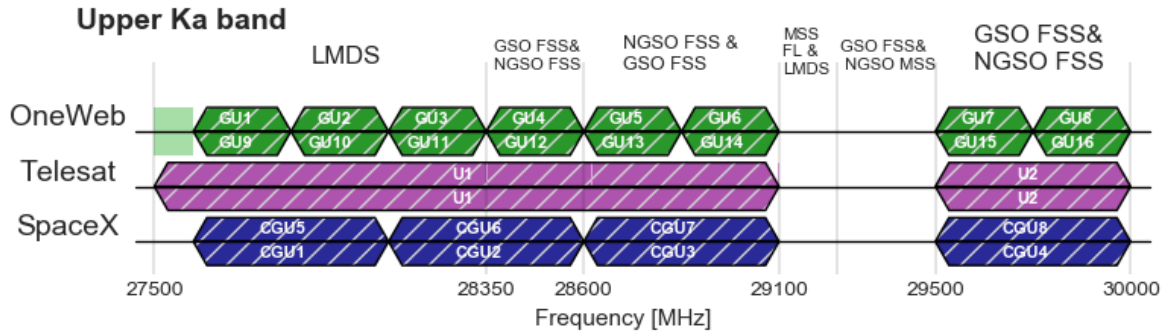
Frequency allocations

- OneWeb and SpaceX use Ku-band for user links. Single polarization, RHCP, and Ka-band for gateway links.
- Telesat shares the Ka-band spectrum between user and gateways links.
- Potential interferences during in-line events between:
  - OneWeb and SpaceX user links.
  - Telesat user links and OneWeb and SpaceX feeder links









Methodology: Model overview

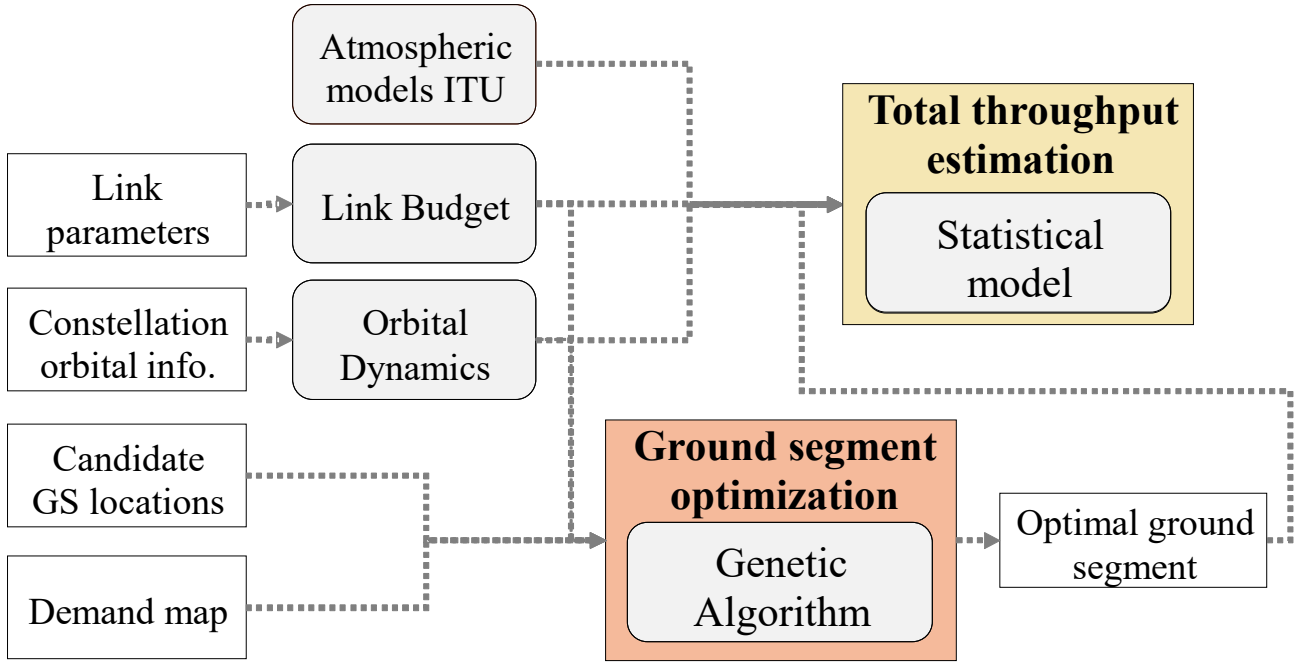
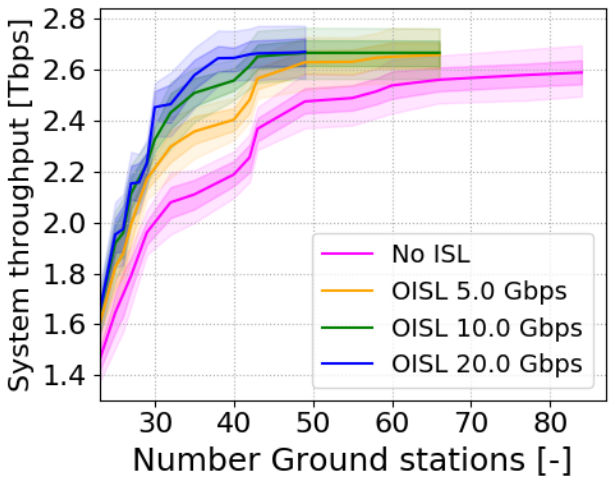


Table 8. Average and maximum potential data-rate per satellite (author's estimation)

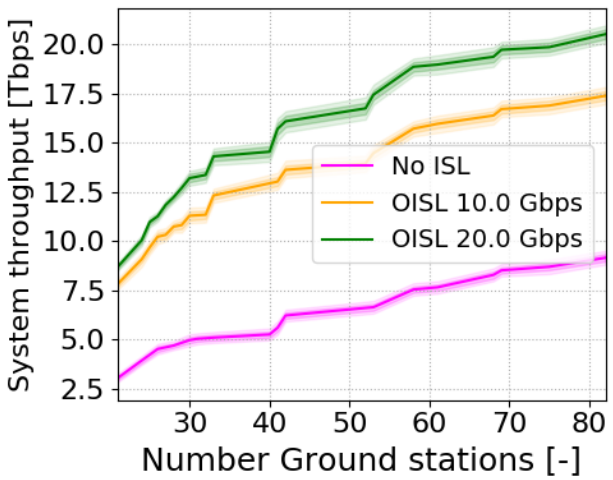
Parameter	*Telesat*	*OneWeb*	*SpaceX*	
Avg. Data-rate	35.65	8.80	20.12	Gbps
Max. Data-rate	38.68	9.97	21.36	Gbps
# Active GW antennas	2	1	1	-
Limiting factor	GW uplink	User downlink	GW uplink	-

Results: Throughput estimation

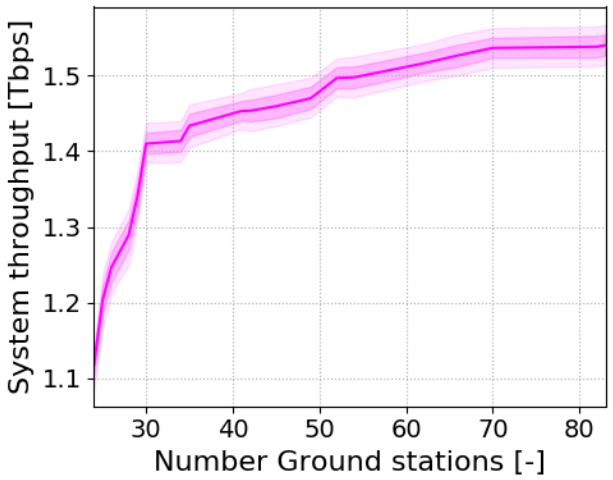
Telesat



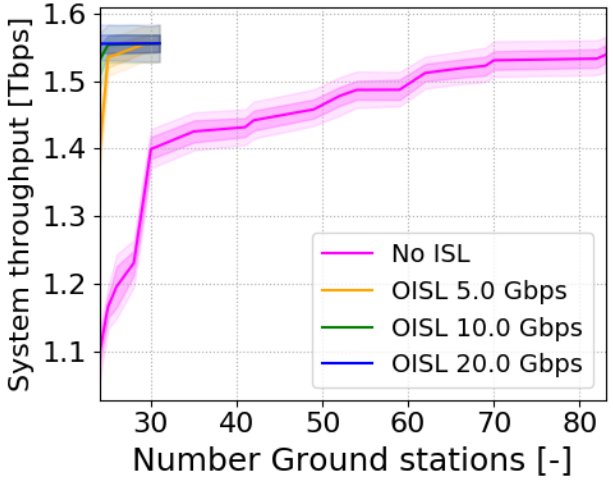
SpaceX



OneWeb



OneWeb + ISL



Telesat:

- Maximum throughput is 2.66 Tbps and 42 ground stations are required to achieve it.

SpaceX:

- Maximum throughput of 23.7 Tbps with > 100 GS.

OneWeb

- Maximum throughput is 1.56 Tbps, and need 71 ground station to achieve it.

Results: Summary of values

Telesat:

- Telesat is the most efficient system in terms of average Gbps/satellite, with more than 4x SpaceX and 10x OneWeb.

SpaceX:

- SpaceX limiting factor will be the ground segment, as they need to deploy a very large number of ground stations and gateways to operate at full power.

OneWeb

- For OneWeb the space segment will be the limiting factor (user links data-rate).

	Telesat	OneWeb	SpaceX	
Num. satellites	117	720	4,425	-
Max. total system FWD capacity	2.66	1.56	23.7	Tbps
Number of ground locations for max. FWD capacity	42	71	123	-
Number of gateway antennas for max FWD capacity	221	725	~3,500	-
Required number of gateways per ground station	5-6	11	30	-
Average data-rate per satellite (real)	22.74	2.17	5.36	Gbps
Max. data-rate per satellite	38.68	9.97	21.36	Gbps
Satellite efficiency	58.8	21.7	25.1	%

Conclusions

- Estimated maximum system throughputs in the forward direction:
  - OneWeb's 1.56 Tbps with 71 ground stations (720 satellites)
  - Telesat 2.66 Tbps with 40 ground stations (117 satellites)
  - SpaceX 23.7 Tbps with 123 ground stations (4,425 satellites)
- The most effective system in terms of Gbps/satellite is Telesat (22.7 Gbps/sat), thanks to:
  - Low number of high capacity satellites, low elevation angles to user links, use of ISL and digital payloads, and use of two active gateway antennas.
- SpaceX constellation will require an extremely large ground segment with hundreds of ground stations and ~3,500 gateway antennas to operate at maximum throughput.
- OneWeb's constellation could significantly reduce their ground segment if they had used inter-satellite links (even at moderate data-rates ~5 Gbps).

THANK YOU!

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