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A Sky Full of Satellites

The changing orbital population and the impact of satellite constellations on astronomy

Jonathan McDowell

2023 Jan 31

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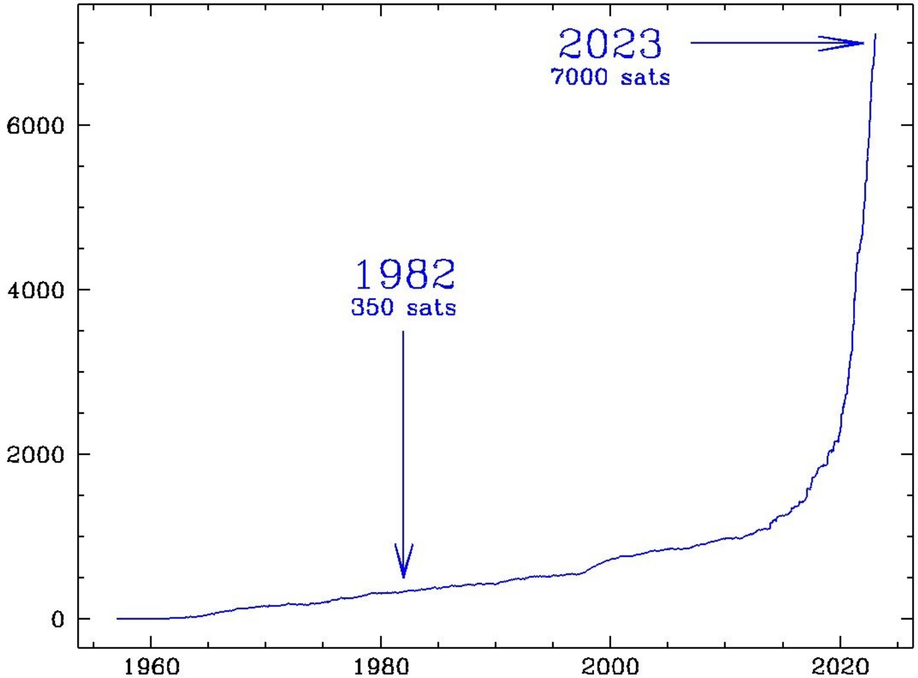
HM Astronomer Royal Sir Francis Graham Smith, 1982:

"the cumulative effect of an increasing number of long-lived satellites represents a very serious hazard [to optical observations]"
[Adv.Sp.Res. v2.n3.p7, 1982]



ACTIVE SATELLITES
1957-2023

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Plan of talk

1. INTRODUCTION
2. SATELLITE DEMOGRAPHICS
3. SIMULATIONS
4. MONITORING
5. MITIGATION
6. RESPONSE

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1. INTRODUCTION

In which we notice a problem...

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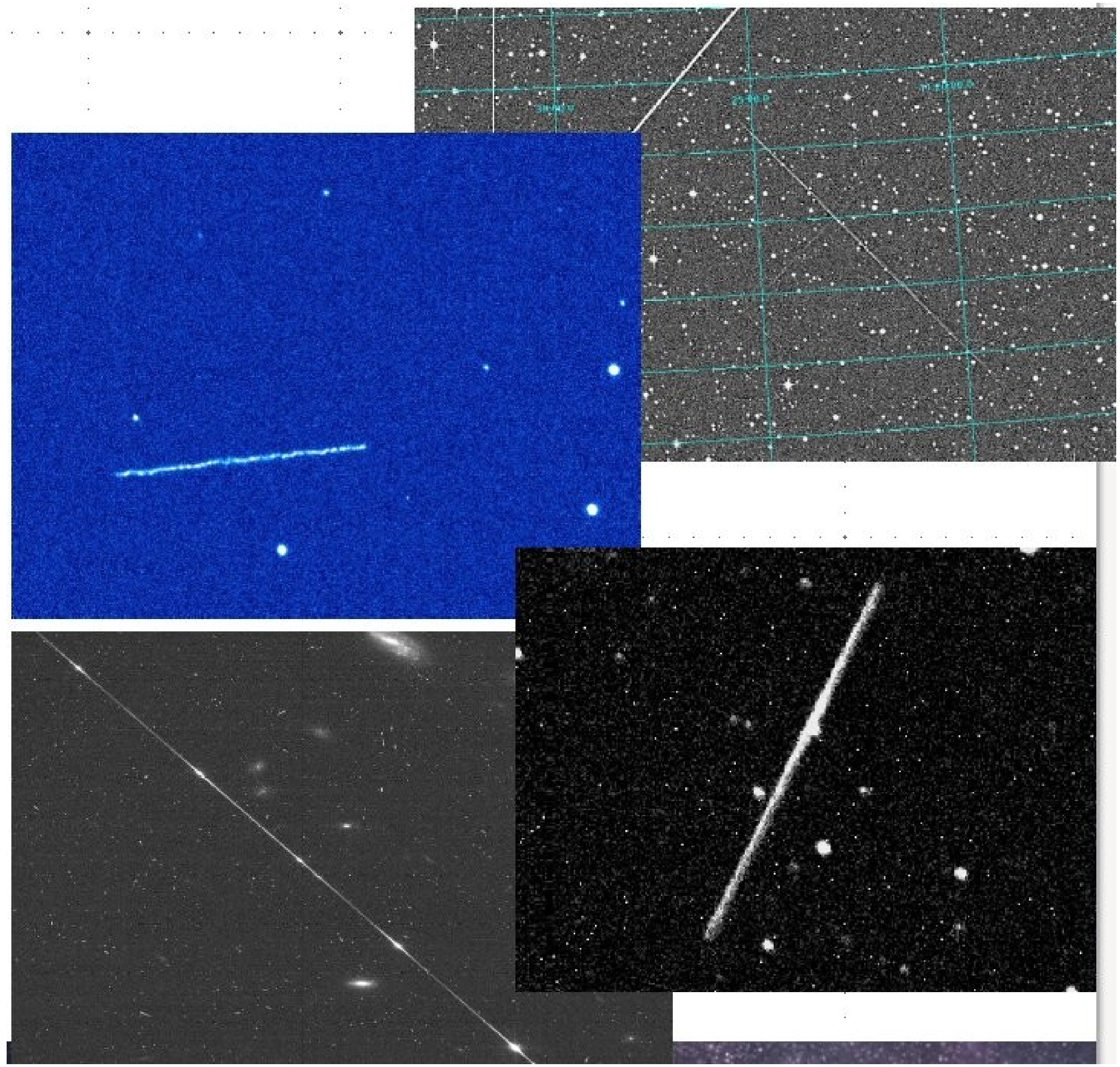
More and more frequently our astronomical images are marred by satellite streaks

These streaks vary in intensity and morphology With the increasing industrialization of low earth orbit (LEO) we may soon reach the limit of N >> 1 streaks per wide field ground based optical exposure which will be hard to handle in automated processing



Images via R. Seaman, M. Rawls

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------ DISCLAIMER -----

This talk will cover optical astronomy only

There is also a very big threat to radio astronomy

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------ DISCLAIMER -----

This talk will cover optical astronomy only

There is also a very big threat to radio astronomy

Which I will completely fail to address due to lack of time and lack of relevant expertise

(Ashley Zauderer-Vanderley at NSF and Harvey Liszt at NRAO are among those leading the defense of astronomy in the radio band)

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May 2019, first Starlink launch:
Astronomers see a train of satellites across the sky as bright as the familiar constellations.
What happens when there are 100,000 of these?

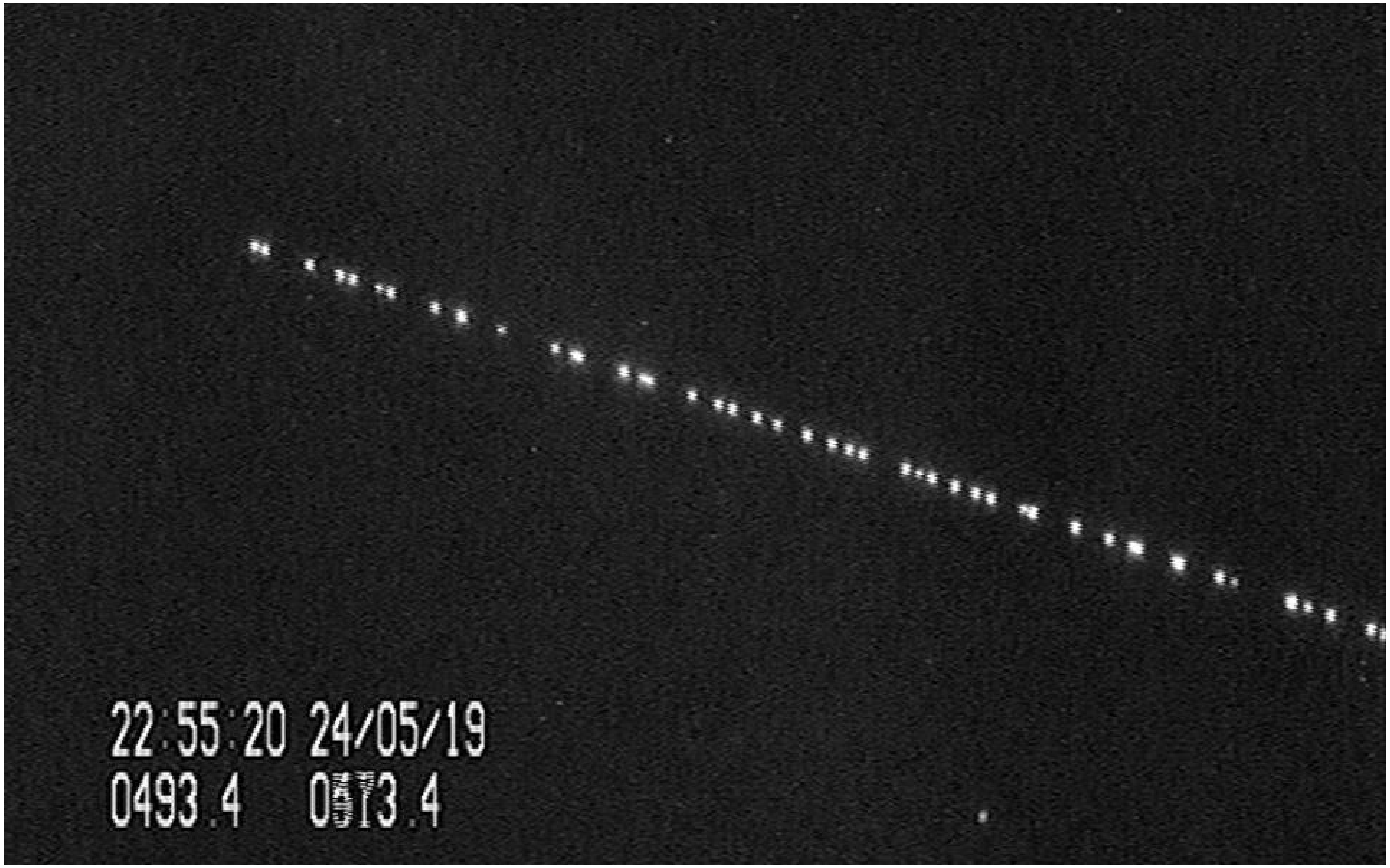

Image:
Marco Langbroek

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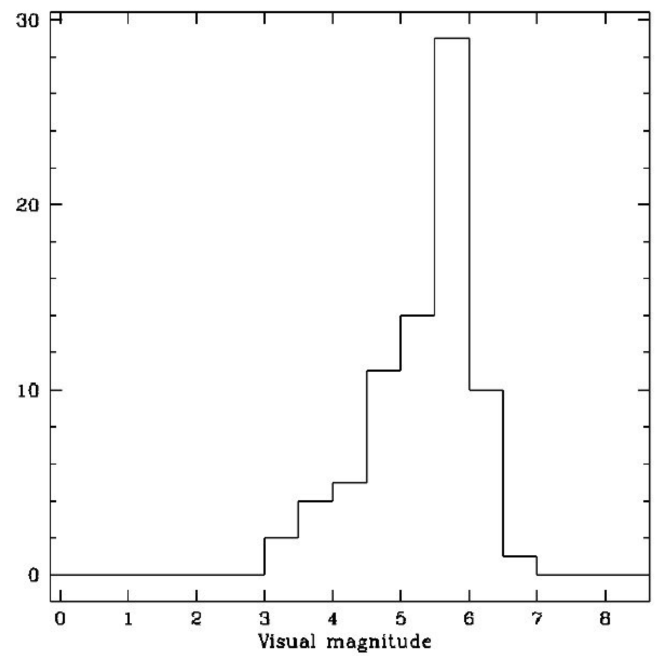

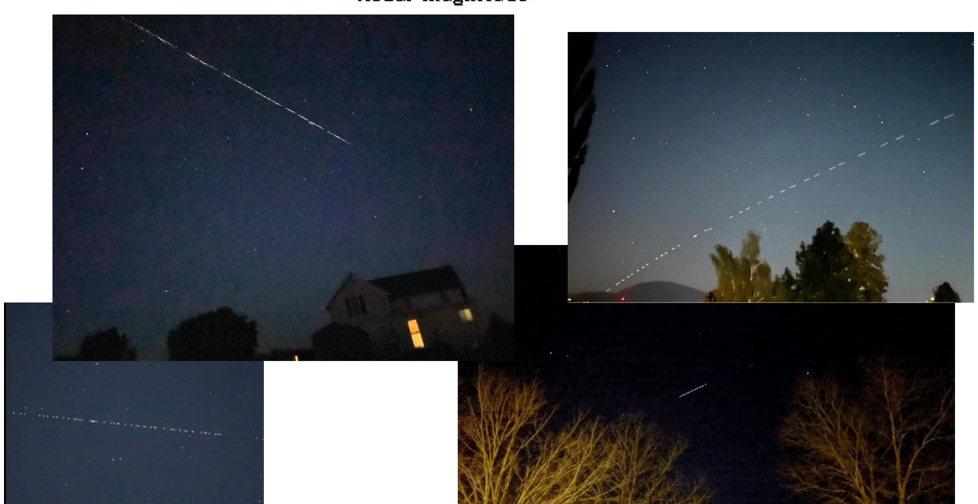

Satellite hobbyists measured the brightness of the first 60 Starlinks in their operational 550 km orbits during summer 2019.

Usually they were mag 5 to 6: just visible to naked eye from dark site – but sometimes much brighter

Figure: McDowell (2020)

During early flight/deployment phases, see train of 60 at mag 2 or brighter

(Images: Adrienne Hope, Riley Christie, Vicky Reynolds via wire services)

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- Satellites became fainter once they switched to operational orientation
- Fainter still once orbit was raised to 550 km operational altitude
- Current Starlinks even fainter once visors were added
- Still naked-eye in dark skies for part of the time

BUT

- This very first observation made it clear that it is TECHNICALLY POSSIBLE to launch a bright naked eye constellation that would outnumber the visible stars

- Change the night sky for everyone? Everyone in the world, including non-spacefaring nations that may not have paid attention but have cultural connections to the night sky....

- Next generation Starlinks will include some in a lower operational orbit and will be much bigger. Not clear yet how bright they will be.

- Nothing to stop some other country licensing a very bright LEO megaconstellation

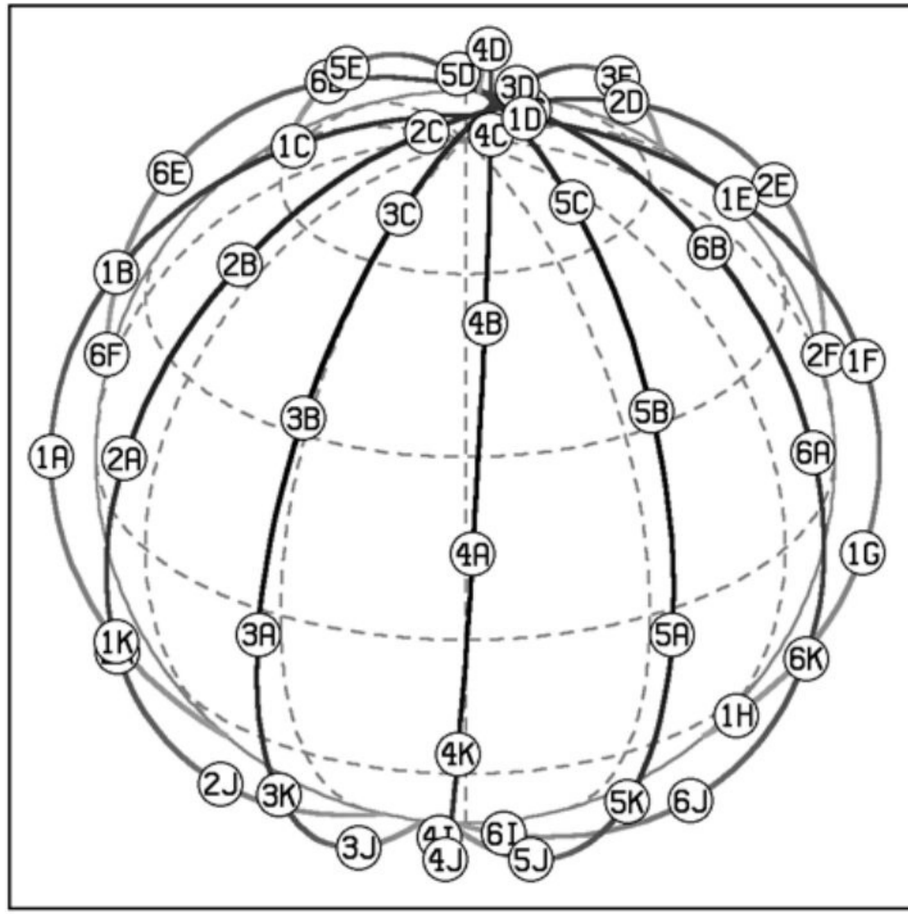
Constellation Shells:

Circular orbit at given height and inclination

Multiple orbital planes spaced in longitude around the Earth

Multiple satellites spaced around the orbit

Repeat for different heights and inclinations!



Iridium constellation, from Kidder and Vonder Haar 1995 (inclination 86 deg)

Existing large, but not “mega”, LEO constellations (50-500 sats):

Cold war constellations: a few working at a time, but dead ones left in orbit

Strela-1M	360 in orbit, 0 working
Strela-3/Gonets	185 in orbit, 51 working
Parus	143 in orbit, 4? working

Modern constellations: many working simultaneously, old ones actively deorbited or placed in short lifetime orbits

Orbcomm	58 in orbit, 31 working
Iridium	106 in orbit, 75 still working
Globalstar	85 in orbit, 31 still working
Planet Doves	279 in orbit, 198 still working
Spire Lemur	117 in orbit, 58? still working

Image: SpaceX

A new era in space utilization has arrived: the `megaconstellations'.

As of Jan 31: 3822 SpaceX Starlink satellites and 544 OneWeb satellites have been launched.

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Constellations we expected based on mid-2022 FCC and ITU filings:

Starlink Generation 1/2:	34408 satellites at 328 to 614 km
OneWeb:	6372 satellites at 1200 km
Amazon Kuiper:	7774 satellites at 590-630 km
Guangwang	13000 satellites at 590-1145 km
Boeing V-band	5921 satellites at 380-700 km
E-Space (US/Rwanda)	337,323 satellites at 530-630 km !!

and others totalling over 430,000 satellites planned

"Megaconstellations" (well, really only myriaconstellations... nevertheless unprecedented)

Starlinks currently V ~ 5 to 7
OneWeb sats are smaller and higher than Starlink – V ~ 8 -- 9 or so:
too faint to see with naked eye but glaringly bright by astronomical detector standards.

Following bankruptcy and reorganization last year, OneWeb has reduced its original proposal from 48000 to only 6372 satellites (factor 7.5 reduction)

Major proposed constellations as of Oct 2021 – more since

Constellations made up of shells defined by:
  altitude,
  inclination,
  number of planes,
  number of satellites per plane:

MODEL III-B: Starlink Constellation, Modified Gen 2 Config 1 (Aug 2021 Filing, 30000 satellites)

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
		(km)	(deg)			
A	1	340	53.0	48	110	5280
A	2	345	46.0	48	110	5280
A	3	350	38.0	48	110	5280
A	4	360	96.9	30	120	3600
B	5	525	53.0	28	120	3360
B	6	530	43.0	28	120	3360
B	7	535	33.0	28	120	3360
C	8	604	148.0	12	12	144
C	9	614	115.7	18	18	324

MODEL V: (KP1) Kuiper Constellation (2019 filing, 3236 satellites)

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
		(km)	(deg)			
A	1	630	51.9	34	34	1156
B	2	610	42.0	36	36	1296
C	3	590	33.0	28	28	784

MODEL VI: (OW2R) OneWeb Constellation (2021 revision, 6372 satellites)

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
		(km)	(deg)			
A	1	1200	87.9	36	49	1764
B	2	1200	40.0	32	72	2304
C	3	1200	55.0	32	72	2304

MODEL VII: (GW) Chinese Guangwang Constellation (2021 revision, 12992 satellites)

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
		(km)	(deg)			
A	1	590	85.0	16	30	480
A	2	600	50.0	40	50	2000
A	3	508	55.0	60	60	3600
B	4	1145	30.0	48	36	1728
B	5	1145	40.0	48	36	1728
B	6	1145	50.0	48	36	1728
B	7	1145	60.0	48	36	1728

MODEL III-B: Starlink Constellation, Modified Gen 2 Config 1 (Aug 2021 Filing, 30000 satellites)

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
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A	4	360	96.9	30	120	3600

Major proposed
constellations as of

A	2	345	46.0	48	110	5280
A	3	350	38.0	48	110	5280

Constellations made

SG2 Layer 3:
350 km, 38.0 deg inclination
48 planes with 110 satellites per plane ==> 5280 sats

MODEL VII: (GW) Chinese Guangwang Constellation (2021 revision, 12992 satellites)

satellites per plane:

Layer	Element	Altitude	Inclination	No of planes	Sats per plane	Total sats
		(km)	(deg)			
A	1	590	85.0	16	30	480
A	2	600	50.0	40	50	2000
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B	4	1145	30.0	48	36	1728
B	5	1145	40.0	48	36	1728
B	6	1145	50.0	48	36	1728
B	7	1145	60.0	48	36	1728

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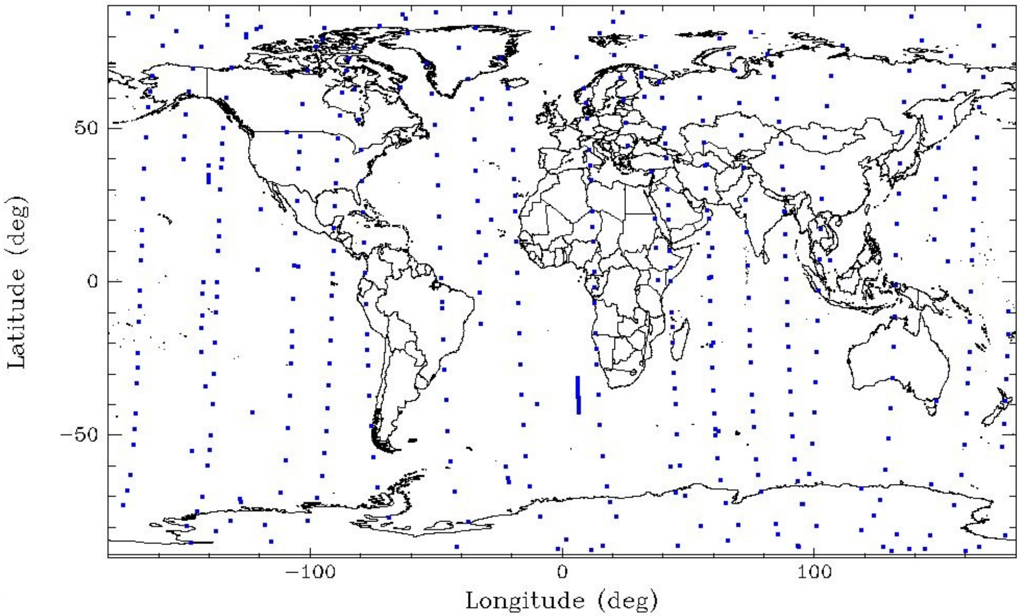
OneWeb
2022 Oct 24 at 0h GMT
426 in orbit



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New entrants every few months:

Yinhe Hangtian – Six Yinhe-2 test sats launched Mar 2022
E-Space - Three test sats launched May 2022
Boeing - Sherpa LTC2/Varuna, test sat launched Sep 2022
AST Space Mobile - BlueWalker-3, test sat launched Sep 2022
ISS Reshetnev - Skif-D, test sat launched Oct 2022

BlueWalker-3
V ~ 2 in some orientations

2. SATELLITE DEMOGRAPHICS

In which we quantify the recent population explosion in low Earth orbit

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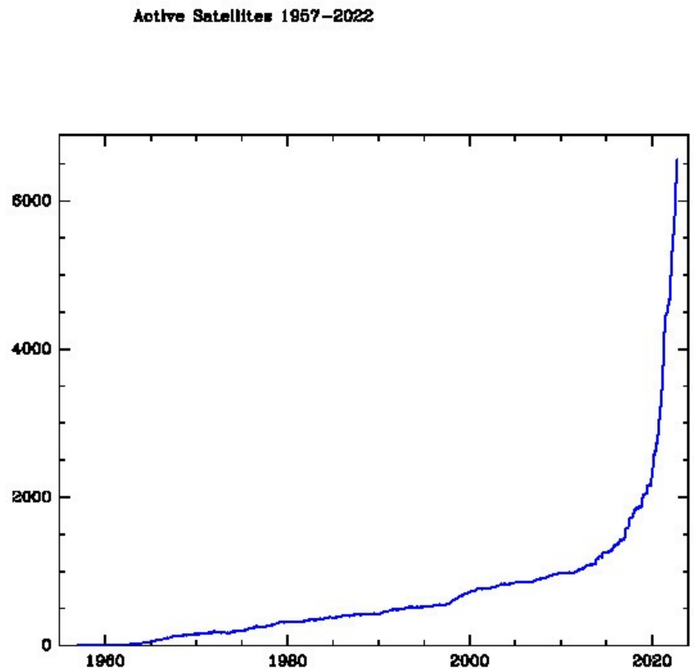

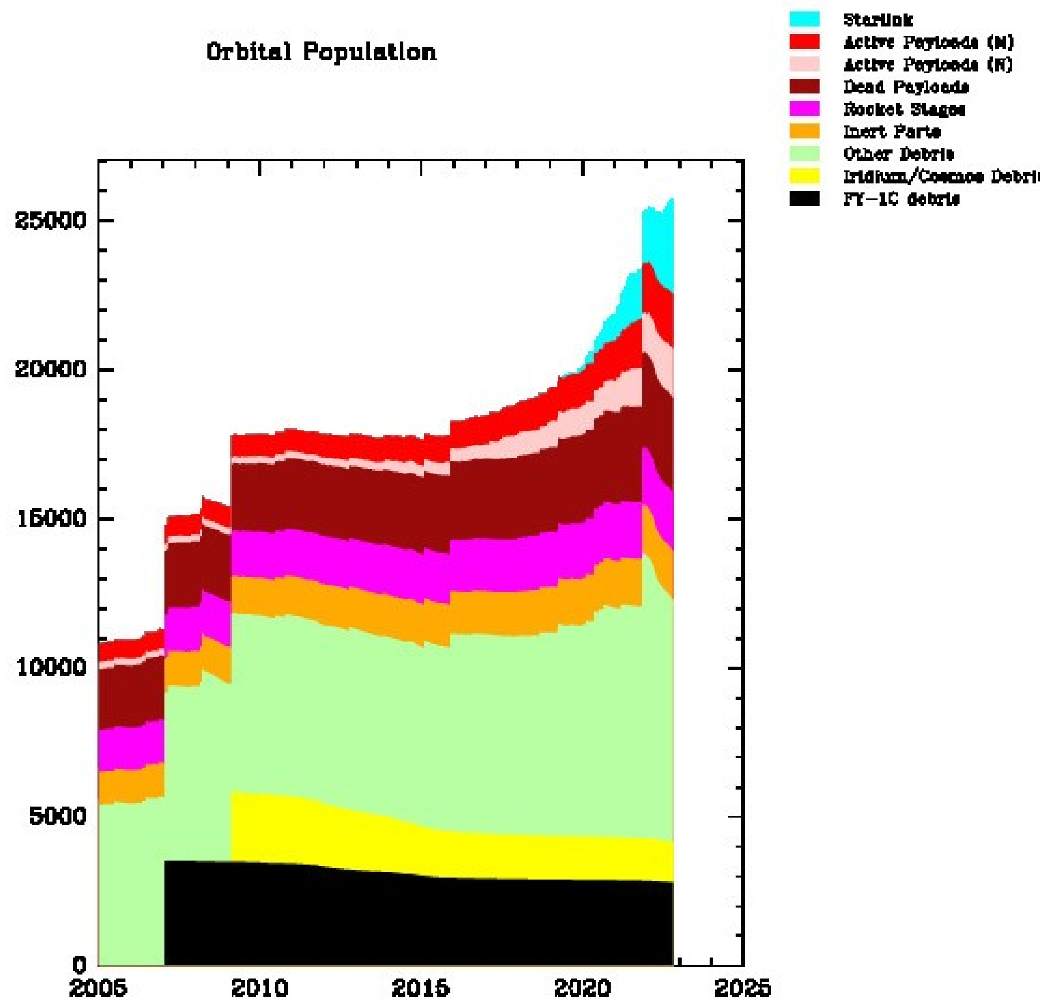

Unprecedented rise in number of active satellites in past few years

Tracked orbital debris population stable since 2010
~25000 objects tracked (> 10cm)
1 million estimated: 1- 10 cm
0.1-1 billion above 1 mm?

Data: General Catalog of Space Objects (McDowell, 2023)
planet4589.org/space/gcat

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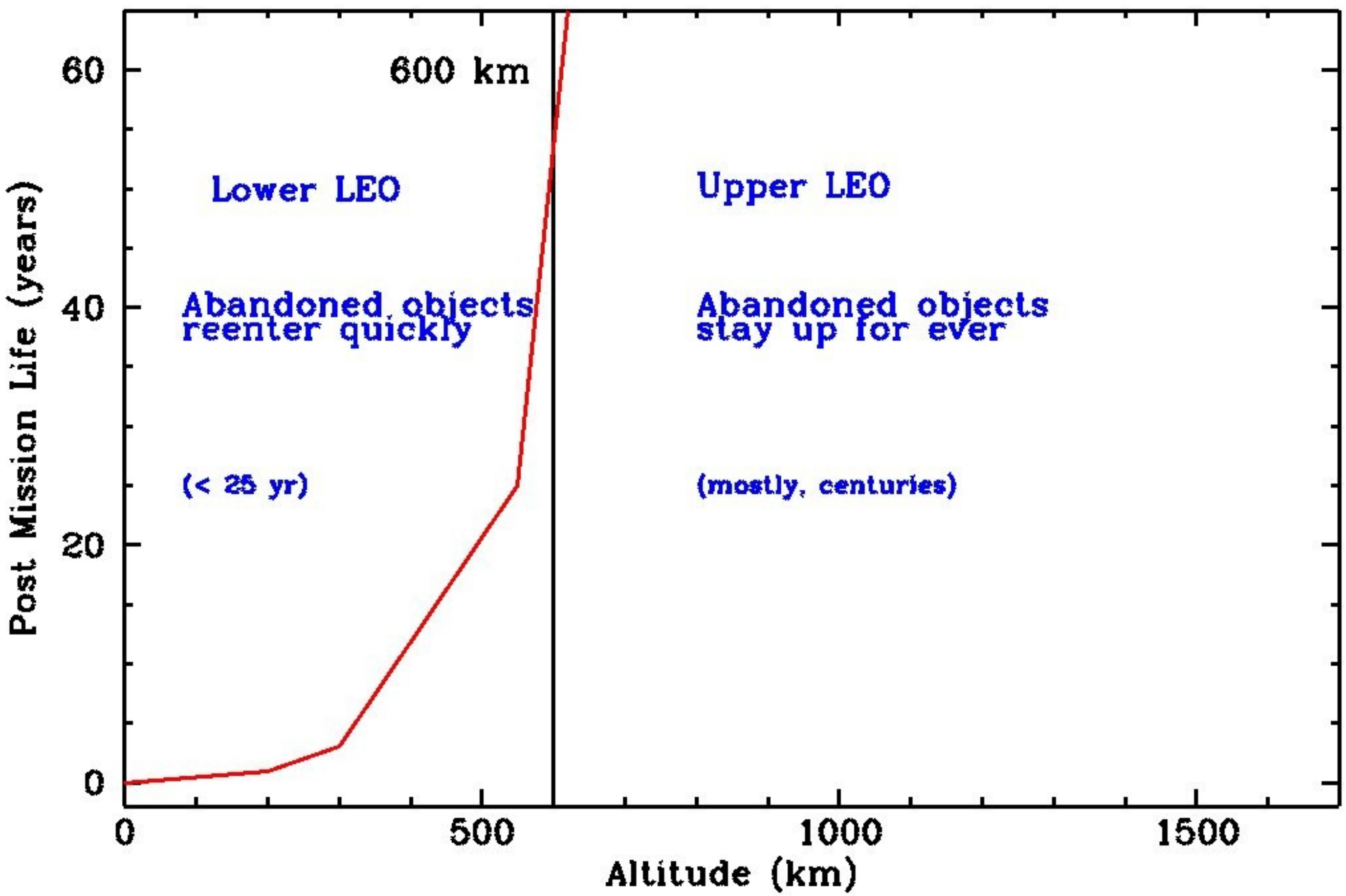
Low Earth Orbit (LEO) orbit life



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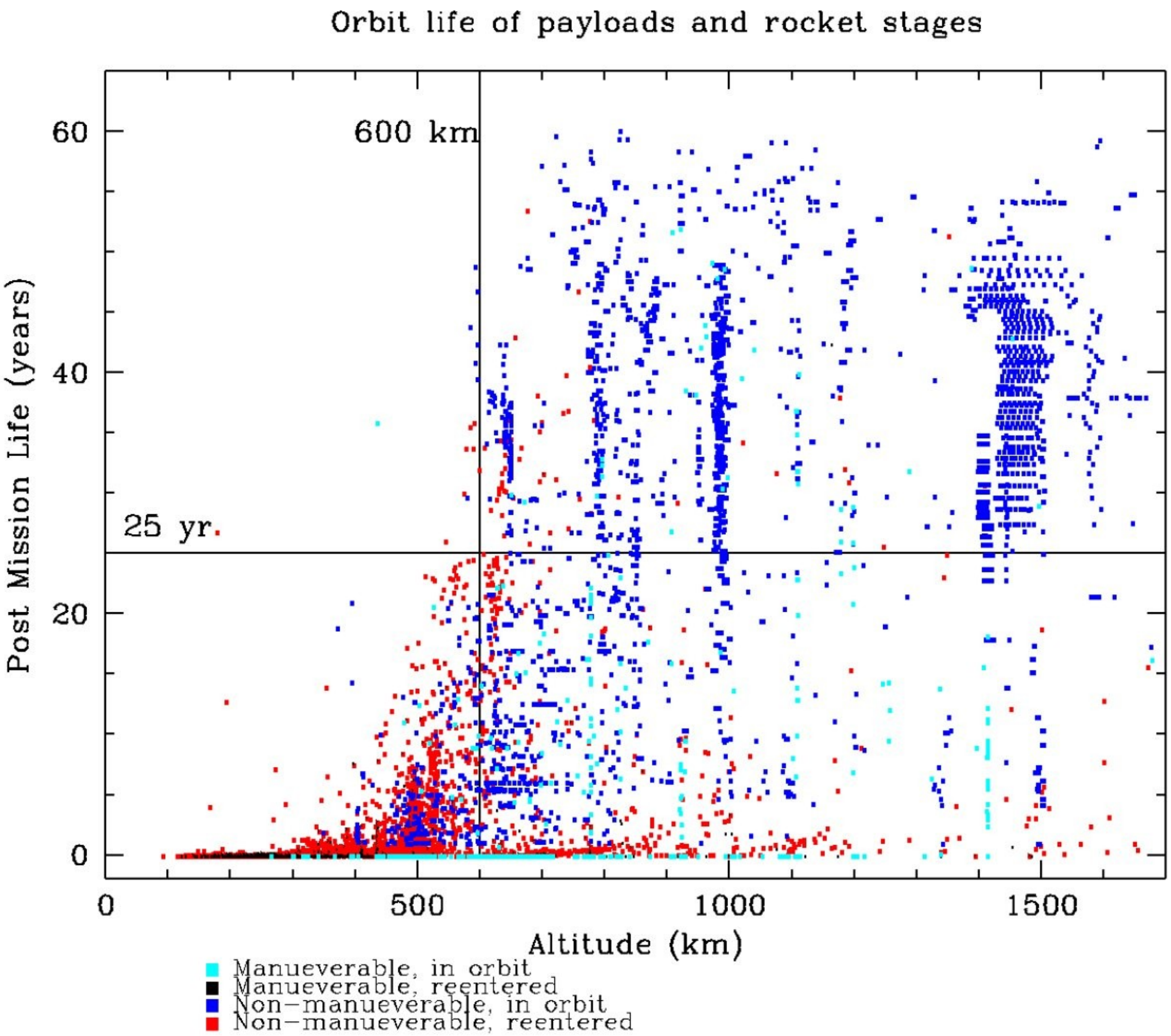


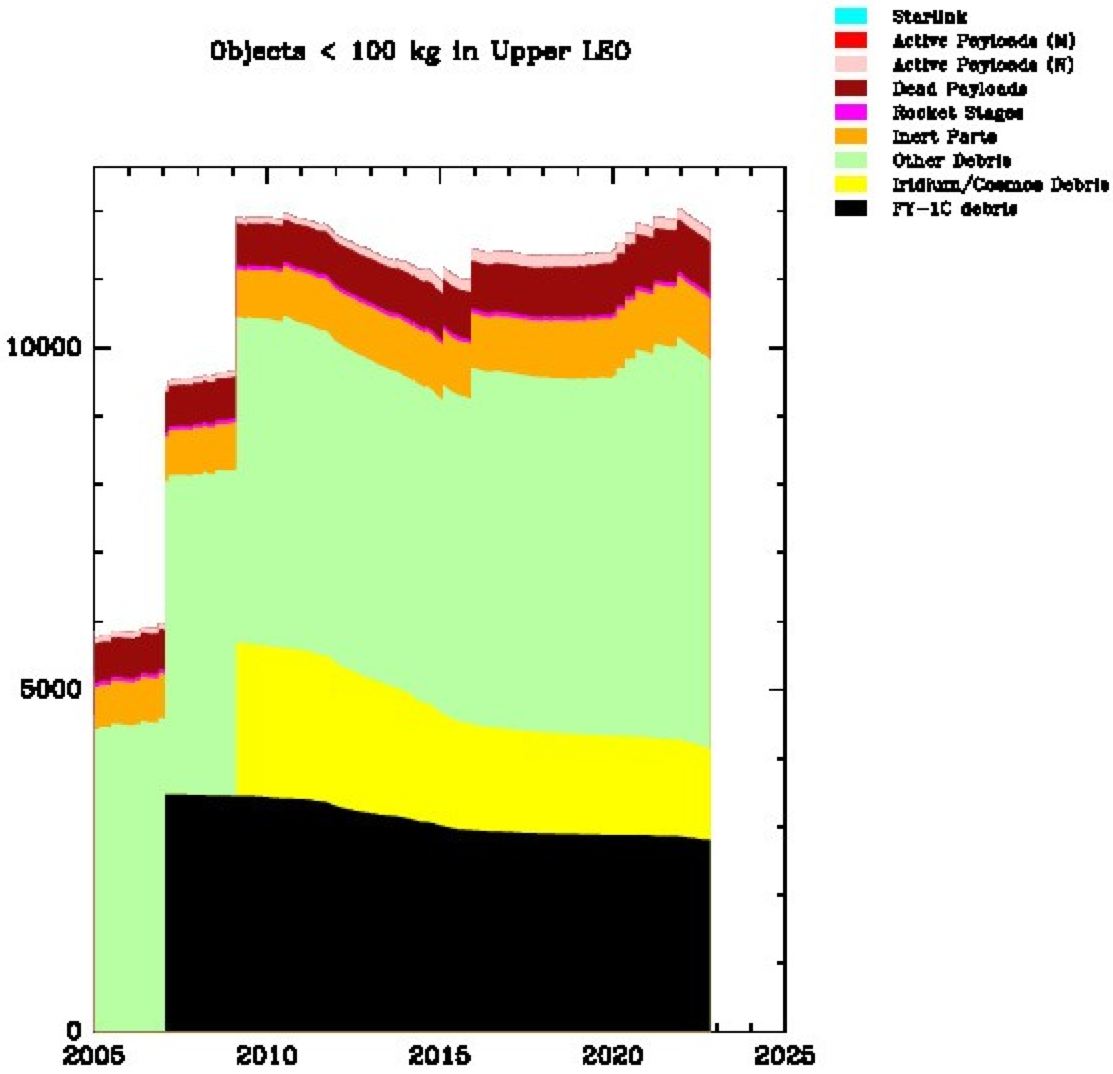
Red: reentered
Blue: lower limits

The density of the atmosphere drops off really quickly with altitude.

As a result, orbital lifetime (against natural decay) changes rapidly with height.

This is especially true in the 500-600 km region where lifetimes rise from ~years to centuries.

I pick 600 km as a working boundary between lower and upper LEO.



Following the large 2007 and 2009 debris events, the (tracked) small debris population in upper LEO is almost steady state over the past 10 years.

Dominated by debris from satellite collisions, ASAT tests and by rocket stage breakups caused by ignition of residual propellants (often years after launch).

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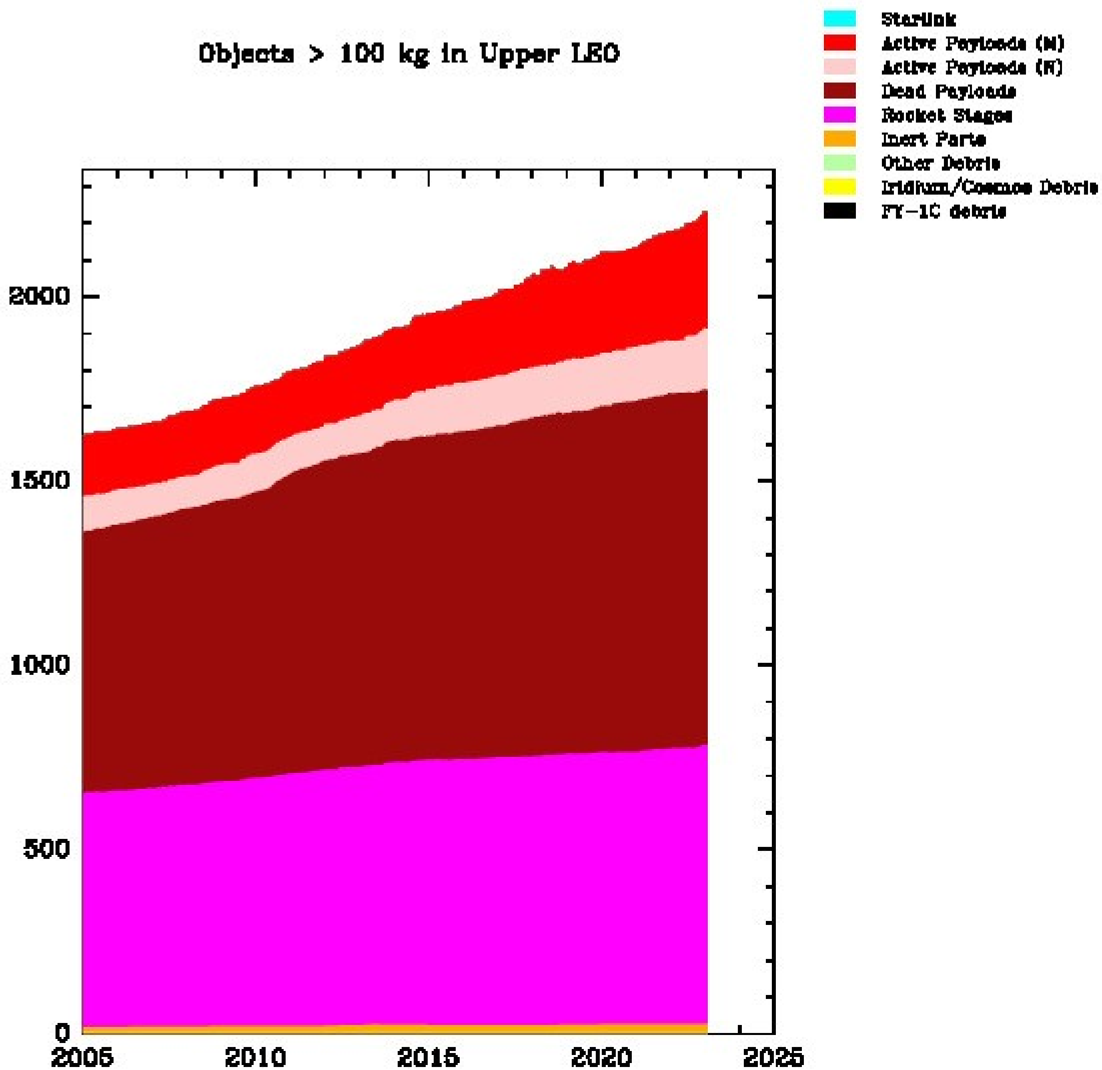

In contrast to the situation in lower (<600 km) LEO, the population is evolving only slowly in upper (>600 km) LEO. (This will change if OneWeb is deployed).

Current population of large objects: about 2000, mostly dead payloads and discarded rocket stages. **Not** currently dominated by active satellites.

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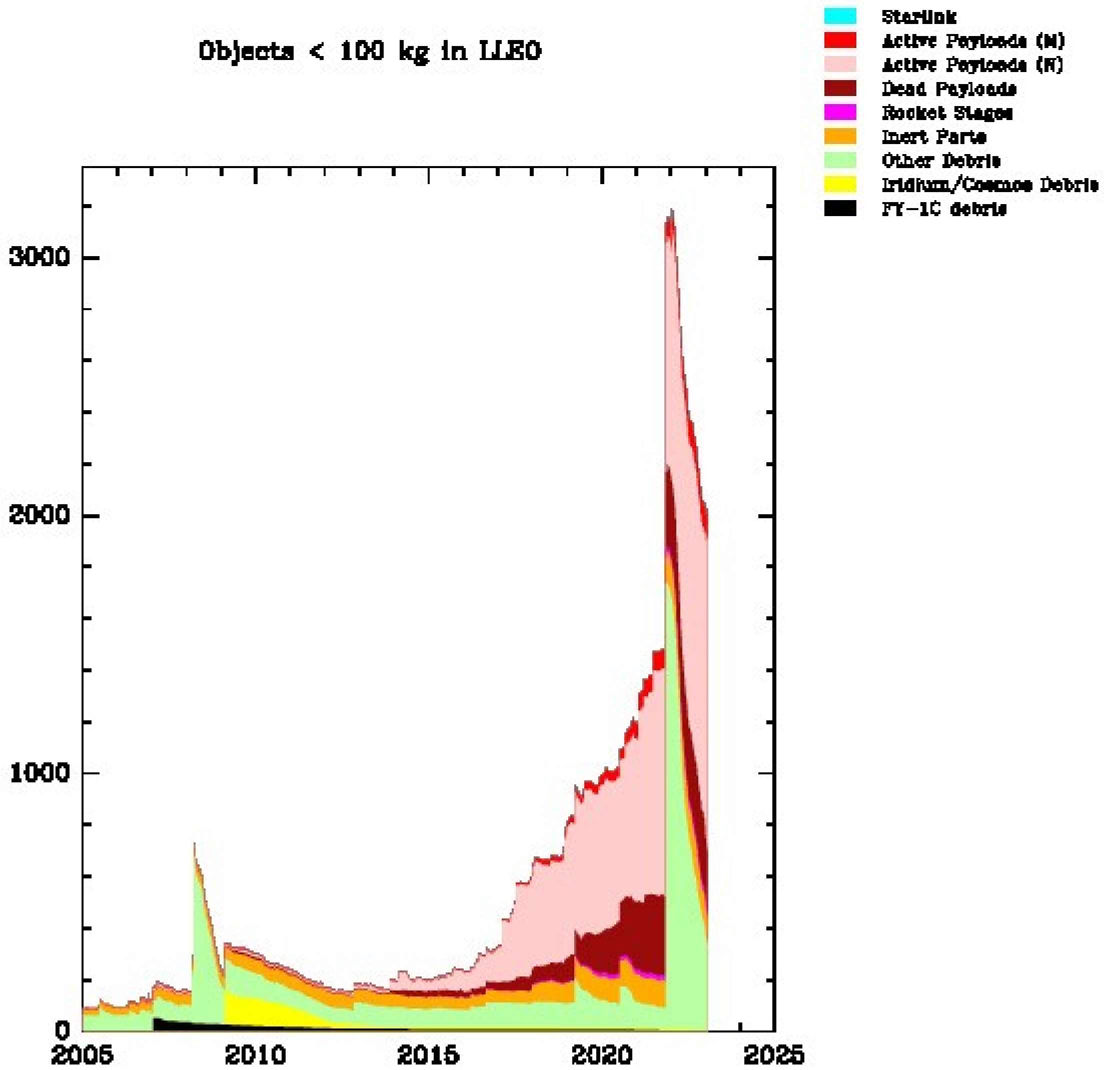

Population of tracked SMALL, LOW objects (<100 kg, < 600 km) has also changed in past 5 years: the cubesat revolution

Tracked population was debris-dominated: now dominated by active (but not manueverable) payloads.

The green spike in 2021-2022 is debris from the Russian ASAT, already many of these debris have reentered

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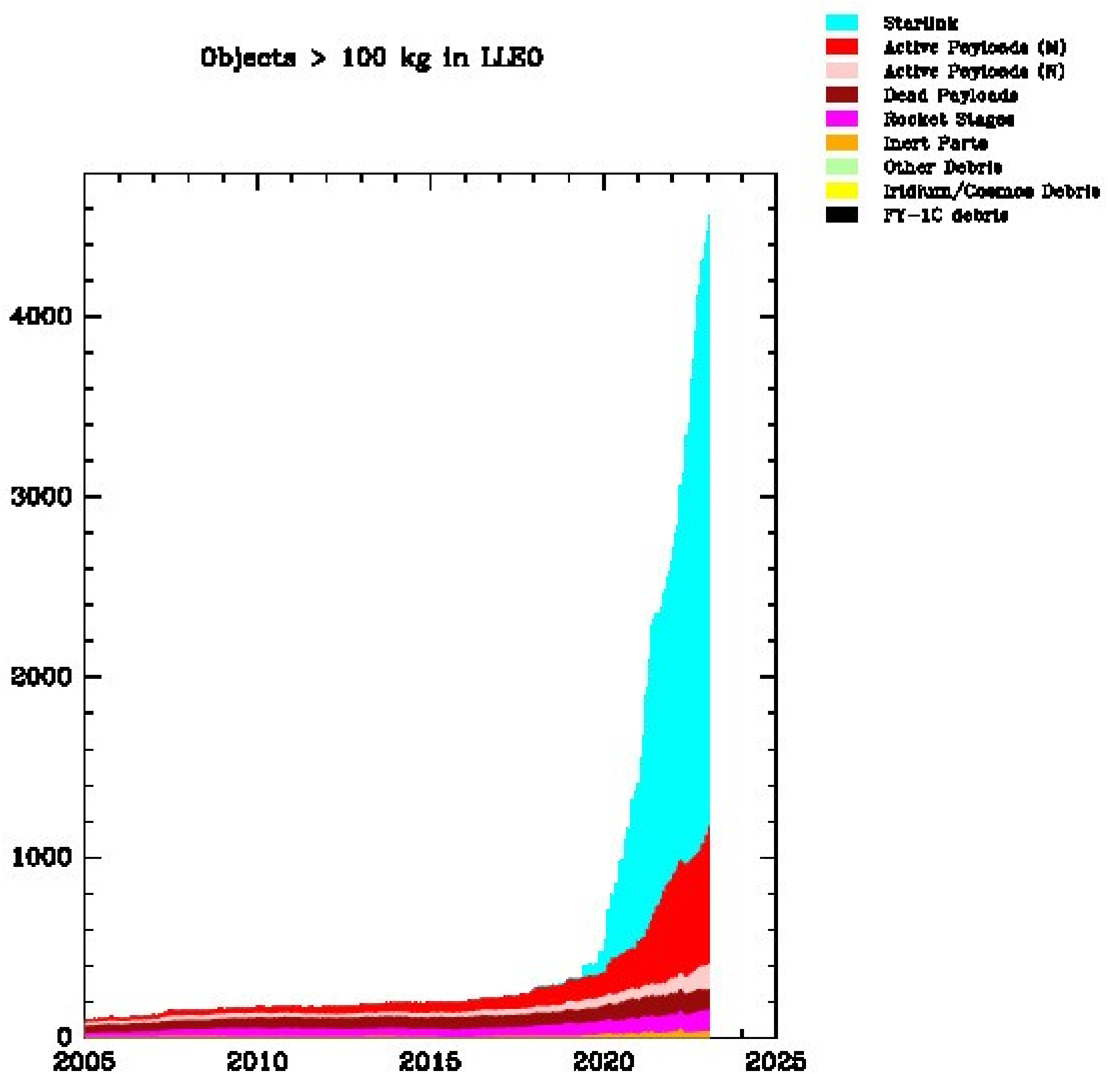

Musk: there are thousands of sats up already

BUT: mostly small debris or in high orbits

Not so many BIG and LOW: Starlink already dominates this subclass in 2022

Plot shows tracked objects below 600 km and more massive than 100 kg as of Jan 24 (Starlink in cyan)

Summary of satellite population trends:

- Upper LEO dominated by debris, slow change
- Lower LEO now dominated by payloads, rapid increase
- Commercial satellites are now dominant over govt ones
- Chinese commercial space (sats and launchers) starting to take off (pun intended)

What are the challenges to space governance and space law as a result?

3. SIMULATIONS

In which we assess how bad it might get...

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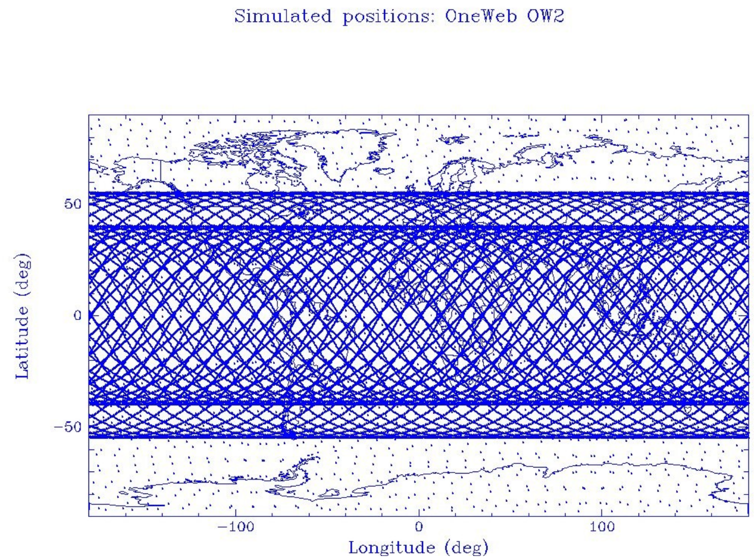
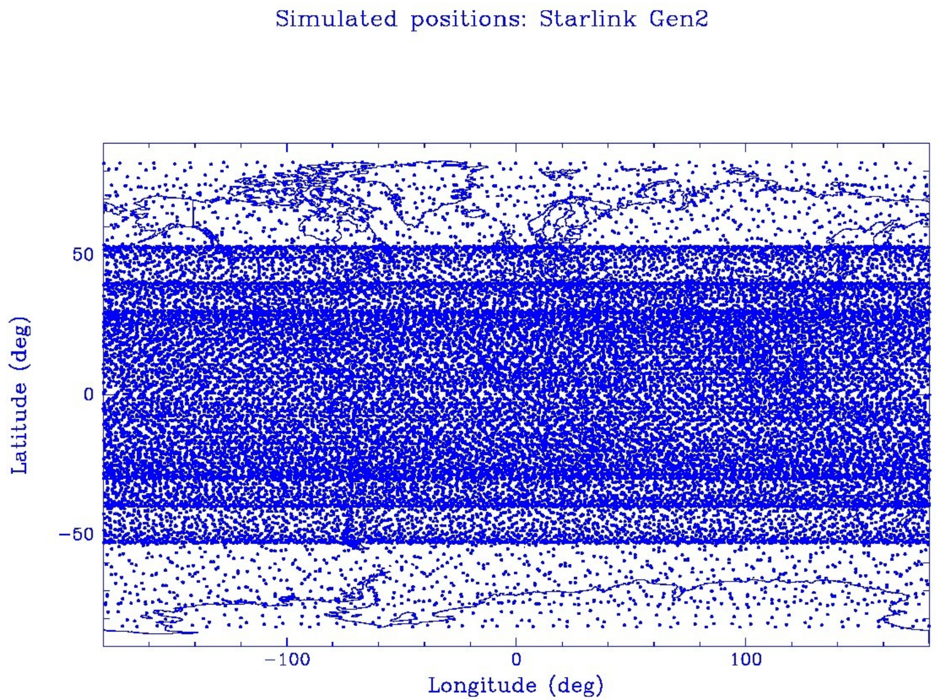
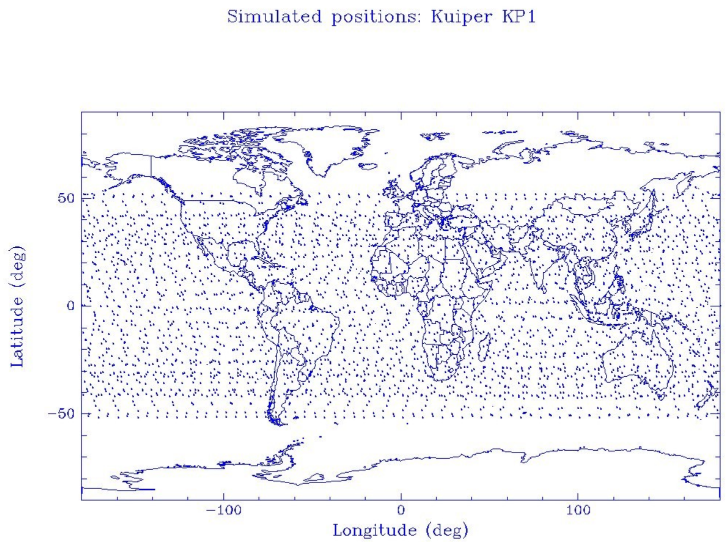
Realization of constellations showing latitude/longitude distributions.

Limited polar coverage







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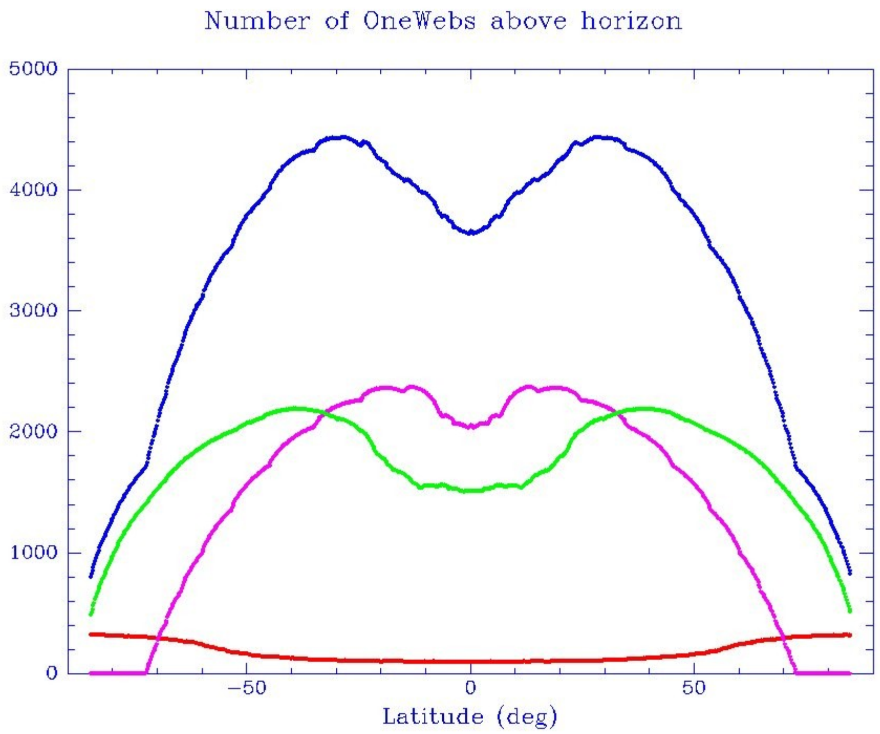

We can plot these realizations versus latitude from the point of view of an observer at those latitudes

Here, based on an early OneWeb planned constellation, I show how three shells at three different inclinations (40,55 and 88 deg) contribute to the overall number above the horizon as a function of latitude

Contribution peaks at latitudes somewhat less than the orbital inclination. Combination peaks at 30 deg – where lots of observatories are. But not all these satellites will be illuminated all night...

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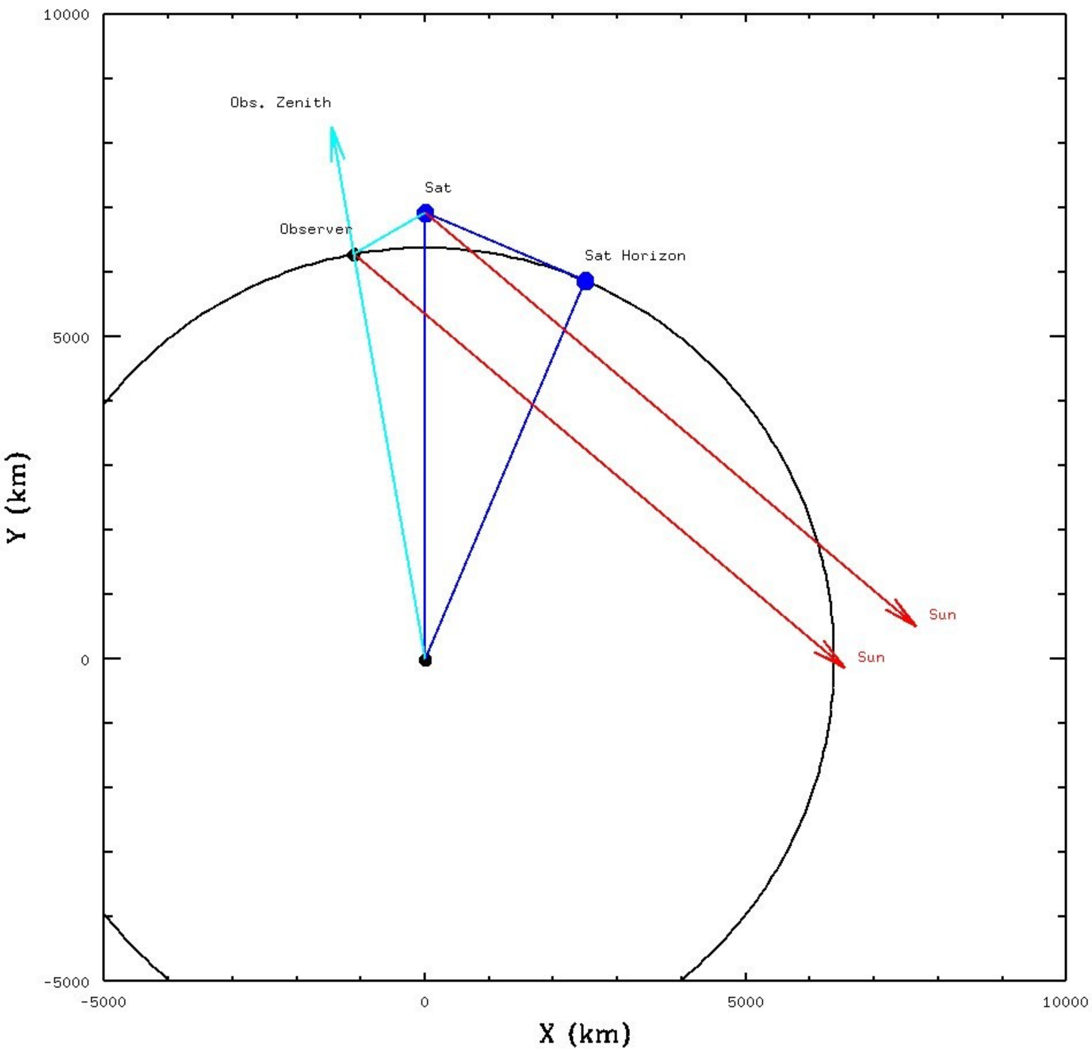

How many satellites are high in the sky and illuminated when it's dark outside and astronomers are at work?

Geometry of problem involves three angles:

1) Zenith-Observer-Sat angle – **is the Sat above the horizon,** and is it above 30 deg elevation (airmass 2)?

2) Zenith-Observer-Sun angle: **is it night where the observer is?** How far below the horizon is the Sun? (e.g. "Astronomical twilight")

3) Sat Horizon-Sat-Sun angle: is it night where the satellite is? **Is the satellite illuminated?**

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Constellations to be modelled based on early 2022 FCC filings:

Starlink Generation 1:	4408 satellites at 540 to 570 km
Starlink Generation 2:	30,000 satellites at 328 to 614 km
OneWeb:	6372 satellites at 1200 km
Amazon Kuiper:	7,774 satellites at 590-650 km
Guanwang:	12992 satellites at 590-1145 km
Boeing	5921 satellites at 670-1085 km
Total:	67,467 satellites!

“Megaconstellations” (well, really only myriaconstellations... nevertheless unprecedented)
Will add in the proposed 300,000 sats for E-Space in some plots

Others are working on predicted actual brightnesses for simulations but I haven’t bothered on the grounds that all the LEO constellations are basically going to be annoyingly bright much of the time. (and because it’s a really hard problem)/
Most of these satellites will be V ~ 5 to 10 mag.

Higher orbits:

- each satellite visible by more observers
- so, more of the constellation visible to each observer

- satellite illuminated by the sun longer into the night

- angular velocity lower, so surface brightness of trailed image is higher

Lower orbits:

Rubin Obs experiments show V < 7 sats can cause electronic ghosts in CCD affecting whole field
(Tyson et al 2020, AJ 160, 226)

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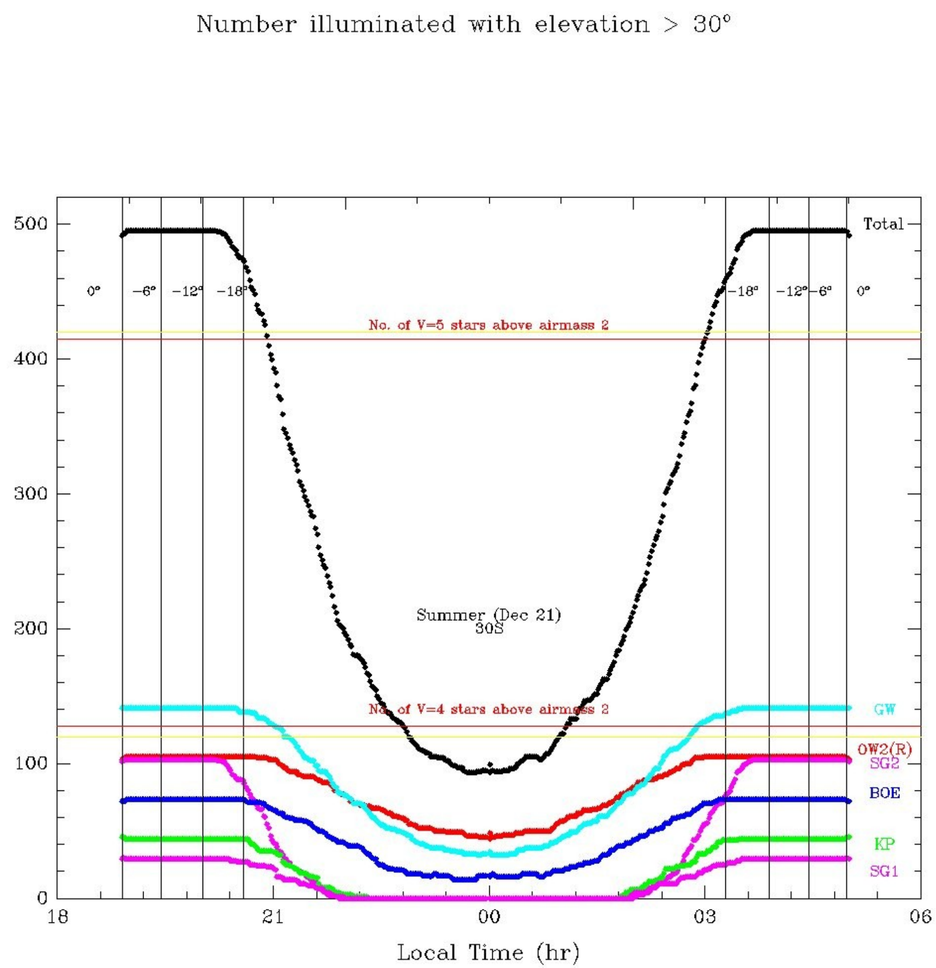
Simulation 1: Summer solstice, mid-latitude, airmass < 2



30 deg S corresponds to Cerro Tololo (Chile) and other major observatories

Simulate Starlink, OneWeb, Amazon, Guanwang, Boeing

At summer solstice, 100 illuminated satellites high in the sky (airmass<2) all night long

Dominated by the OneWeb constellation because its satellites are in higher orbits

At twilight, Guanwang dominates

Simulations updated from McDowell (2020) ApJ 892, L36

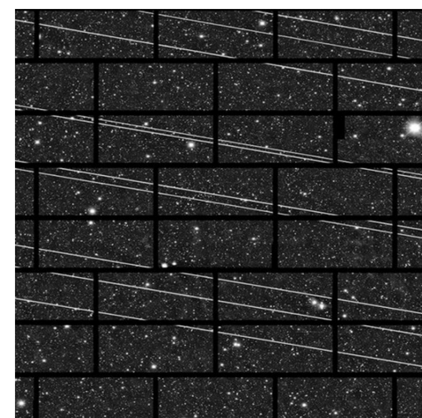
Implications:

n = 100 satellites above 30 deg elevation corresponds to 0.04 sats per square degree

They are mostly OneWebs at 1200 km, angular velocity at zenith is
ω = 0.35 deg/s (scales roughly as 1/height)

The expected number of satellite streaks on an astronomical image with field-of-view width D and exposure time T is

$$N = 0.7 \; (n/100) \; (\omega \,/\, 0.35 \text{ deg/s}) \; (T \,/\, 60\text{s}) \; (D \,/\, 1 \text{ deg})$$



in other words:
N ~ 1 or more for plausible values
So for LONG EXPOSURES with a WIDE FIELD OF VIEW all images will have multiple streaks, very hard to mitigate.

(Note: yes, I'm ignoring a D^2 term above, small for long T)

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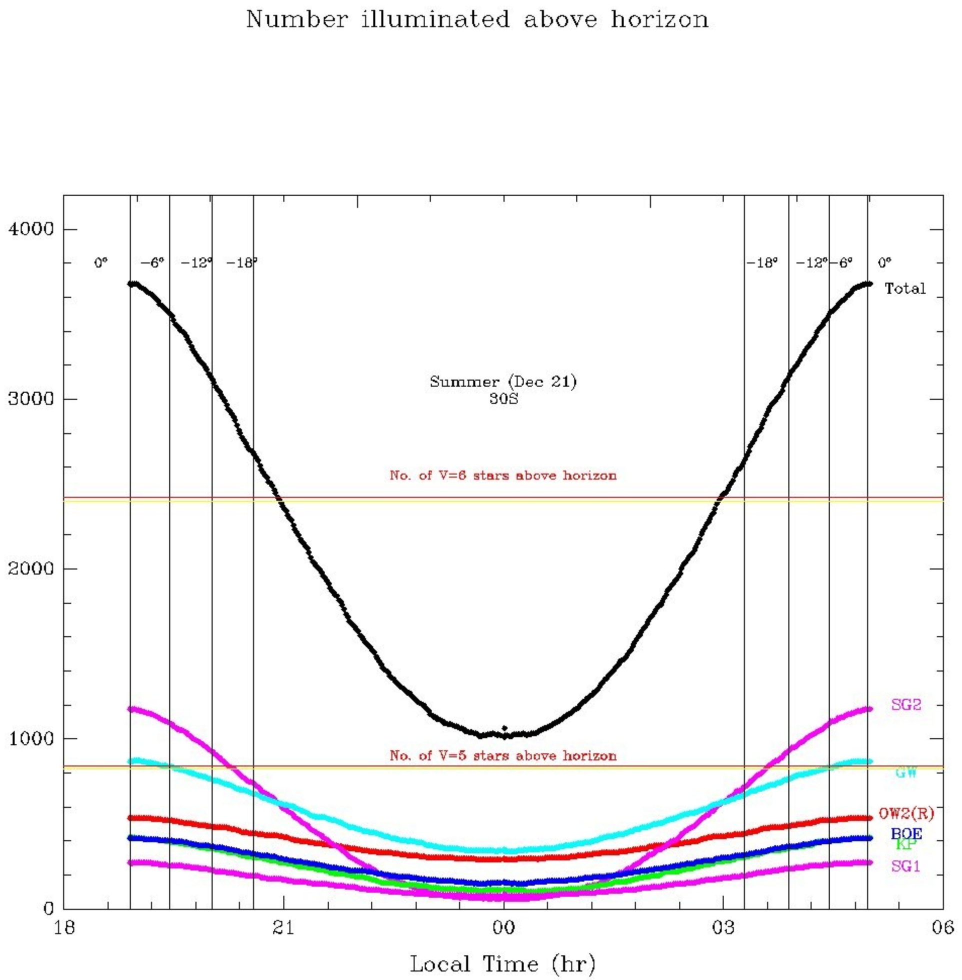
Simulation 2: Summer solstice, mid-latitude, all sats down to horizon



Worst case: observing near horizon during twilight.

Geometry ==> many more sats illuminated near horizon than at high elevation

Over 3000 satellites illuminated (30S, summer)

700-1400 during twilight hours from Starlink Gen2

The simulations show us:

Large constellations at 500 km or lower are likely to be naked-eye, with hundreds or even thousands of visible satellites at once for the first and last few hours of the night, but probably not a problem at midnight

--- changes the experience of the night sky for people around the world

Large constellations at higher (1000 km) altitudes are usually too faint to be naked-eye, but can be illuminated throughout the night in summer in very large numbers

--- wide field ground based imaging will be seriously affected by satellite streaks (for 1 deg FOV 1 min exposure, typical image may have one or even multiple sat streaks)

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Similar studies:

Hainaut and Williams (2020) A&A 636, A121
Seitzer (2020) BAAS 52, 311.07
Bassa et al (2022) A&A 657, 75
Lawler et al (2022) AJ 163, 21

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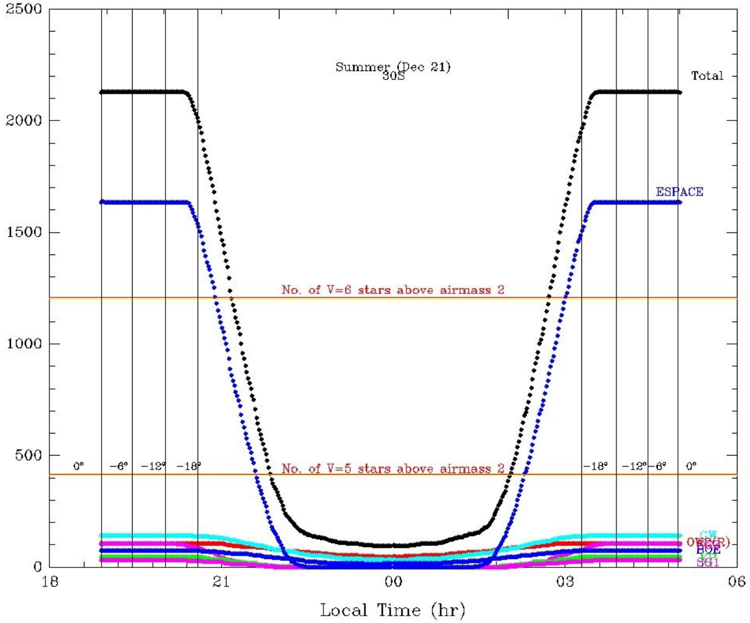
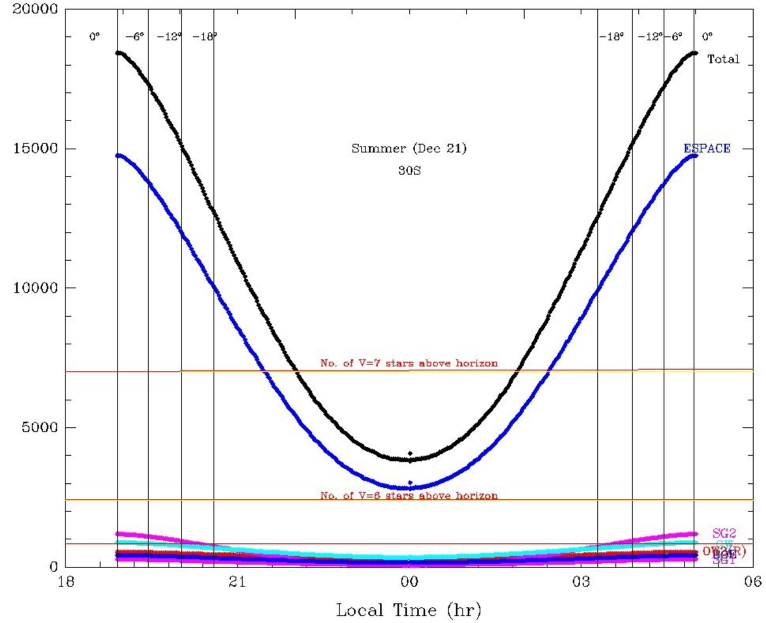
Number illuminated with elevation > 30°

Number illuminated above horizon

Simulations 3a, 3b: What if E-Space are serious??
Summer, mid-lat, elevation >30 deg and elevation > 0 deg





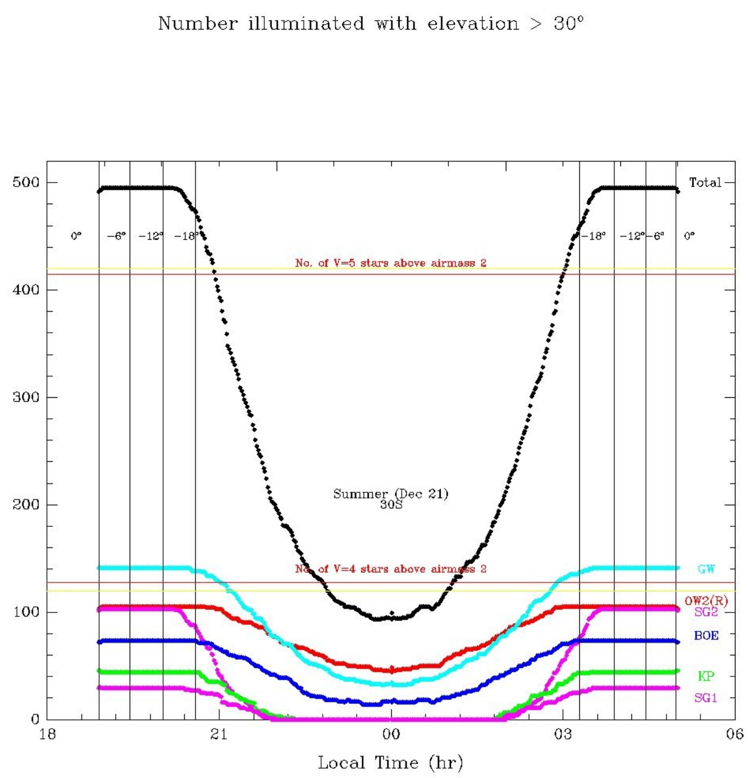
Oct 2021 ITU filing from Rwanda: 320,000 satellites proposed!!
Actually from E-Space, company led by telecom mogul Greg Wyler
Is this real?? It's a real filing with the ITU, so we have to consider it

Illuminated sats above horizon will exceed the number of V=6 stars all night long. Unclear if ESpace sats will be V>6 or not

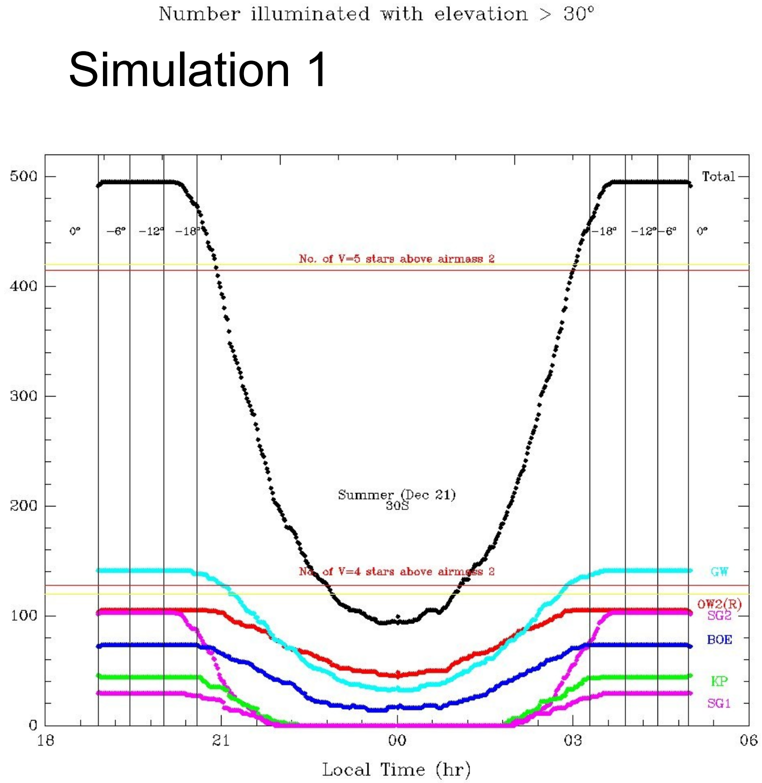
Back to Simulation 1
It's the worst time of year – sun not far below horizon at midnight

How do these predictions vary with time of year and observer latitude?

Simulation 1: Summer, mid-latitude, airmass < 2

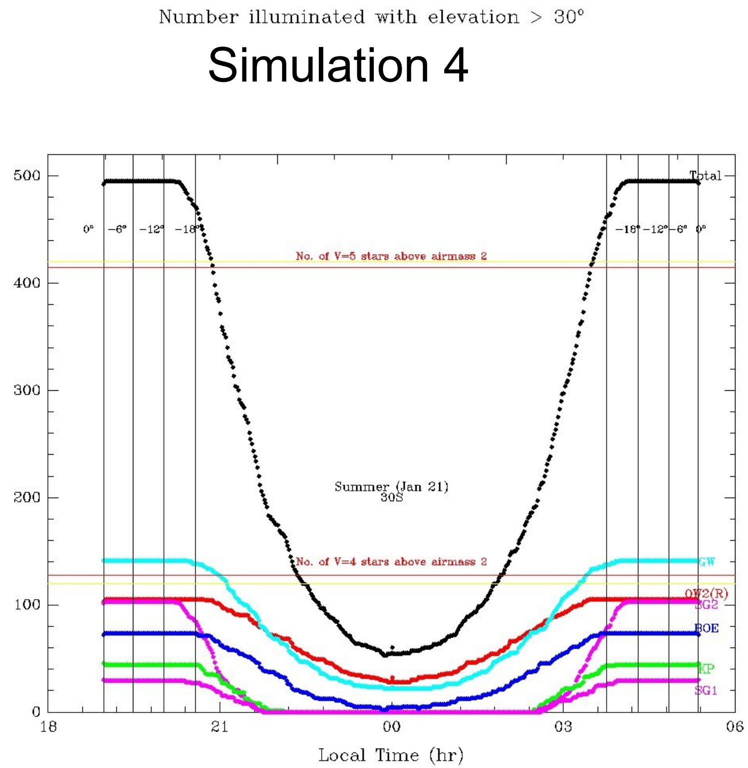


Simulation 1



Summer Solstice

Simulation 4



Solstice + 1 month

A month after solstice it is still pretty bad – 60 satellites at midnight

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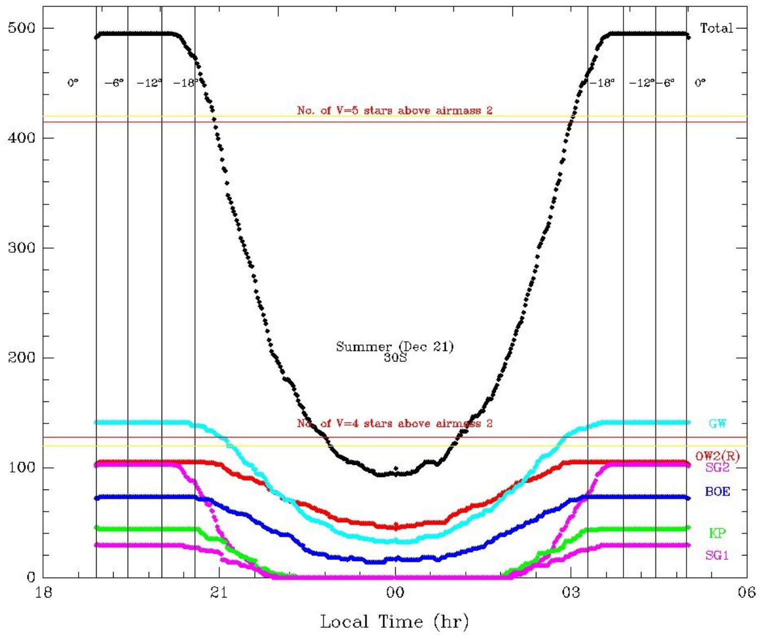
Number illuminated with elevation > 30°

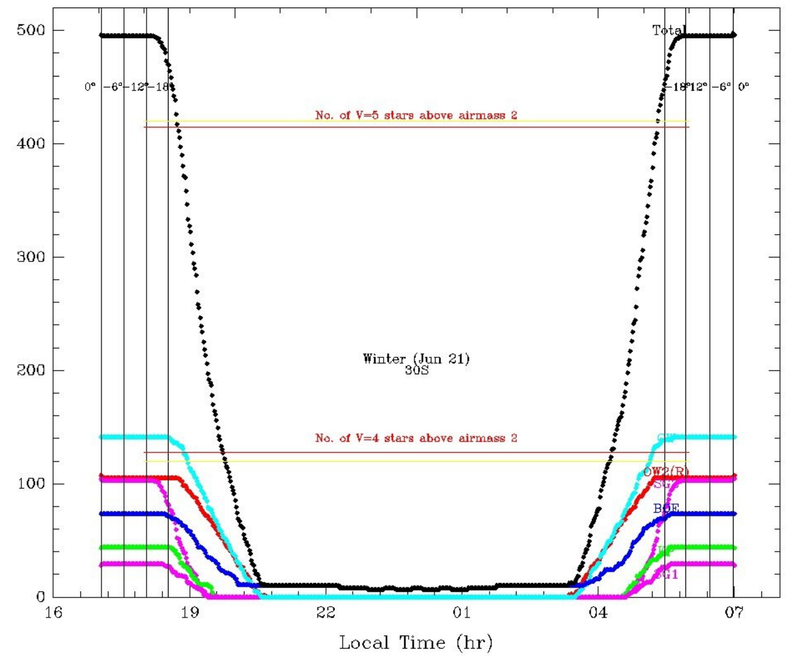
Simulation 1



Summer Solstice

Number illuminated with elevation > 30°

Simulation 5



Winter Solstice

In winter, things are dramatically better
– as long as you don’t need to observe in twilight

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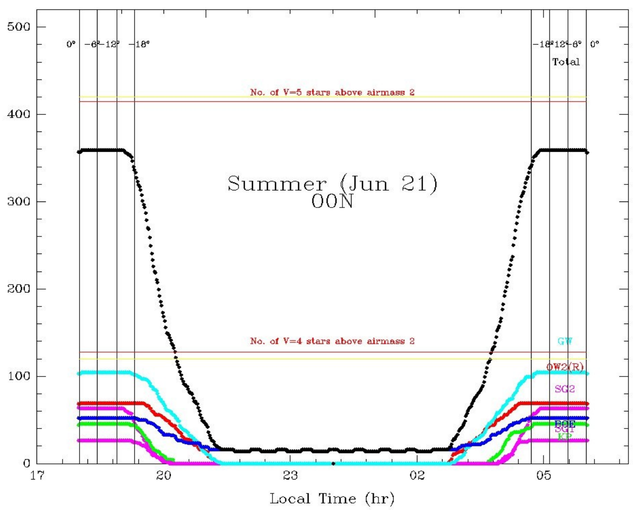
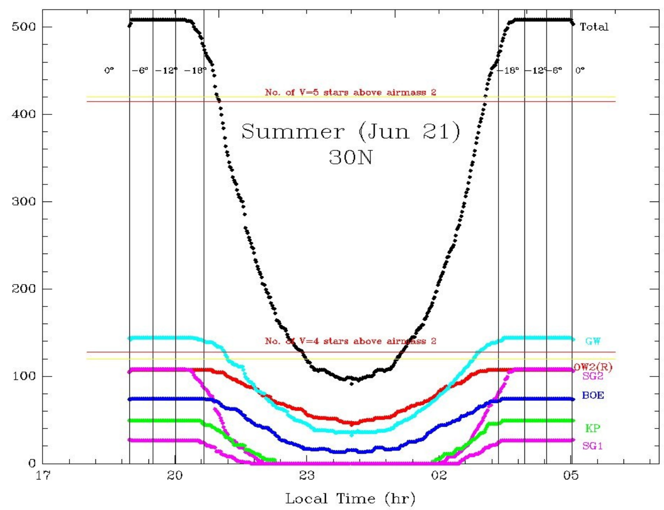
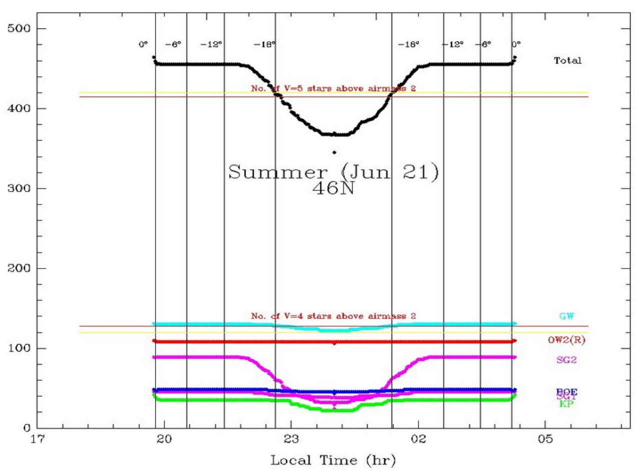
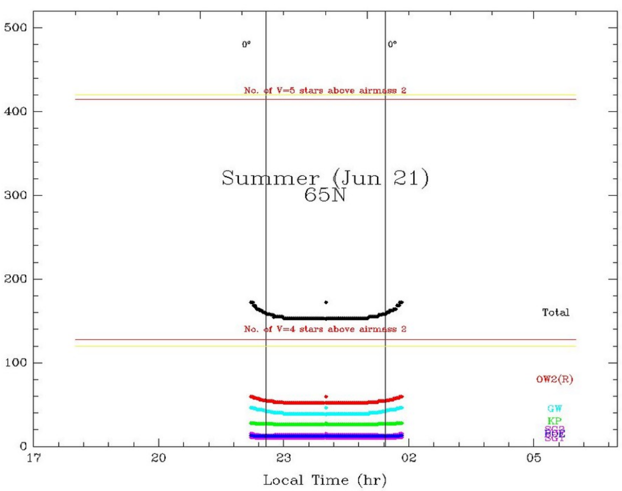
Number illuminated with elevation > 30°



Number illuminated with elevation > 30°







Illuminated sats in summer vs latitude

Gets worse as you go to higher latitudes (due to sun angle change) until you get beyond max lat of main constellation when number of satellites drops.

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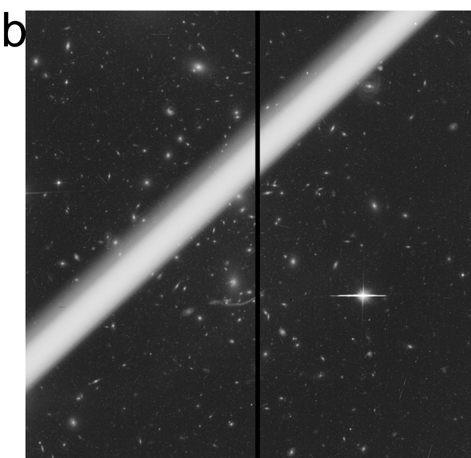
What about LEO space telescopes?
OneWeb at 1200 km is above them

Hubble Space Telescope, currently at 540 km, has narrow field of view (3') but long exposures (20 min to 1 hr?). Starlinks are 10 km above it.
Orbit geometry changes angular velocity factor (but only by O(1)-O(10) or so)
BUT   HST pixels are small, streak surface brightness reduced

Kruk, S, et al 2022: The impact of satellite trails on HST observations - 3% of 10 min exposures, affected,
expected to increase to 20%; 8 % of composite images currently affected PRIOR to Starlink
Thanks to Mark McCaughrean (ESA) and ESA intern Megan Perks (now grad stu, Southampton) for extensive discussions

Conclusion: Problem exists for HST but less severe
Any wide-field telescope in LEO (Xuntian?) will be in very b

Image courtesy Judy Schmidt: Chinese rocket stage CZ-4C-Y33 passes 35 km above HST in Feb 2020, right in direction telescope was looking.



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4. MONITORING

In which I present the Starlink traffic report...

MONITORING

What are these satellites up to?
Are they doing what they told the FCC they would do?

- We can keep track of them from public US Space Force radar tracking orbital data (space-track.org)
  - Typically 1 or more orbital element determinations per day
  - Doesn't require the sat to be still working
  - Only available starting ~ 1 to 2 weeks after launch

- Additionally a few companies (notably SpaceX) provide higher accuracy ephemerides from onboard GPS
  - T.S. Kelso provides orbital fits to this data (celestrak.org)
  - Only available if the sat is working
  - Available starting ~ 1 day after launch

Allows us to study orbital height, maneuvers, deployment strategies typically not described by the companies

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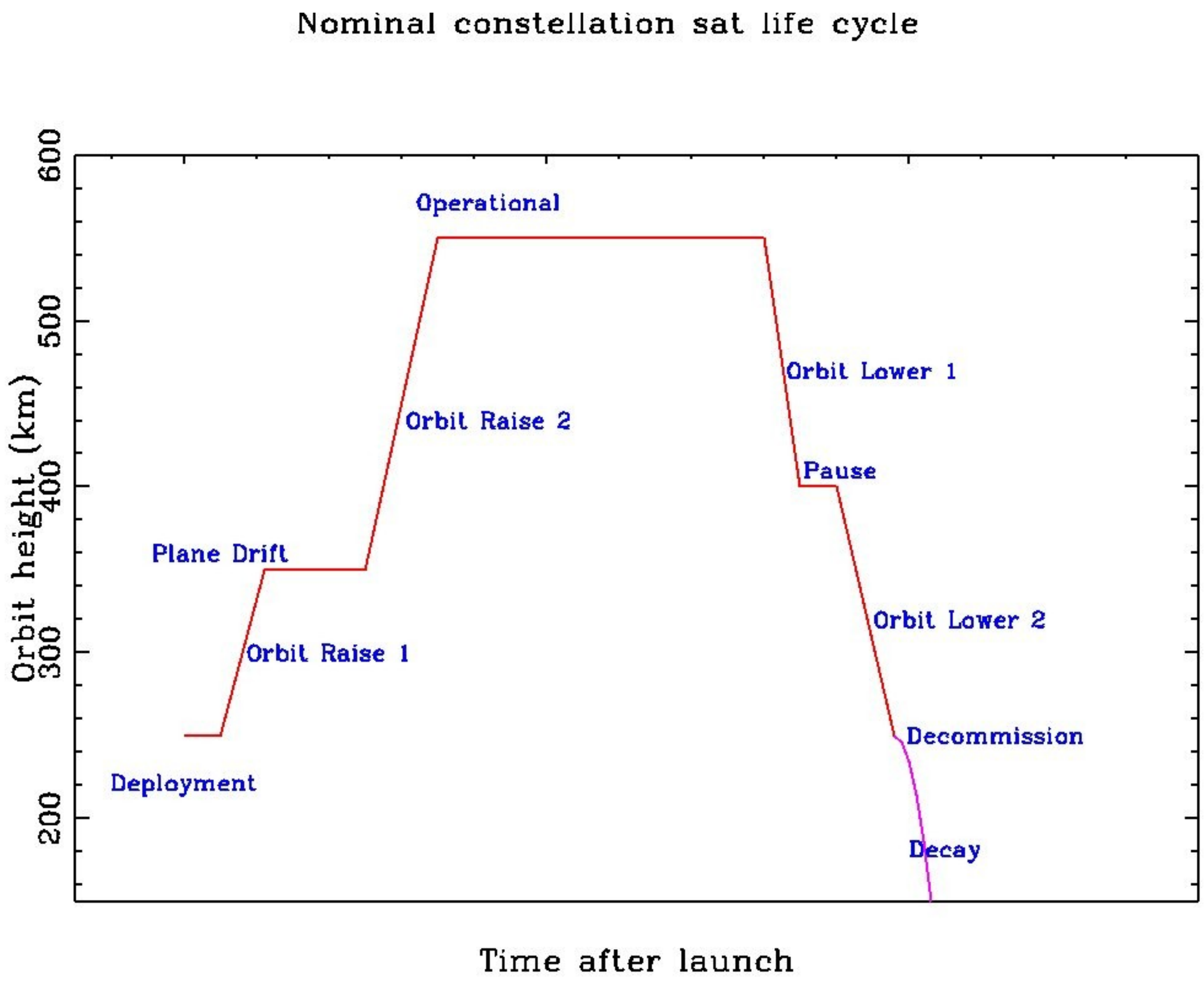
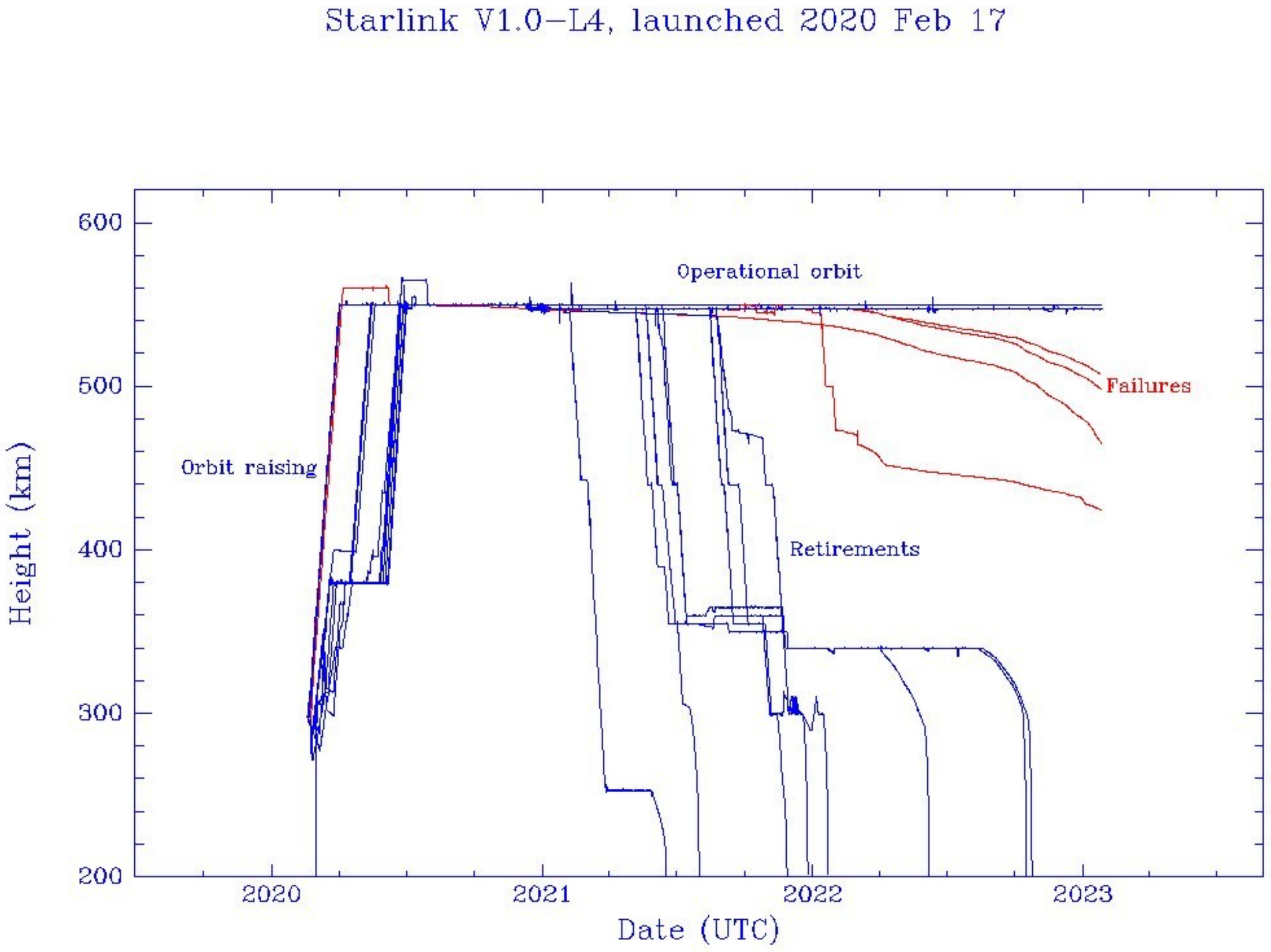


Actual example: 60 sats from one Starlink launch
(data from McDowell, planet4589.org/space/con/star/stats.html)



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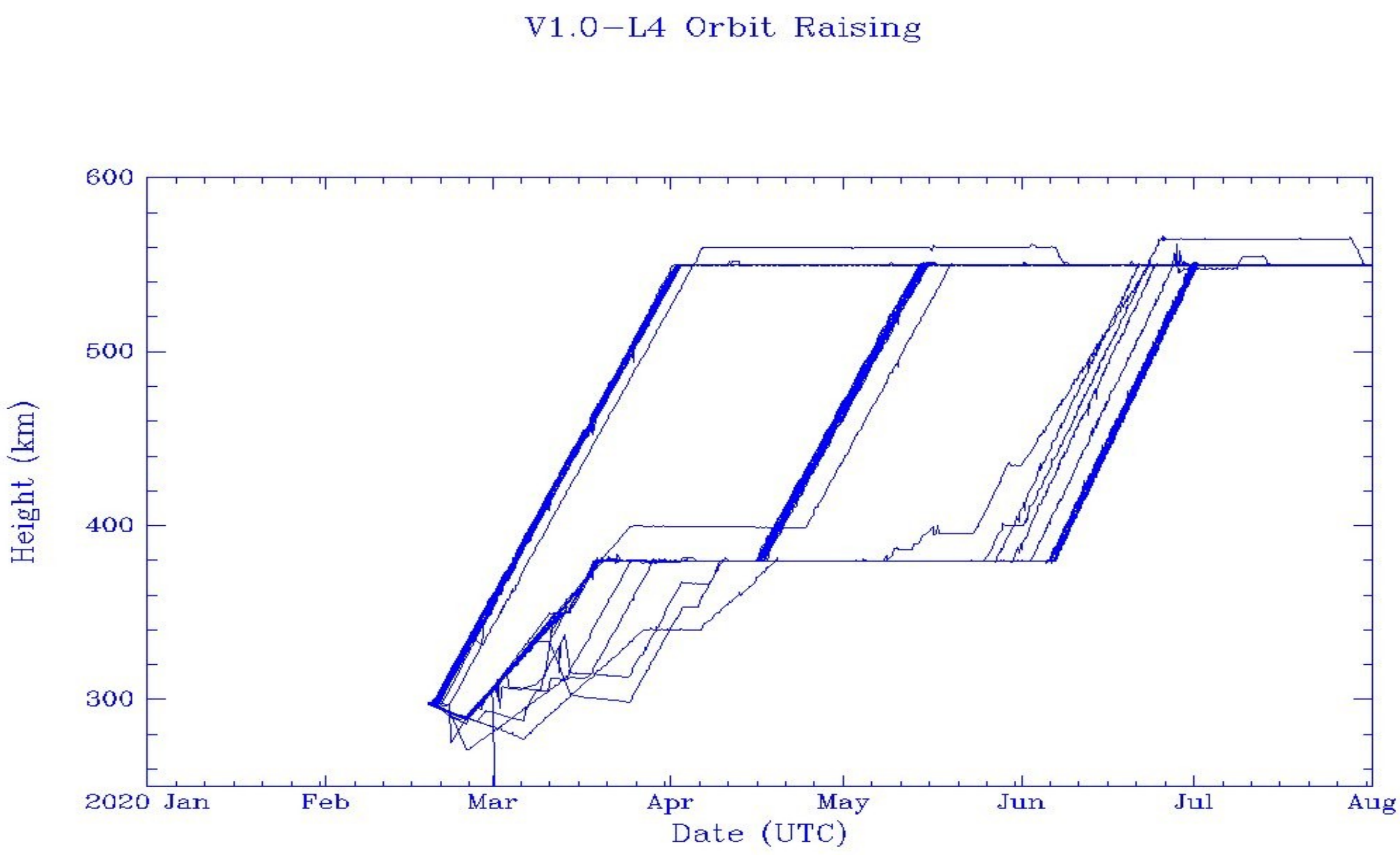
Zoom in on orbit raising phase
60 sats split into 3 groups of 20, with different durations of pause at intermediate height (here 380 km, usually 350 km)
Orbit raising takes > 4 months!
(data from McDowell, planet4589.org/space/con/star/stats.html)



Orbit plane fixed in inertial space for perfect Kepler orbit round perfect sphere planet.

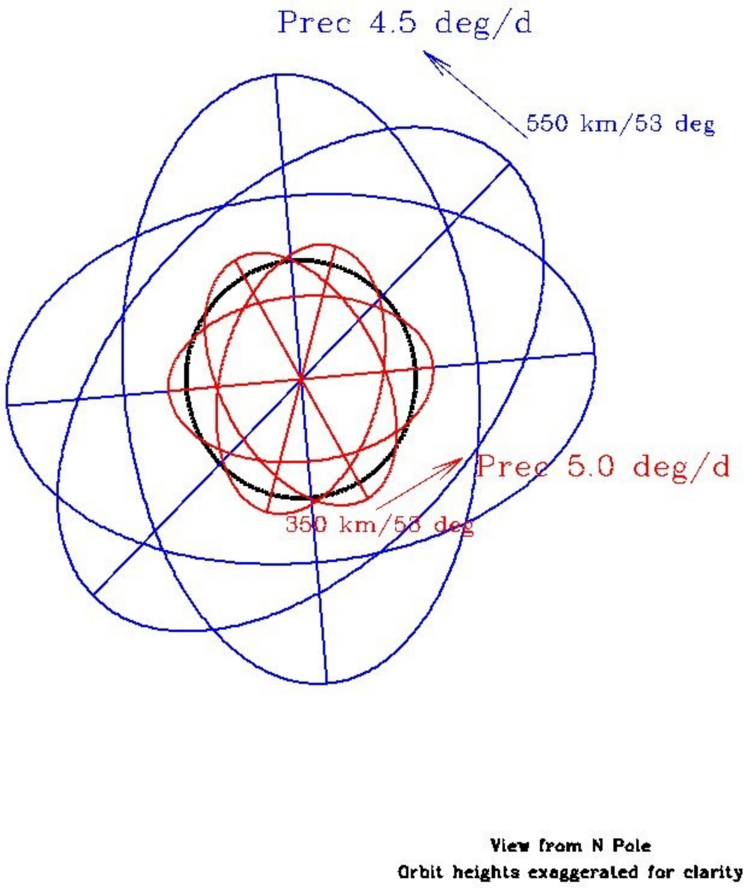
But Earth is oblate, J2 term causes orbital plane precession

Using differential precession to change orbital plane:

system of 550 km orbit planes in rigid rotation at 4.5 degrees per day

system of 350 km orbit planes rotates at 5.0 deg/day.

So, for every month you pause at 350 km before completing raise to 550 km, you change the final orbital plane by 0.5 deg/d * 30 days = 15 degrees.



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Starlink assessment as of Jan 31:
3822 sats launched
3530 still in orbit
  52 (1.4%) failed after orbit raising began – most prior mid-2020
  106 (2.9%) failed early or ‘screened’, reentered before orbit raise
3129 in or near licensed operational orbit (h, inc) shells
  364 (10% of those in orbit) in orbit raising, plane drift, or lowering

In general at any one time 10-15% of system is NOT at the nominal operational altitude -
so brighter (bad for astro) and passing other systems’ orbits (bad for traffic)

Summary status table

Data last updated: 2023 Jan 21 20:53:51

planet4589.org/space/con/star/stats.html

Mission	Total Sats	Early Deorbit	Disposal complete	Reentry after Fail	Total in Orbit	Screened	Failed, decaying	Total Working	Disposal underway	Out of constellation	Anom.	Reserve	Special	Drift	Ascent	Operationa
		F	R	M		F	M		R	L	U	T	S	D	A	O
Starlink Prototype Launch 0 (Tintin)	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Starlink Prototype Launch 1 (V0.9)	60	0	50	10	0	0	0	0	0	0	0	0	0	0	0	0
Starlink Group 1 Early Launches 2-8 (V1.0 L1-7)	420	9	36	3	372	0	25	347	5	6	0	0	0	0	0	336
Starlink Group 1 Visorsat Launches 9-17 (V1.0 L8-16)	533	13	61	2	457	0	5	452	9	9	1	1	0	0	0	432
Starlink Group 3 Launch 18/31 (TSP-1/2)	13	0	10	0	3	0	0	3	0	0	0	0	0	0	0	3
Starlink Group 1 Visorsat Launches 19+ (V1.0 L17+)	712	20	10	1	681	0	2	679	4	3	0	0	0	0	0	672
Starlink Group 2 V1.5 Launches	102	0	0	0	102	0	1	101	0	0	0	0	0	0	51	50
Starlink Group 4 V1.5 Launches	1637	63	2	0	1572	1	2	1569	1	10	3	2	0	45	64	1444
Starlink Group 3 V1.5 Launches	184	0	0	0	184	0	0	184	0	0	0	3	0	0	0	181
Starlink Group 5 V1.5 Launches (Gen2 G5 shell)	54	0	0	0	54	0	0	54	0	0	0	0	0	26	28	0
Total	3717	105	171	16	3425	1	35	3389	19	28	4	6	0	71	143	3118

Another form of monitoring:

- targeted photometric observations of constellation sats
Super important to let us assess the impact
Extensive work underway

J. Tregloan-Reed et al (2020) (A&A 637, L1) V ~ 5 to 6
A. Mallama (2021) (arxiv 2111.09735) V ~ 5 (std), 6 (visorsats)
A. Mallama (2022) (arxiv 2203.05513) V ~7 to 8 (OneWeb)
A. Boley et al (2022) AJ 163, 199 V ~ 5
G. Halferty et al (2022) MNRAS 516, 1502 V ~ 6 (visorsats)
H. Krantz et al (2022) (arxiv 2210.03215)
SATCON2 reports (NoirLab 2021)

- assessment of serendpitious streak statistics in archives

Mroz et al 2022, arxiv 2201.05343 (ZTF data)

5. MITIGATION

What SpaceX are doing to help us...

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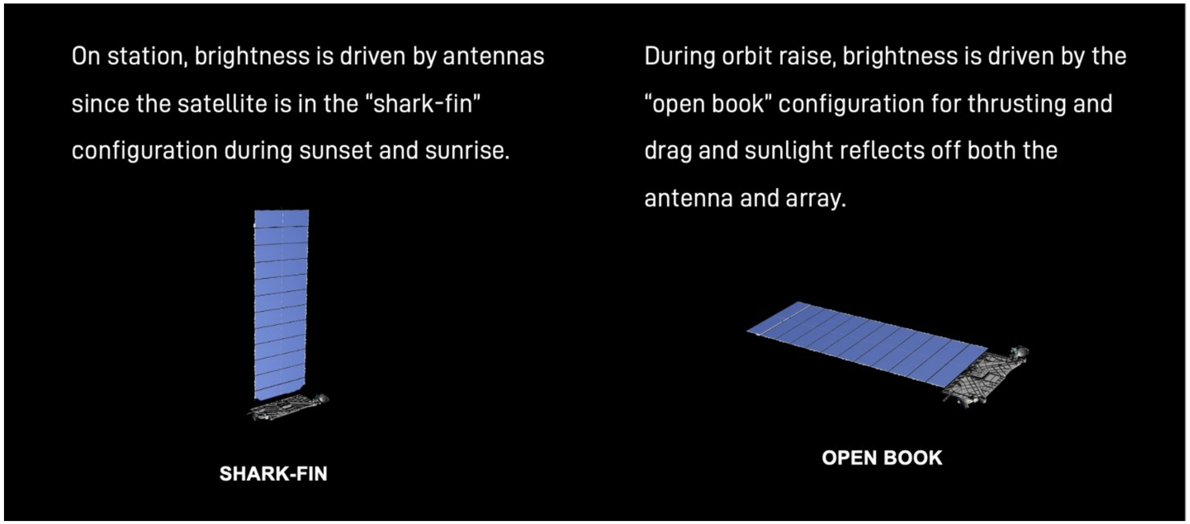

Starlinks are:
LARGE (300 kg, ~10m)
and LOW (300-550 km)
and REFLECTIVE.
- Bright (~naked-eye) objects)

Images: SpaceX

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SpaceX brightness mitigation attempts:

Operational changes (all sats?) - change attitude control strategy to minimize reflections during orbit raising

Darksat (1 test sat, Jan 2020) - paint on antennas; caused thermal issues

Visorsat (1245 sats, Jun 2020 to May 2021) – visors shielding antennas; abandoned for more recent sats due to excessive drag and need not to block laser crosslink system

2022 sats: solar cell backing material changed from white to dark red; reduced performance due to increased solar array temperature, but SpX accepting this hit.

Gen2 sats: (per 2022 document, first launches expected 2023)

- x 5 bigger mass (1500 kg vs 300 kg)
- x 5 bigger bus cross-section (6.4x 2.7m vs 2.8 x 1.3m)
- dielectric mirror film to reduce brightness
- opaque paint for back side of solar arrays
- terminator tracking strategy to point edge of solar array at earth limb (reduces reflections, but causes 25 % power reduction)
- low-reflection black paint for parabolic dishes and other components
- improved attitude control and solar array orientation strategies during orbit raising, maneuvers

SpaceX claim this will make Gen2 fainter than Gen1 despite bigger size

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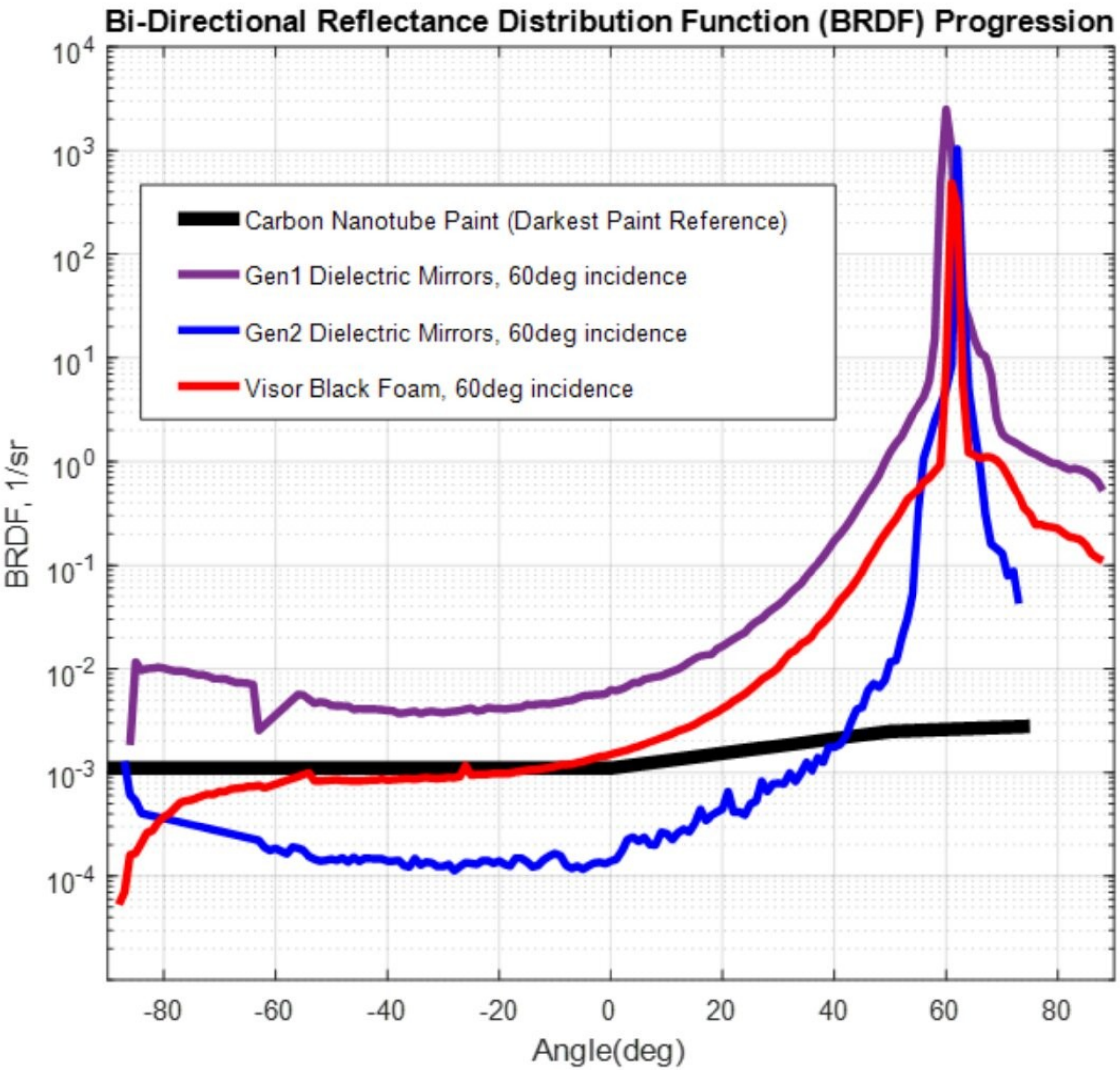

SpaceX figure showing expected lowered reflectivity of Gen2 sats (blue) vs current sats (purple)
as a function of reflection angle

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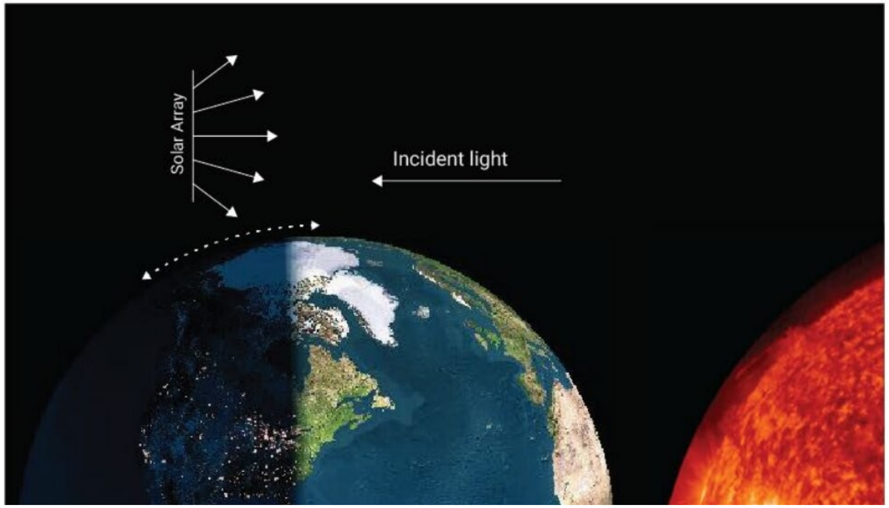
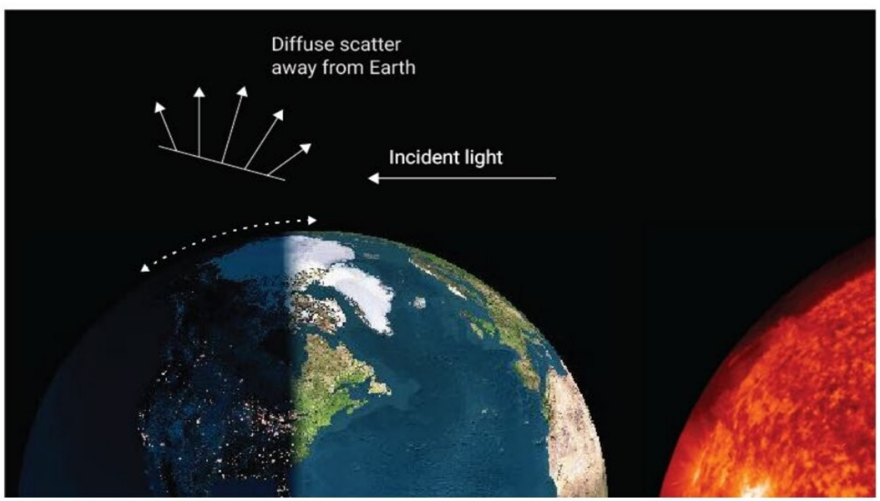
Sun Tracking Ideal Power Generation



Brightness Mitigation Reduced Power Generation



SpaceX illustration showing terminator tracking mitigation to reduce reflections while crossing Earth terminator

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That’s nice.

BUT:

- This is just SpaceX
- There are MANY companies in MANY countries planning to deploy very large constellations
- We can’t rely on them all trying to help us.

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6. RESPONSE

The astronomical community is organizing to protect the night sky

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Astronomical community response:

SATCON working group at AAS LPRISD committee
NoirLab/AAS SATCON1, SATCON2 conferences 2020, 2021
IAU/UN Dark and Quiet Skies conferences,2020 & 2021:
report presented to UN COPUOS Apr 2021
Splinter sessions at January 2023 AAS
SATCON2 report briefings to US State, WH OSTP, FCC, DoD, etc

IAU Center for the Protection of Dark and Quiet Skies – est Apr 2022
cps.iau.org
Still getting organized, but will be online center for relevant info

Going forward

- Work with satellite companies on mitigation
- Continue public pressure and build coalitions
- Work with UN COPUOS on protecting the sky?

The night sky as part of humanity's heritage and environment

Policy and legal issues:

Is the night sky part of "the environment", subject to environmental regulations?

Is astronomy a "space activity" under the Outer Space Treaty and does the "due regard" clause apply?

Can we get the UN to say that the night sky is part of humanity's heritage and should be protected?

Current US licensing requires companies to do a debris assessment. Can we require them to do a brightness assessment as well?

Living with big constellations: can we regulate along the lines of 'no more than X satellites above brightness Y at altitude Z' ?

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I am your local representative on

AAS LPRISD

Committee on
Light Pollution
Radio Interference
and
Space Debris

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Conclusion:

The megaconstellations will be a significant change to the LEO environment and to the night sky

Impact on astronomy depends sensitively on constellation architecture

Lower (500 km and less) orbit satellites may be naked eye objects but this can perhaps be mitigated with changes to satellite design. They are illuminated near horizon so are a threat to some (NEO search?) but not most astronomical observations

Higher (~1000 km) constellation shells will be illuminated all night long in summer and so, although not naked-eye, will be a threat to professional astronomy.

More info and resources: planet4589.org/astro/starsim