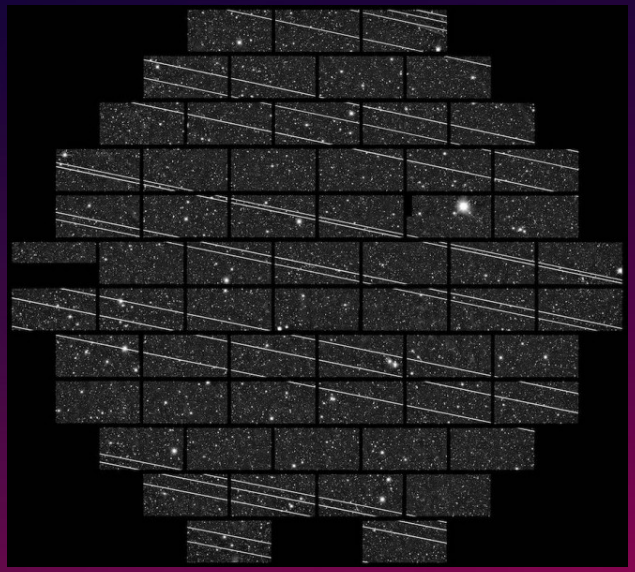
Satellite Megaconstellations and Their Impact on Astronomy



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Astronomy Associates of Lawrence
September 27, 2020

Starlink Satellite Train Over the Netherlands

Current and Planned Constellations

- Starlink (SpaceX) – up to 12,000 satellites with orbit altitudes ranging from 328 km to 614 km. Up to 30,000 satellites planned for the Gen2 constellation
- Kuiper (Amazon) - 3,236 satellites that will have orbit altitudes ranging from 590 km to 630 km
- OneWeb (Airbus and OneWeb) - 47,844 satellites in orbits with altitudes of 1,200 km
- Constellations by other operators are planned

Impact to Astronomy

- Hundreds to thousands of satellites will be visible after sunset
- NEO asteroid search programs – operate in twilight hours when impact is the worst
- Deep wide field extra-galactic surveys
- Transient programs
- Deep multi-object spectroscopic surveys
- Deep wide-field NIR imaging

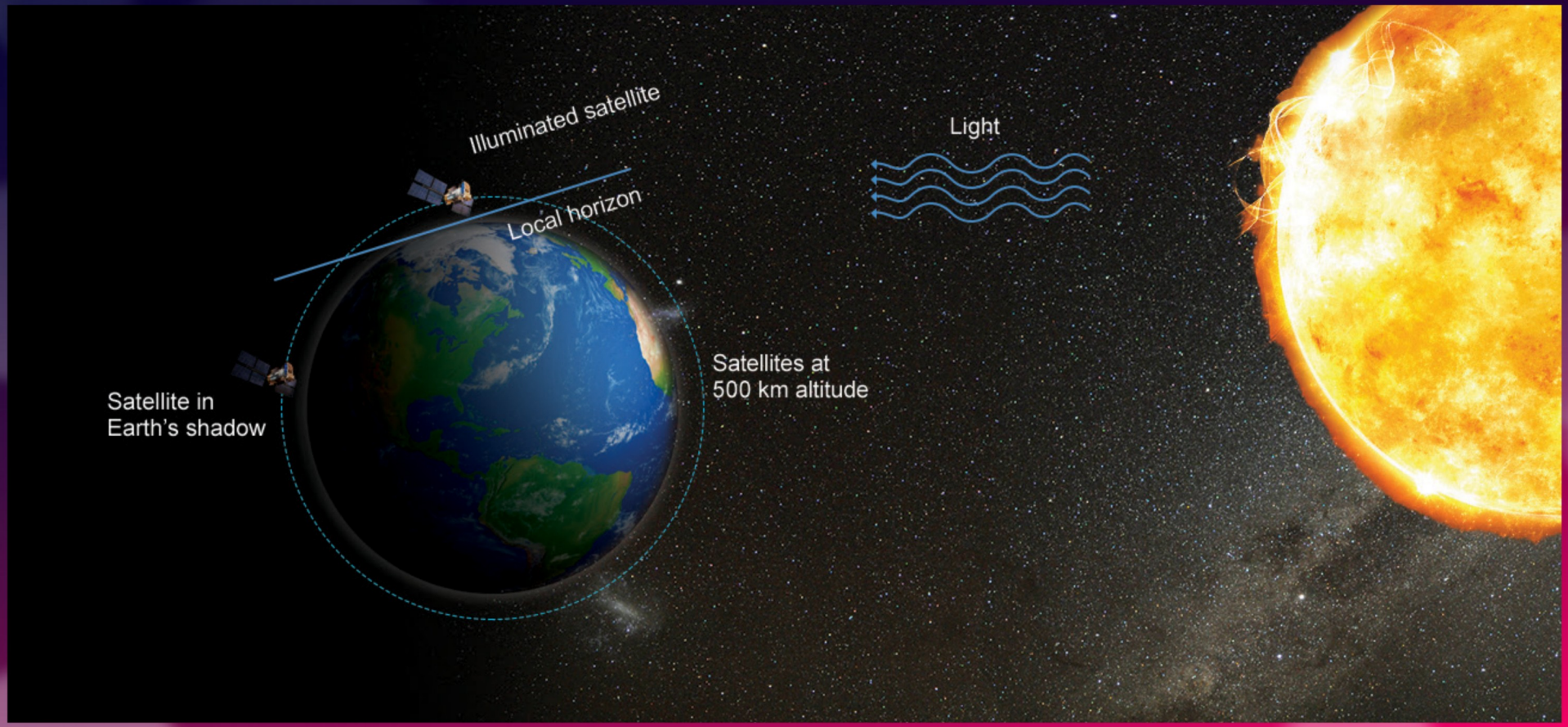
Impact to Astronomy

- Imaging of large extended low surface brightness targets
- Exoplanet transits in wide-field surveys
- Hubble Space Telescope (impacted by OneWeb satellites)
- Discovery of new phenomena
- Citizen science, amateur astronomers, and stargazers worldwide
- Environmental impact – migratory birds that use stellar navigation

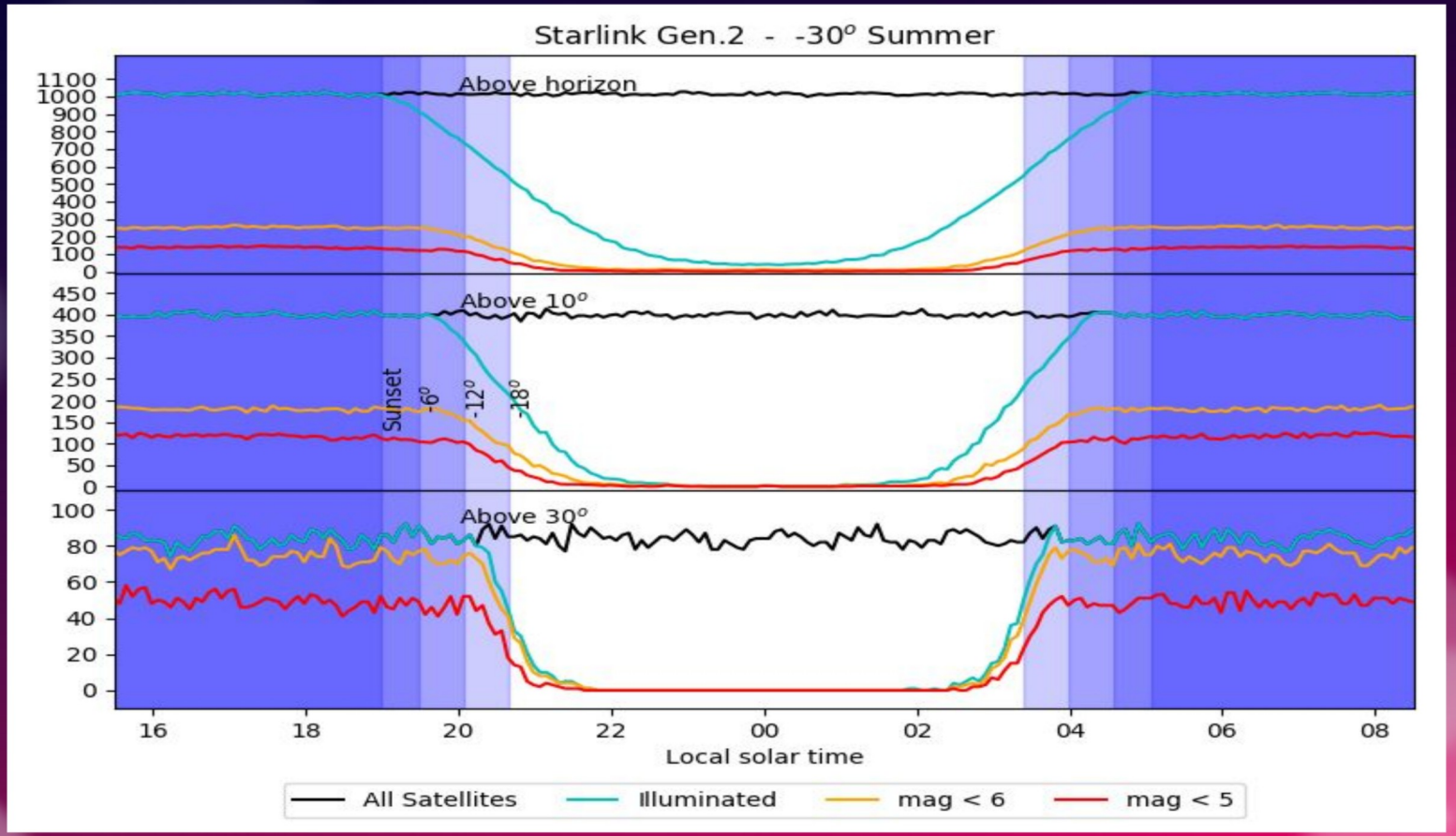
Factors that Influence the Apparent Brightness of a Satellite

- Satellite size
- Reflective properties of the satellite
- Orientation of the satellite’s reflective surfaces relative to the observer
- Specular reflections result in flares
- Altitude of the satellite

Satellite Visibility



Impact of Starlink Satellites (550 km Orbit)



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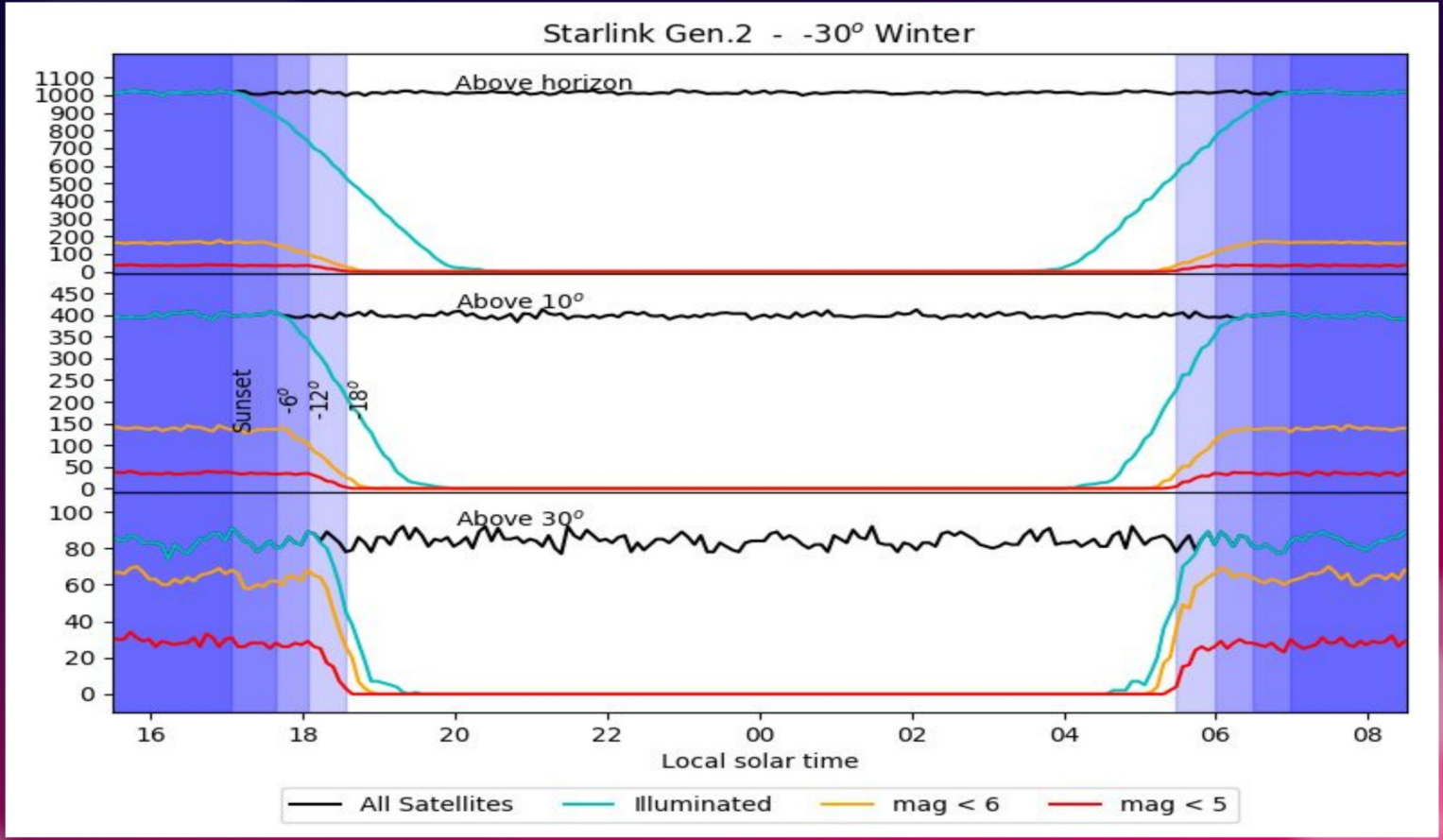
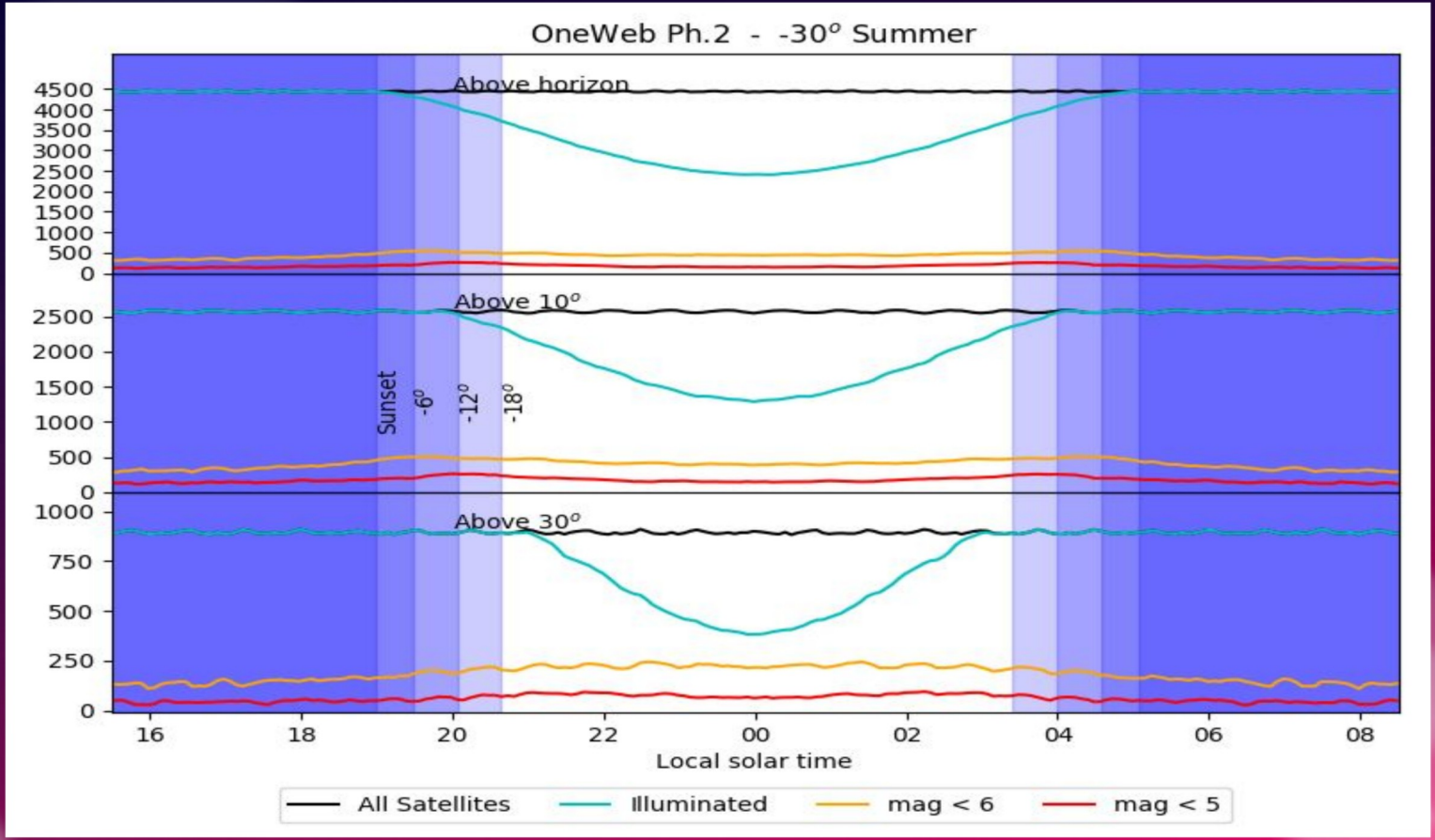


Impact of OneWeb Satellites (1200 km Orbit)



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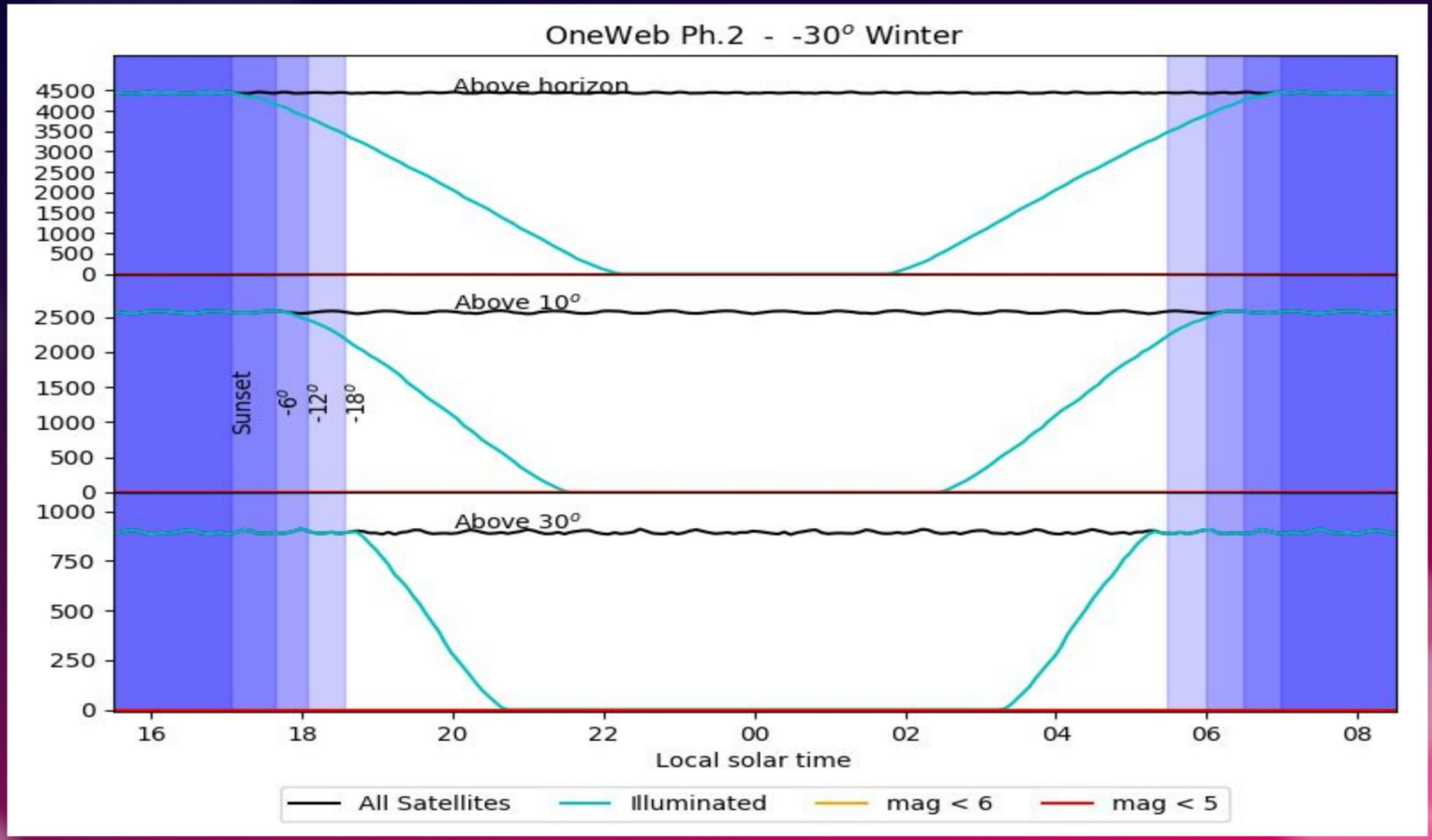
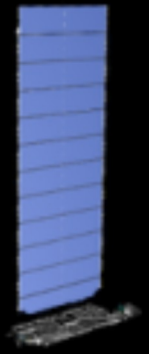


Starlink Satellite

Each satellite is about 3 meters across. The communications antennae on the underside are primarily responsible for the apparent brightness of the Starlink satellites when they are in their operational phase.

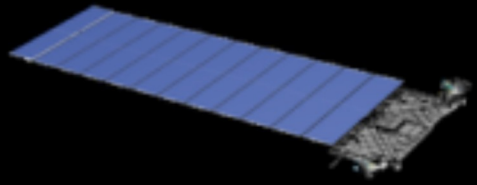
Starlink Satellite

On station, brightness is driven by antennas since the satellite is in the "shark-fin" configuration during sunset and sunrise.



SHARK-FIN

During orbit raise, brightness is driven by the "open book" configuration for thrusting and drag and sunlight reflects off both the antenna and array.

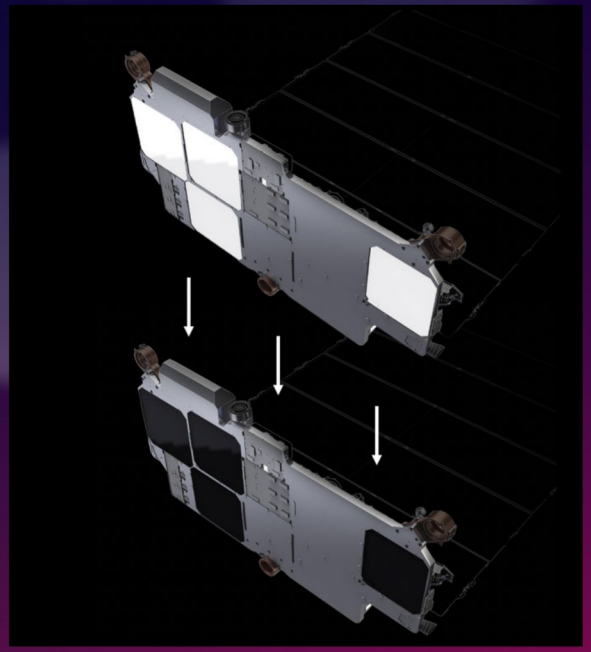


OPEN BOOK

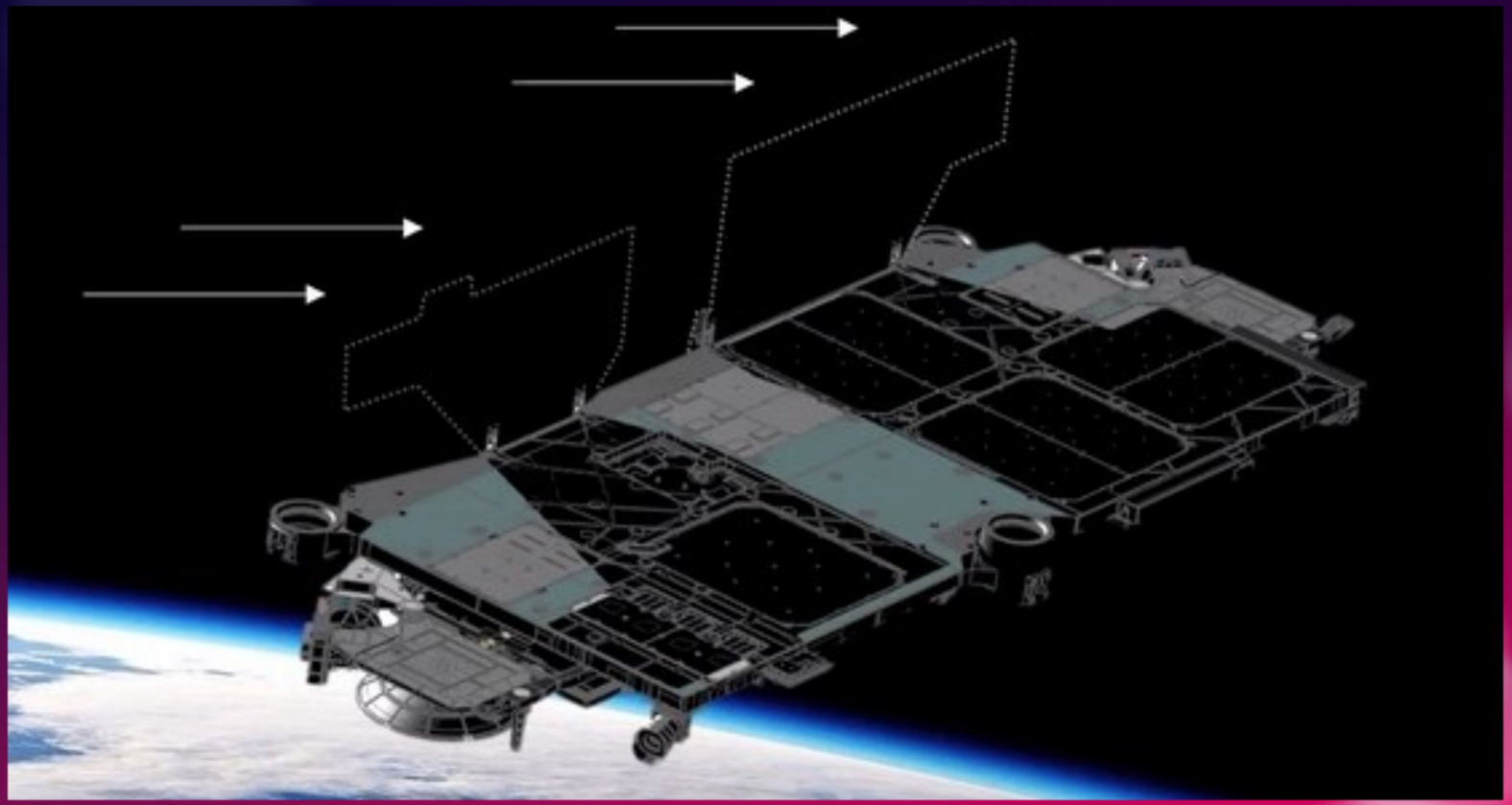
DarkSat

- Painted the communications antennae with matte black paint
- Reduced visual apparent brightness by about one magnitude
- Experienced thermal issues with the electronics
- Very little reduction in the infrared

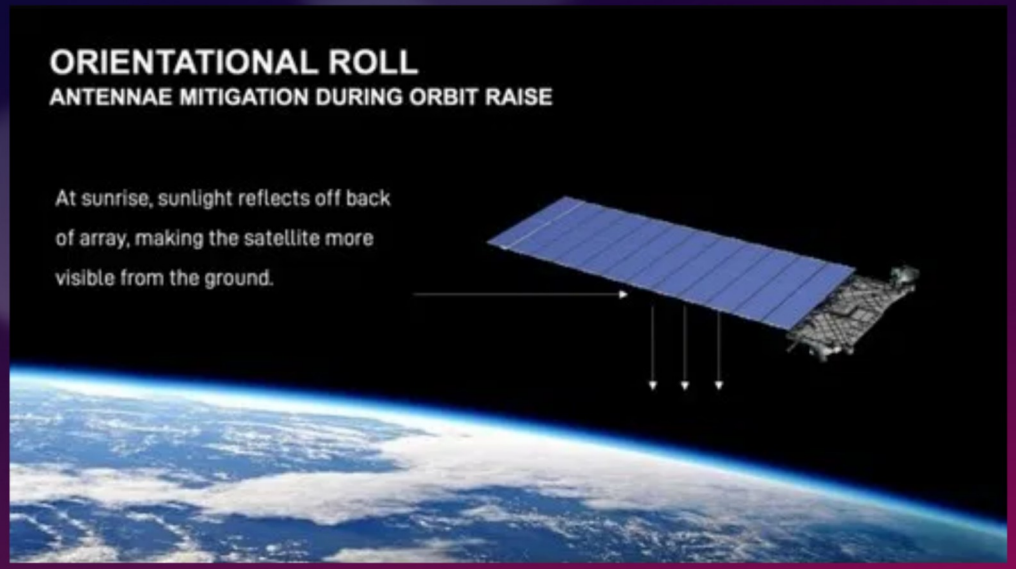
DarkSat

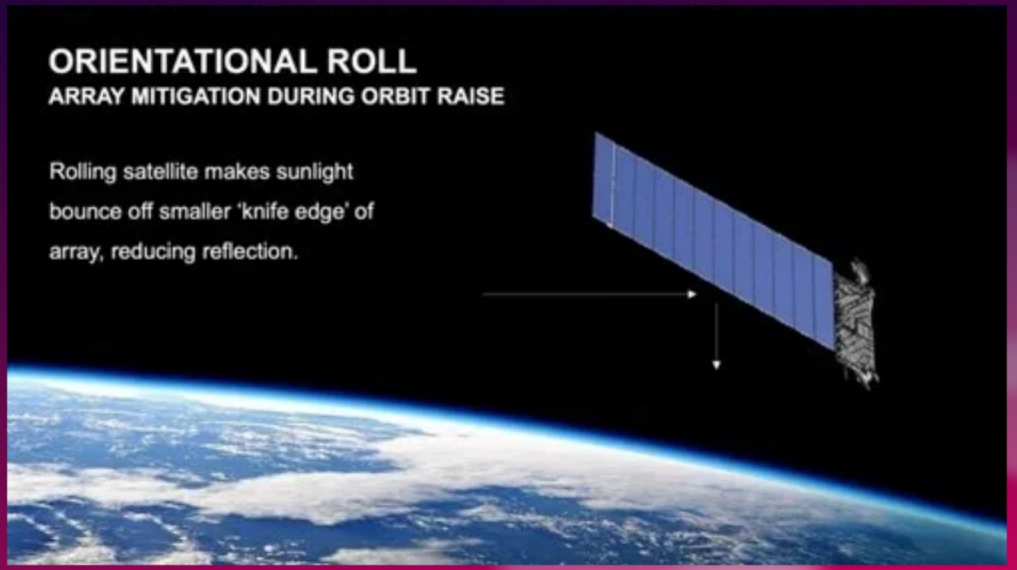


VisorSat



Orientational Roll - Orbit Raise Phase





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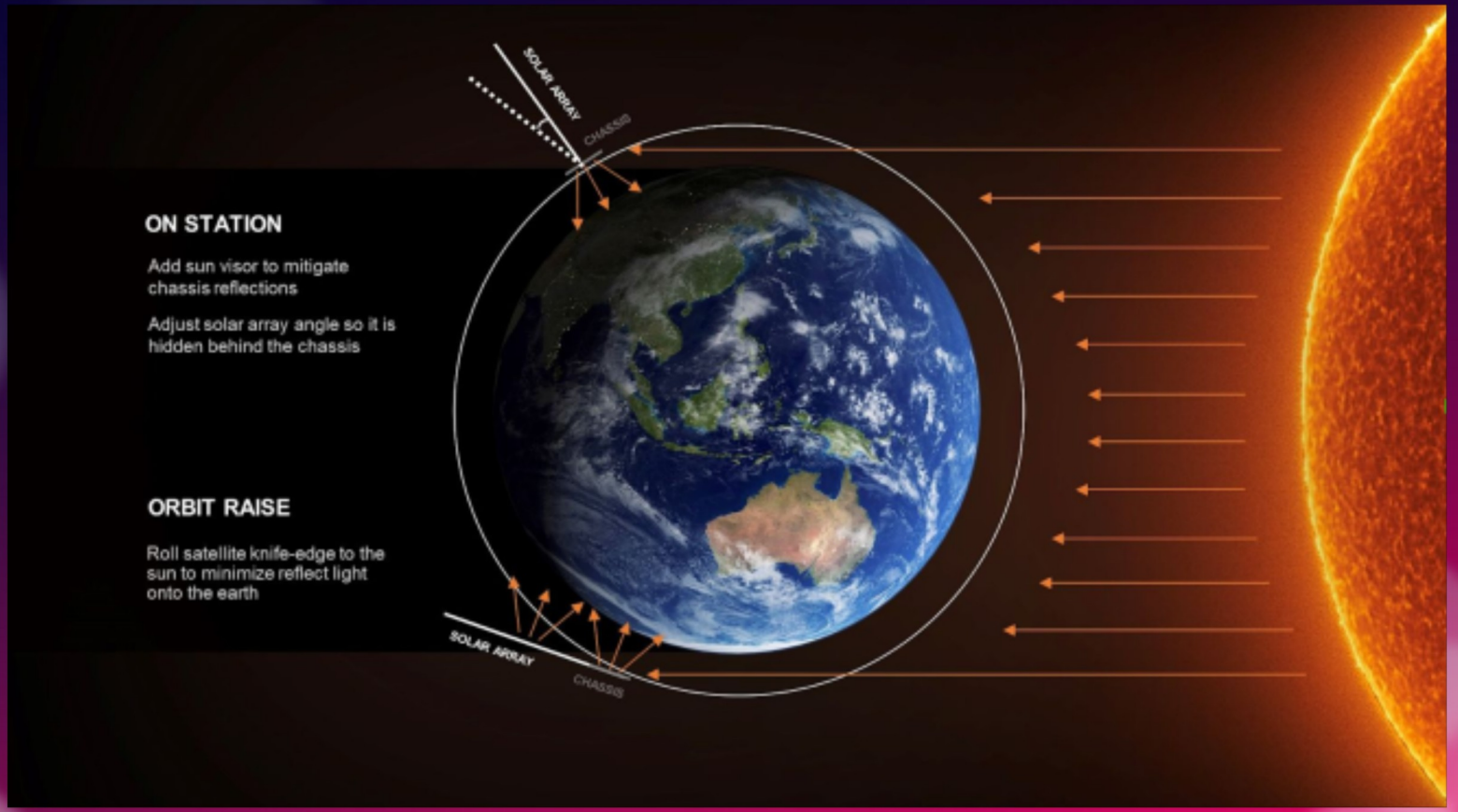

Mitigation - Operators

- Surface darkening
- Sun shielding
- Avoiding the use of non-rigid specular materials on the nadir face of the satellites to reduce false transients
- Potentially adjusting attitude to avoid flares projecting onto major ground-based observatory sites
- Best efforts for attitude control of satellites within communications and power constraints to minimize effective reflectivity and ensure predictable nadir-facing specular surfaces in direction of ground-based observatories.

Mitigation - Observatories Near Term

- Image post-processing to identify, model, subtract, and mask affected pixels associated with the satellite trail
- With precise ephemerides of entire constellation suites, and for those facilities where it may be practical, close shutters for the seconds around predicted passage
- Pointing avoidance when possible

Mitigation - Observatories Long Term

- New instruments designed for mid-exposure shuttering
- Exploration of CMOS detectors for pixel shuttering

Mitigation - Collaborative

- Sufficiently accurate ephemerides of flares for pointing avoidance
- Publicly available ephemerides as accurate as possible

Summary

- Astronomy will never be the same
- Wide field, long exposure imaging will be impacted the most
- The impact will be felt by both amateurs and professionals
- No way to fully mitigate the impact
- Science will be lost
- Expect more constellations in the future

Acknowledgments

“Satellite Constellations 1 Workshop Report”, American Astronomical Society, August 25, 2020

Questions?