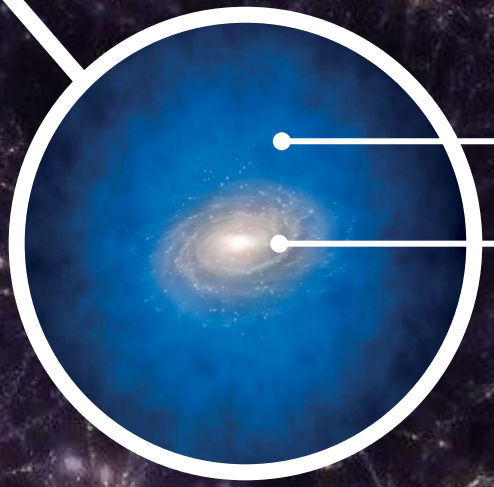

VERA RUBIN
vs
ELON MUSK
Understanding the dark universe under brightening skies
Sébastien Carassou, PhD

THE COSMIC WEB

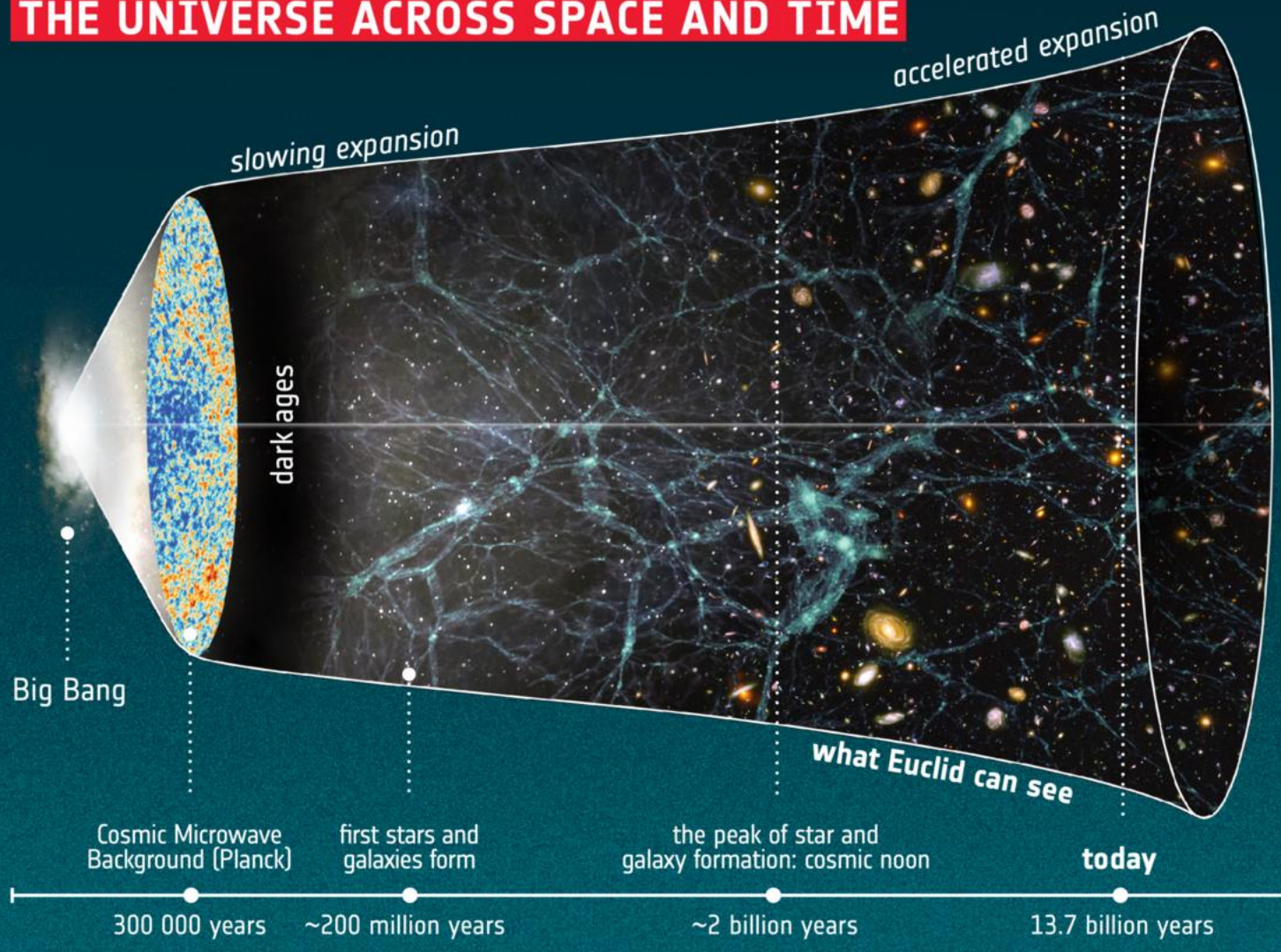
The universe at the largest scales

Dark matter filament

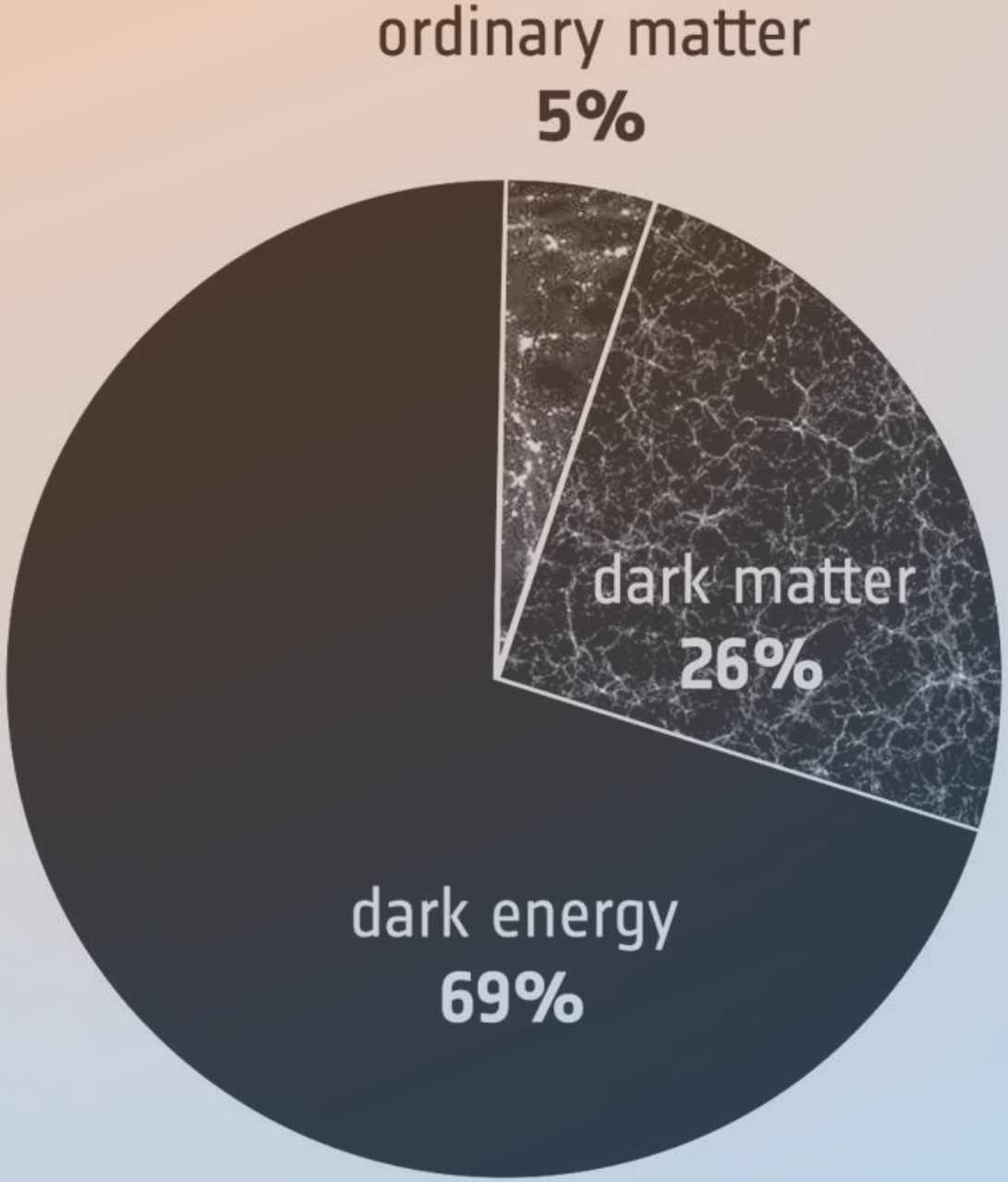


Crédit : Kaze Wong / CAMELS collaboration

THE UNIVERSE ACROSS SPACE AND TIME



An unknown 'dark energy' appears to drive the current accelerated expansion of our Universe, but scientists do not understand how and why. Euclid will map the last 10 billion years of cosmic history across more than a third of the sky – from cosmic 'noon', the time when most stars were forming, until today. This 'looking back in time' will show us the variations in the cosmic acceleration with extreme precision, revealing the nature of dark energy in this process.



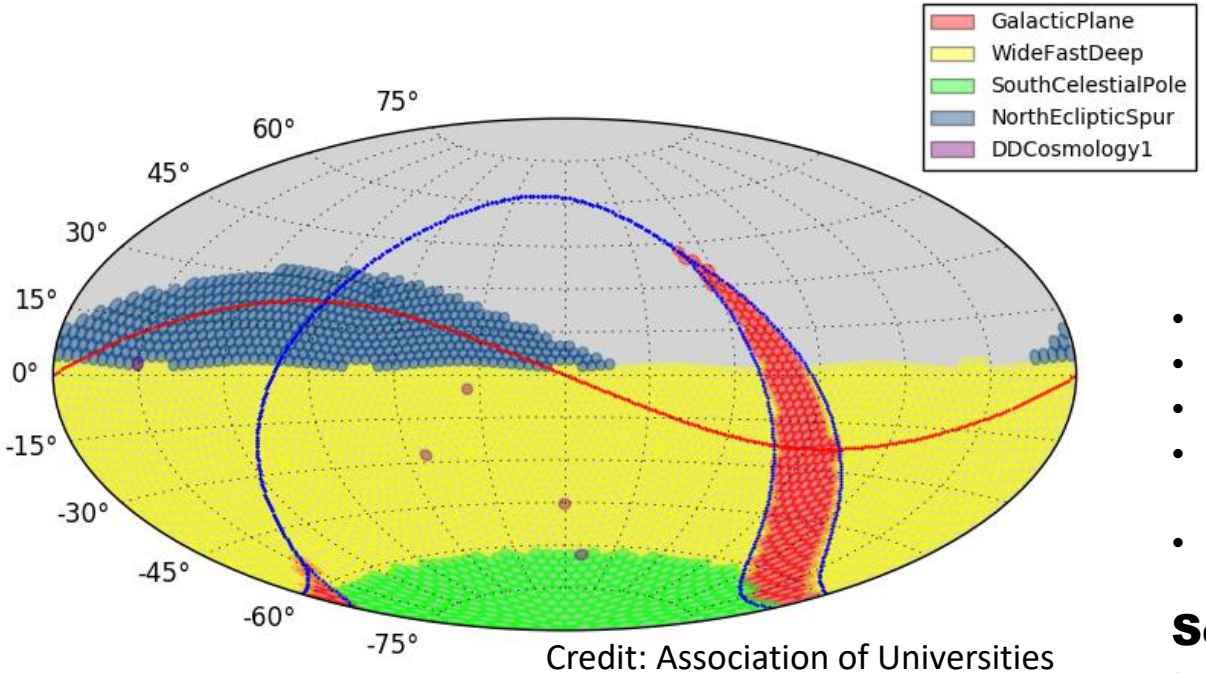
Crédit : ESA

THE VERA C. RUBIN OBSERVATORY

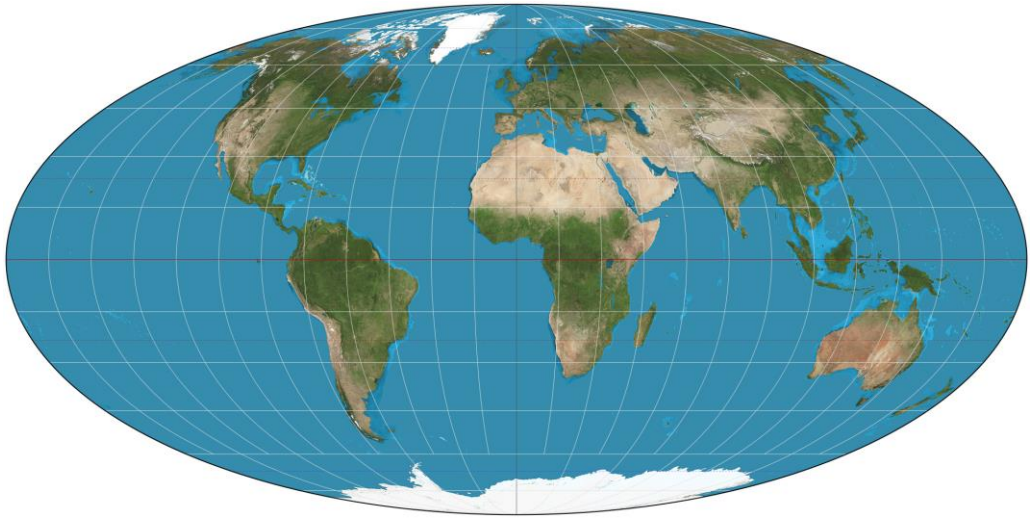
Cerro Pachón, Chile
First light in 2025

Crédit : Rubin Obs./NSF/AURA

The Large Synoptic Survey of Space and Time (LSST)



Credit: Association of Universities for Research in Astronomy, Inc



Credit: Strebe

- 10-year optical/near-IR survey of half of the sky (2025-2035)
- 1000 photos of the sky every night
- covers the whole observable sky every 3 nights
- after 10 years, each location of the sky will be imaged ~1,000 times (“first motion picture of our Universe”)
- 500 PB (5×10^6 GB) of images and data products in total (~20TB per night!)

Science goals :

- Probing dark energy and dark matter
- Taking an inventory of the solar system
- Exploring the transient optical sky
- Mapping the Milky Way

8.4-meter primary mirror

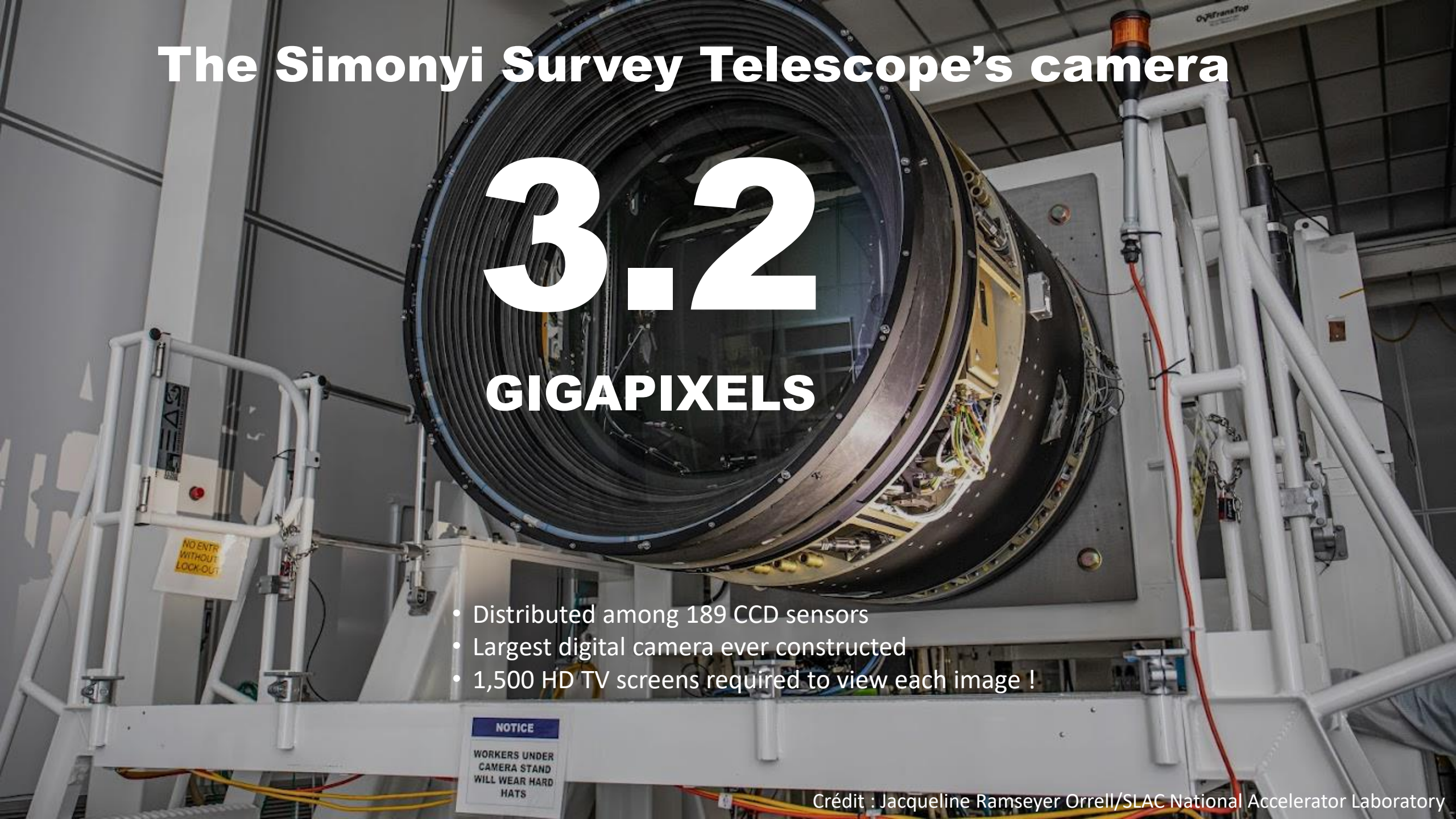
LSST
Legacy Survey of Space and Time

The Simonyi Survey Telescope's camera

3.2

GIGAPIXELS

- Distributed among 189 CCD sensors
- Largest digital camera ever constructed
- 1,500 HD TV screens required to view each image !



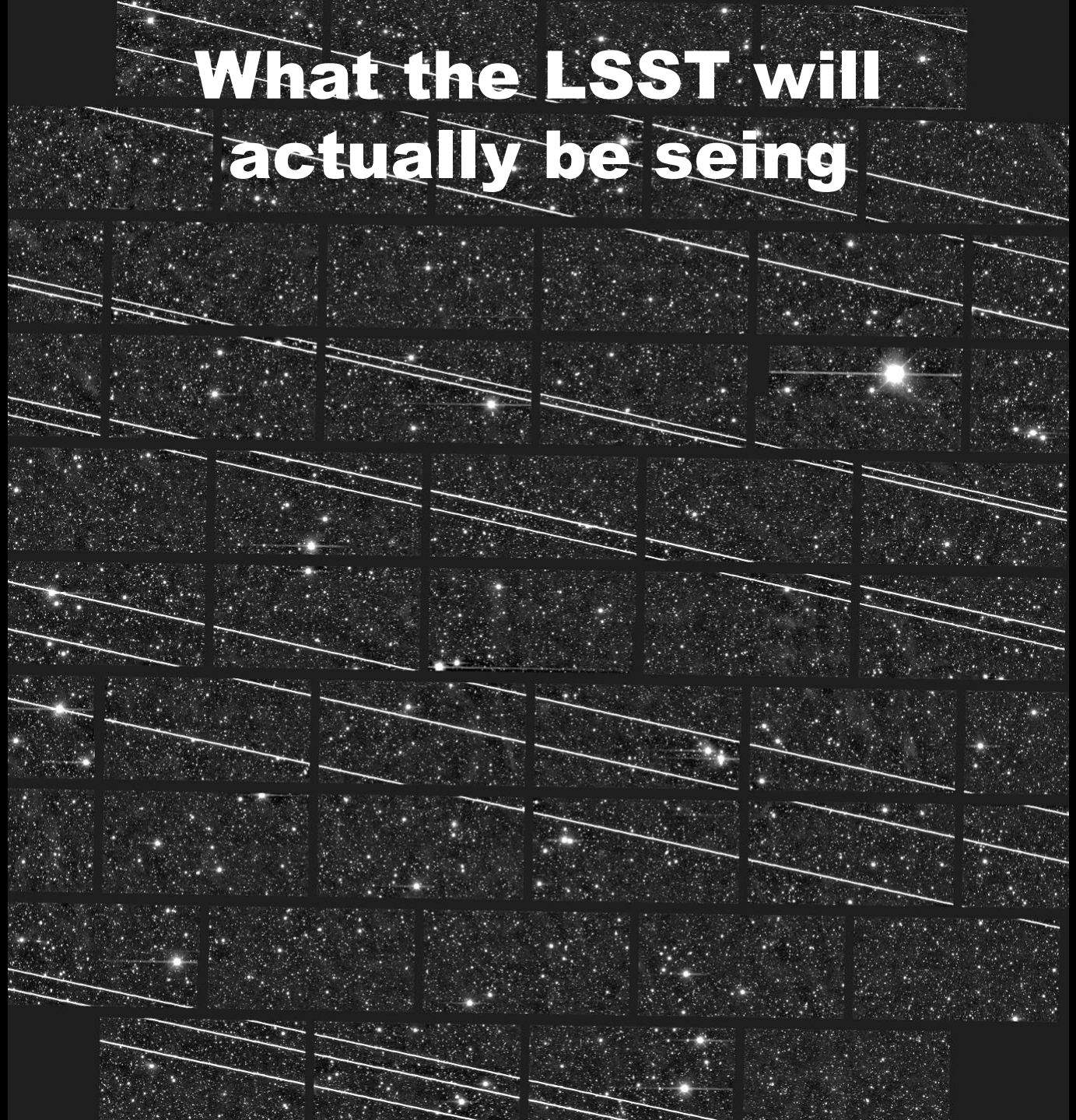
Crédit : Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory

What the LSST should see

2.6 ppm of LSST's ultimate sky coverage (20,000 square degrees)

Credit: LSST

What the LSST will actually be seing

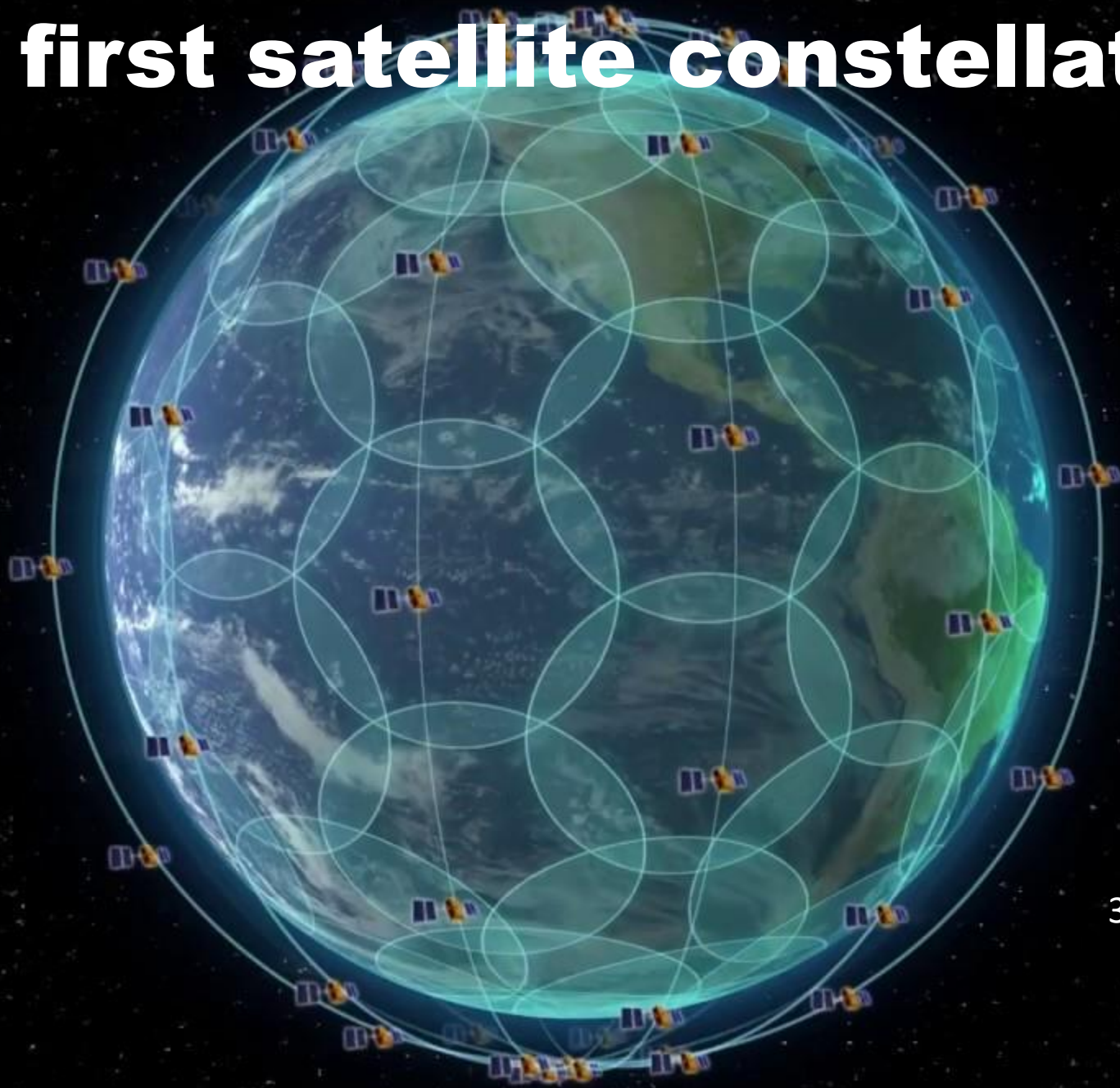


Crédit : NOIRLab/NSF/AURA

Satellite megaconstellation

A group of 100-100,000 artificial satellites working together as a system to serve a common goal

The first satellite constellations



Iridium (Motorola)
(1997-2002)
66 satellites in LEO

Globalstar
(1999-2002)
48 satellites in LEO

Orbcomm
(1995-2000)
31 satellites in LEO

2019: First Starlink batch

(60 satellites)

Credit: SpaceX

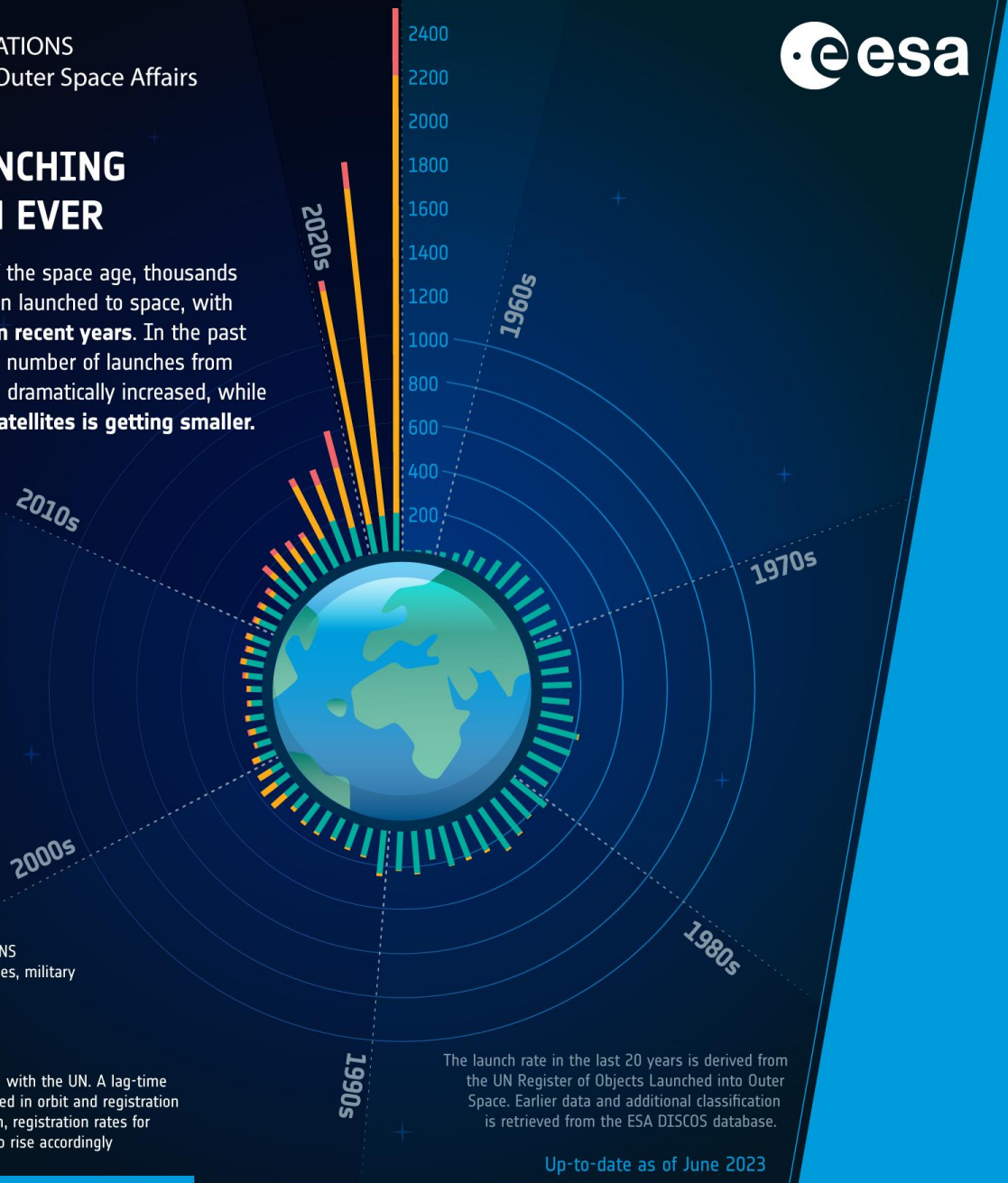
Credit: Marco Langbroek

UNITED NATIONS
Office for Outer Space Affairs

esa

WE'RE LAUNCHING MORE THAN EVER

Since the beginning of the space age, thousands of spacecraft have been launched to space, with a **dramatic increase in recent years**. In the past couple of decades, the number of launches from private companies has dramatically increased, while the **average size of satellites is getting smaller.**



- NON-COMMERCIAL MISSIONS
  e.g. civil agencies, universities, military
- COMMERCIAL MISSIONS
  e.g. private companies
- UNREGISTERED OBJECTS
  Objects yet to be registered with the UN. A lag-time between objects being placed in orbit and registration is common practice. As such, registration rates for recent years will continue to rise accordingly

The launch rate in the last 20 years is derived from the UN Register of Objects Launched into Outer Space. Earlier data and additional classification is retrieved from the ESA DISCOS database.

Up-to-date as of June 2023

#SpaceSustainability **#SpaceCare**

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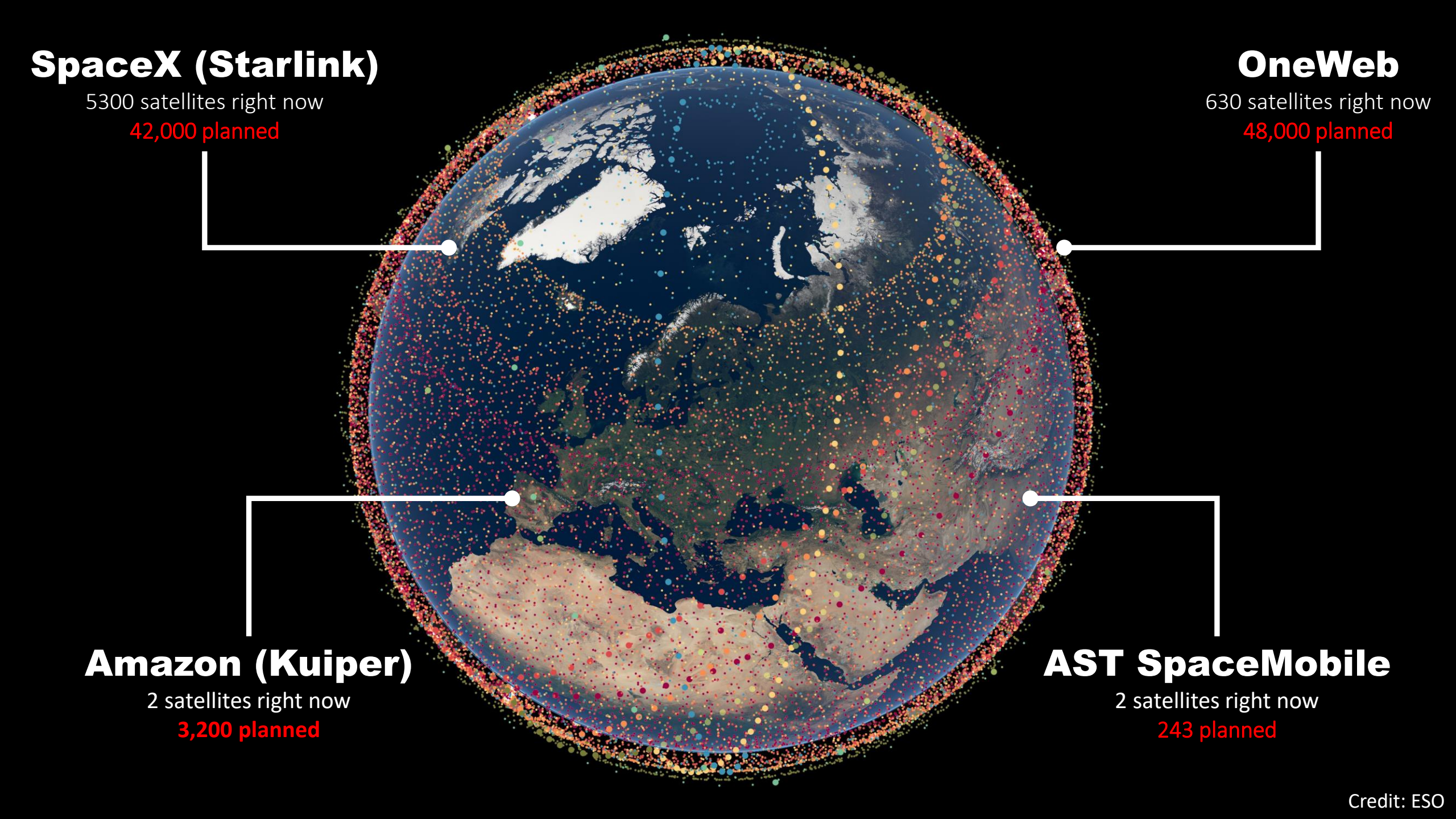
ORBITING NOW

active satellite orbit data

9200+

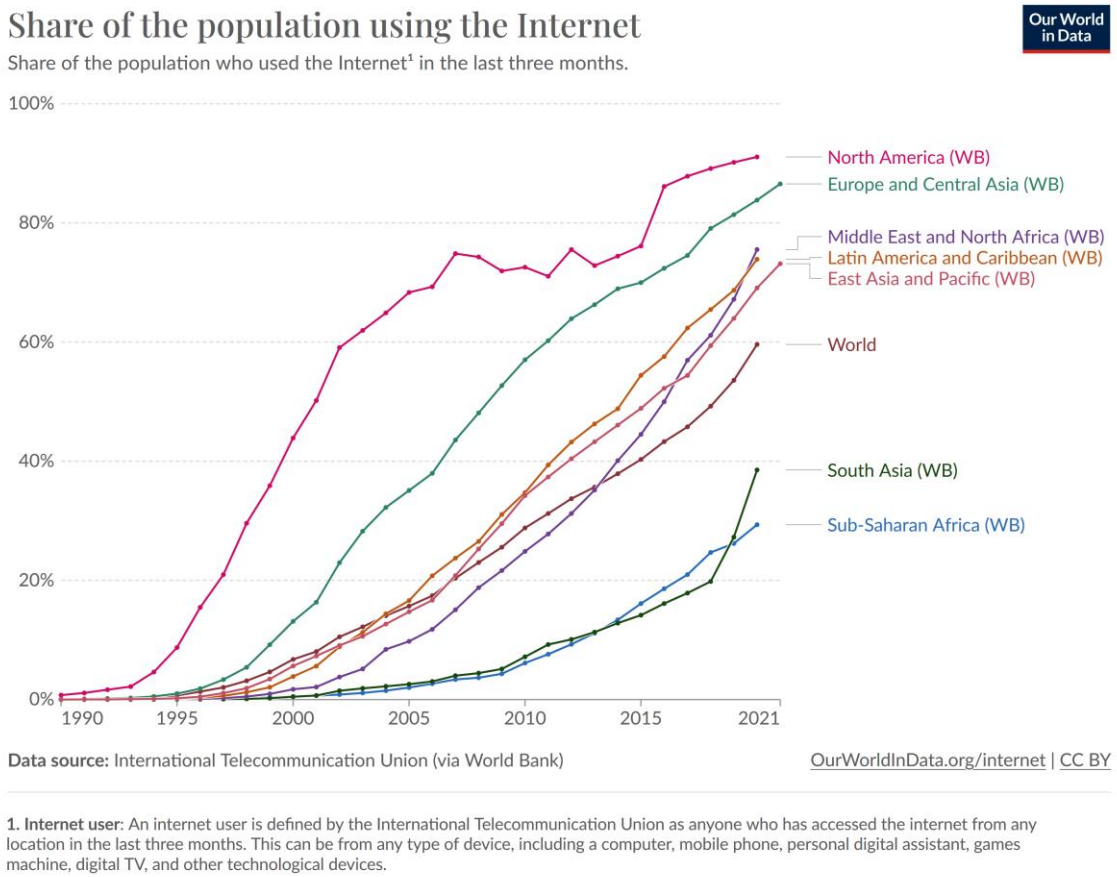
(as of January 2024)

https://orbit.ing-now.com/

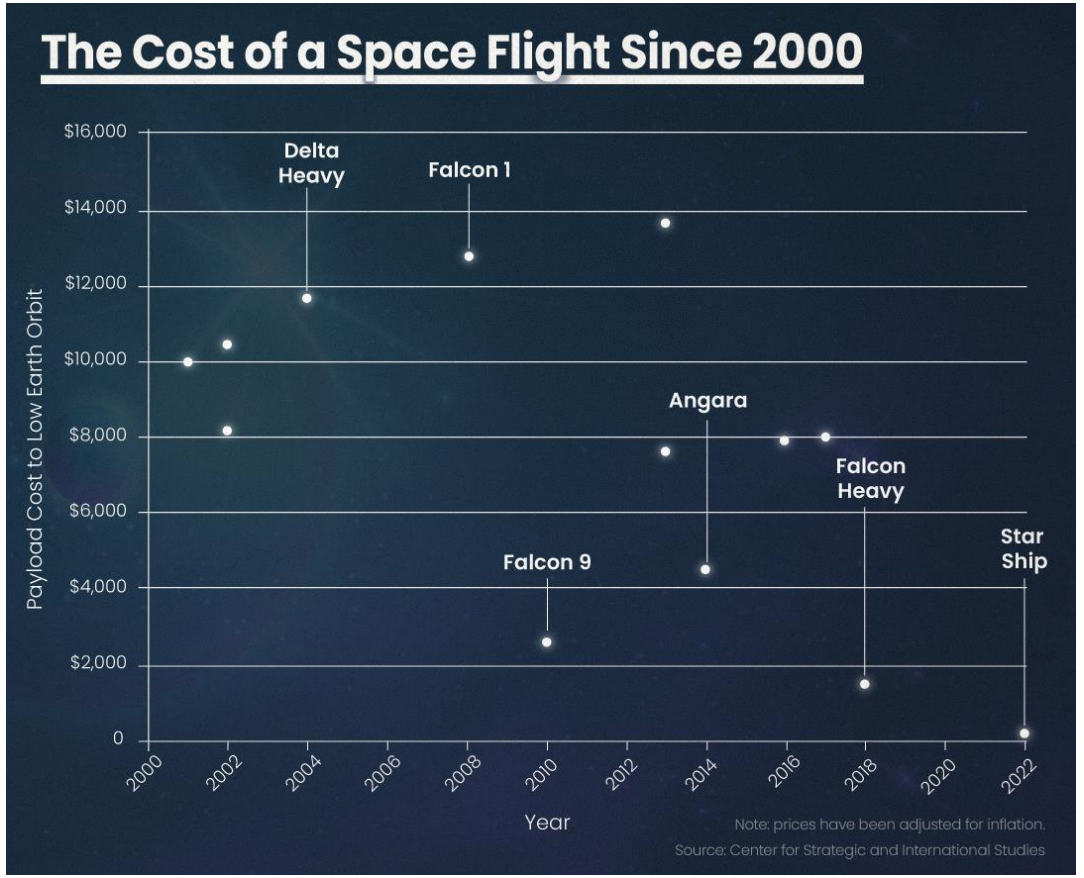

SpaceX (Starlink)
5300 satellites right now
42,000 planned
OneWeb
630 satellites right now
48,000 planned
Amazon (Kuiper)
2 satellites right now
3,200 planned
AST SpaceMobile
2 satellites right now
243 planned
Credit: ESO

Why now?

About **3 billion people** globally don't have internet access



Reusable rockets have reduced the cost of launch per kilogram



"The global space industry could generate revenue of more than **$1 trillion or more in 2040**, up from $350 billion, currently" (Morgan Stanley)

ann19035 — Announcement

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3 June 2019

IAU Statement on Satellite Constellations

Click to Enlarge

Over the past decades, considerable effort has gone into designing, building, and deploying satellites for many important purposes. Recently networks, known as satellite constellations, have been deployed and are planned in ever greater numbers in mainly low-Earth orbits for a variety of purposes, including providing communication services to underserved or remote areas [1]. Until this year, the number of such satellites was below 200, but that number is now increasing rapidly, with plans to deploy potentially tens of thousands of them. In that event, satellite constellations will soon outnumber all previously launched satellites.

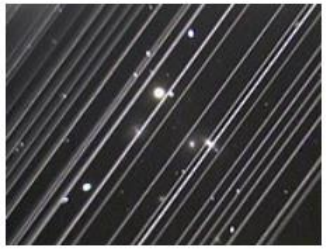
The International Astronomical Union (IAU) is concerned about these satellite constellations. The organisation, in general, embraces the principle of a dark and radio-quiet sky as not only essential to advancing our understanding of the Universe of which we are a part, but also as a resource for all humanity and for the protection of nocturnal wildlife. We do not yet understand the impact of thousands of these visible satellites scattered across the night sky and despite their good intentions, these satellite constellations may threaten both.

The scientific concerns are twofold. Firstly, the surfaces of these satellites are often made of highly reflective metal, and reflections from the Sun in the hours after sunset and before sunrise make them appear as slow-moving dots in the night sky. Although most of these reflections may be so faint that they are hard to pick out with the naked eye, they can be detrimental to the sensitive

About the Announcement

Id:
ann19035

Images



PR Image ann19035a
Trails made by Starlink satellites

Twitter, May 27, 2019

Credit: James Duncan Davidson

How Starlink will affect the LSST

- Simulations assuming 42,000 satellites show that 30% of all LSST images would contain at least one satellite trail.
- Nearly every LSST image taken during twilight would be affected by at least one satellite trail.

(Source : Vera C. Rubin observatory, 2020)

Credit: Rubin Observatory/NSF/AURA/B. Quint

Mitigating the effects of Starlink satellites

- Taking multiple exposures (2x15s instead of 1x30s)

This mitigation scenario would cost 8% of LSST observing time

- Decreasing satellite brightness below saturation threshold (7th magnitude)

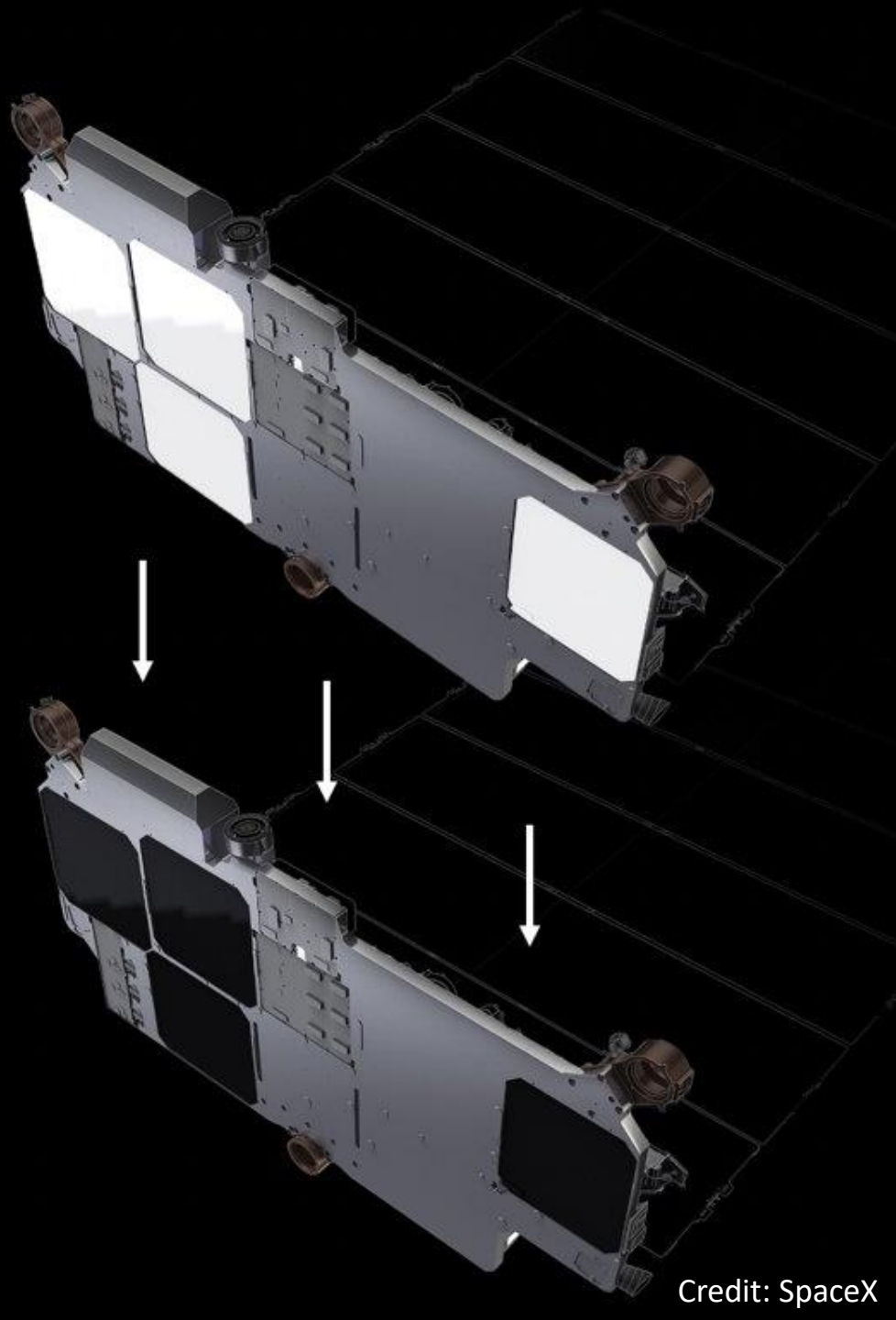
(Source : Vera C. Rubin observatory, 2020)

Credit: Rubin Observatory/NSF/AURA/B. Quint

DARKSAT

ANTENNAE MITIGATION ON STATION

Ground-based observations of our initial test experiment proved we can significantly reduce brightness. Subsequently, we developed a higher-performance option.

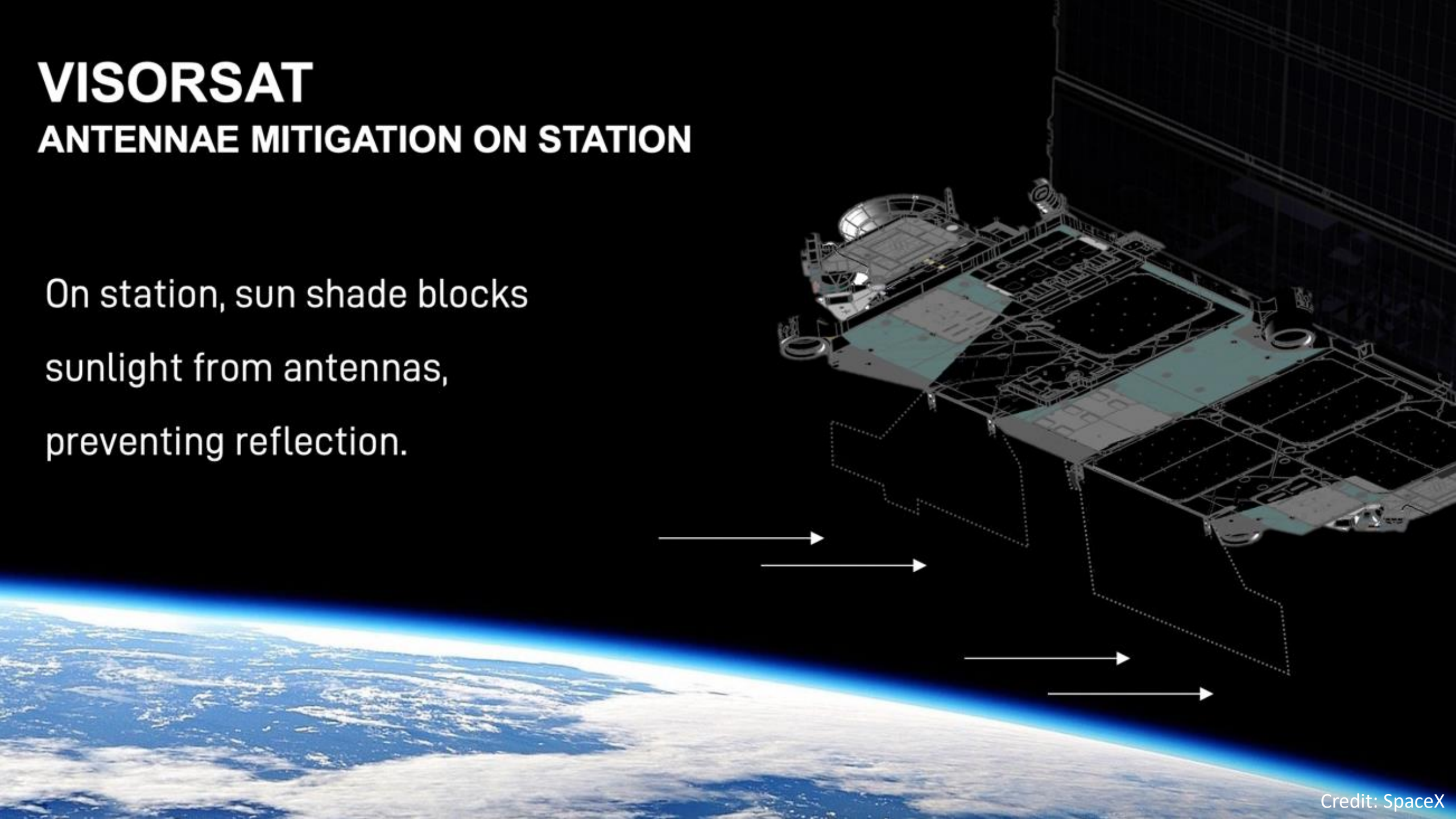


Credit: SpaceX

VISORSAT

ANTENNAE MITIGATION ON STATION

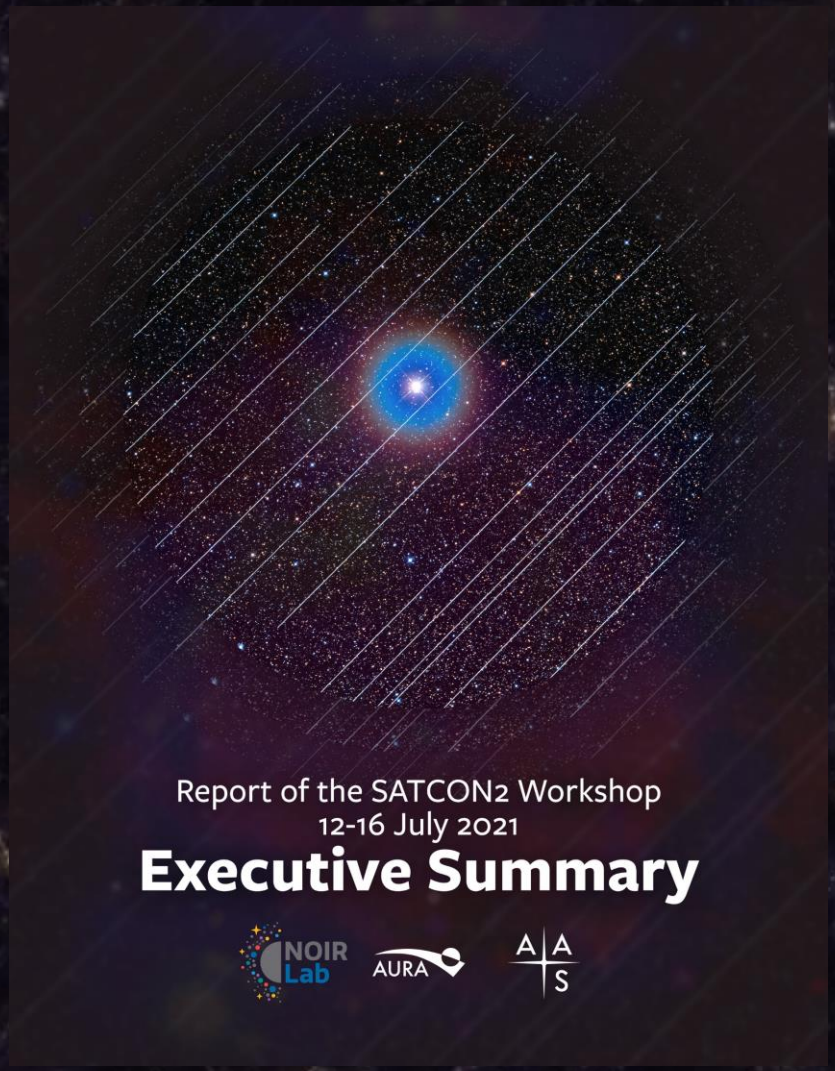
On station, sun shade blocks sunlight from antennas, preventing reflection.



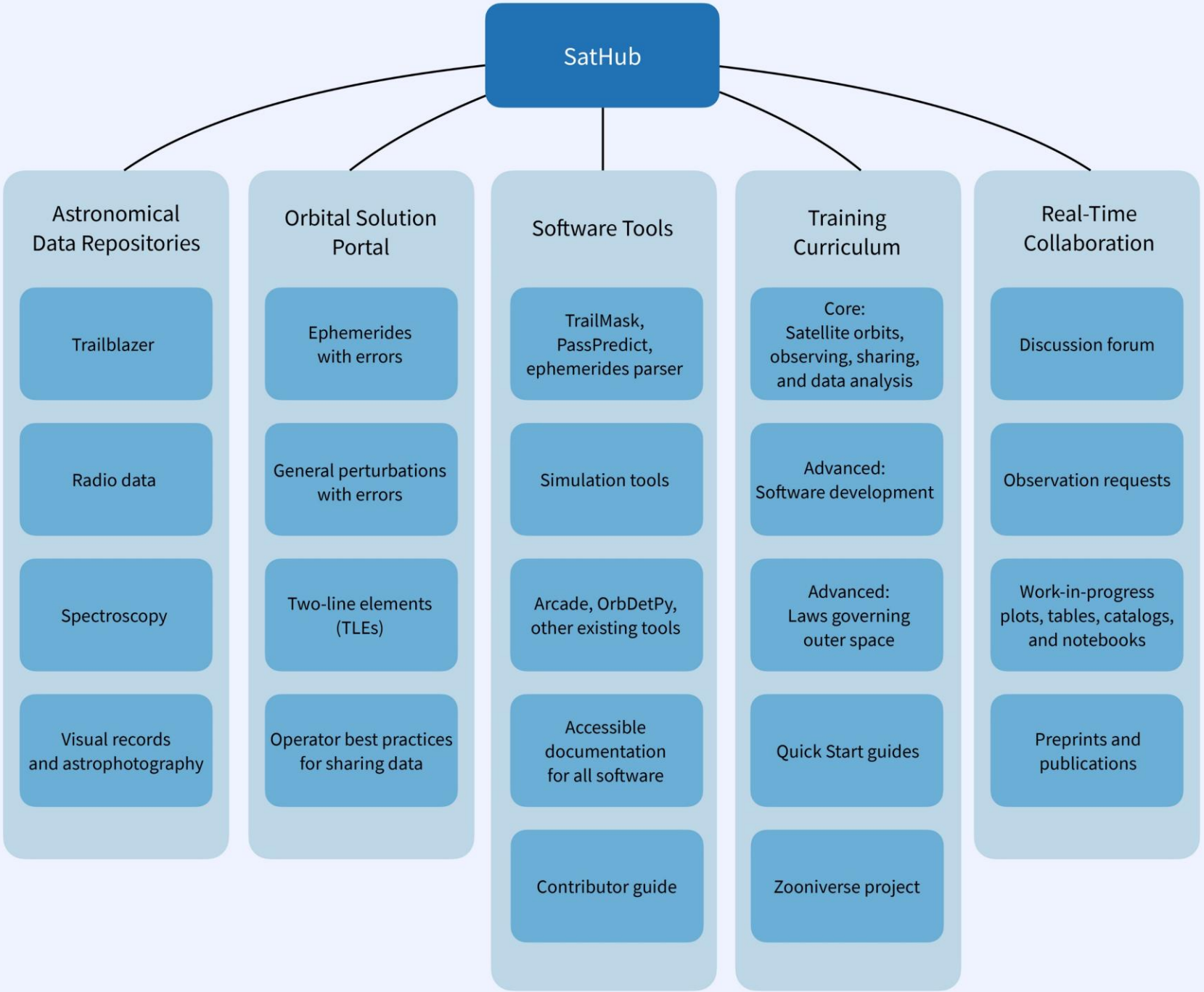
Credit: SpaceX

The SATCON workshops

2020



2021



Volunteers needed!

https://cps.iau.org/sathub/

https://cps.iau.org/

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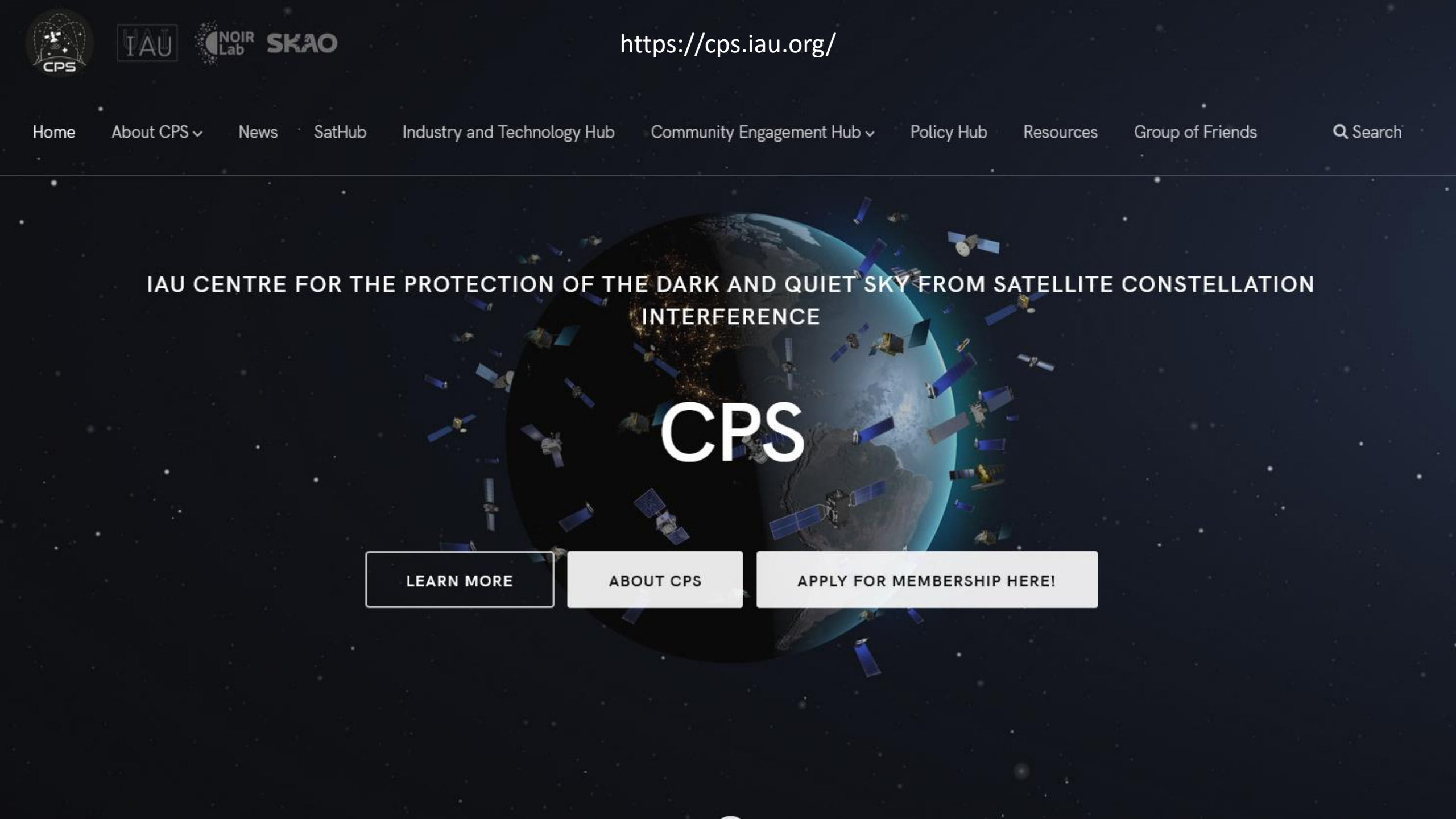
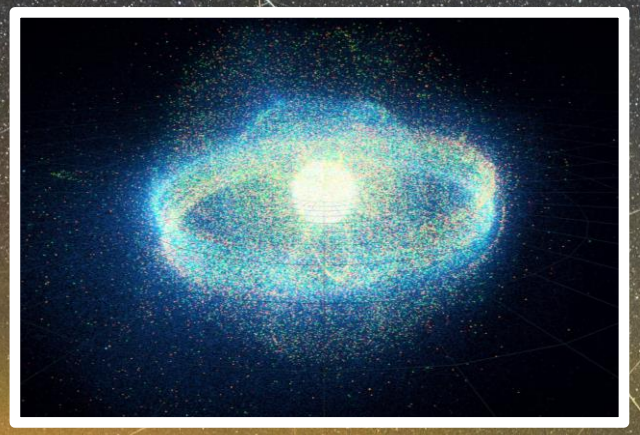


The impacts of megaconstellations are NOT limited to science



Exponential growth of orbital debris
(Kessler et al, 2016)

Ozone layer depletion through rocket launches
(Ross, 2018)

Loss of the night sky for indigenous peoples
(Hamacher et al, 2020)

Disruption of bird migration
(Lintott & Lintott, 2020)

Credit: Joshua Rozells

Regulating space traffic

- The **1967 Outer Space Treaty** (OST) is currently the primary framework for international space law.

  - *Article I : There shall be freedom of scientific investigation in outer space […], and States shall facilitate and encourage international cooperation in such investigation.*
  - *Article II : Outer space […] is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.*
  - *Article III : States Parties to the Treaty shall carry on activities in the exploration and use of outer space […] in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding.*

- According to the OST, signatory States are **already required** to conduct environmental assessments **before** licensing megaconstellations. **States are therefore already violating international law**.
- The OST might prove insufficient to regulate megaconstellations : **no enforcement mechanism**
- There's a growing need for a new international legal framework designed to explicitly include private actors.

Conclusion

- There’s a new space race going on, and **we are losing the night sky** over it
- Current space laws are **underdeveloped** and **unenforceable**
- **Urgent work is needed** at all levels (technical, scientific, policy) to mitigate the environmental impact of satellite megaconstellations

Crédit : Keesscherer

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