

Planetary Sunshades for Solar Radiation Management

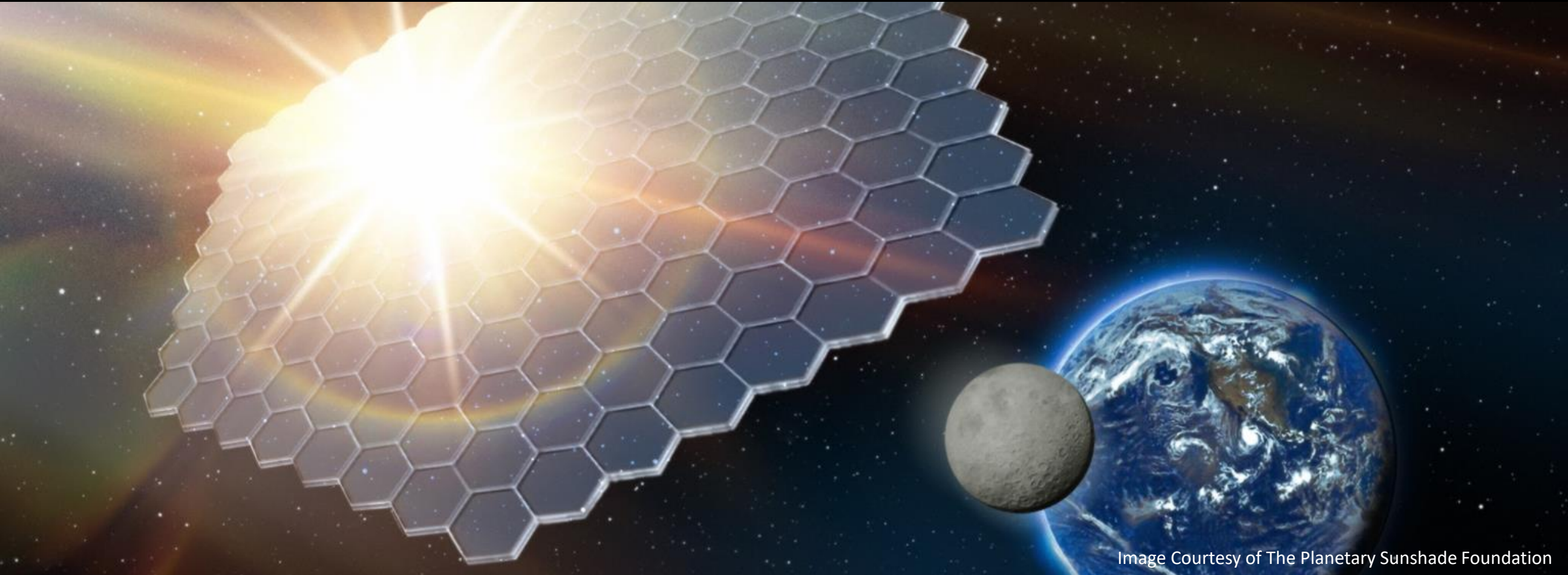


Image Courtesy of The Planetary Sunshade Foundation

Les Johnson (NASA MSFC, USA)

Ross Centers (Ethos Space, USA)

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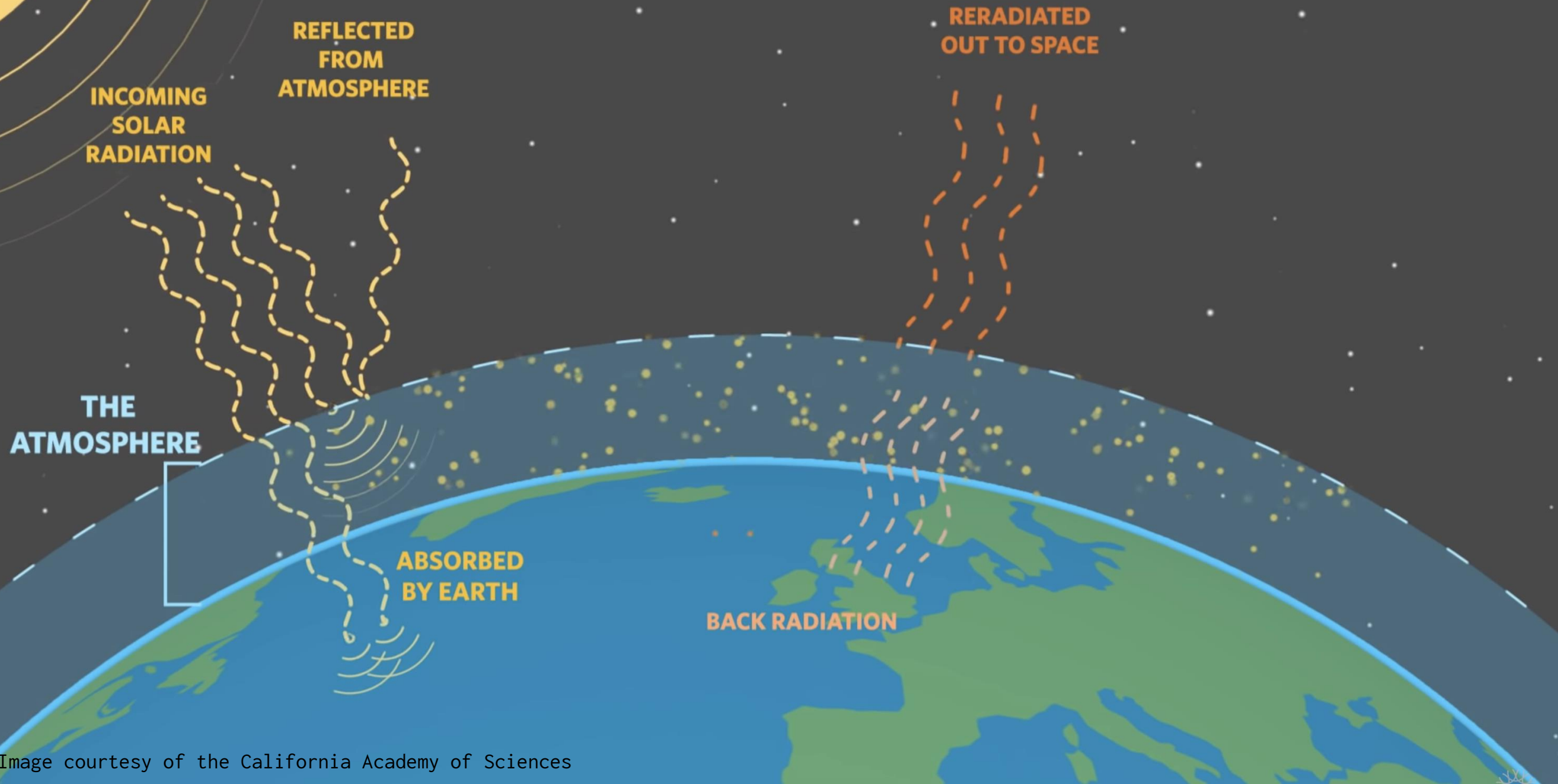
Patric Seefeldt (Institute of Space Systems, DLR, Germany)

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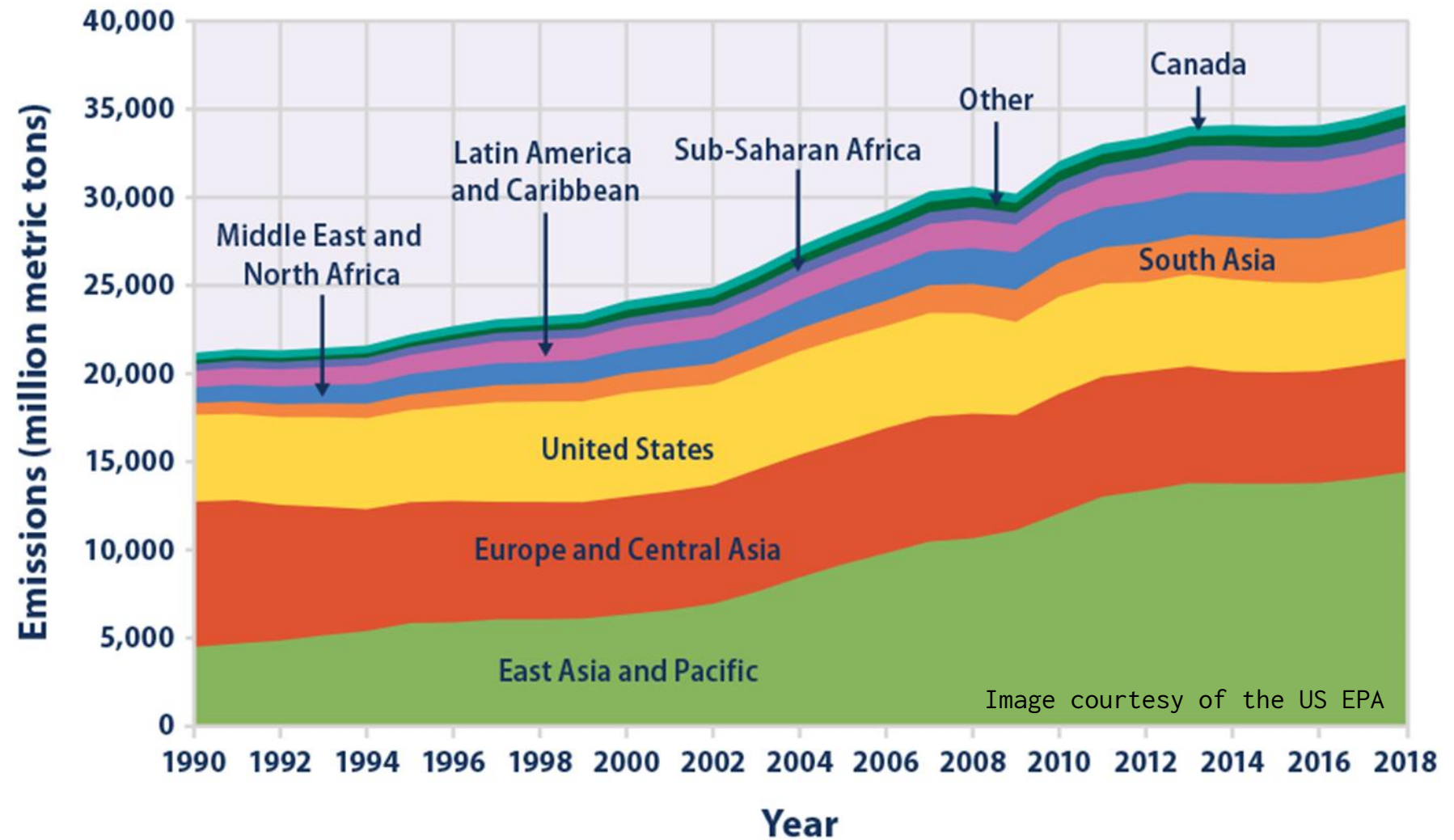
Dana Turse (Redwire, USA)

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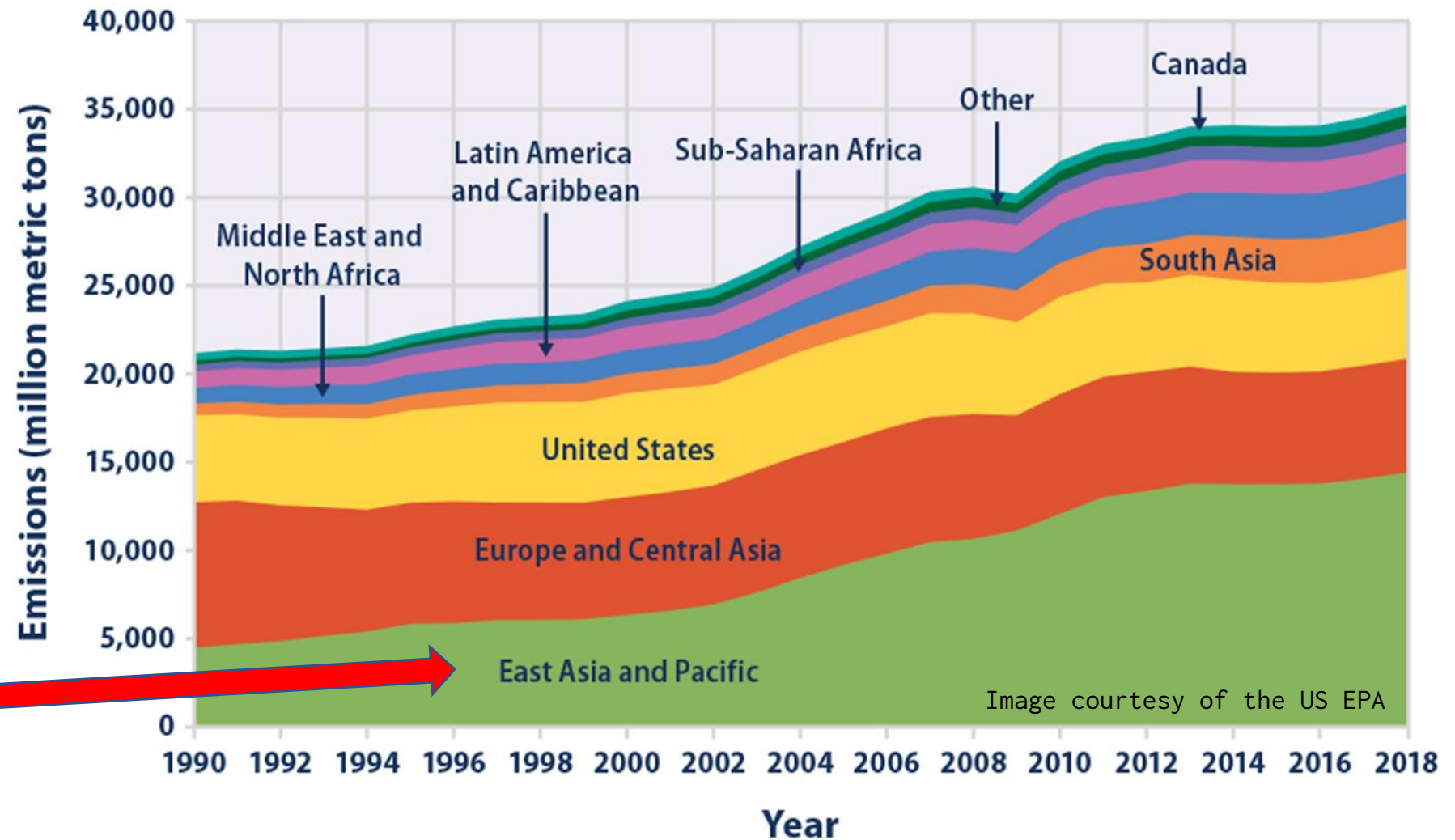
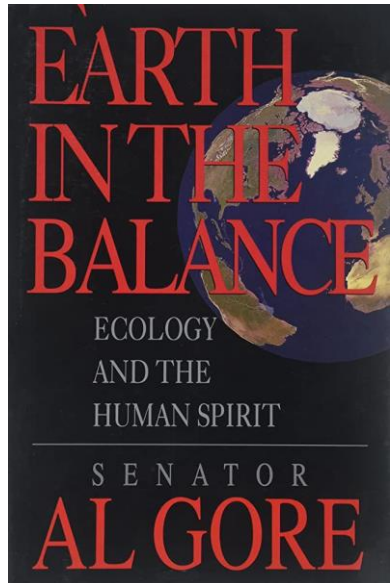
The Earth's Radiation Balance is Out of Balance!



The data that should cause you to wake up and pay attention



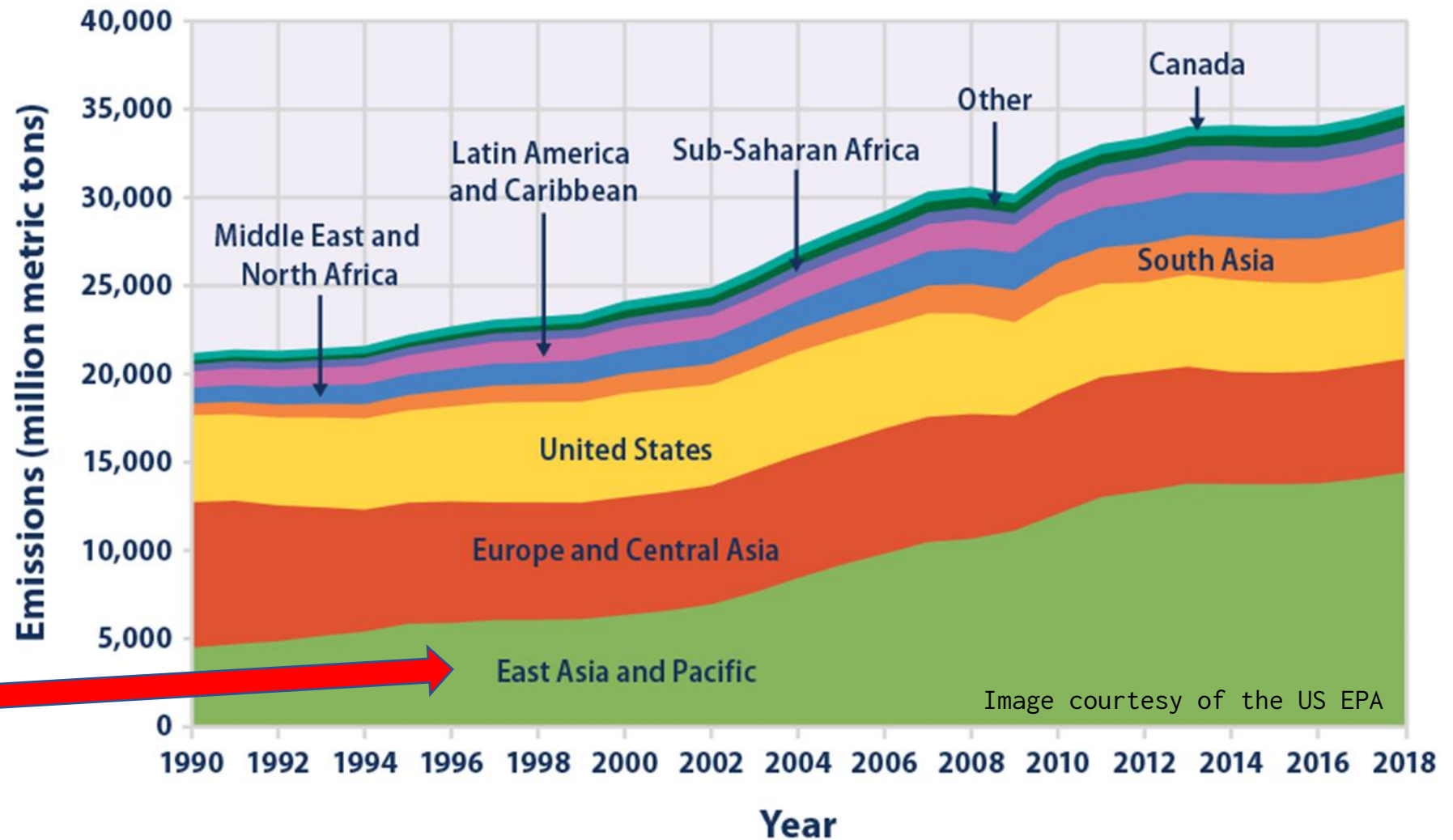
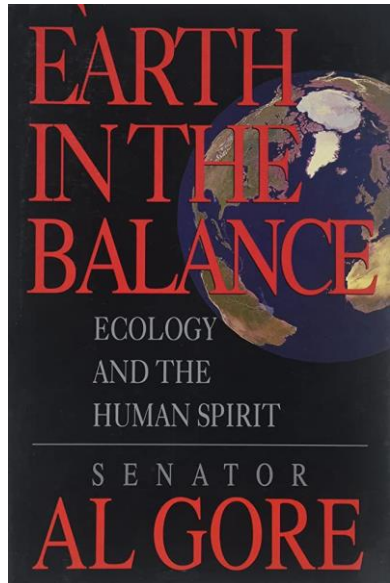
The data that should cause you to wake up and pay attention



When published, the green (Carbon) emissions were less than half of what they are today.

The problem has only gotten harder to solve...

The data that should cause you to wake up and pay attention

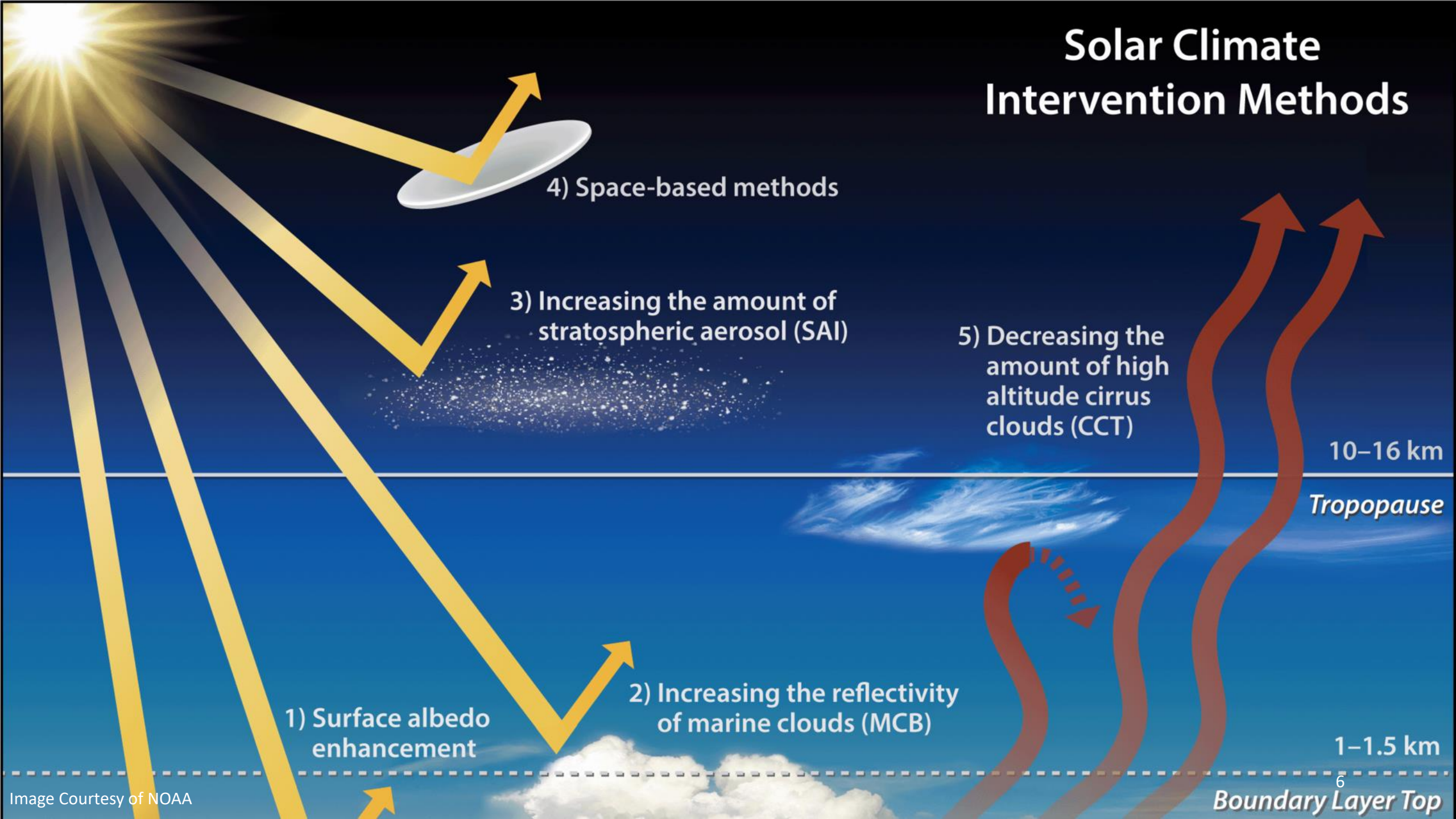


When published, the green emissions were less than half of what they are today.

The problem has only gotten harder to solve...

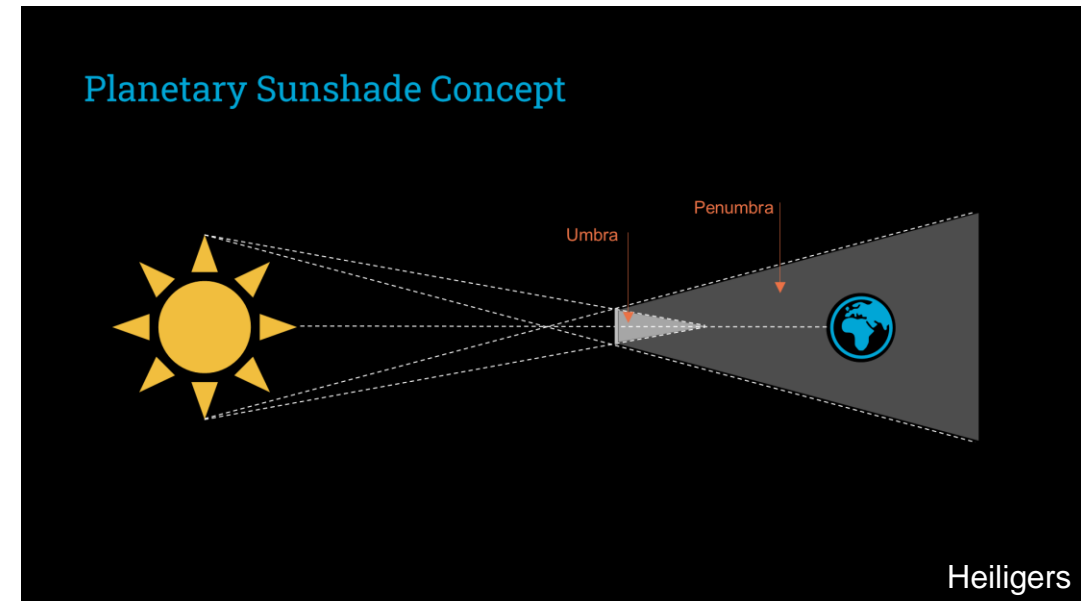
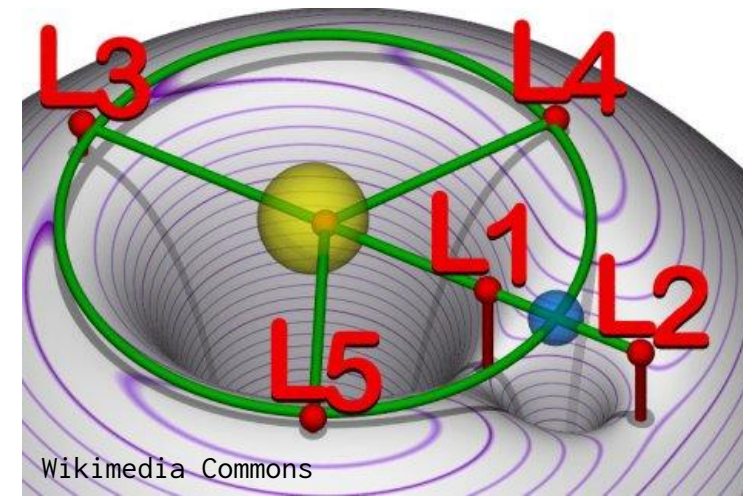
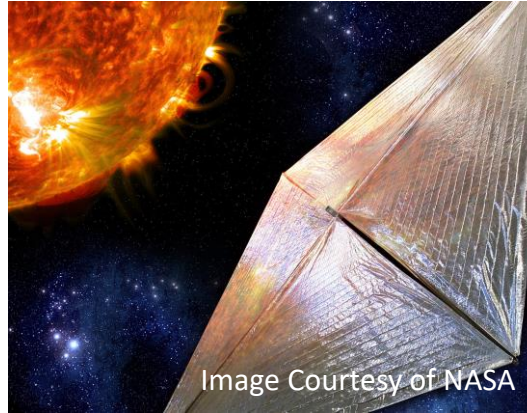
In May 3, 2023 US Congressional testimony from the US Deputy Secretary of Energy, it will take an estimated \$50 Trillion to decarbonize the US economy alone

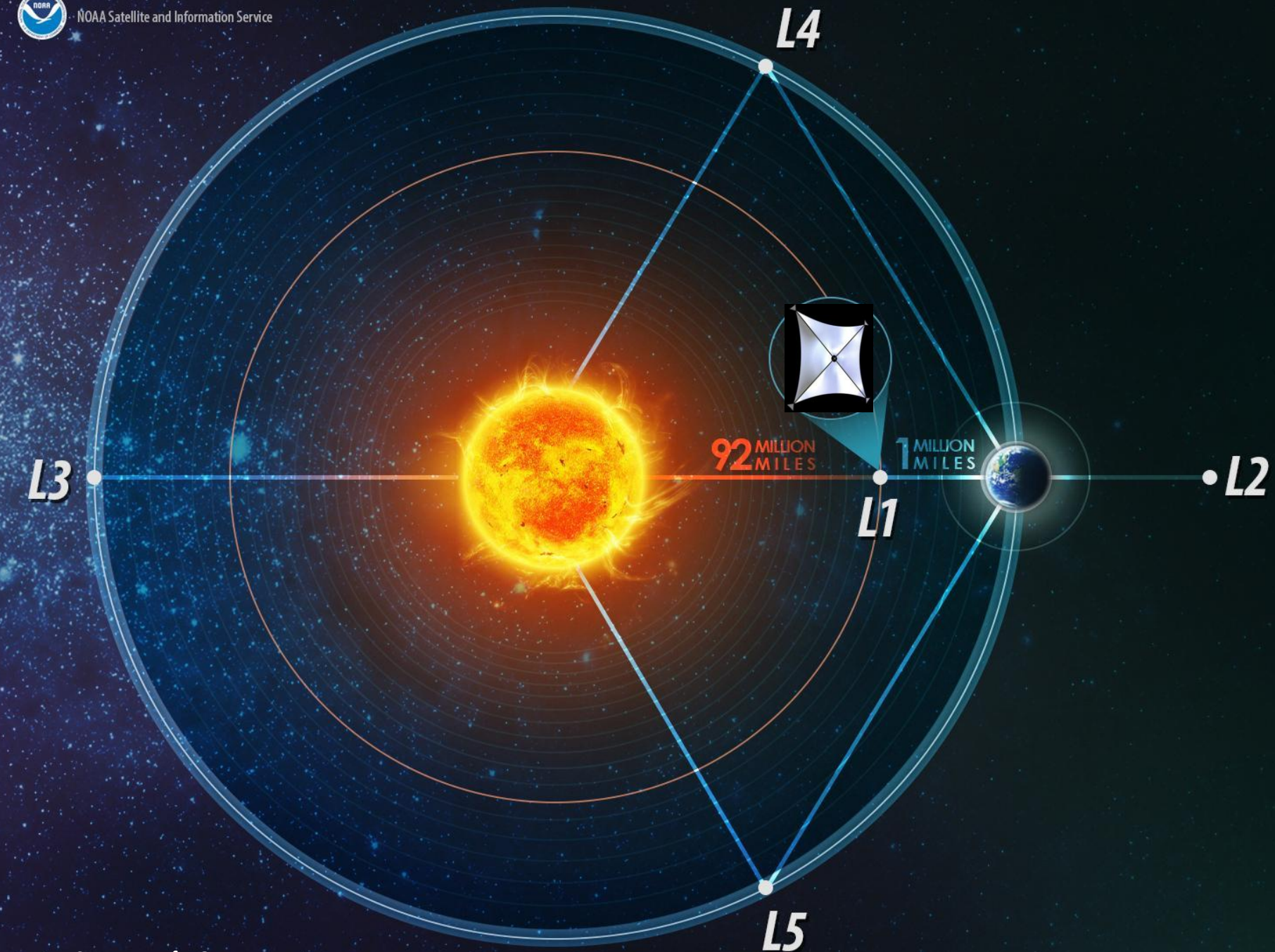
Solar Climate Intervention Methods



Planetary Sunshade Fundamentals

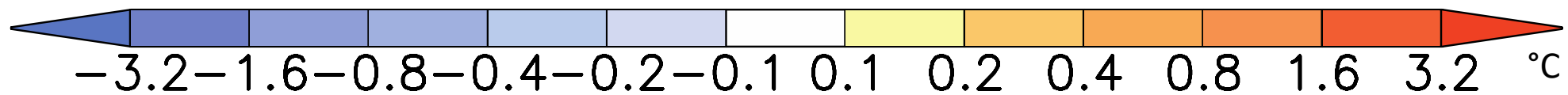
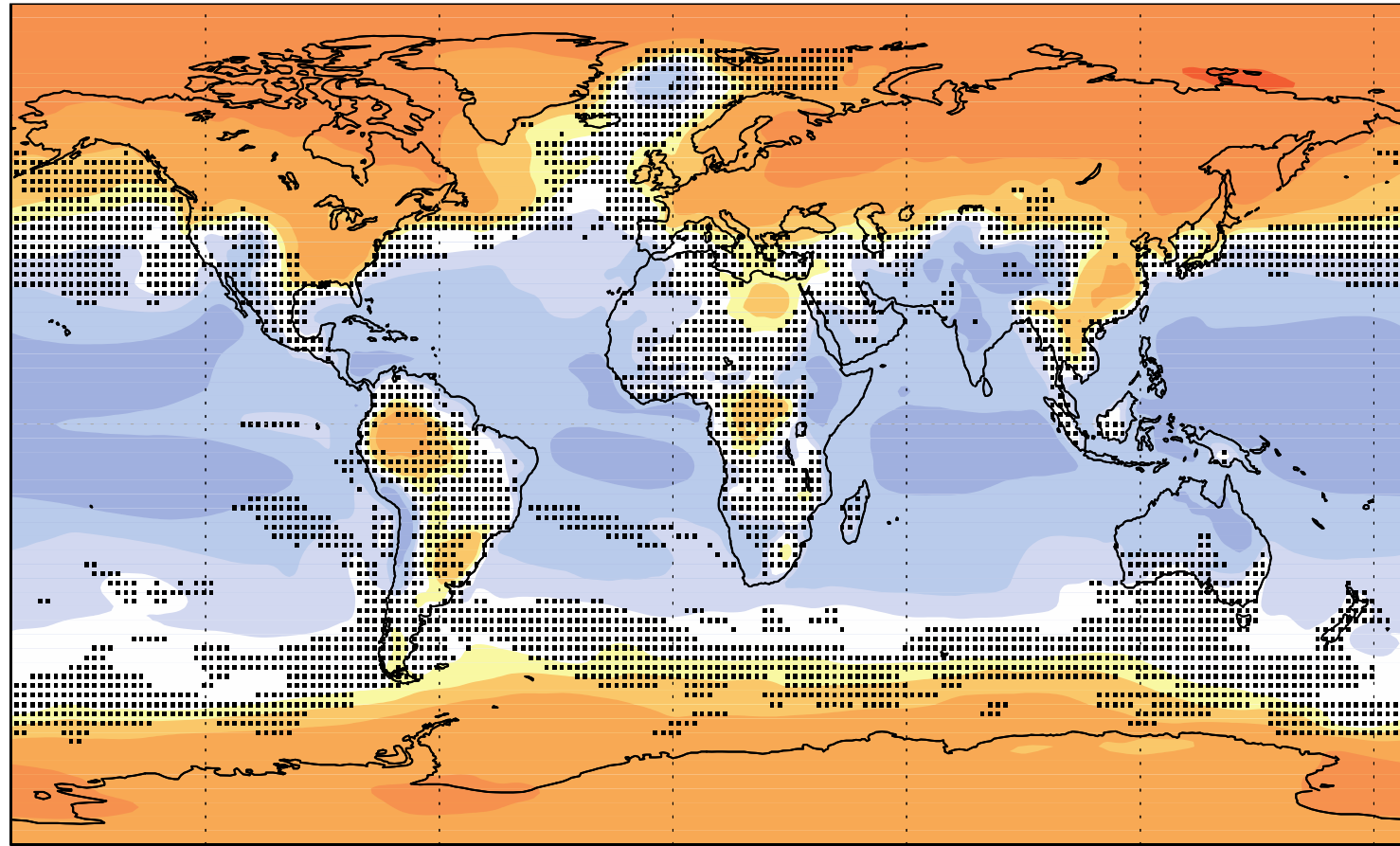
- Orbits at Sun-Earth Lagrange 1
- Control by solar sailing
- Area: $\sim 2\text{M km}^2$ for 1° cooling
 - Multiple small sunshades
- Positive externalities:
 - Easy to control and turn “on” and “off,” if needed
 - Can be a multinational collaboration
 - Could send 70TW to Earth if coupled with embedded photovoltaics and power beaming
 - Possible application to Planetary Defense





A Planetary Sunshade Can Mitigate Some Effects of Global Warming

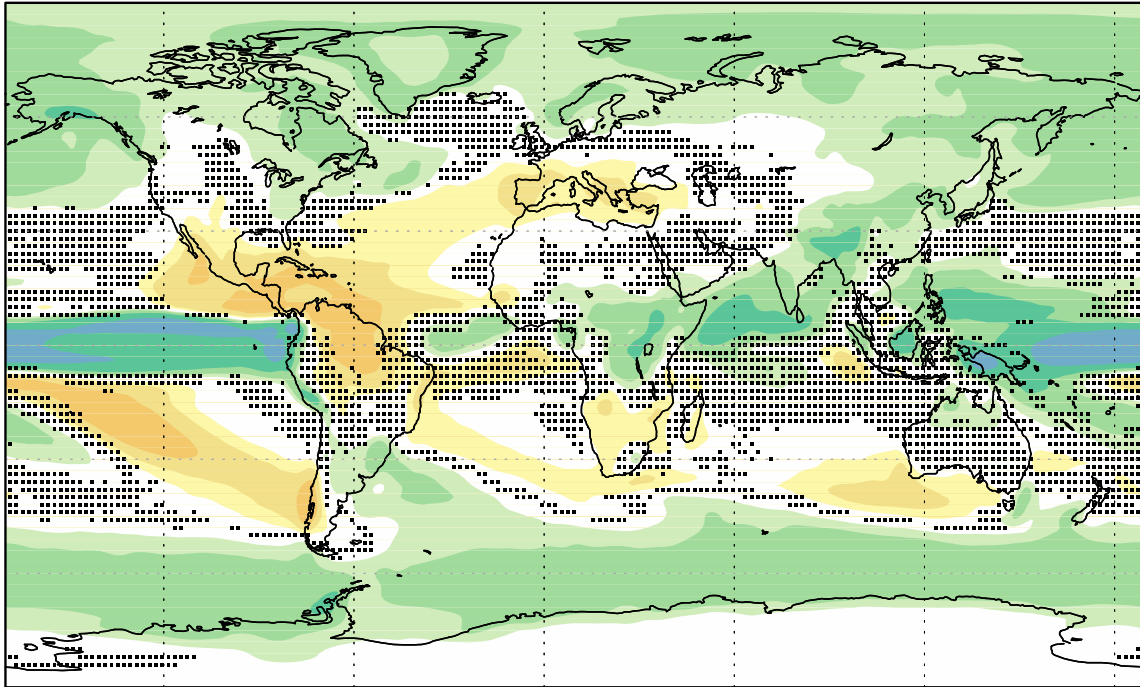
If you increase CO₂ and turn down the sun
Sunshades “overcool” the tropics and “undercool” the poles



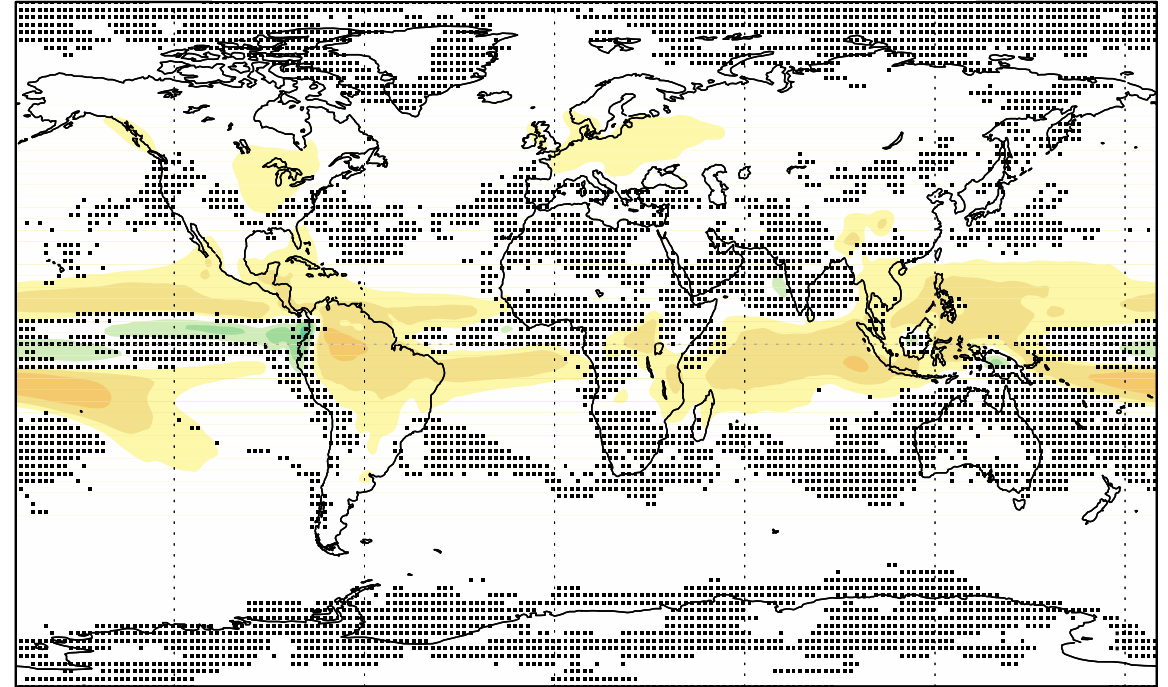
Stippling: disagreement on sign amongst 12 models

If you increase CO₂ and turn down the sun
Precipitation goes down (but it would have gone up under global warming)

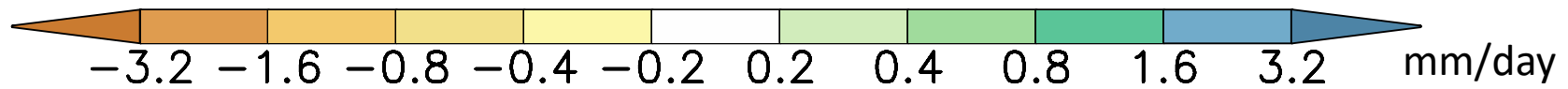
Change due to high CO₂



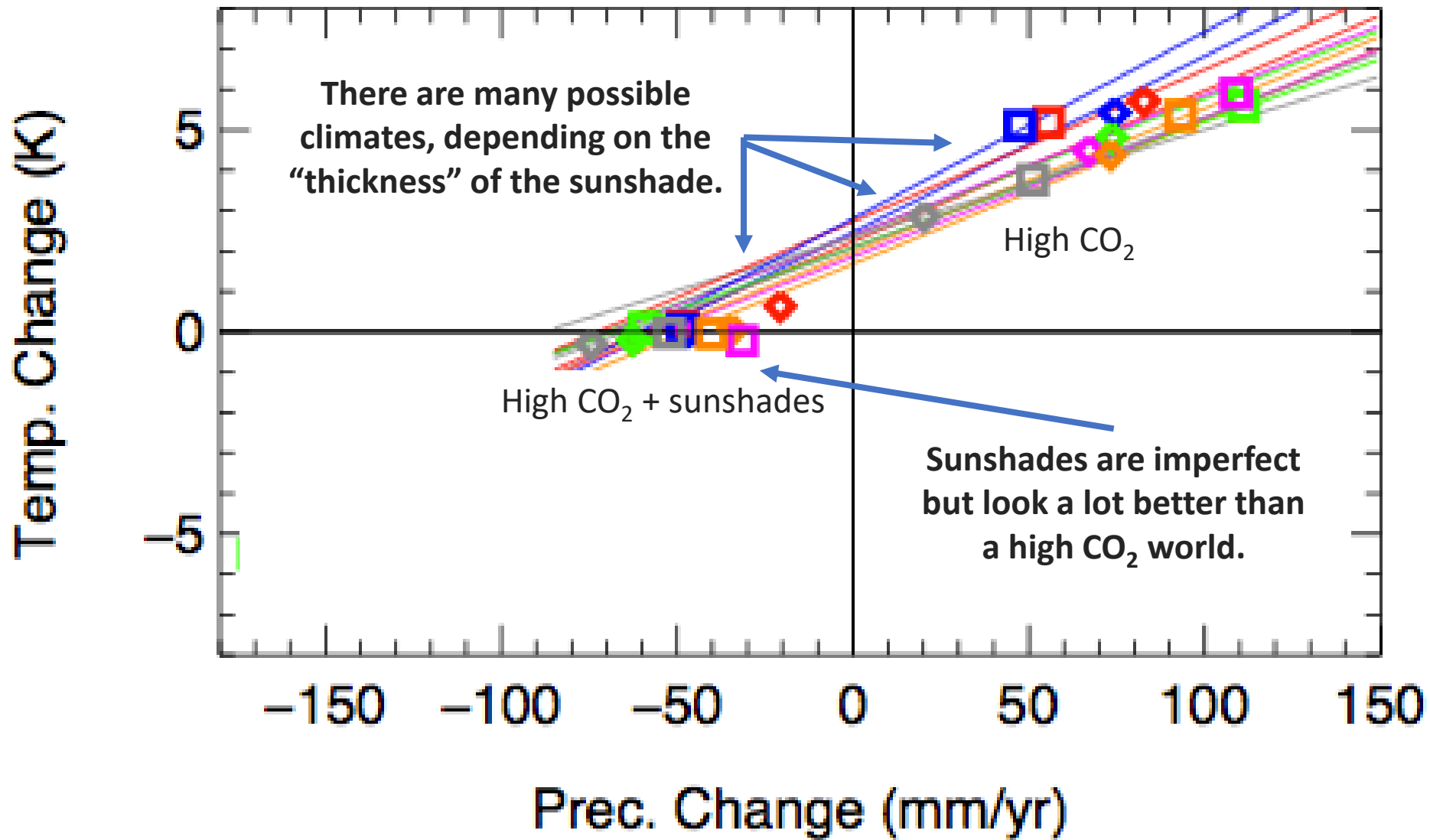
Change due to sunshades



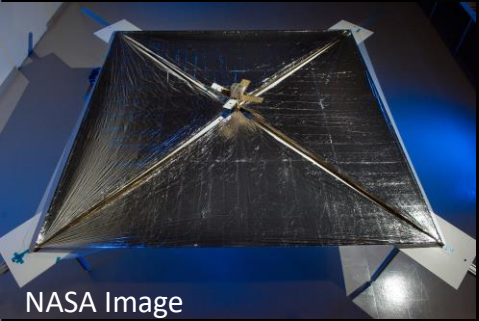
Precipitation



Stippling: disagreement on sign amongst 12 models



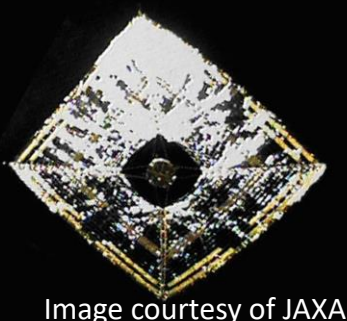
Sunshade Technology is Being Developed for Solar Sails



NanoSail-D (2010)
NASA

Earth Orbit
Deployment Only

3U CubeSat
10 m²



IKAROS (2010)
JAXA

Interplanetary
Full Flight

315 kg Smallsat
196 m²

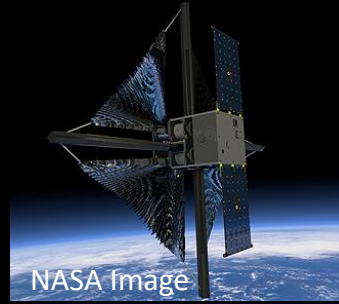


LightSail-1 & 2
(2015/2019)
The Planetary
Society

Earth Orbit
Flight

3U CubeSat

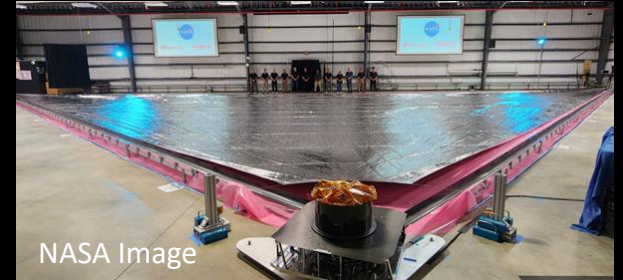
32 m²



ACS3 (2023)
NASA

Earth Orbit
Deployment Only

6U CubeSat
84 m²

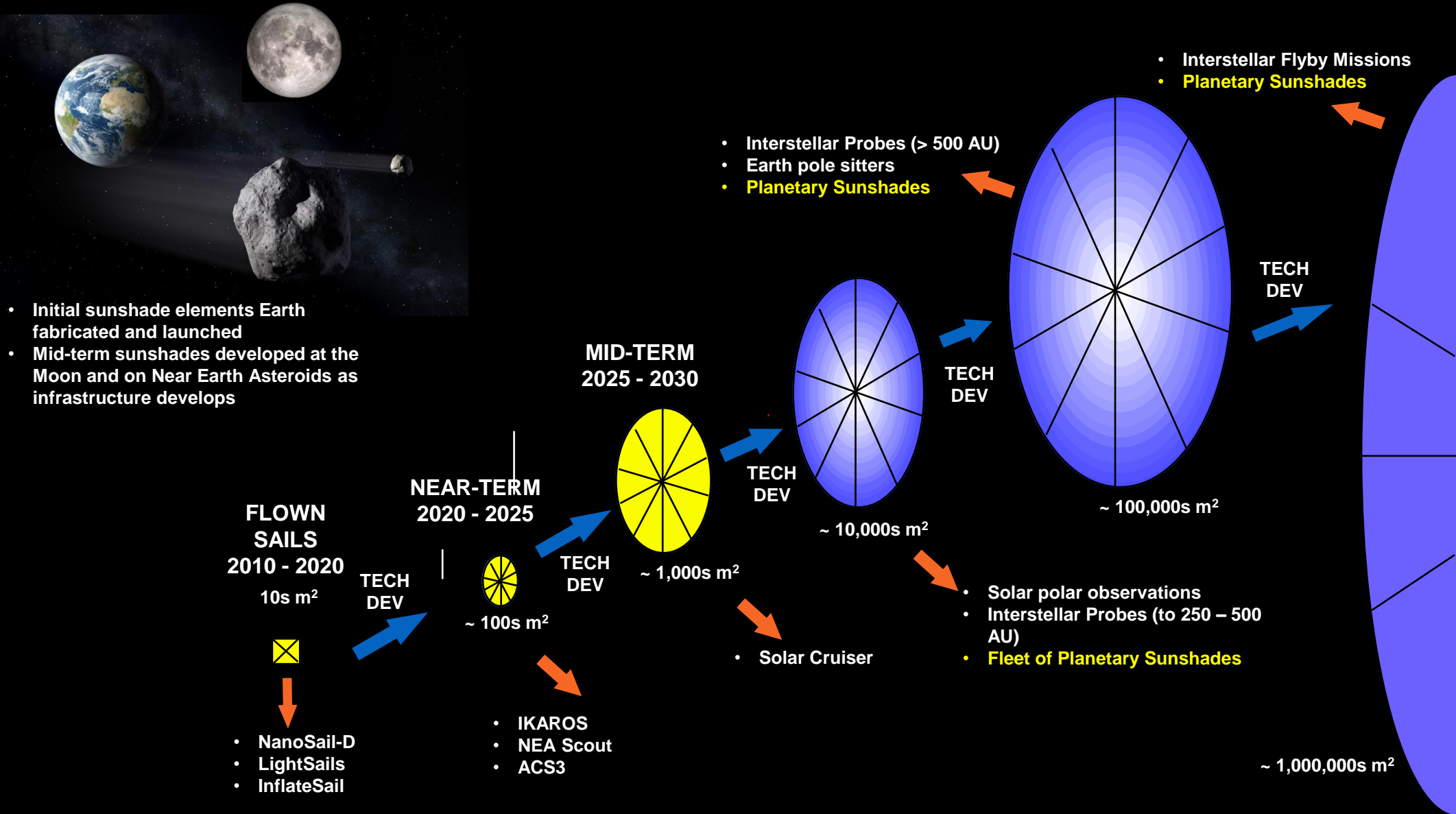


NASA/Ball/Redwire
(2028)

Interplanetary Full
Flight

111 kg smallsat
1653 m²

The Future of Solar Sail Propulsion





Elon Musk ✓
@elonmusk



Replying to [@elonmusk](#) and [@Erdyastronaut](#)

Building 100 Starships/year gets to 1000 in 10 years or
100 megatons/year or maybe around 100k people per
Earth-Mars orbital sync

6:01 PM · Jan 16, 2020 · Twitter for iPhone



Elon Musk ✓
@elonmusk

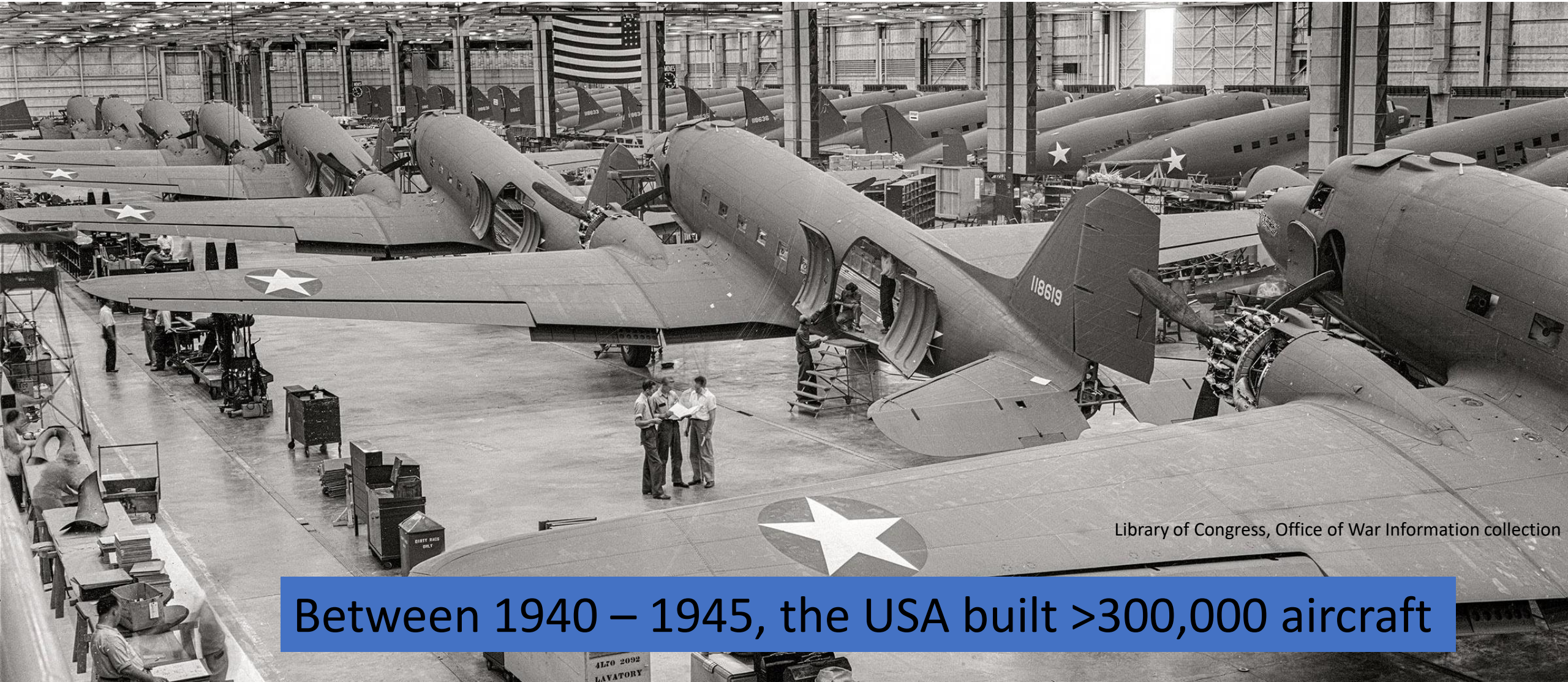


Replying to [@Erdyastronaut](#)

Starship design goal is 3 flights/day avg rate, so ~1000
flights/year at >100 tons/flight, so every 10 ships yield 1
megaton per year to orbit

5:56 PM · Jan 16, 2020 · Twitter for iPhone

Building and Launching Sunshade Sailcraft at Industrial Scale is Doable



Library of Congress, Office of War Information collection

Between 1940 – 1945, the USA built >300,000 aircraft

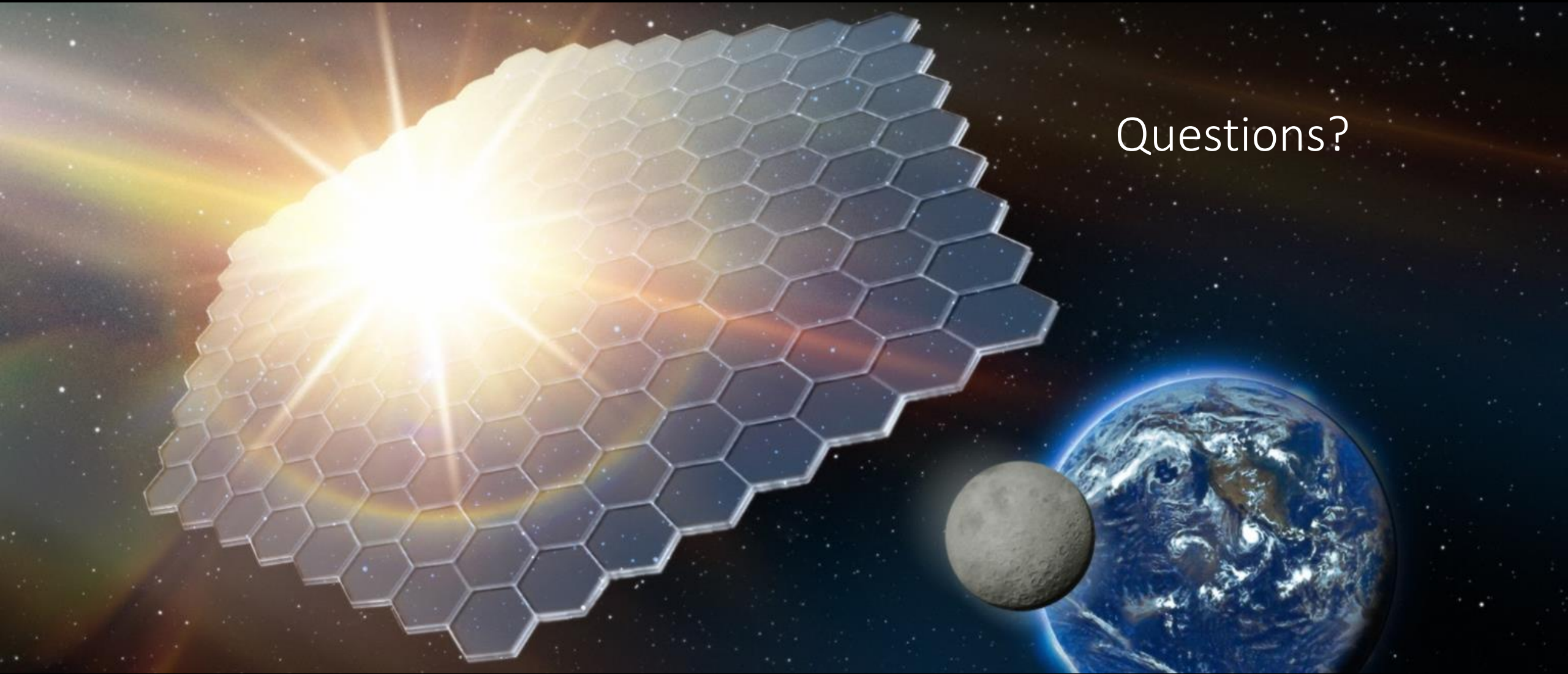
Planetary Sunshades Are Part of a Comprehensive Strategy

- Reuse / Recycle
- Improve energy efficiency
- Net zero or negative carbon emissions
- Carbon capture
- Solar radiation management using planetary sunshades



The Earth straddling the limb of the moon, as seen from above Compton crater by NASA's Lunar Reconnaissance Orbiter on October 12, 2015
NASA / GSFC / Arizona State University

Planetary Sunshades for Solar Radiation Management



Questions?