Introduction to Weather and Climate

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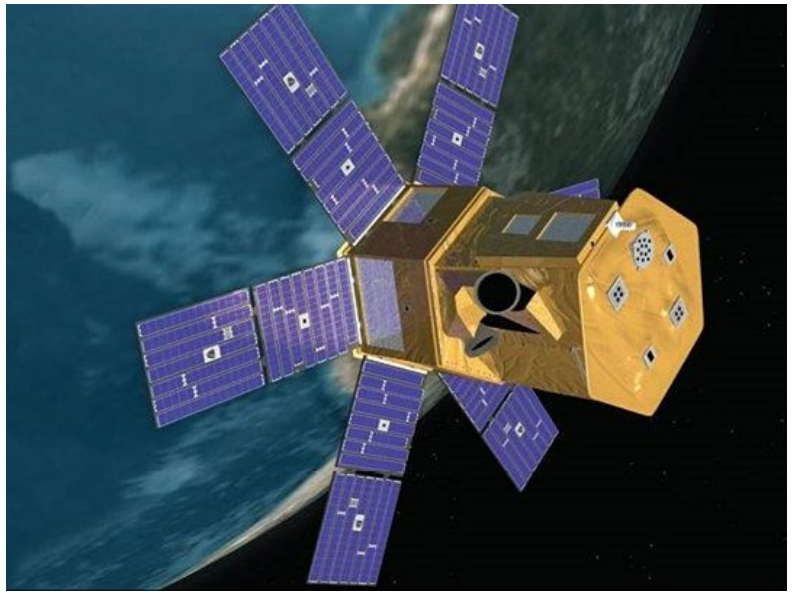
UNC Asheville Pre-College Space Camp

June 20, 2022

Objectives For This Science Camp Overview

(1) Introduction to Weather and Climate , Earth and Space, DeWayne



(2) Assembly of Weather Station and Intro to Programming, Austin

(3) Assembly of Programmable Robotic Rover, Autumn

(4) Introduction to Data Reporting and Analytics, All

(5) Demonstration of a tethered weather balloon launch, All

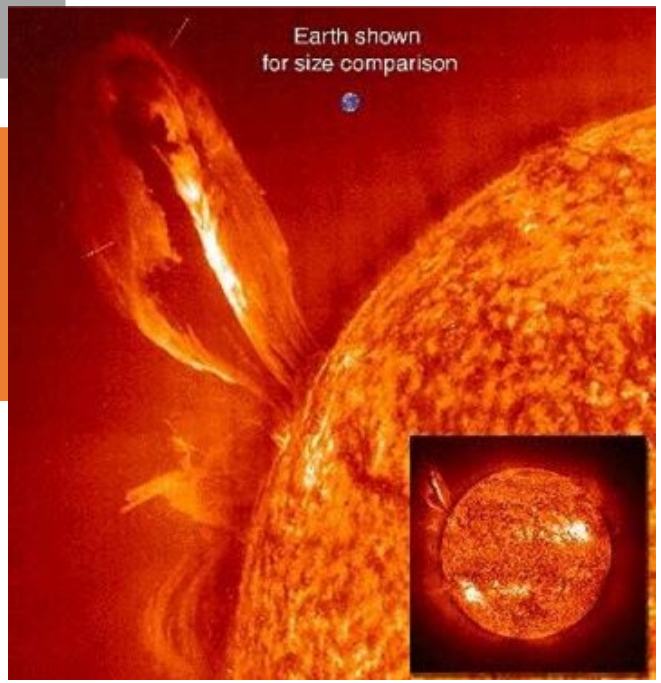
Objectives For Intro To Weather and Climate

Introduction to Weather and Climate

Deep-Space STEM CubeSat Mission

COVID: Impact On/From Weather

Introduction to Space Weather



Introduction to Weather, Climate, our Atmosphere and Space

- What is Weather?
- What is Climate?
- How do we Measure Them? Track Trends? Build Confidence in the Science?
- What do we Know?
- Famous Mark Twain quotes:
  - “Climate is what we expect, weather is what we get.”
  - “It is best to read the weather forecasts before we pray for rain.”

What is Weather?

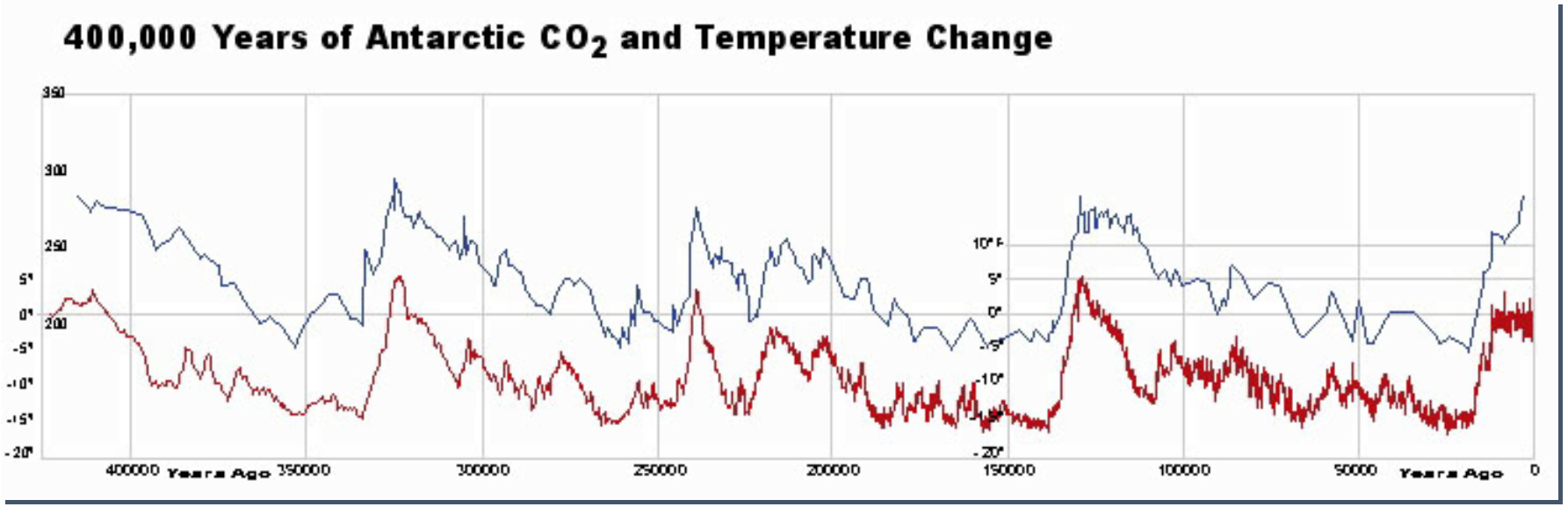
- Weather describes the state of the atmosphere at any particular time.
- Weather can be described in terms of temperature, precipitation (snow, rain & hail), wind speed and direction, visibility and cloud amounts.

What is Climate?

- Climate describes the average weather of a particular part of the world at different times of the year
- In North Carolina we would expect hot and humid summers and mild winters with significant precipitation throughout the year

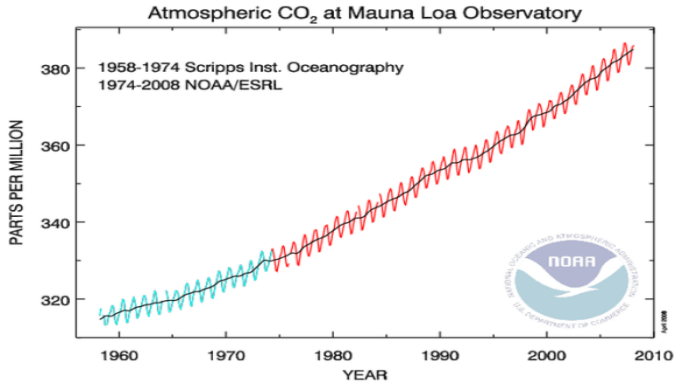
The Weather and Climate Systems, What We Know With Some Confidence

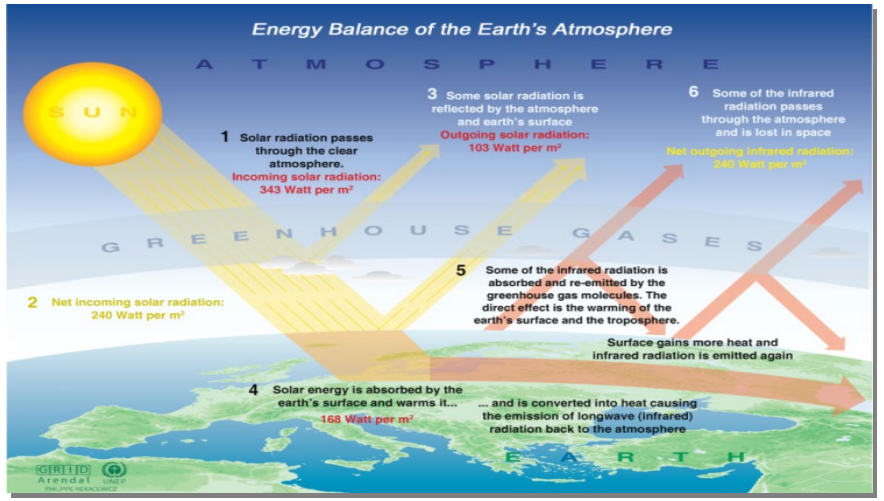
Current CO_2



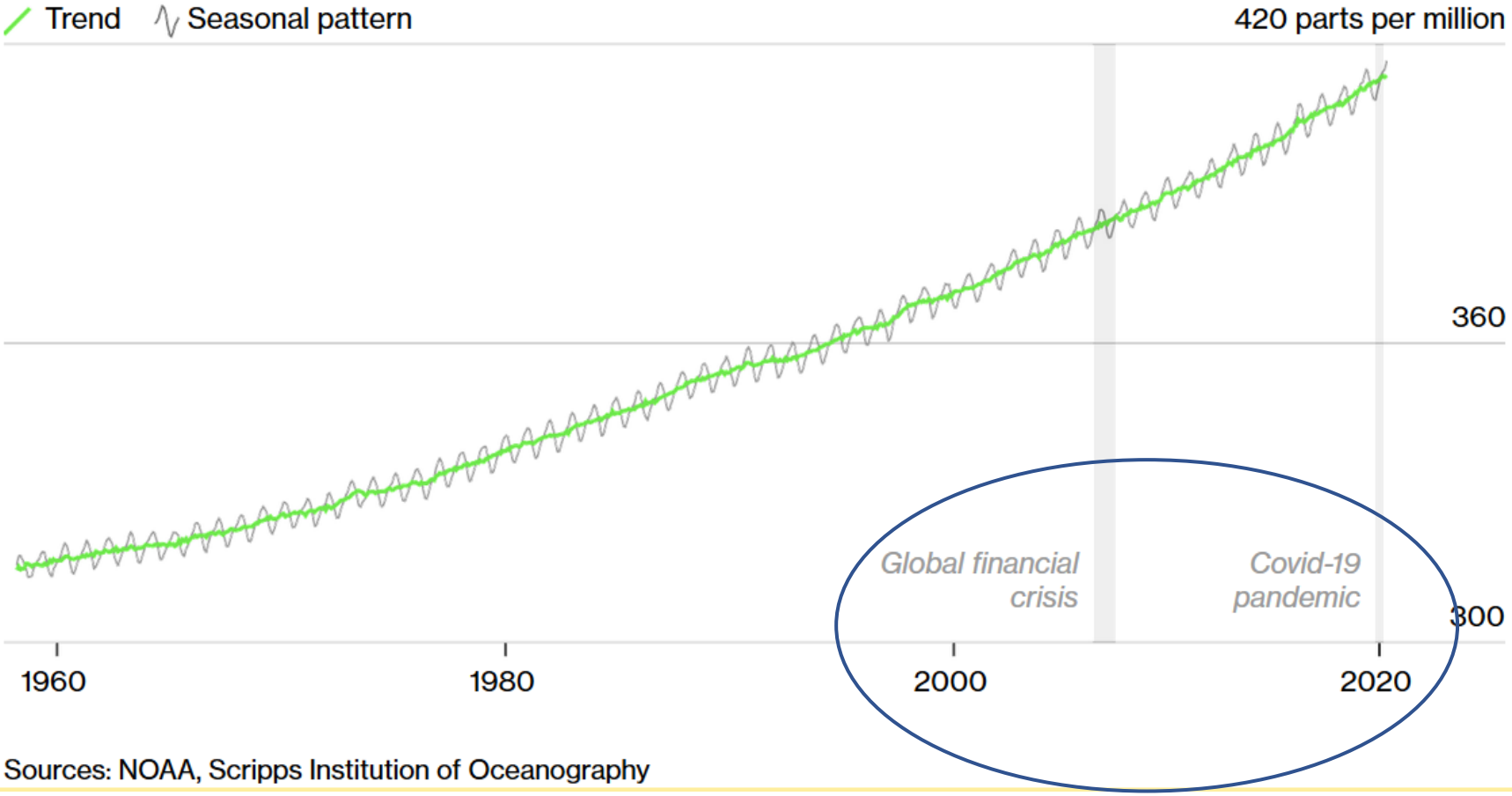
Upper, blue line = $C0_2$ level

Lower, red line = temperature

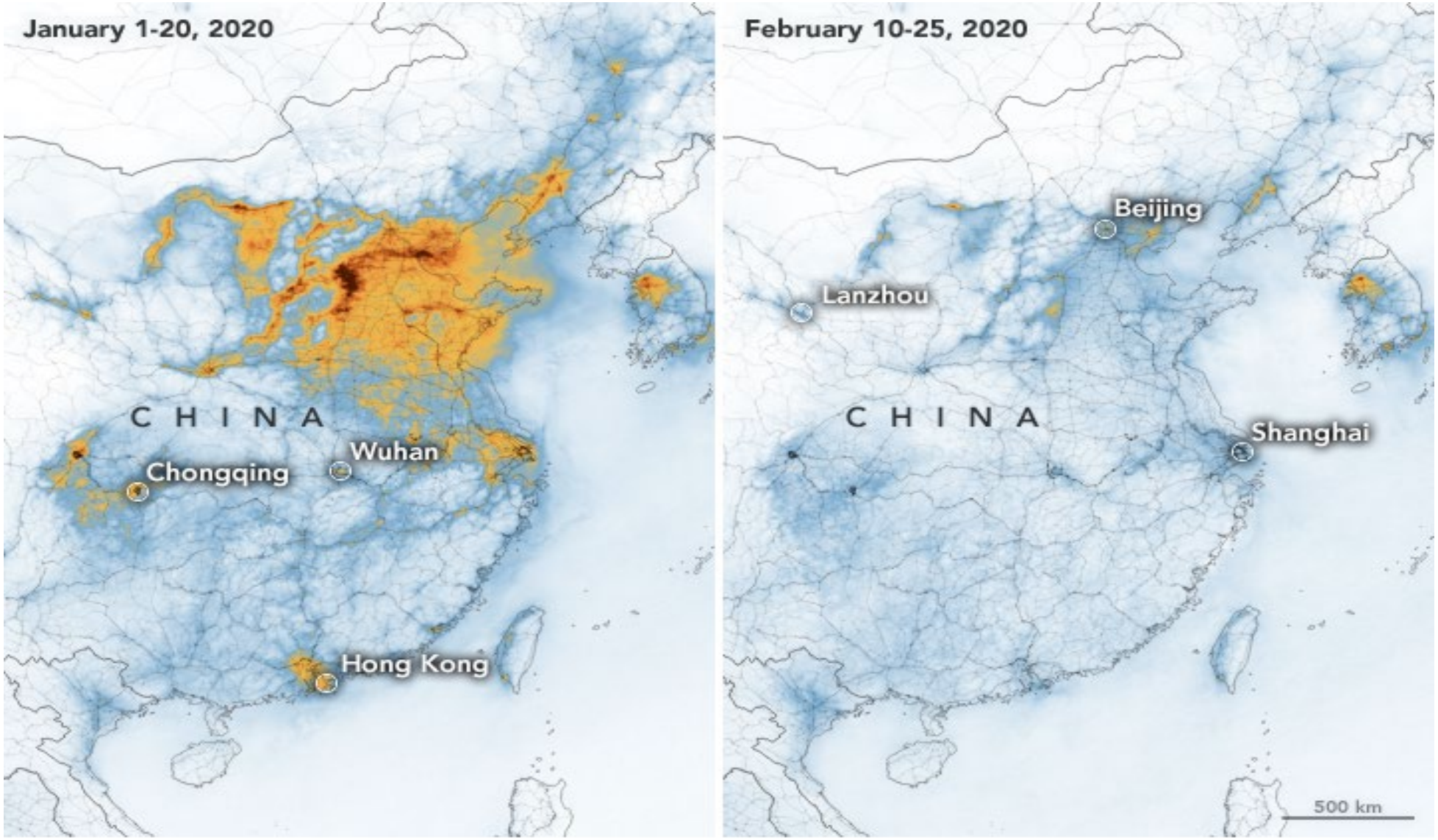




CO_2 in the atmosphere will continue to go up



Sources: NOAA, Scripps Institution of Oceanography



Satellite Imagery Of the Decline in NO2 As a Result of the COVID-19 Lockdown, China

Imagery from NASA

Parameters we Measure for Understanding Weather and Climatic Processes

- **Temperature**
- Precipitation and **Humidity**
- **Barometric Pressure**
- Wind Speed and Direction
- Cloud Cover
- UVA, UVB (irradiance)
  - UVA 400 nm - 320 nm
    UVB 320 nm - 290 nm

Where should our focus be to address the causes of Climate Change and it's Impacts?

Example of Moving to Carbon Neutrality:

https://vimeo.com/609433822/fee6ba17af

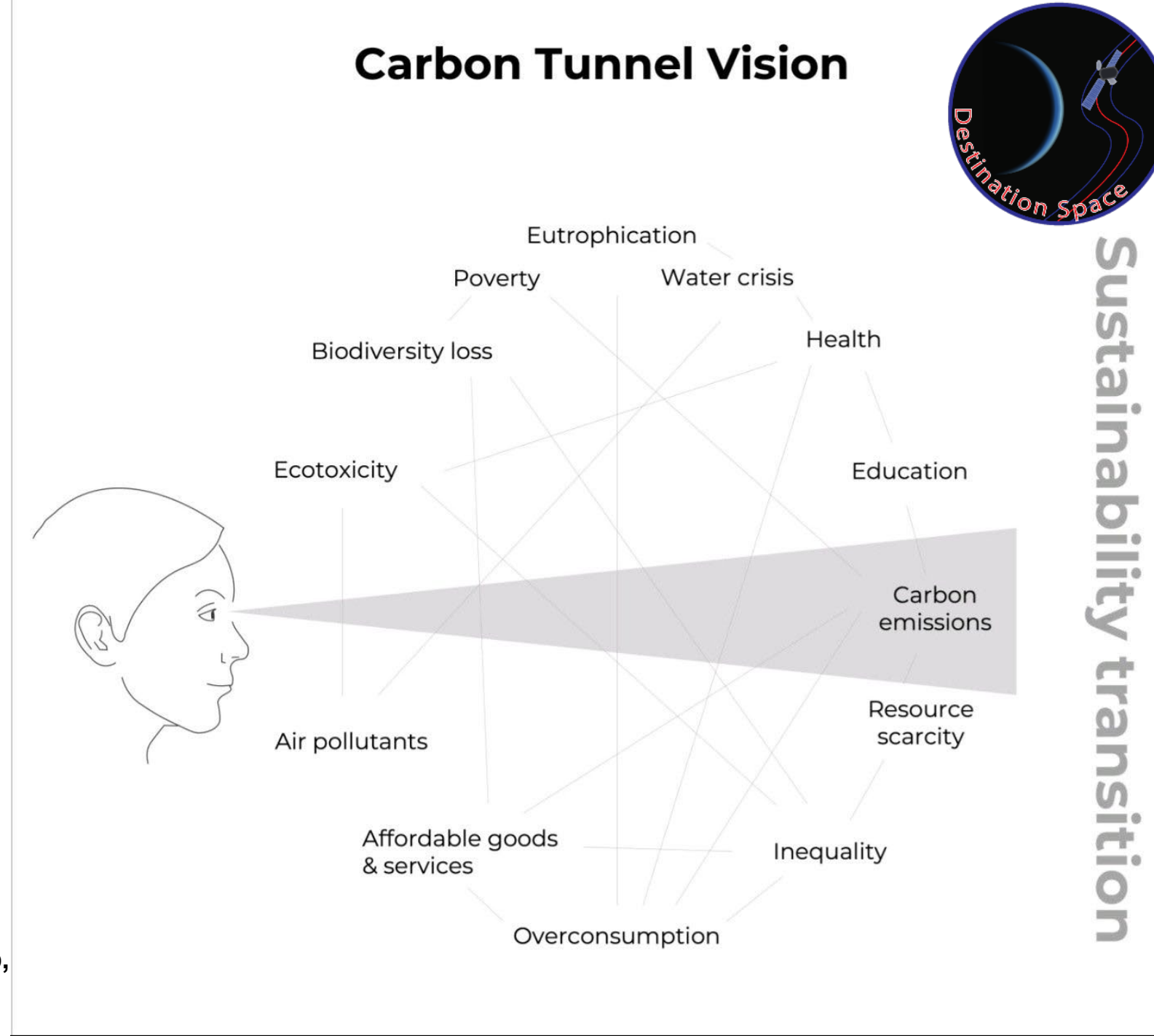


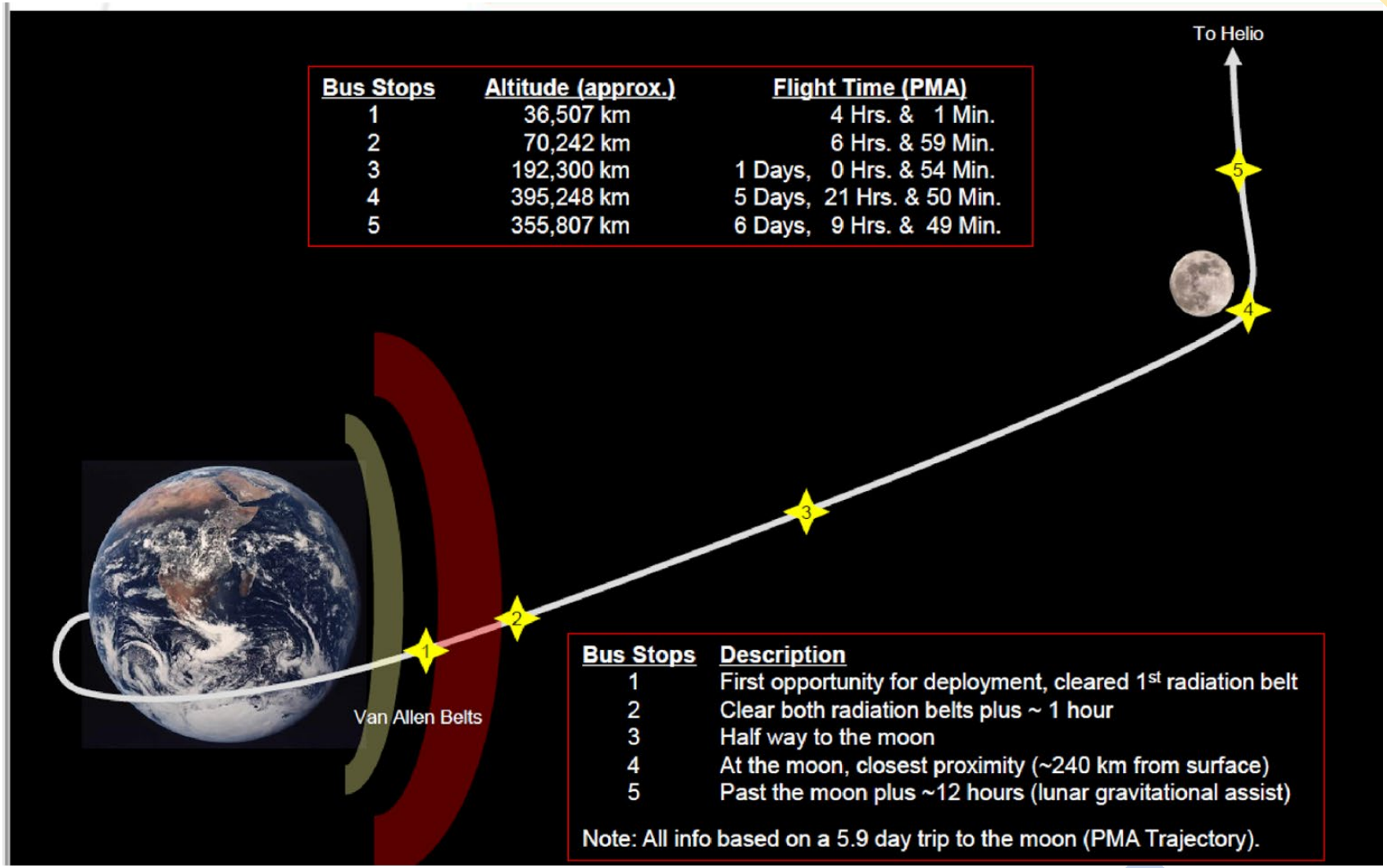
Figure from: Climate Change Professionals Group, LinkedIn

Deep-Space STEM CubeSat Mission

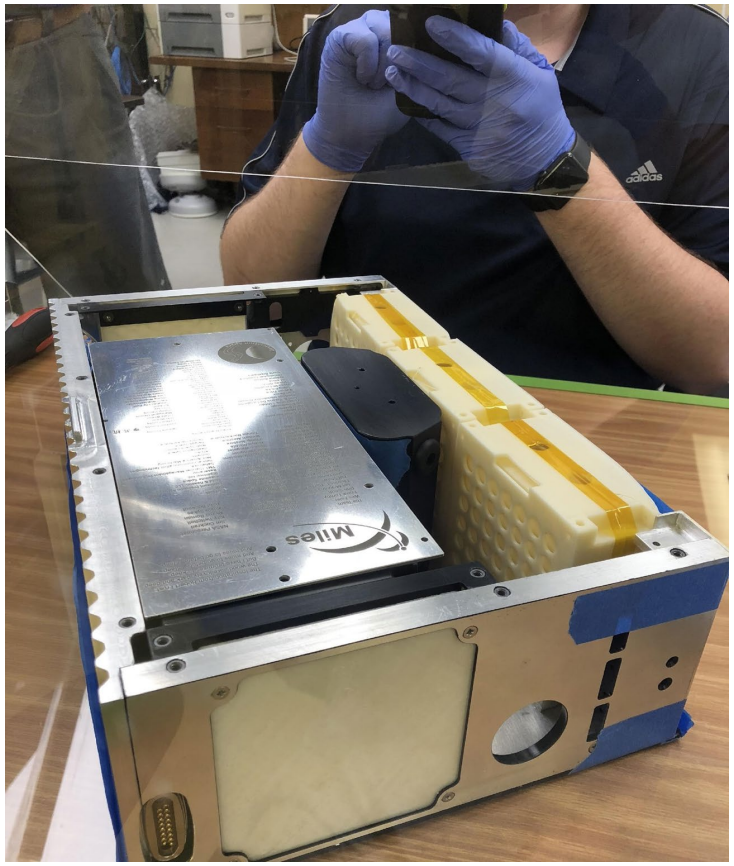
- The Second time NASA has launched CubeSats into Deep Space
- Deep-Space CubeSat Mission includes:
  - 13 CubeSats will be on Artemis-1; two are Deep-Space, eleven are Lunar and Asteroids missions
- The first ever STEM Deep Space CubeSat will fly with propulsion power for around 200 Days after launch
  - Data transmitted up to 1 year CubeSat will travel 15-45 million km from earth.

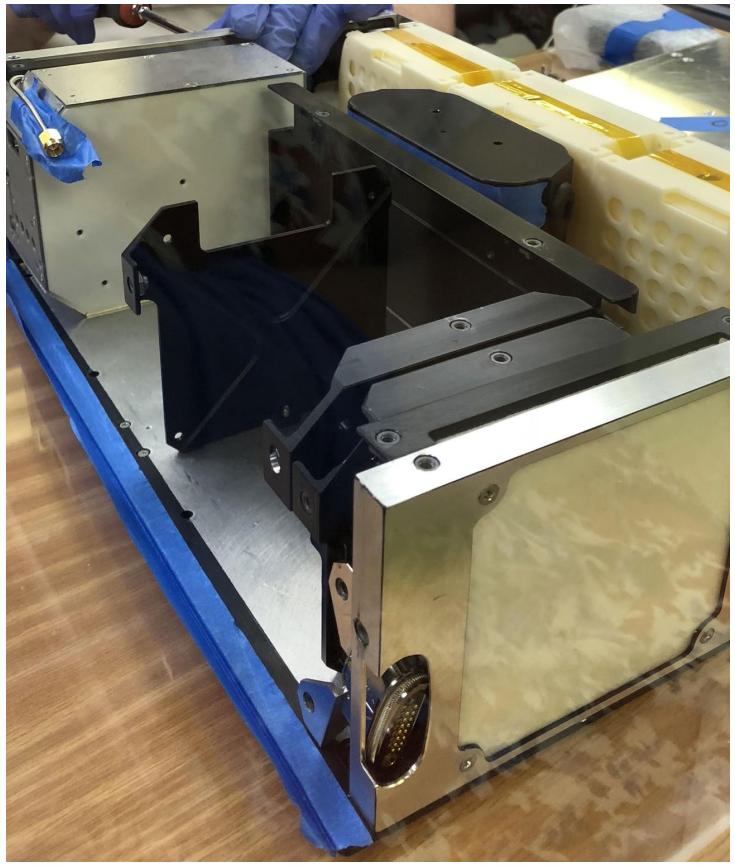
Launch Date: Thursday, Nov 4, 2021

Space Launch System, Artemis-1 Mission



Deep-Space STEM CubeSat Remote Sensors





Located within the ExoSat STEM Sensor Suite

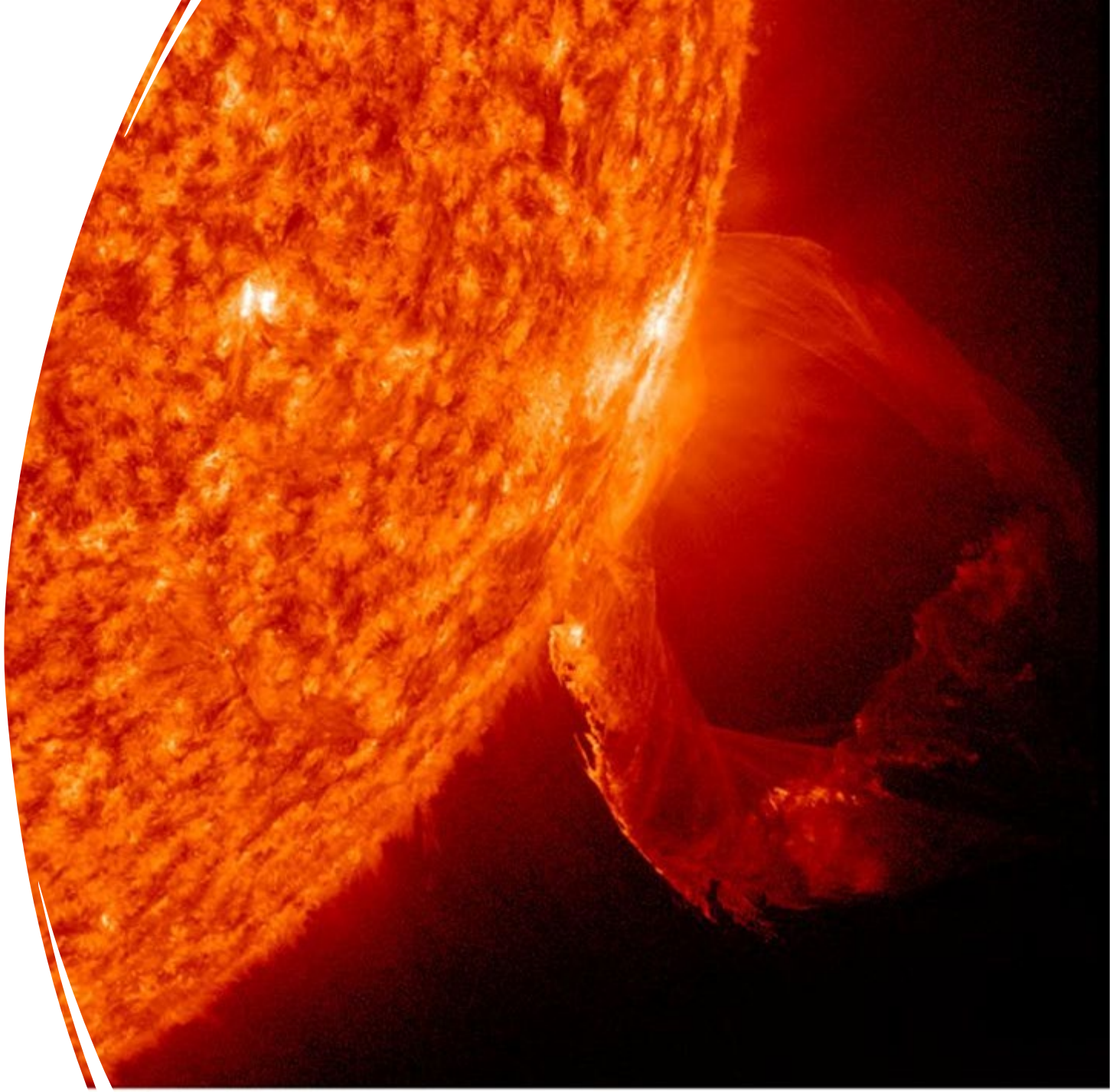
- Particle Detector, inside and outside the craft
- Plasma Probe
- IR Sensor
- Magnetometer
- Temperature (several on board throughout the craft as well)
- Electron Flux Detector

Space Weather

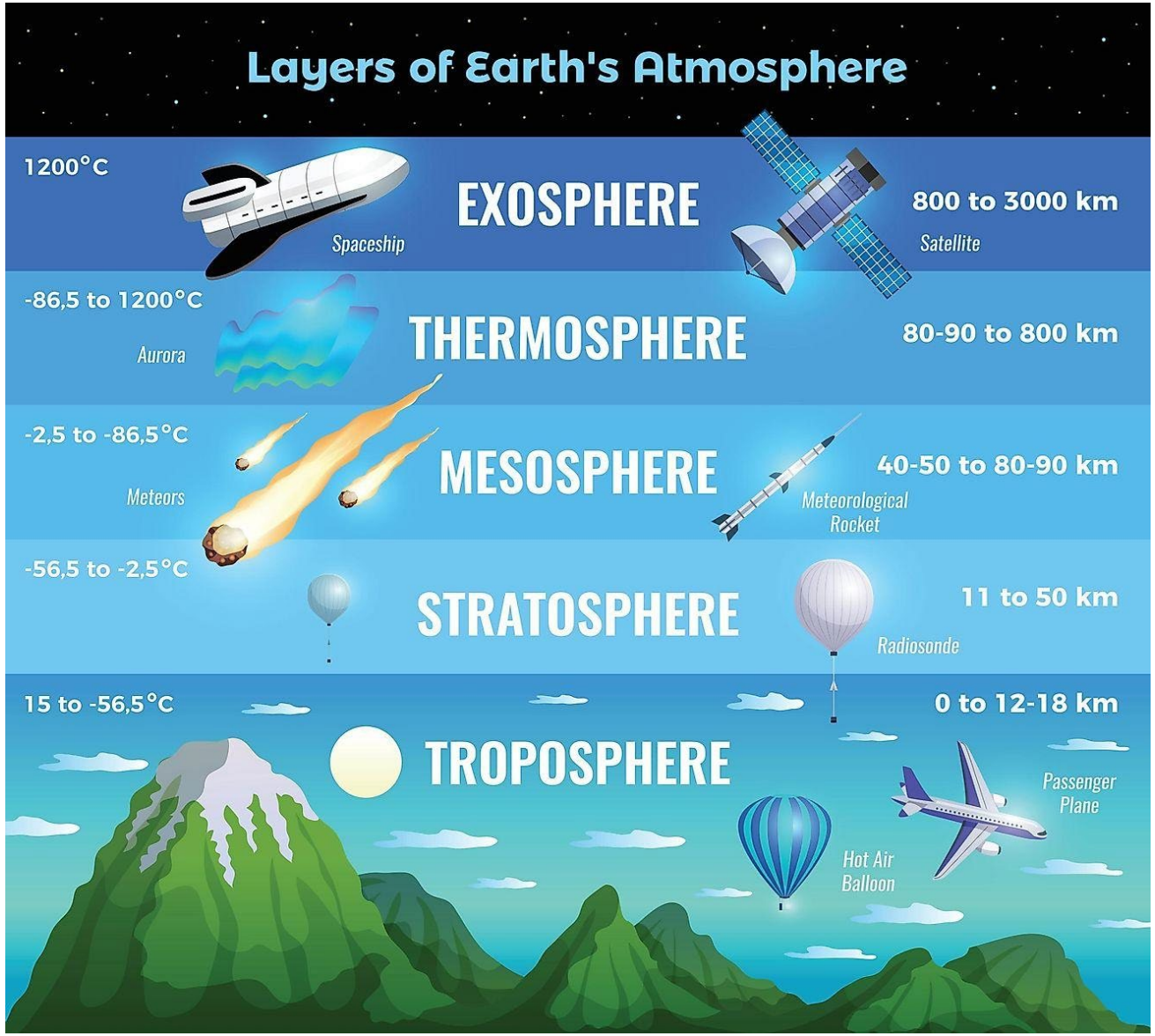
The Energy Source is the Sun

“Eruptions of plasma and magnetic field structures from the sun's atmosphere, called coronal mass ejections (CMEs), and sudden bursts of radiation, called solar flares, can cause space weather effects at or near Earth.”

-National Weather Service

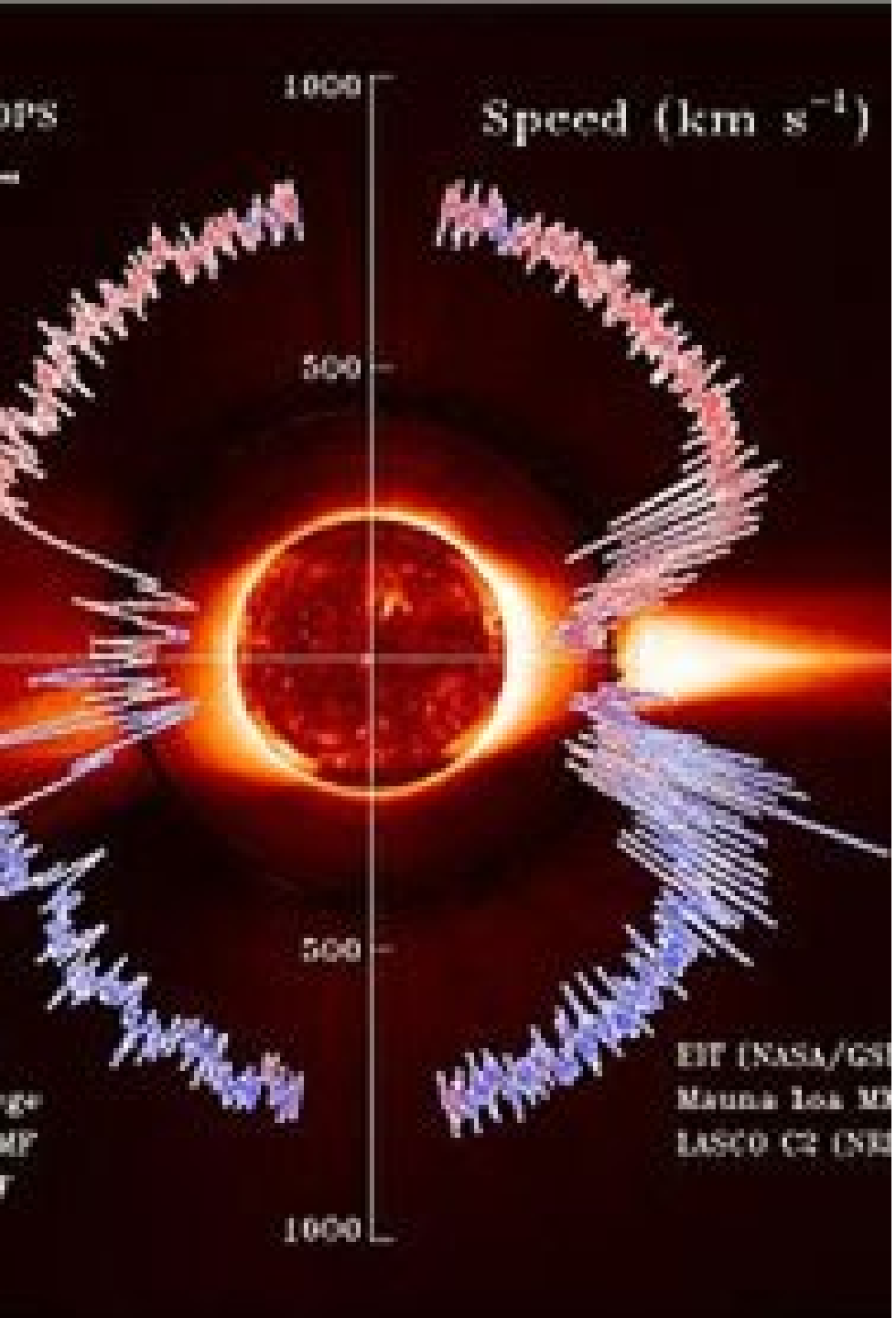


What do you think protects us the most against the harmful effects of space weather?


Layers of Earth's Atmosphere
1200°C
EXOSPHERE
800 to 3000 km
Spaceship
Satellite
-86,5 to 1200°C
THERMOSPHERE
80-90 to 800 km
Aurora
-2,5 to -86,5°C
MESOSPHERE
40-50 to 80-90 km
Meteors
Meteorological Rocket
-56,5 to -2,5°C
STRATOSPHERE
11 to 50 km
Radiosonde
15 to -56,5°C
TROPOSPHERE
0 to 12-18 km
Passenger Plane
Hot Air Balloon

Space Weather Intro Video

https://youtu.be/JncTCE2NWgc



Solar Winds

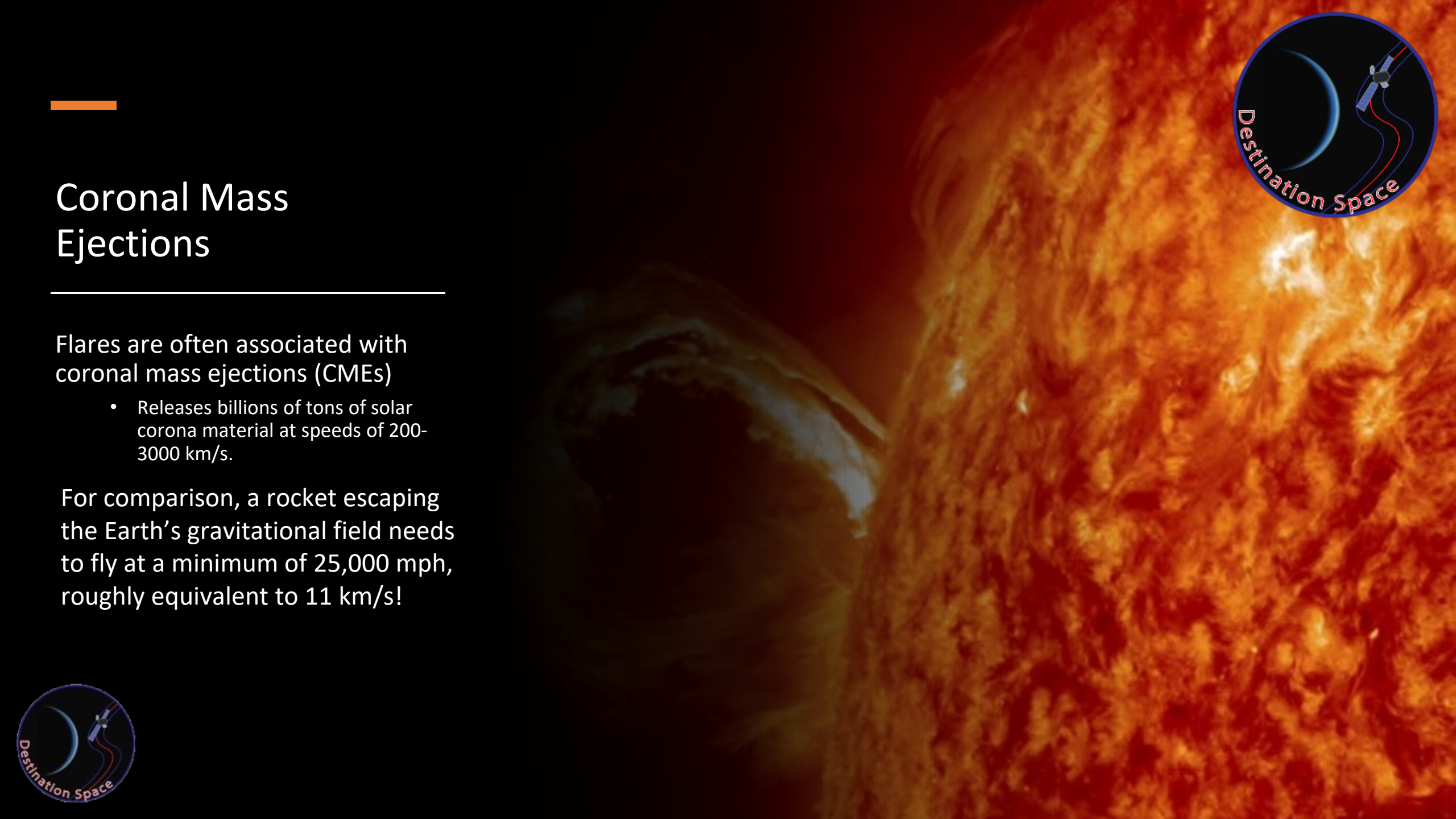
- Solar wind like on Earth is driven by temperature differences.
  - The temperature differences on the Sun are between the Sun's upper atmosphere and interplanetary space.
- Solar wind expands into the Solar System, carrying the Sun's magnetic field which then carves out a region of interstellar space called the **heliosphere**.

Coronal Mass Ejections

Flares are often associated with coronal mass ejections (CMEs)

- Releases billions of tons of solar corona material at speeds of 200-3000 km/s.

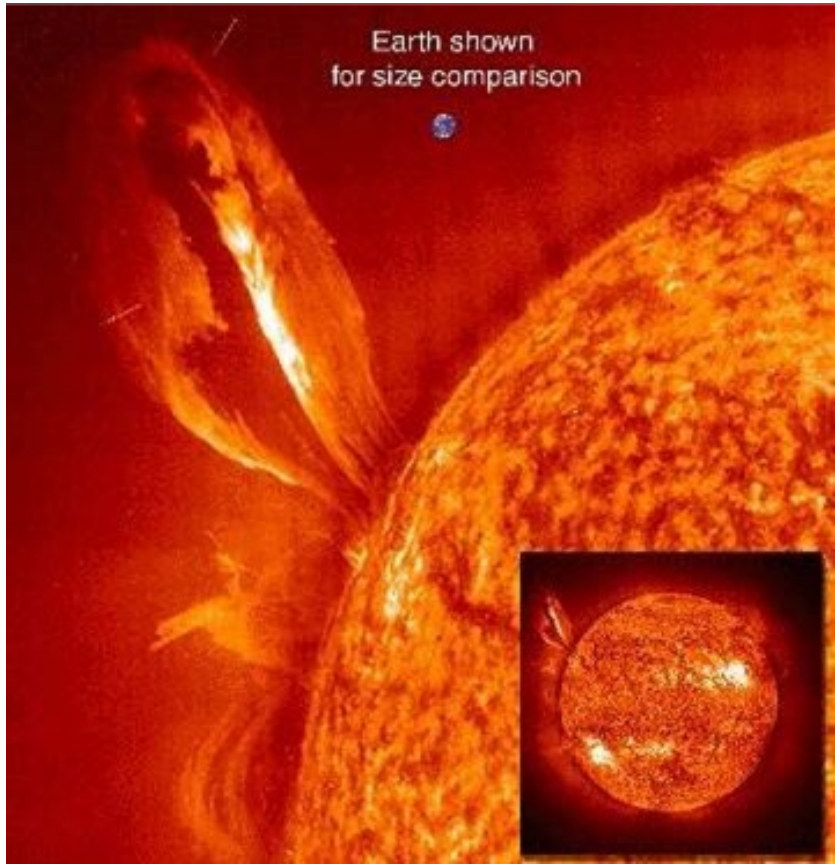
For comparison, a rocket escaping the Earth's gravitational field needs to fly at a minimum of 25,000 mph, roughly equivalent to 11 km/s!



Solar Flares

- Large explosive releases of energy that occur when magnetic energy is rapidly converted into particle kinetic energy.
- The tremendous amount of energy released in a few minutes can reach temperatures of 100,000,000 K (much hotter than even the core of the Sun)

The **intensity** of the explosion sends charged particles and electromagnetic radiation into interplanetary space and often can impact Earth's space environment - **one of the causes of space weather.**



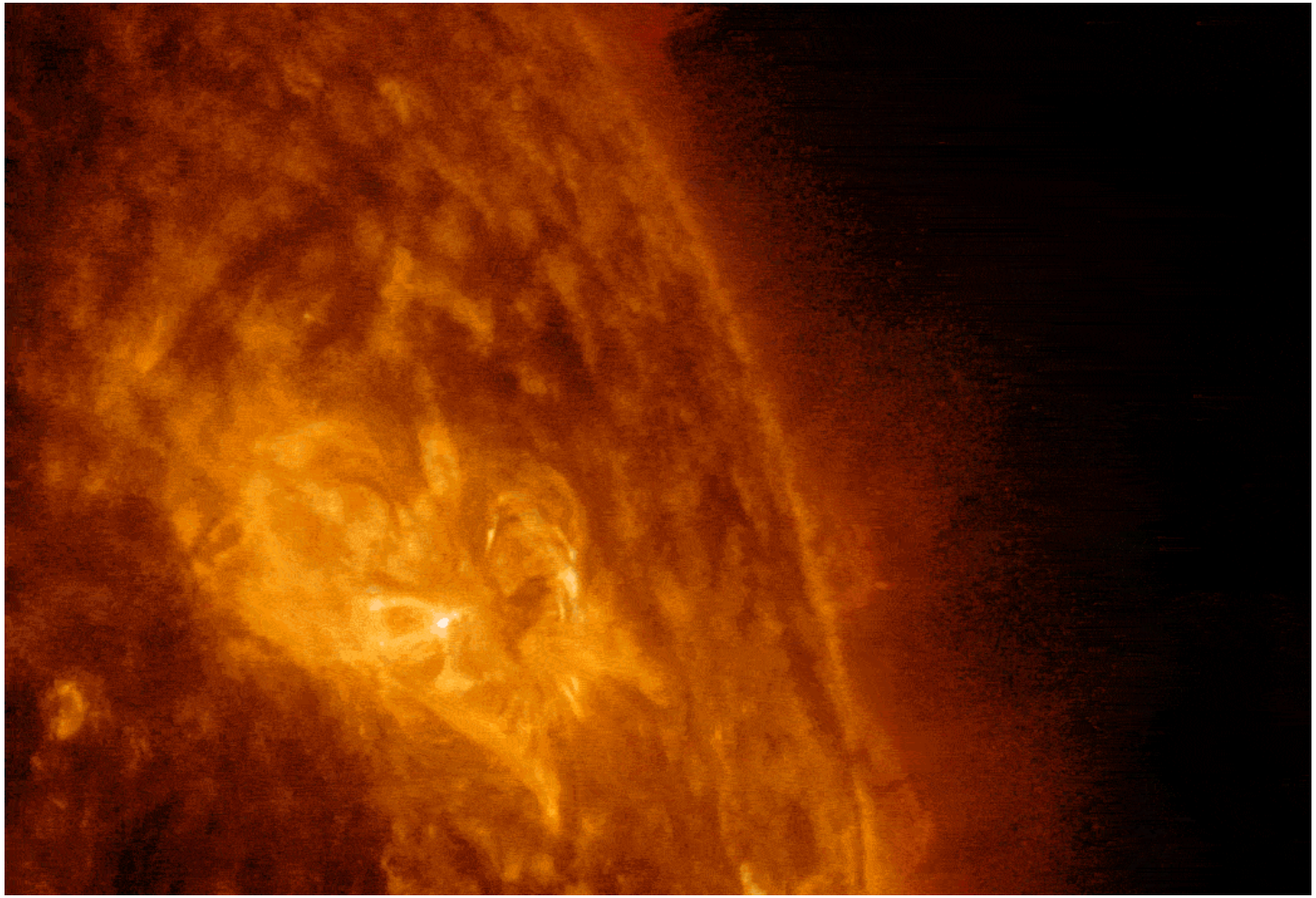
Solar Flares

- Solar flares are the **largest eruptions** in the solar system.
- Energy of the order of 10^{25} J can be released by flares, compared to the World's annual world energy consumption $\approx 10^{20}$ J(credit CUA Space Weather Center)

- **Effects of solar flares**
  - In solar flares, a free magnetic energy is converted into heat, non-thermal particle acceleration and electromagnetic radiation.
  - Solar flares generate, for example, X-ray, Extreme Ultraviolet (EUV) and radio emissions, and solar energetic particles (SEPs).
  - All of the above effects have significant space weather consequences.

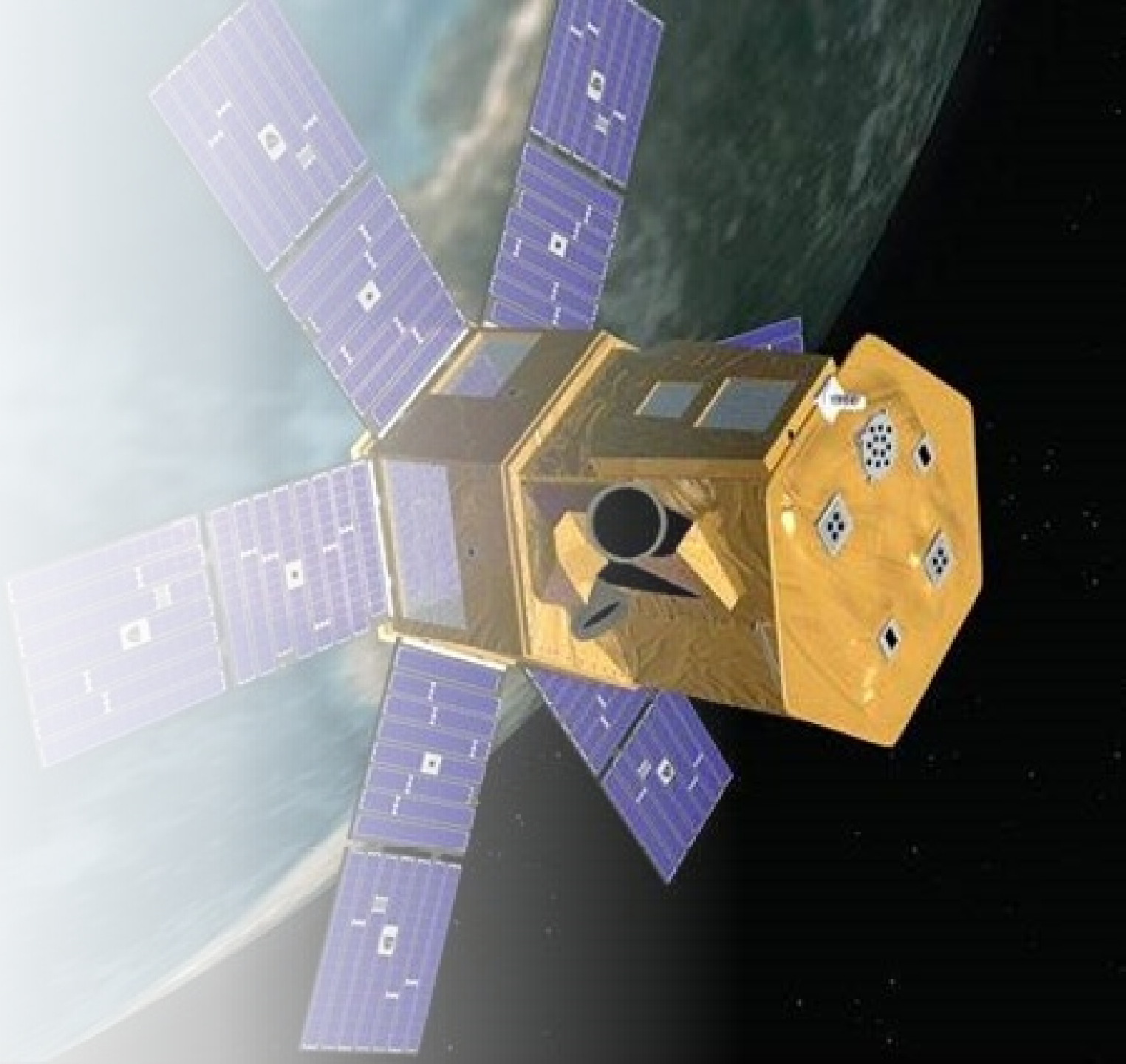
Solar Flare

NASA's Solar Dynamics Observatory captured this imagery of a solar flare, as seen in the bright flash. A loop of solar material, a coronal mass ejection (CME), can also be seen rising up off the right limb of the Sun. Image credit: NASA/SDO/Goddard



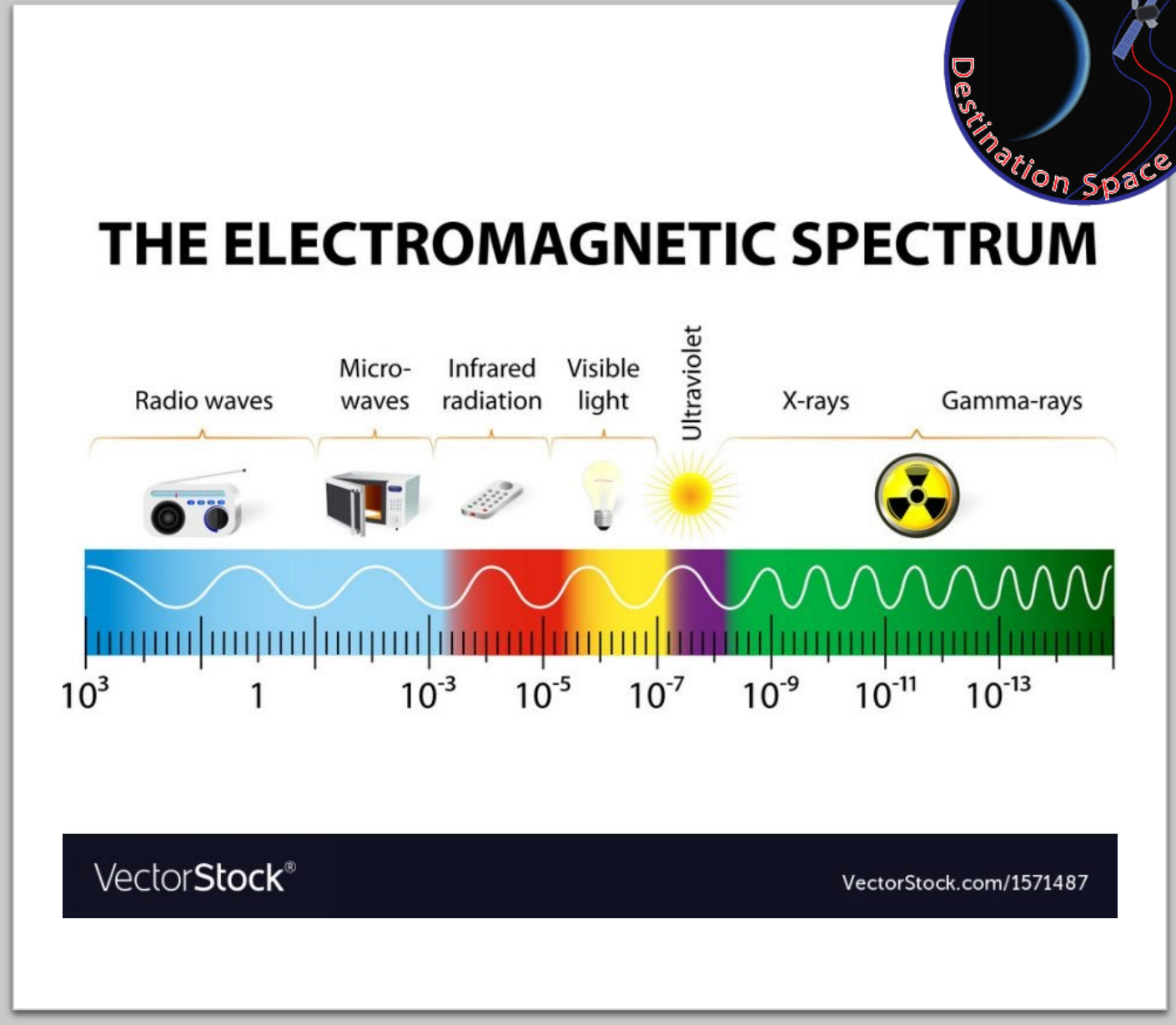
Impact of Space Weather on Society

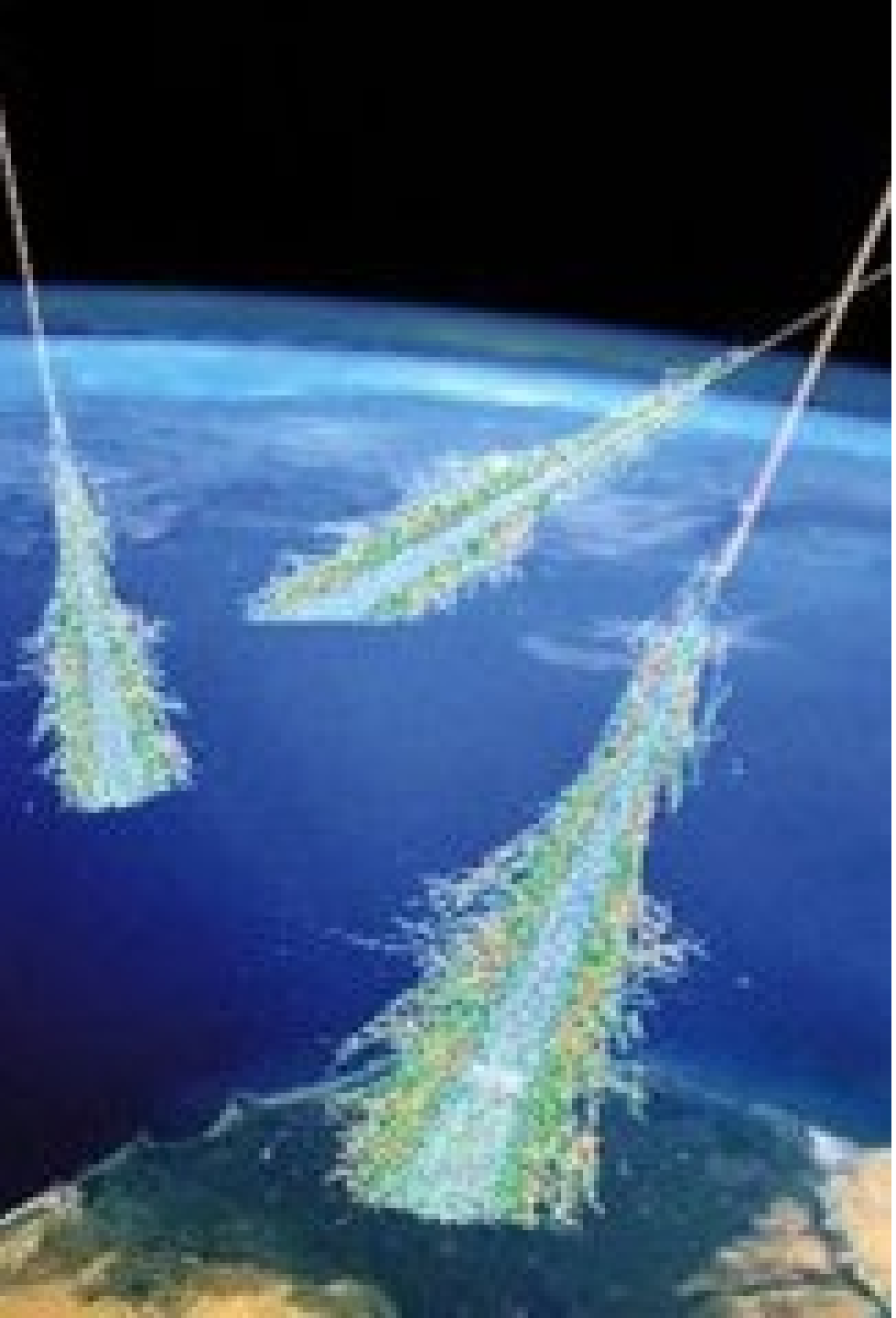
- How many operational satellites do you think are currently orbiting earth?
- What Are Satellites Used For?
- All Satellites are susceptible to damage and degradation due to the harsh environment of space.



Photons and Energy

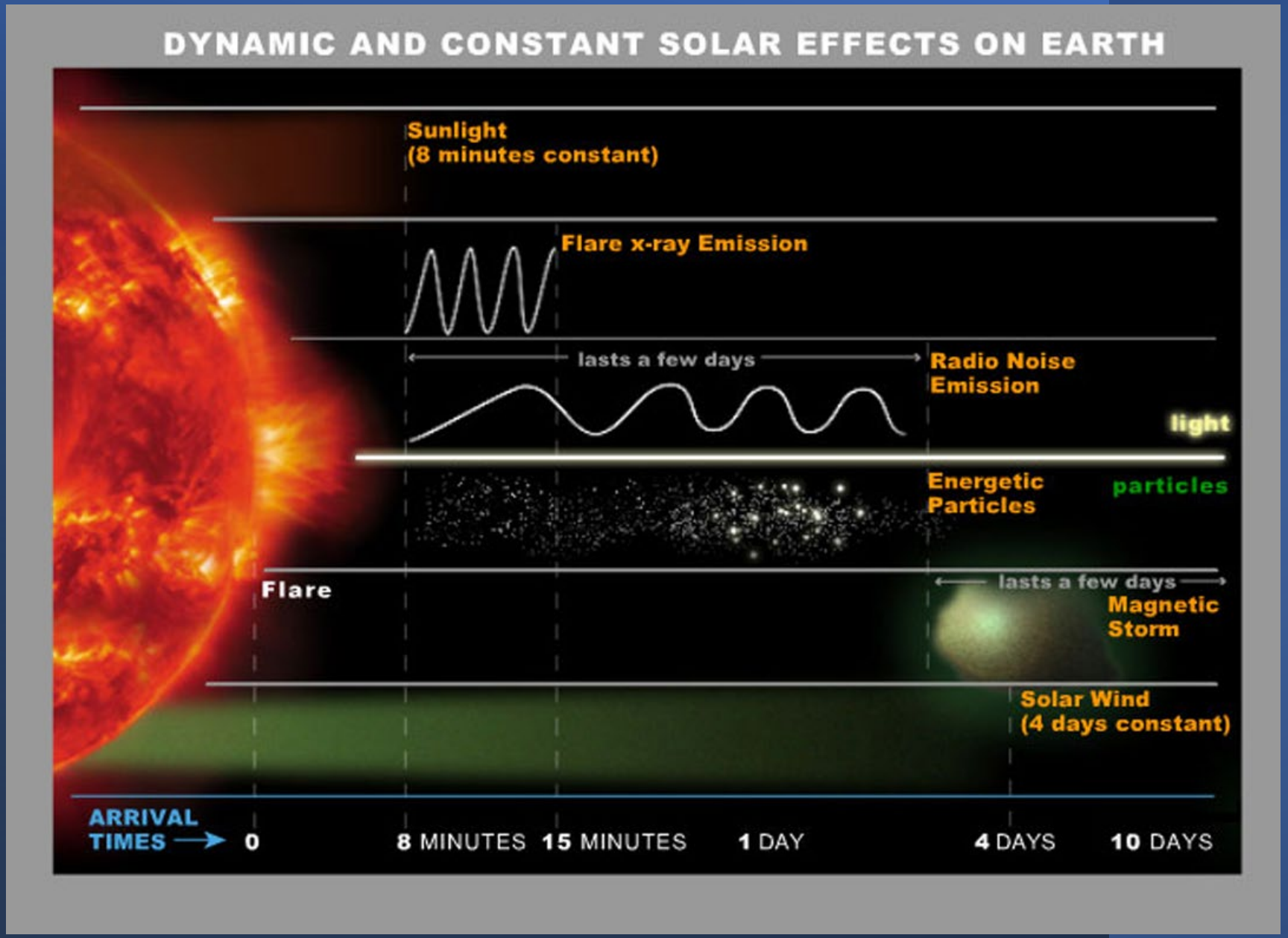
- **Light** is a form of electromagnetic radiation
- The radiation behaves both as a wave and as a discrete particle.
- Shining light at a high enough energy level (frequency) at metal will cause electrons to be emitted - photoelectric effect
- The energy of light is dependent on frequency.





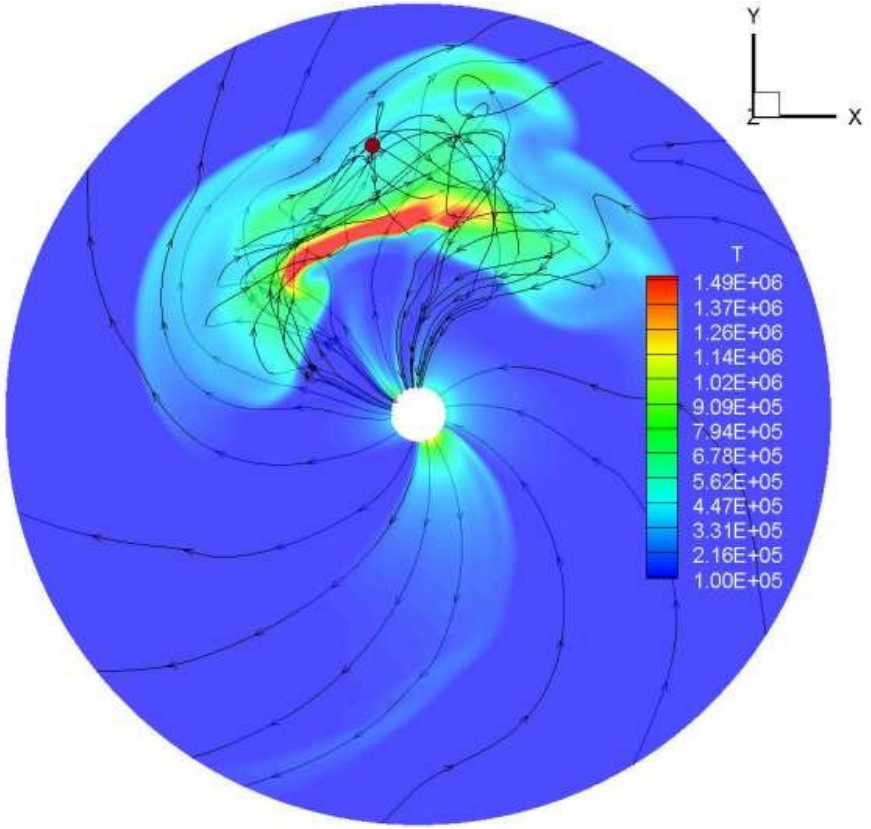
Cosmic Rays

- Our Earth is constantly bombarded from every direction with highly ionized atoms and other subatomic particles know as cosmic rays.
- Cosmic rays travel at nearly the speed of light, and most nuclei of atoms.
- The current theory is that galactic cosmic rays originate in supernovae (star explosions).
- Cosmic rays are charged particles, and their motion is deflected by galactic magnetic fields as they propagate through interstellar space. Therefore it is not directly possible to identify their source.


DYNAMIC AND CONSTANT SOLAR EFFECTS ON EARTH
Sunlight
(8 minutes constant)
Flare x-ray Emission
lasts a few days
Radio Noise
Emission
light
Energetic
Particles
particles
Flare
lasts a few days
Magnetic
Storm
Solar Wind
(4 days constant)
ARRIVAL
TIMES
0
8 MINUTES
15 MINUTES
1 DAY
4 DAYS
10 DAYS

Which direction does Solar Wind Blow?

- PROSWIFT Act
- Challenge: Correctly forecasting the arrival of Coronal Mass Ejections and determining the direction of the magnetic field it carries with it
- Multi-institutional efforts are being taken to improve the models and methods used in space weather forecasting
  - Use of supercomputers



Exercise: Each Team makes a 2-5 PowerPoint Slide Presentation of an Element of Space Weather with Impacts

See: HTTPS://WWW.SWPC.NOAA.GOV/IMPACTS

References and Resources:

An Introduction to Space Weather, Mark Moldwin, Cambridge University Press, 2008
Amazon Books, around $30 used or $50 new
Notes and exercises through the Destination SPACE Discord Link on our website: https://www.destinationspace-stem.org/discord

Fun Exercises on the US Geological Survey EROS Center Remote Sensing Classroom website
https://eros.usgs.gov/remote-sensing-classroom

Solar Noon, Related to Viewer's Location Determine from NOAA's ESRL, Boulder, CO

- https://www.esrl.noaa.gov/gmd/grad/solcalc/

- Solar noon is, "Defined for a given day for a specific longitude, it is the time when the sun crosses the meridian of the observer's location." (Taken from NOAA's Earth Systems Research Laboratory)

- Data needed for determination, Latitude and Longitude of Viewer's Location, Calendar Date, and Time Zone
  - Hartsville, South Carolina, Latitude, 34° 22' 27" N Longitude, 80° 4' 23" W

Next Sessions:

Weather Station Assembly, Programming Overview, and Data Collection
Austin Gleydura

Robotic Rover Assembly, Testing, and Competition Demonstration
Autumn Gleydura

Data Analytics and Reporting
DeWayne and Austin

Demonstration of a Tethered Weather Balloon Launch with Wx Station Payload, Conclusions
All