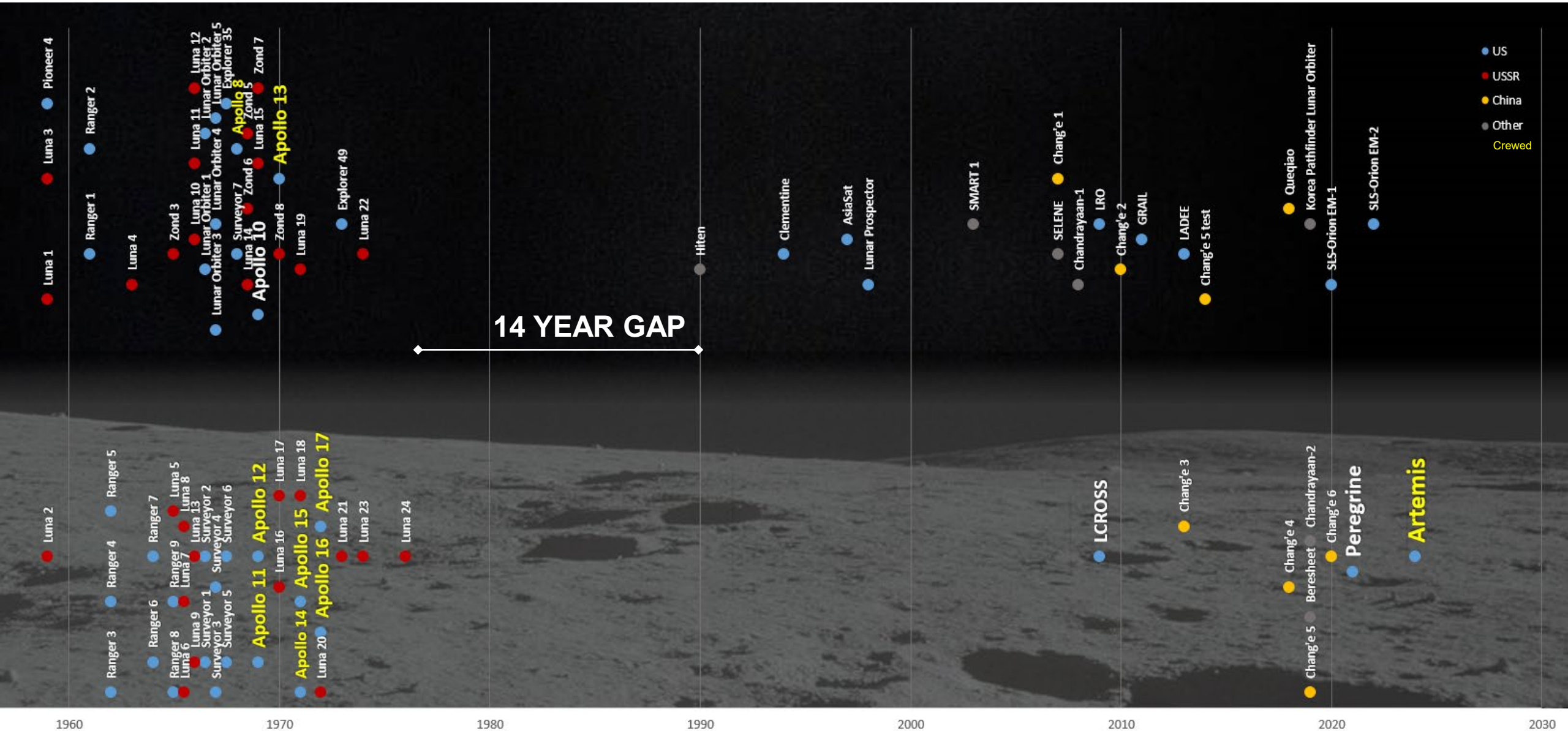
THIS TIME TO STAY:

HOW THE MOON WILL OPEN UP A CISLUNAR ECONOMY AND HUMAN EXPLORATION OF MARS

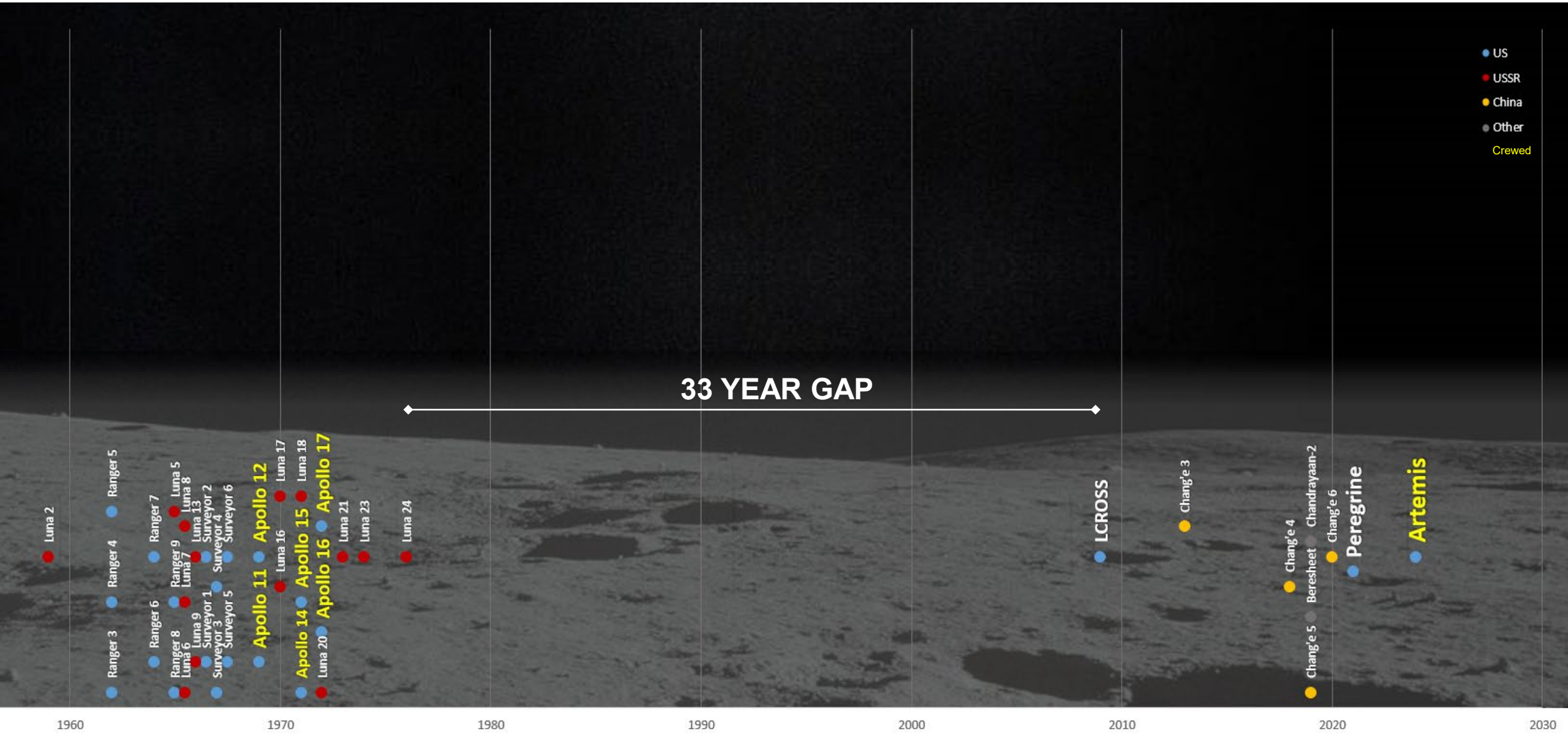
Tory Bruno

May 2023

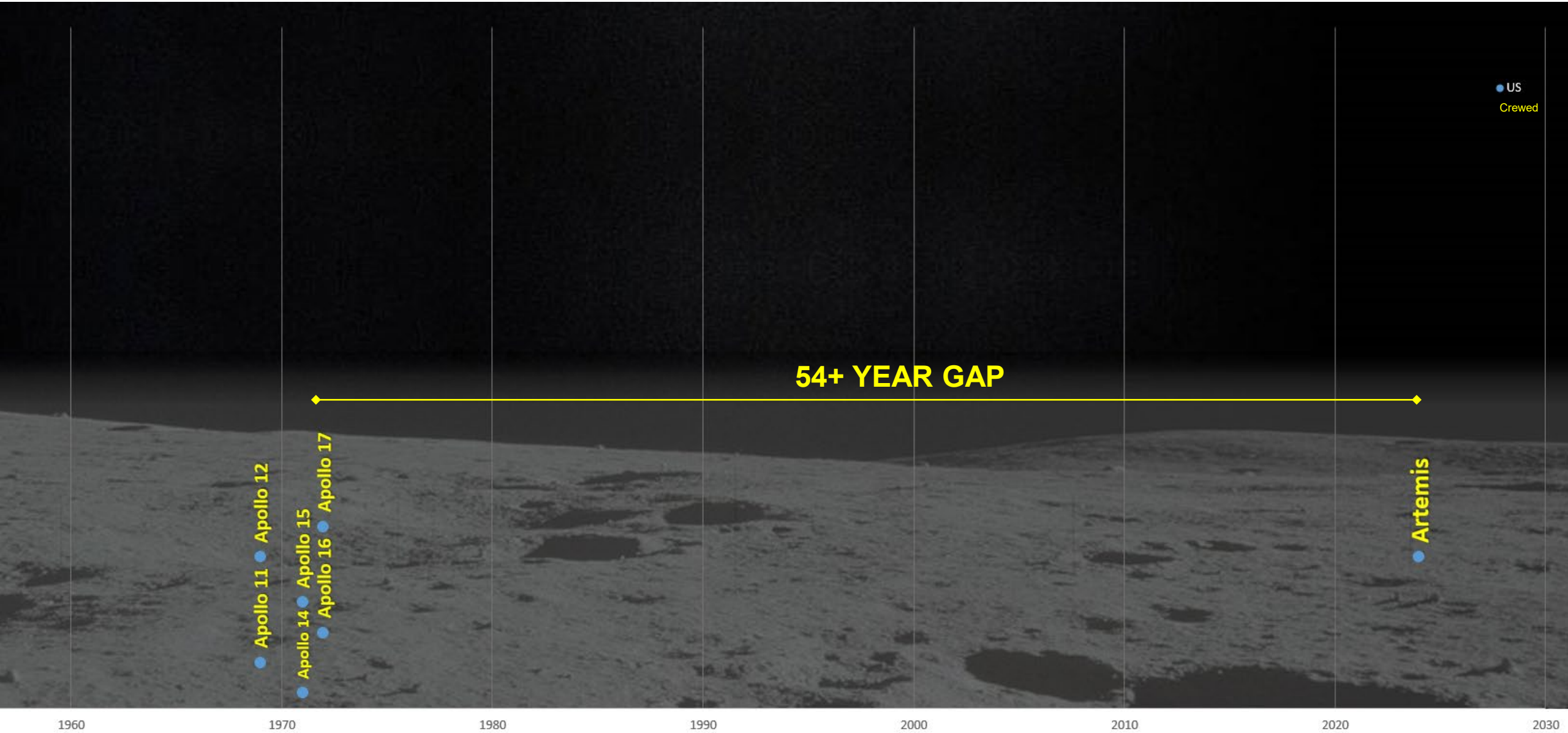
HISTORY OF LUNAR EXPLORATION



LUNAR SURFACE EXPLORATION



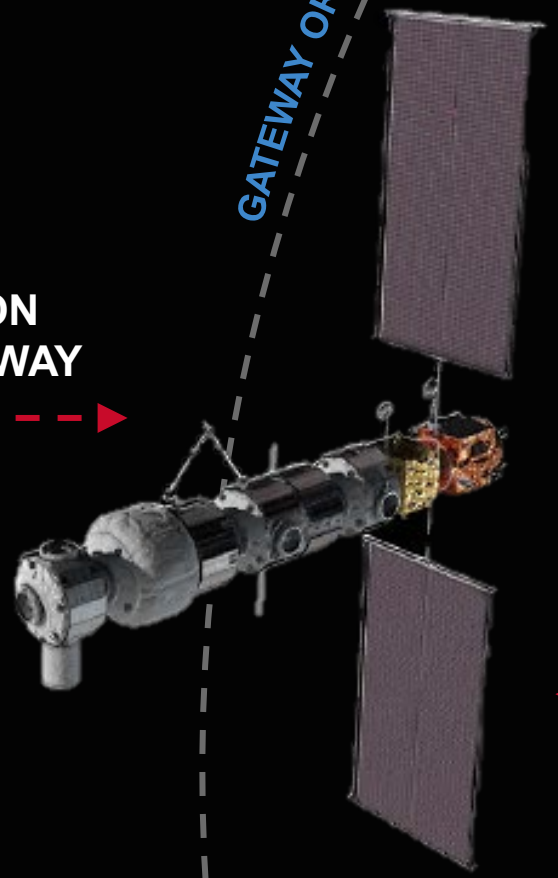
LUNAR HUMAN EXPLORATION



RETURNING HUMANS TO THE MOON

SLS/ORION
TO GATEWAY

GATEWAY ORBIT



LANDER
TO LLO

LANDER
TO MOON

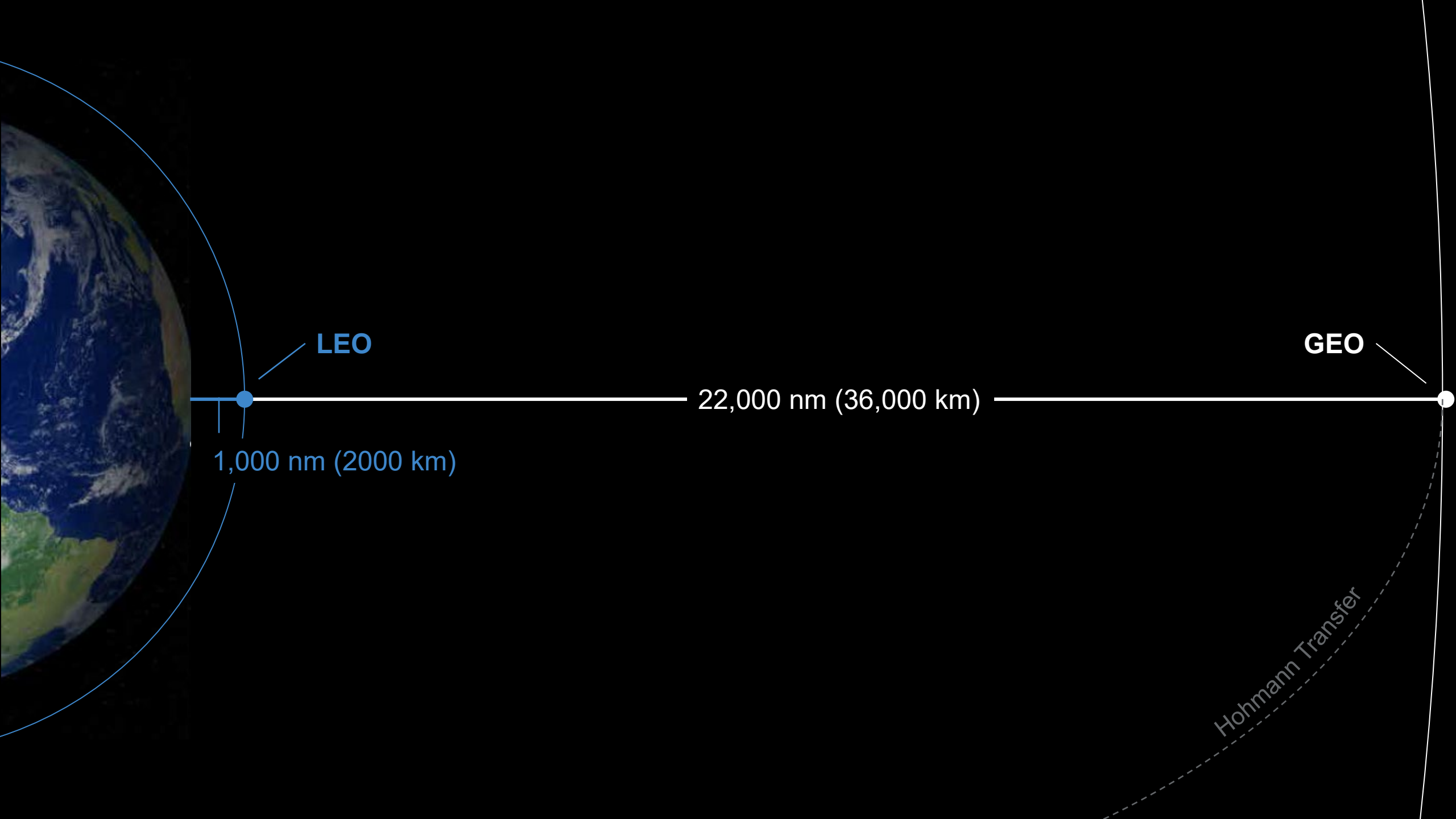
LOW LUNAR ORBIT

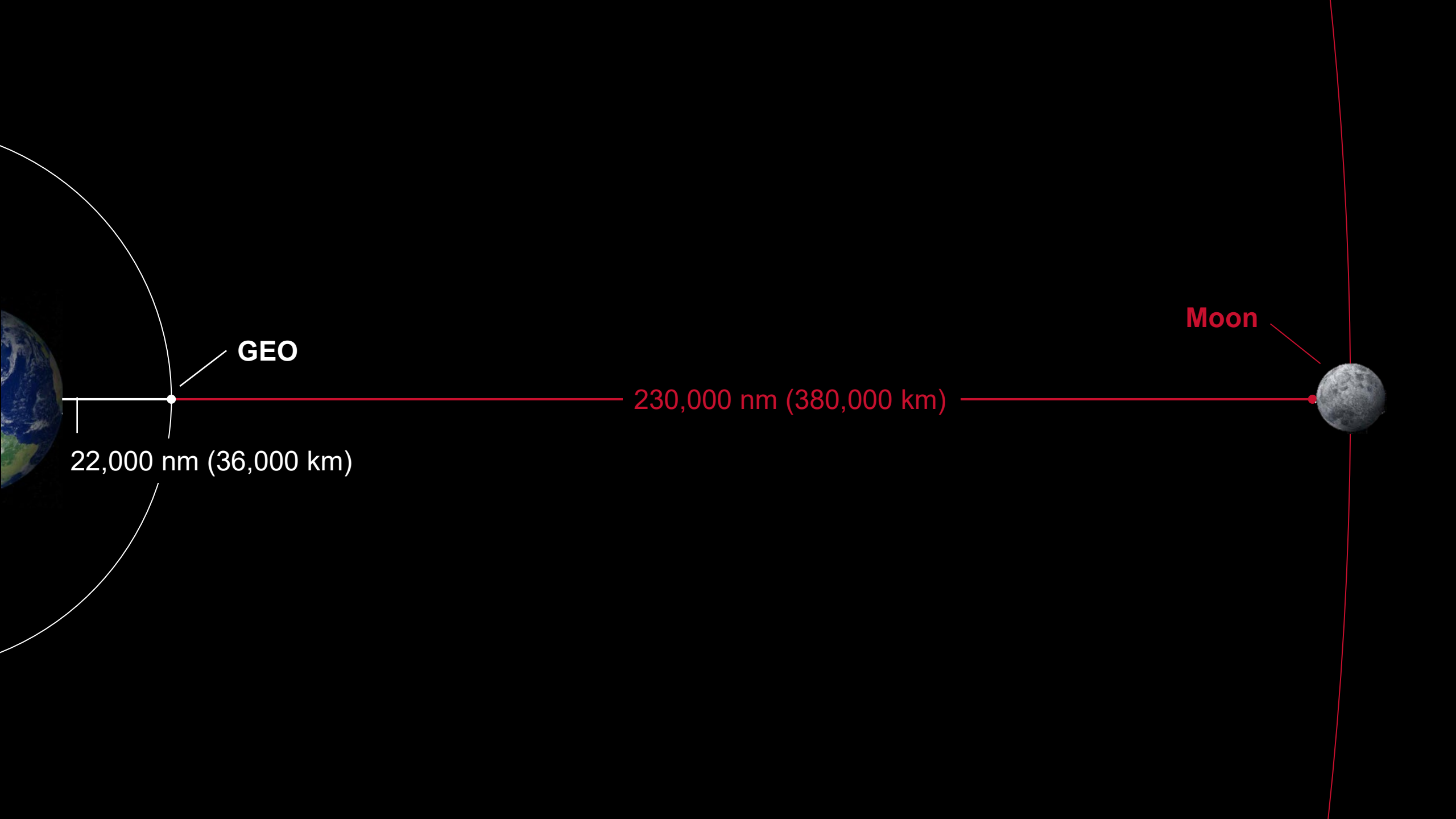
TRANSFER VEHICLE
SEPARATES, BACK TO GATEWAY

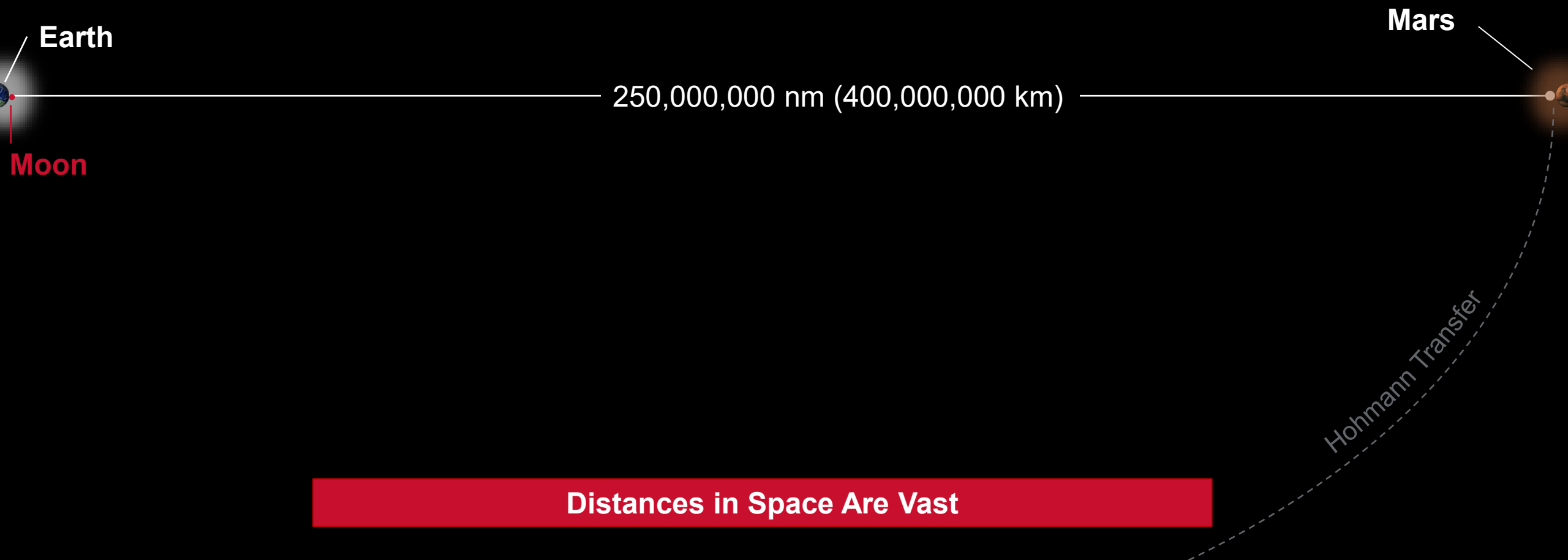
ASCENDER
BACK TO GATEWAY

DESCENDER
REMAINS ON MOON

Images Courtesy of NASA


LEO
GEO
22,000 nm (36,000 km)
1,000 nm (2000 km)
Hohmann Transfer


GEO
Moon
230,000 nm (380,000 km)
22,000 nm (36,000 km)



Distances in Space Are Vast

"KNOW HOW" REQUIRED BEFORE MARS

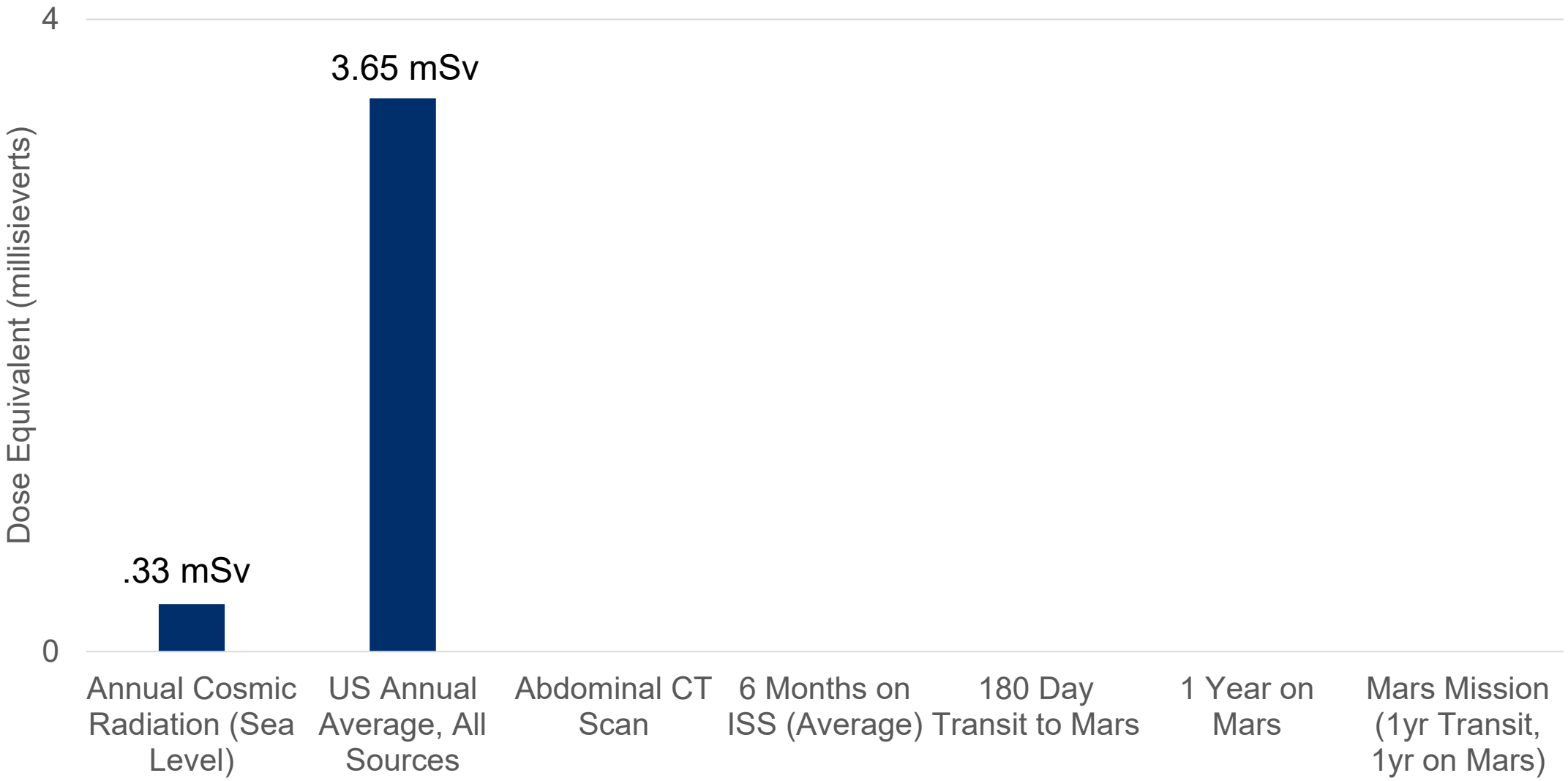
- Tools
  - Exploration and Extraction
  - Low Gravity Manipulation
  - Resource Utilization
  - 3-D printing
- Mobility
  - Personnel and Safety
  - Working away from Shelter
  - Move beyond Ops Planning
  - Resource Transport
- Habitation
  - Day and Night ECLS
  - Radiation
  - Dust Attraction & Migration
  - Communication Lag
- Power
  - Command and Control
  - Distribution/Beaming
  - Radiation
  - Lunar Night

Most Hostile Place We Have Ever Inhabited

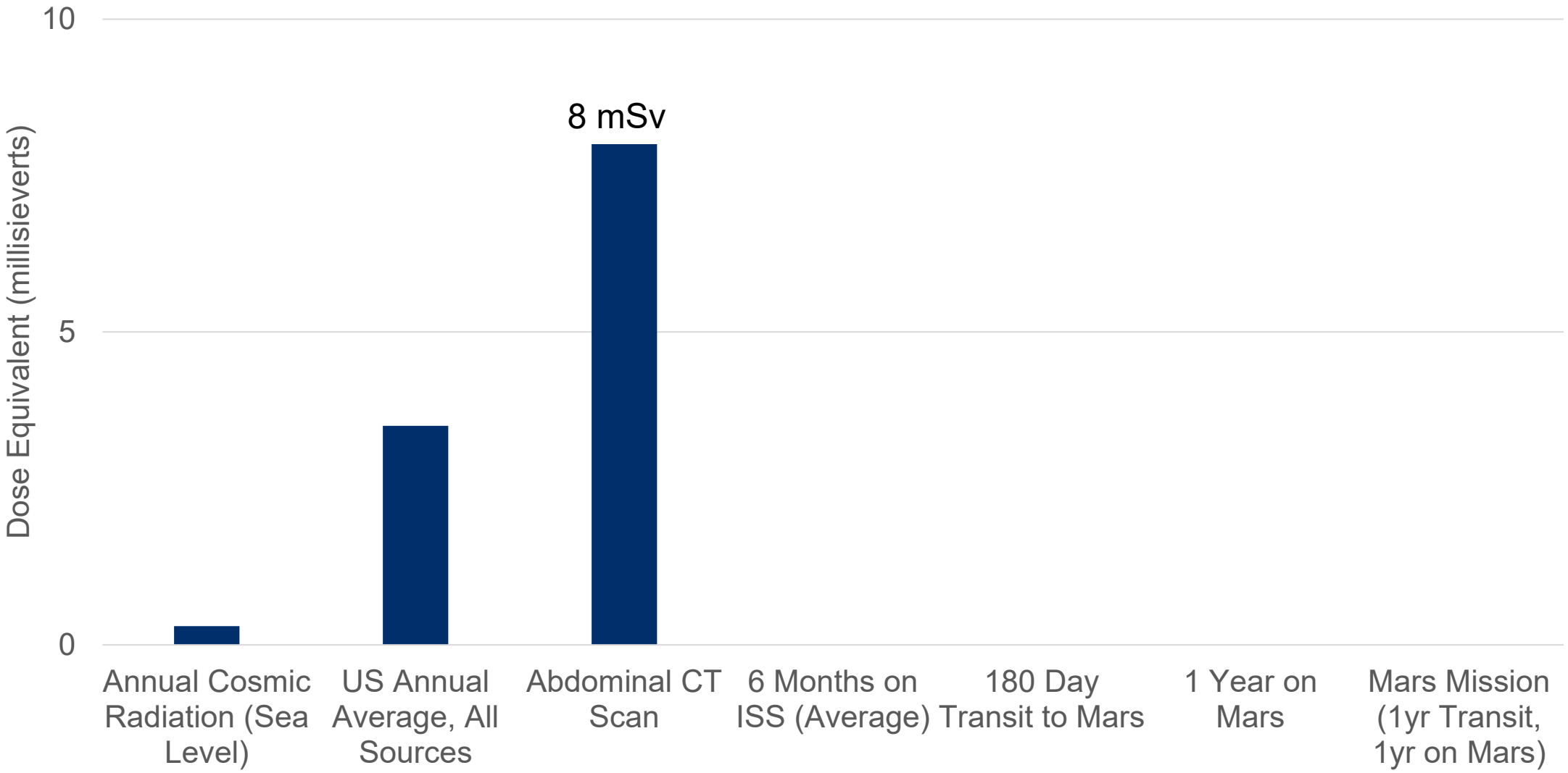
Earthrise Image - Credit NASA


Astro Gubbeh

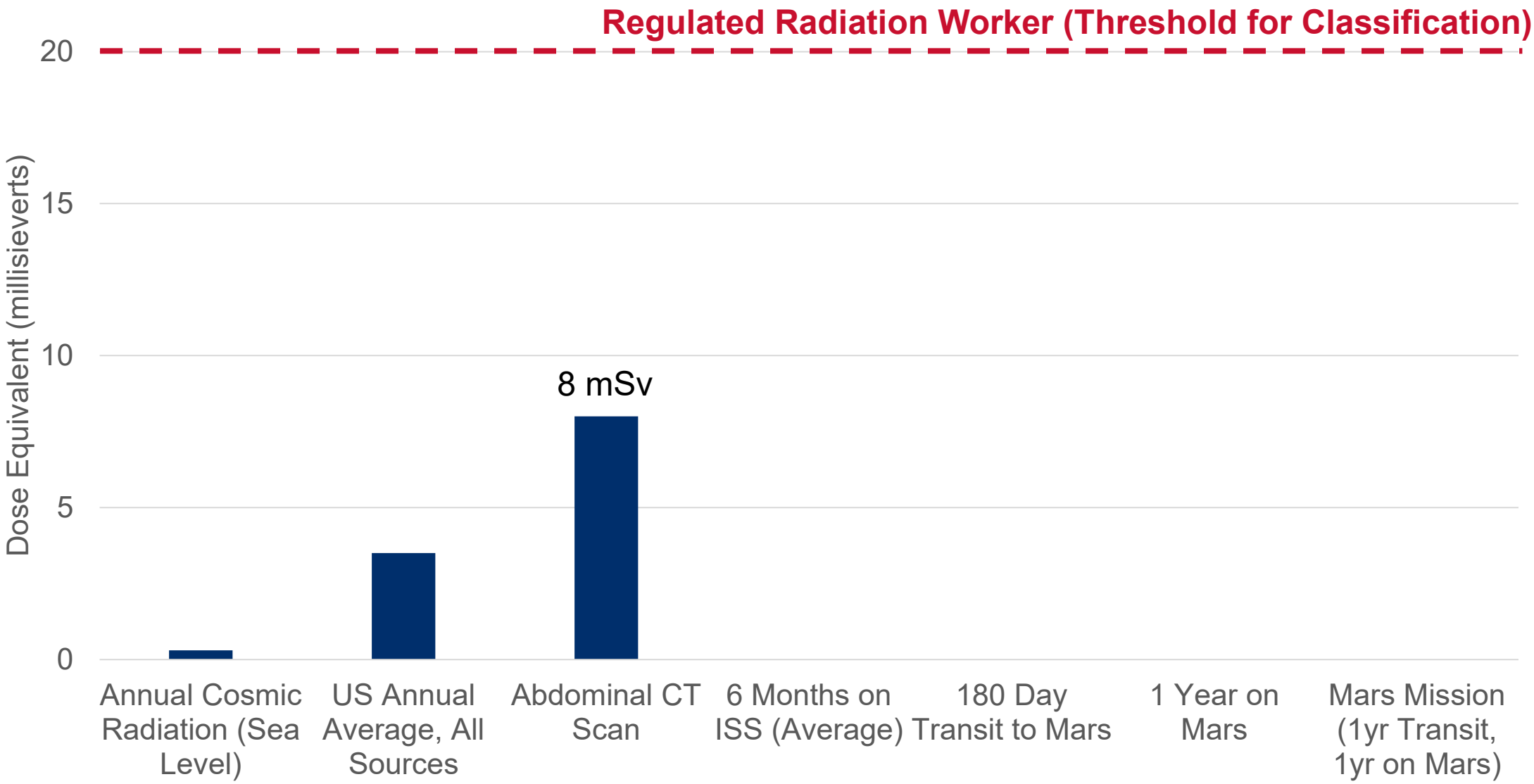
RADIATION EXPOSURE



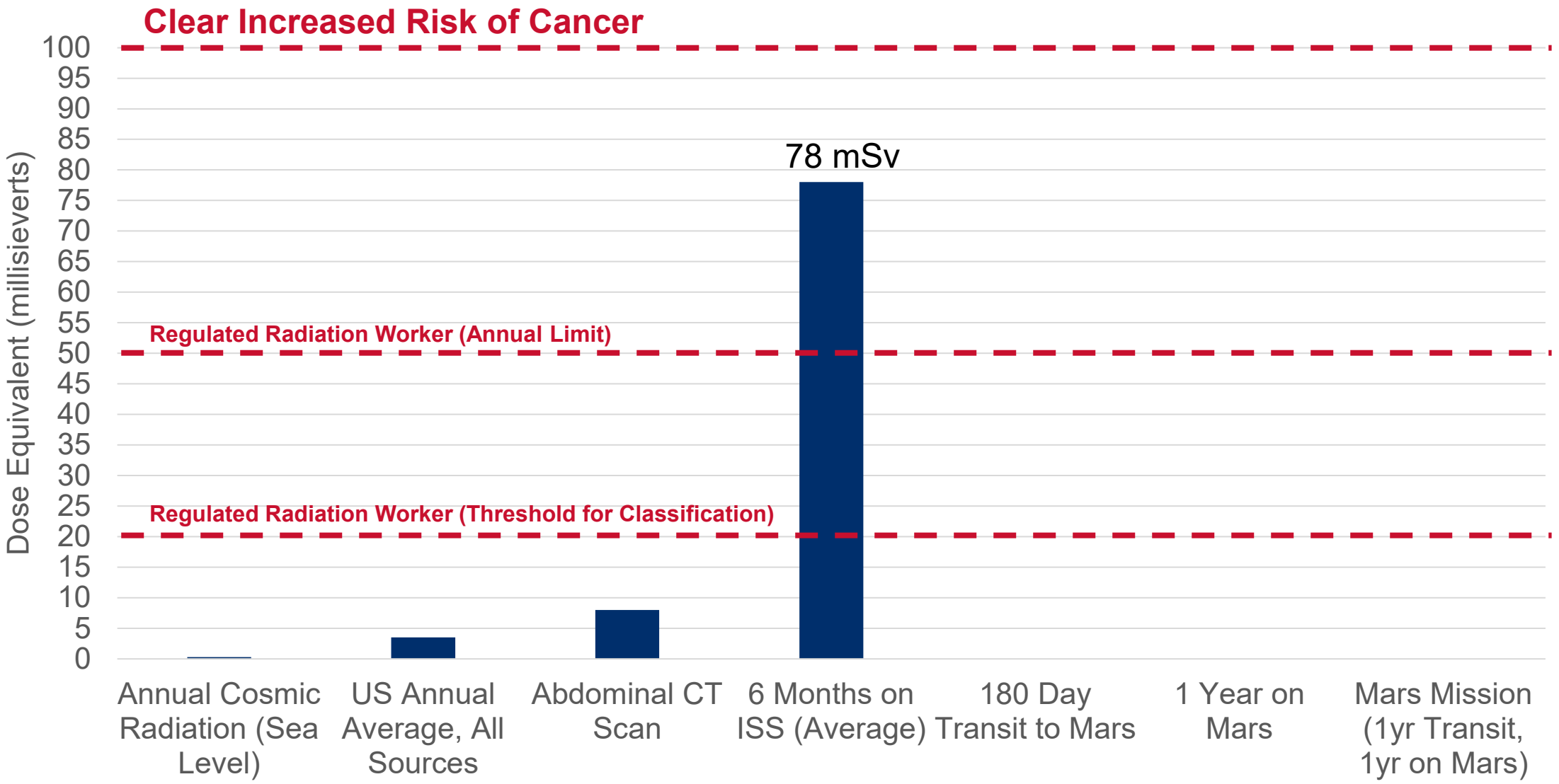
RADIATION EXPOSURE



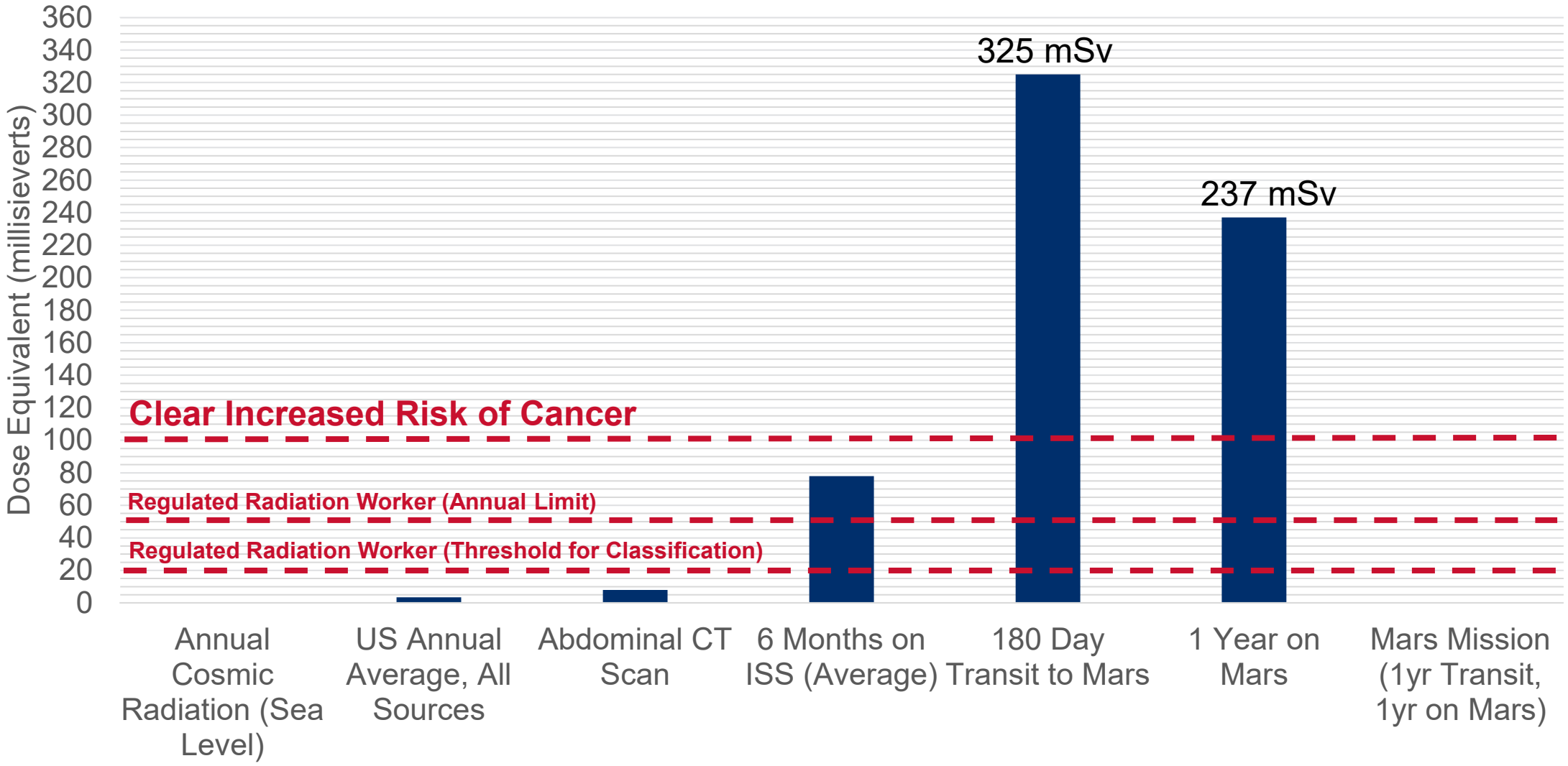
RADIATION EXPOSURE



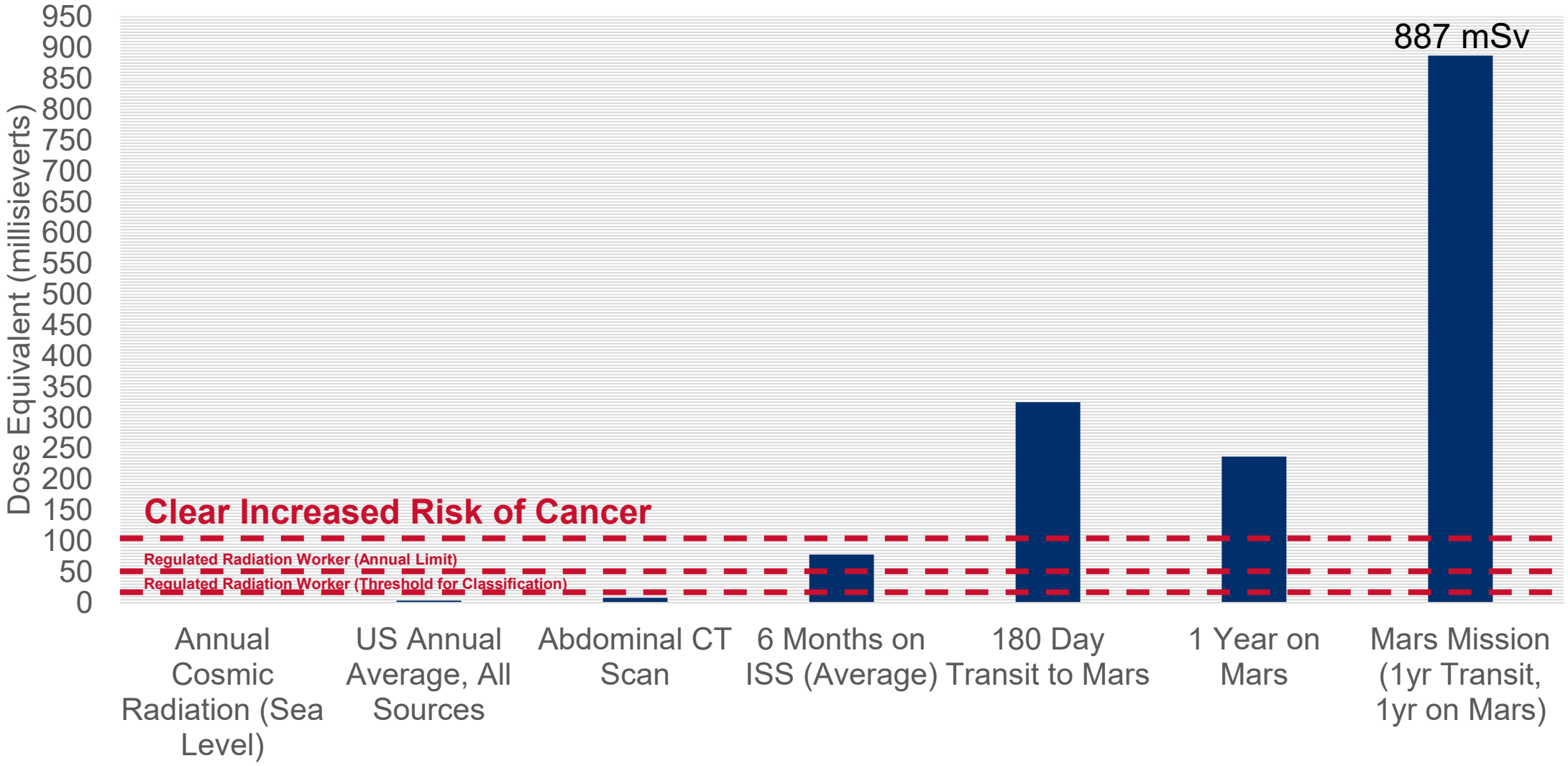
RADIATION EXPOSURE



RADIATION EXPOSURE

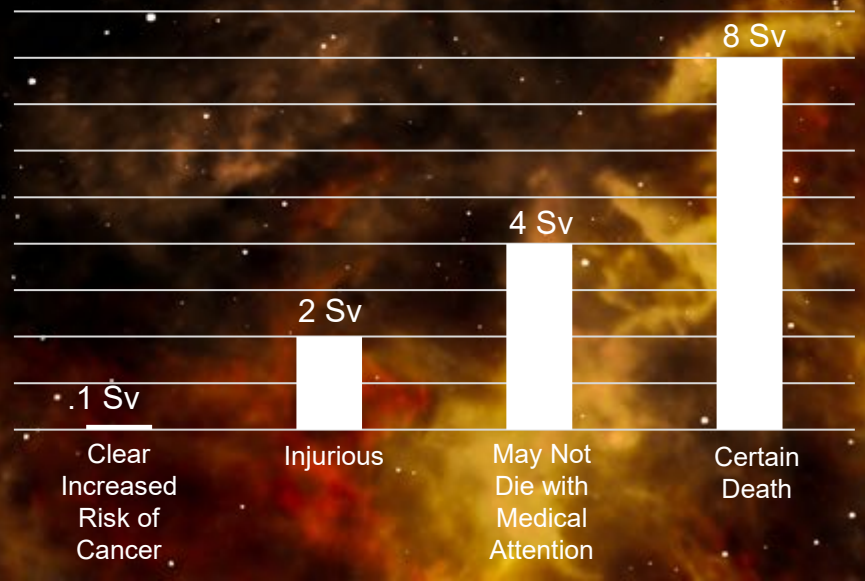


RADIATION EXPOSURE

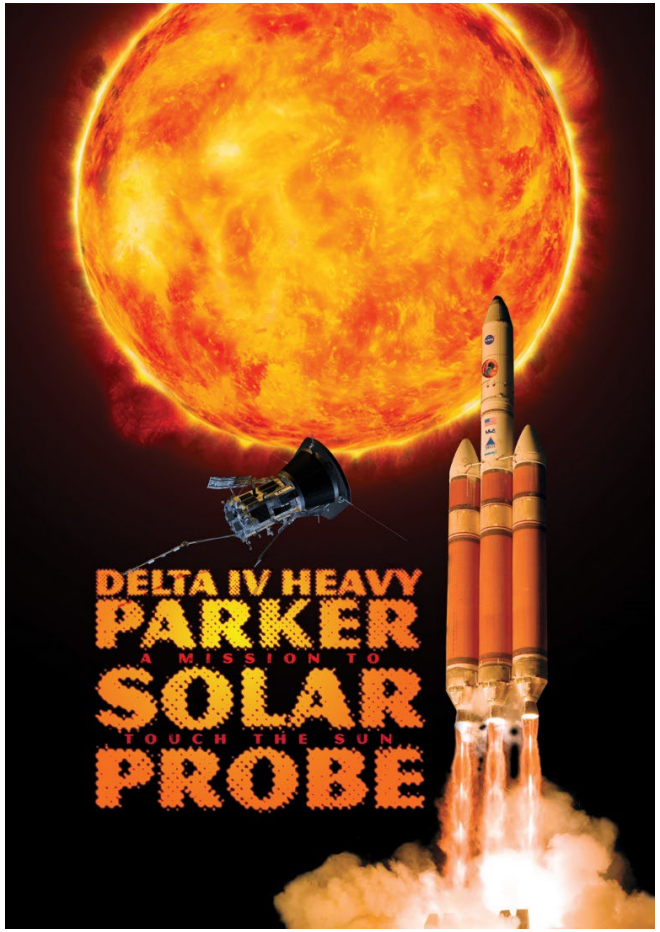


SIGNIFICANT SOLAR PARTICLE EVENTS (POTENTIALLY INJURIOUS)

Apollo 16 – Apr. 1972
Solar Storm of Aug. 1972
Apollo 17 – Dec. 1972
Mar. 1989 Geomagnetic Storm
Hubble Servicing Mission – Dec. 1999
Bastille Day Solar Storm – Jul. 2000
Halloween Solar Storms – Oct. 2003
Solar Storm – Jul. 2012
ISS Repair (8 hr 17 min) – Aug. 2012



LEARNING ABOUT DEEP SPACE RADIATION & HOW TO SURVIVE

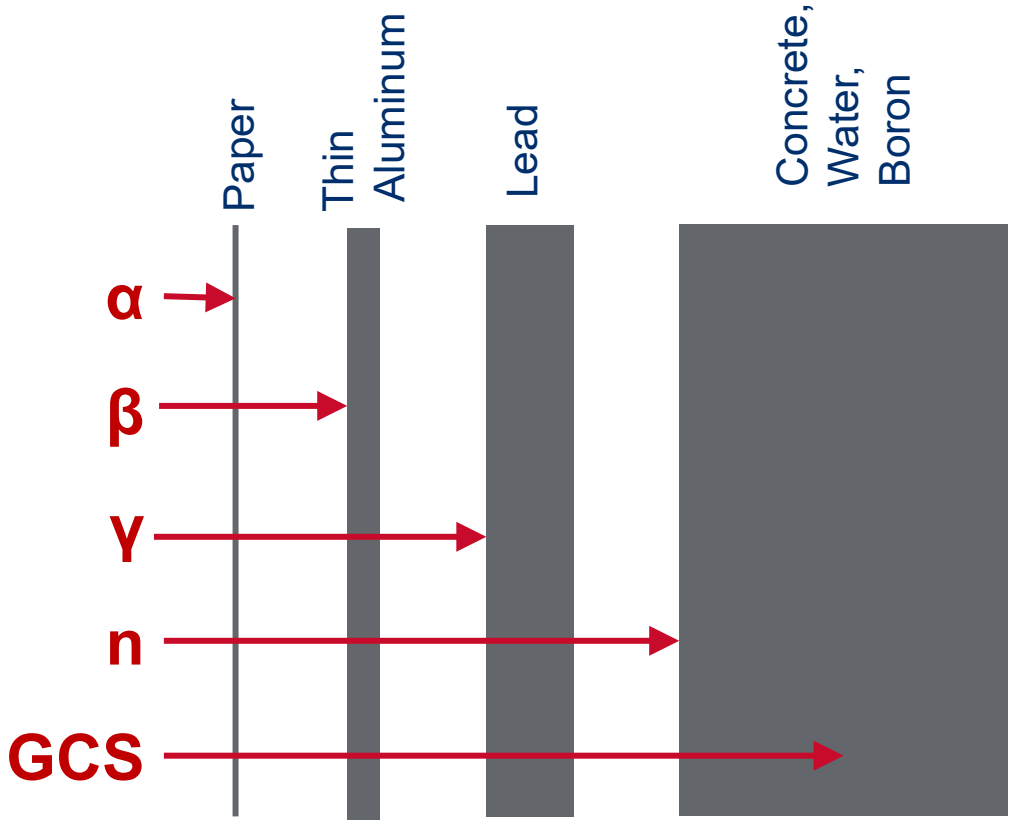


ARTEMIS

SPACE RADIATION

5 Types Of Radiation

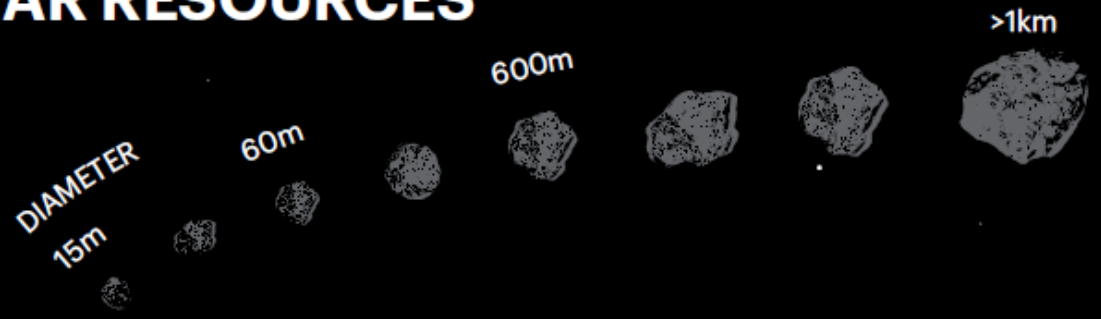
Type	Quality Factor	Nature
Alpha	20	Helium Nucleus
Beta	1	Electrons
Gamma	1	Photons (higher frequency than xray)
Neutron	5 - 20	Neutrons
Cosmic Rays	2 - 5	Protons with Heavy Atomic Nuclei



Research and Development of New Materials is Essential

A COMPELLING REASON TO STAY

CISLUNAR RESOURCES



>20 Billion Metric Tons of H20*

29,000 NEAR EARTH OBJECTS (NEO)

18,000
C-Type: Carbon, Water, Industrial Metals

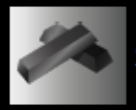
4,100
S-Type: Minerals, Industrial Metals

1,900
M-Type: Precious & Industrial Metals

3 Trillion Kg of Industrial Metals
210 Metric Tons of Precious Metals

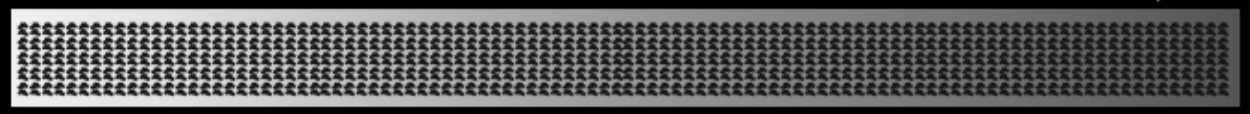
Industrial Production Metals (Kg)

EARTH



2 B

NEAR EARTH OBJECTS



2 T

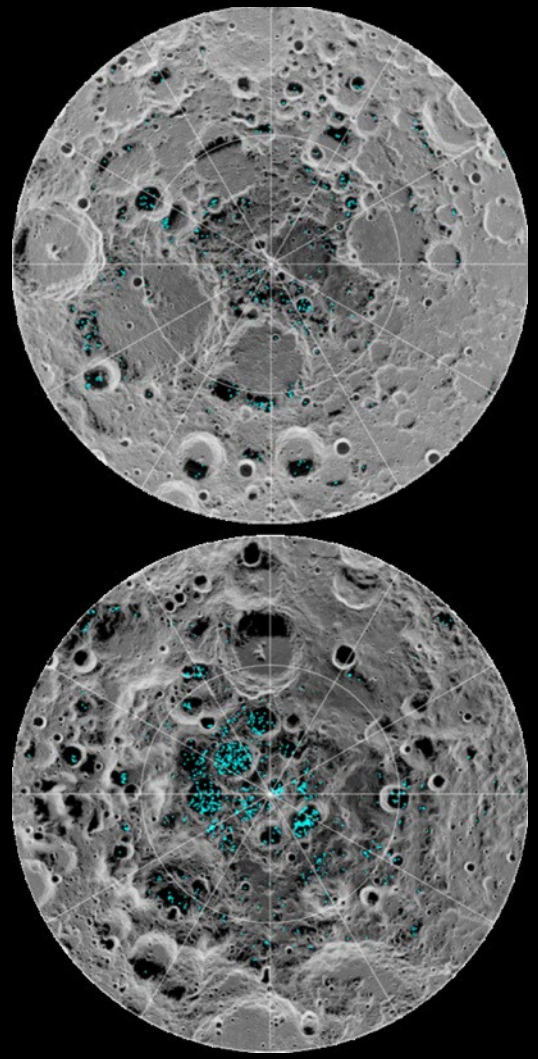
> 1,000 Years of Earth's Production of Industrial Metal

+

More than the World's Entire Gold/Silver/Platinum Reserves

*Paul Spudis, Lunar Institute

IN-SPACE PROPELLANT



Distribution of Surface Ice on the Moon
Credits: NASA

Harvesting H20

1. Insitu Thermal Mining
2. Dig and Process
3. Chemical Extraction

Making Propellant

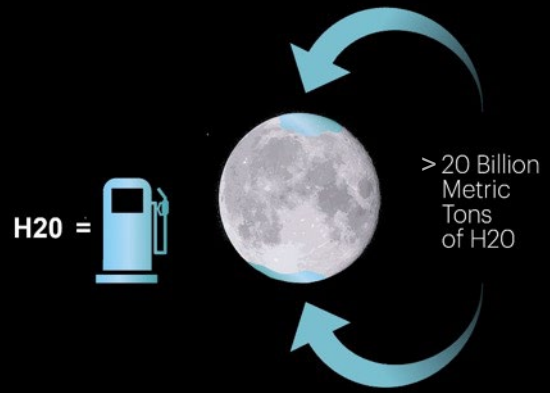
Power: Solar Panel, Nuclear Electrolysis

Liquefaction

➡ LH2 & LO2

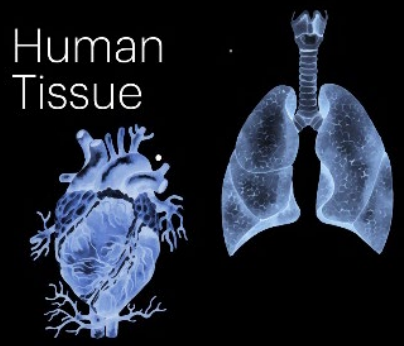
200 tons/yr current in space propellant demand

>100 million years @ current demand



NEW MATERIALS AND MANUFACTURING

Zero - G



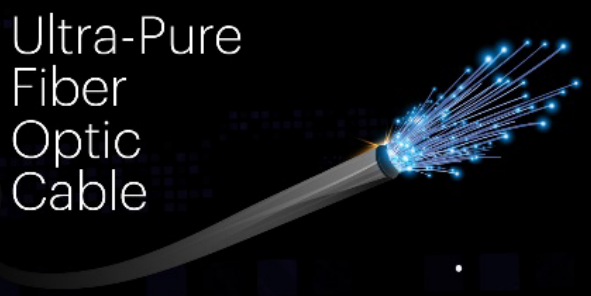
Blended Materials

Metal Foams

Crystals

Drugs

Zero – G & Vacuum



Unique Space Environment Enables Specialty Manufacturing

Vacuum

Vacuum Deposition

3D Printing

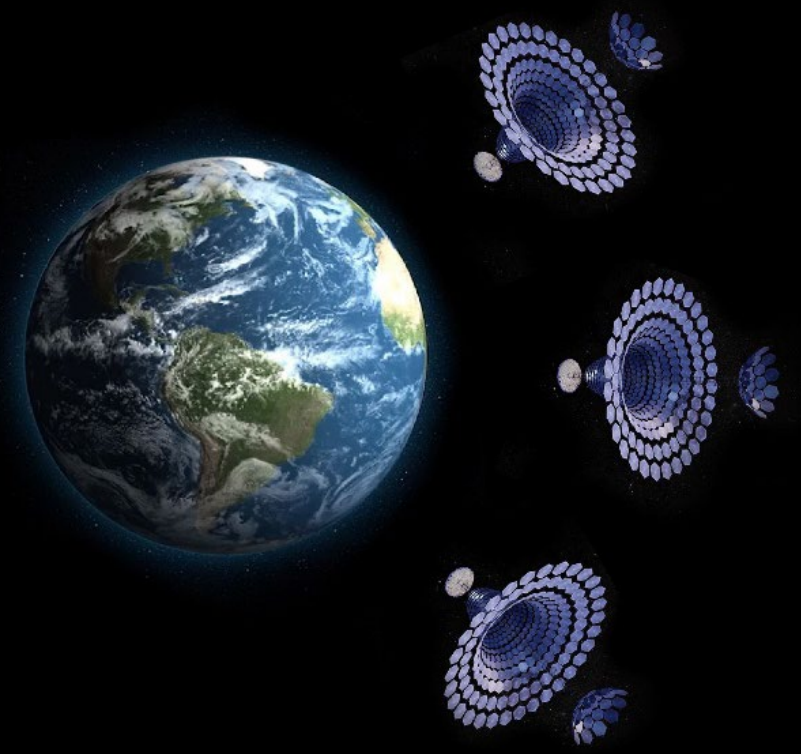
Hazardous Materials

UBIQUITOUS ENERGY

Annual Energy Market: **$8 Trillion**

Hydrocarbons currently satisfy 87% of energy

Sun emits **10^{13} more energy** than humans consume

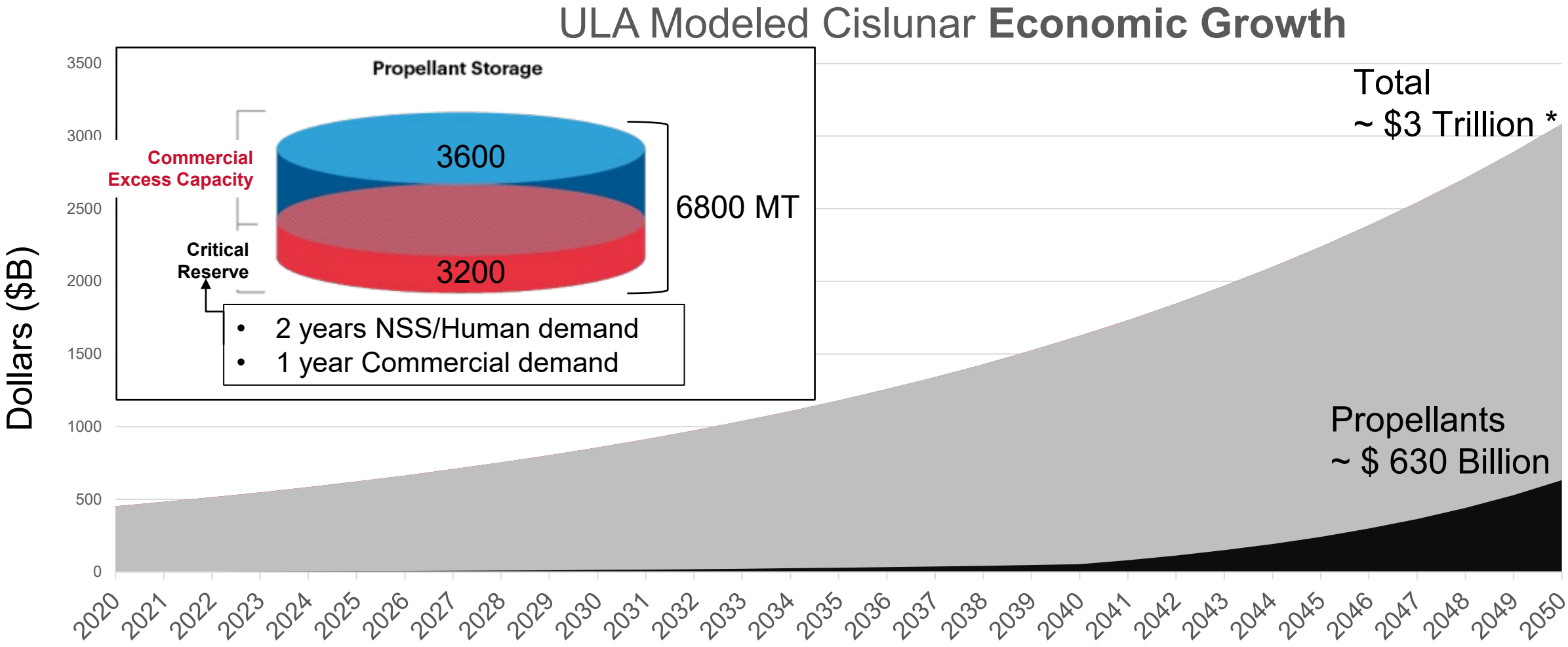


Transitioning Industry To Space Opens Essentially Unlimited Resources And Energy

GSO Solar Power Satellites

- **1,000X** global energy consumption
- Environmental benefits

STRATEGIC SPACE PROPELLANT RESERVE AS STIMULUS



* Merrill Lynch: Bank of America (2018), The Space industry will be worth nearly $3 Trillion in 30 Years

USG Investment of $20B Stimulates a $3T per Year Economy

CISLUNAR TIMELINE

2023
6 People
$330 Billion

ISS Expansion Grants
- Axiom
- Free Flyer

NASA Gateway, Space Tourism

Large-scale ZBLAN Production

2030
14 People
$500 Billion

Axiom Segment, Drug Production, Stem Cells, Semiconductor Chips

On-Orbit Satellite Assembly

Lunar Outpost, Lunar Ice Mining, LEO Village, Regenerative Medicine

Strategic Propellant Reserve

2035
100 People
$715 Billion

Artificial Gravity Station, LEO Settlement Production, Zero G Sports

Assisted Living Facilities, Orbital Solar Array, Mars Dress Rehearsal

LEO Settlement

Human Organ Manufacturing, Traffic Management

2040
300 People
$900 Billion

Solar Power Beaming Demo, Orbital Manufacturing

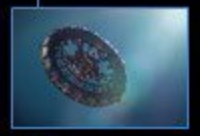
Crewed Mars Missions

L5 Settlement Production, Inter-Station Transport

Lunar Mass Driver

2045
600 People
$1.2 Trillion

Commercial Asteroid Mining



L5 Settlement

Luxury Hospitality Stations, Orbital Manufacturing

Mars Outpost

2050
850 People
$1.9 Trillion

Second L5 Settlement, Expanded Lunar Village

Second LEO Settlement

Solar Power Beaming Station

2055 and beyond
1,100 People
$2.7 Trillion

THANK YOU