

Back to the Moon



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Augustine Committee, 2009



“The Committee concludes that the ultimate goal of human exploration is to chart a path for human expansion into the solar system.”

Augustine Committee, 2009



“Humanity should become a spacefaring civilization... If that is not the point of human spaceflight, what the hell are we doing?”

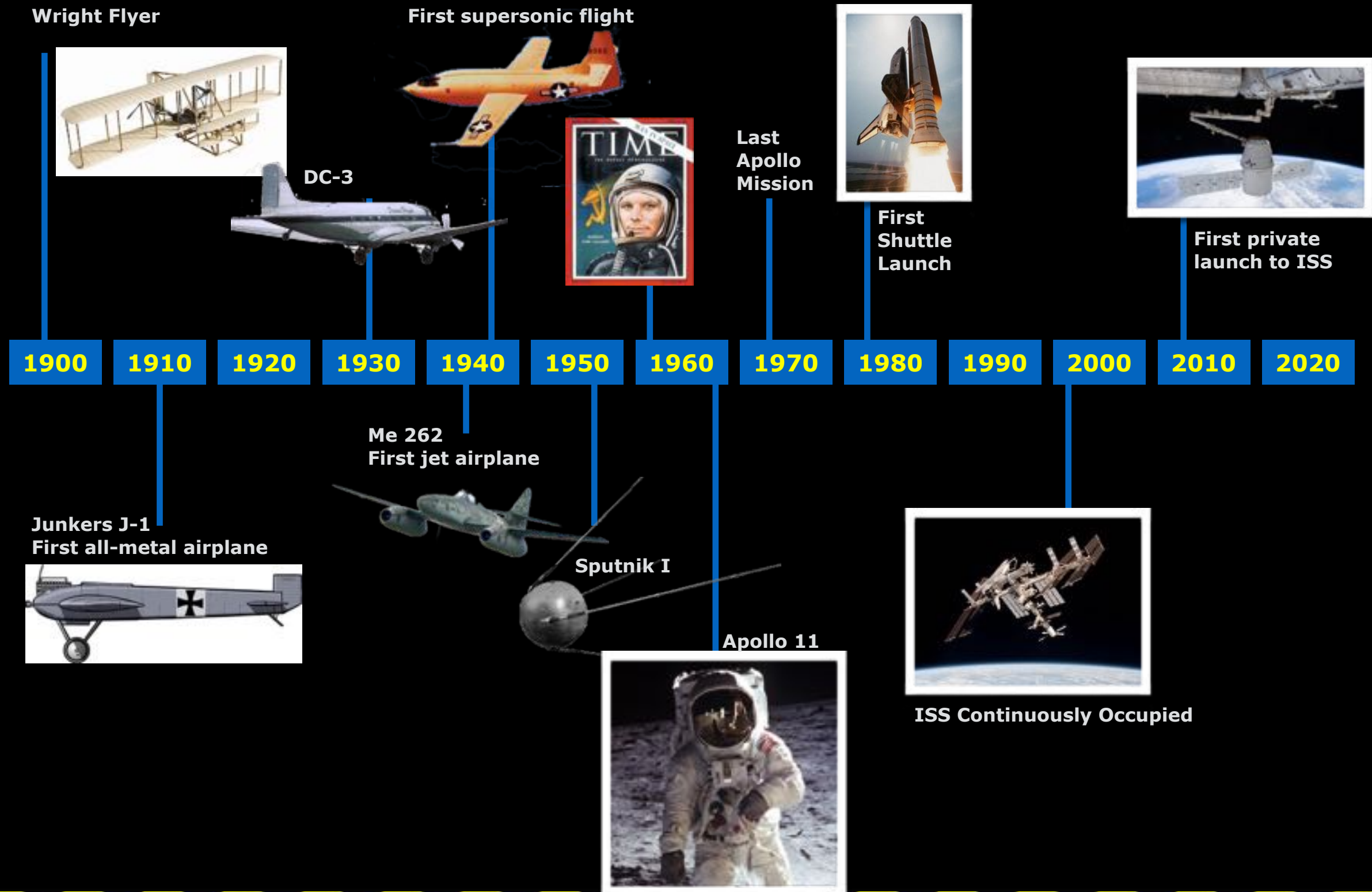
— *Chris Chyba, Princeton*

We Went to the Moon Too Early

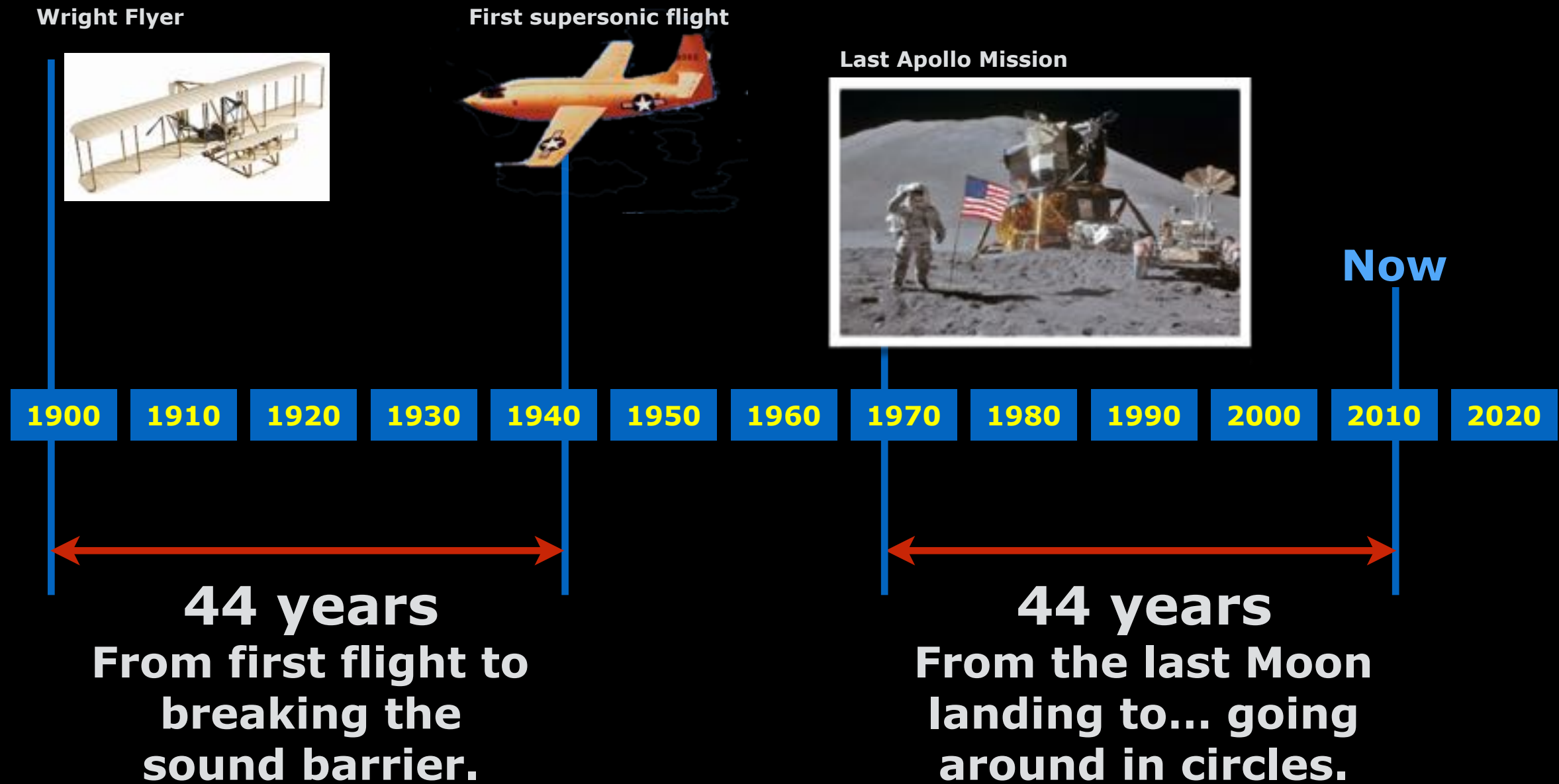
**...in the wrong way...
...for the wrong reasons...
...and we never went back!**



What Happened to Human Flight?



What Happened to Human Flight?



Earth-Moon System (*to scale*)



ISS Orbit *(to scale)*



No Humans Past LEO since 1972

We've been going around in circles in Low Earth Orbit for 44 years.

Even Moses Only Wandered 40 Years!





What
happened?

Where Did We Go Wrong?

“First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.”

—*Pres. Kennedy, May 1961*



Where Did We Go Wrong?

“First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more **impressive** to mankind, or more important for the **long-range** exploration of space; and none will be so **difficult** or **expensive** to accomplish.”

—Pres. Kennedy, May 1961



Decision Made: Flags and Footprints

Forty years later,
what remains of the
Moon missions?

Zero presence.

Zero industry.

Zero infrastructure.

Zero economic value.

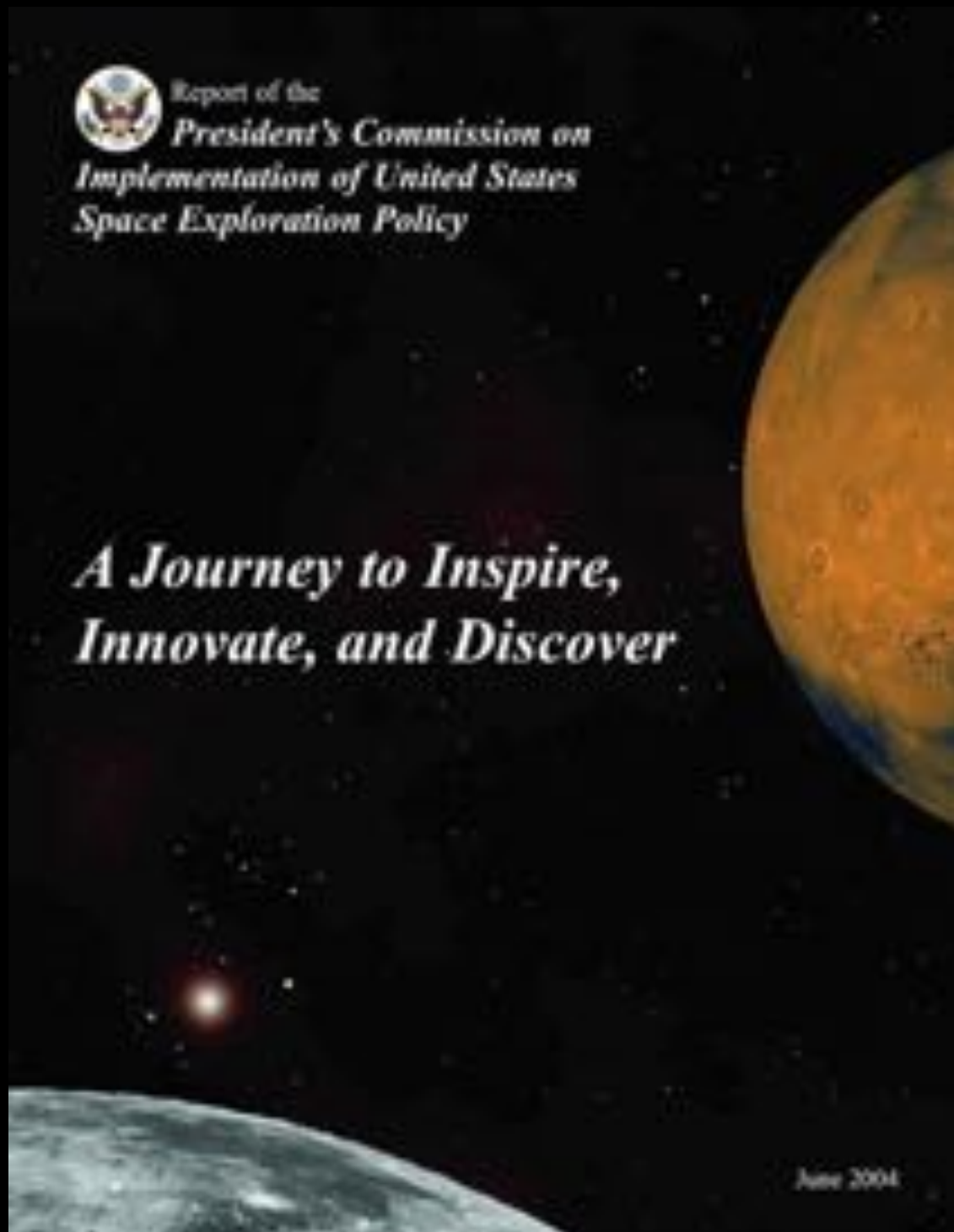


From Day One—not a model which could get traction on Wall Street!



What if we tried
something
different this time?

Vision for Space Exploration



We tried that in 2004 with the “Vision for Space Exploration.”

- “Apollo on steroids”
- Launchers, capsules, and lunar landers, oh my!
- Hijacked by existing fiefdoms thinking happy days were here again.
- Pigs get fed, hogs get slaughtered.
- Mostly cancelled in 2009/10.



What if we tried
something *really*
different this time?

Back to the Moon? Or On to Mars?



“Now, I understand that some believe that we should attempt a return to the surface of the Moon first. But I just have to say pretty bluntly here: We’ve been there before.”

—*Pres. Obama, April 2010*

Back to the Moon? Or On to Mars?

“For the United States... no human exploration capability to go beyond Earth orbit for an indeterminate time into the future destines our nation to become one of second or even third-rate stature.”


—*Neil Armstrong, April 2010*



Reasons to Go Back to the Moon

1. What we can learn there.
2. What we can learn *how* to do there.
3. What we can do there.
4. Where we can go next from there.

What We Can Learn There

A photograph of the lunar surface. In the foreground, the rear wheel and part of the orange rover are visible. To the right, a large, multi-lobed gold-colored antenna is mounted on a tripod. In the center, an astronaut in a white spacesuit stands next to a large, dark, craggy rock. The ground is covered in dark lunar soil and small rocks. The background shows the dark, cratered horizon of the Moon under a black sky.

**Understanding the
formation of the
Solar System**

What We Can Learn There

**Understanding
how the Moon
split off from
the Earth.**



What We Can Learn There



***Farside
Observatory:
Best location
in the Solar System
for radio astronomy***

What We Can Learn There



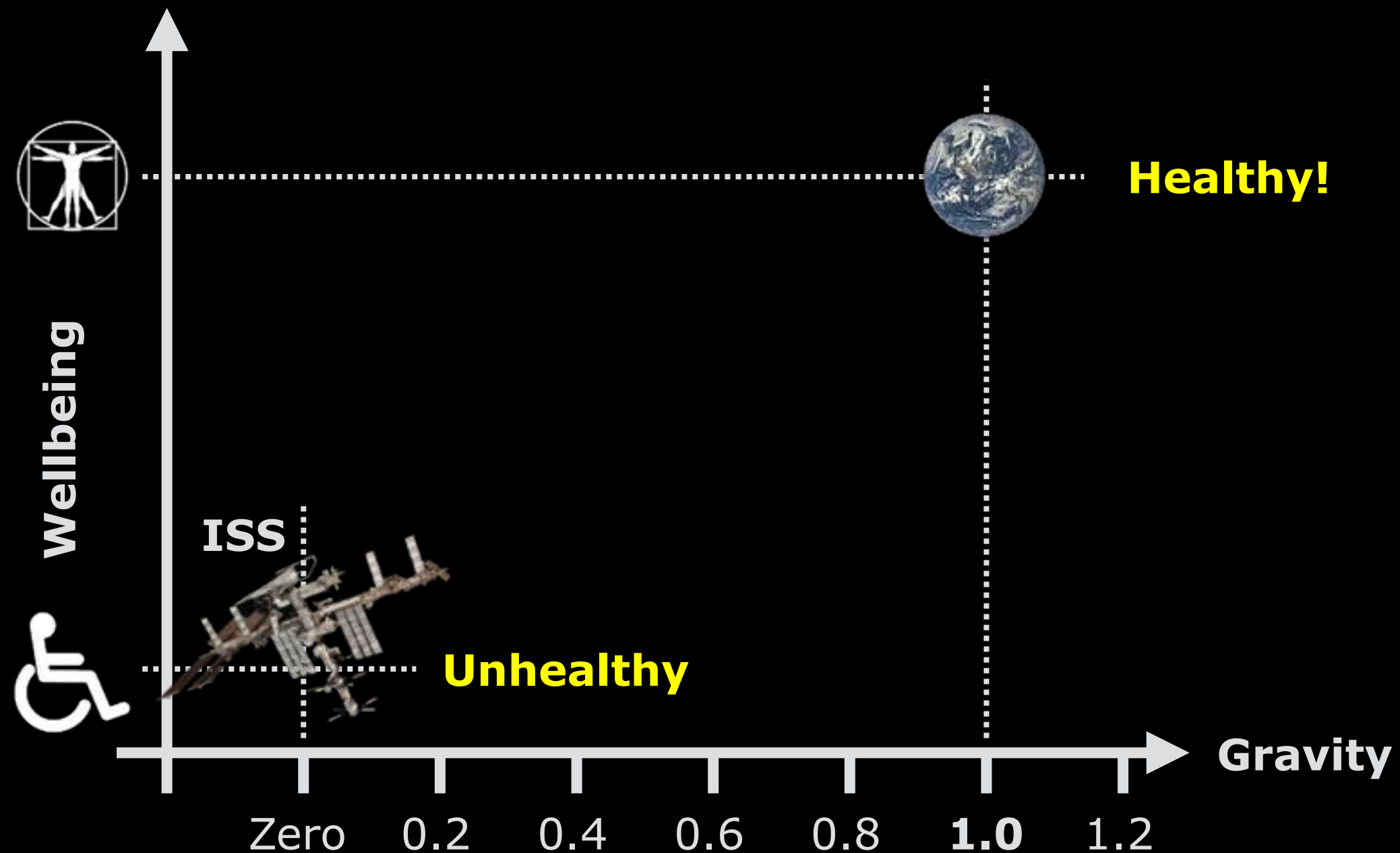
Science!

Thomas Dolby
"The Blinded Men With Senses"
The Best Of Thomas Dolby Retrospectacle

Reasons to Go Back to the Moon

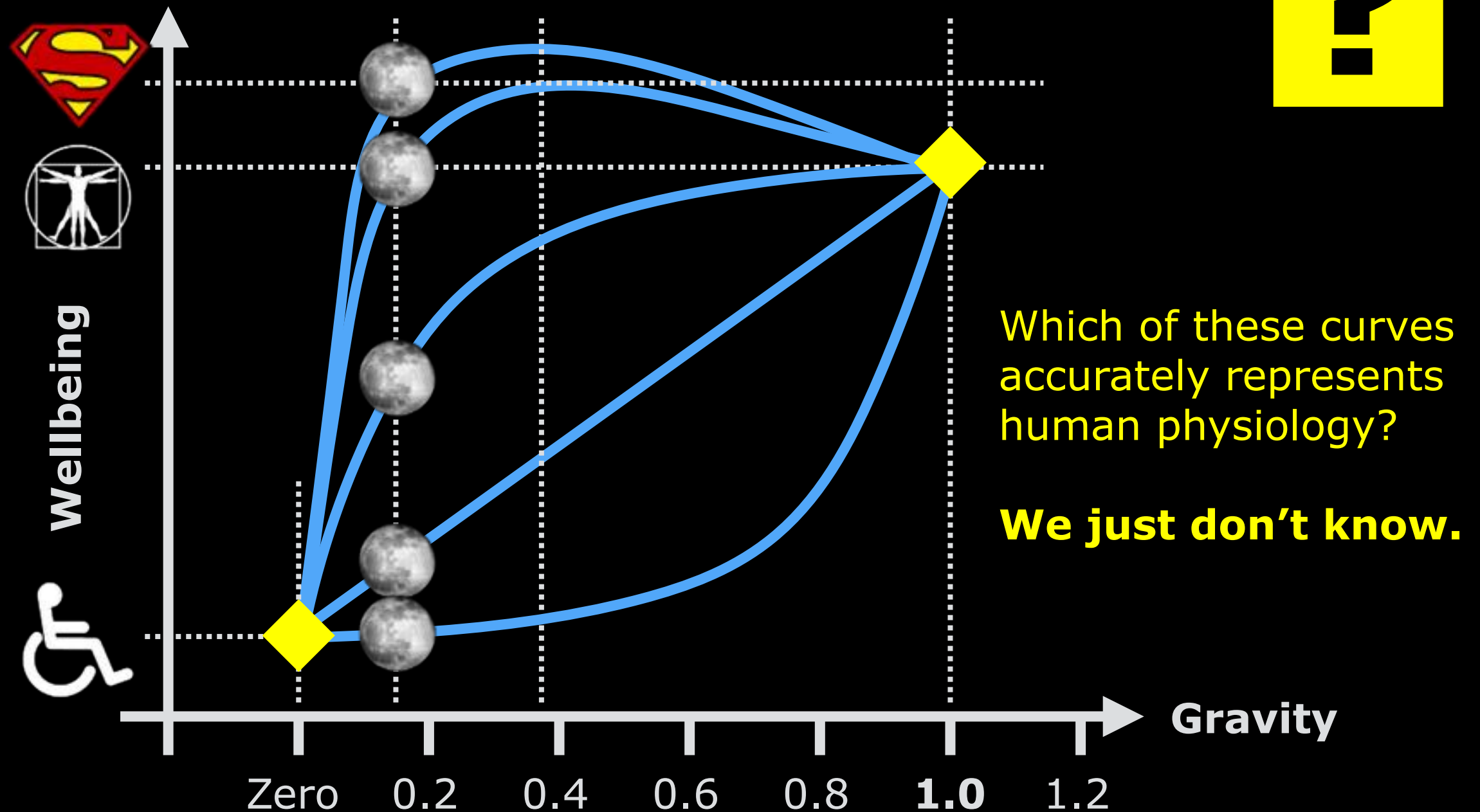
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What We Can Learn *How* to Do There



Adapted from <http://selenianboondocks.com/2005/11/if-youre-going-to-be-snarky/>

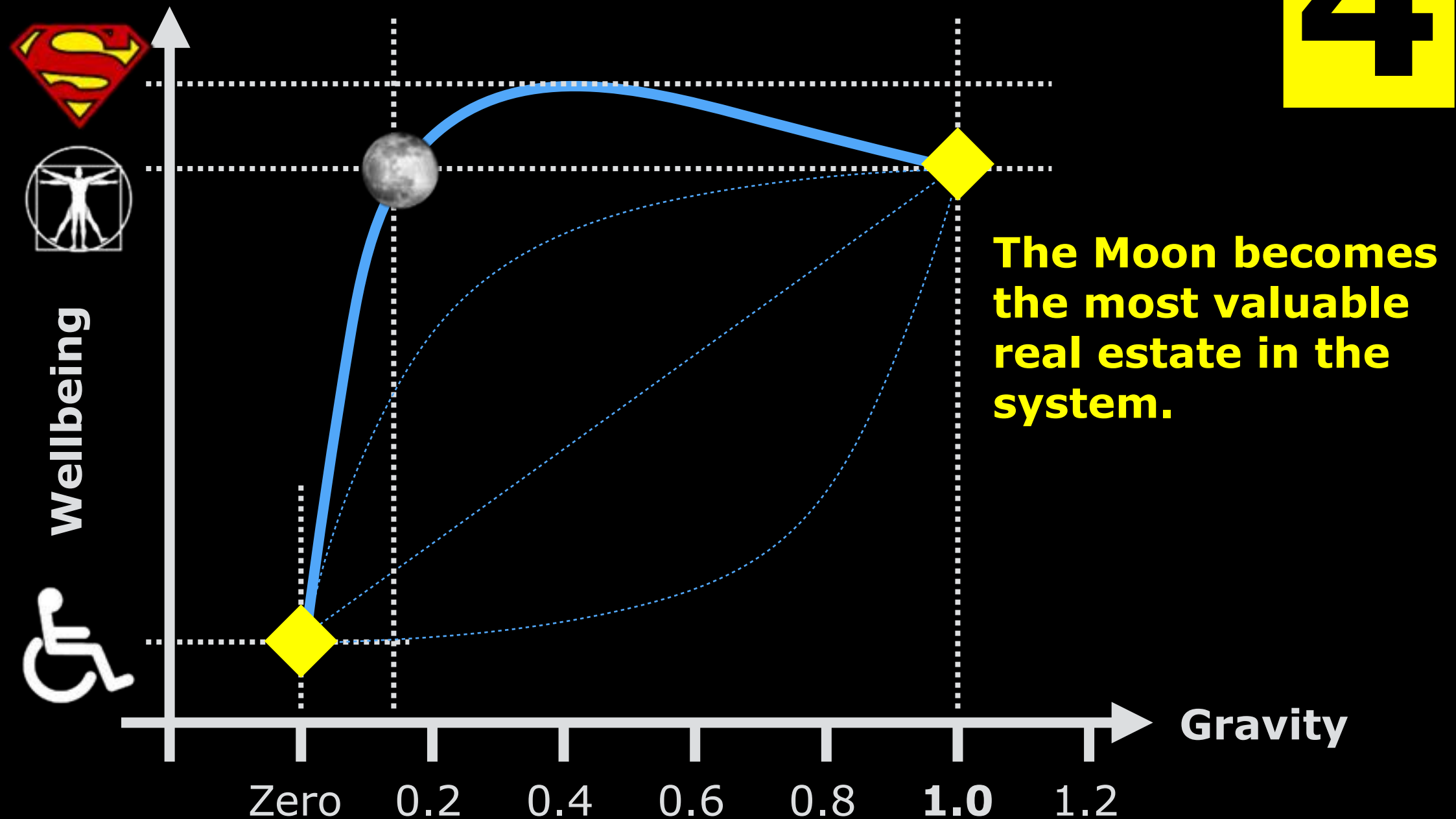
We Only Have Two Data Points!



Adapted from <http://selenianboondocks.com/2005/11/if-youre-going-to-be-snarky/>

Learn How to Thrive in Low Gravity

4



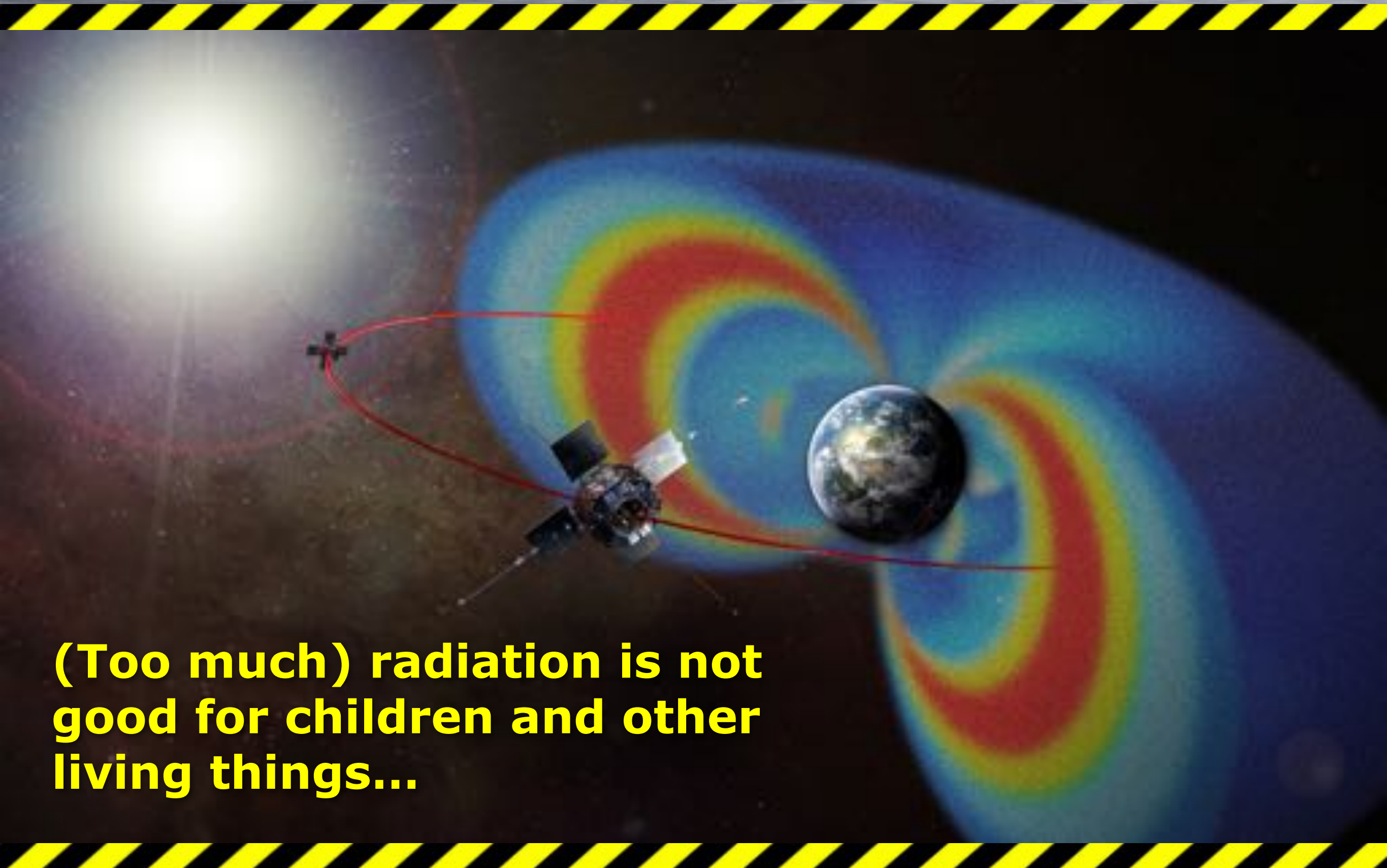
Adapted from <http://selenianboondocks.com/2005/11/if-youre-going-to-be-snarky/>

What We Can Learn *How* to Do There

Closing the loop on life support

**Water-only
recycling:
93% efficient**

Space is Radioactive!



(Too much) radiation is not good for children and other living things...

What We Can Learn *How* to Do There

Buried habitats for radiation shielding

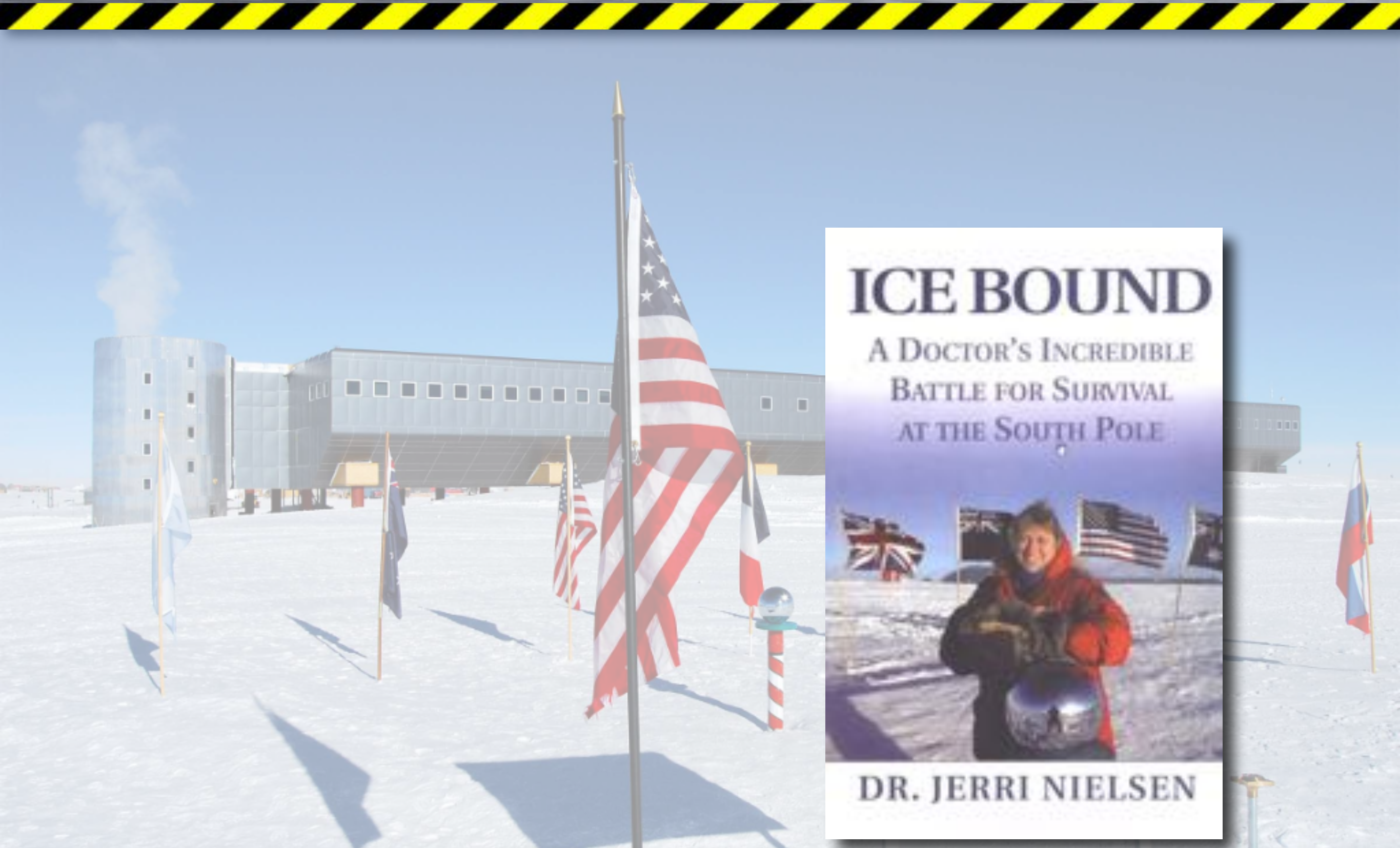


What We Can Learn *How* to Do There

Truly isolated operations
(but only 3 days from Earth)



Dr. Jerri Nielsen, 1999



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1. What we can learn there.
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What We Can Do There

**A new world to
explore...**



The Moon is Earth's Eighth Continent!

Landmass	Area (sq km)
Asia	43,820,000
Moon	37,900,000
Africa	30,370,000
North America	24,490,000
South America	17,840,000
Antarctica	13,720,000
Europe	10,180,000
Australia	9,008,500

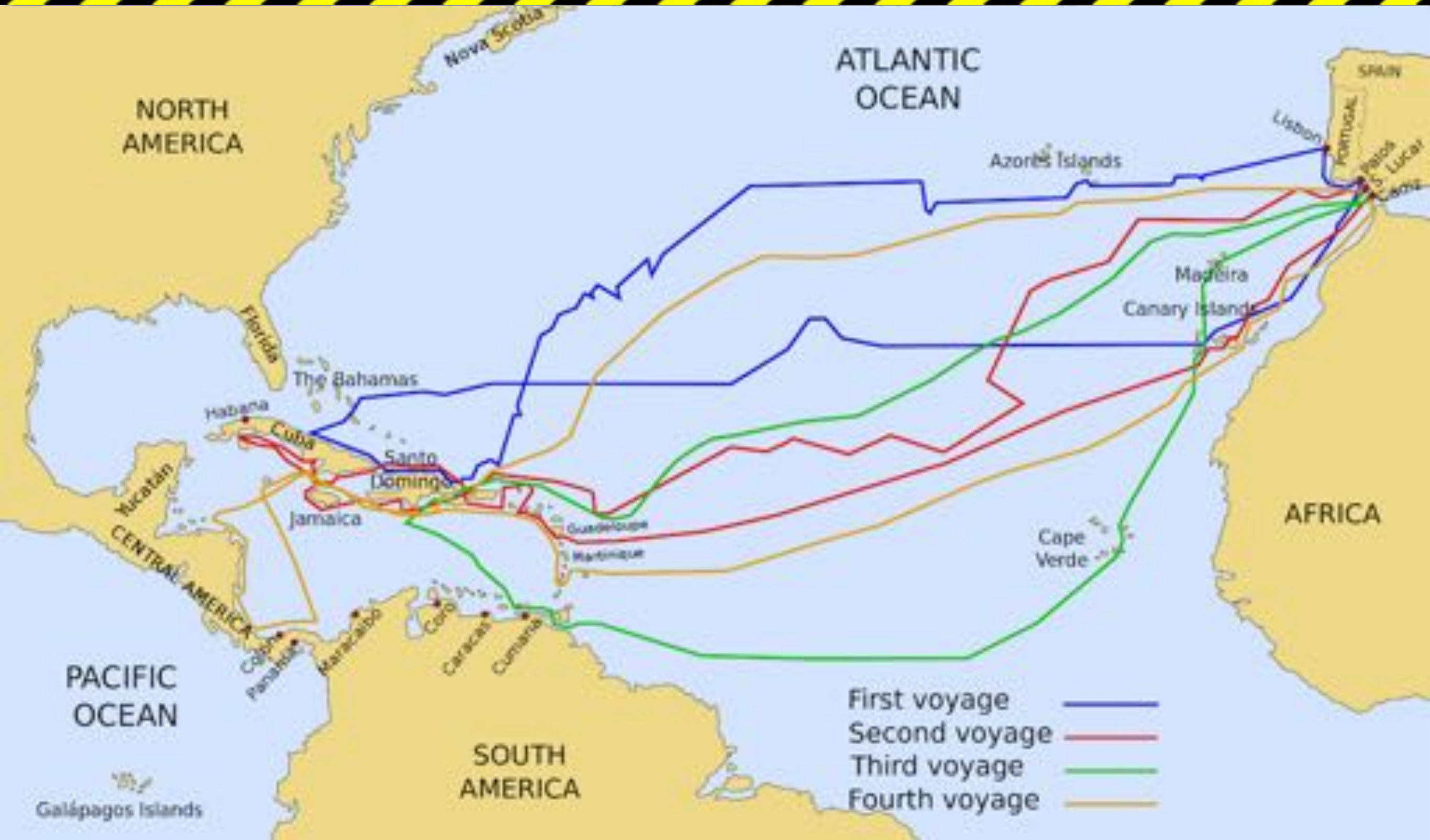
Total of Six Apollo Landing Sites

**Six football fields,
in a land bigger
than Africa.**



Apollo:
*Equatorial
orbits, easy
 ΔV for
rendezvous,
nothing on
Farside at all.*

Voyages of Columbus



What We Can Do There



What We Can Do There


A photograph of three mining workers in a rugged, mountainous landscape. The workers are wearing heavy brown jackets and hard hats (yellow, red, and green). They are gathered around a large yellow piece of mining equipment, possibly a drill or a pump. In the background, there are orange shipping containers and a large pile of rocks or ore. The word "Mining!" is overlaid in large white letters across the center of the image.

Mining!

What We Can Do There

**Planet-hopping
gets cheaper with
lunar mining!**

Primary goal isn't science or "flags and footprints"... it's spreading humanity through the solar system.

 SpaceWorks
CHANGE ORBITAL COLLECTORS, INC. 2015/2016

What We Can Do There

Resource prospecting:
Moon Express launching in 2017
Competing for
Google Lunar X Prize



What We Can Do There

Lunar mining:

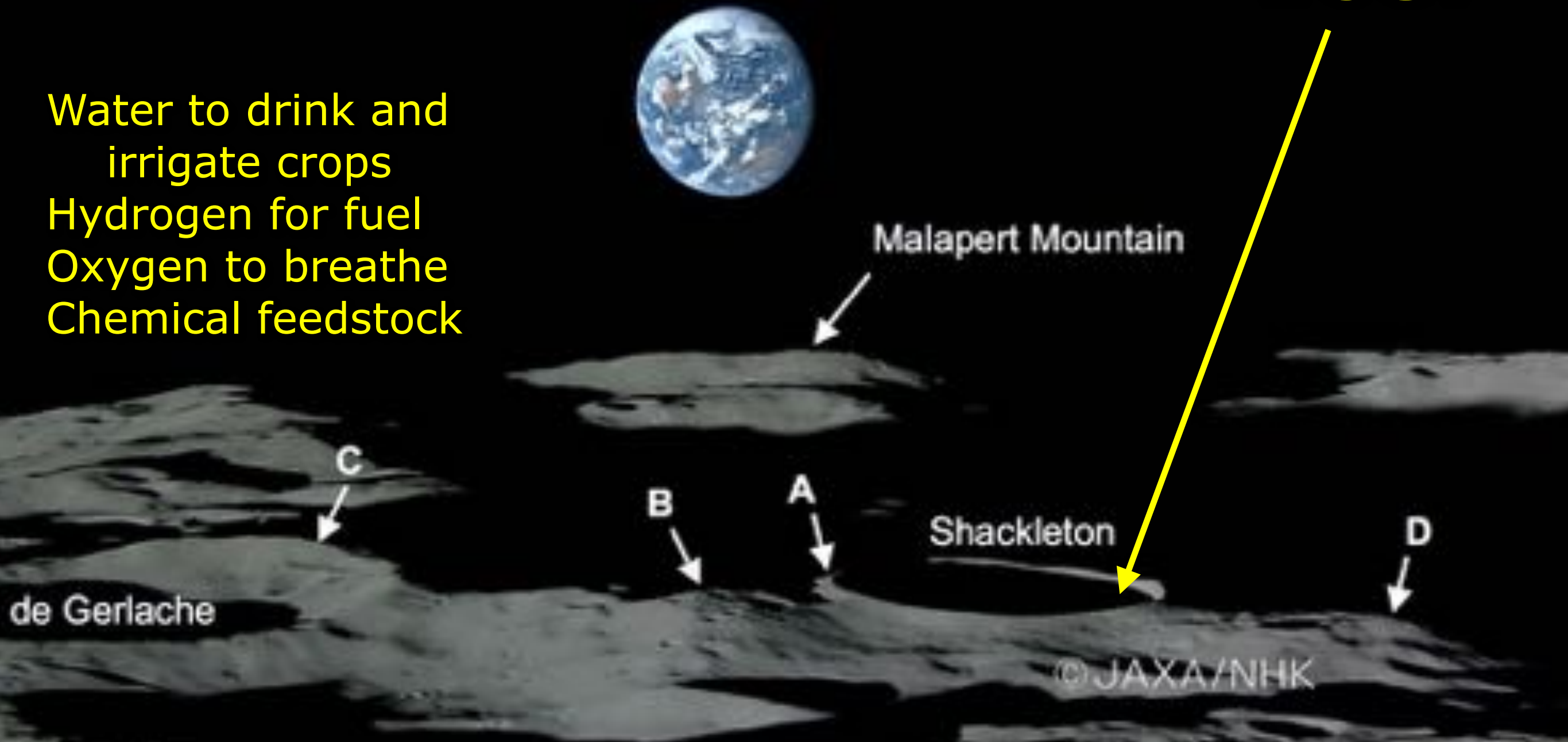
In Situ Resource Utilization
Effective teleoperations
Vacuum chemistry
Dust control



What We Can Do There

Water to drink and
irrigate crops
Hydrogen for fuel
Oxygen to breathe
Chemical feedstock

Ice!

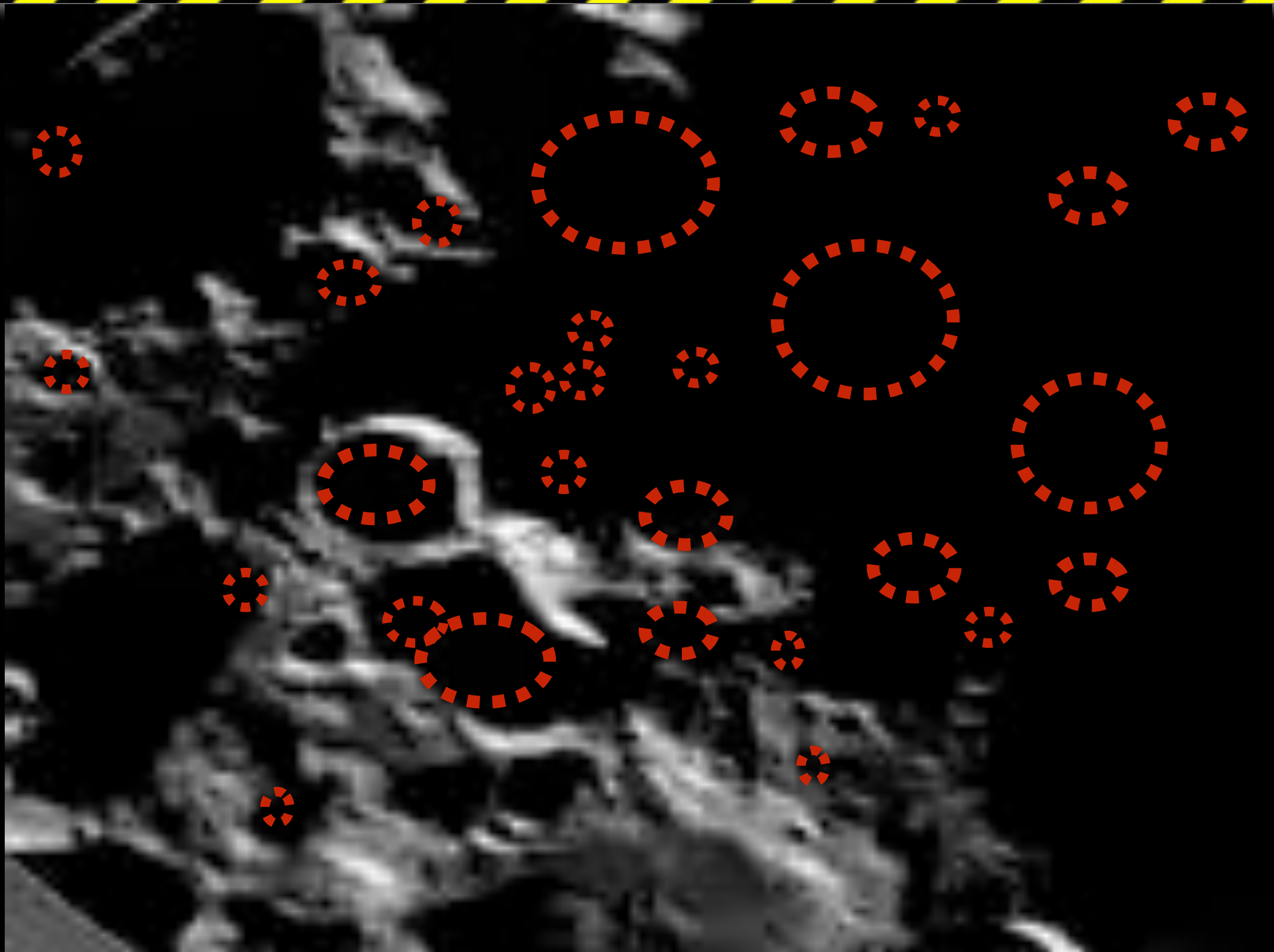


The Lunar South Pole is Unique



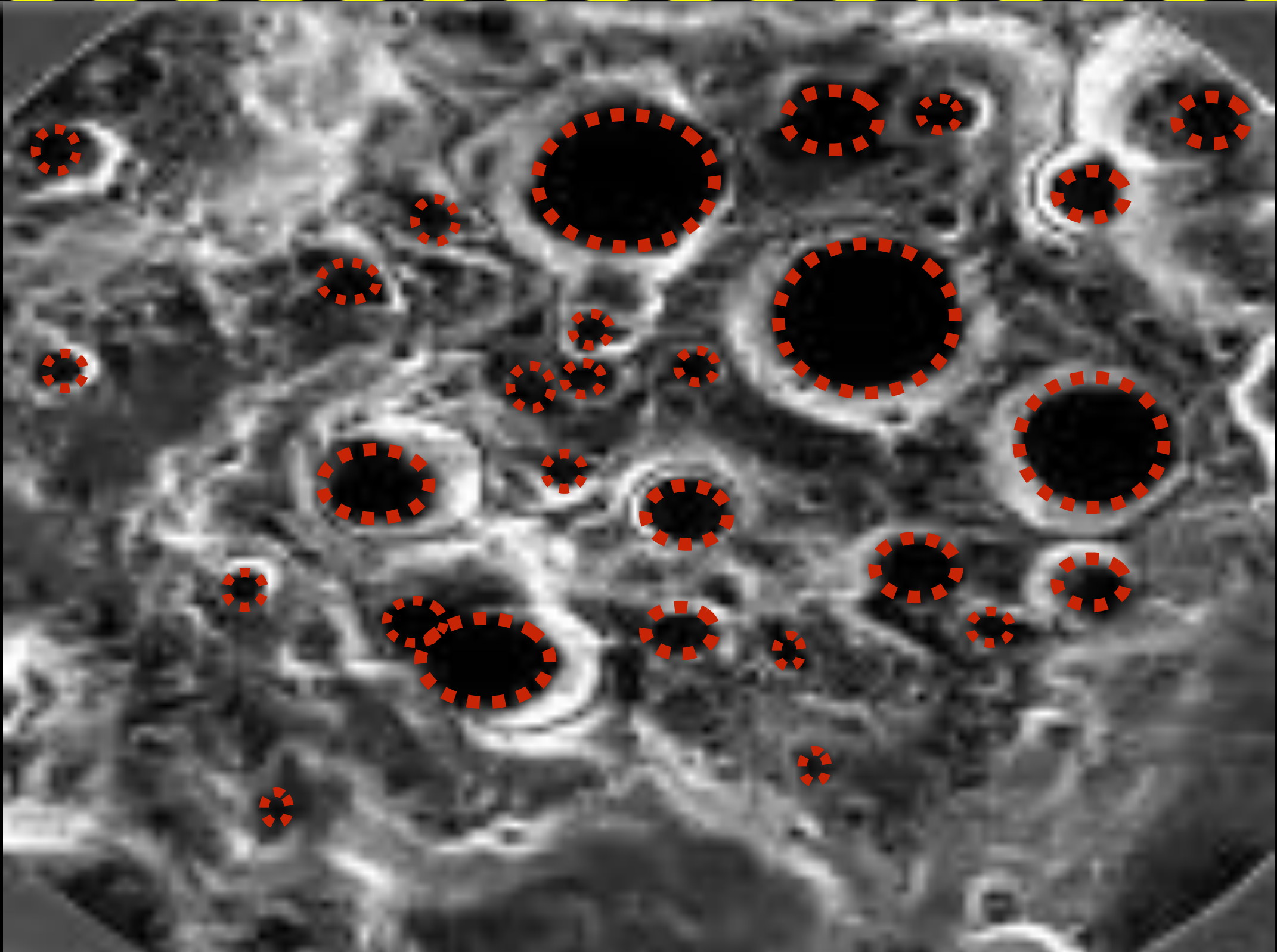
JAXA KAGUYA video

Permanently Shadowed Craters



JAXA KAGUYA video

Permanently Shadowed Craters



The Moon Gets Hit... A Lot!

**All those craters came
from somewhere!**



Comet Shoemaker-Levy, 1994

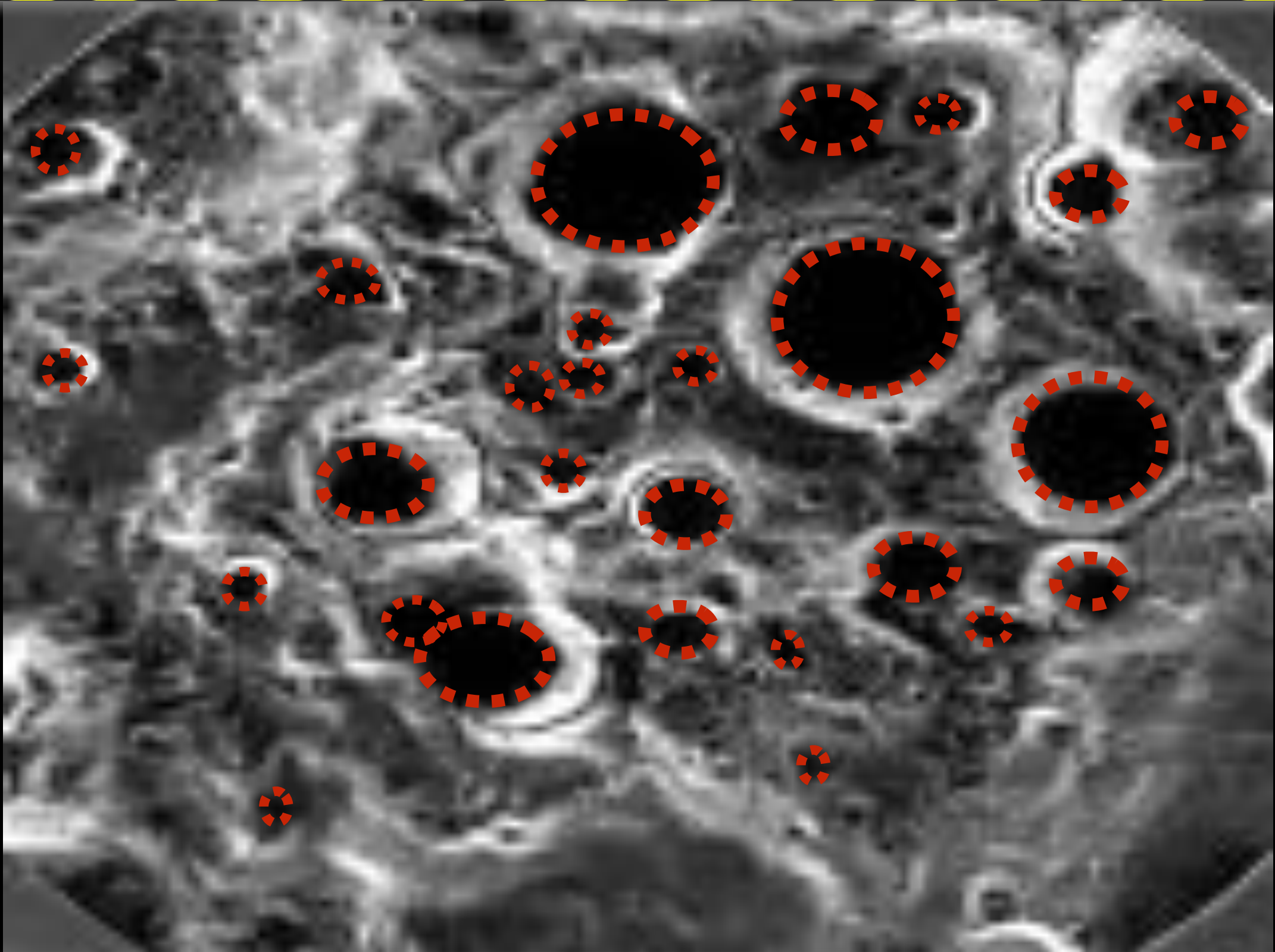
Remember?



Comets are Dirty Snowballs

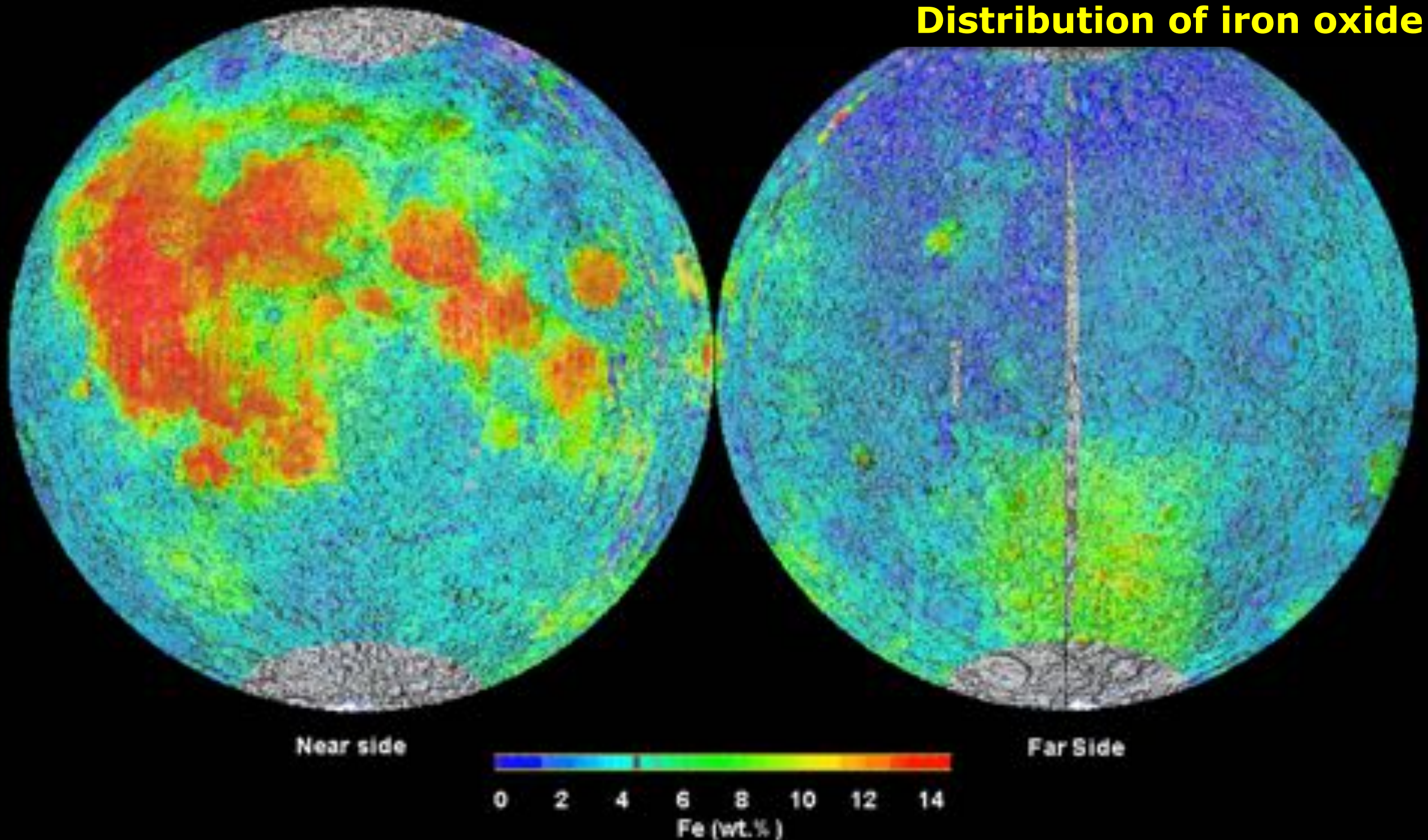


Shadowed Craters Act as “Cold Traps”



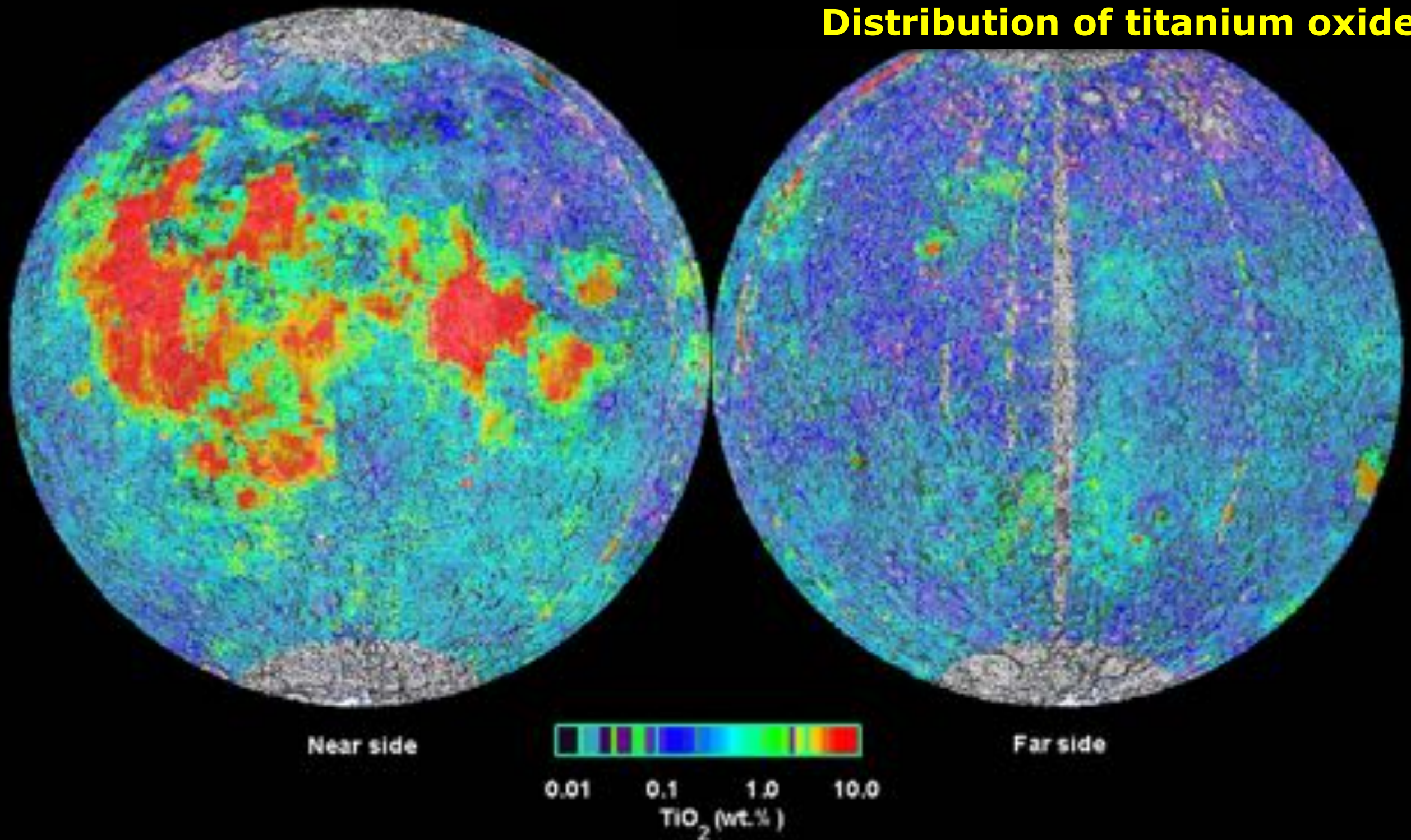
Lunar "Geology" is Complex

Distribution of iron oxide



Lunar "Geology" is Complex

Distribution of titanium oxide



What Can You Mine/Make on the Moon?

**Iron
Aluminum
Titanium
Silicon
Glass**

**Oxygen
Hydrogen
Regolith
...and more**



What We Can Do There



**Send lunar materials to build
space-based solar power satellites**

We've Gotten Good at Orbital Assembly

**...but at \$10,000/pound
from Earth, it doesn't matter.**



Solar-Powered Mass Driver



What We Can Do There

@ 2012 Washington Post



**Platinum-
group metals**
(maybe)

Extract Helium-3 (*double maybe!*)

Mining the Lunar Dust

Regolith, the loose soil on the moon's surface, contains more than 1 million tons of helium 3. In theory, this nonradioactive isotope could provide an abundant source of clean nuclear energy. How it might be done:



Reasons to Go Back to the Moon

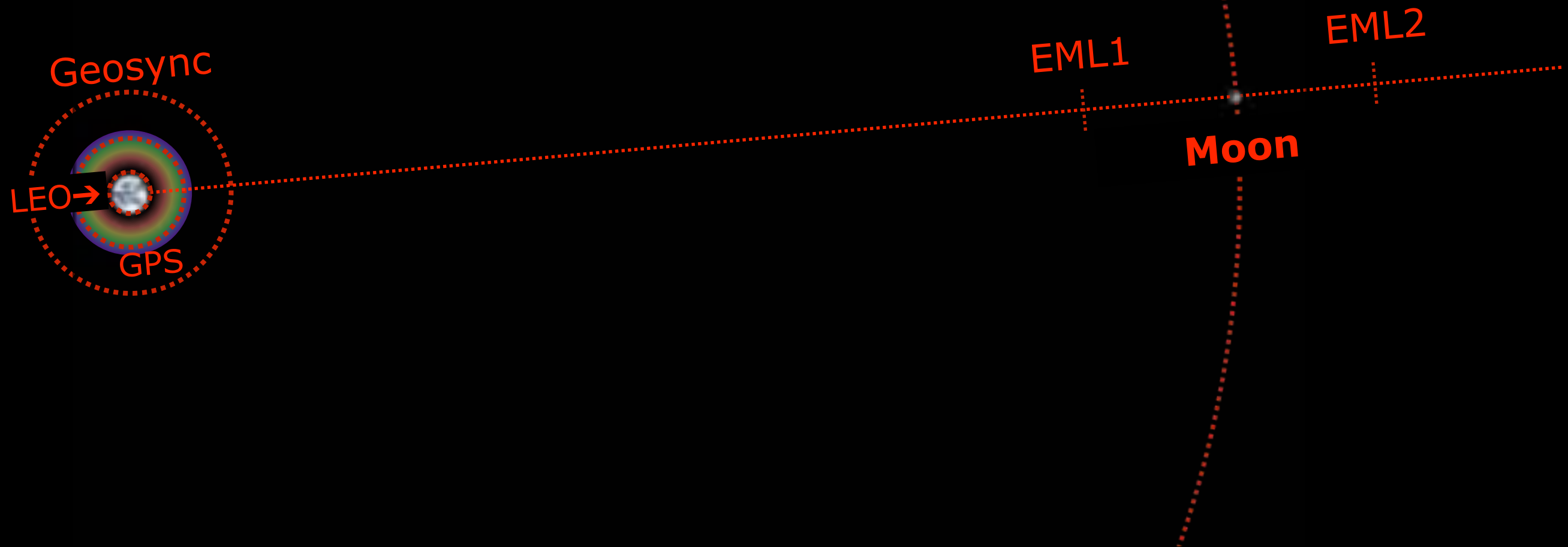
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Earth-Moon System (*to scale*)

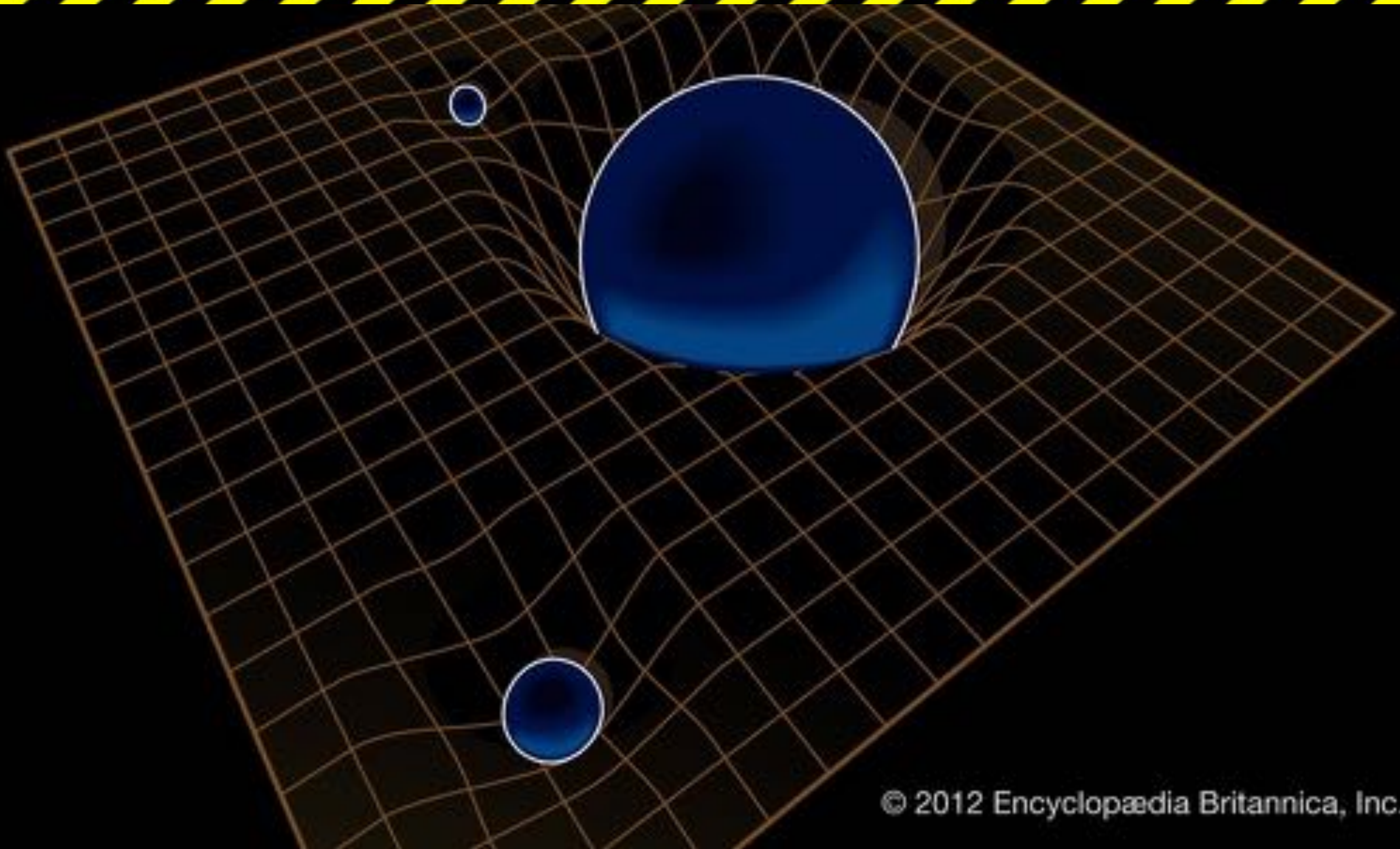


At this scale, the Sun is 2.4 screens wide and 250 screenwidths away.


Earth-Moon System (*to scale*)



Rubber Sheet Model of Gravity



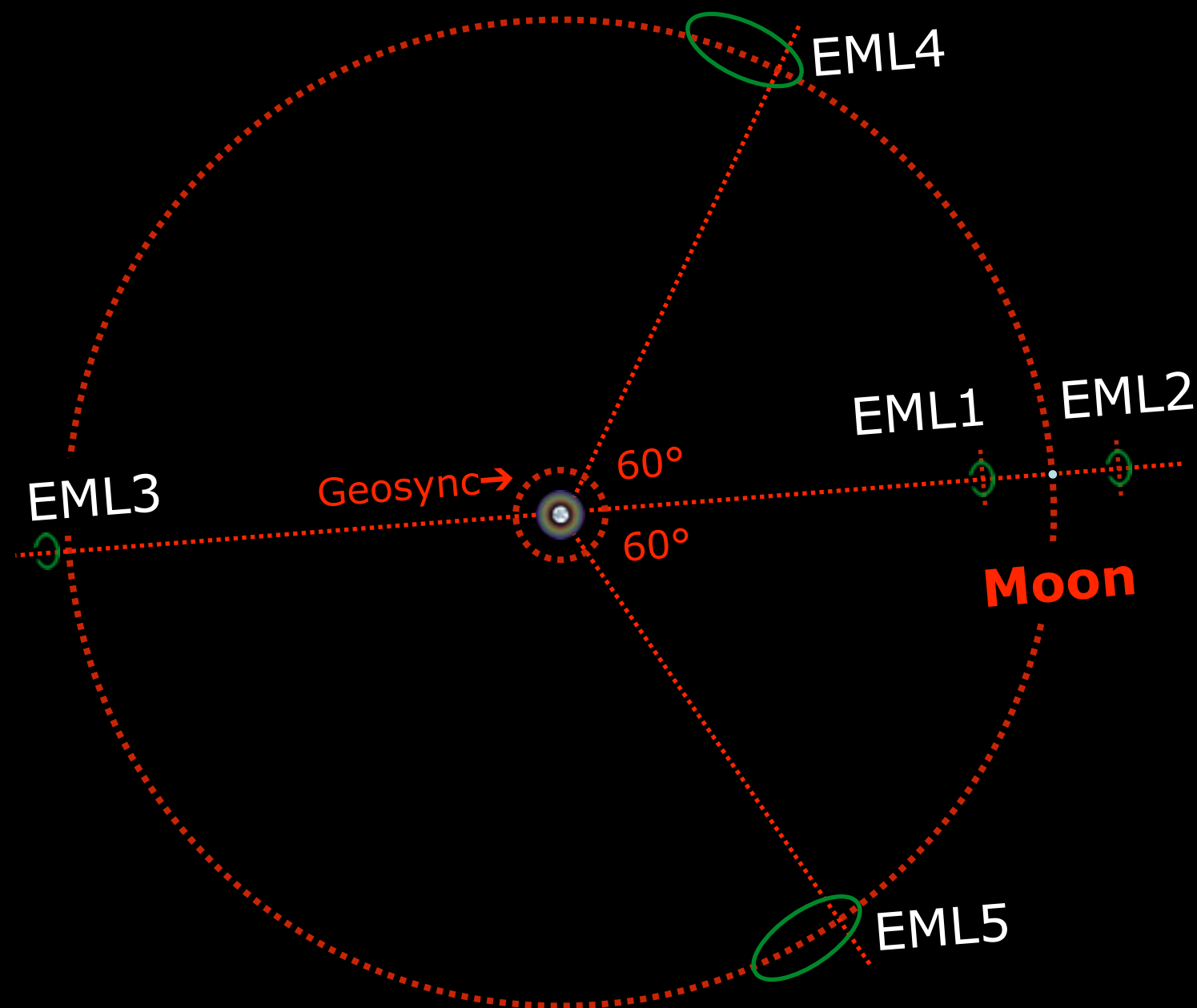
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In space, transport costs
are measured in *energy*,
not time or distance.

(Unless you have passengers.)

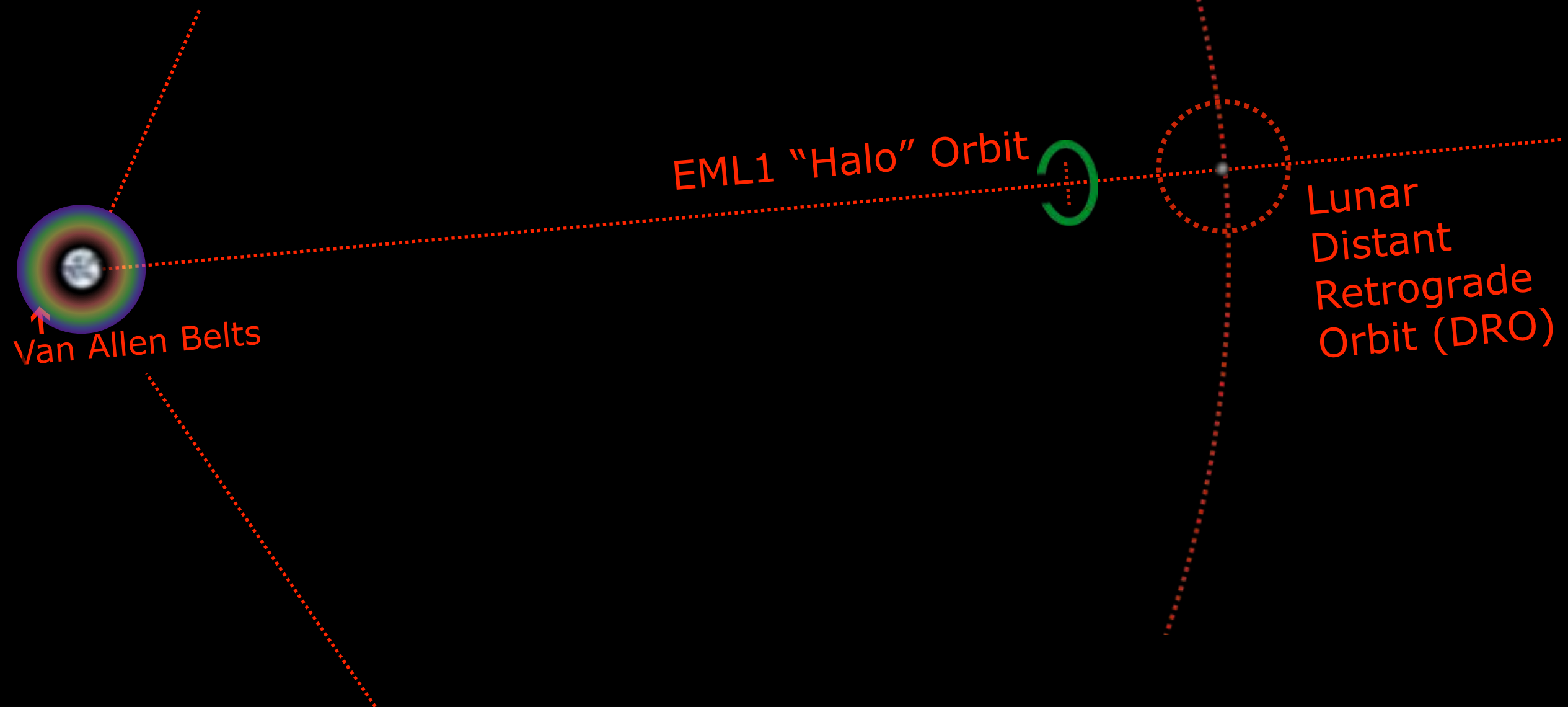
Lagrange Points (*to scale*)



**Gravitationally
semi-stable for
small bodies**
(like space stations)

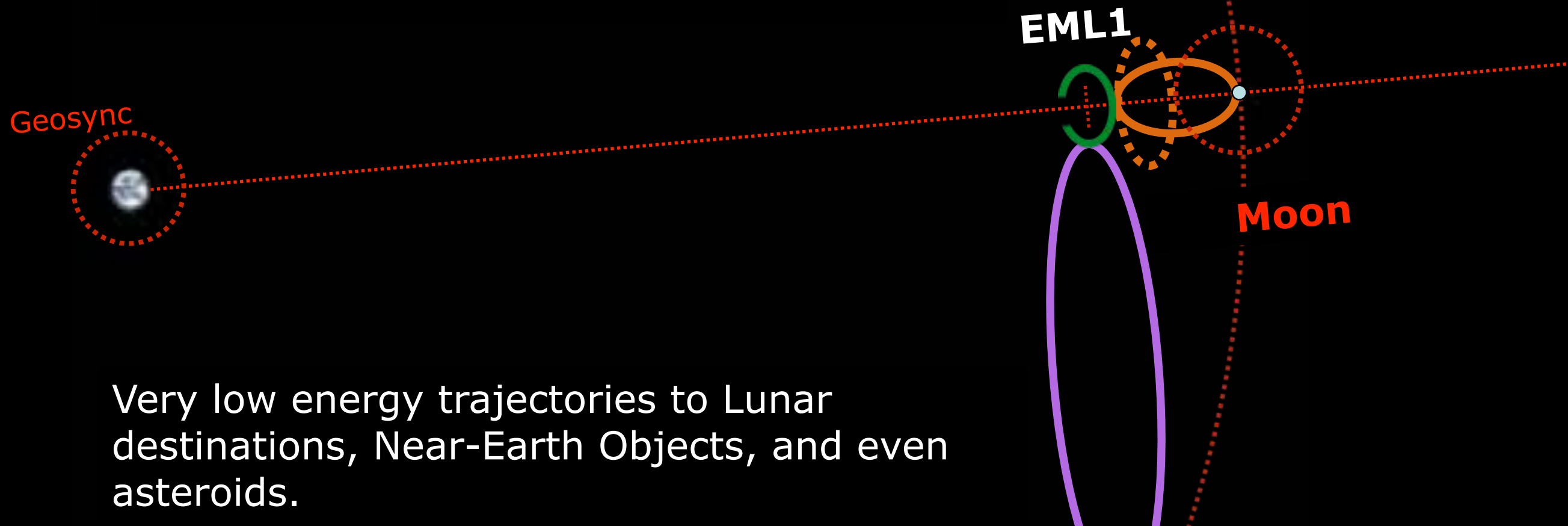
Earth-Moon System (*to scale*)

Interesting places for the cislunar economy



Cislunar Trade Routes

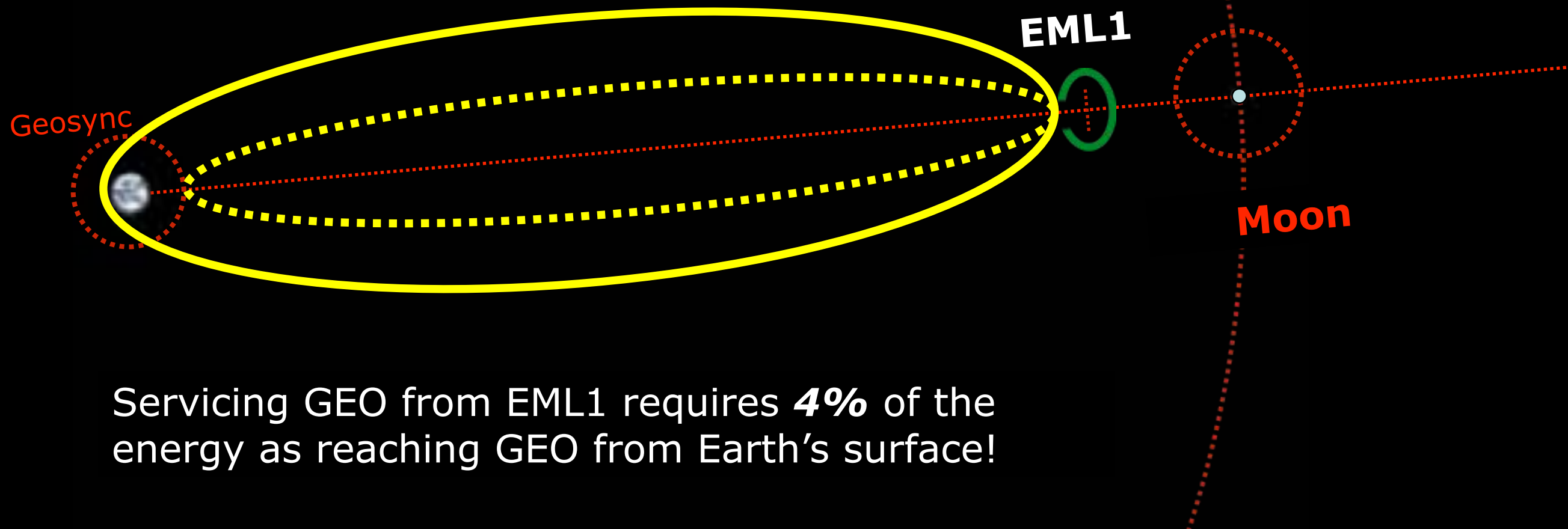
- **EML-1 to Lunar Surface**
- **EML-1 to DRO**
- **EML-1 to NEOs, elsewhere...**



Very low energy trajectories to Lunar destinations, Near-Earth Objects, and even asteroids.

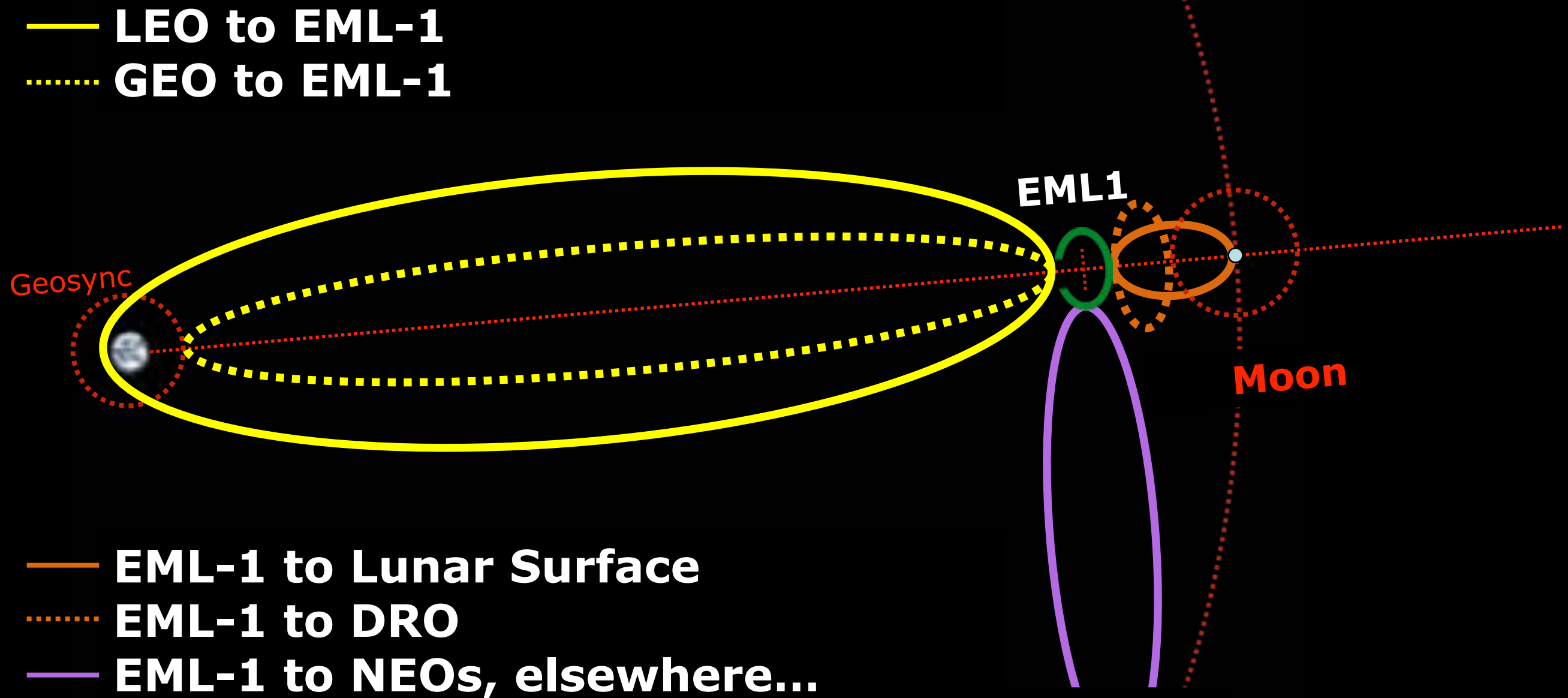
Cislunar Trade Routes

- LEO to EML-1
- GEO to EML-1

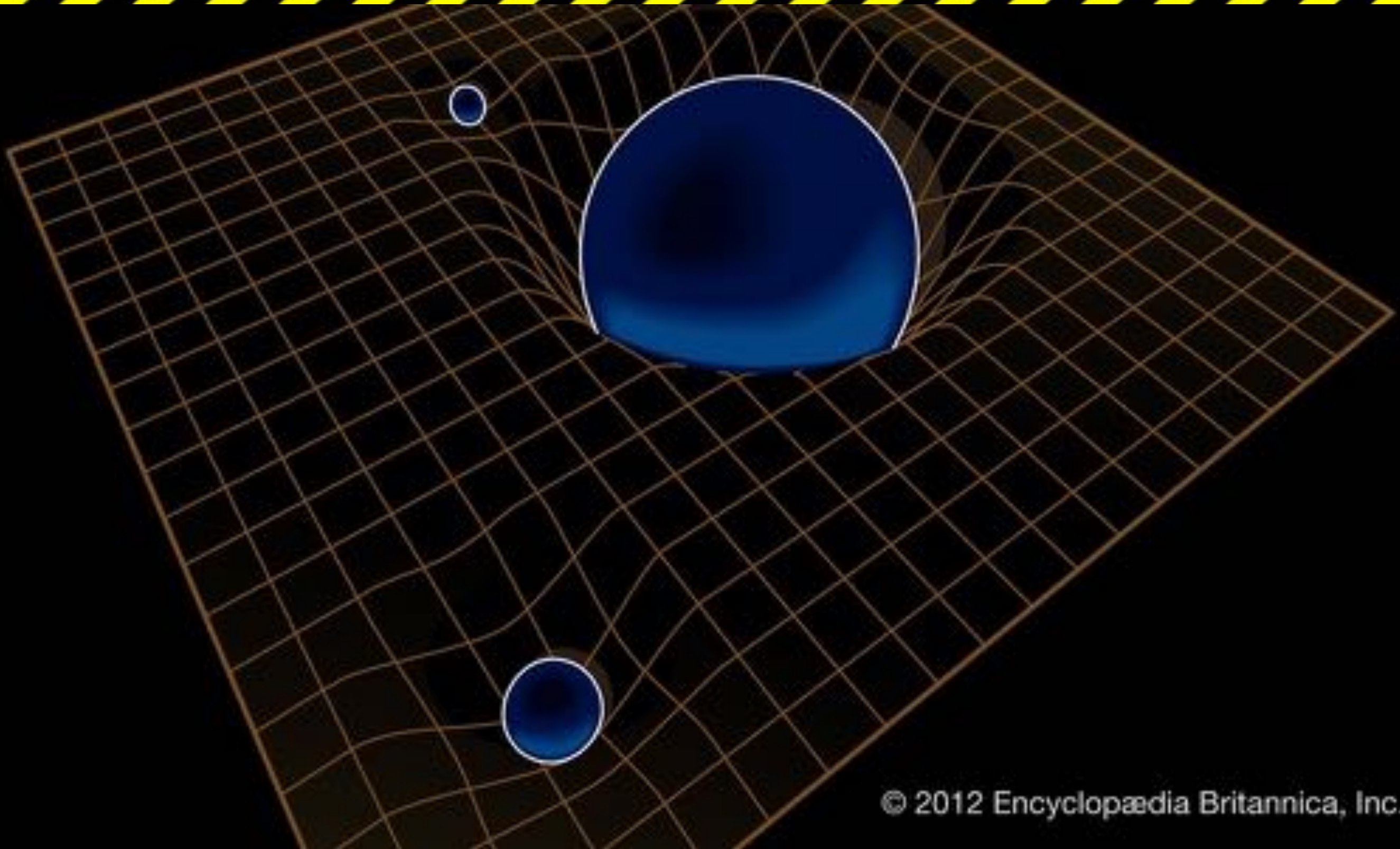


Servicing GEO from EML1 requires **4%** of the energy as reaching GEO from Earth's surface!

Cislunar Trade Routes

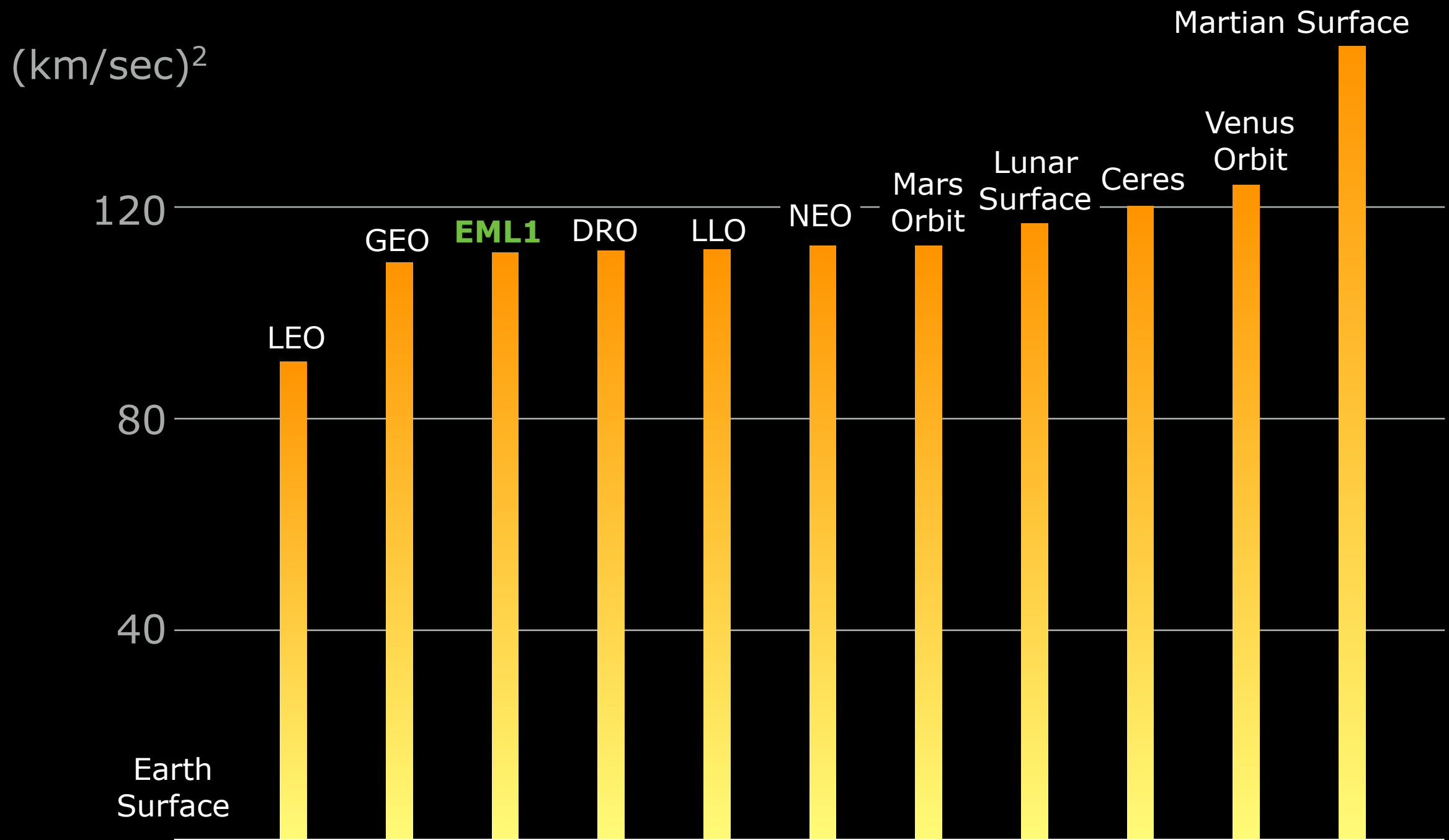


Rubber Sheet Model of Gravity

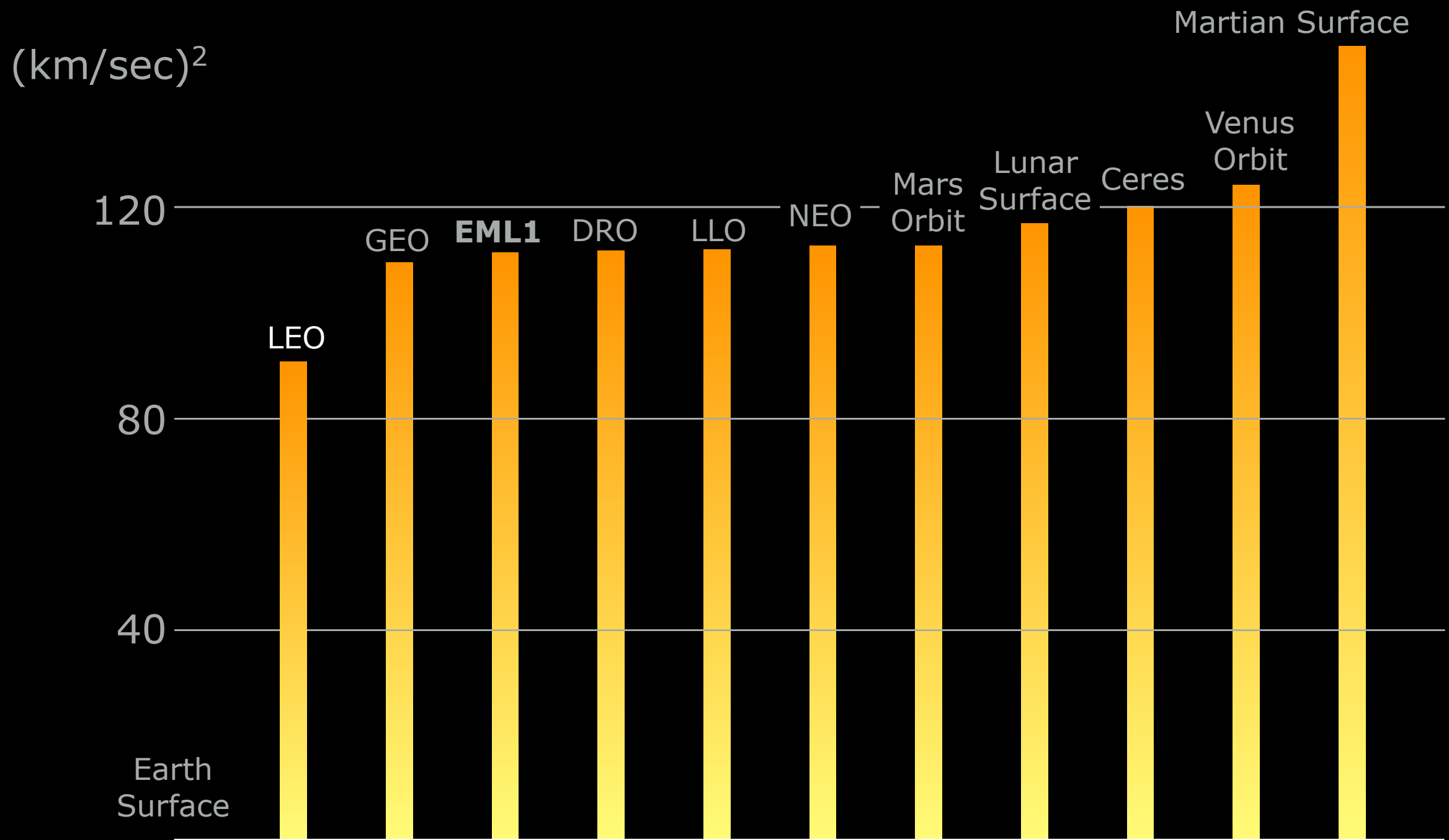


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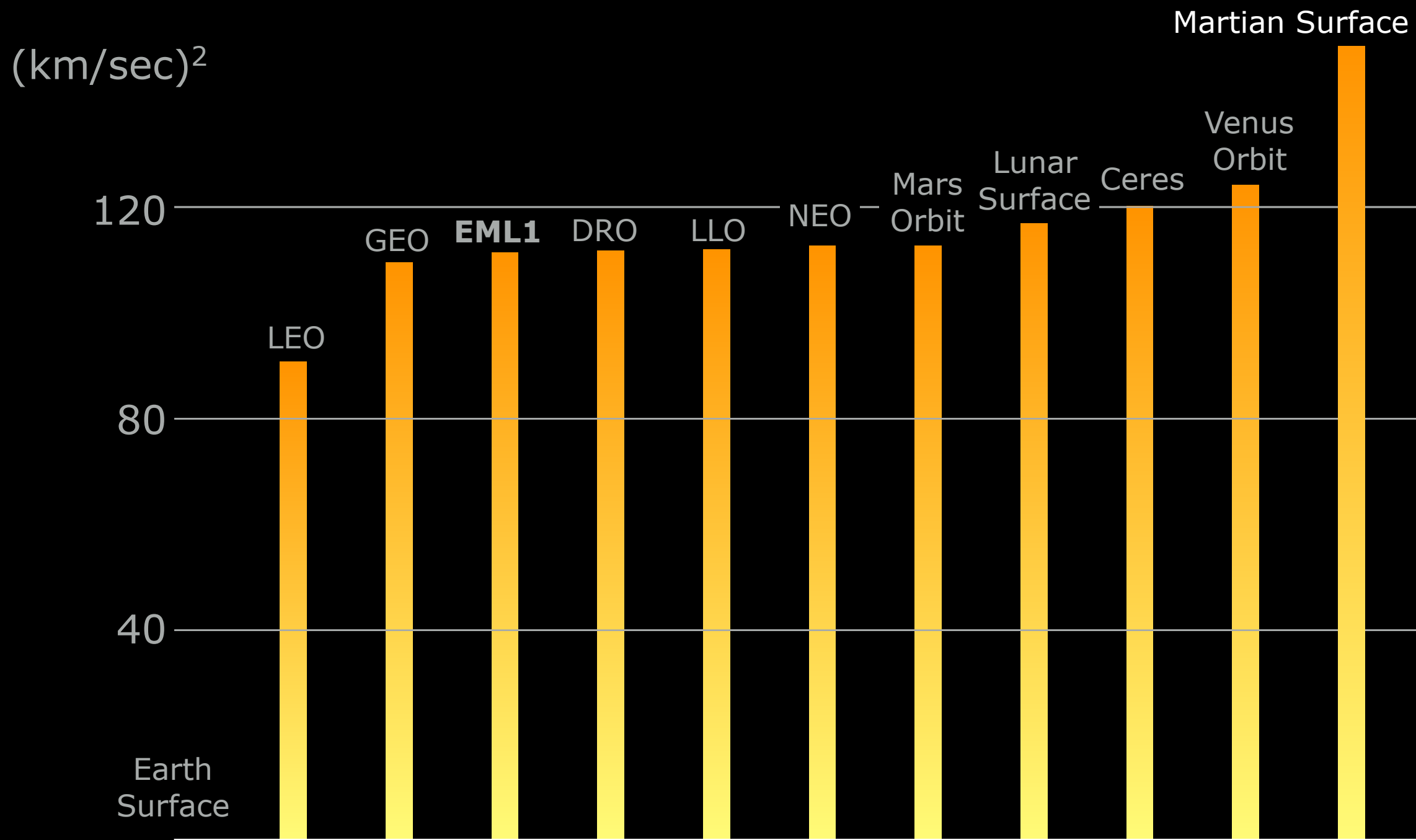
Orbital Energy Requirements: ΔV^2



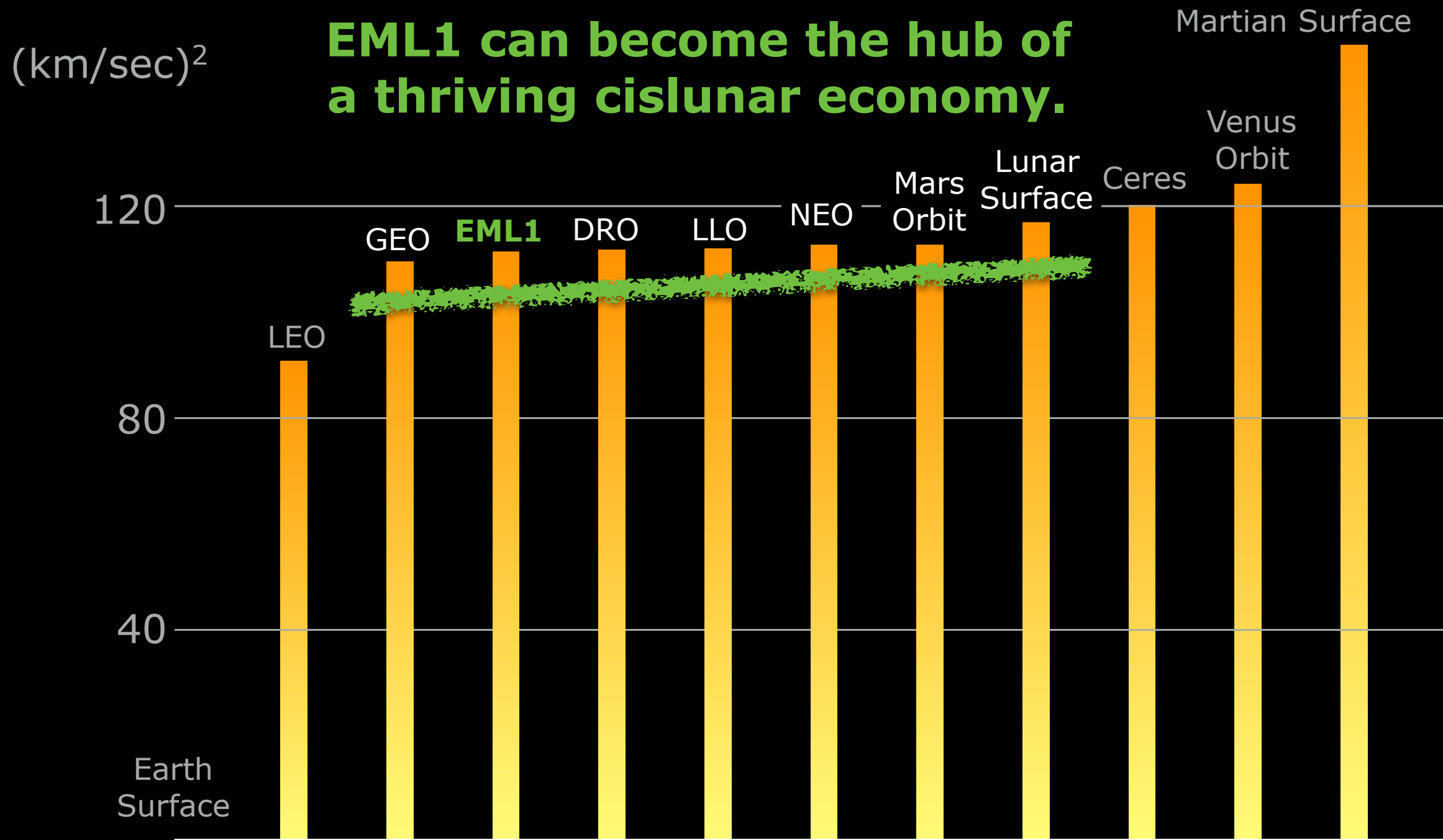
The First Step is a Doozy!



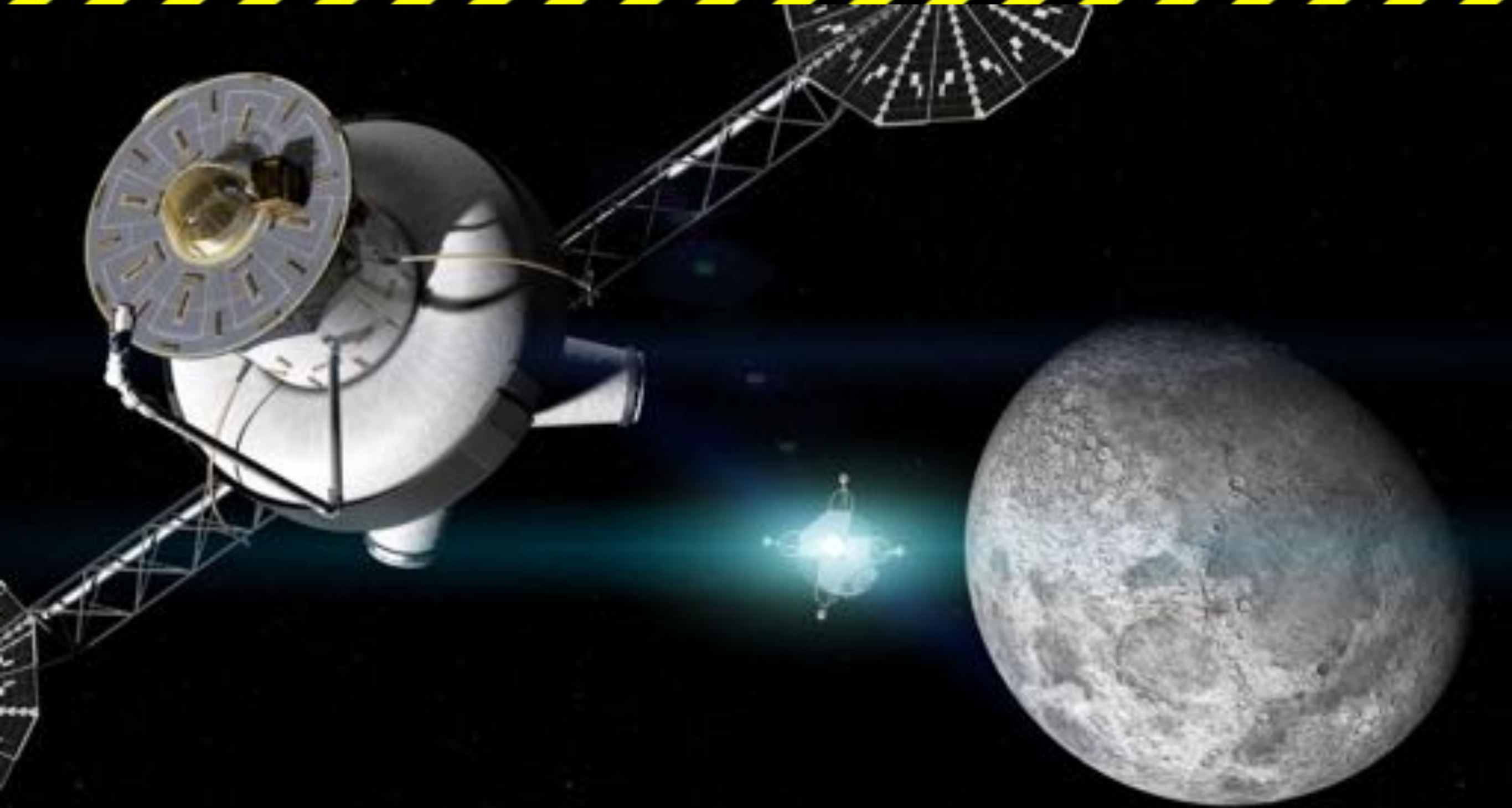
Why Mars Landings Should Wait...



The Flat Spot is the Sweet Spot!



EML1 Station: Access to Deep Space



EML1: Geosync Satellite Servicing



EML1: Midpoint for Lunar Elevator



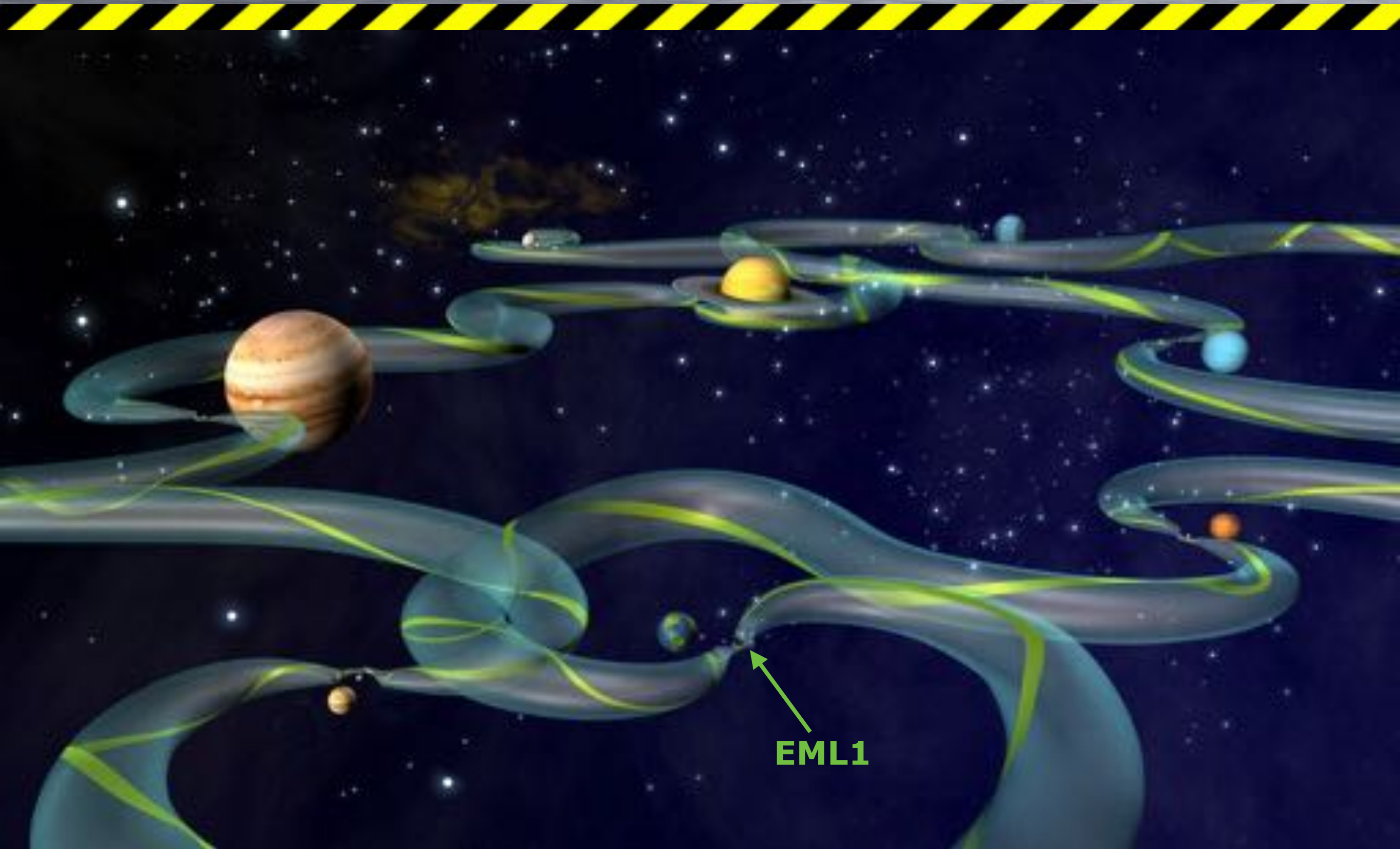
EML1: Staging Point for Asteroids



EML1: Interplanetary Superhighway



EML1: Interplanetary Superhighway



EML1: Three Days from Home!



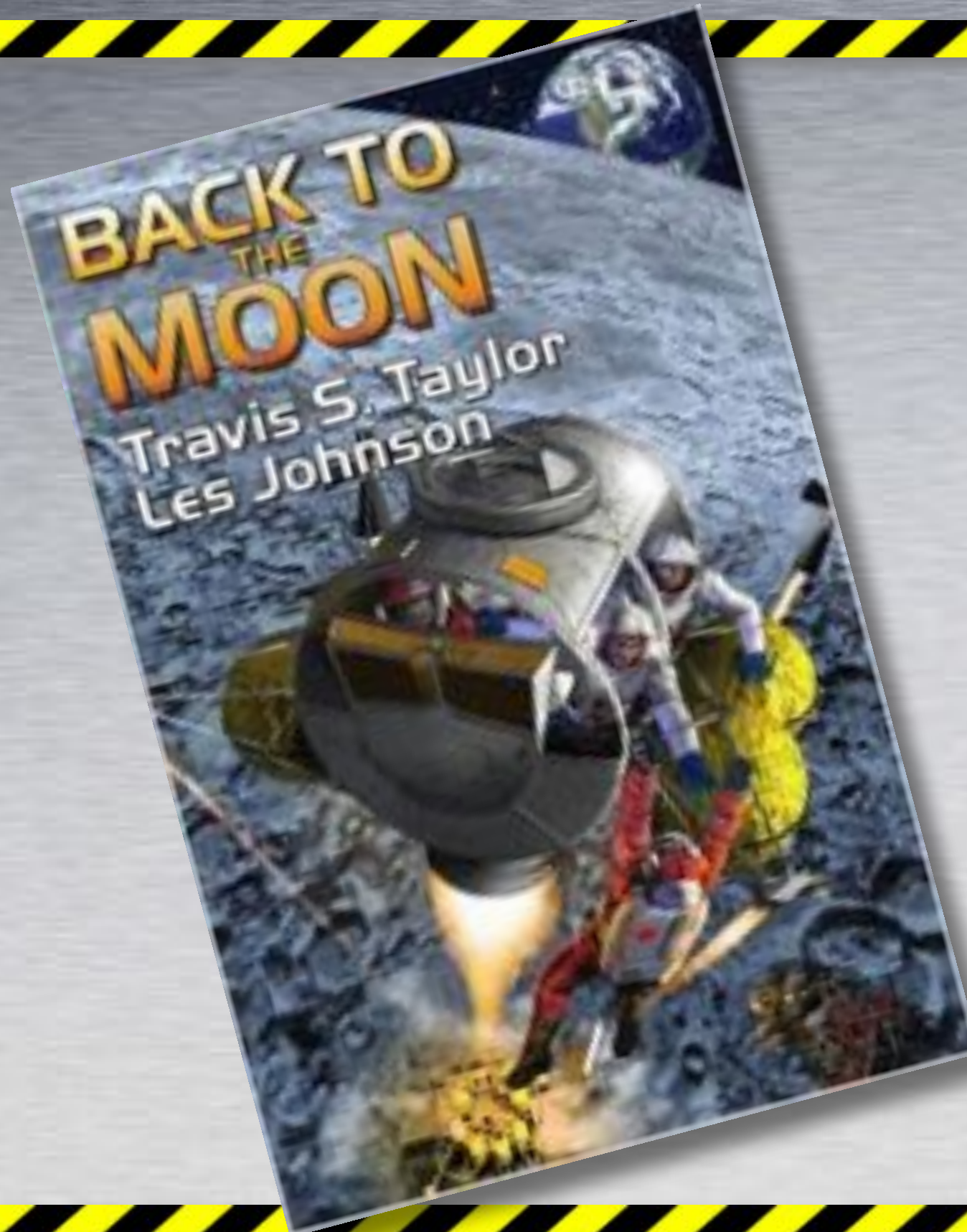
We Need to Go Back to the Moon!



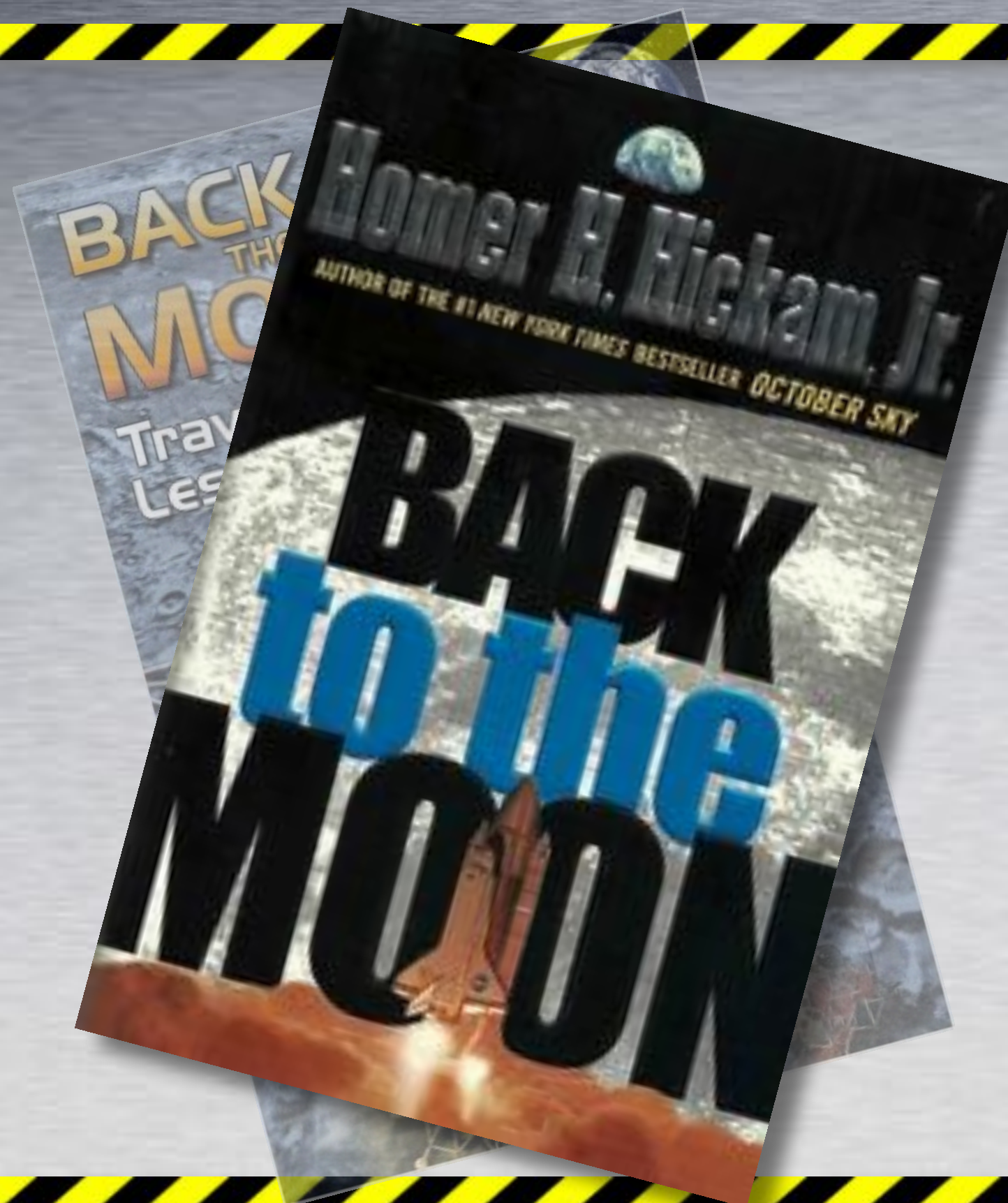
**If God wanted
man to become
a spacefaring
species, He
would have
given Earth a
moon.**

—Krafft Ehricke

We Need to Go Back to the Moon!



We Need to Go Back to the Moon!



Back to the Moon

...this time to stay!



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