The cosmic evolution project celebrates the 50th anniversary of

Apollo 10

Wednesday May 22
Baker room 180-101
7:00 pm - 8:30 pm
doors open at 6:30 pm

- Apollo mission **videos**
- **origin** of the Moon
- **co-evolution** of the Earth and the Moon
- **influence** of the Moon on life on Earth
- **lunar brain games**

Apollo 10 was the dress rehearsal for the Apollo 11 lunar landing. On this date 50 years ago, two astronauts entered the lunar module and descended to within 8.4 miles of the surface of the moon.

to learn more visit https://evolution.calpoly.edu/moon

https://evolution.calpoly.edu/moon

How did a cold dilute cloud of gas and dust evolve into astronauts on the moon?

COSMIC EVOLUTION PROJECT

The cosmic evolution project provides inspiration, educational resources, and training to help current and future teachers, informal science educators, and others explore the evolutionary history of the Earth and the universe.

rfield@calpoly.edu


APOLLO
X
STAFFORD
YOUNG
CERNAN

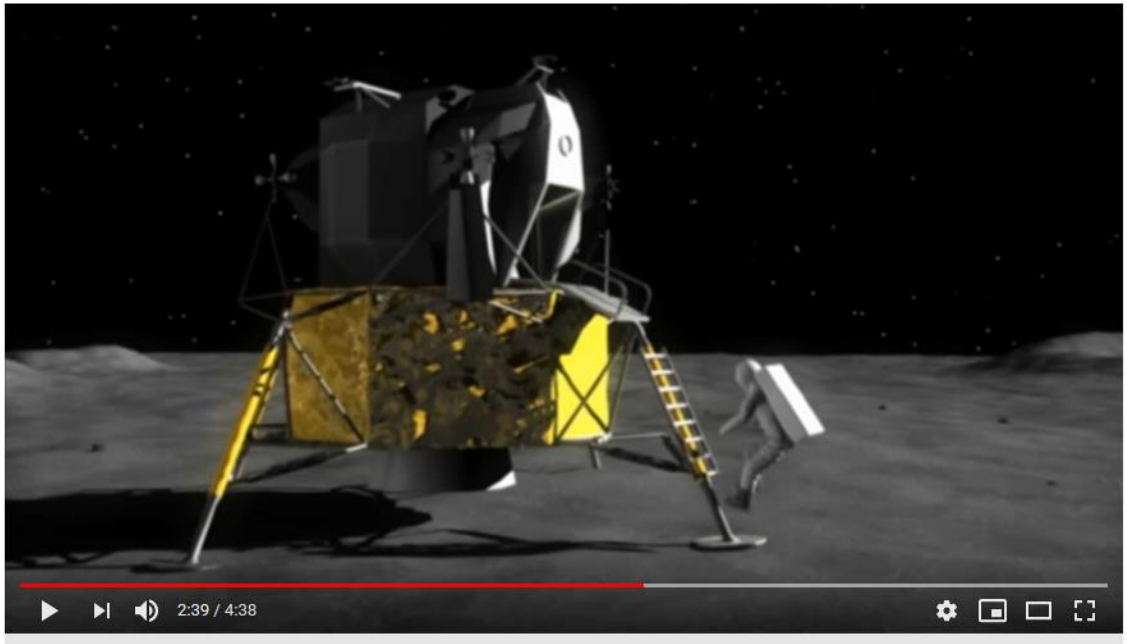
Apollo 10 was the mission fated to be a footnote, the one just one shy of the landmark lunar landing of Apollo 11. But there would have been no 11 had 10 not succeeded, and in a few critical moments on the fifth day of the mission, that was very much in doubt.

Astronauts Tom Stafford and Gene Cernan found themselves in a near-fatal barrel roll just 50,000 feet above the lunar surface, in a tin can that had no business surviving such a crisis and barely did.

The tale of the Apollo 10 emergency is one of quick wits, fast reflexes and touch and go maneuvering that saved the lives of the crew and set the table for the Apollo 11 landing two months later.

http://time.com/4866242/apollo-ten-10-tom-stafford-gene-cernan-space-nasa/

https://www.youtube.com/watch?v=8VvfTY-tVzI



Apollo 11 moon mission animated

Danoz Manoz
Published on Jul 14, 2009

SUBSCRIBE 360

40th anniversary of the moon mission

Category Science & Technology

Music in this video

Learn more

Listen ad-free with YouTube Premium

Song PIANO CONCERTO NO21 ELVIRA MADIGAN ANDANTE

Album SONI0460 - MOZART

Writers Troy Cassar-Daley

https://www.youtube.com/watch?v=F2c9LPNRonQ

It Took 83 Engines to Get to the Moon

Vintage Space
Published on Jan 15, 2018

JOIN SUBSCRIBE 307K

Want weekly Vintage Space ? Don't forget to subscribe!

https://www.youtube.com/watch?v=pb0bV5CPIUM

1969: Apollo 10 - NASA

Apollo 10 was the fourth manned mission in the Apollo programme. The mission included the second crew to orbit the Moon, and the test of the lunar module in lunar orbit. The module came to within 15.6 km of the lunar surface during practice manoeuvers.

The lunar module on Apollo 10 was not equipped to land.

Apollo 10 also added a first — broadcasting live colour TV from space.

https://www.youtube.com/watch?v=g5N2pygq42A

Apollo 10 nearly crashes on Moon

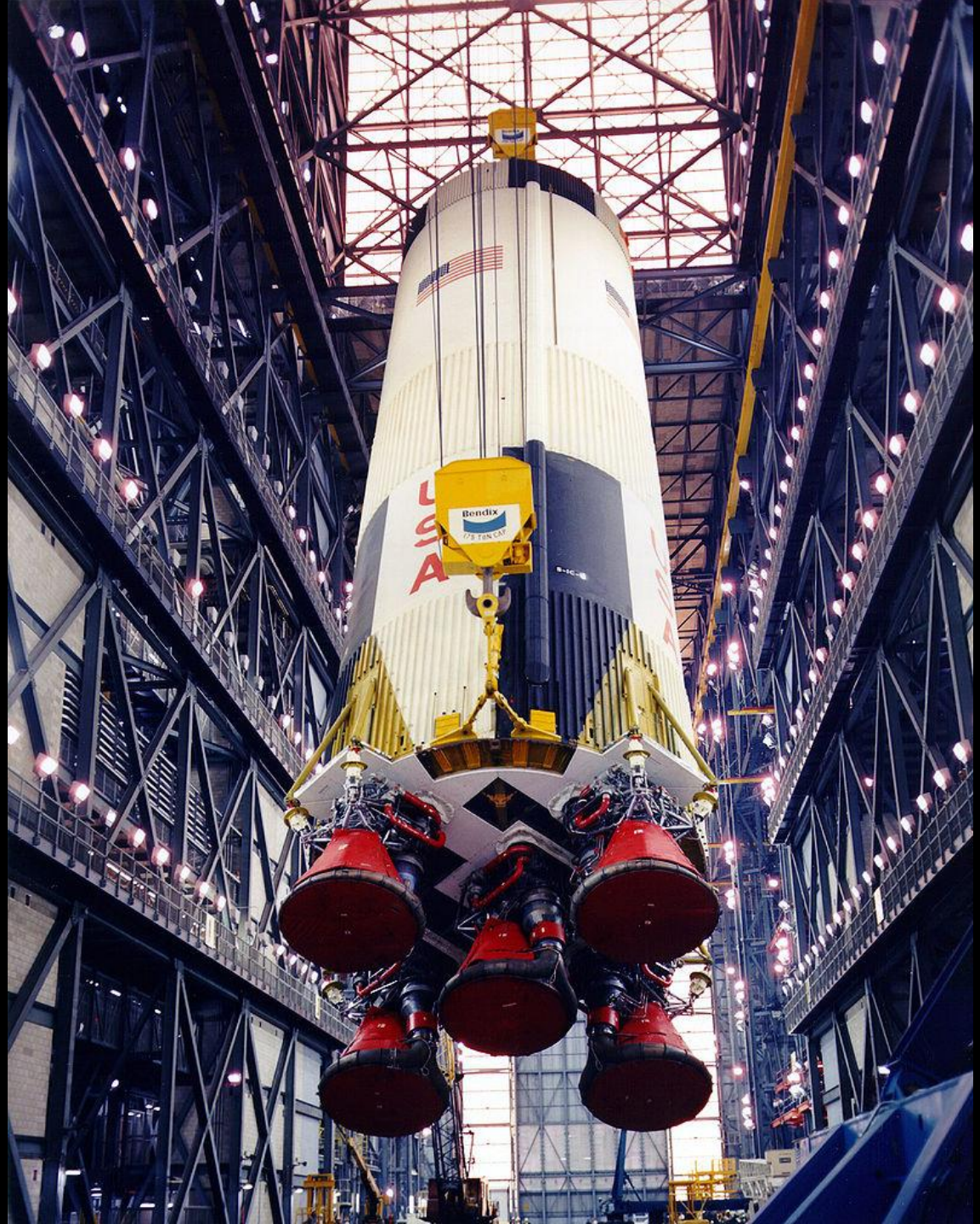
Michael Lennick
Published on Feb 28, 2010

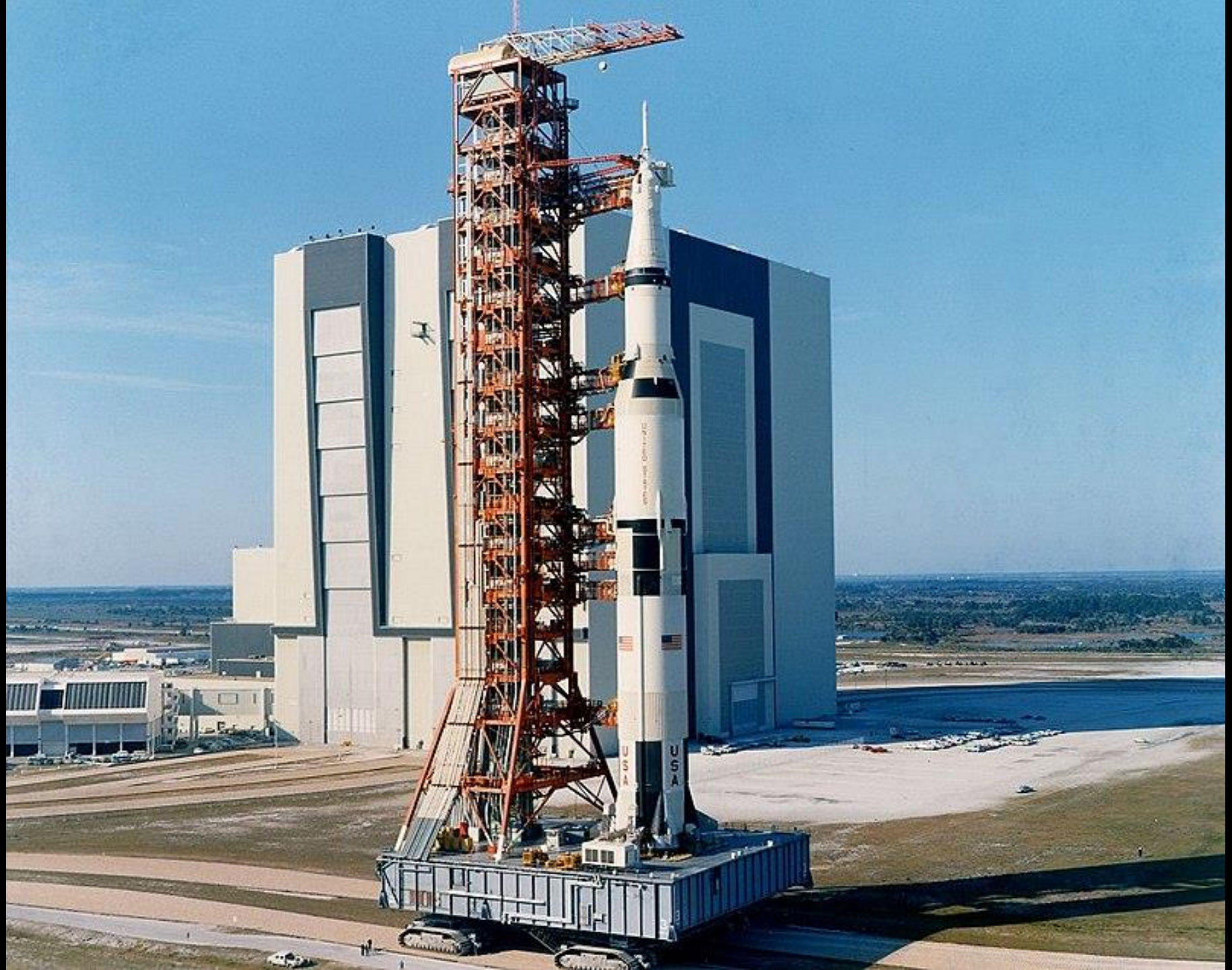
SUBSCRIBE 2.3K

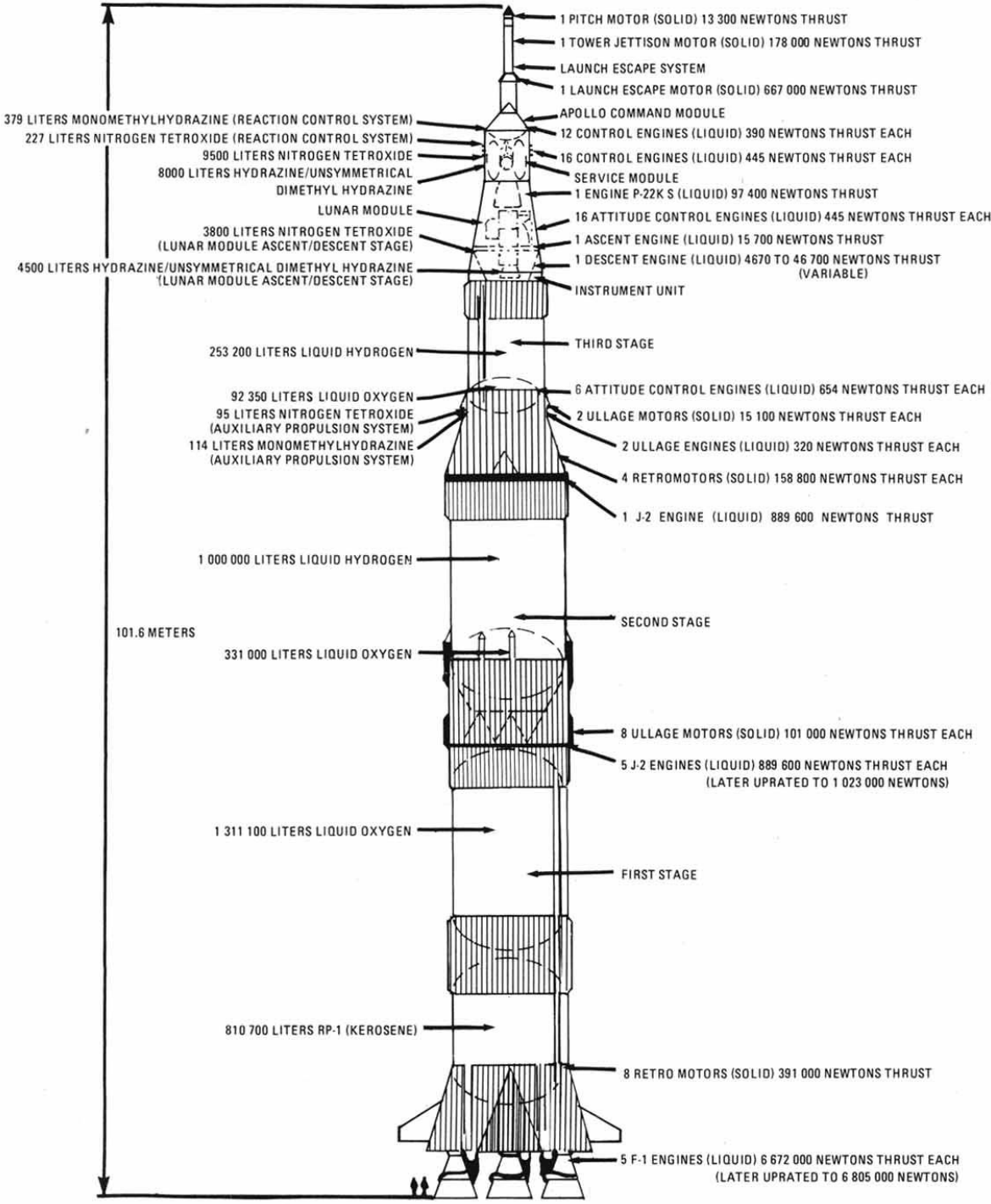
From Episode 11 of our Discovery Channel series "Rocket Science": Gene Cernan recalls a little-reported near-calamity during the lunar landing rehearsal. (Full 13-part series available at www.foolishearthling.com)

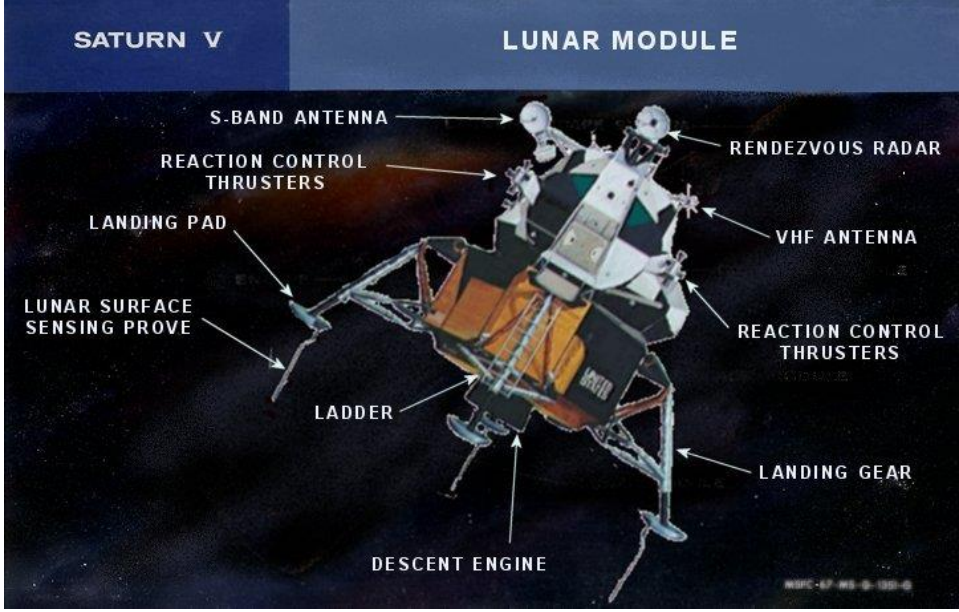
Category Science & Technology

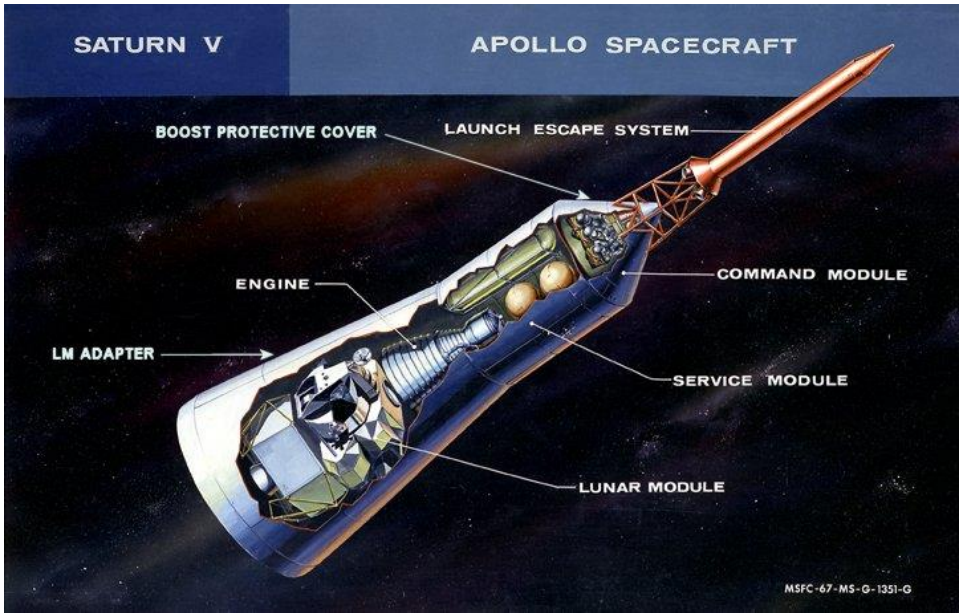

NASA
NASA
NASA

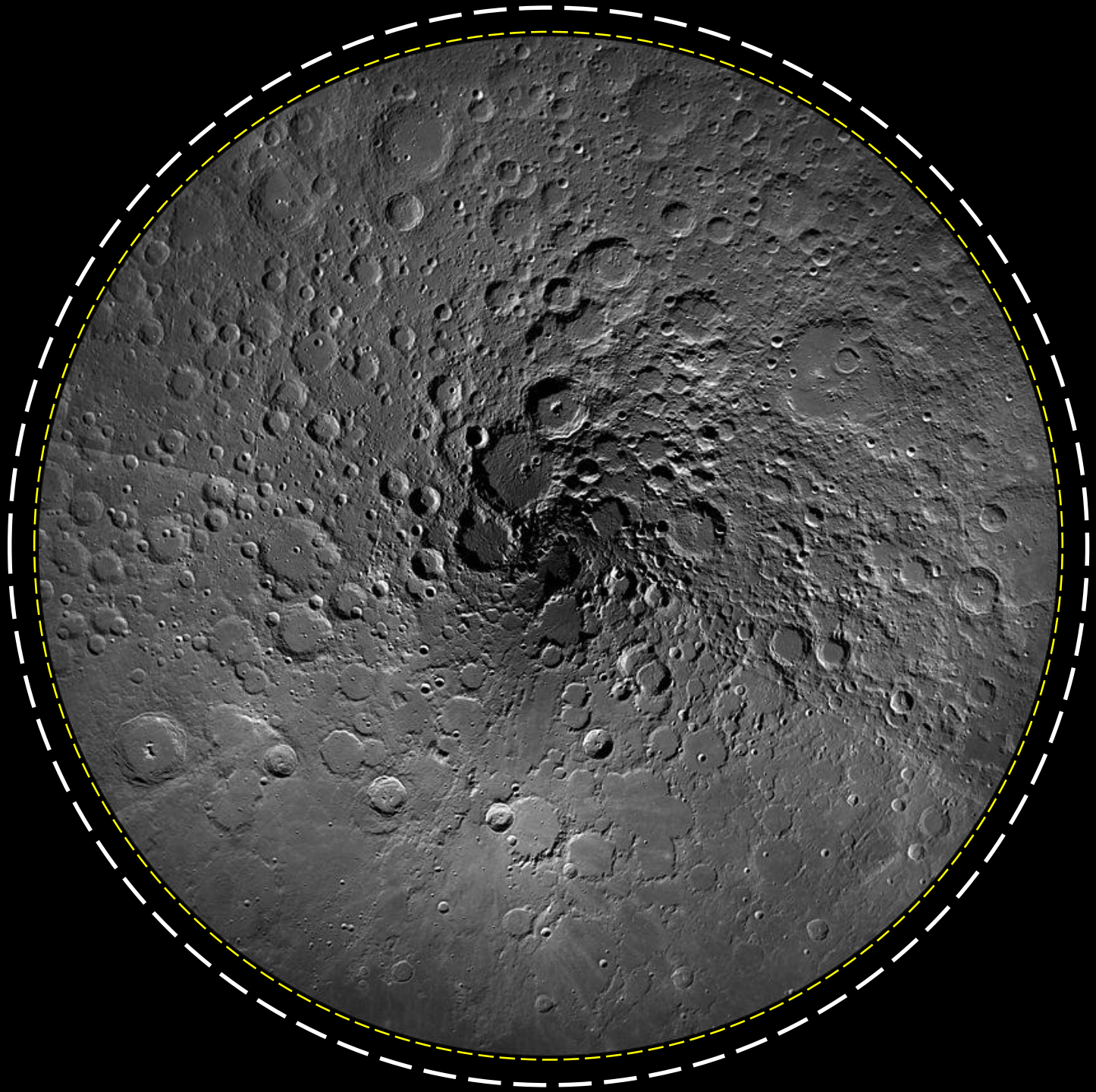

Bendix
175 TON CAP

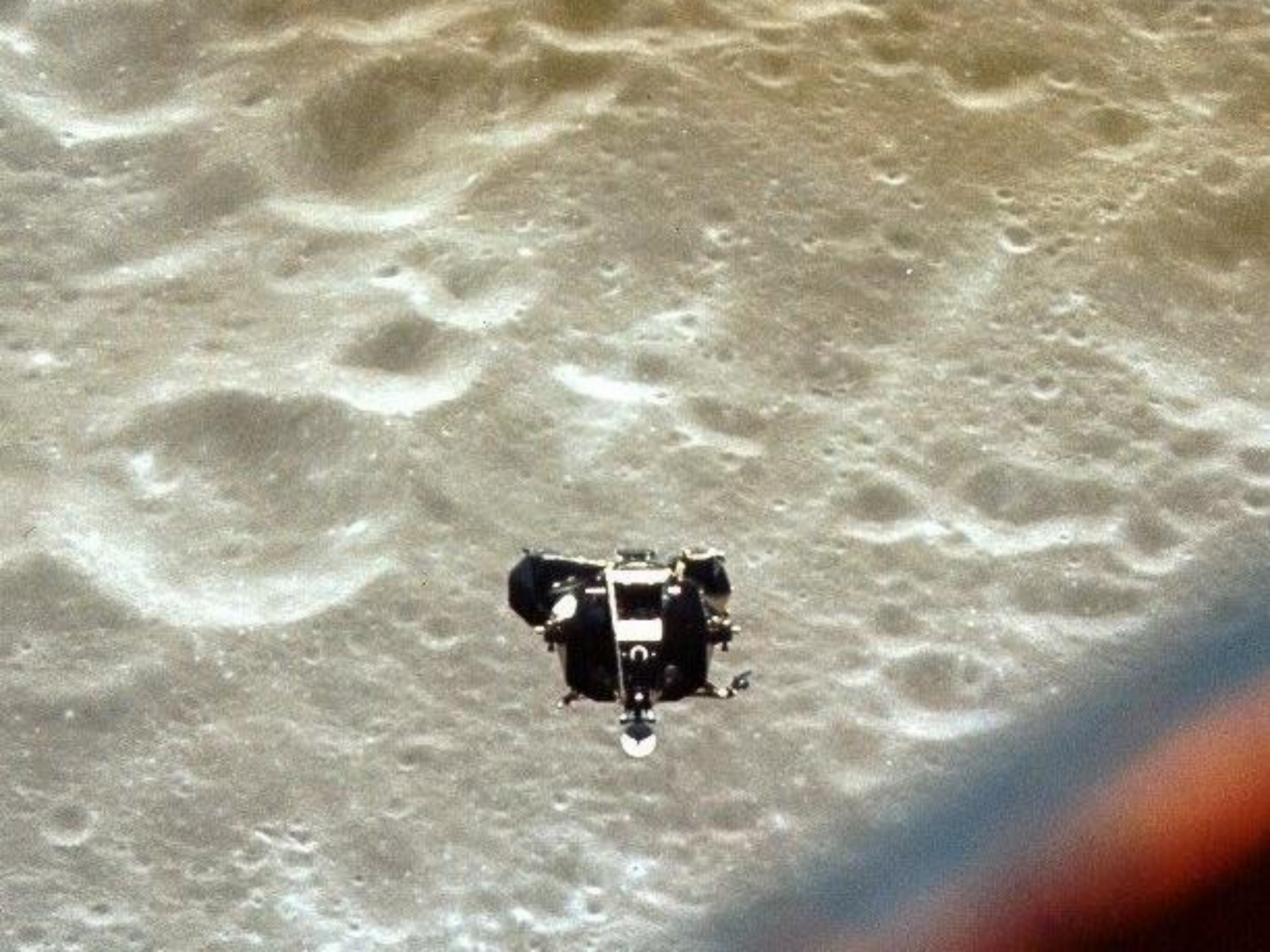

USA
USA


1 PITCH MOTOR (SOLID) 13 300 NEWTONS THRUST
1 TOWER JETTISON MOTOR (SOLID) 178 000 NEWTONS THRUST
LAUNCH ESCAPE SYSTEM
1 LAUNCH ESCAPE MOTOR (SOLID) 667 000 NEWTONS THRUST
APOLLO COMMAND MODULE
379 LITERS MONOMETHYLHYDRAZINE (REACTION CONTROL SYSTEM)
227 LITERS NITROGEN TETROXIDE (REACTION CONTROL SYSTEM)
12 CONTROL ENGINES (LIQUID) 390 NEWTONS THRUST EACH
9500 LITERS NITROGEN TETROXIDE
16 CONTROL ENGINES (LIQUID) 445 NEWTONS THRUST EACH
8000 LITERS HYDRAZINE/UNSYMMETRICAL DIMETHYL HYDRAZINE
SERVICE MODULE
1 ENGINE P-22K S (LIQUID) 97 400 NEWTONS THRUST
LUNAR MODULE
16 ATTITUDE CONTROL ENGINES (LIQUID) 445 NEWTONS THRUST EACH
3800 LITERS NITROGEN TETROXIDE (LUNAR MODULE ASCENT/DESCENT STAGE)
1 ASCENT ENGINE (LIQUID) 15 700 NEWTONS THRUST
4500 LITERS HYDRAZINE/UNSYMMETRICAL DIMETHYL HYDRAZINE (LUNAR MODULE ASCENT/DESCENT STAGE)
1 DESCENT ENGINE (LIQUID) 4670 TO 46 700 NEWTONS THRUST (VARIABLE)
INSTRUMENT UNIT
THIRD STAGE
253 200 LITERS LIQUID HYDROGEN
92 350 LITERS LIQUID OXYGEN
6 ATTITUDE CONTROL ENGINES (LIQUID) 654 NEWTONS THRUST EACH
95 LITERS NITROGEN TETROXIDE (AUXILIARY PROPULSION SYSTEM)
2 ULLAGE MOTORS (SOLID) 15 100 NEWTONS THRUST EACH
114 LITERS MONOMETHYLHYDRAZINE (AUXILIARY PROPULSION SYSTEM)
2 ULLAGE ENGINES (LIQUID) 320 NEWTONS THRUST EACH
4 RETROMOTORS (SOLID) 158 800 NEWTONS THRUST EACH
1 J-2 ENGINE (LIQUID) 889 600 NEWTONS THRUST
1 000 000 LITERS LIQUID HYDROGEN
SECOND STAGE
101.6 METERS
331 000 LITERS LIQUID OXYGEN
8 ULLAGE MOTORS (SOLID) 101 000 NEWTONS THRUST EACH
5 J-2 ENGINES (LIQUID) 889 600 NEWTONS THRUST EACH (LATER UPRATED TO 1 023 000 NEWTONS)
1 311 100 LITERS LIQUID OXYGEN
FIRST STAGE
810 700 LITERS RP-1 (KEROSENE)
8 RETRO MOTORS (SOLID) 391 000 NEWTONS THRUST
5 F-1 ENGINES (LIQUID) 6 672 000 NEWTONS THRUST EACH (LATER UPRATED TO 6 805 000 NEWTONS)

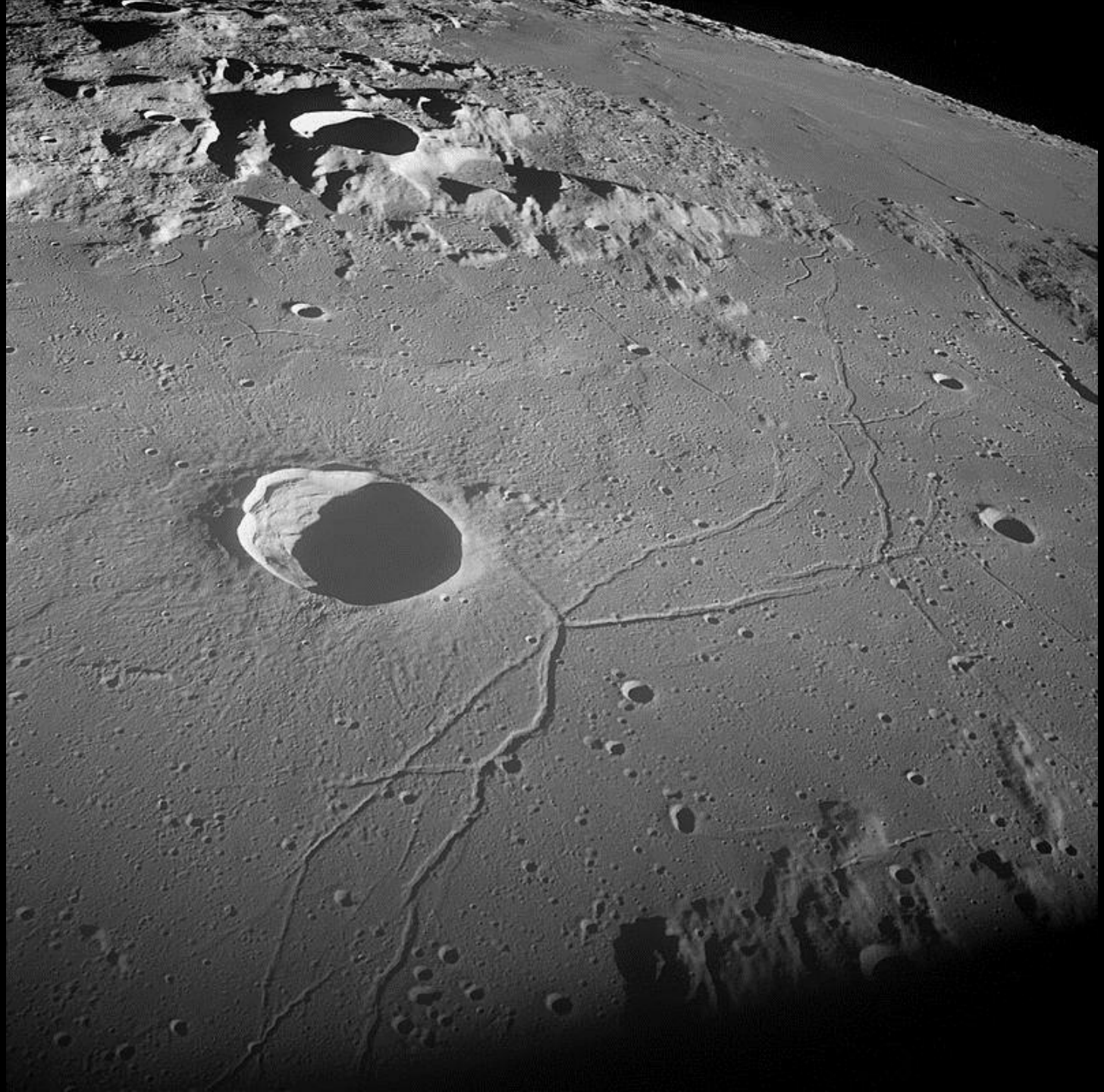

SATURN V
LUNAR MODULE
S-BAND ANTENNA
REACTION CONTROL THRUSTERS
LANDING PAD
LUNAR SURFACE SENSING PROVE
LADDER
DESCENT ENGINE
RENDEZVOUS RADAR
VHF ANTENNA
REACTION CONTROL THRUSTERS
LANDING GEAR

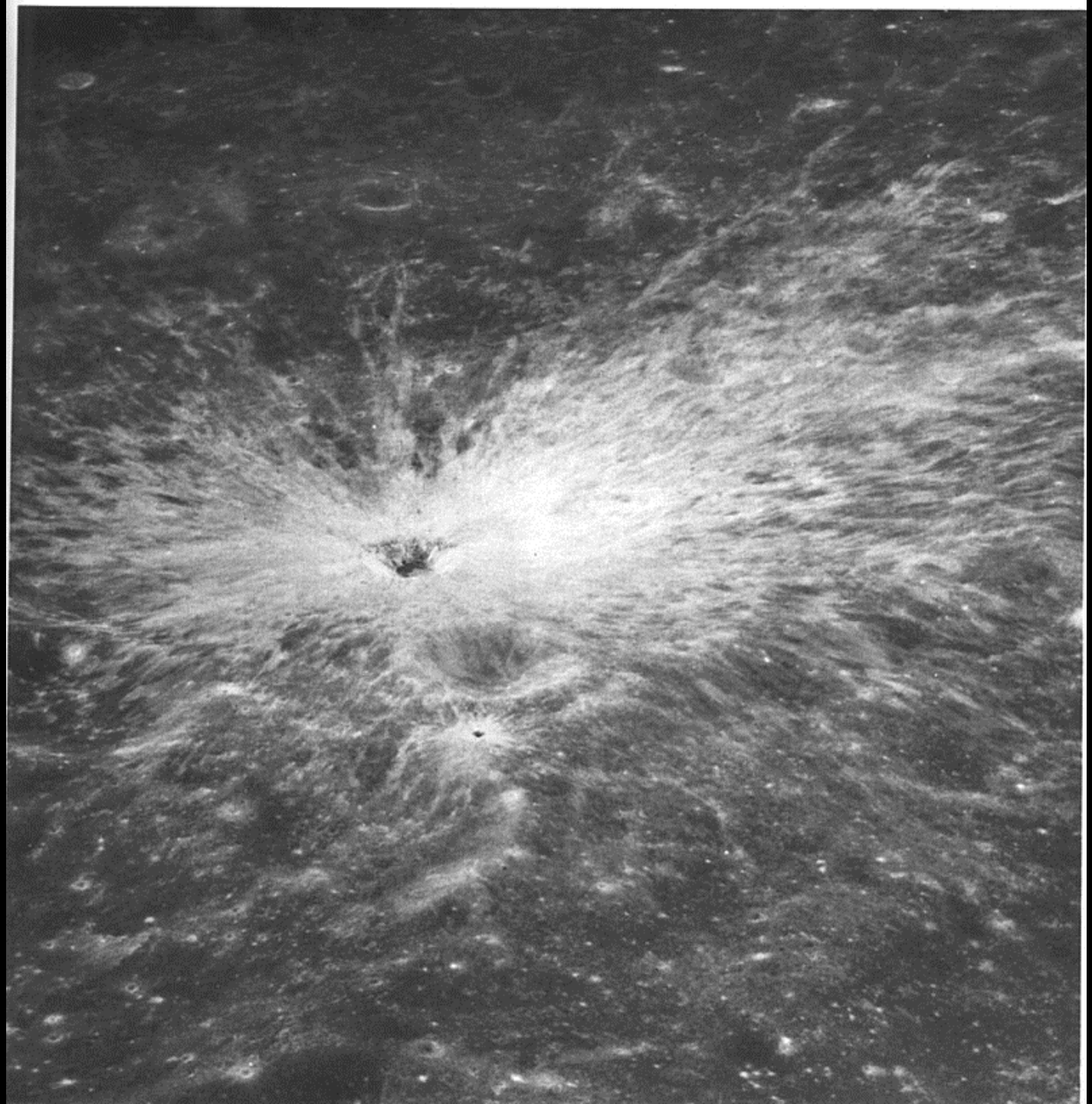

SATURN V
APOLLO SPACECRAFT
BOOST PROTECTIVE COVER
LAUNCH ESCAPE SYSTEM
ENGINE
LM ADAPTER
COMMAND MODULE
SERVICE MODULE
LUNAR MODULE
MSFC-67-MS-G-1351-G






UNITED
STATES






NAVY
66

Apollo 10 Mission highlights

Shortly after trans-lunar injection, Young performed the transposition, docking, and extraction maneuver, separating the command and service module from the S-IVB stage, turning around, and docking its nose to the top of the lunar module (LM), before separating from the S-IVB. Apollo 10 was the first mission to carry a color television camera, and made the first live color TV transmissions from space.

After reaching lunar orbit three days later, Young remained in the command module while Stafford and Cernan entered the lunar module and flew it separately.

The LM crew performed the descent orbit insertion maneuver by firing their descent engine, and tested the landing radar as they approached the 50,000-foot altitude where powered descent would begin on Apollo 11. They surveyed the landing site in the Sea of Tranquility, then separated the descent stage and fired the ascent engine to return to the command module.

https://www.youtube.com/watch?v=c0FCE4H0Dro

Where did the Moon come from? – BBC Two

More on this programme:
http://www.bbc.co.uk/programmes/b00yb5jp

Space scientist and lunar fanatic Dr Maggie Aderin-Pocock explores our intimate relationship with the Moon and how it was created. The debris from a huge collision of another planet on Earth formed what is now our moon, 14,000 miles from Earth, the closest it has ever been.

http://sarahtstewart.net/

Where did the Moon come from? A new theory

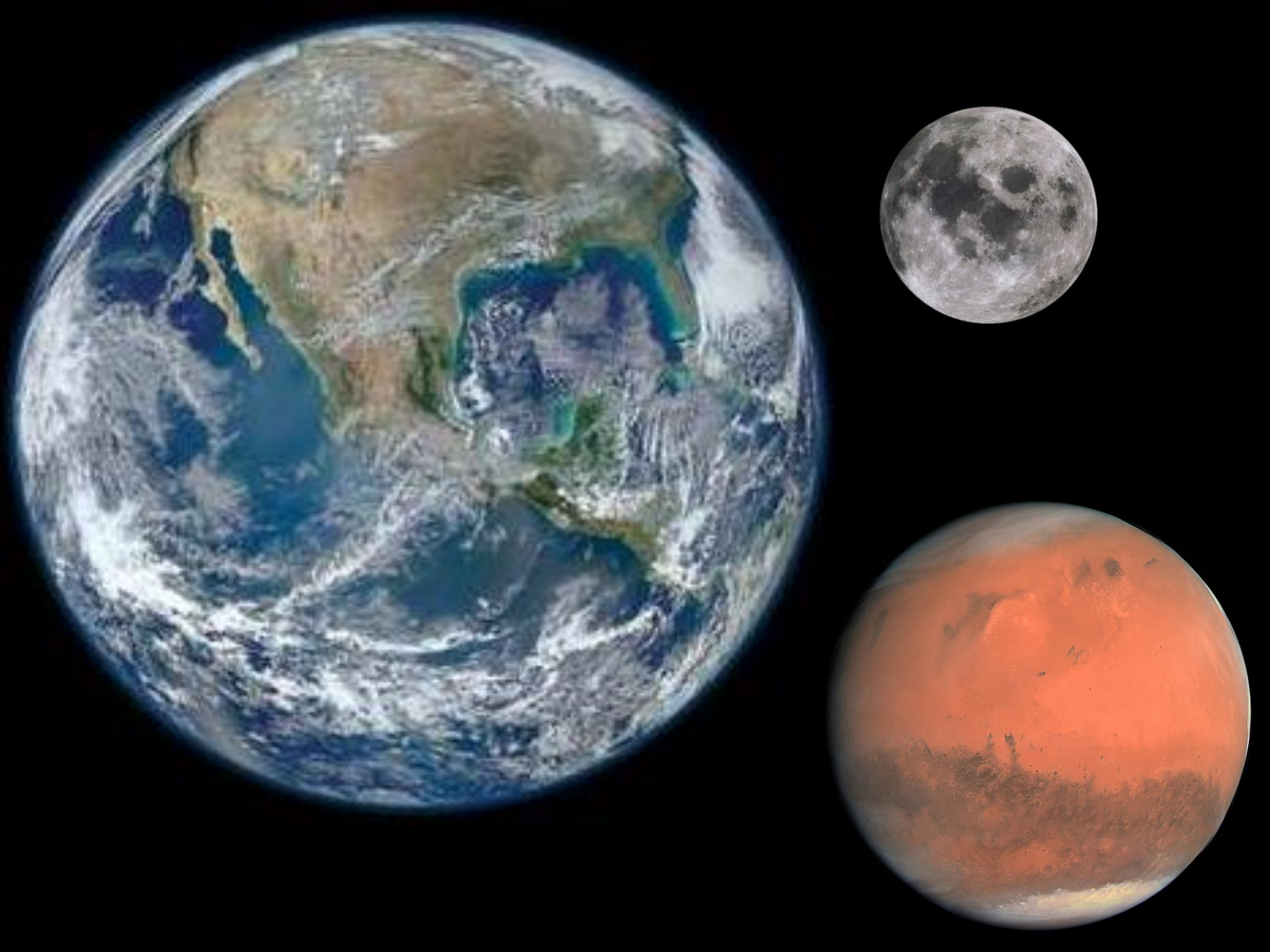
TED Talk by Sarah T. Stewart https://youtu.be/7uRPPaYuu44

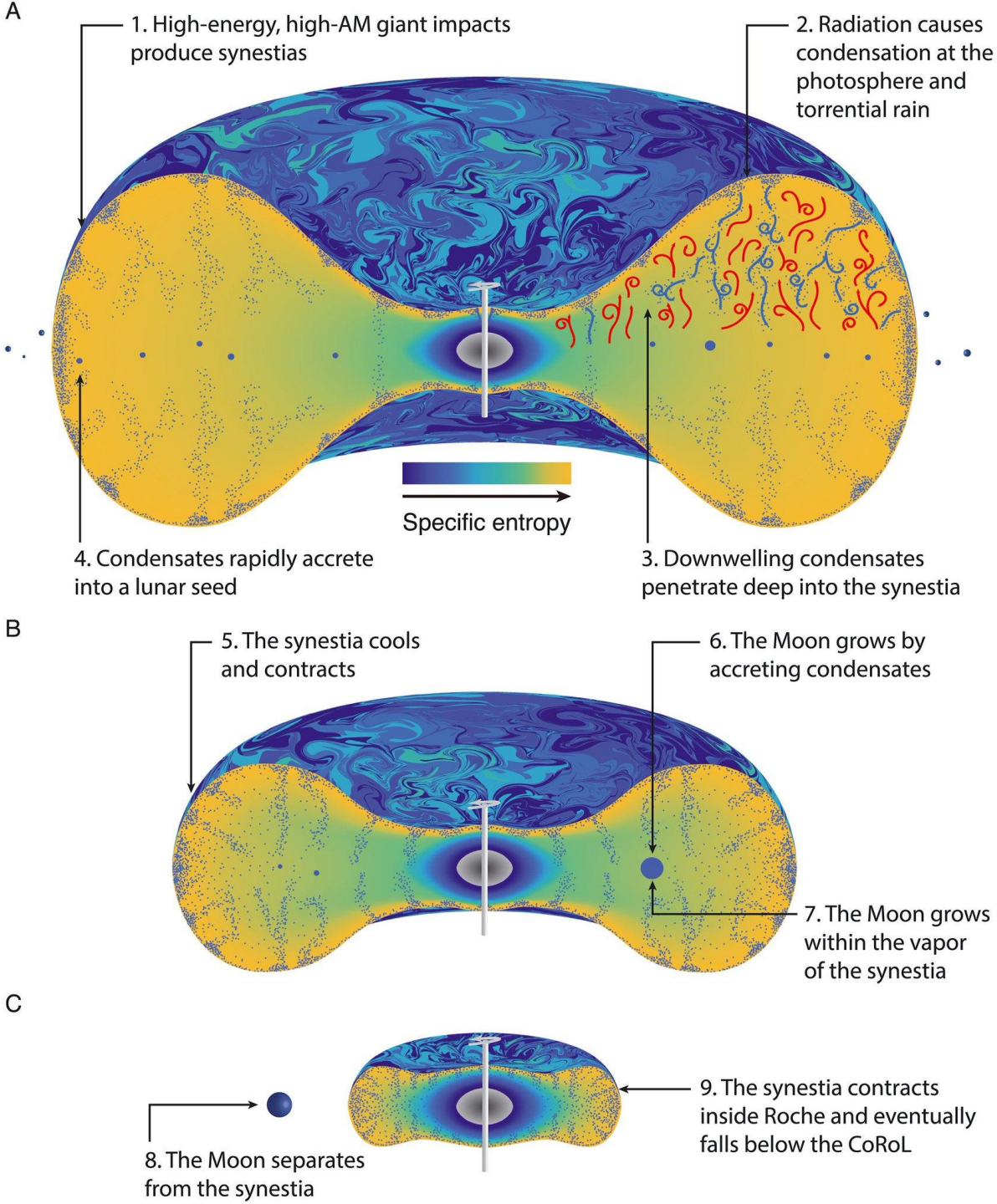
The Earth and Moon are like identical twins, made up of the exact same materials -- which is really strange, since no other known celestial bodies share this kind of chemical relationship.
What's responsible for this special connection?
Planetary scientist Sarah T. Stewart discovered a new kind of astronomical object – a synestia -- and a new way to solve the mystery of the Moon's origin.

https://www.youtube.com/watch?v=ObI18hOdAZQ

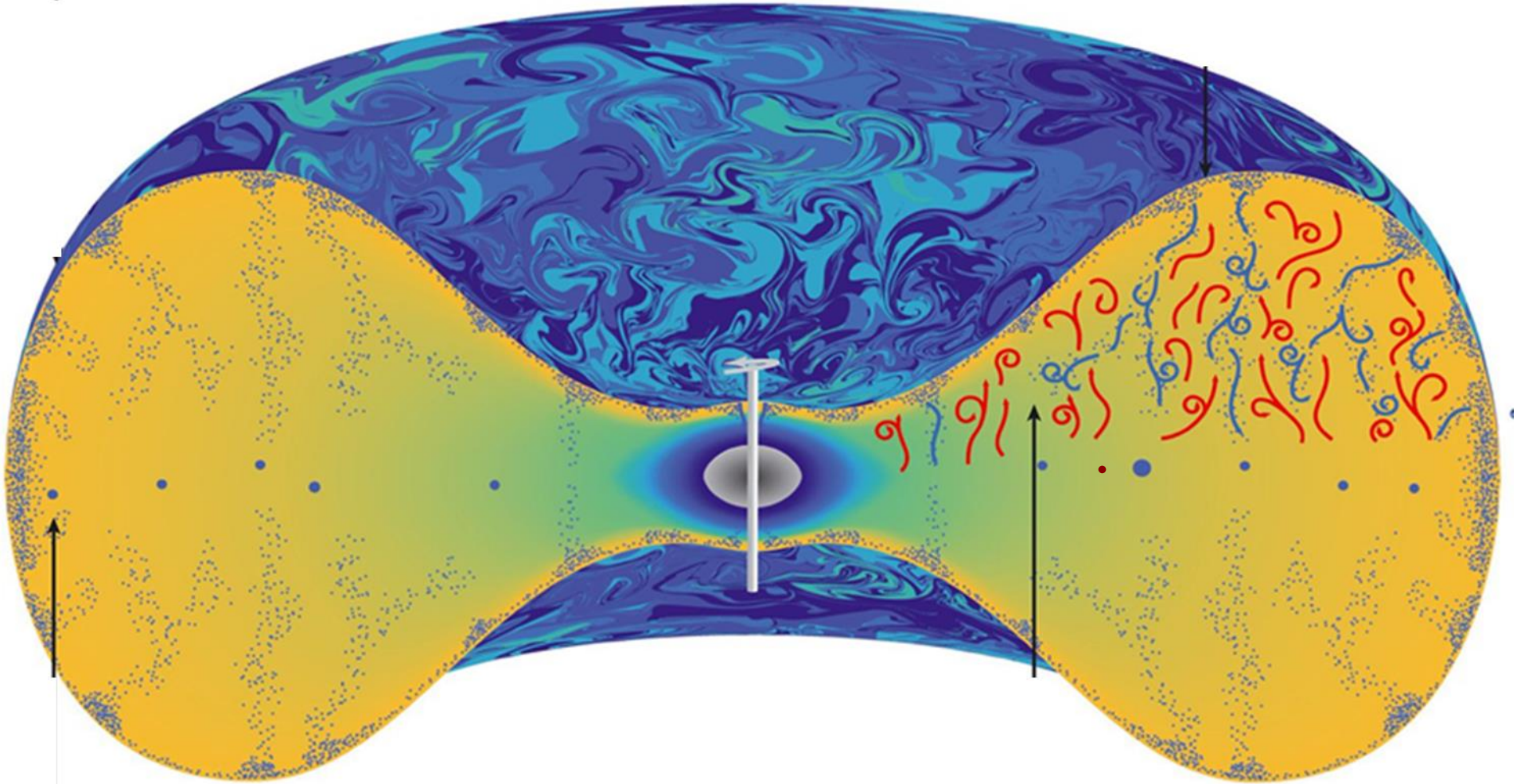
https://youtu.be/7uRPPaYuu44

https://theaggie.org/2018/11/28/uc-davis-professor-sarah-stewart-wins-genius-grant/





After the giant impact, the moon formed within the synestia before the synestia condensed into our spherical planet



After the giant impact,
the moon formed within the synestia before the synestia condensed into our spherical planet

When the dust settled the Earth was nearly 10% larger than before the impact and the Moon was 1/81 of the mass of Earth

property	Moon	Earth
mass	$M_\oplus$ / 81 = $7.37*10^{22}$ kg	$5.97*10^{24}$ kg
diameter	2159 miles = 3474 km	7918 miles = 12742 km
density	0.6 * Earth	5500 kg / m^3
composition	oxides of Si, Al, Ca, Fe, Mg	mostly Fe, O, Si, Mg
rotation period	tidal lock	23 hours 56 min 4 sec
orbital period	27.3 days = 656 hours	365.256 days
orbital radius	384,400 km	1 AU = 152 million km

Date: 2005 Sep 1 02:23:28 UT

The Moon's gravitational pull decreases with distance, causing bulges on Earth.

As the Earth rotates, points on the surface experience high and low tides.

Reality is much more complicated than this simple model.

https://scijinks.gov/tides/

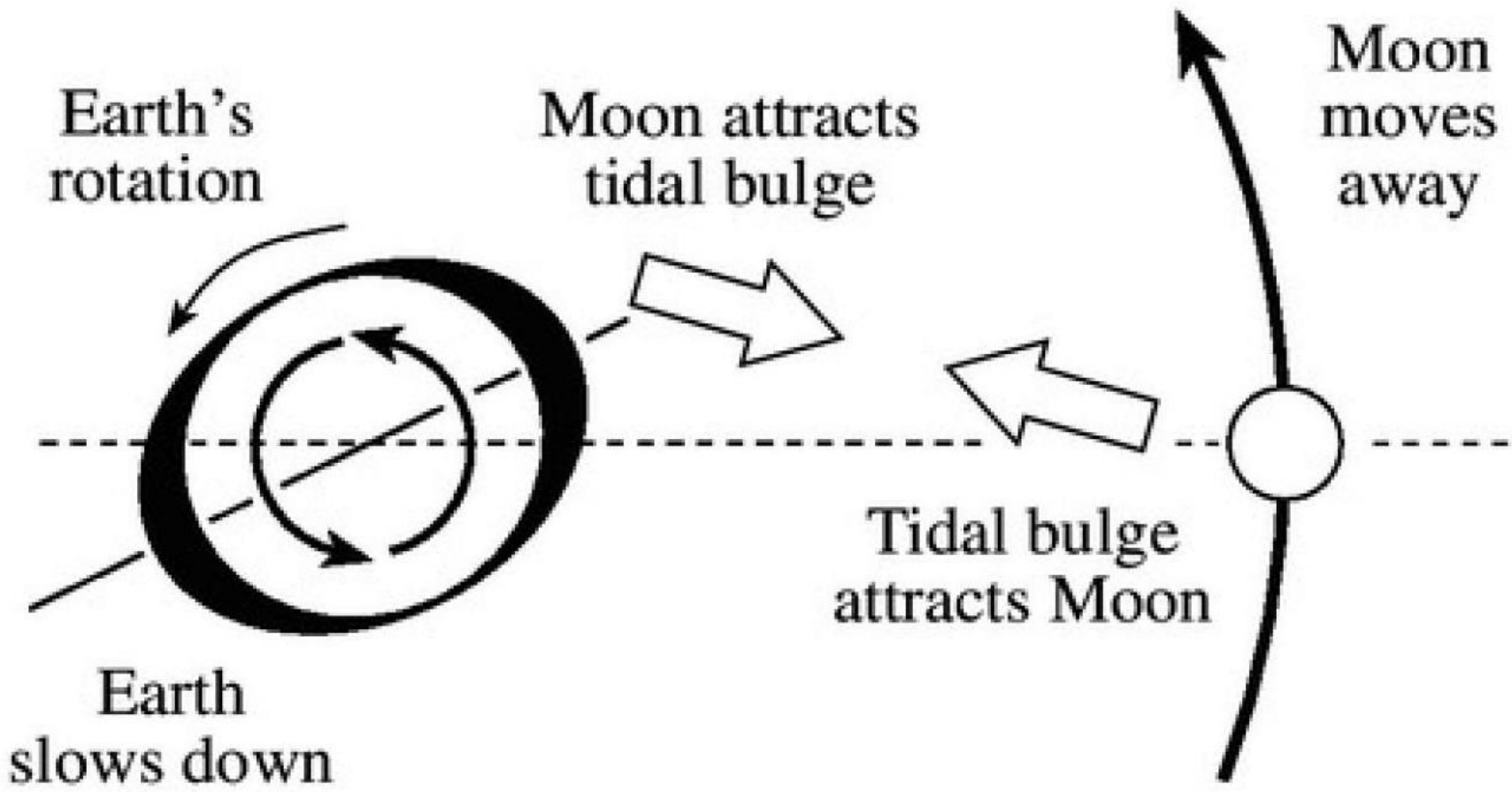
The Moon's gravitational pull decreases with distance, causing bulges on the Earth.

The bulges do not line up with the Moon because the Earth's rotation pulls them ahead.

The resulting torque slows the rotation of the Earth.

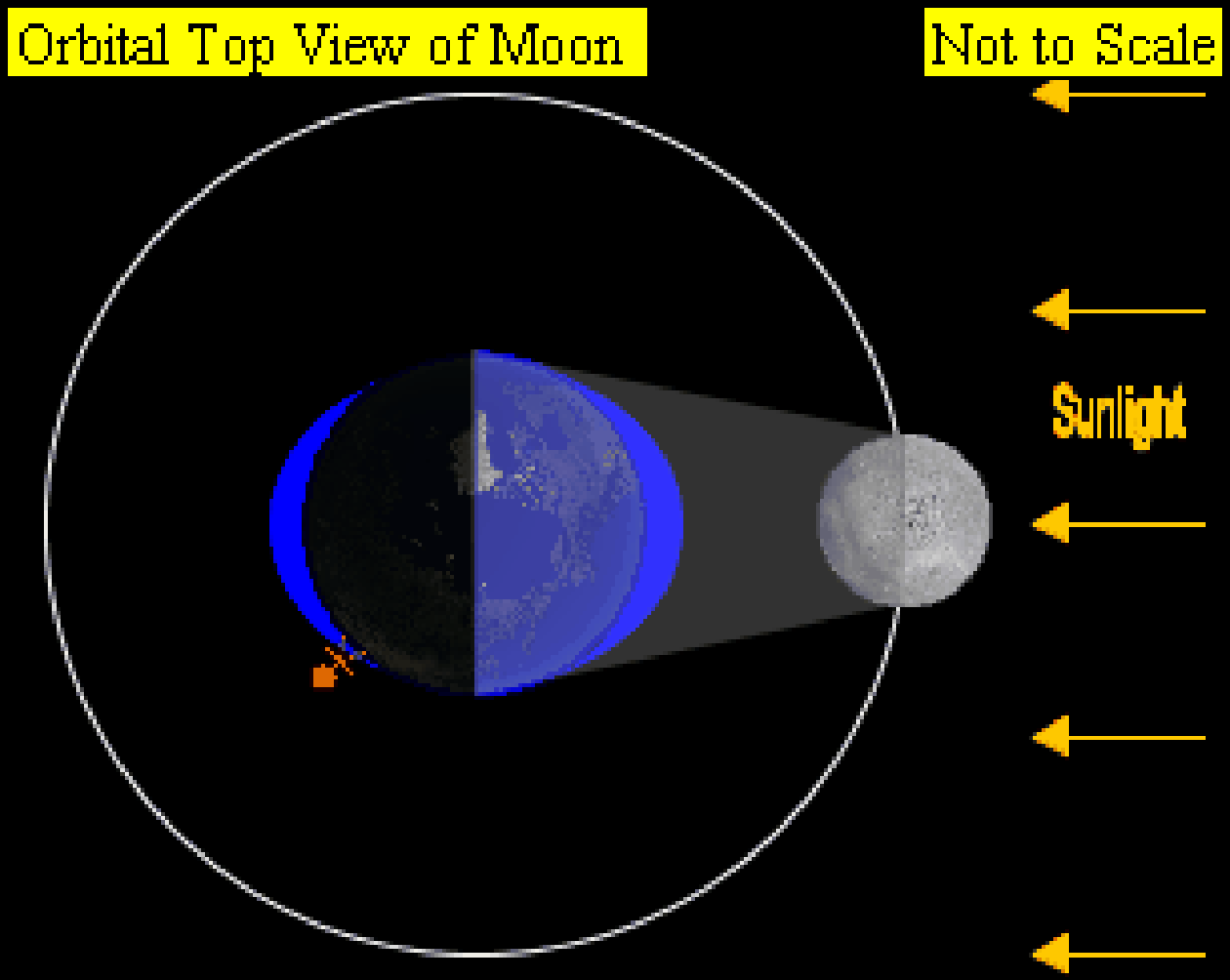
The Earth's influence slows the Moon's rotation and causes it to recede.

Angular momentum is conserved.



https://airandspace.si.edu/multimedia-gallery/tidal-forces-earth

Early in its history, the moon became tidally locked to Earth. The Moon continues to recede and slow due to tidal braking.



Newton's law of universal gravitation and laws of motion relate velocity, period, energy, angular momentum to orbital radius

$$vm(rm) \equiv \sqrt{\frac{G \cdot Me}{rm}} \qquad vm(rm0) = 1.017 \times 10^{3}$$

$$Pm(rm) \equiv \frac{2 \cdot \pi \cdot rm}{vm(rm)} \qquad \frac{2 \cdot \pi}{\sqrt{G \cdot Me}} \cdot rm^{1.5} \qquad \frac{Pm(rm0)}{Pe0} = 27.597$$

$$KEm(rm) \equiv 0.5 \cdot Mm \cdot vm(rm)^{2} \qquad \frac{0.5 \cdot G \cdot Me \cdot Mm}{rm} \qquad KEm(rm0) = 3.803 \times 10^{28}$$

$$PEm(rm) \equiv -\frac{G \cdot Me \cdot Mm}{rm} \qquad PEm(rm0) = -7.607 \times 10^{28}$$

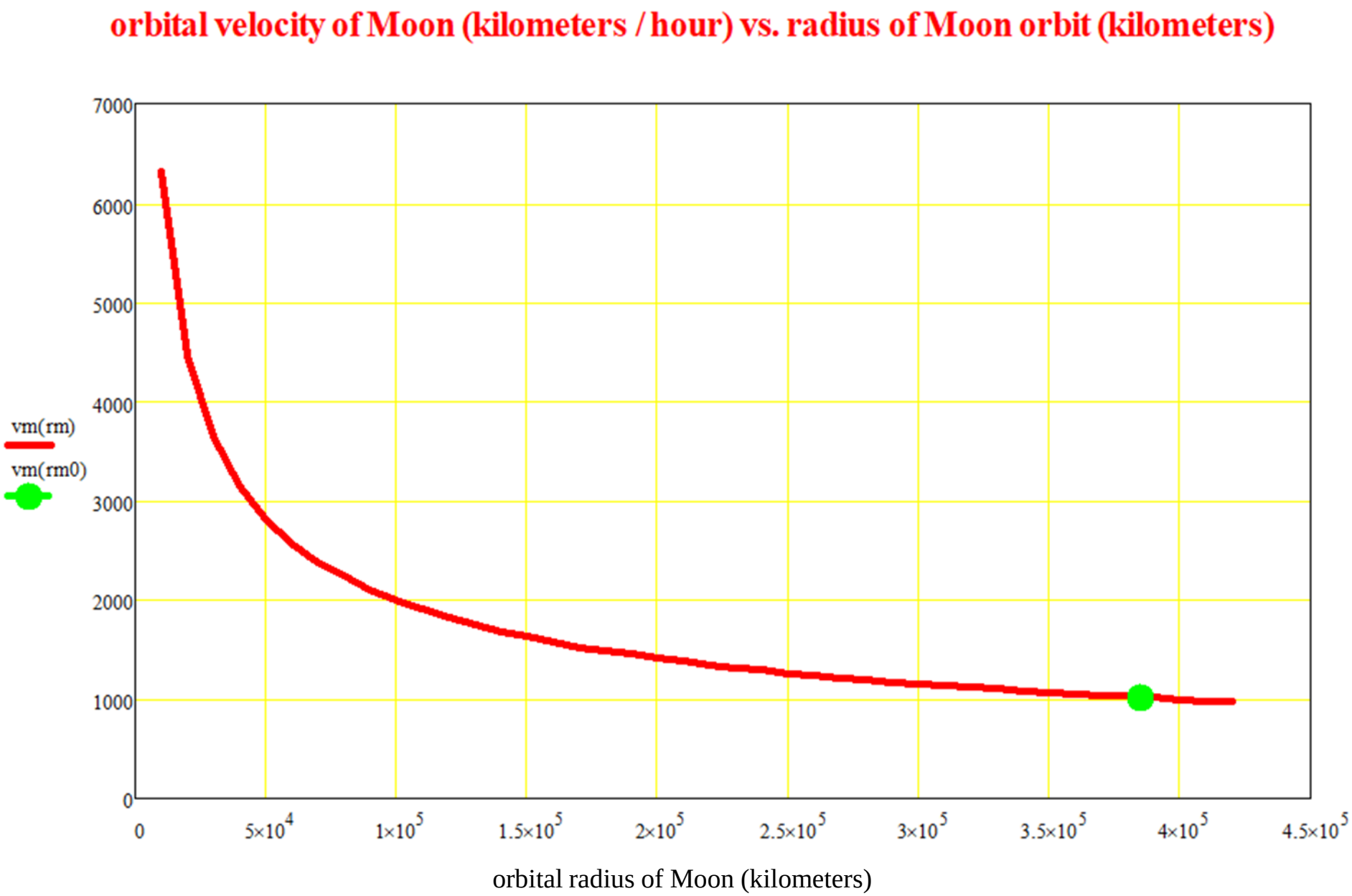
$$Em(rm) \equiv KEm(rm) + PEm(rm) \qquad -\frac{0.5 \cdot G \cdot Me \cdot Mm}{rm} \qquad Em(rm0) = -3.803 \times 10^{28}$$

$$Lm(rm) \equiv Mm \cdot vm(rm) \cdot rm \qquad Mm \cdot \sqrt{G \cdot Me} \cdot rm^{0.5} \qquad Lm(rm0) = 2.879 \times 10^{34}$$

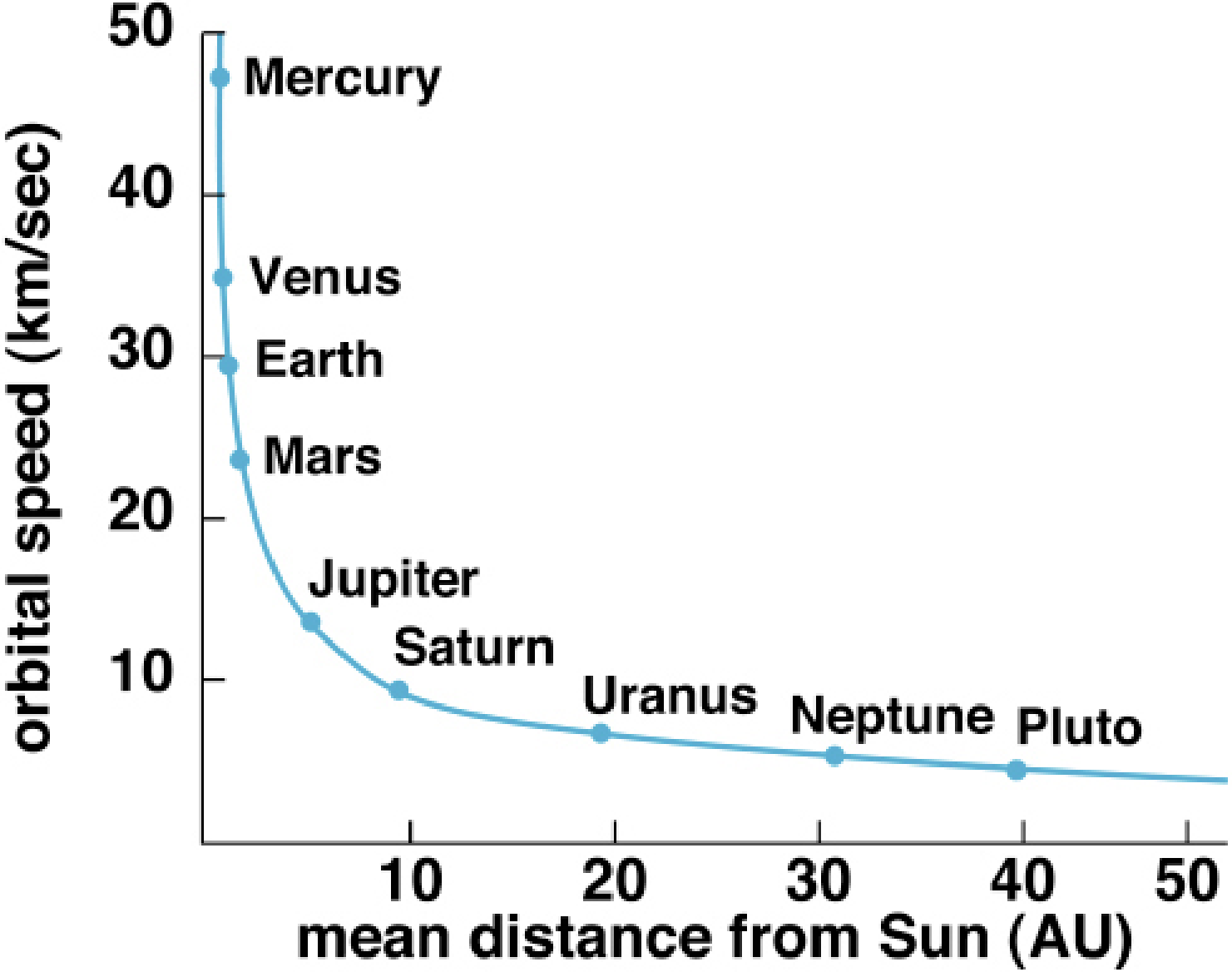
$$Pe(rm) \equiv \frac{0.4 \cdot Me \cdot Re^{2} \cdot 2 \cdot \pi}{L0 - Lm(rm)} \qquad \frac{0.4 \cdot Me \cdot Re^{2} \cdot 2 \cdot \pi}{L0 - Mm \cdot \sqrt{G \cdot Me} \cdot rm^{0.5}} \qquad \frac{Pe\left(3.85 \cdot 10^{8}\right)}{3600} = 23.934$$

$$Le(rm) \equiv Ier0 \cdot \frac{2 \cdot \pi}{Pe(rm)} \qquad L0 - Mm \cdot \sqrt{G \cdot Me} \cdot rm^{0.5} \qquad Le(rm0) = 7.068 \times 10^{33}$$

$$KEe(rm) \equiv 0.5 \cdot Ier0 \cdot \left(\frac{2 \cdot \pi}{Pe(rm)}\right)^{2} \qquad \frac{0.5}{0.4 \cdot Me \cdot Re^{2}} \cdot \left(L0 - Mm \cdot \sqrt{G \cdot Me} \cdot rm^{0.5}\right)^{2} \qquad KEe(rm0) = 2.577 \times 10^{29}$$

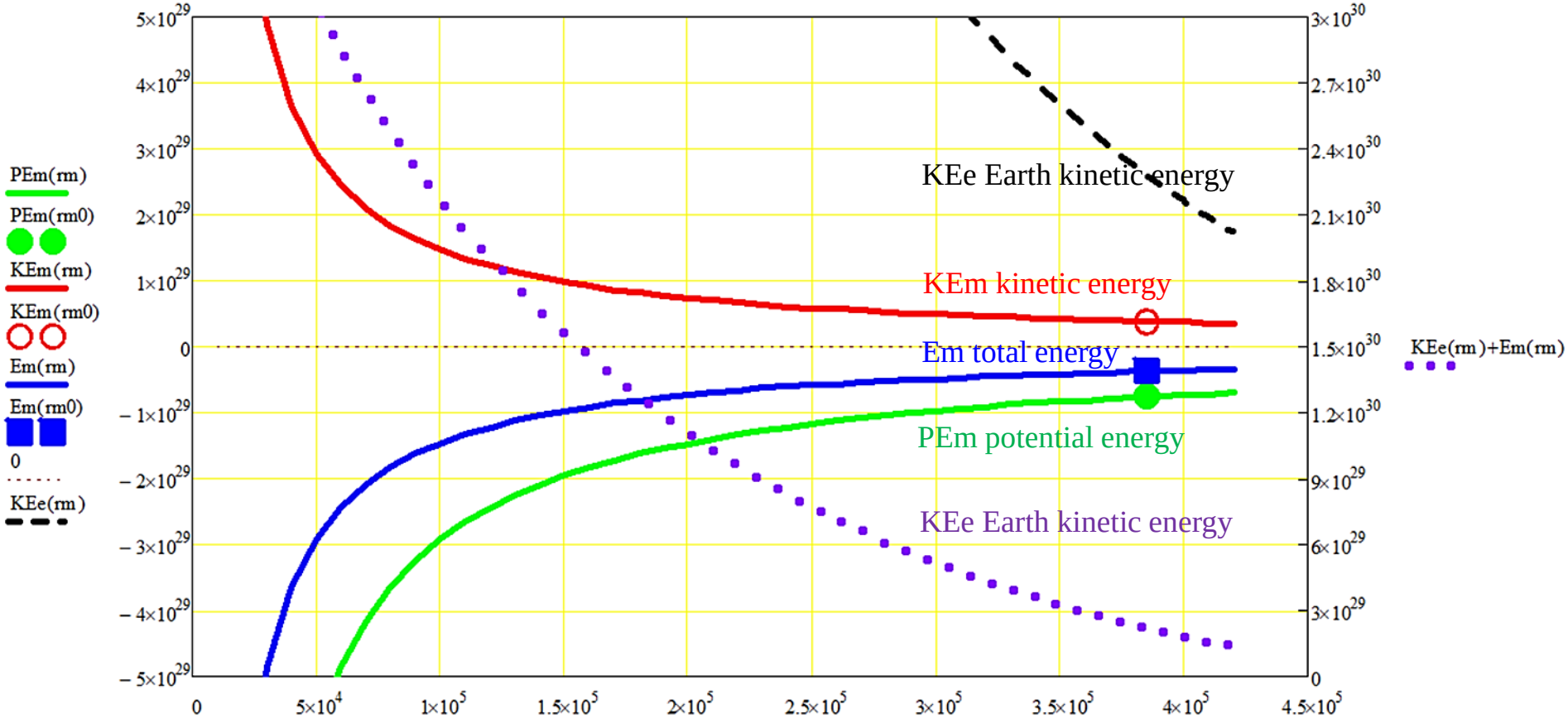

orbital velocity of Moon (kilometers / hour) vs. radius of Moon orbit (kilometers)
7000
6000
5000
4000
3000
2000
1000
0
vm(rm)
vm(rm0)
0
5×10^4
1×10^5
1.5×10^5
2×10^5
2.5×10^5
3×10^5
3.5×10^5
4×10^5
4.5×10^5
orbital radius of Moon (kilometers)

Kepler's Third Law was published in 1619 - 400 years ago
Orbital velocity is smaller further from a gravitating body

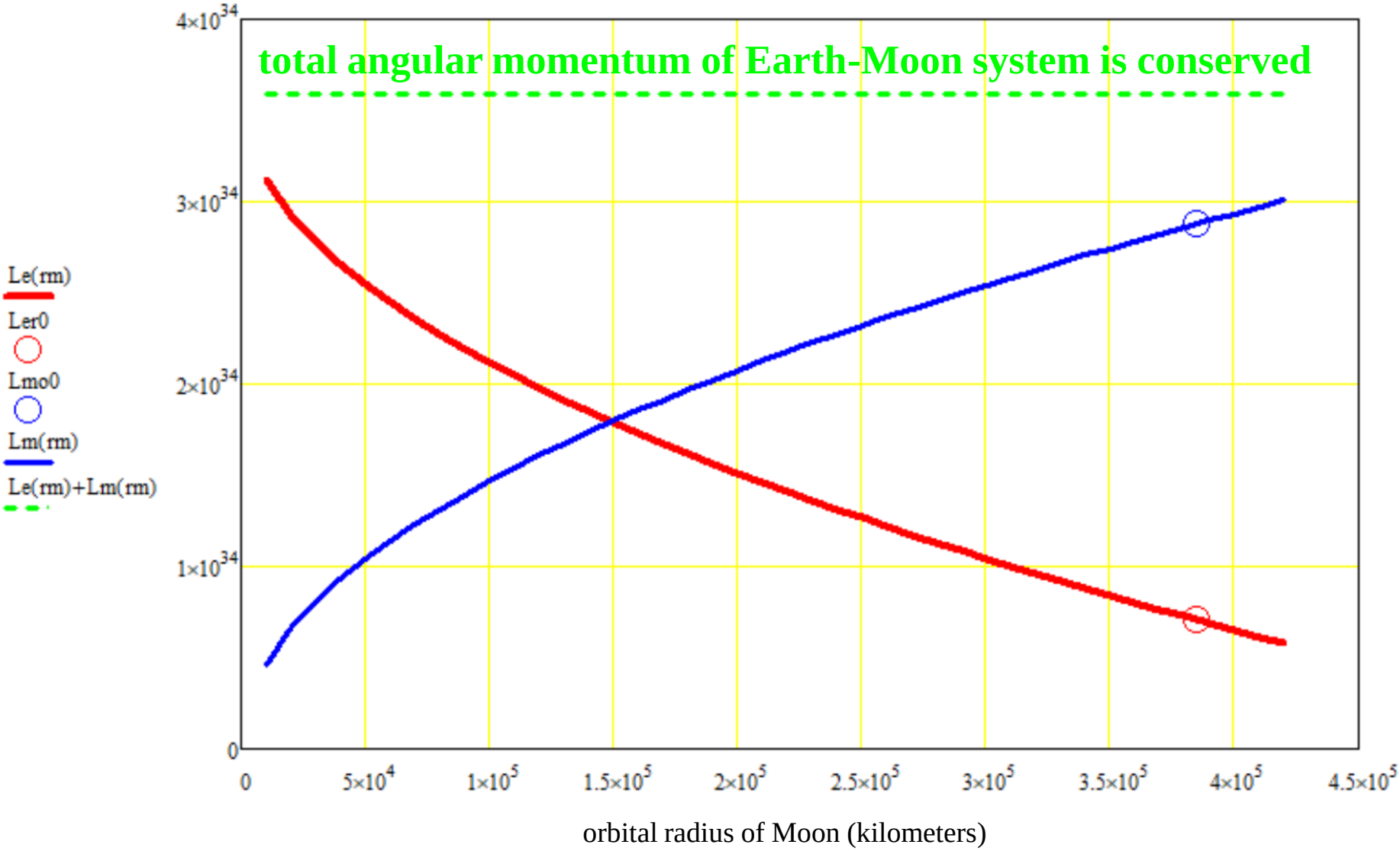


The potential energy that the Moon gains is greater than the kinetic energy that it loses as it recedes from the Earth.

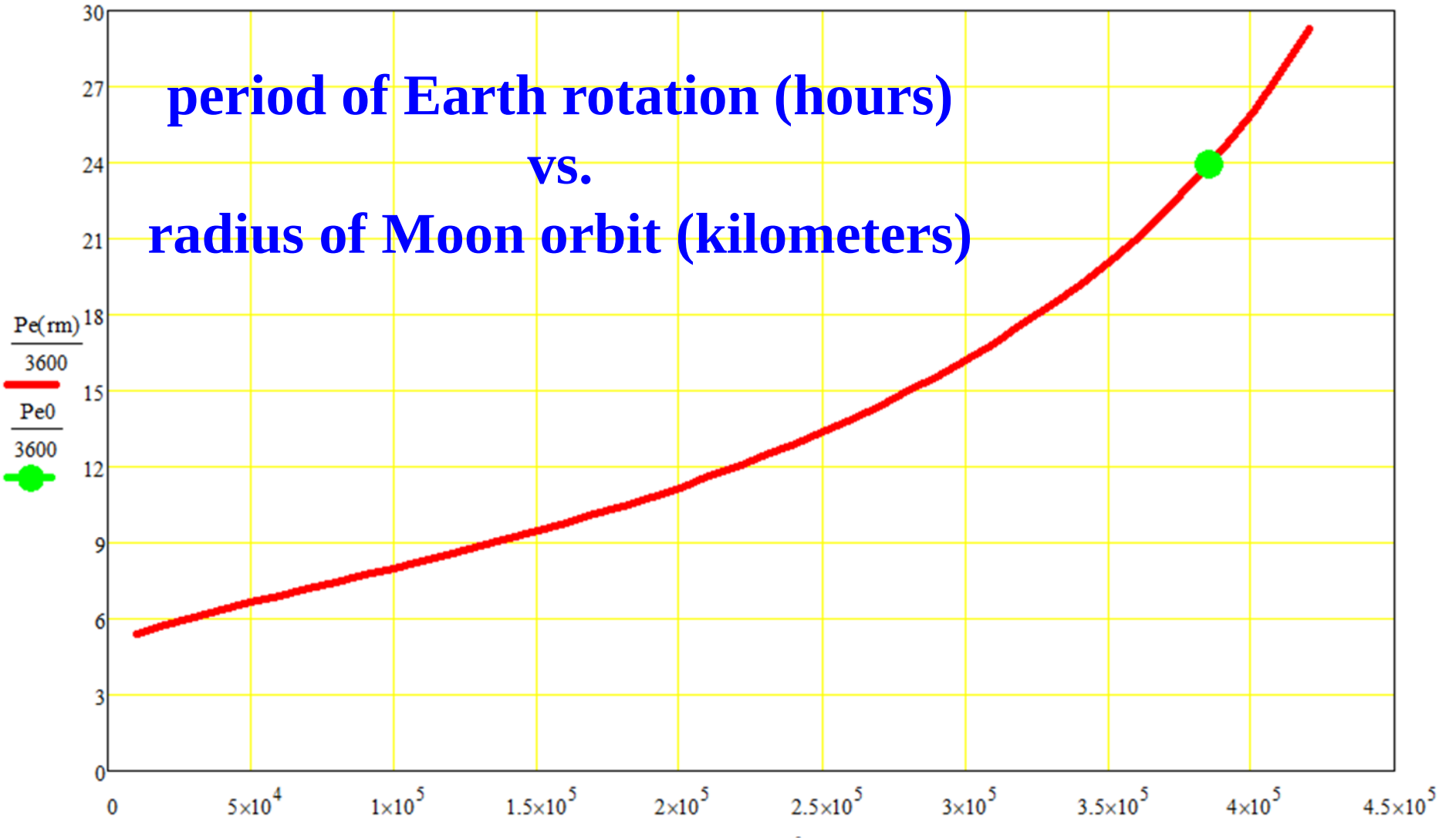
Most of the kinetic energy lost by the Earth during tidal braking is dissipated as heat.



angular momentum (kg m^2 / s) of Earth rotation and Moon orbit vs. radius of Moon orbit (kilometers)

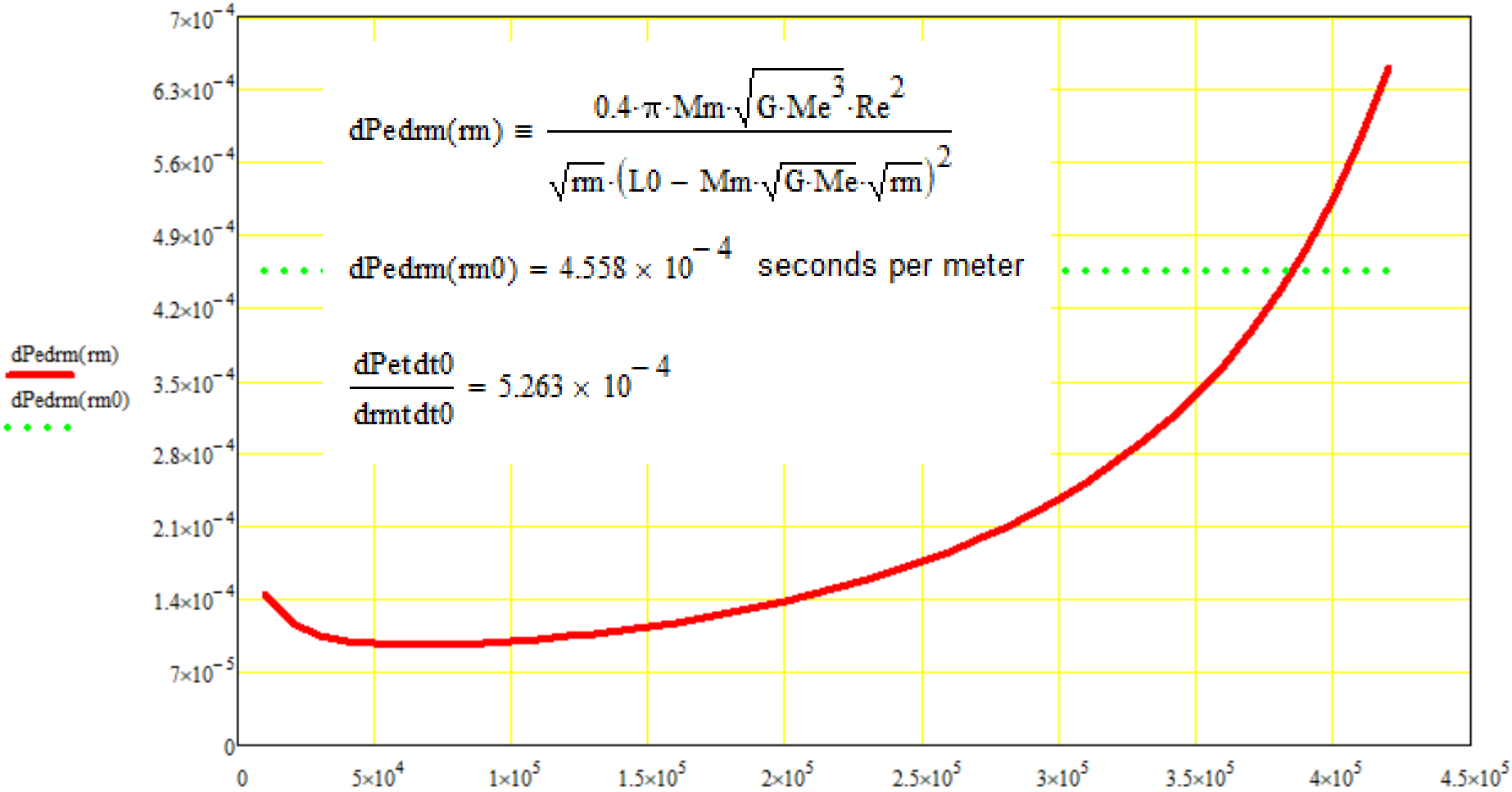


conservation of angular momentum connects the length of an Earth day (rotational period) to the distance to the Moon



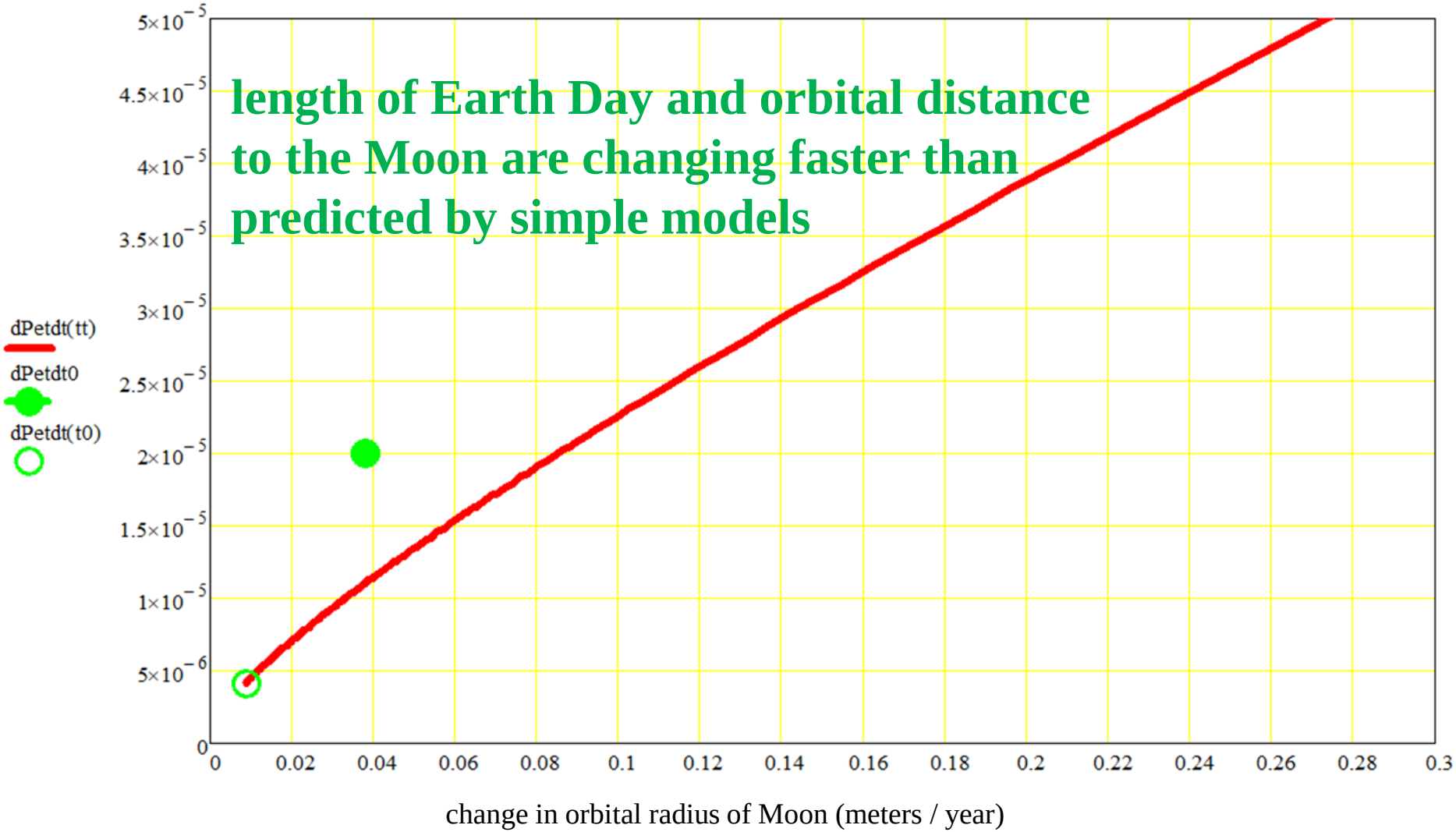
orbital radius of Moon (kilometers)

change in period of Earth rotation per change in radius of Moon orbit (seconds / meter) vs. radius of Moon orbit (kilometers)



orbital radius of Moon (kilometers)

change in period of Earth rotation (seconds / year)
vs.
change in radius of Moon orbit (meters / year)



inverse r^6 model of change in Earth rotation as Moon recedes

$t0 \equiv 4.543 \cdot 10^{9}$ $\quad t1 := 0.001 \cdot t0$

$drmtdt0 \equiv 0.038$ meters / year $\quad dPetdt0 \equiv 2 \cdot 10^{-5}$ seconds / year $\quad dPetdt1 \equiv 0.438 \cdot 10^{-5}$

Given

$$\frac{d}{dt}Pet(t) = \left[\frac{G \cdot Me \cdot rm0 \cdot Mm^{2}}{\left(L0 - 0.4 \cdot Me \cdot Re^{2} \cdot \frac{2 \cdot \pi}{Pet(t)}\right)^{2}}\right]^{6} \cdot dPetdt1 \qquad Pet(t1) = Pe1$$

$Pet := Odesolve(t, 1.157 \cdot t0)$ $\quad$ note the final time t = 1.157*t0

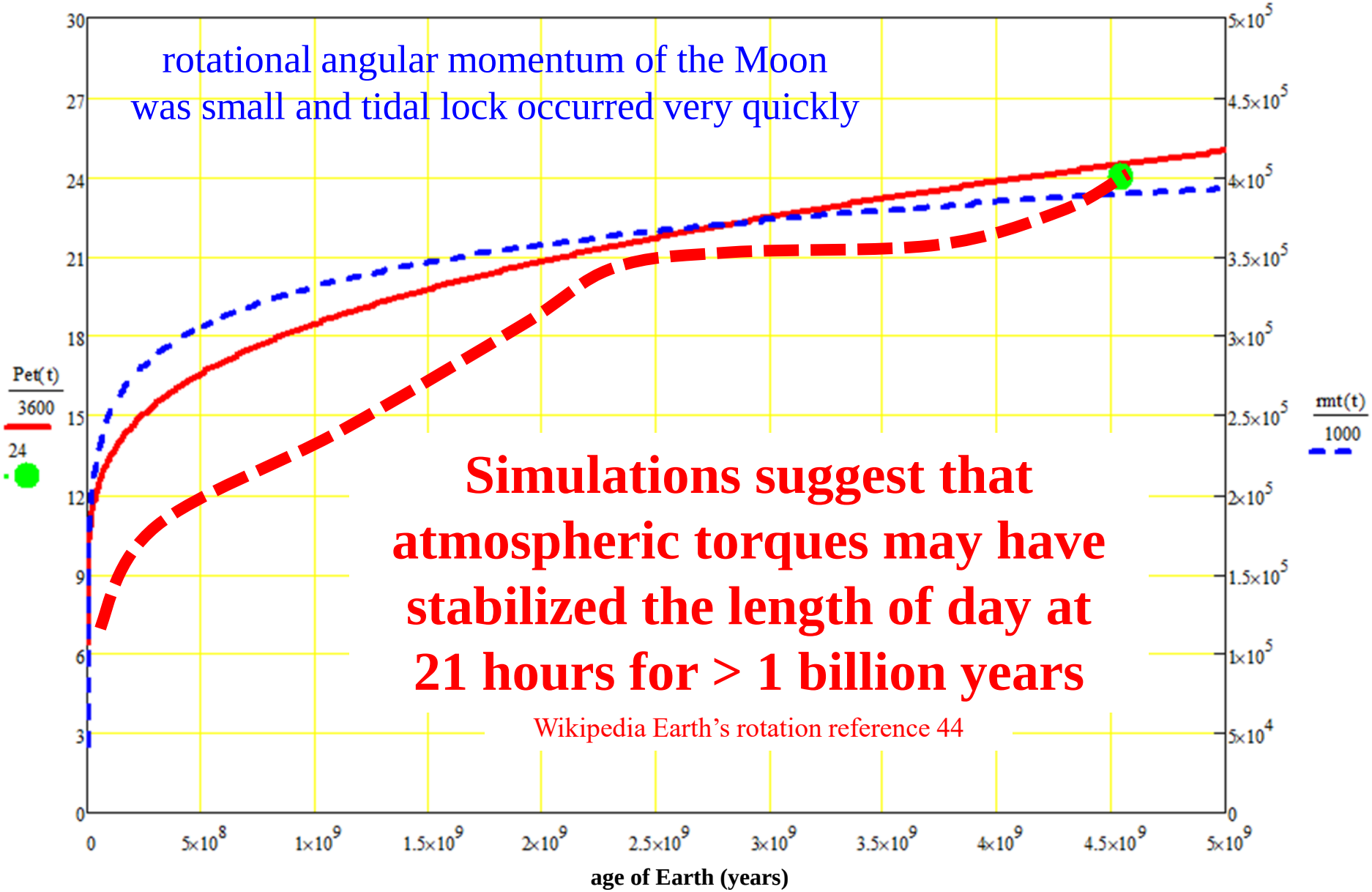
$Pet(1.157 \cdot t0) = 9.087 \times 10^{4}$ $\quad \frac{Pet(1.157 \cdot t0)}{3600} = 25.241$ $\quad \frac{Pet(t1)}{3600} = 5.984$

$dPetdt(t) := \frac{d}{dt}Pet(t)$ $\quad \frac{Pet(t0)}{Pe0} = 1.022$ $\quad \frac{dPetdt0}{dPetdt(t0)} = 4.866$ $\quad Let(t) := 0.4 \cdot Me \cdot Re^{2} \cdot \frac{2 \cdot \pi}{Pet(t)}$ $\quad \frac{Let(t1)}{L0} = 0.789$

$Lmt(t) := L0 - Let(t)$ $\quad rmt(t) := \frac{Lmt(t)^{2}}{G \cdot Me \cdot Mm^{2}}$ $\quad \frac{rmt(t0)}{rm0} = 1.011$

$Pmt(t) := Mm \cdot rmt(t)^{2} \cdot \frac{2 \cdot \pi}{Lmt(t)}$ $\quad drmtdt(t) := \frac{d}{dt}rmt(t)$ $\quad \frac{drmtdt0}{drmtdt(t0)} = 4.378$ $\quad tt := 10^{6}, 2 \cdot 10^{6} .. 1.157 \cdot 4.5 \cdot 10^{9}$

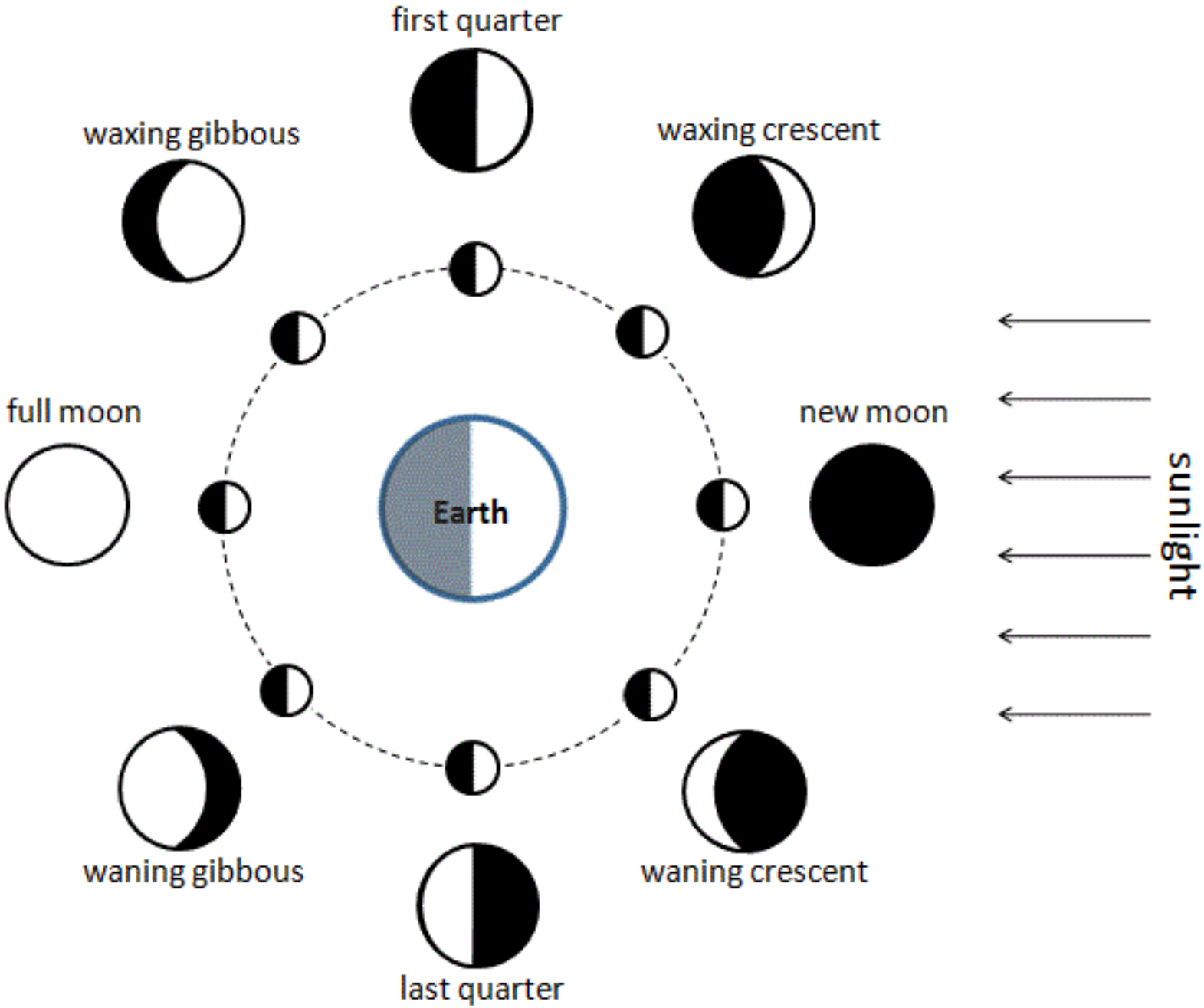
gravitational torques transfer angular momentum from the rotation of the Earth Day to the orbital distance to the Moon



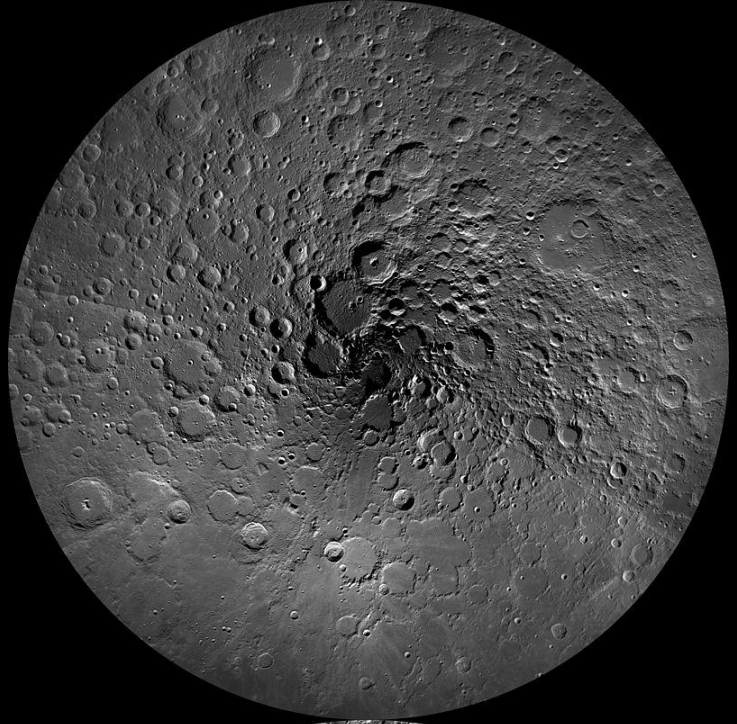
moments of inertia depends on mass distribution and diameter
angular momentum depends on moment of inertia and period

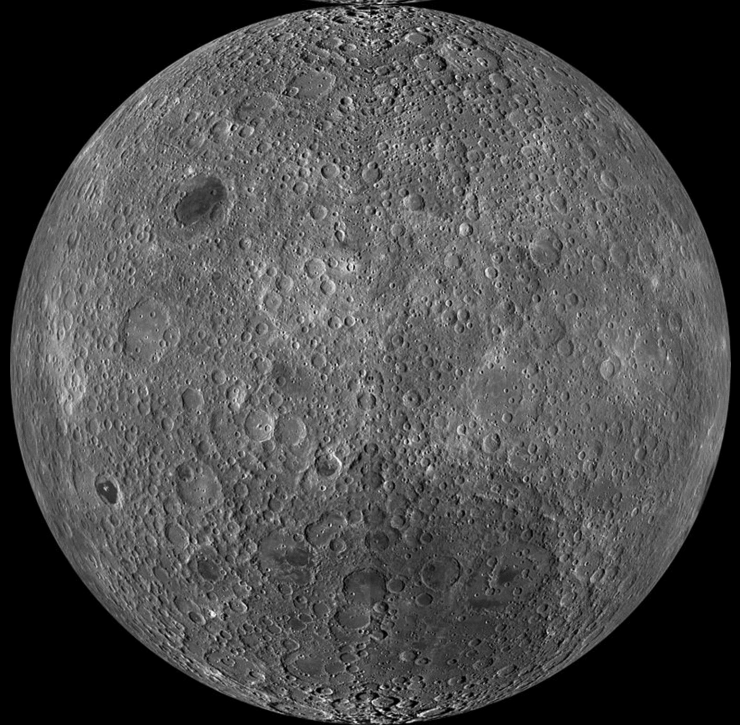
property	Moon	Earth
mass	$M_\oplus$ / 81 = $7.37*10^{22}$ kg	$5.97*10^{24}$ kg
diameter	2159 miles = 3474 km	7918 miles = 12742 km
rotational moment of inertia	$7.46*10^{34}$ kg m^2	$9.7*10^{37}$ kg m^2
rotation period	tidal lock	23.93 hrs = 86,160 s
rotational angular momentum	$1.97*10^{29}$ kg m^2 / s	$7.07*10^{33}$ kg m^2 / s
orbital radius	384,400 km	1 AU = $1.52*10^8$ km
orbital moment of inertia	$1.09 * 10^{40}$ kg m^2	$1.34 * 10^{47}$ kg m^2
orbital period*	27.3 days = 656 hrs	365.256 days
orbital angular momentum	$2.9*10^{34}$ kg m^2 / s	$2.67*10^{40}$ kg m^2 / s

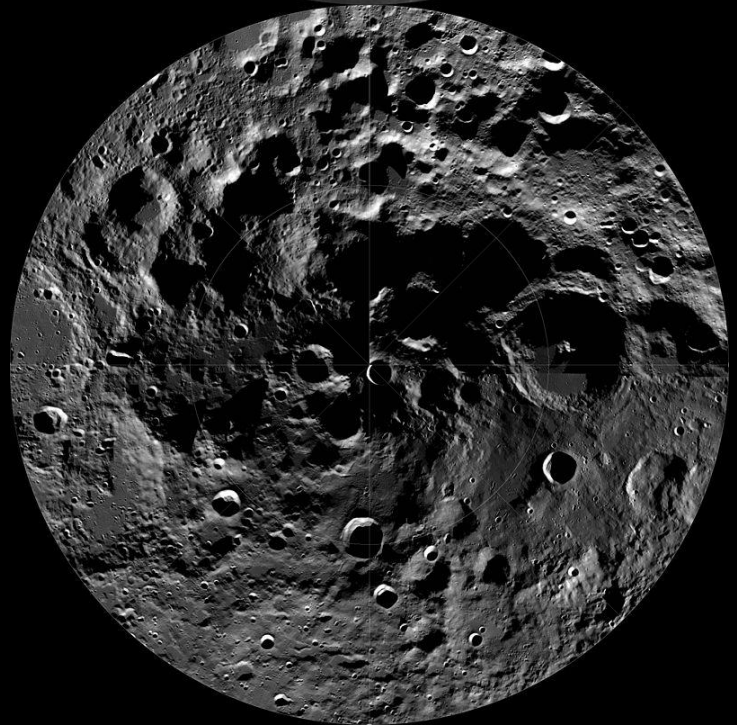
* Depends on mass of body it is orbiting and orbital radius


first quarter
waxing gibbous
waxing crescent
full moon
new moon
Earth
sunlight
waning gibbous
waning crescent
last quarter

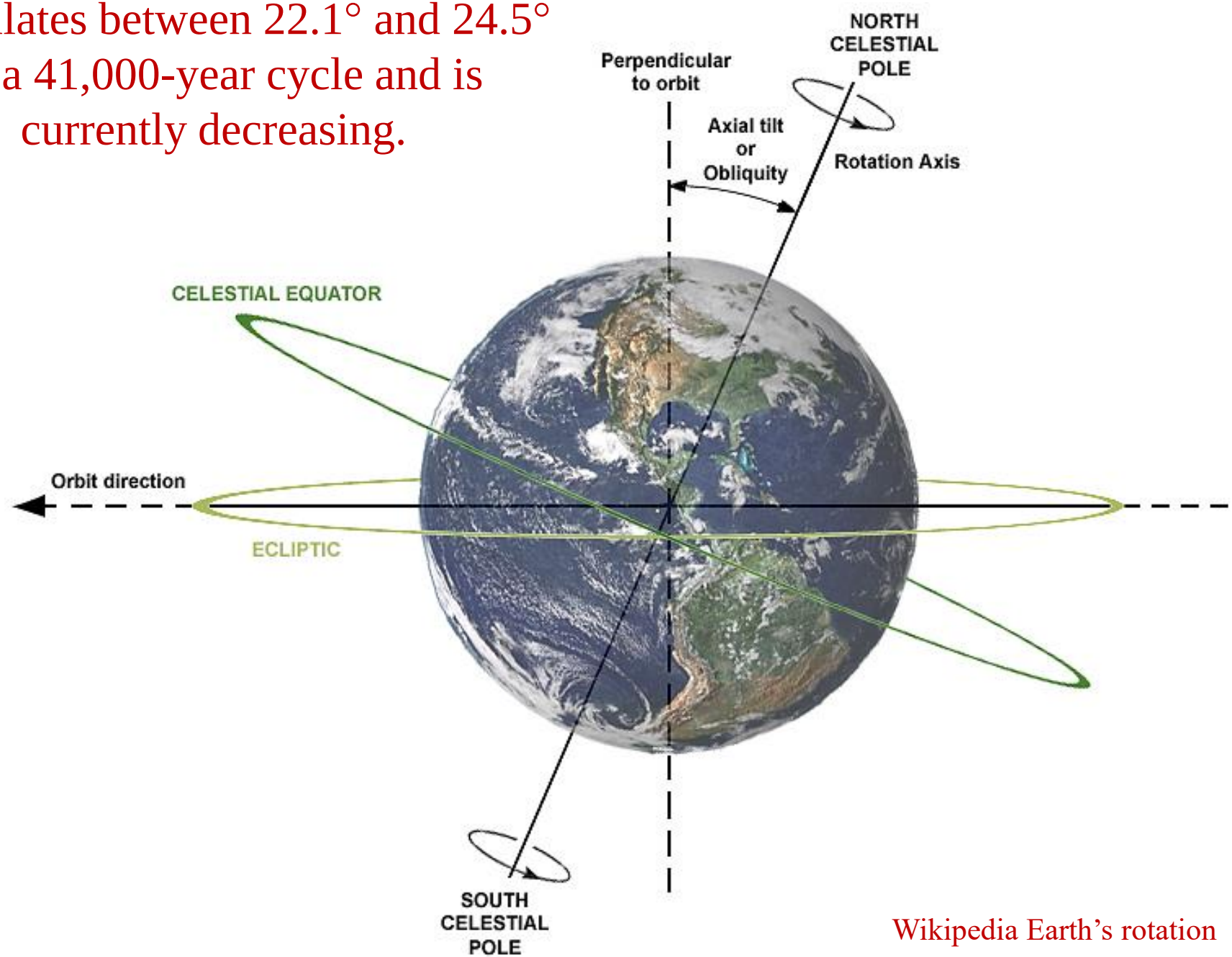
Where is the camera?







Earth's axial tilt is about 23.4°.
It oscillates between 22.1° and 24.5°
on a 41,000-year cycle and is
currently decreasing.



Wikipedia Earth's rotation

Extreme High Tide - Windy Cove

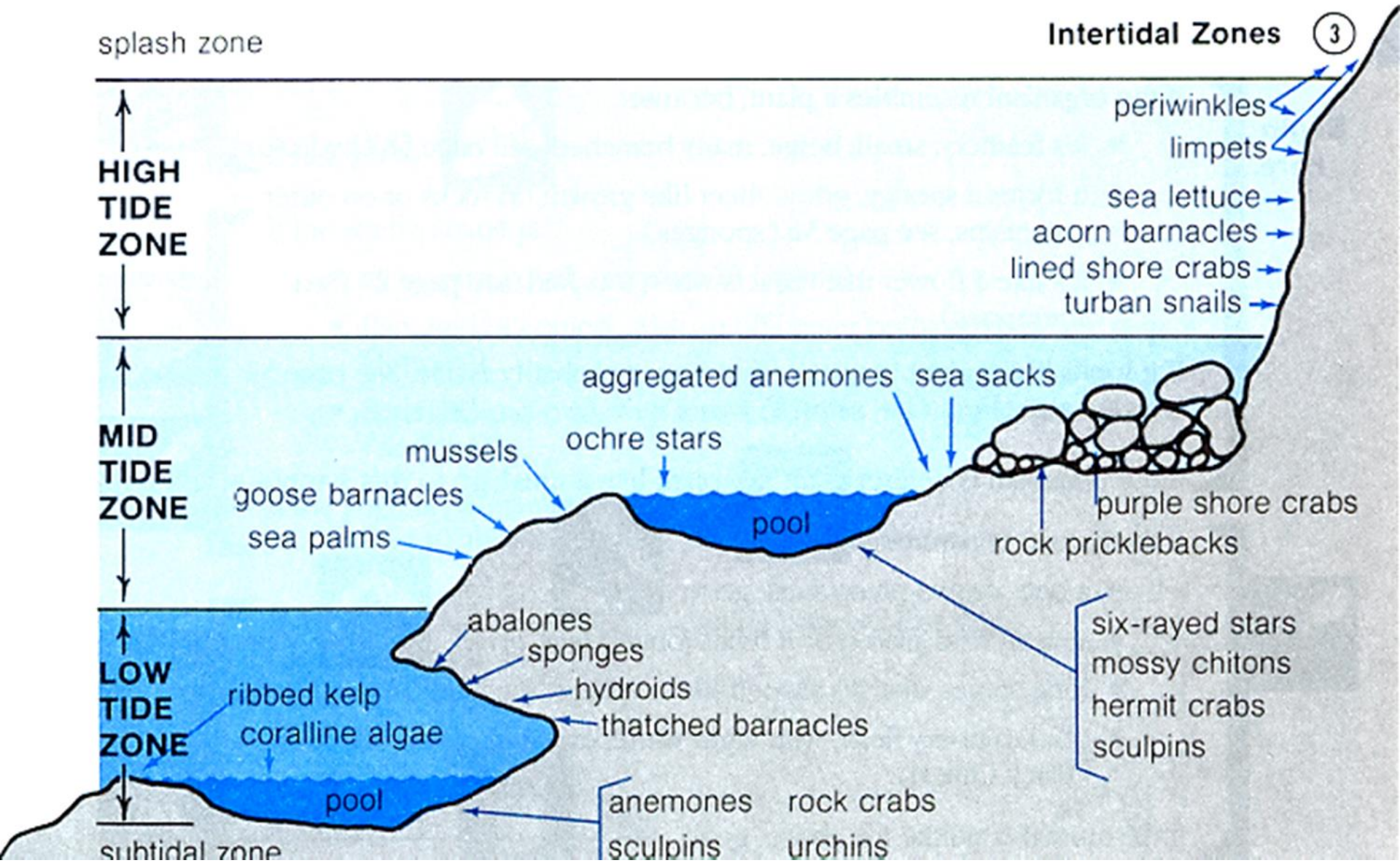
Extreme Low Tide - Windy Cove

Low Tide in Glacier Bay, Alaska

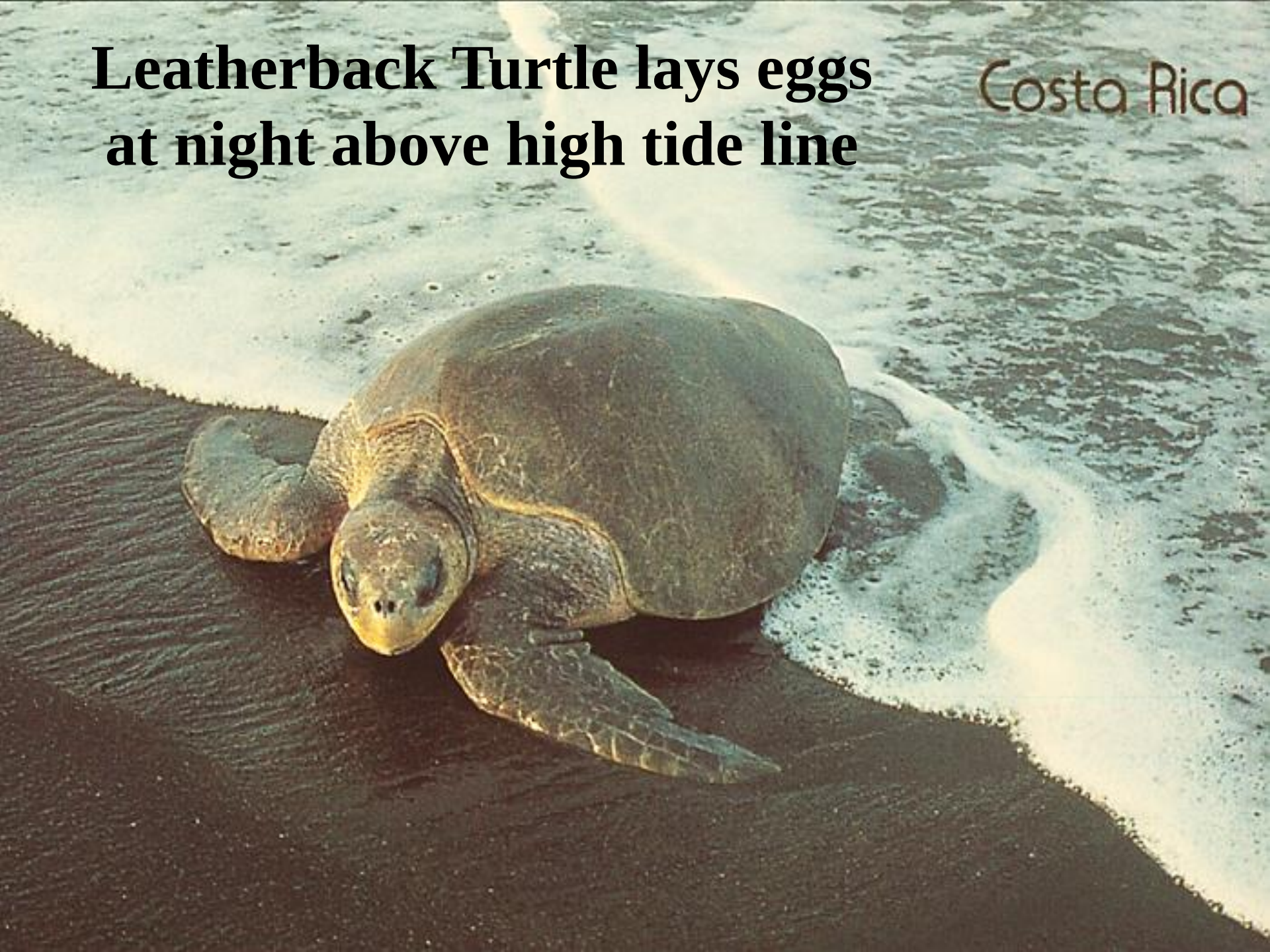
Notice that the piers of the dock are taller than the bridge of the ship.

Hopefully the piers are slightly higher than the highest tide expected in the bay. The simple tide model predicts smaller tidal bulges in more Northern latitudes. But local geography may funnel the rising tide into a narrow channel, forcing the water to rise.

Ron Russo & Pam Olhausen, Pacific Intertidal Life



Leatherback Turtle lays eggs at night above high tide line



The Baja California, in common with most parts of the world, has two tidal cycles per day. If the two highest tides per day are plotted on a graph, the plotted positions can be joined together by two curves, one for each tide. The grunion's spawning runs, occurring immediately after the full and new moons, are timed to coincide with the highest tides during hours of darkness.

Marty Snyderman, California Marine Life

Robin Baker, The Mystery of Migration, Viking 1981

No Moon, no life on Earth, suggests theory

https://www.newscientist.com/article/dn4786-no-moon-no-life-on-earth-suggests-theory/

Without the Moon, there would have been no life on Earth. Four billion years ago, when life began, the Moon orbited much closer to us than it does now, causing massive tides to ebb and flow every few hours. These tides caused dramatic fluctuations in salinity around coastlines which could have driven the evolution of early DNA-like biomolecules.

According to molecular biologist Richard Lathe, self-replicating molecules such as DNA or RNA emerged when small precursor molecules in the primordial "soup" polymerized into long strands. These strands served as templates for more precursor molecules to attach along the templates, creating double-stranded polymers similar to DNA. But the whole theory fails without an external force to separate the double strands to keep the process going.

As an analogy, PCR is used to amplify DNA in the lab. DNA is cycled between two temperatures in the presence of appropriate enzymes. At about 50 °C, single DNA strands act as templates for synthesizing complementary strands. At about 100 °C, the double strands break apart, doubling the number of molecules. Lower the temperature, and the synthesis starts again. Using this process, a single DNA molecule can be converted into a trillion identical copies in just 40 cycles.

Four billion years ago, the Moon was much closer to us than it is now and the Earth rotated more rapidly. Tidal cycles every two to six hours and tides extended several hundred kilometers inland. Coastal areas therefore saw dramatic cyclical changes in salinity, and this led to repeated association and dissociation of double-stranded molecules similar to DNA.

When massive tides rolled in, salt concentration was very low. Double-stranded DNA breaks apart under such conditions because electrically charged phosphate groups on each strand repel each other. But when tides went out, precursor molecules and precipitated salt was present in high concentrations. This would have encouraged double-stranded molecules to form, since high salt concentrations neutralize DNA's phosphate charges, allowing strands to stick together. These unrelenting saline cycles would have amplified molecules such as DNA in a process similar to PCR.

The tidal force is absolutely important because it provides the energy for association and dissociation of polymers.

Many researchers do not believe DNA and RNA were the first replicating molecules. They think much simpler "genetic" material formed first, from the crystallization of clay minerals. Whatever the replicating entities were that started the evolutionary process, it would be significant that they lived in an environment in which the conditions were changing.

Journal reference: Icarus (vol 168, p 18)

Without the Moon, Would There Be Life on Earth?

By driving the tides, our lunar companion may have jump-started biology--or at least accelerated its progression By Bruce Dorminey on April 21, 2009

https://www.scientificamerican.com/article/moon-life-tides/

The ocean tides mirror life itself. Their ebb and flow pay homage to the cyclic nature of the cosmos along even the most secluded seashores. But is life itself also ultimately a fluke of the tides?

If so, life may ultimately owe its origins to our serendipitously large moon. The sun and wind also drive the ocean's oscillations, but it is the moon's gravitational tug that is responsible for the lion's share of this predictable tidal flux.

It all started some 4.5 billion years ago when, as theory has it, our nascent Earth was blindsided by a Mars-size planetary embryo, believed to have spun Earth into its initial fast rotation of roughly 12 hours per day. The molten mantle thrown into orbit after the catastrophic lunar-forming impact quickly coalesced into our moon. Within a few thousand years, Earth cooled to an object with a molten surface and a steam atmosphere.

Life emerged some 700 million years later, or about 3.8 billion years ago. But four billion years ago a cooling Earth already had an ocean, but remained barren. The moon was perhaps half as distant as it is now, and as a result, the ocean tides were much more extreme.

At an average distance of 235,000 miles, the moon is currently receding from Earth at a rate of 1.5 inches per year. As it does, Earth's own spin rate is slowing. And, in the process, roughly 10^{20} joules of gravitational energy is shed into the oceans annually. Three terawatts (3 TW) are shed into the oceans continually.

Over the eons, all that energy has had an evolutionary impact.

"The oceans' tidal flow helps transport heat from the equator to the poles," says Bruce Bills, a geodynamicist at the NASA Jet Propulsion Laboratory in Pasadena, Calif. "Without the lunar tides, it's conceivable that climate oscillations from the ice age to the interglacial would be less extreme than they are. Such glaciations caused migrations of animal and plant species that probably helped speed up speciation."

Bills also points out that such tidal heat transfer could have also mitigated climate fluctuations. The problem in determining which "tidal forcing" scenario is correct, he says, is that climate researchers currently lack data spanning extremely long timescales. Even so, Peter Raimondi, an ecologist at the University of California, Santa Cruz, says the tools of evolution are also driven by the tides' influence on these intertidal regions.

"In a rocky intertidal area," Raimondi says, "it's very clear there are strong evolutionary pressures brought on by a changing environment over a short spatial scale. Without our moon, our marine environment would be much less rich in terms of species diversity."

But is the influence of the lunar tides actually responsible for life itself?

If life originated around deep ocean hydrothermal vents (so-called black smokers), then the lunar tides played a minor role, if any, says James Cowen, a biogeochemical oceanographer at the University of Hawaii at Manoa. If, however, life originated in tidal waters, he says, then tidal cycles could have played a major role.

Both DNA and RNA—the messengers of life as we know it—almost certainly were selected and evolved from a large diverse group of protonucleic acid molecules. But for DNA and RNA to evolve from this group of protonucleic acid structures, first they had to be able to replicate. That involved organizing their copying via cyclic assembly and dissociation.

"A lot of origin-of-life reactions involve getting rid of water," says Kevin Zahnle, a planetary scientist at the NASA Ames Research Center at Moffett Field, Calif. "So you look for means to concentrate your solutions. One way to do that is to throw water up on a hot rock, then have the waters recede and evaporate."

Molecular biologist Richard Lathe of Pieta Research, a biotech consultancy in Edinburgh, Scotland, contends that some 3.9 billion years ago, fast tidal cycling caused by the influence of our moon enabled the formation of precursor nucleic acids. Lathe says that a 12-hour Earth day would have produced high tides "a little faster than every six hours."

He believes these lunar tides would have moved many miles inland, beyond the crashing waves driven by the sun or surface winds, and onto a vast, flat sandscape.

In the early Earth environment, Lathe notes that such fast lunar tidal oscillations would result in the highly saline low-tide environment that protonucleic acid fragments would have needed to associate and assemble complementary molecular strands.

Having bonded in pairs at low tide, these newly formed molecular strands would then dissociate at high tide, when salt concentrations were reduced, providing what Lathe terms a self-replicating system. Lathe believes that DNA would ultimately have arisen from such protonucleic acids.

Our disproportionately large nearby moon certainly gave Earth an early tidal nudge. But unlike Venus and Mars, our moon's gravitational influence also helped ensure that Earth's spin axis and climate remained stable over long timescales. That's arguably just as important as our oceans' tidal ebb and flow.

Still, as Bruce Lieberman, a paleobiologist at the University of Kansas in Lawrence, points out: "I suspect that eventually life would have made land without the tides. But the lineages that ultimately gave rise to humans were at first intertidal."

Wikipedia has everything – I saved articles as pdfs and posted them at https://evolution.calpoly.edu/moon

Age_of_the_Earth

Apollo_10

Apollo_program

Circular_orbit

Day_length_fluctuations

Earth

Earth's_rotation

Exploration_of_the_Moon

Geological_history_of_Earth

Giant-impact_hypothesis

History_of_Earth

Kepler's_laws_of_planetary_motion

Late_Heavy_Bombardment

Moon

Newton's_law_of_universal_gravitation

Newton's_laws_of_motion

Origin_of_the_Moon

Origin_of_water_on_Earth

Roche_limit

Rocketdyne_F-1

Saturn_V

Synestia

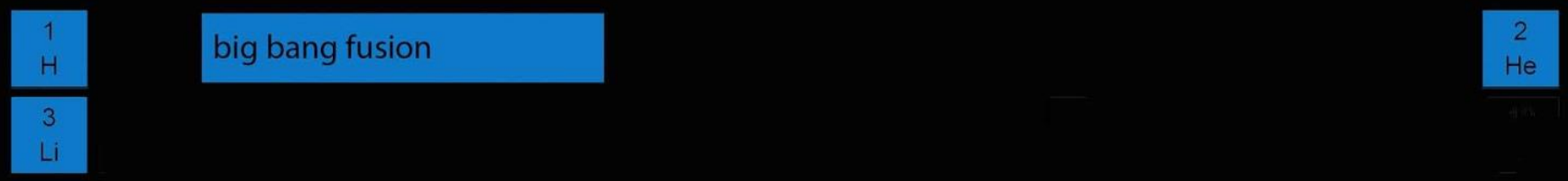
Theia_(planet)

Tidal_acceleration

Tidal_locking

How did a cold dilute cloud of gas and dust evolve into astronauts roaming the moon orbiting a planet orbiting a star?

Universe at ~15 minutes old



Shortly after the Big Bang,
the universe did not have any elements or protons or neutrons.

microseconds later quarks cooled and formed protons and neutrons

minutes later, some protons and neutrons fused into helium and some lithium.

For about 100 million years, that was all there was in the Periodic Table.

This fall the cosmic evolution project will celebrate the 150th anniversary of the Periodic Table with a special event on the cosmogenesis of the elements and the cosmic origins of the building blocks of life.

brain games related to Newton's laws

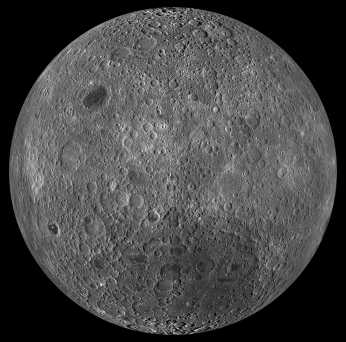
Newtons Laws of motion

$F + u\, dm/dt = m\, dv/dt$

Wikipedia Newton's Laws

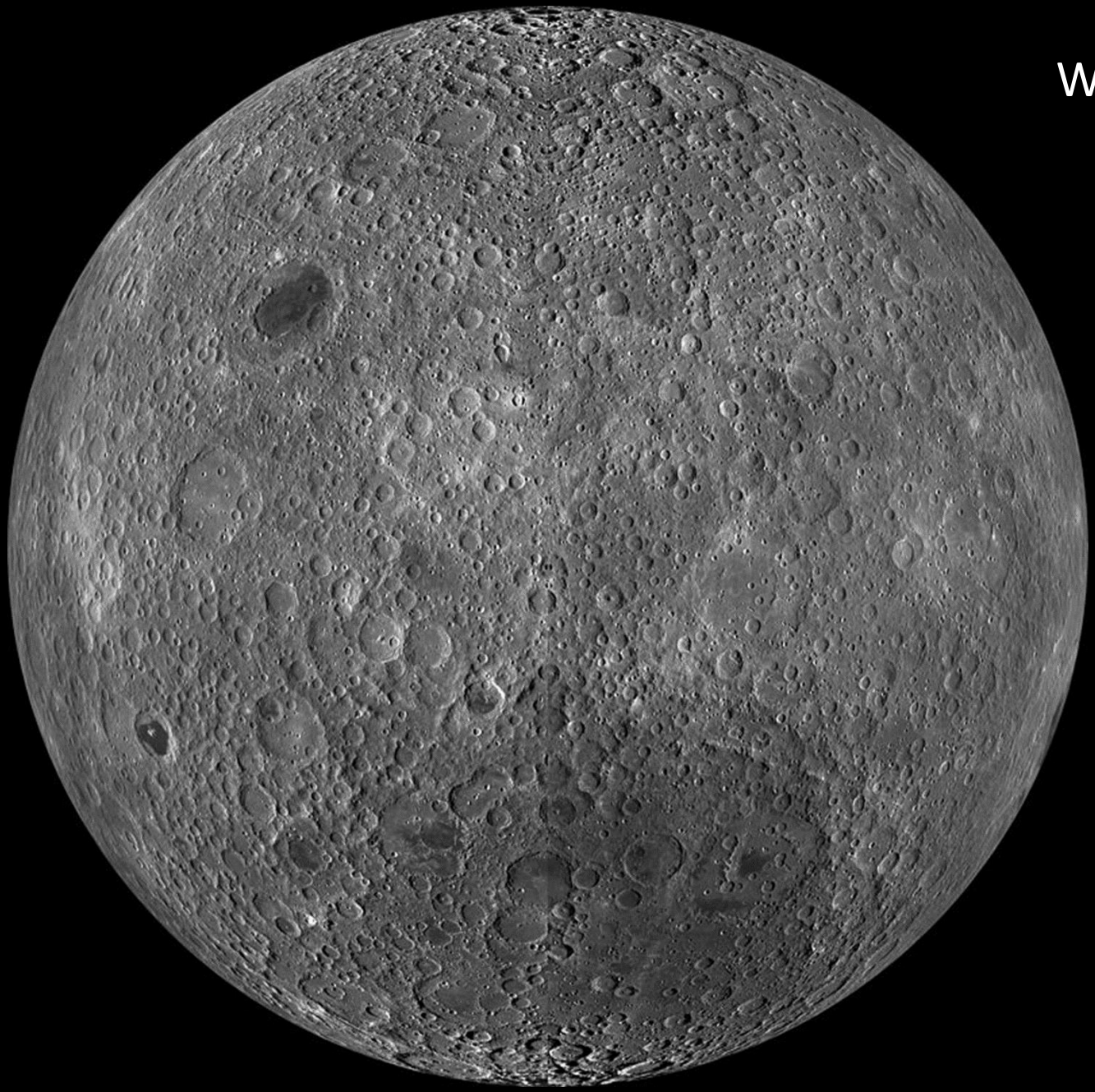
Where is the camera?

Where is the camera?

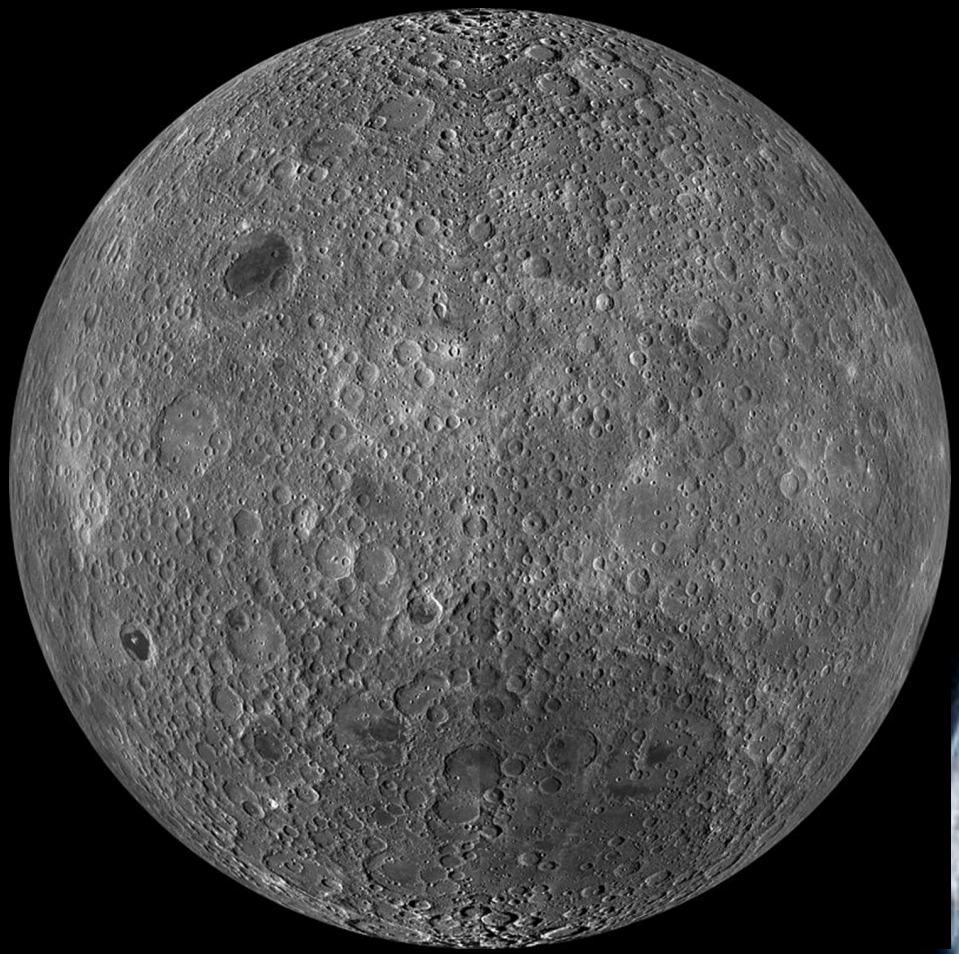


Where is the camera?

Where is the camera?



Where is the camera?



https://evolution.calpoly.edu/moon

rfield@calpoly.edu