




Formation

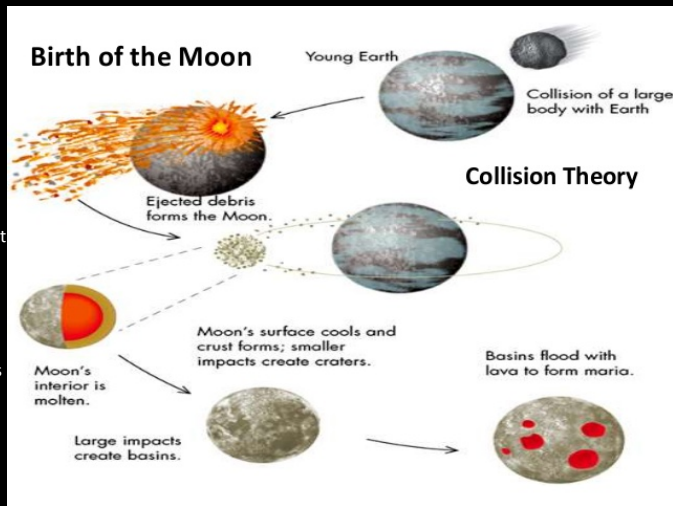
- Impact 4.3 billion years ago by Mars size planet Thea
- Moon is about 50 million years younger than Earth
- Completely melted Earth
- Imparted a very fast spin to Earth
- ~ 5 hour day
- + 2.3 milliseconds per century



National Geographic

Evolution

- Moon forms in about 100 years
- ~ 20,000 km from Earth
- Tides 8,000 X stronger
- Tidal forces synchronized Moon's spin and orbital period
- Late Heavy Bombardment 4.1-3.8 billion years ago creates large impacts
- Mare volcanism 3.8 - 1 billion years ago
- Ray craters 1 billion years ago to present
- Tycho 109 million years



Slideshare.net



Steve Mandel

Physical Characteristics

- 1/4 size of Earth
- 1/6 gravity of Earth
- Slightly > 1 % Earth's mass
- Extensive cratering
- Average distance 384,000 km
- 27.3 day orbit and rotation
- Temperature range -233° to 123°C
- Extremely dry
- Far side thicker crust, few maria
- Light areas – highlands
- Dark areas – maria



Russell Croman/SPL/ Getty

Historical Importance

Ancient Observatories

- El Caracol - Observatory at Chichén Itzá

Time

- Earliest Calendars based on observations of the moon
- Month
- Monday

Illumination

- Work and travel at night
- Harvest Moon

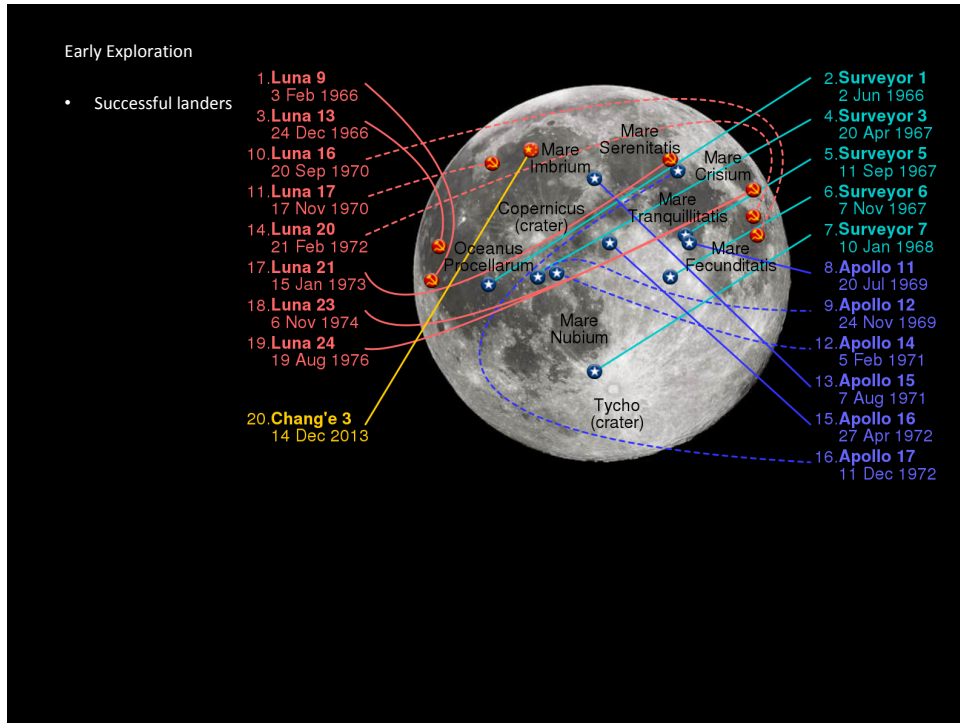
Navigational Beacon and Indicator of Tides

Cultural Significance

- Myth
- Visual Art: painting, photography
- Poetry
- Literature



Rob Shenk



Historical Missions

USSR

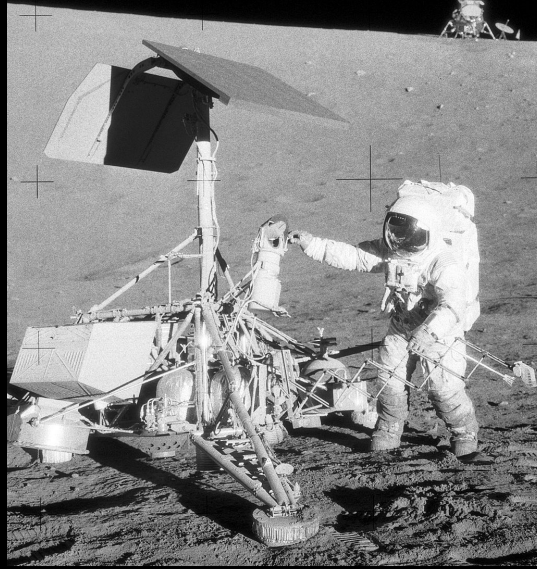
- Luna 2 – 1959
- Luna 3 – 1959 First to image far side
- Zond 3 – 1965 Flyby
- Luna 9 – 1966 First soft landing
- Luna 10 – 1966 First successful orbiter (10-12,14,15,19,21,22)
- Luna 13 – 1966 Lander
- Zond 5 – 1968 Circumlunar
- Zond 6 – 1968 Circumlunar
- Zond 7 – 1969 Circumlunar
- Zond 8 – 1970 Circumlunar
- Luna 16 – 1970 sample return
- Luna 17 – 1970 deployed first rover Lunokhod 1
- Lifespan 322 days, 10.5 km
- Luna 20 – 1972 sample return
- Luna 21 – 1973 deployed Lunokhod 2
- Lifespan 4 months, 42 km
- Luna 23 – 1974 Lander
- Luna 24 – 1976 sample return
- 0.311 kg

Wikipedia

Historical Missions

NASA

- Ranger 7 - 1964
- Ranger 8,9 - 1965
- Lunar Orbiter 1 & 2 - 1966
- Surveyor 1 - 1966
- Lunar Orbiter 3,4,5 - 1967
- Surveyor 3 - 1967
- Surveyor 5 - 1967
- Surveyor 6 - 1967
- Surveyor 7 - 1968
- Apollo 8 - 1968 First manned lunar orbit
- Apollo 10 - 1969 First manned lunar test of LM
- Apollo 11 - 1969 First manned landing
- Apollo 12 - 1969 First pinpoint landing
- Apollo 14 - 1971
- Apollo 15 - 1971 First lunar rover
\$ 38,000,000
- Apollo 16 - 1972 (lunar rover)
- Apollo 17 - 1972 (lunar rover)



Recent Missions

India
Chandrayaan 1 – 2008 Orbiter & Moon Impact Probe

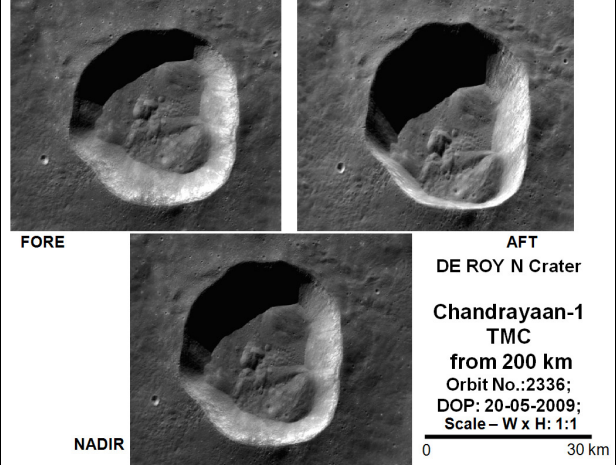
China
Chang'e 1 – 2007 Orbiter

JAXA
Hiten – 1990 Orbiter
KAGUYA – 2007 Orbiter

Israel
Beresheet – 2019 Lander crashed
SpaceIL - First private company lunar attempt

NASA
Clementine – 1994 Orbiter (DOD)
Lunar Prospector – 1998 Orbiter
LCROSS – 2009 Orbiter
GRAIL – 2011 Orbiter
LADEE – 2013 Orbiter

ESA
SMART 1 – 2003 Orbiter



FORE

AFT

NADIR

DE ROY N Crater

**Chandrayaan-1
TMC
from 200 km**
Orbit No.:2336;
DOP: 20-05-2009;
Scale – W x H: 1:1

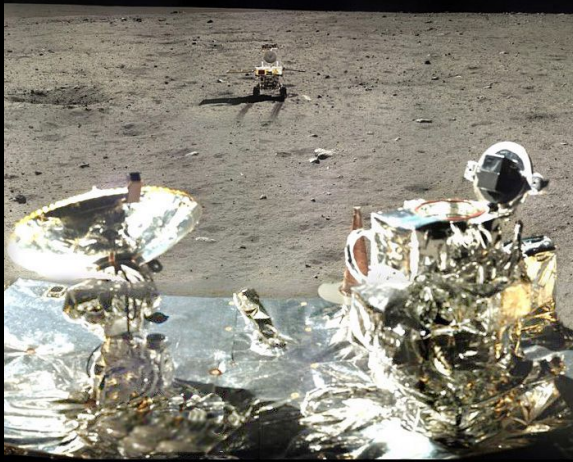
0 30 km

Current Exploration

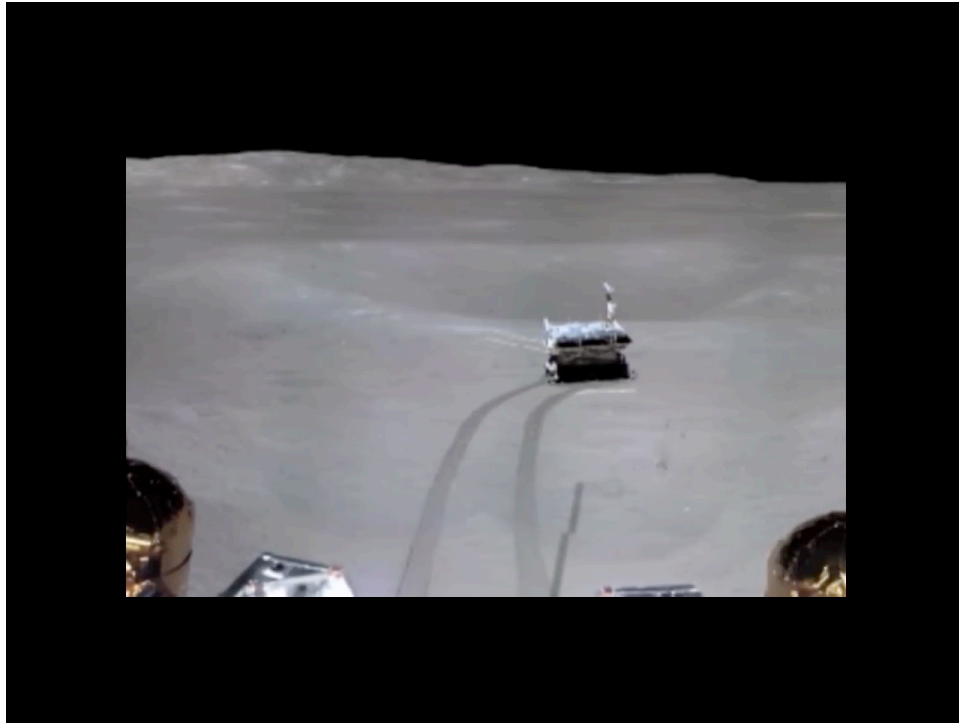
Chinese
Chang'e 2 – 2010 Orbiter
Chang'e 3 – 2013 Lander & rover
Queqiao – 2018 Orbiter & radio relay for Chang'e 4
Chang'e 4 – 2019 Lander & rover
Chang'e 5 – 2020 Sample return

NASA
Lunar Reconnaissance Orbiter – 2009
ARTEMIS - 2011 Twin orbiter spacecraft

India
Chandrayaan 2 – 2019 Orbiter, lander & rover (lander crashed)



Chang'e-3 Timelapse Color Panorama
Credit: CNSA/Chinanews/Ken Kremer/Marco Di Lorenzo



Discoveries

- Lunar geology: soil properties and chemical composition
- Rocks and soil contain same isotope content as Earth
- No global magnetic field
- Tenuous exosphere
- Global magma ocean
- 700 million year span of lava flooding
- Enormous lunar pits
- Lunar samples provided evidence for Late Heavy Bombardment 3.9 billion years ago
- Large impacts – Aitken Basin provides evidence for Earth extinction events
- A window into Earth's formation and evolution
- Very little iron in core
- Retreating ~ 3.8 cm/year
- Water Ice discovered at north and south poles by Chandrayaan 1 in 2008
- High resolution imaging of entire surface



USRA

Future

NASA
 Capstone – 2022 CubeSat orbiter
 Artemis Program – 2024 Crewed lander
 VIPER: Volatiles Investigating Polar Exploration Rover - November 2023
 Deep Space Gateway – Manned orbiter & Mars staging – 20??

China
 Chang'e 6 – 2024 Sample return
 Chang'e 7 – TBA Lunar survey
 Chang'e 8 – TBA Lunar Technology Test Manned lander – 20??

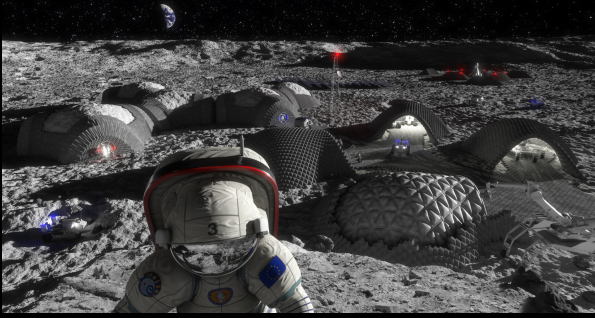
Japan
 Yaoki – 2024 Lander

South Korea
 Pathfinder – August 2022 Orbiter

ESA
 Lunar Resource Lander – Mid 2020's
 Heracles – Mid 2020's Lander & rover

Private Sector
 Space X
 Blue Origin

Habitation



ESA

Personal Exploration

- Books
- Apps: Virtual Moon Atlas
 - <https://ap-i.net/avl/en/start>
- Google Earth
- Stellarium
 - <https://stellarium.org/>
- Observing programs
 - RASC Explore the Moon
- Binoculars
- Telescope with neutral density filter



Victor Walsh Photography/ Getty Images

Novice Astronomy Class #6
The Sun, Earth, Moon System
September 2, 2022