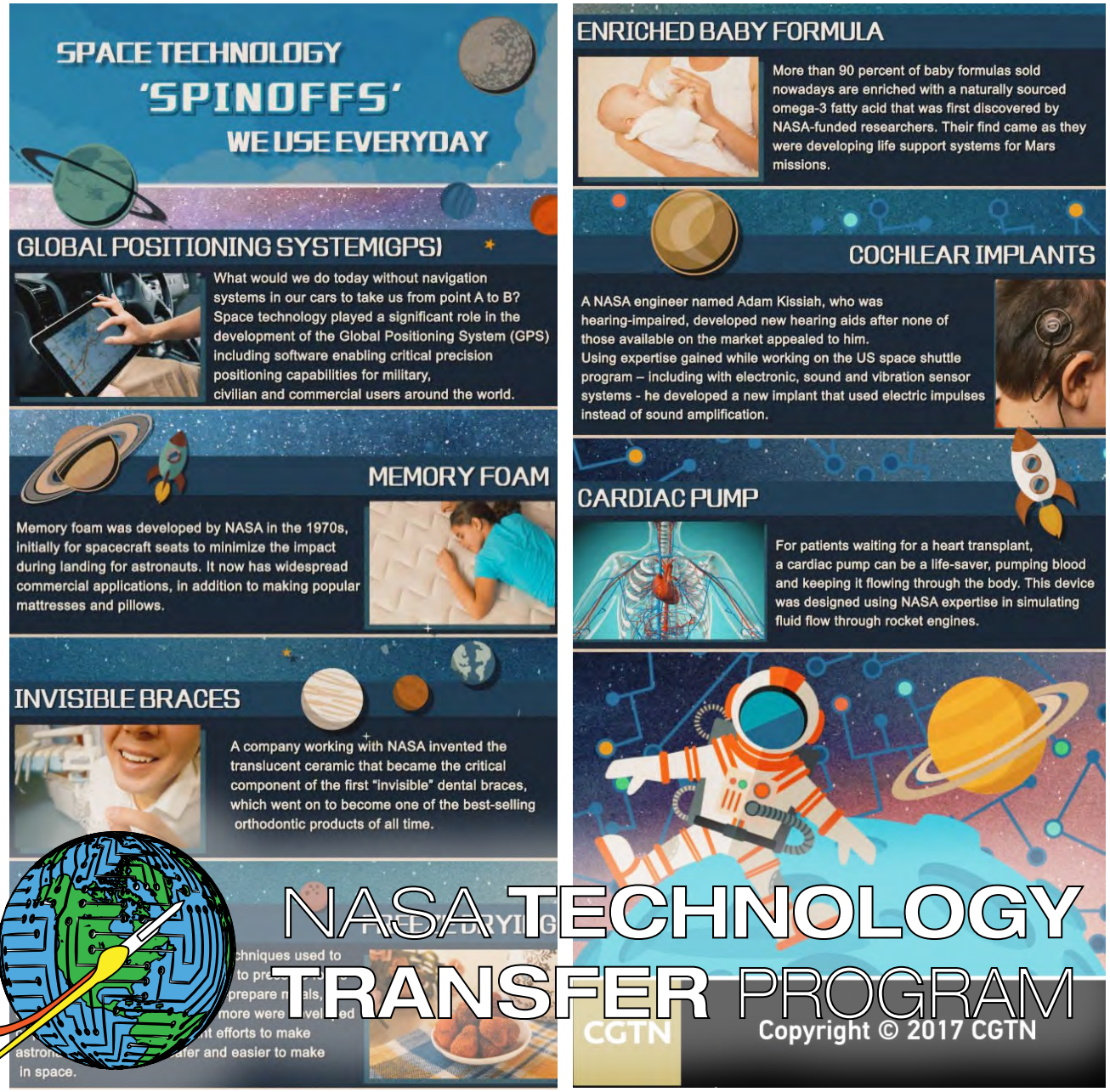
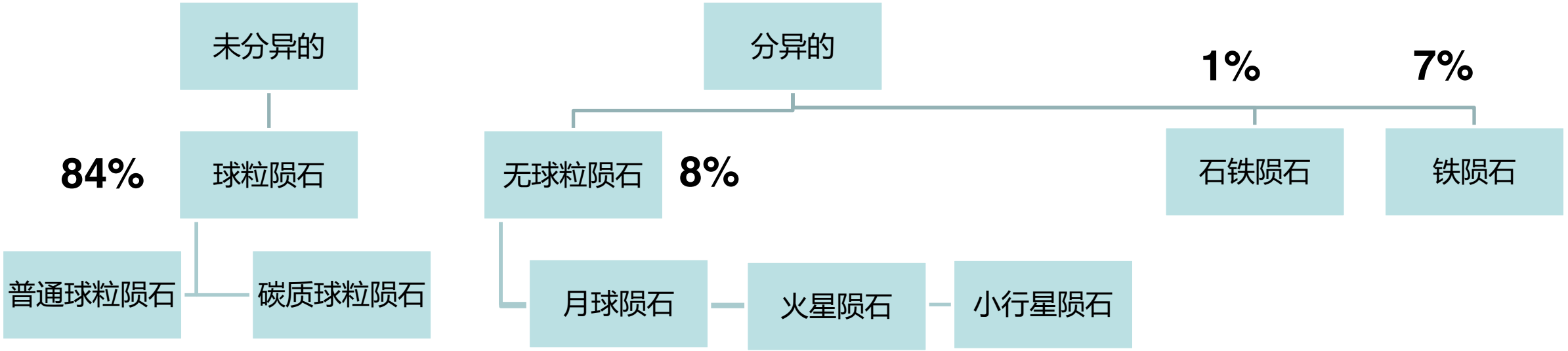
1. 类地行星探测手段

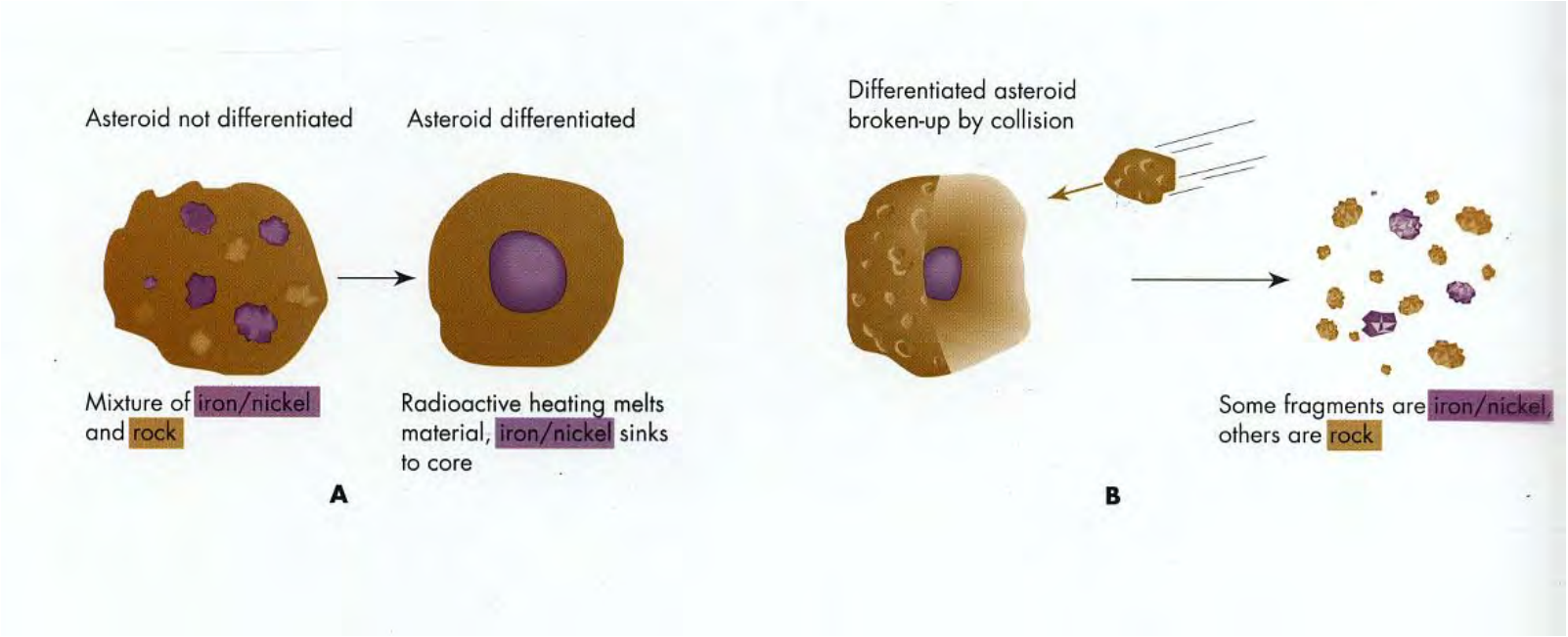
- 月球和火星陨石
- 天文望远镜观测
- 遥感观测
- 就位观测
- 采样返回



1.1 陨石


未分异的
分异的
1%
7%
84%
球粒陨石
无球粒陨石
8%
石铁陨石
铁陨石
普通球粒陨石
碳质球粒陨石
月球陨石
火星陨石
小行星陨石

陨石成因

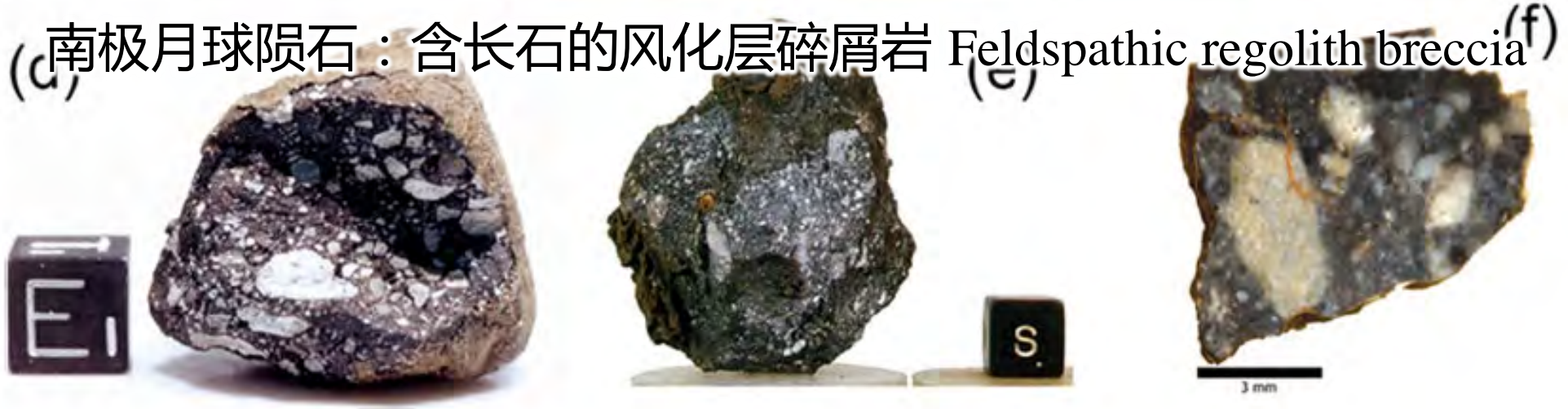

Asteroid not differentiated
Asteroid differentiated
Mixture of iron/nickel and rock
Radioactive heating melts material, iron/nickel sinks to core
A
Differentiated asteroid broken-up by collision
Some fragments are iron/nickel, others are rock
B

1.1 月球陨石 Lunar Meteorites

月岩样本：原生斜长石 Pristine anorthosite

侵入型岩浆岩 Igneous intrusion

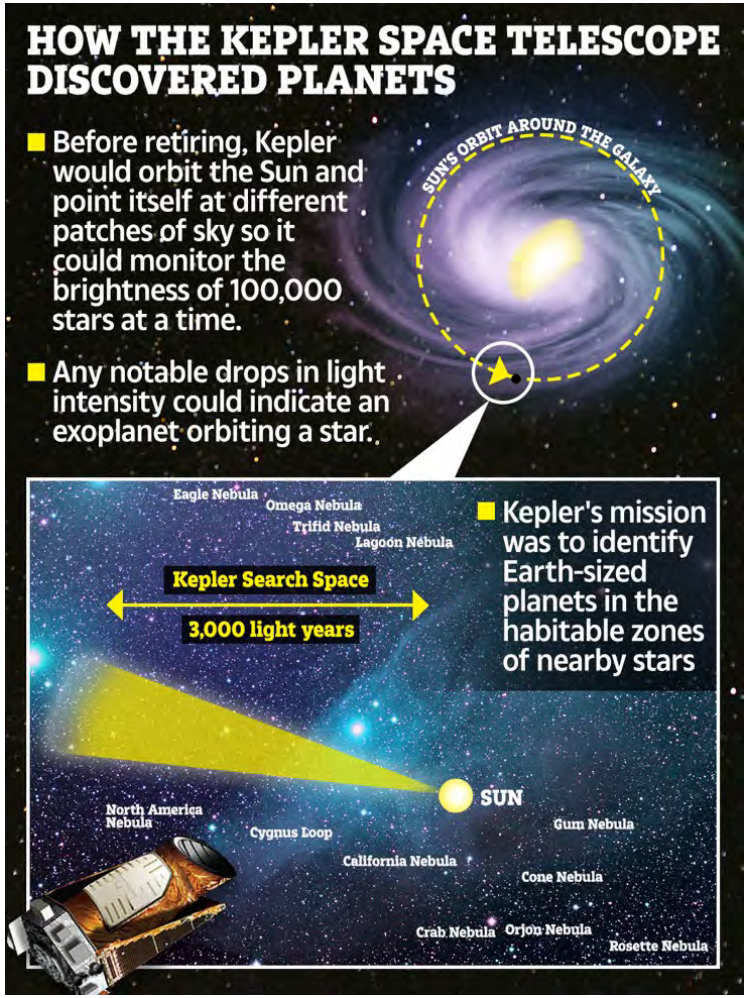
南极月球陨石：含长石的风化层碎屑岩 Feldspathic regolith breccia



（Gross and Joy, 2016）

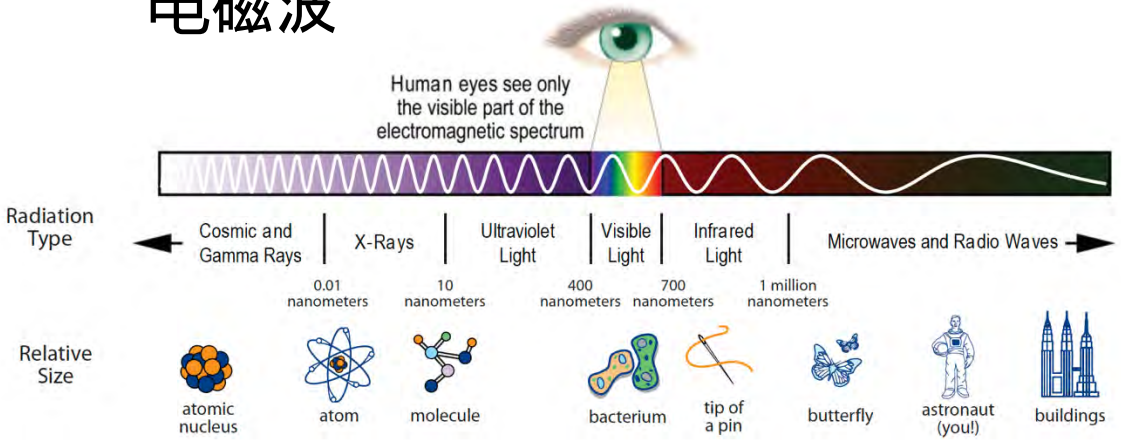
1.2 天文望远镜观测


• Moons of Jupiter
(4 Galilean moons)
(What he really saw)
• Rings of Saturn
(What he really saw)


HOW THE KEPLER SPACE TELESCOPE DISCOVERED PLANETS
Before retiring, Kepler would orbit the Sun and point itself at different patches of sky so it could monitor the brightness of 100,000 stars at a time.
Any notable drops in light intensity could indicate an exoplanet orbiting a star.
SUN'S ORBIT AROUND THE GALAXY
Kepler's mission was to identify Earth-sized planets in the habitable zones of nearby stars
Kepler Search Space
3,000 light years
Eagle Nebula
Omega Nebula
Trifid Nebula
Lagoon Nebula
SUN
North America Nebula
Cygnus Loop
California Nebula
Gum Nebula
Cone Nebula
Crab Nebula
Orion Nebula
Rosette Nebula

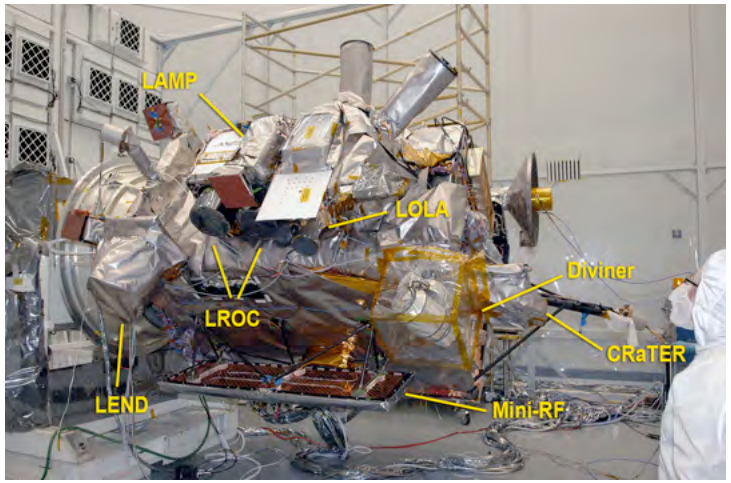
1.3 环绕器遥感观测

电磁波



- 光学影像
- 激光测高
- 反射光谱
- 伽马射线
- 雷达
- 其他

月球勘测轨道飞行器 (2009-present)

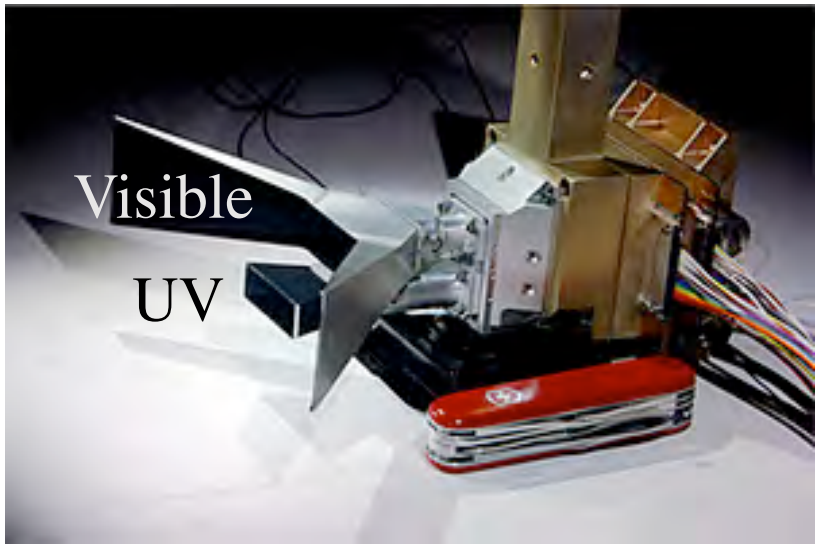


1.3 环绕器遥感观测 – 光学影像

LROC (1/2 NAC)

- 50 cm/pixel at 50 km orbit
- 5 km swath

LROC (WAC)

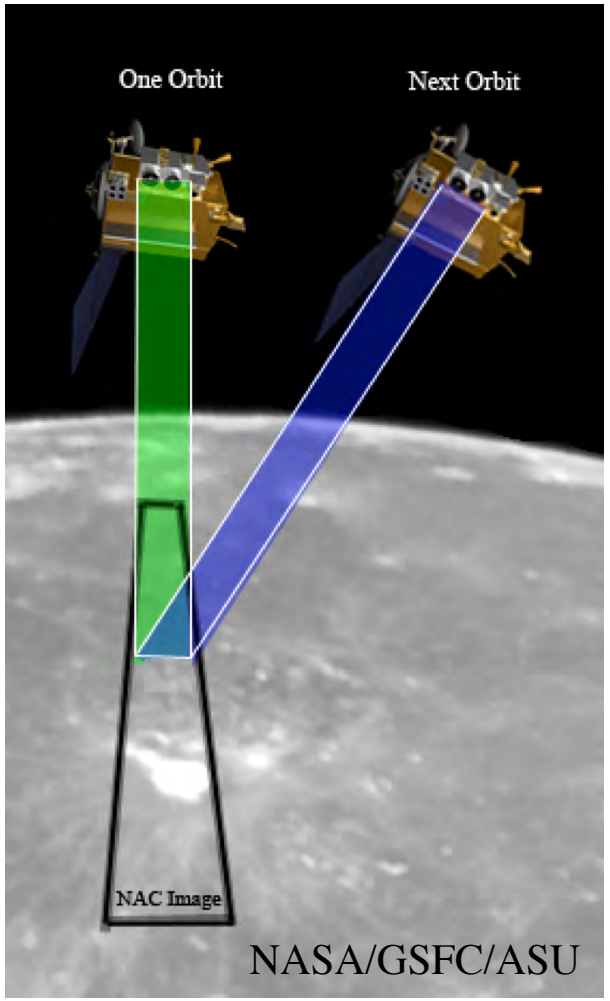


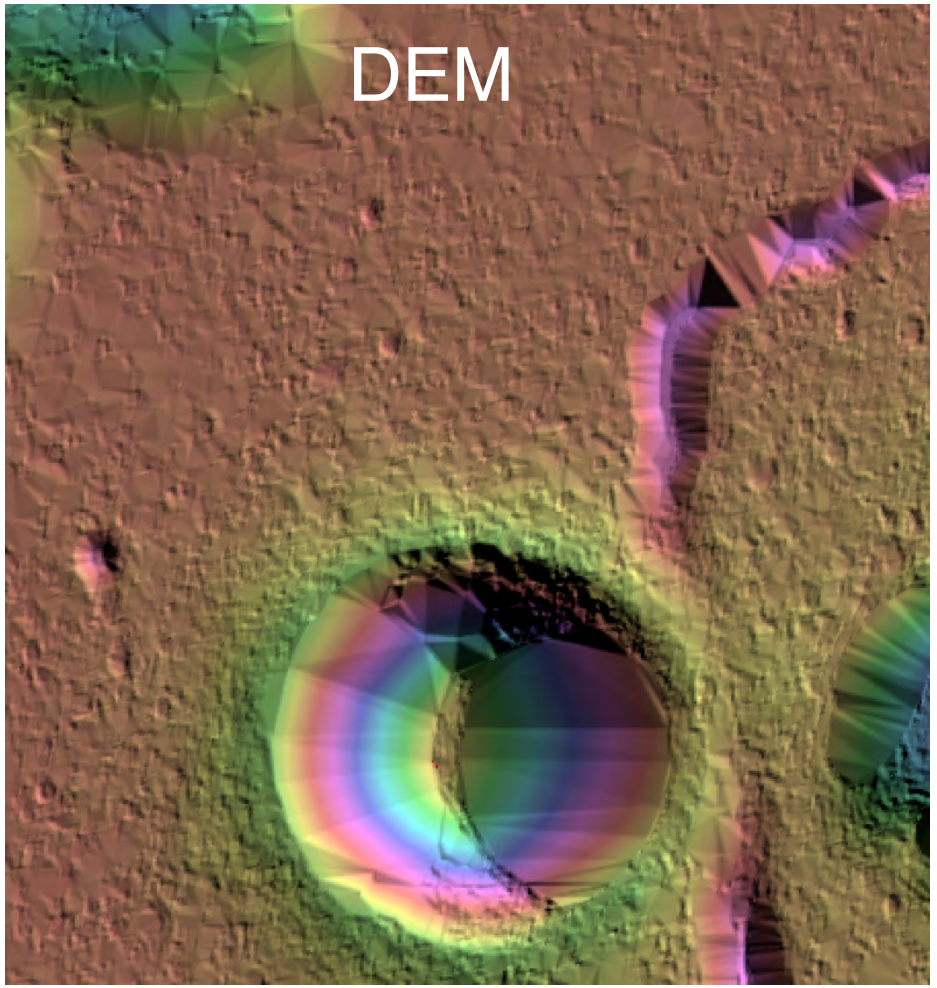
- 100 m/pixel
- 100 km swath
- Multispectral images (310-680 nm)

https://www.msss.com/all_projects/lro-camera.php

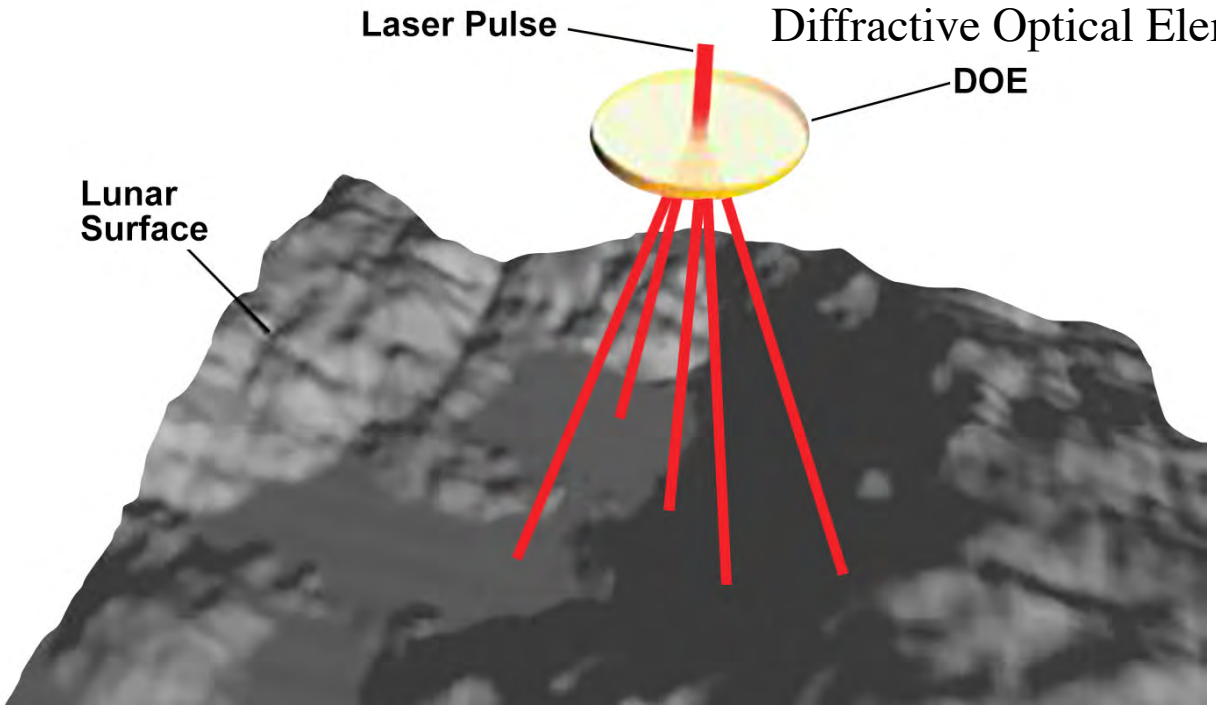
1.3 环绕器遥感观测 –光学影像

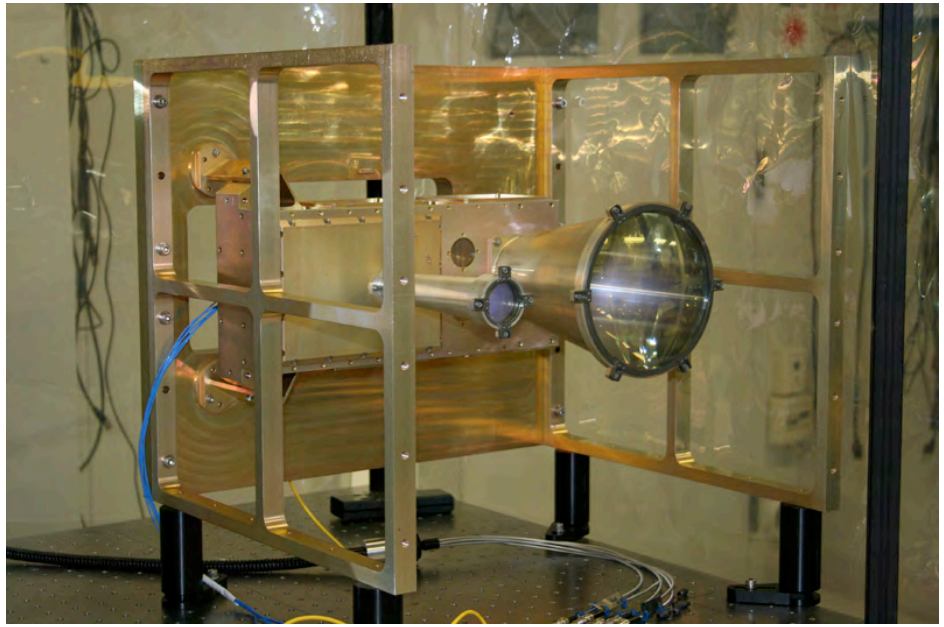
- Use stereo images (a pair of images to show the same location with different illumination conditions) to generate DEM





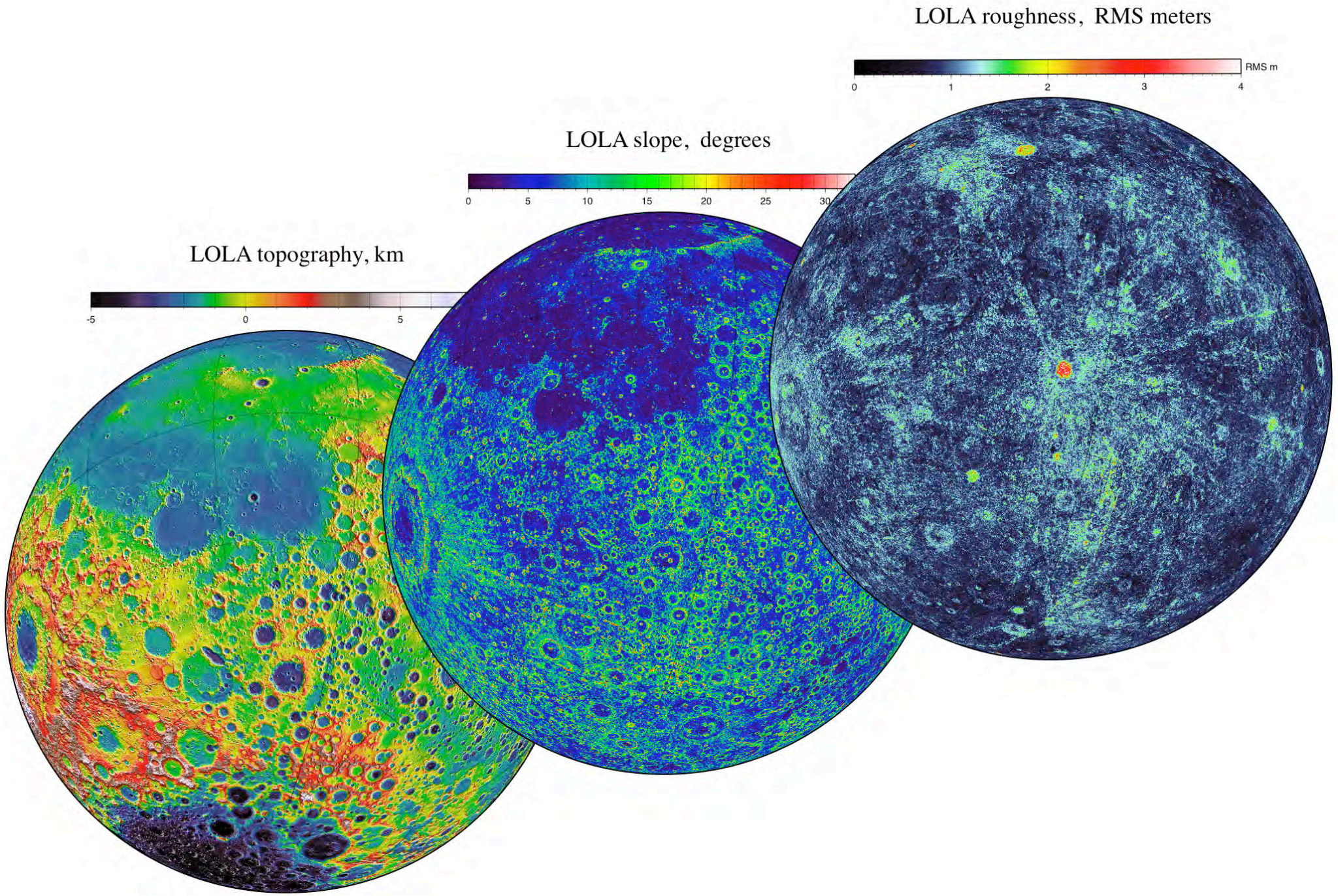
1.3 环绕器遥感观测 – 激光测高



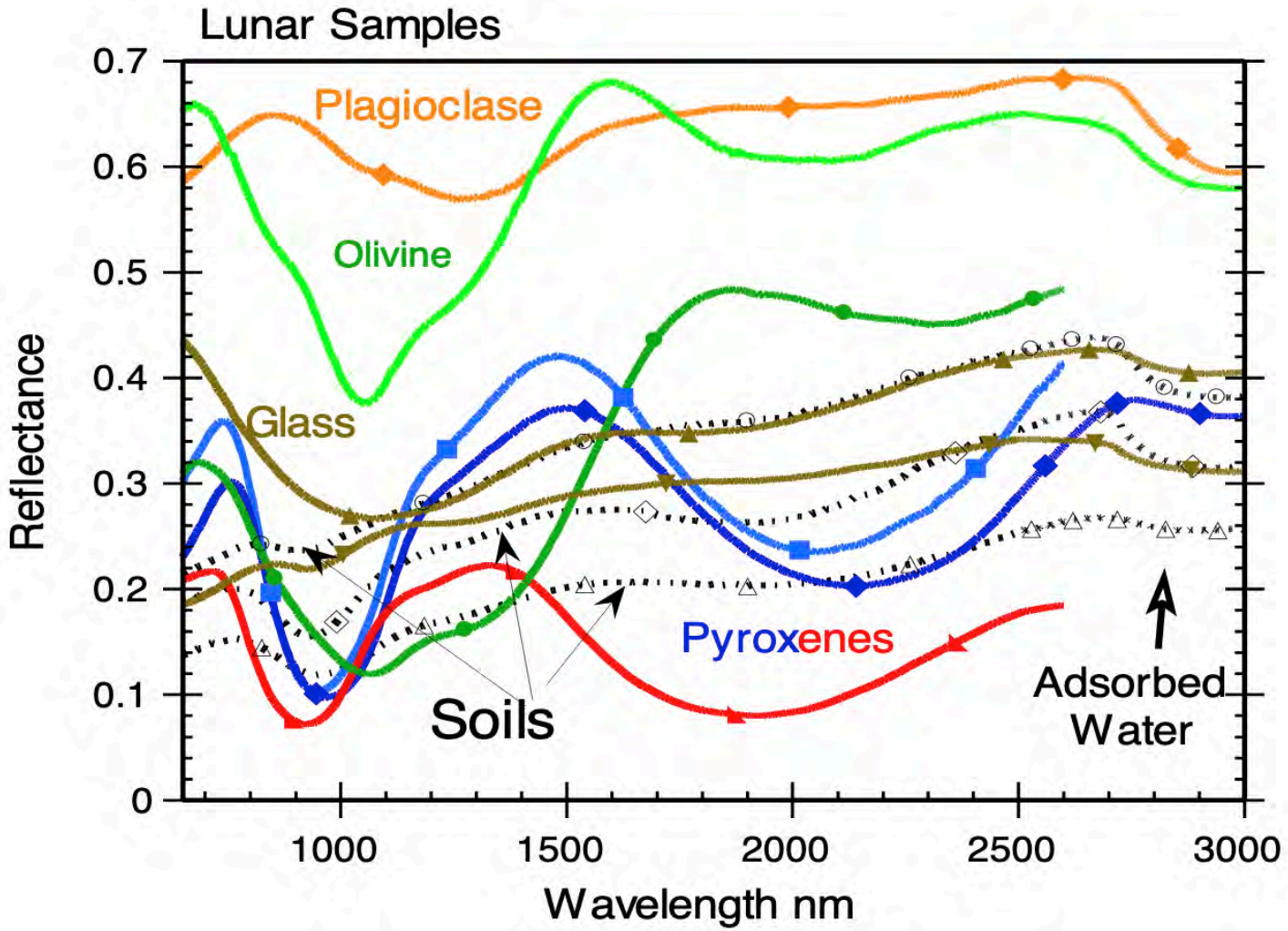


- Laser at 28 Hz
- Measure altimeter (range), roughness (pulse spreading), reflectance
- ~ 1.25 km resolution
- ~ 50 m swath

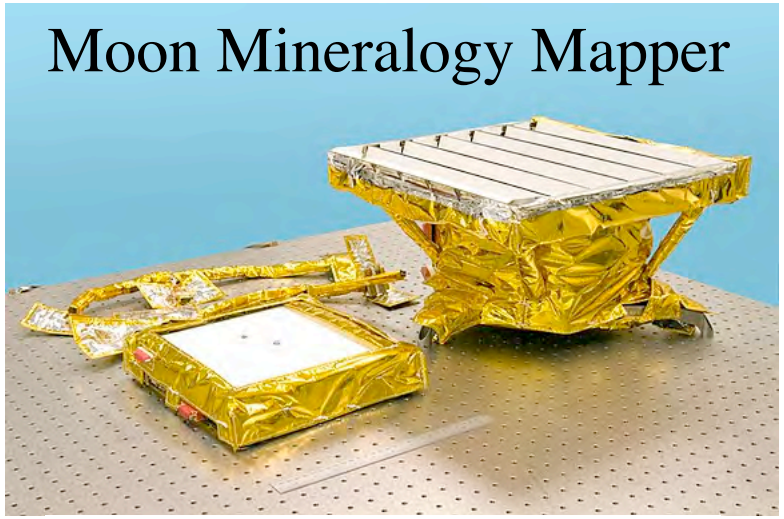
https://lunar.gsfc.nasa.gov/lola/index.html

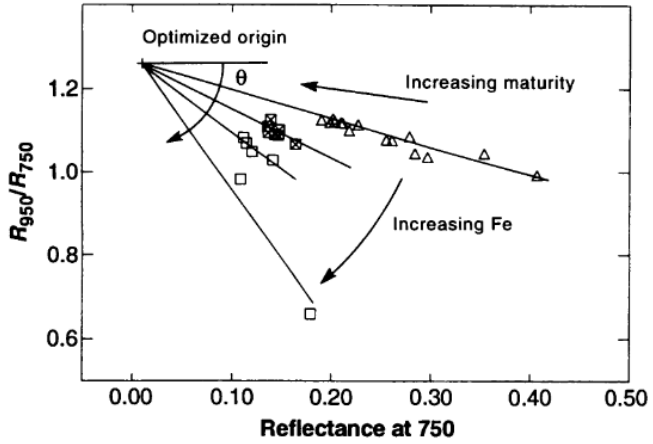

LOLA roughness, RMS meters
RMS m
0
1
2
3
4
LOLA slope, degrees
0
5
10
15
20
25
30
LOLA topography, km
-5
0
5

1.3 环绕器遥感观测 – 反射光谱



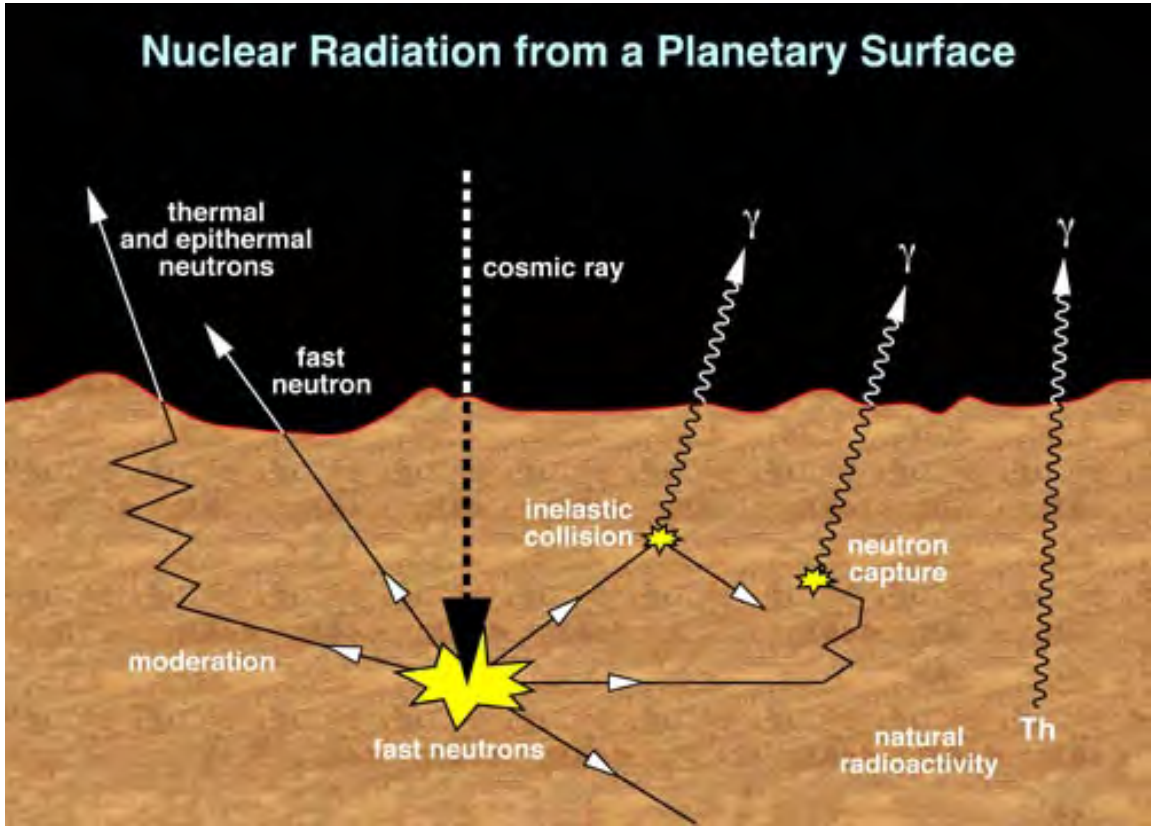
Infrared light

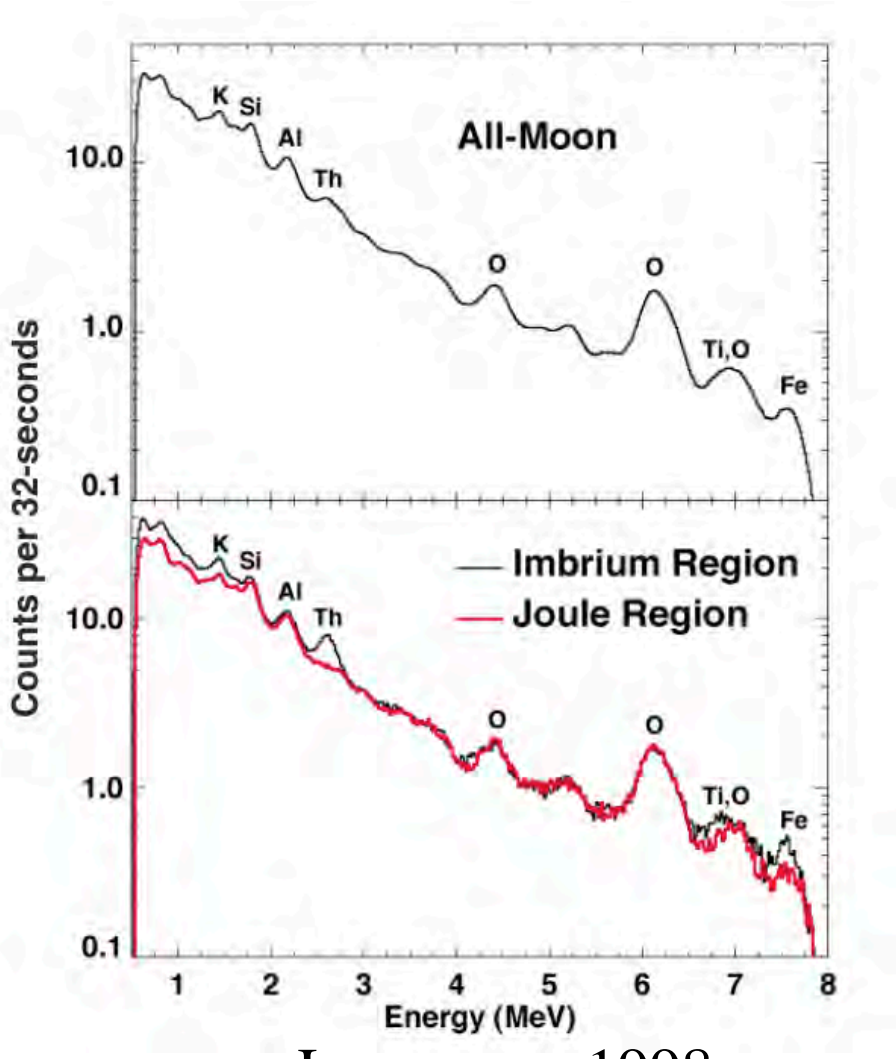




Fe content (Lucey+1995)
Based on Clementine data

1.3 环绕器遥感观测 – 伽马射线谱仪





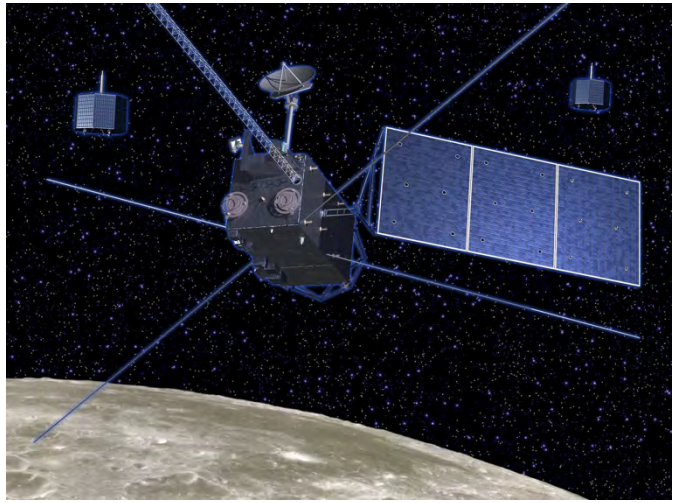
Lawrence+1998

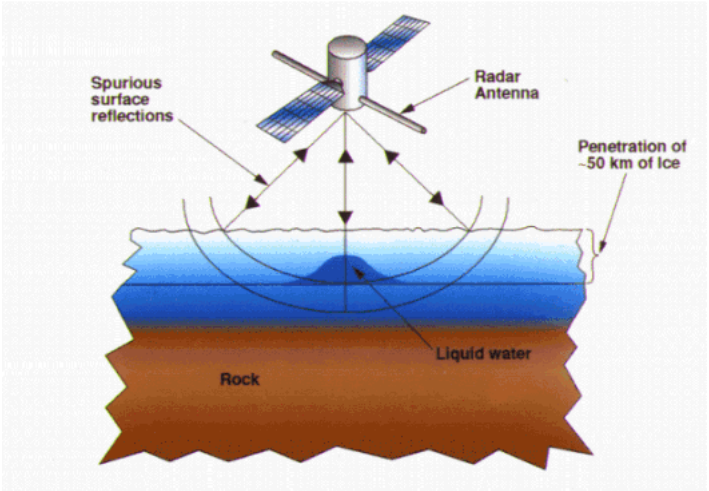
Lunar Prospector gamma-ray spectrometer

- 放射性元素衰变/激发态原子释放光子

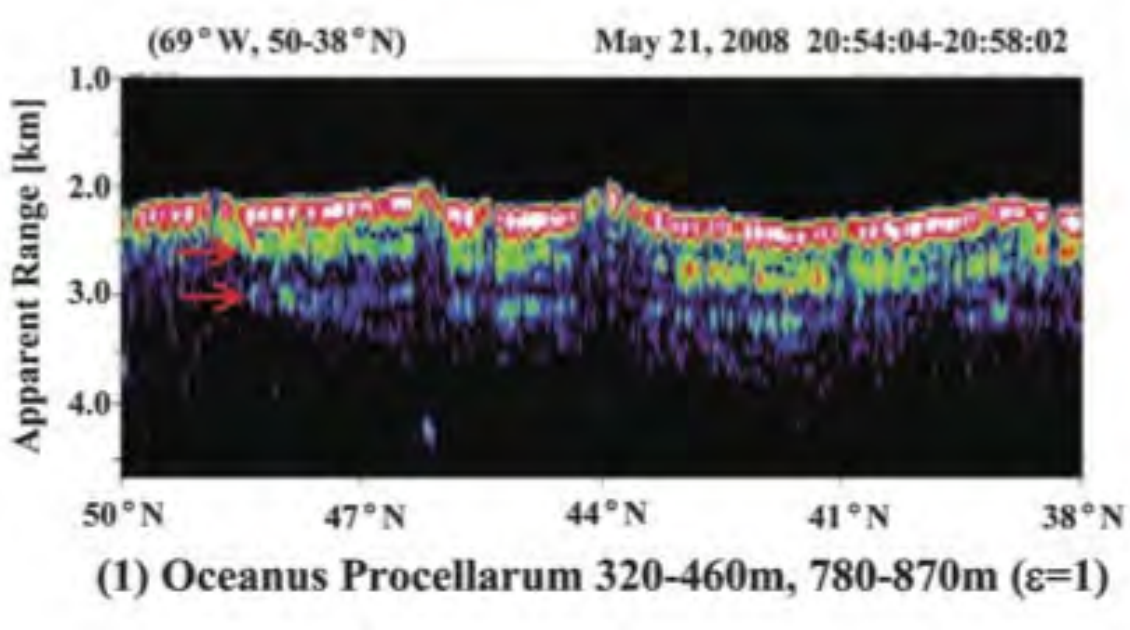
1.3 环绕器遥感观测 – 微波雷达

- Microwave remote sensing: radar, radar altimeter, SAR, InSAR…





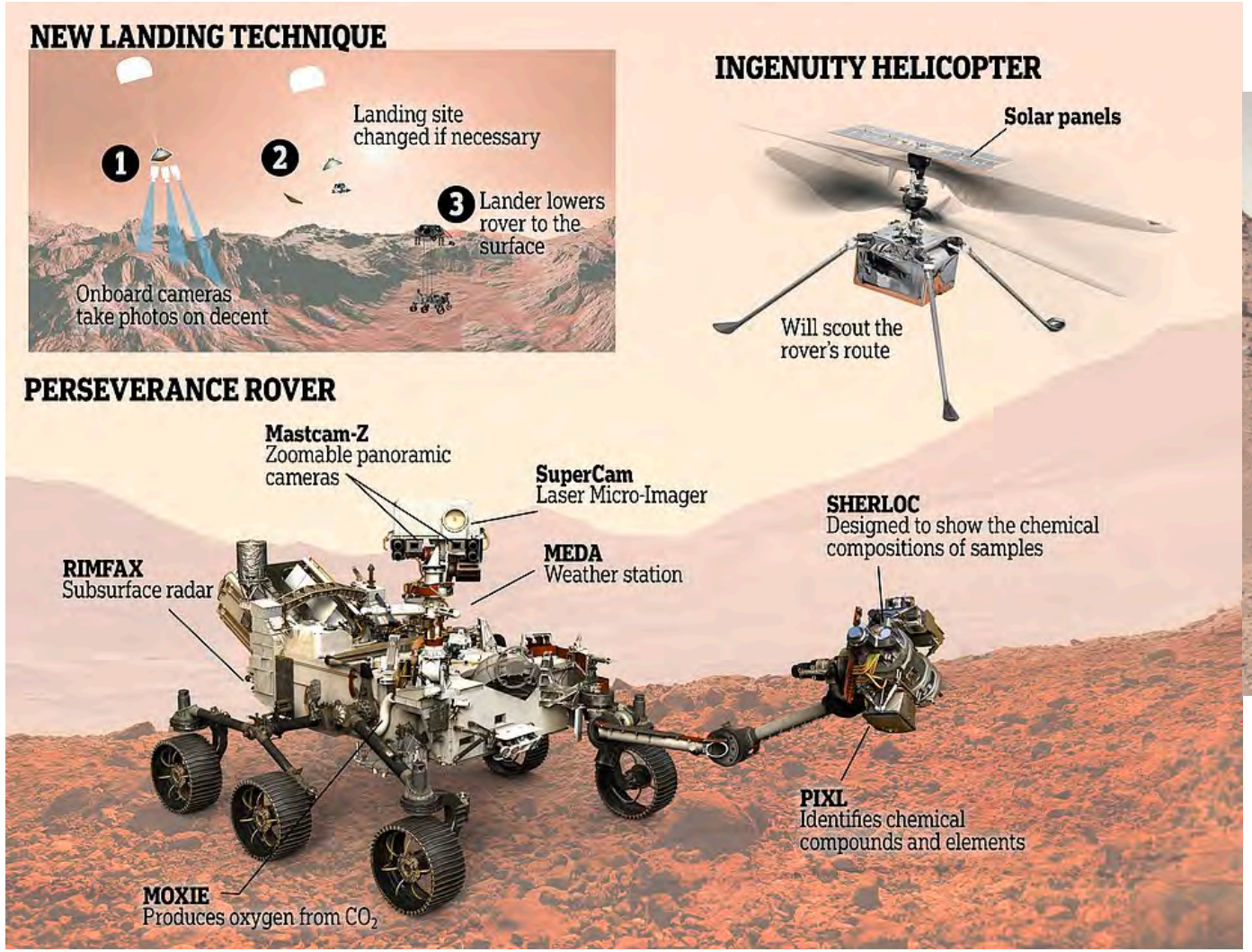
Kaguya Lunar Radar Sounder (LRS), 4-6 MHz

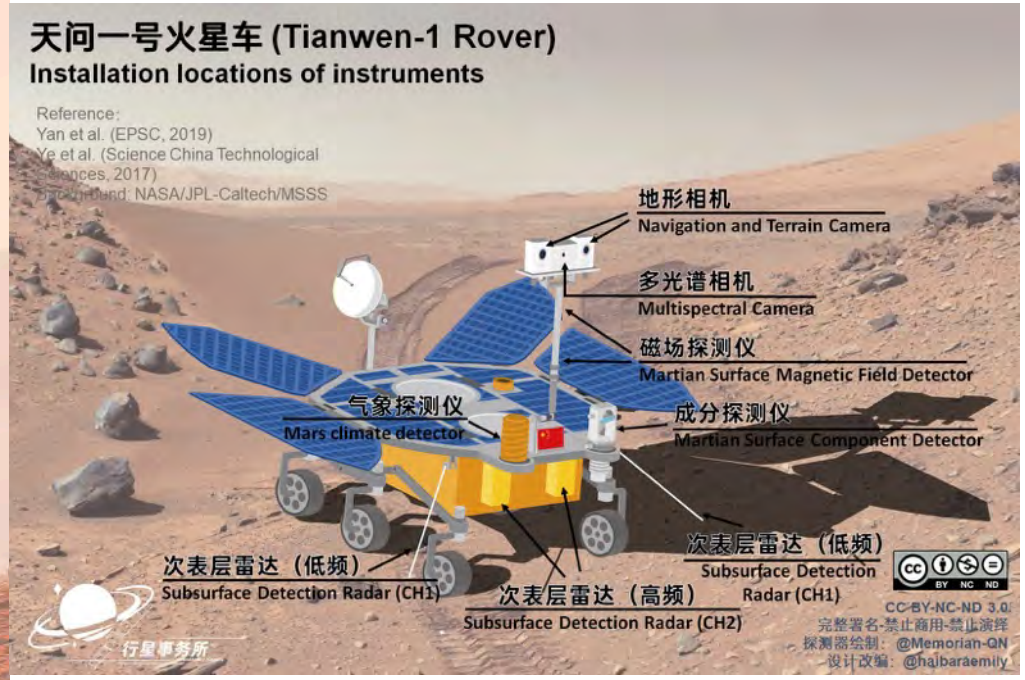


Ono et al. 2009
Oceanus Procellarum

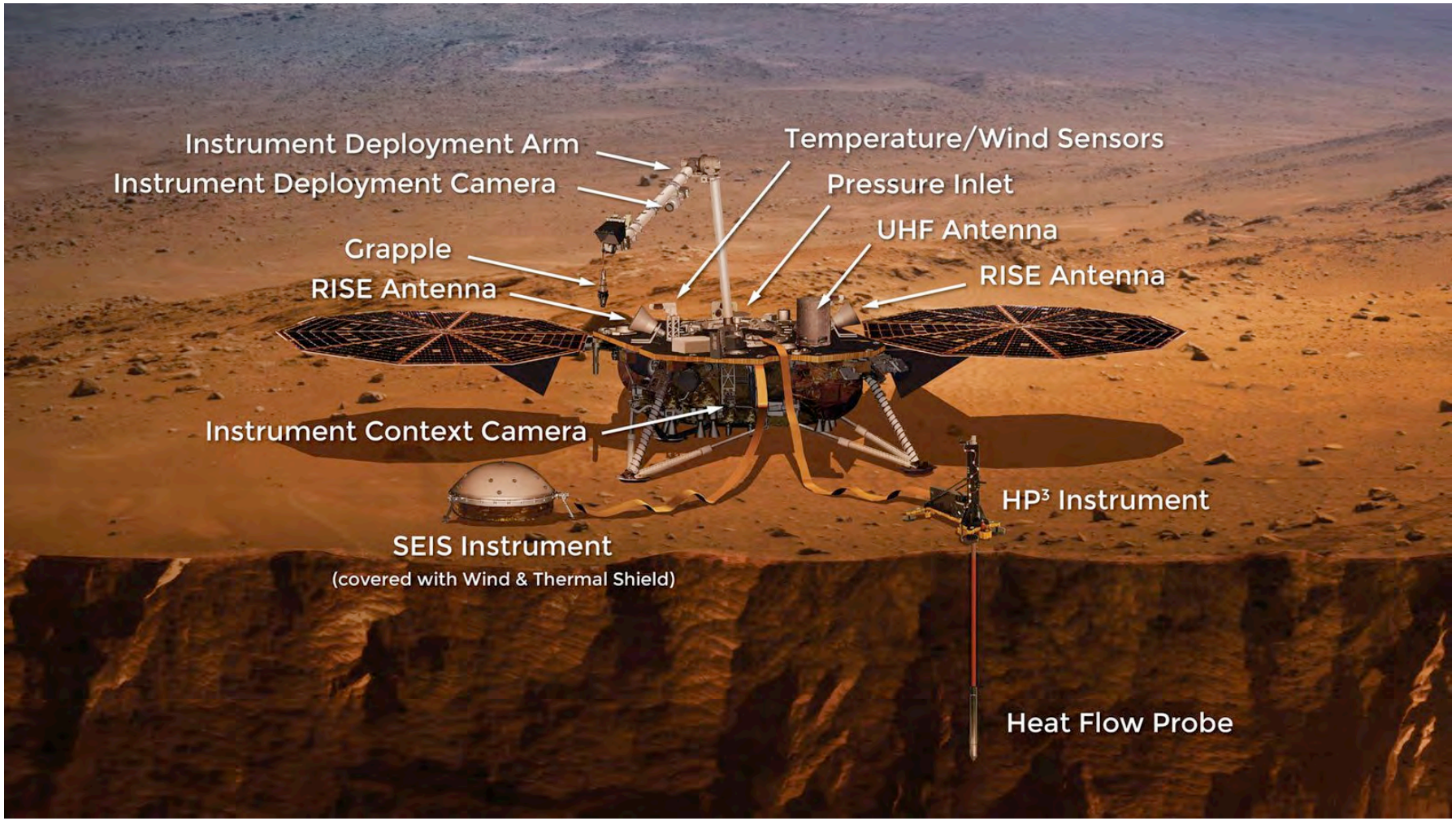
1.4 就位观测

毅力号

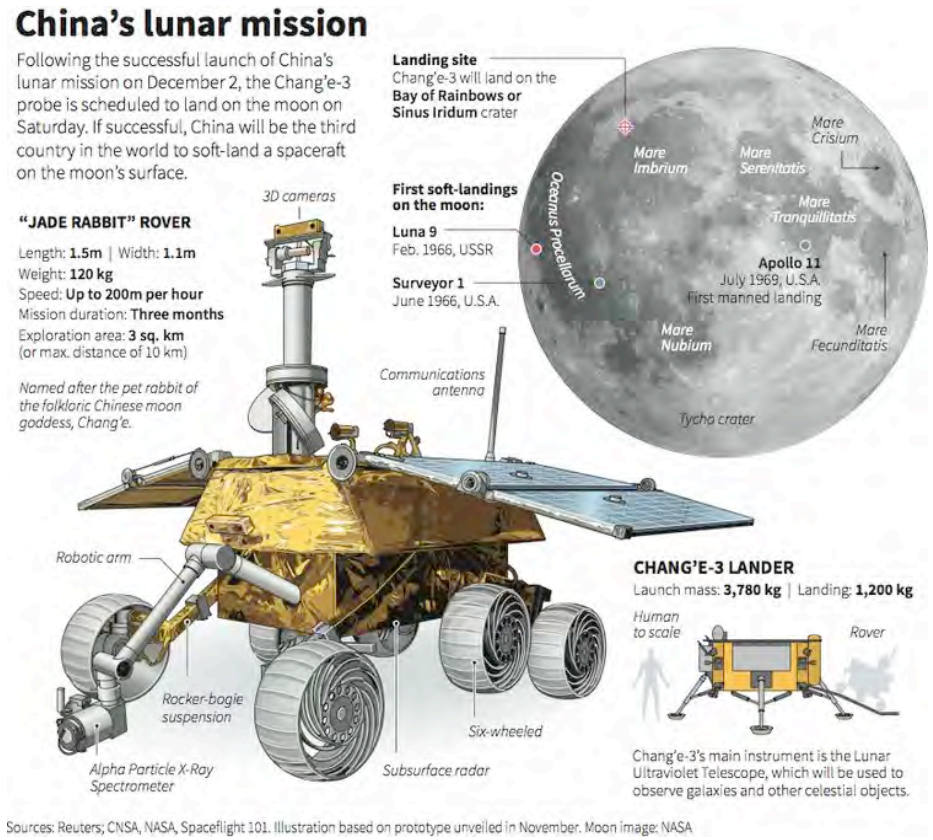

NEW LANDING TECHNIQUE
Landing site changed if necessary
1
2
3 Lander lowers rover to the surface
Onboard cameras take photos on decent
INGENUITY HELICOPTER
Solar panels
Will scout the rover's route
PERSEVERANCE ROVER
Mastcam-Z
Zoomable panoramic cameras
SuperCam
Laser Micro-Imager
SHERLOC
Designed to show the chemical compositions of samples
RIMFAX
Subsurface radar
MEDA
Weather station
PIXL
Identifies chemical compounds and elements
MOXIE
Produces oxygen from CO_2

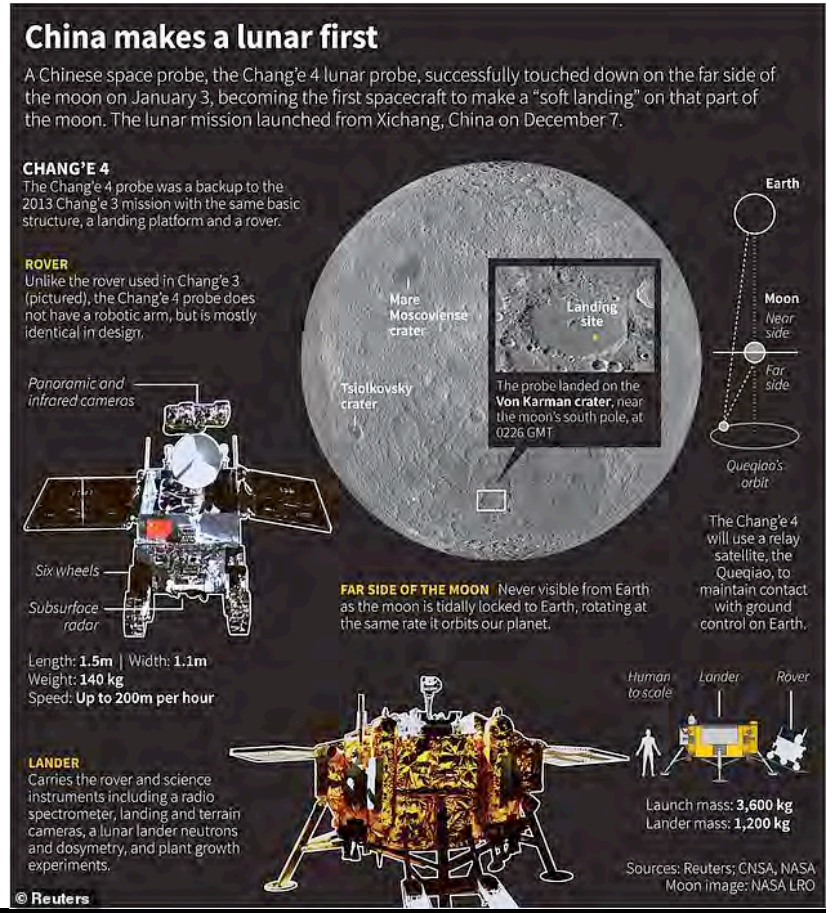

天问一号火星车 (Tianwen-1 Rover)
Installation locations of instruments
Reference:
Yan et al. (EPSC, 2019)
Ye et al. (Science China Technological Sciences, 2017)
Background: NASA/JPL-Caltech/MSSS
地形相机
Navigation and Terrain Camera
多光谱相机
Multispectral Camera
磁场探测仪
Martian Surface Magnetic Field Detector
气象探测仪
Mars climate detector
成分探测仪
Martian Surface Component Detector
次表层雷达（低频）
Subsurface Detection Radar (CH1)
次表层雷达（高频）
Subsurface Detection Radar (CH2)
次表层雷达（低频）
Subsurface Detection Radar (CH1)
行星事务所
CC-BY-NC-ND 3.0
完整署名-禁止商用-禁止演绎
探测器绘制：@Memorian-QN
设计改编：@haibaraemily

洞察号着陆器


Instrument Deployment Arm
Instrument Deployment Camera
Grapple
RISE Antenna
Temperature/Wind Sensors
Pressure Inlet
UHF Antenna
RISE Antenna
Instrument Context Camera
HP³ Instrument
SEIS Instrument
(covered with Wind & Thermal Shield)
Heat Flow Probe

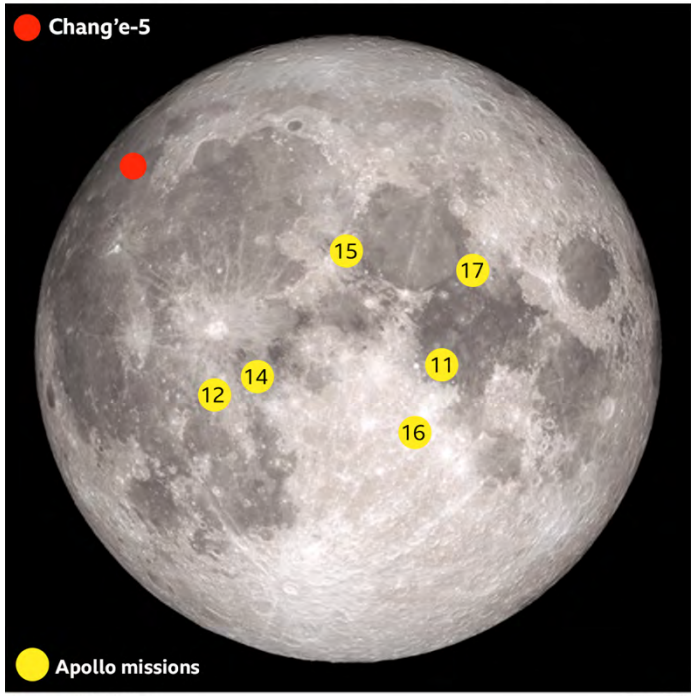
嫦娥3-4号


China's lunar mission
Following the successful launch of China's lunar mission on December 2, the Chang'e-3 probe is scheduled to land on the moon on Saturday. If successful, China will be the third country in the world to soft-land a spacecraft on the moon's surface.
"JADE RABBIT" ROVER
Length: 1.5m | Width: 1.1m
Weight: 120 kg
Speed: Up to 200m per hour
Mission duration: Three months
Exploration area: 3 sq. km (or max. distance of 10 km)
Named after the pet rabbit of the folkloric Chinese moon goddess, Chang'e.
3D cameras
Communications antenna
Robotic arm
Rocker-bogie suspension
Six-wheeled
Alpha Particle X-Ray Spectrometer
Subsurface radar
Landing site
Chang'e-3 will land on the Bay of Rainbows or Sinus Iridum crater
First soft-landings on the moon:
Luna 9
Feb. 1966, USSR
Surveyor 1
June 1966, U.S.A.
Apollo 11
July 1969, U.S.A.
First manned landing
Mare Imbrium
Mare Serenitatis
Mare Crisium
Mare Tranquillitatis
Mare Nubium
Mare Fecunditatis
Oceanus Procellarum
Tycho crater
CHANG'E-3 LANDER
Launch mass: 3,780 kg | Landing: 1,200 kg
Human to scale
Rover
Chang'e-3's main instrument is the Lunar Ultraviolet Telescope, which will be used to observe galaxies and other celestial objects.
Sources: Reuters; CNSA, NASA, Spaceflight 101. Illustration based on prototype unveiled in November. Moon image: NASA

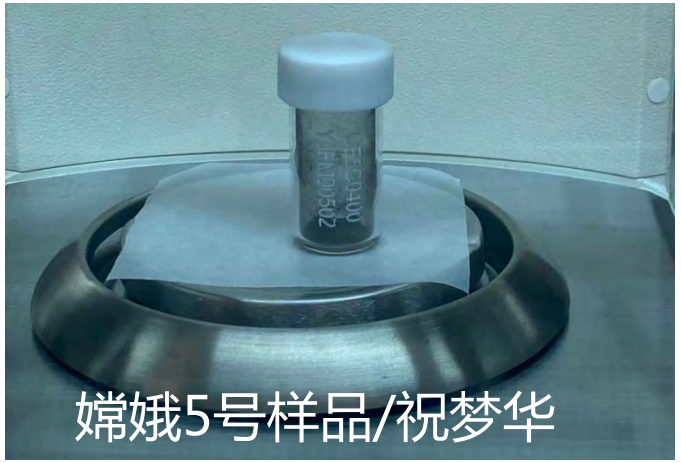

China makes a lunar first
A Chinese space probe, the Chang'e 4 lunar probe, successfully touched down on the far side of the moon on January 3, becoming the first spacecraft to make a "soft landing" on that part of the moon. The lunar mission launched from Xichang, China on December 7.
CHANG'E 4
The Chang'e 4 probe was a backup to the 2013 Chang'e 3 mission with the same basic structure, a landing platform and a rover.
ROVER
Unlike the rover used in Chang'e 3 (pictured), the Chang'e 4 probe does not have a robotic arm, but is mostly identical in design.
Panoramic and infrared cameras
Six wheels
Subsurface radar
Length: 1.5m | Width: 1.1m
Weight: 140 kg
Speed: Up to 200m per hour
Mare Moscoviense crater
Tsiolkovsky crater
Landing site
The probe landed on the Von Karman crater, near the moon's south pole, at 0226 GMT
Earth
Moon
Near side
Far side
Queqiao's orbit
The Chang'e 4 will use a relay satellite, the Queqiao, to maintain contact with ground control on Earth.
FAR SIDE OF THE MOON Never visible from Earth as the moon is tidally locked to Earth, rotating at the same rate it orbits our planet.
LANDER
Carries the rover and science instruments including a radio spectrometer, landing and terrain cameras, a lunar lander neutrons and dosymetry, and plant growth experiments.
Human to scale
Lander
Rover
Launch mass: 3,600 kg
Lander mass: 1,200 kg
Sources: Reuters; CNSA, NASA
Moon image: NASA LRO
© Reuters

1.5 采样返回

Chang'e-5 lunar sample return mission

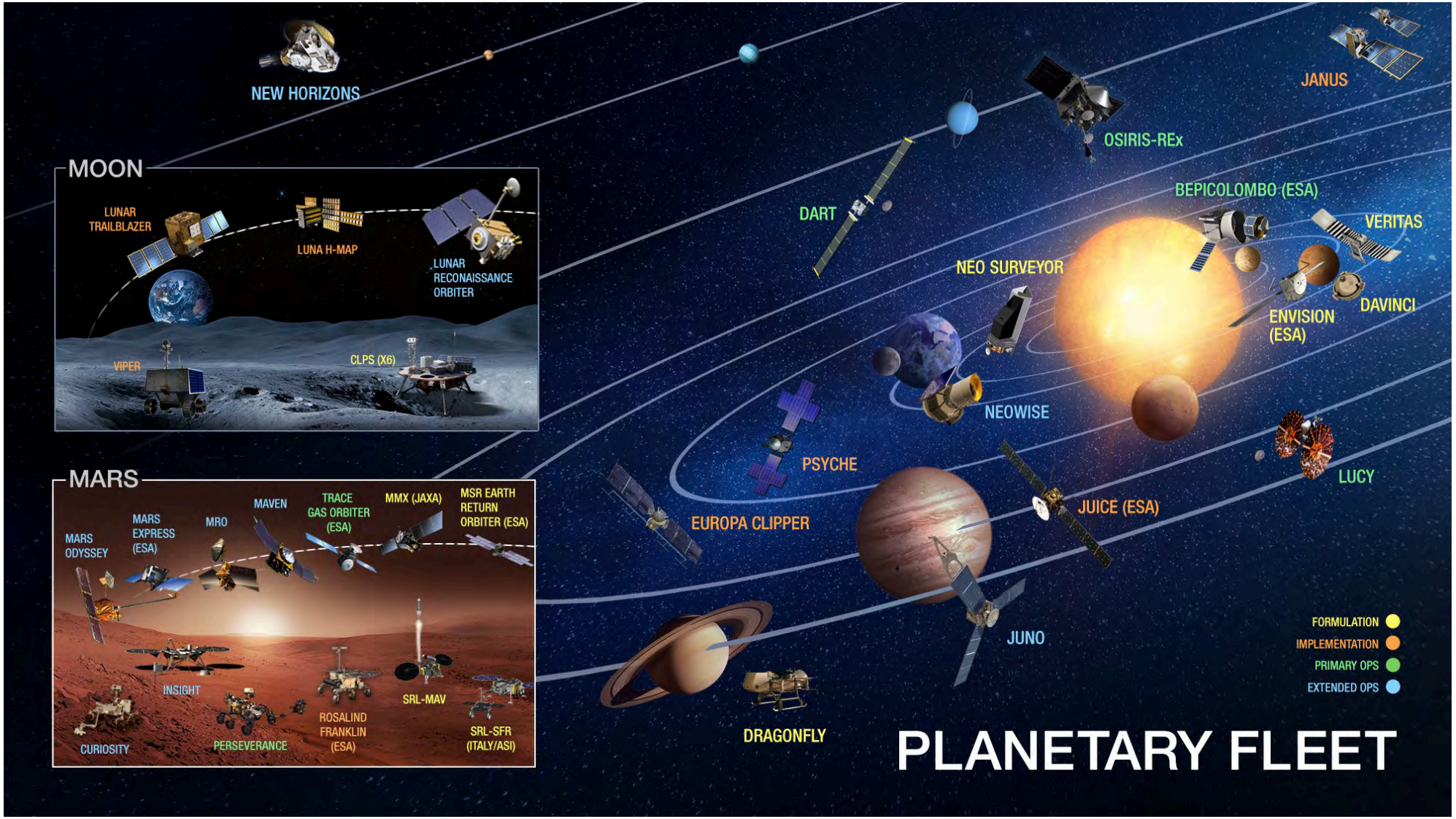


Source: NASA/JPL BBC



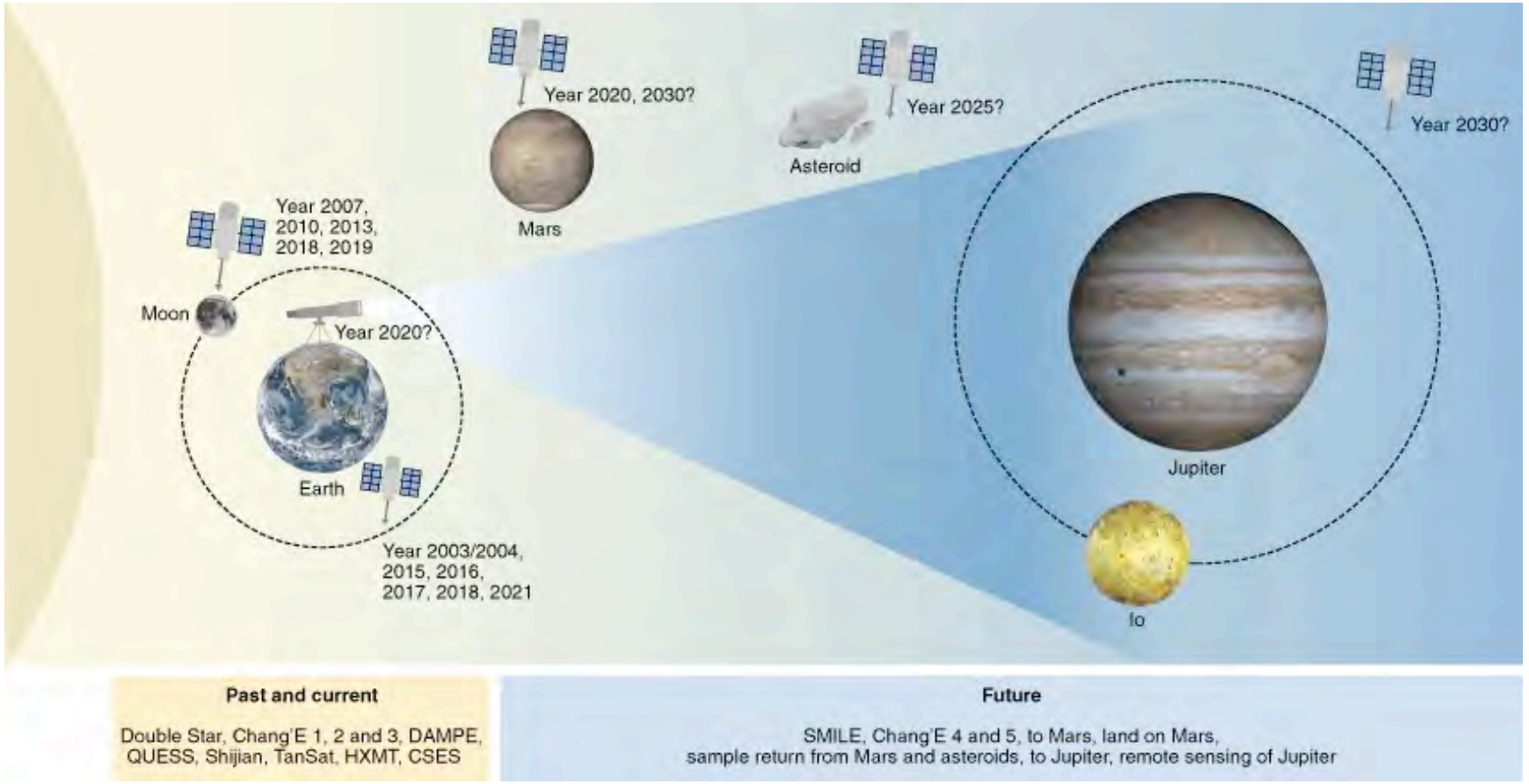
NASA's OSIRIS-REx ission
Sample Return from Asteroid Bennu

Space Missions of NASA, ESA, JAXA



NASA Planetary Science Division, Dated 03/09/2022

China's Roadmap



Wei+2018