

Exploring the Solar System II – Spacecraft



Exploring the Solar System II

Spacecraft

How Do We Get There?

What Do We Do Then?

How Do We Get Images Back?

What Next?



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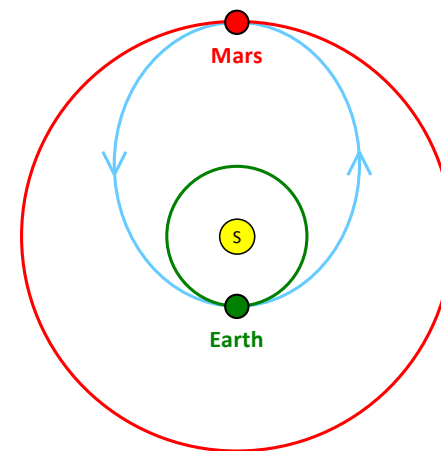
70 Years of Spacecraft

Sputnik 1	Luna 10	Zond 7	Pioneer Venus 1	Genesis	PROTON
Sputnik 2	Surveyor 1	Apollo 12	Pioneer Venus 2	CONTOUR	DISCOVER
Explorer 1	Explorer 33	Apollo 13	ISEE-3	Hayabusa	ExoMars
Vanguard 1	Lunar Orbiter 1	Venera 7	Venera 11	Beagle 2	OSIRIS-REx
Luna 1	Pioneer 7	Luna 16	Venera 12	Spirit rover	InSight
Pioneer 4	Luna 11	Zond 8	Venera 13	Opportunity rover	Quejiao
Luna 2	Surveyor 2	Luna 17	Venera 14	SMART-1	Parker Solar Probe
Luna 3	Luna 12	Apollo 14	Venera 15	Rosetta/Philae	BeqColombo
Pioneer 5	Lunar Orbiter 2	Venera 16	Vega 1	MESSENGER	Chang'e 4
Venera 1	Luna 13	Mars 2	Vega 2	Deep Impact	Beresheet
Vostok 1	Lunar Orbiter 3	Mars 3	Sakigake	Mars Reconnaissance	Chandrayaan-2
Ranger 1	Surveyor 3	Mariner 9	Giotto	Venus Express	Solar Orbiter
Ranger 2	Lunar Orbiter 4	Apollo 15	Suisei	New Horizons	Mars Hope
Ranger 3	Venera 4	Luna 18	Phobos 1	Hinode	Zhurong rover
Ranger 4	Mariner 5	Luna 19	Phobos 2	STEREO	Perseverance rover
Mariner 2	Surveyor 4	Luna 20	Magellan	Phoenix	Chang'e 5
Ranger 5	Explorer 35	Pioneer 10	Galileo	SELENE	Lucy
Mars 1	Lunar Orbiter 5	Venera 8	Venera 9	Dawn	CAPSTONE
Luna 4	Surveyor 5	Apollo 16	Apollo 17	Chang'e 1	Damru
Cosmos 21	Surveyor 6	Apollo 17	Luna 21	Chandrayaan-1	Artemis 1
Ranger 6	Pioneer 8	Pioneer 11	Ulysses	Solar Dynamics Obs	HALO-1
Ranger 7	Surveyor 7	Explorer 49	Yohkoh	AKARI	JUICE
Voshkod 1	Apollo 4	Clementine	Mars Observer	PICARD	Chandrayaan-3
Mariner 3	Zond 4	Mars 4	WIND	Chang'e 2	Luna 25
Mariner 4	Luna 14	Mars 5	SOHO	Aditya-L1	SLIM
Zond 2	Zond 5	Mars 6	NEAR Shoemaker	GRAIL	Psyche
Ranger 8	Apollo 7	Mariner 10	Mars Global Surv	Fobos-Grunt	Peregrine One
Voshkod 2	Surveyor 9	Luna 22	Mars 7	Yinghuo-1	Nova-C
Ranger 9	Zond 6	ACE	Mars 96	Curiosity rover	Odyssey
Luna 5	Apollo 8	Helios-A	Mars Pathfinder	Van Allen Probes	DIO A/B
Luna 6	Venera 5	Venera 9	ACE	IRIS	QuakeSat-2
Zond 3	Venera 6	Venera 10	Cassini-Huygens	LADEE	Chang'e 6
Luna 7	Mariner 6	Viking 1	Lunar Prospector	Hiaki	Hera
Venera 2	Venera 7	Viking 2	Helios-8	Mars Orbiter	Europa Clipper
Venera 3	Mariner 7	Apollo 9	Deep Space 1	MAVEN	
Luna 8	Apollo 10	Voyager 1	Mars Climate Orb	Chang'e 3	
Pioneer 6	Luna 15	Voyager 2	Deep Space 2	Chang'e 4	
Luna 9	Apollo 11	Voyager 2	Stardust	Chang'e 5-T1	
			2001 Mars Odyssey	Hayabusa2	



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From Earth To Mars



Not to scale



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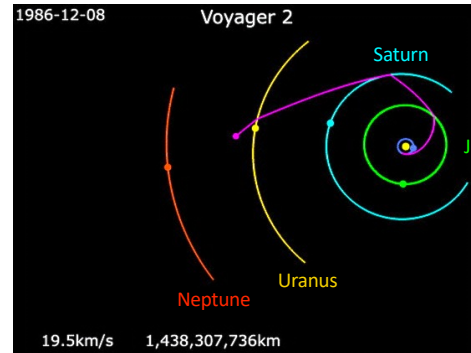
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Gravity Assists

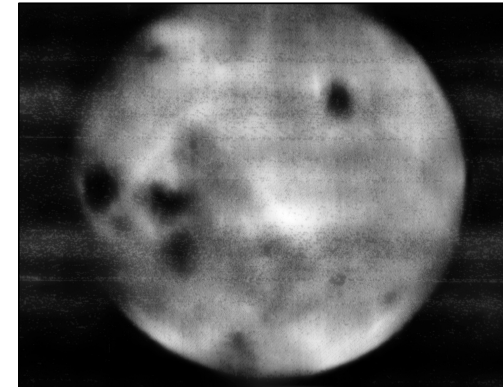
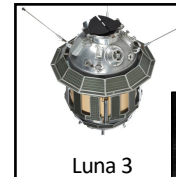
What about getting to other planets in the solar system?

In the 1960s it was realised that flying a spacecraft close to a planet can 'slingshot' it onwards at higher velocities.

Hence exploring the outer solar system can be carried out faster and cheaper.



Imaging Technology



Far side of the Moon – Oct 1959

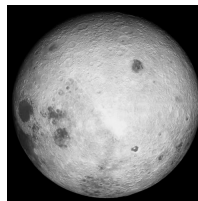
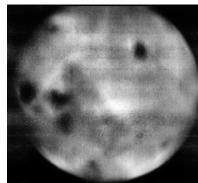
Imaging Technology

After exposure, the **film** was developed, fixed and dried.

The developed film was then **scanned** by a CRT (cathode ray tube) spot projected through the film onto a photomultiplier.

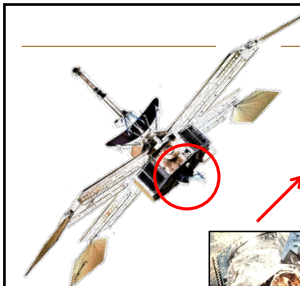
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

For comparison, an image taken 50 years later from the NASA Lunar Reconnaissance Orbiter (LRO).

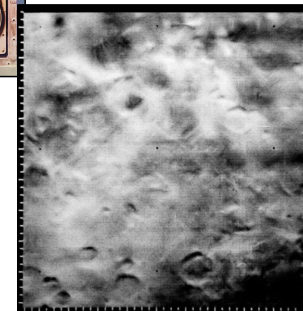


LRO 2009

Imaging Technology



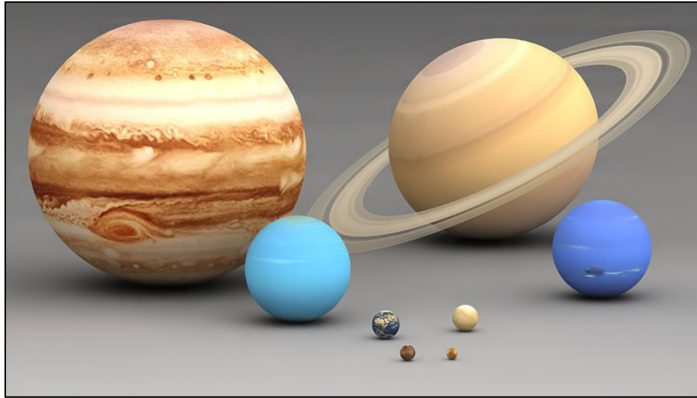
World's first **digital** camera



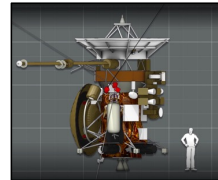
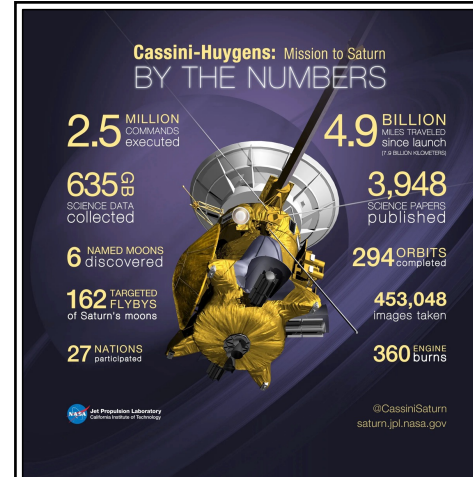
Mars – July 1965

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Planets of the Solar System

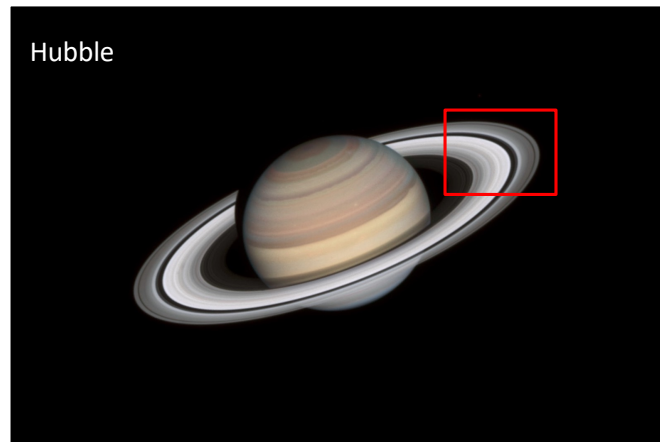


Cassini

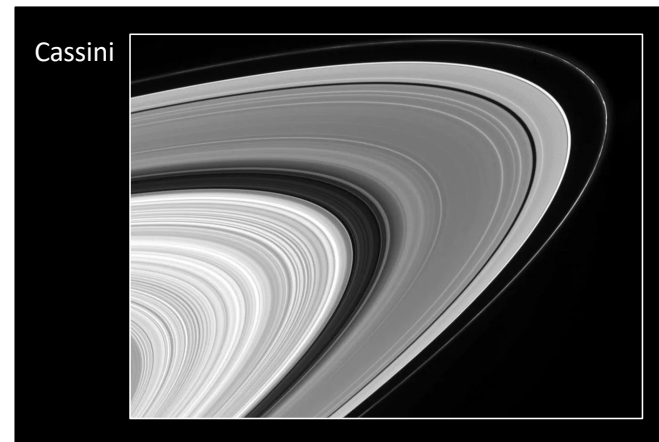


Cassini explored Saturn and its rings and moons from 2004 until it was crashed into Saturn in 2017.

Saturn

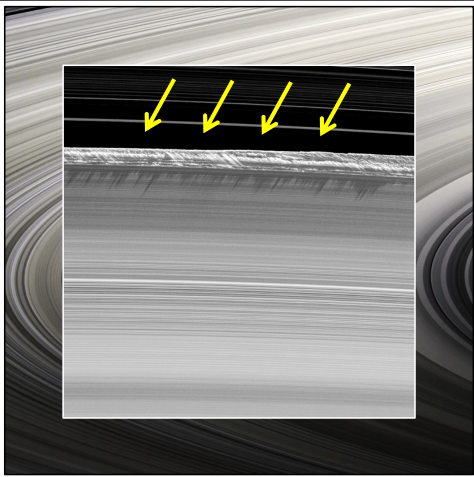


Saturn's Rings



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Saturn's Rings



The ring system is very flat: more than 250,000 km in diameter, but only a few metres thick.


When the Sun was in the plane of the rings, some ring particles cast long shadows.

The 'bumps' are ~km in height.

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Saturn




Cassini took this image as it flew into Saturn's shadow – a view not possible from telescopes on Earth.

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Cassini–Huygens

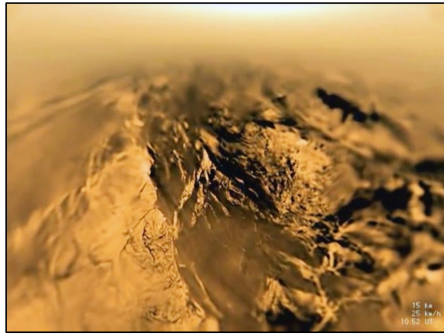


Huygens hitched a ride on Cassini and was released in 2005 to land on the moon Titan.

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Cassini–Huygens



As the Huygens lander plunged through Titan's hazy atmosphere, it took images of a landscape of mountains and lakes.

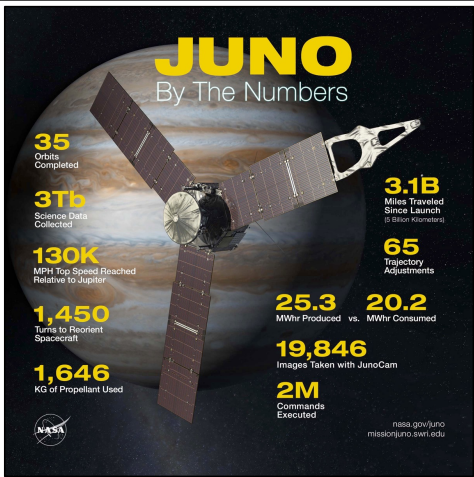
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Juno

Juno arrived at Jupiter in 2016 after a five-year journey.



35 Orbits Completed

3Tb Science Data Collected

130K MPH Top Speed Reached Relative to Jupiter

1,450 Turns to Reorient Spacecraft

1,646 KG of Propellant Used

3.1B Miles Traveled Since Launch (5 Billion Kilometers)

65 Trajectory Adjustments

25.3 MWhr Produced vs. **20.2** MWhr Consumed

19,846 Images Taken with JunoCam

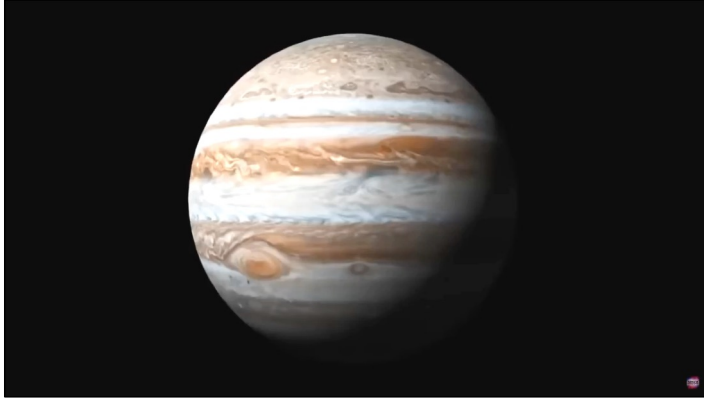
2M Commands Executed

nasa.gov/juno
mission@uno.swin.edu

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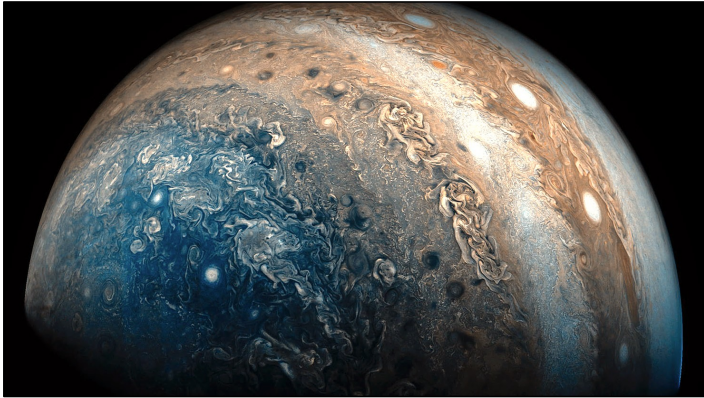
Unwrapping Jupiter



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South Pole of Jupiter




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Storms On Jupiter

Juno images of Jupiter's storm systems can look like watercolour paintings left out in the rain.

The dark spot is a deep vortex of swirling clouds, imaged when Juno passed only 15,000 km above the cloud tops.

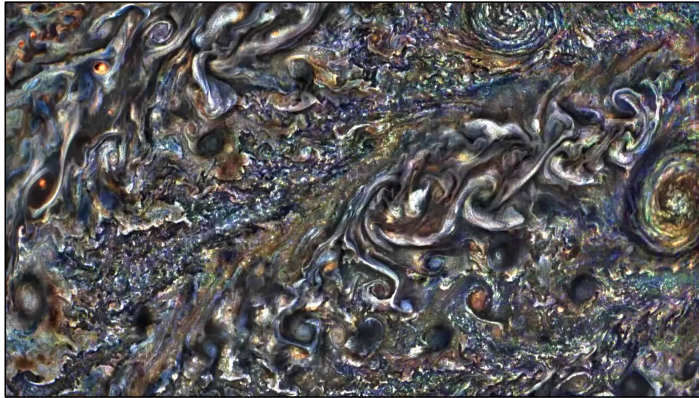


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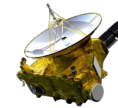
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Storms On Jupiter



Solar System

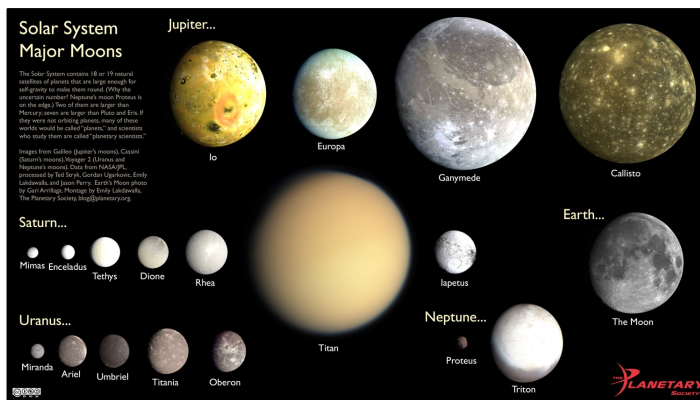
The Solar System is not just the Sun and 8 planets



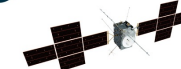
New Horizons is exploring beyond Pluto

There are also over 300 moons!

300+ Moons



Future Missions



Juice



Europa Clipper

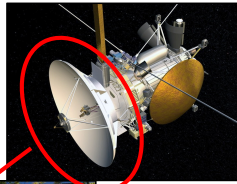


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Future Communications

Data is sent back to Earth by radio using a big dish on the spacecraft ...

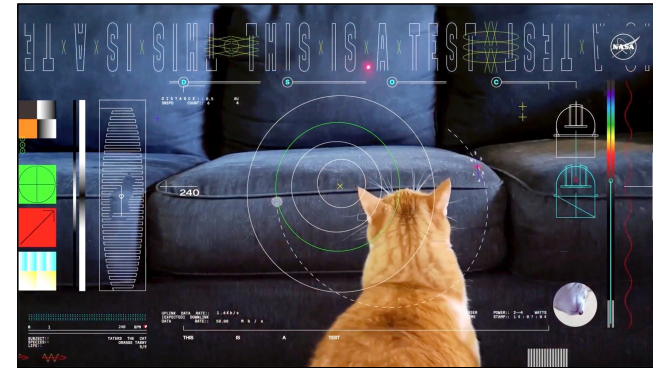
... and an even bigger radio dish on Earth.



Lasers would provide faster transmission and need less power.



Future Communications



Laser data rates: 260 Mb/s at a distance of 50 million km
8 Mb/s at a distance of 400 million km

Want To Know More?

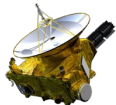
[ESA.int/Science_Exploration/
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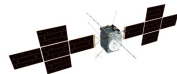
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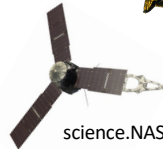
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SPACECRAFT

www.liverpool.ac.uk/~sdb/Talks

Dr Steve Barrett
Southport U3A
25 Mar 2025