

Exploring the Solar System II – Spacecraft



Exploring the Solar System II
Spacecraft

How Do We Get There?

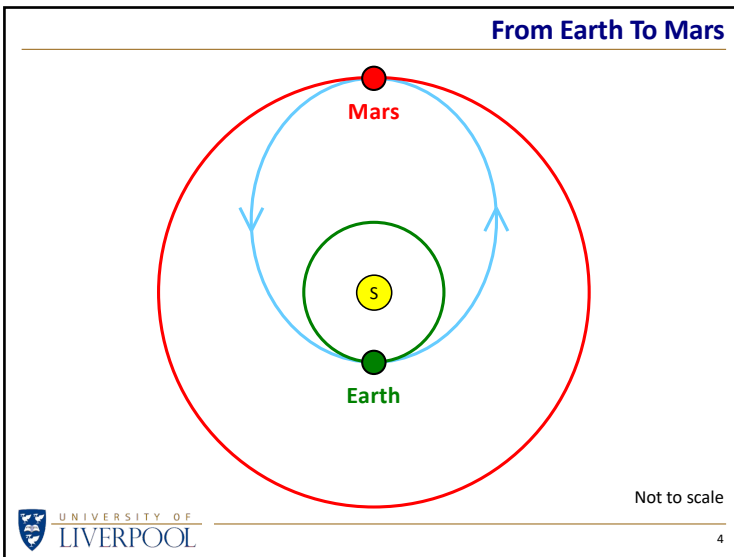
What Do We Do Then?

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
Sputnik 2	Surveyor 1	Apollo 12	Pioneer Venus 2	CONTOUR
Explorer 1	Explorer 33	Apollo 13	ISEE-3	Hayabusa
Vanguard 1	Lunar Orbiter 1	Venera 7	Venera 11	Beagle 2
Luna 1	Pioneer 7	Venera 12	Venera 12	Spirit rover
Pioneer 4	Luna 11	Zond 8	Venera 13	Opportunity rover
Luna 2	Surveyor 2	Luna 17	Venera 14	SMART-1
Luna 3	Luna 12	Apollo 14	Venera 15	Rosetta/Philae
Pioneer 5	Lunar Orbiter 2	Venera 16	Venera 16	MESSENGER
Venera 1	Luna 13	Mars 2	Vega 1	Deep Impact
Vostok 1	Lunar Orbiter 3	Mars 3	Vega 2	Mars Reconnaissance
Ranger 1	Surveyor 3	Mariner 9	Sakigake	Venus Express
Ranger 2	Lunar Orbiter 4	Apollo 15	Giotto	New Horizons
Ranger 3	Venera 4	Luna 18	Suisei	Hinode
Ranger 4	Mariner 5	Luna 19	Phobos 1	STEREO
Mariner 2	Surveyor 4	Luna 20	Phobos 2	Phoenix
Ranger 5	Explorer 35	Magellan	Galileo	SELENE
Mars 1	Lunar Orbiter 5	Venera 8	Venera 8	Dawn
Luna 4	Surveyor 5	Venera 9	Venera 9	Chang'e 1
Cosmos 21	Surveyor 6	Apollo 16	Apollo 16	Chandrayaan-1
Ranger 6	Explorer 36	Apollo 17	Luna 21	Lunar Reconnaissance
Ranger 7	Pioneer 8	Pioneer 11	Pioneer 11	Solar Dynamics Obs
Ranger 7	Surveyor 7	Explorer 49	Clementine	AKARI
Voshkod 1	Apollo 4	Mars 4	WIND	PICARD
Mariner 3	Zond 4	Mars 5	SOHO	Chang'e 2
Mariner 4	Luna 14	Mars 6	NEAR Shoemaker	Aditya-L1
Zond 2	Zond 5	Mars 7	Mars Global Sur	GRAIL
Ranger 8	Apollo 7	Mariner 10	Mars 96	Fobos-Grunt
Voshkod 2	Surveyor 9	Luna 22	Mars Pathfinder	Yinghuo-1
Ranger 9	Zond 6	ACE	Curiosity rover	Novae-C. Odysseus
Luna 5	Apollo 8	Helios-A	Cassini-Huygens	DIO A/B
Luna 6	Venera 5	Venera 9	Lunar Prospector	IRIS
Zond 3	Venera 6	Venera 10	Nozomi	Chang'e 6
Luna 7	Mariner 6	Viking 1	Deep Space 1	Hera
Venera 2	Venera 7	Viking 2	Mars Climate Orb	Europa Clipper
Venera 3	Mariner 7	Helios-8	Mars Polar Lander	
Luna 8	Apollo 10	Luna 24	Deep Space 2	
Pioneer 6	Luna 15	Voyager 2	Chang'e 3	
Luna 9	Apollo 11	Voyager 1	Chang'e 5-T1	
			2001 Mars Odyssey	Hayabusa2



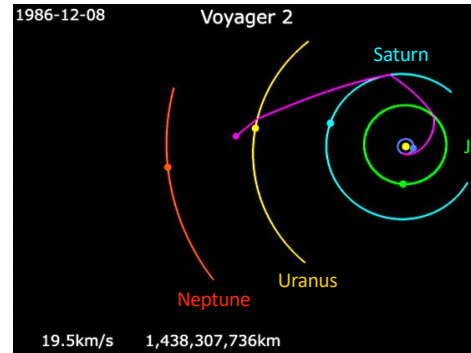
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Gravity Assists

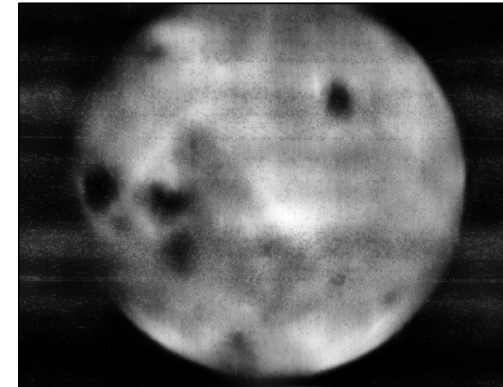
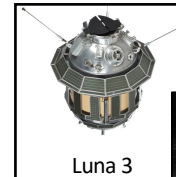
What about getting to other planets in the solar system?

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

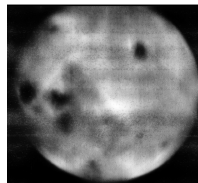
Imaging Technology

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.

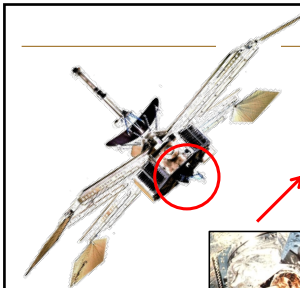
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

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

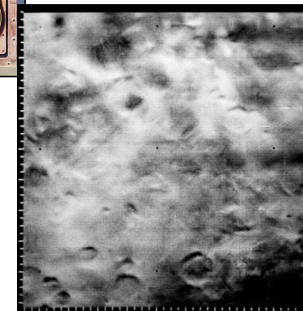
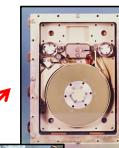


LRO 2009

Imaging Technology



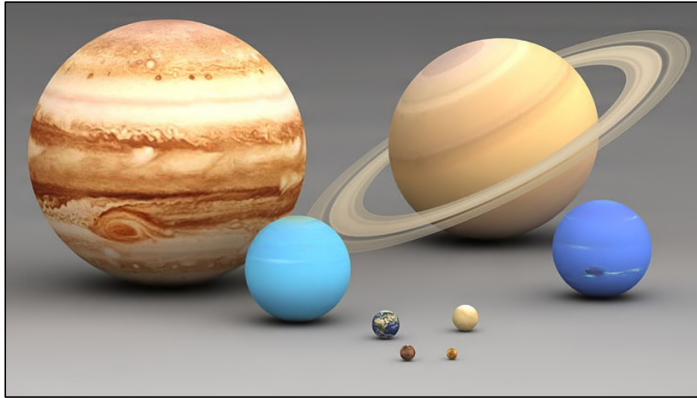
World's first **digital** camera



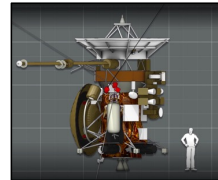
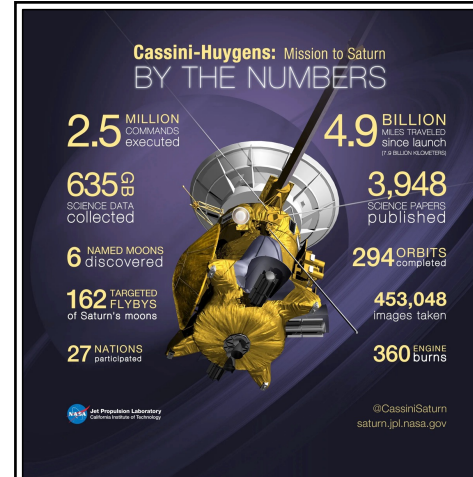
Mars – July 1965

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Planets of the Solar System

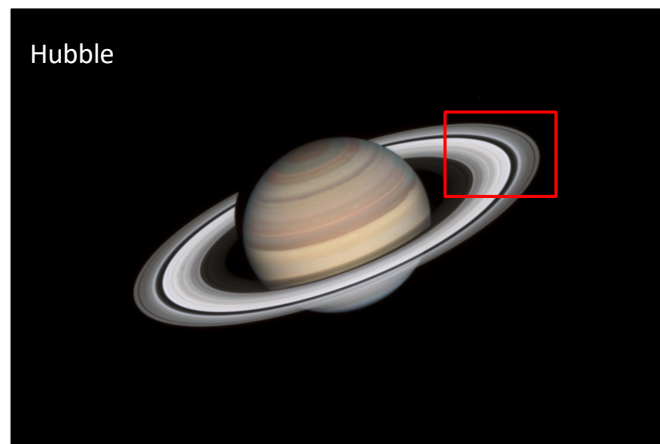


Cassini

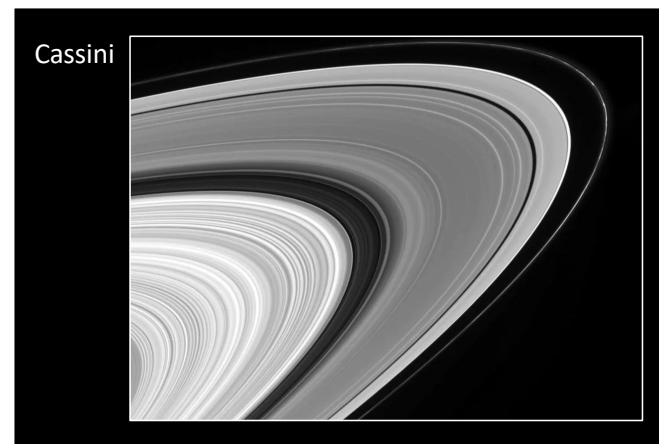


Cassini explored Saturn and its rings and moons from 2004 until it was crashed into Saturn in 2017.

Saturn

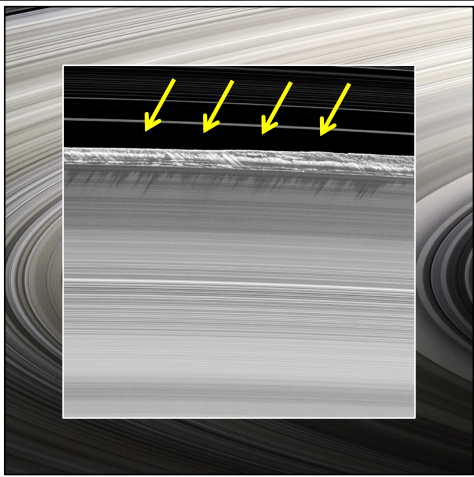


Saturn's Rings



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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

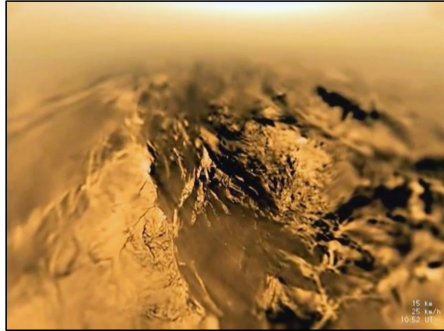


Huygens hitched a ride on Cassini and was released in 2005 to land on the moon Titan.

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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.

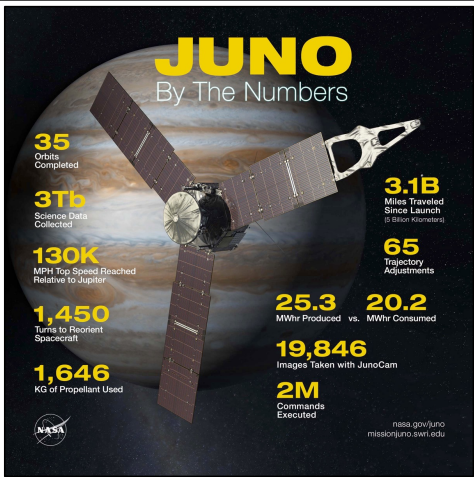
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Juno

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

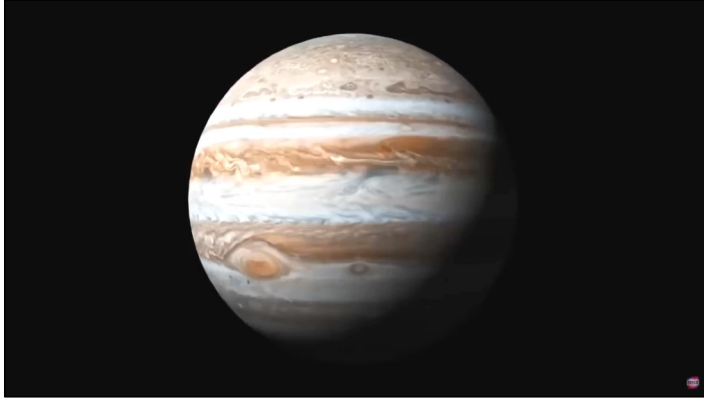
2M Commands Executed

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

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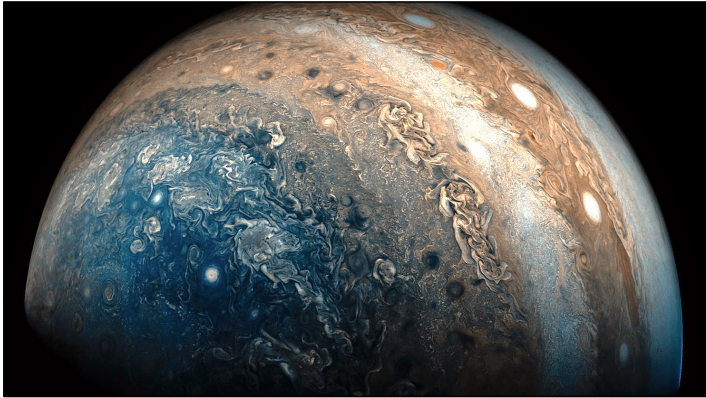
Unwrapping Jupiter



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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.

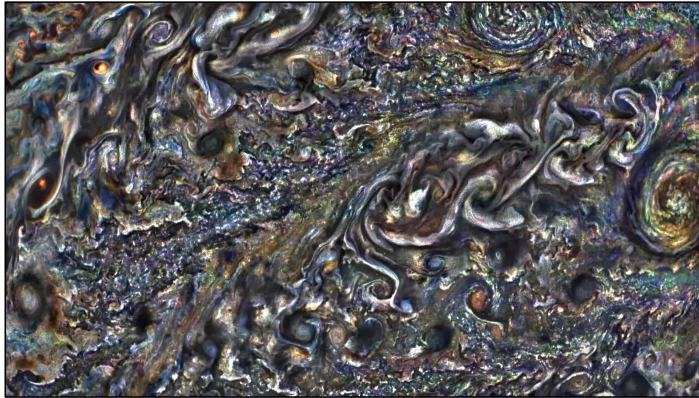


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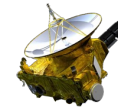
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Storms On Jupiter



Solar System

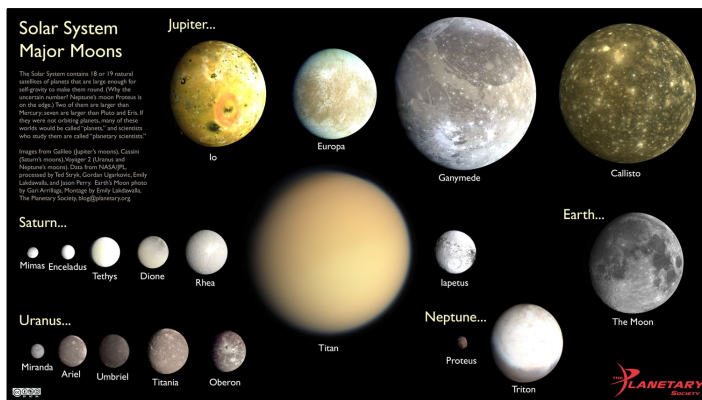
The Solar System is not just the Sun and 8 planets



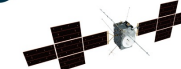
New Horizons is exploring beyond Pluto

There are also over 300 moons!

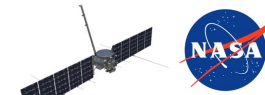
300+ Moons



Future Missions



Juice



Europa Clipper

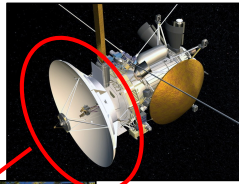


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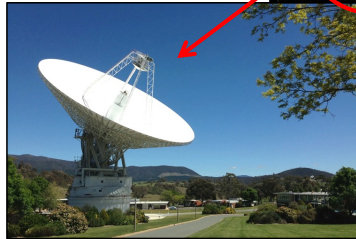
Future Communications

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

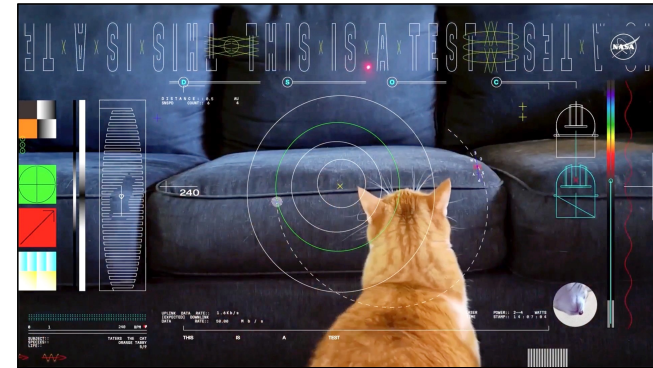
... and an even bigger radio dish on Earth.



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?

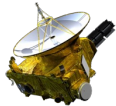
[ESA.int/Science_Exploration/
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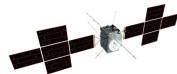
[science.NASA.gov/
mission/cassini](http://science.NASA.gov/mission/cassini)



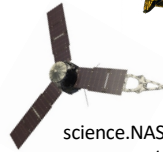
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