

# Exploring the Solar System II – Spacecraft



Exploring the Solar System II

Spacecraft

How Do We Get There?

What Do We Do Then?

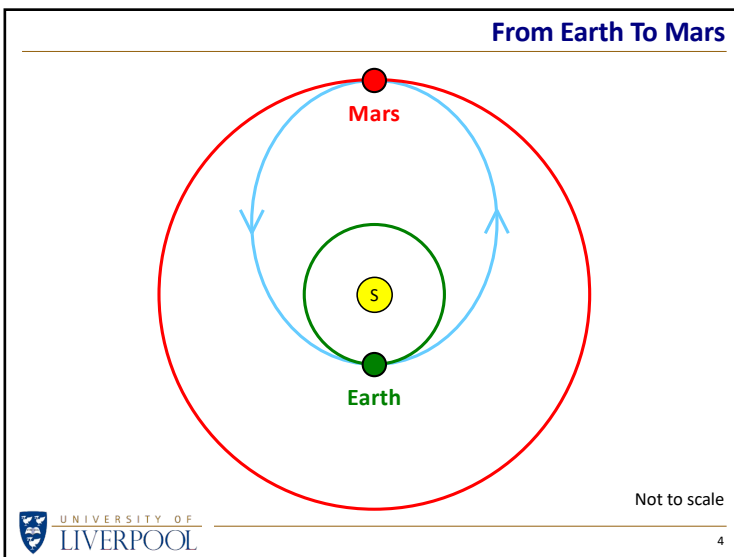
How Do We Get Images Back?

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	Brigade 2
Luna 1	Pioneer 7	Luna 16	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	Salyut 1	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	Pioneer 10	Magellan	SELENE
Mars 1	Lunar Orbiter 5	Venera 8	Galileo	Dawn
Luna 4	Surveyor 5	Venera 9	Hiten	Chang'e 1
Cosmos 21	Surveyor 6	Apollo 16	Ulysses	Chandrayaan-1
Ranger 6	Apollo 4	Luna 17	Yohkoh	Lunar Reconnaissance
Ranger 7	Pioneer 8	Pioneer 11	Mars Observer	Solar Dynamics Obs
Voshkod 1	Surveyor 7	Explorer 49	Clementine	ALUKA
Mariner 3	Zond 4	Mars 4	WIND	PICARD
Mariner 4	Luna 14	Mars 5	SOHO	Chang'e 2
Zond 2	Zond 5	Mars 6	NEAR Shoemaker	Juno
Ranger 8	Apollo 7	Mariner 10	Mars Global Sur	GRAIL
Voshkod 2	Pioneer 9	Luna 21	Mars 7	Fobos-Grunt
Ranger 9	Zond 6	Luna 22	ACE	Yinghuo-1
Luna 5	Apollo 8	Helios-A	Cassini-Huygens	Curiosity rover
Luna 6	Venera 5	Venera 9	Lunar Prospector	Van Allen Probes
Zond 3	Venera 6	Venera 10	Nozomi	IRIS
Luna 7	Mariner 6	Viking 1	Deep Space 1	LADEE
Venera 2	Apollo 9	Helios-B	Mars Climate Orb	Hiaki
Venera 3	Mariner 7	Helios-8	Mars Polar Lander	Mars Orbiter
Luna 8	Apollo 10	Luna 24	Deep Space 2	MAVEN
Pioneer 6	Pioneer 15	Voyager 2	Chang'e 3	Chang'e 3
Luna 9	Apollo 11	Voyager 1	Hayabusa2	Hayabusa2



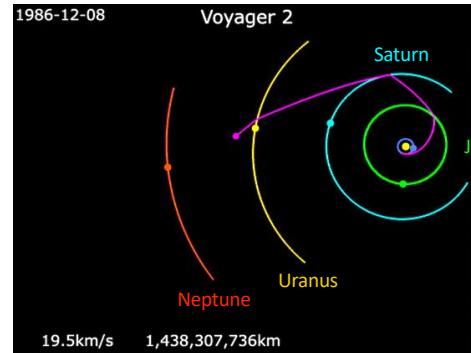
# Exploring the Solar System II – Spacecraft

## Gravity Assists

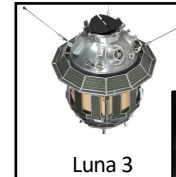
What about getting to other planets in the solar system?

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

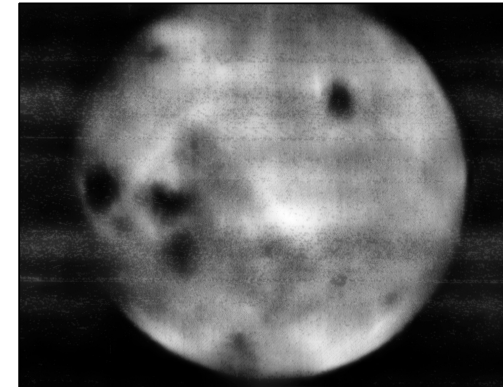
Hence exploring the outer solar system can be carried out faster and cheaper.



## Imaging Technology



Luna 3



Far side of the Moon – Oct 1959

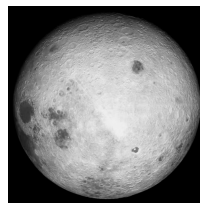
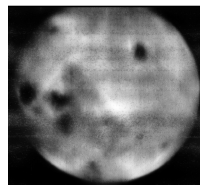
## Imaging Technology

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.

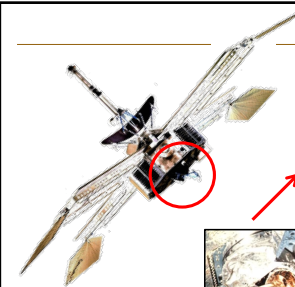
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

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



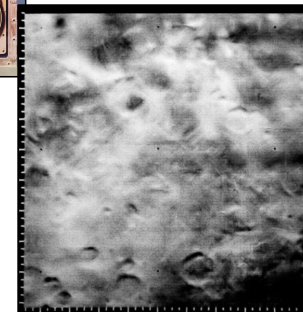
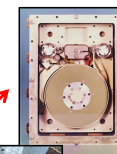
LRO 2009

## Imaging Technology



Mariner 4

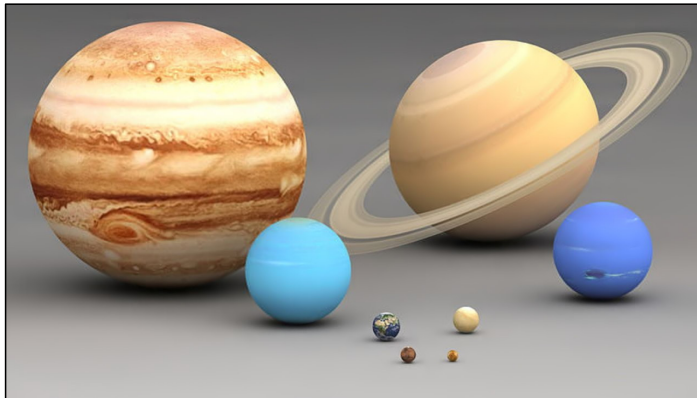
World's first  
**digital** camera



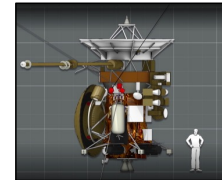
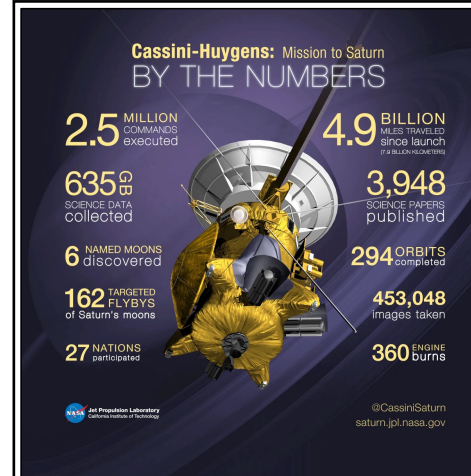
Mars – July 1965

# Exploring the Solar System II – Spacecraft

## Planets of the Solar System

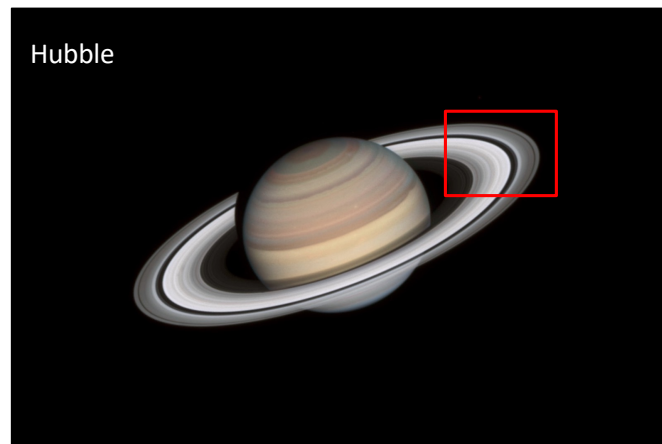


## Cassini

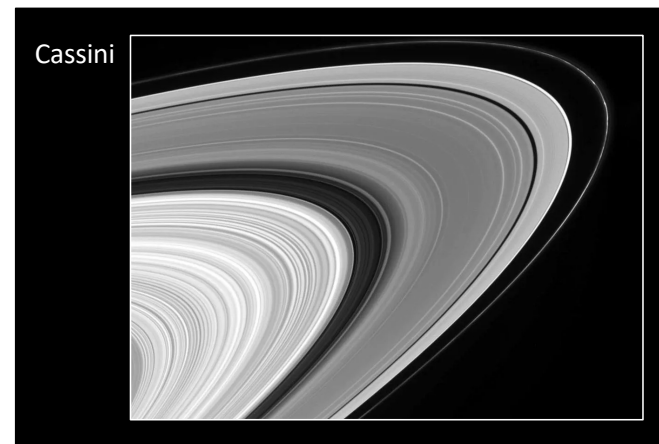


Cassini explored Saturn and its rings and moons from 2004 until it was crashed into Saturn in 2017.

## Saturn

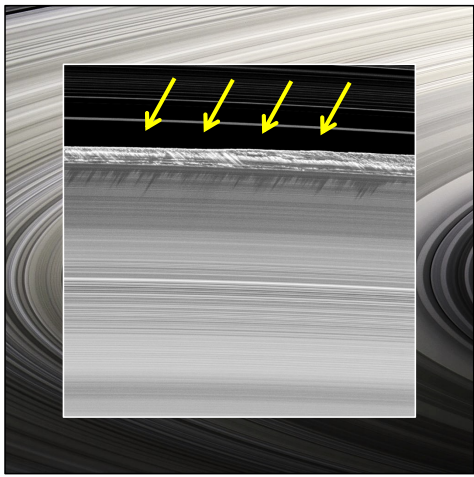


## Saturn's Rings



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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

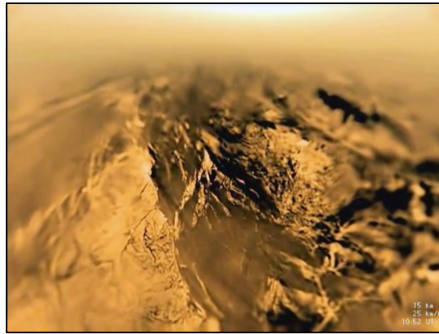


Huygens hitched a ride on Cassini and was released in 2005 to land on the moon Titan.

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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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# Exploring the Solar System II – Spacecraft

## 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.

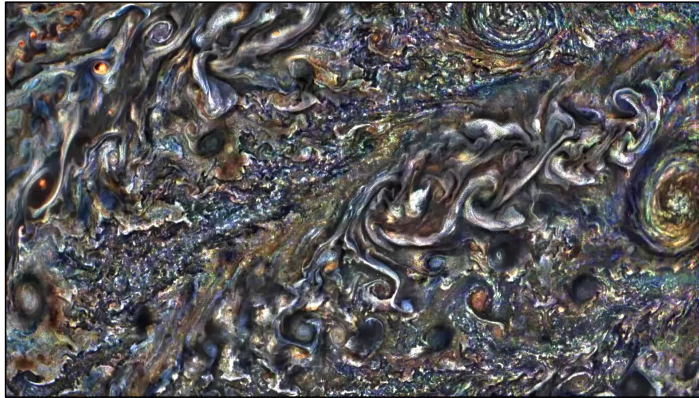
The dark spot is a deep vortex of swirling clouds, imaged when Juno passed only 15,000 km above the cloud tops.

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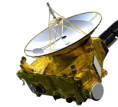
# Exploring the Solar System II – Spacecraft

## Storms On Jupiter



## Solar System

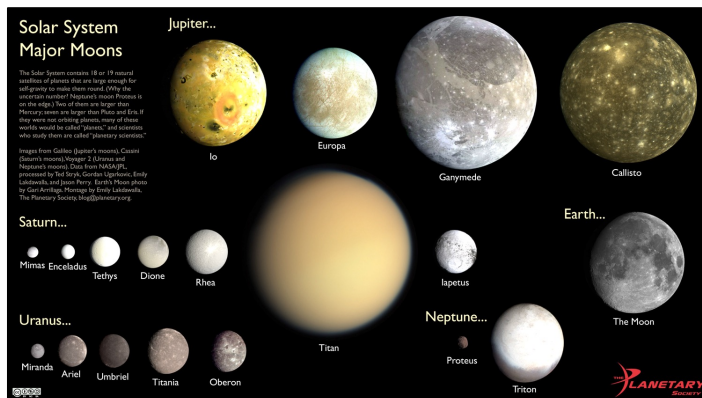
The Solar System is not just the Sun and 8 planets



New Horizons is exploring beyond Pluto

There are also over 300 moons!

## 300+ Moons



## Future Missions



Juice



Europa Clipper

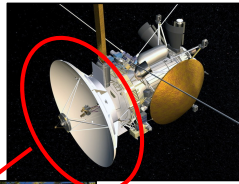


# Exploring the Solar System II – Spacecraft

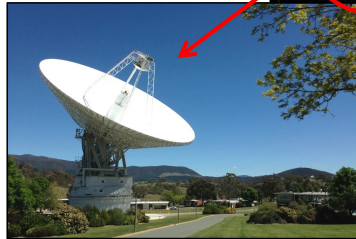
## Future Communications

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

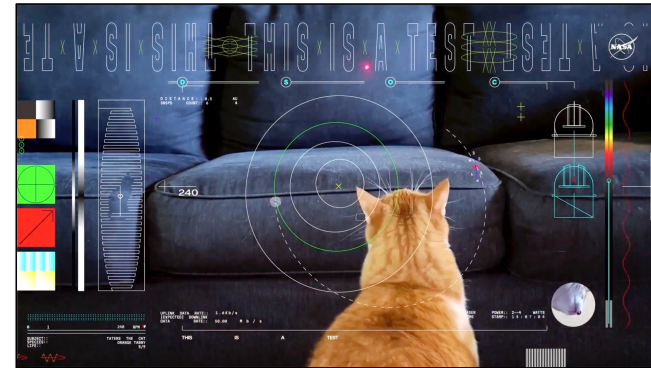
... and an even bigger radio dish on Earth.



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?

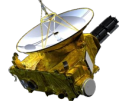
[ESA.int/Science\\_Exploration/  
Space\\_Science/BepiColombo](https://esa.int/Science_Exploration/Space_Science/BepiColombo)



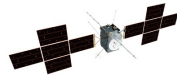
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Exploring the Solar System – II

# SPACECRAFT

[www.liverpool.ac.uk/~sdb/Talks](http://www.liverpool.ac.uk/~sdb/Talks)

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CWCL  
7 Aug 2025