

# 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?

UNIVERSITY OF LIVERPOOL

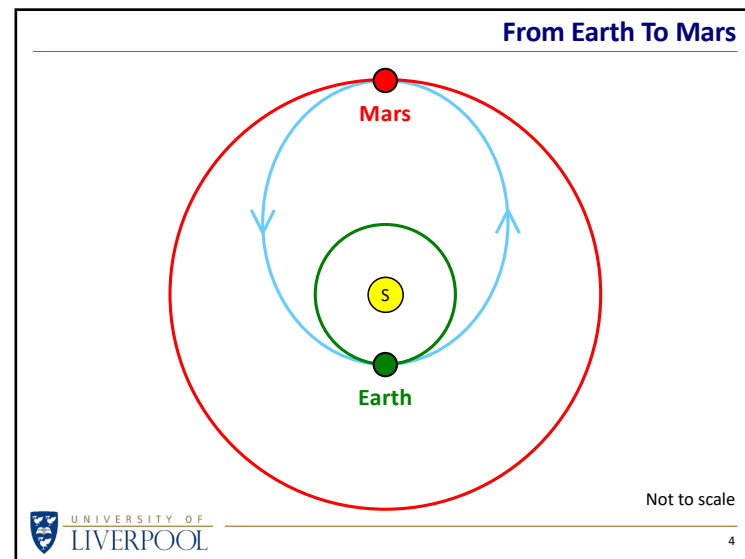
2

**70 Years of Spacecraft**

Sputnik 1	Luna 10	Zond 7	Pioneer Venus 1	Genesis	PROCVON
Sputnik 2	Surveyor 1	Apollo 12	Pioneer Venus 2	CONTOUR	DISCOVER
Explorer 33	Surveyor 3	Apollo 13	ISEE-3	Hayabusa	ExoMars
Vanguard 1	Lunar Orbiter 1	Venera 7	Venera 11	Beagle 2	OSIRIS-REx
Luna 1	Pioneer 7	Venera 8	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	BePicColombo
Pioneer 5	Lunar Orbiter 2	Salyut 1	Venera 16	MESENGER	Chang'e 4
Venera 1	Luna 13	Mars 2	Wega 1	Deep Impact	Beresheet
Vostok 1	Lunar Orbiter 3	Mars 3	Wega 2	Mars Reconnaiss	Chandrayaan-2
Ranger 1	Surveyor 3	Mariner 9	Sakigake	Venus Express	Solar Orbiter
Ranger 2	Lunar Orbiter 4	Apollo 15	Giotto	New Horizons	Mars Hope
Ranger 3	Venera 4	Luna 18	Suisel	Hinode	Zhurong rover
Ranger 4	Mariner 5	Luna 19	Phobos 1	STEREO	Perseverance rover
Mariner 2	Surveyor 4	Luna 20	Phobos 2	Phoenix	Chang'e 5
Ranger 5	Explorer 35	Luna 21	Magellan	SELENE	Lucy
Mars 1	Lunar Orbiter 5	Venera 8	Galileo	Dawn	DART
Luna 4	Surveyor 5	Apollo 16	Hiten	Chang'e 1	CAPSTONE
Cosmos 21	Surveyor 6	Apollo 17	Ulysses	Chandrayaan-1	Danuri
Ranger 6	Apollo 4	Luna 21	Yohkoh	Lunar Reconnaiss	Artemis 1
Ranger 7	Pioneer 8	Pioneer 11	Mars Observer	Solar Dynamics Obs	Hakuto-R 1
Voshkod 1	Surveyor 7	Explorer 49	WIND	Akatsuki	JUICE
Mariner 3	Apollo 5	Mars 4	SOHO	PICARD	Chandrayaan-3
Mariner 4	Zond 4	Mars 5	NEOS Shoemaker	Chang'e 2	Luna 25
Zond 2	Luna 14	Mars 6	Mars 7	SELENE	Aditya-L1
Ranger 8	Zond 5	Mars 7	Mars Global Surv	GRAIL	SLIM
Yoshikazu 2	Ranger 9	Mariner 10	Mars 96	Fobos-Grunt	Psyche
Ranger 9	Luna 5	Luna 23	Mars Pathfinder	Yinghuo-1	Regina One
Luna 5	Luna 6	Zond 6	ACE	Curiosity rover	Novae-C Odysseus
Zond 3	Venera 6	Luna 24	Cassini-Huygens	Van Allen Probes	DRO A/B
Luna 7	Mariner 6	Helios-A	Lunar Prospector	LADEE	OSIRIS-REx
Venera 2	Apollo 9	Venera 9	Nozomi	HiSaki	Chang'e 6
Venera 3	Mariner 7	Viking 1	Deep Space 1	Mars Orbiter	Hera
Luna 8	Apollo 10	Helios-B	Viking 2	Mars Polar Lander	Europa Clipper
Pioneer 6	Luna 9	Luna 24	Deep Space 2	MAVEN	
Luna 9	Apollo 11	Voyager 1	Voyager 2	Chang'e 3	
			2001 Mars Odyssey	Chang'e 4	
				Hayabusa2	

UNIVERSITY OF LIVERPOOL

3



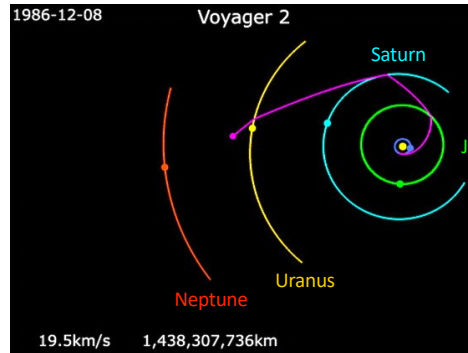
# Exploring the Solar System II – Spacecraft

## 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.

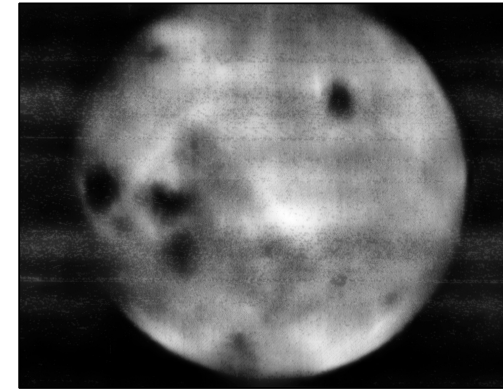
Hence exploring the outer solar system can be carried out faster and cheaper.



## Imaging Technology



Luna 3



Far side of the Moon – Oct 1959

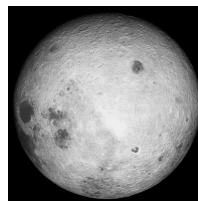
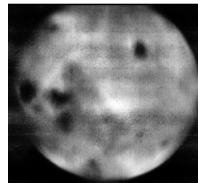
## Imaging Technology

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.

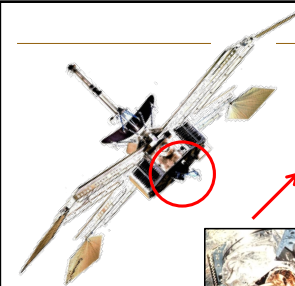
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

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



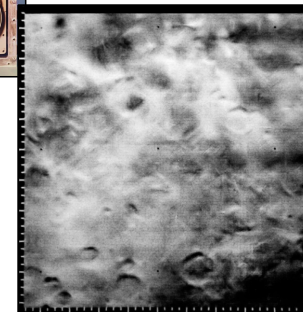
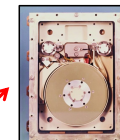
LRO 2009

## Imaging Technology



Mariner 4

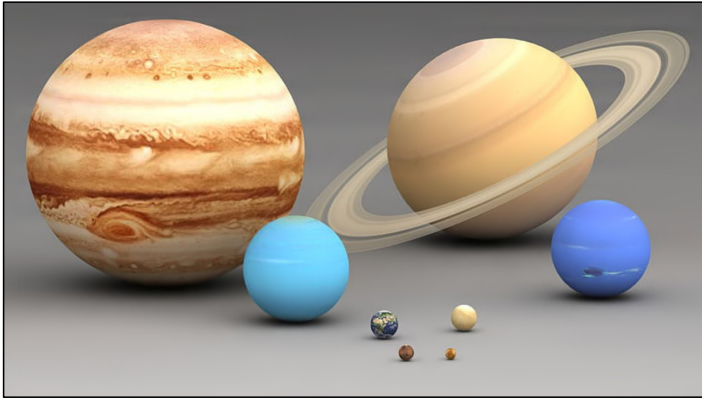
World's first **digital** camera



Mars – July 1965

# Exploring the Solar System II – Spacecraft

### Planets of the Solar System



UNIVERSITY OF LIVERPOOL

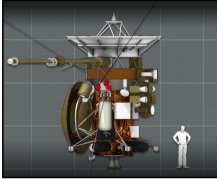
9

### Cassini

**Cassini-Huygens: Mission to Saturn**  
**BY THE NUMBERS**

- 2.5 MILLION COMMANDS executed
- 4.9 BILLION MILES TRAVELED since launch (7.8 BILLION KILOMETERS)
- 635 SCIENCE DATA PARCELS collected
- 3,948 SCIENCE PAPERS published
- 6 NAMED MOONS discovered
- 294 ORBITS completed
- 162 TARGETED FLYBYS of Saturn's moons
- 453,048 images taken
- 27 NATIONS participated
- 360 ENGINE burns

@CassiniSaturn  
saturn.jpl.nasa.gov

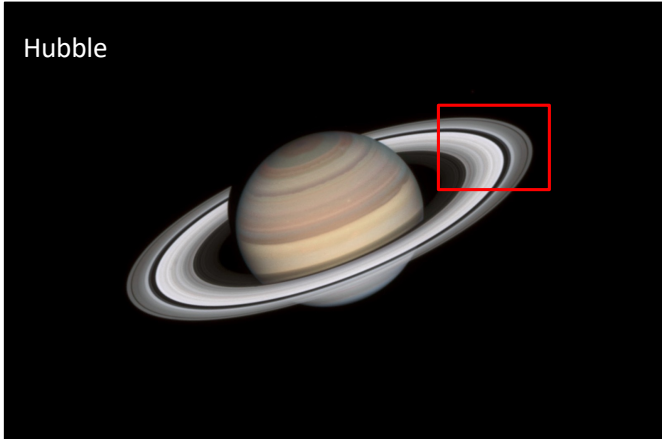


UNIVERSITY OF LIVERPOOL

10

### Saturn

Hubble



UNIVERSITY OF LIVERPOOL

11

### Saturn's Rings

Cassini

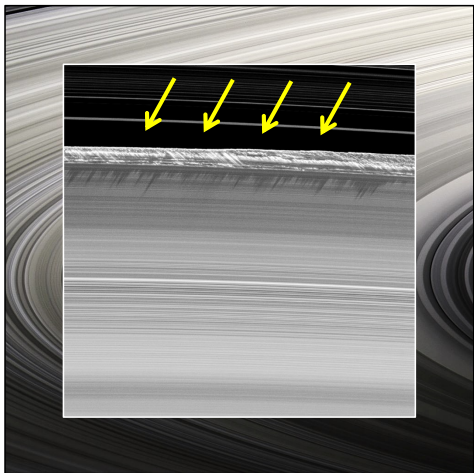


UNIVERSITY OF LIVERPOOL

12

# Exploring the Solar System II – Spacecraft

### 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.

UNIVERSITY OF LIVERPOOL

13

### Saturn




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

UNIVERSITY OF LIVERPOOL

14

### Cassini–Huygens

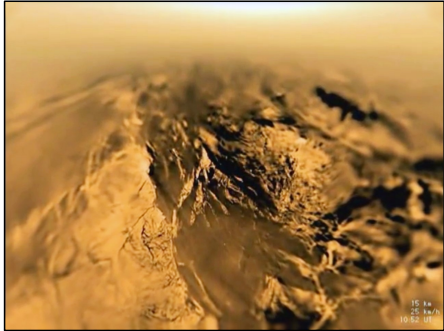


Huygens hitched a ride on Cassini and was released in 2005 to land on the moon Titan.

UNIVERSITY OF LIVERPOOL

15

### Cassini–Huygens



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

UNIVERSITY OF LIVERPOOL

16

# Exploring the Solar System II – Spacecraft

## Juno

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

**UNIVERSITY OF LIVERPOOL**

17

## Unwrapping Jupiter

**UNIVERSITY OF LIVERPOOL**

18

## South Pole of Jupiter

**UNIVERSITY OF LIVERPOOL**

19

## Storms On Jupiter

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

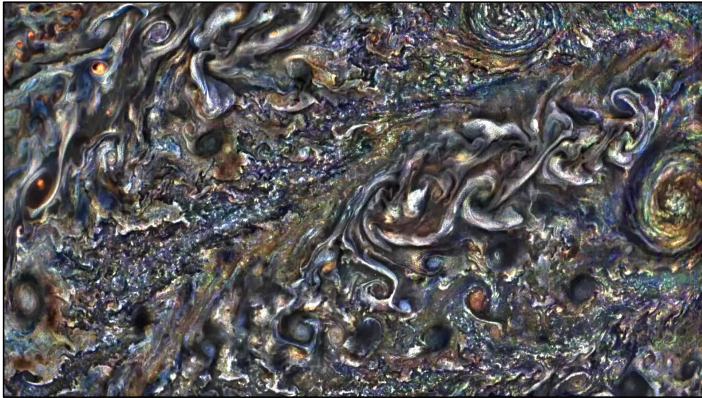
The dark spot is a deep vortex of swirling clouds, imaged when Juno passed only 15,000 km above the cloud tops.

**UNIVERSITY OF LIVERPOOL**

20

# Exploring the Solar System II – Spacecraft

### Storms On Jupiter

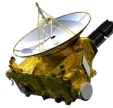


UNIVERSITY OF LIVERPOOL

21

### Solar System

The Solar System is not just the Sun and 8 planets



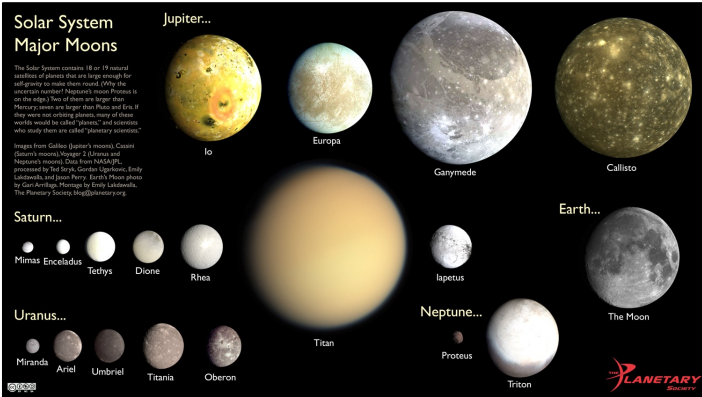
New Horizons is exploring beyond Pluto

There are also over 300 moons!

UNIVERSITY OF LIVERPOOL

22

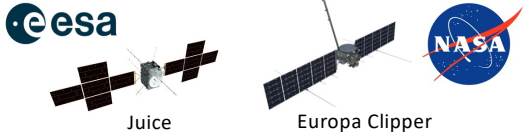

### 300+ Moons



UNIVERSITY OF LIVERPOOL

23

### Future Missions

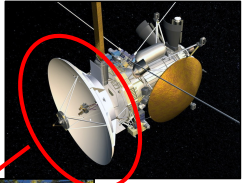
UNIVERSITY OF LIVERPOOL

24

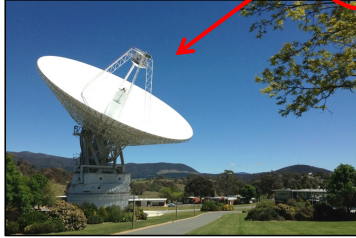
# Exploring the Solar System II – Spacecraft

### 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.



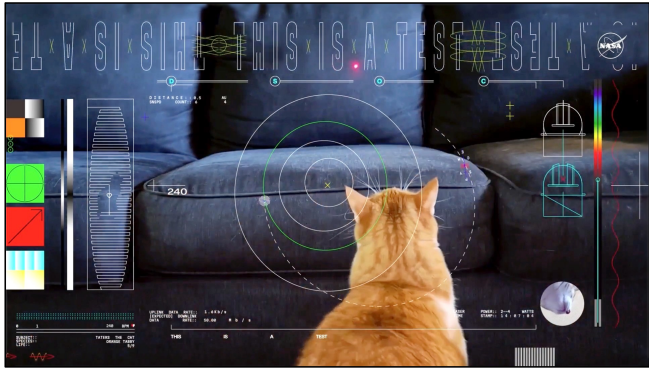
Lasers would provide faster transmission and need less power.



UNIVERSITY OF LIVERPOOL

25

### 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

UNIVERSITY OF LIVERPOOL


26

### Want To Know More?

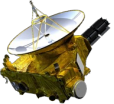
ESA.int/Science\_Exploration/Space\_Science/BepiColombo




science.NASA.gov/mission/cassini




science.NASA.gov/mission/new-horizons




science.NASA.gov/mission/juno



ESA.int/Science\_Exploration/Space\_Science/Juice



science.NASA.gov/mission/europa-clipper



UNIVERSITY OF LIVERPOOL

27

### Exploring the Solar System – II

# SPACECRAFT

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



Dr Steve Barrett  
CDAS 1 Apr 2026