

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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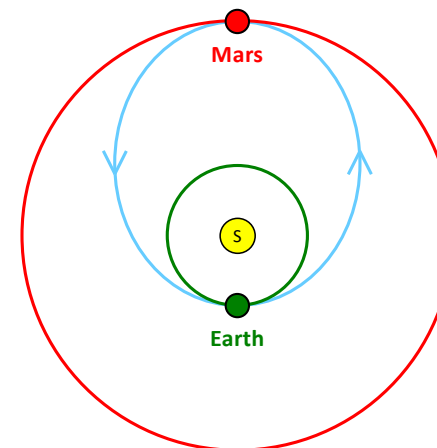
70 Years of Spacecraft

Sputnik 1	Luna 10	Zond 7	Pioneer Venus 1	Genesis	PROTON
Sputnik 2	Surveyor 1	Apollo 12	Pioneer Venus 2	CONTOUR	DISCOVER
Explorer 33	Apollo 13	Apollo 13	ISEE-3	Hayabusa	ExoMars
Vanguard 1	Lunar Orbiter 1	Venera 7	Venera 11	Brigade 2	OSIRIS-REx
Luna 1	Pioneer 7	Luna 16	Venera 12	Spirit rover	InSight
Pioneer 4	Luna 11	Zond 8	Venera 13	Opportunity rover	Queqiao
Luna 2	Surveyor 2	Luna 17	Venera 14	SMART-1	Parker Solar Probe
Pioneer 5	Luna 12	Apollo 14	Venera 15	Rosetta/Philae	BeqColombo
Venera 1	Luna 13	Mars 2	Venera 16	MESSENGER	Chang'e 4
Vostok 1	Lunar Orbiter 3	Mars 3	Vega 1	Deep Impact	Beresheet
Ranger 1	Surveyor 3	Mariner 9	Vega 2	Mars Reconnaissance	Chandrayaan-2
Ranger 2	Lunar Orbiter 4	Apollo 15	Sakigake	Venus Express	Solar Orbiter
Ranger 3	Venera 4	Giotto	Suisei	New Horizons	Mars Hope
Ranger 4	Mariner 5	Luna 18	Phobos 1	Hinode	Zhurong rover
Mariner 2	Surveyor 4	Luna 19	Phobos 2	STEREO	Perseverance rover
Ranger 5	Explorer 35	Luna 20	Magellan	Phoenix	Chang'e 5
Mars 1	Lunar Orbiter 5	Venera 8	Galileo	SELENE	Lucy
Luna 4	Surveyor 5	Venera 9	Hiten	Dawn	CAPSTONE
Cosmos 21	Surveyor 6	Apollo 16	Ulysses	Chandrayaan-1	Dart
Ranger 6	Apollo 4	Luna 17	Yohkoh	Lunar Reconnaissance	Artemis 1
Ranger 7	Pioneer 8	Pioneer 11	Mars Observer	Solar Dynamics Obs	Hakuto-R 1
Voshkod 1	Surveyor 7	Clementine	WIND	PICARD	JUICE
Mariner 3	Zond 4	Mars 5	SOHO	Chang'e 2	Chandrayaan-3
Zond 2	Luna 14	Mars 6	NEAR Shoemaker	June	Luna 25
Ranger 8	Zond 5	Mars 7	Mars Global Surv	GRAIL	Aditya-L1
Voshkod 2	Apollo 7	Mariner 10	Mars 96	Fobos-Grunt	SLIM
Ranger 9	Pioneer 9	Luna 21	Mars Pathfinder	Yinghuo-1	Psyche
Luna 5	Apollo 8	Luna 22	ACE	Curiosity rover	Persingine One
Zond 3	Venera 6	Helios-A	Cassini-Huygens	Van Allen Probes	Novae-C. Odysseus
Luna 7	Mariner 6	Venera 9	Lunar Prospector	MAVEN	DIO A/B
Venera 3	Venera 7	Helios-B	Nozomi	Chang'e 3	Queqiao-2
Luna 8	Apollo 10	Luna 24	Deep Space 1	Chang'e 4	Chang'e 6
Pioneer 6	Luna 15	Voyager 1	Mars Climate Orb	Hayabusa2	Hera
Luna 9	Apollo 11		2001 Mars Odyssey		Europa Clipper



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From Earth To Mars



Not to scale



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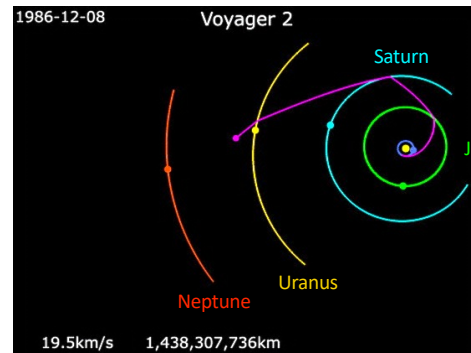
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Gravity Assists

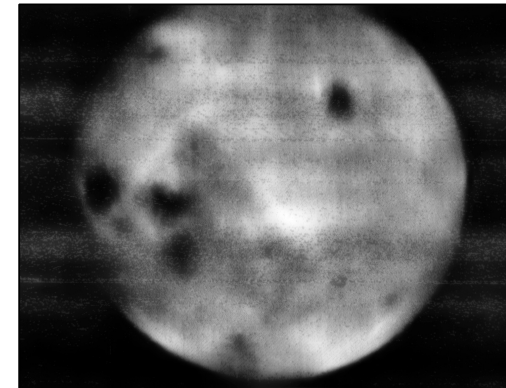
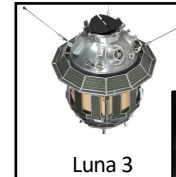
What about getting to other planets in the solar system?

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

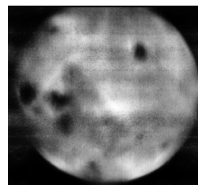
Imaging Technology

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.

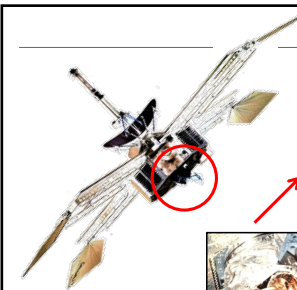
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

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

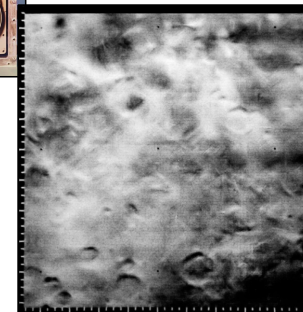


LRO 2009

Imaging Technology



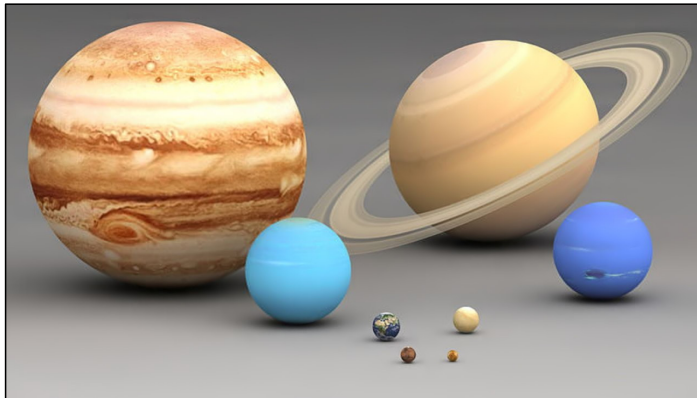
World's first **digital** camera



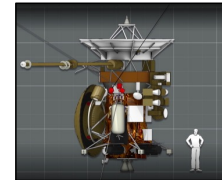
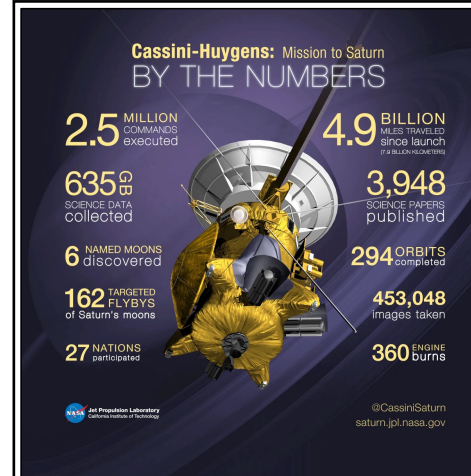
Mars – July 1965

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Planets of the Solar System

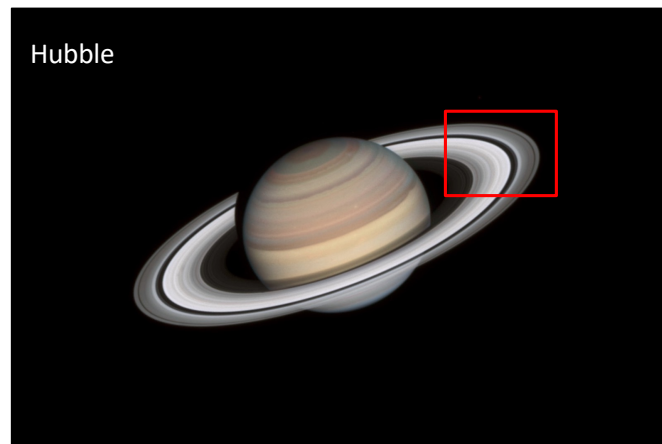


Cassini

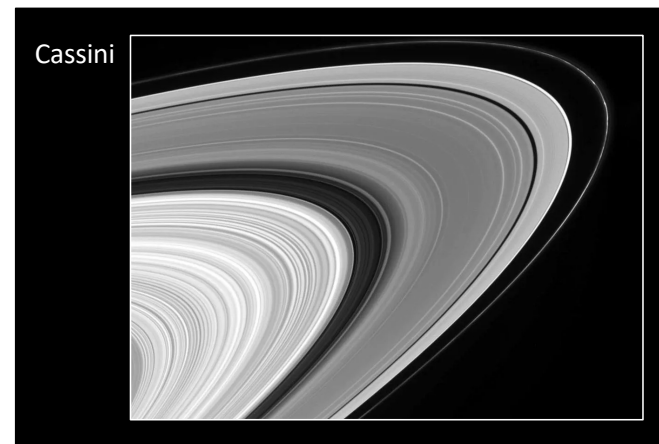


Cassini explored Saturn and its rings and moons from 2004 until it was crashed into Saturn in 2017.

Saturn

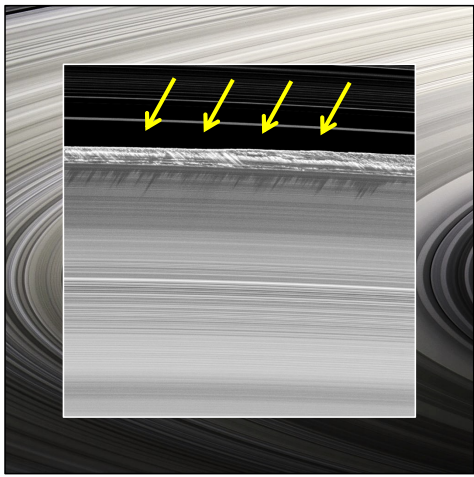


Saturn's Rings



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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

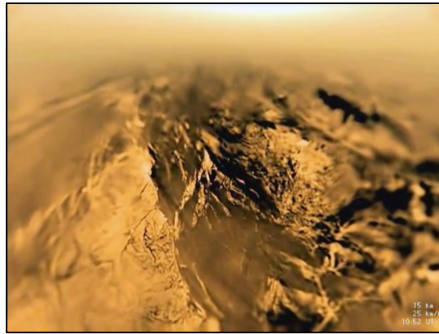


Huygens hitched a ride on Cassini and was released in 2005 to land on the moon Titan.

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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.

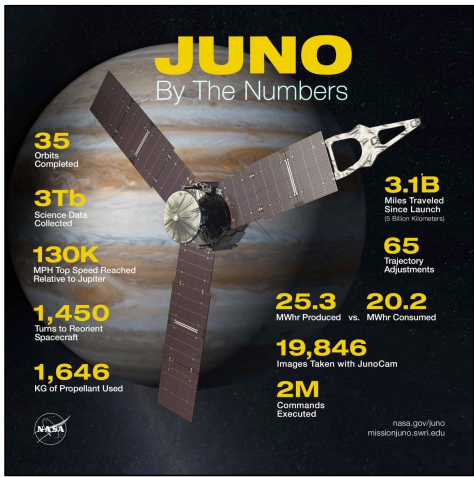
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Exploring the Solar System II – Spacecraft

Juno

Juno By The Numbers



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

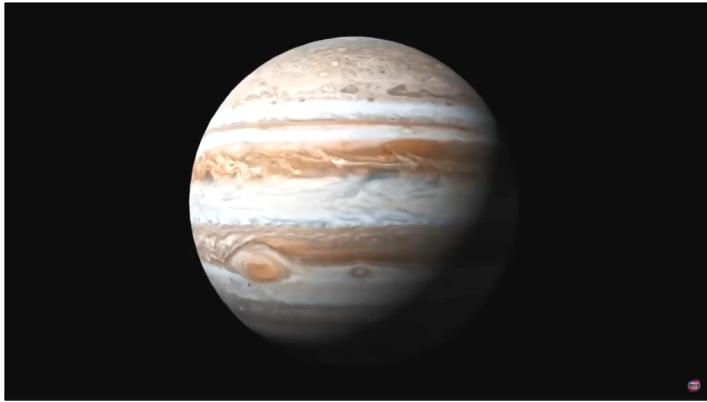
2M Commands Executed

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.

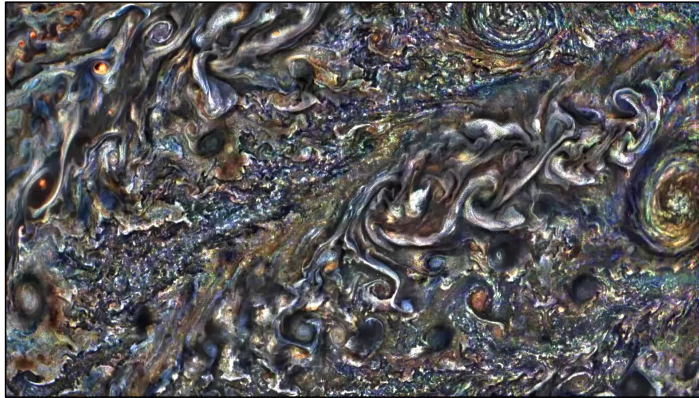
The dark spot is a deep vortex of swirling clouds, imaged when Juno passed only 15,000 km above the cloud tops.

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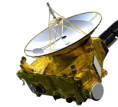
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Storms On Jupiter



Solar System

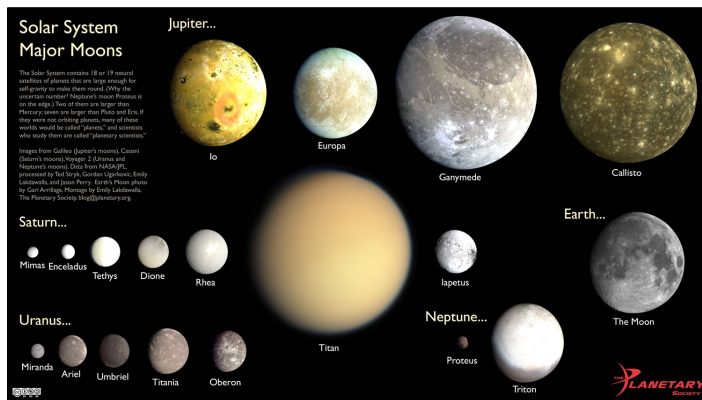
The Solar System is not just the Sun and 8 planets



New Horizons is exploring beyond Pluto

There are also over 300 moons!

300+ Moons



Future Missions



Juice



Europa Clipper

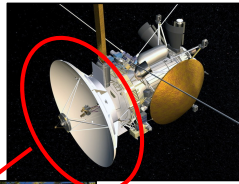


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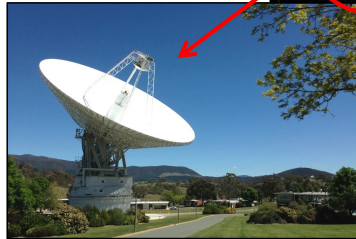
Future Communications

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

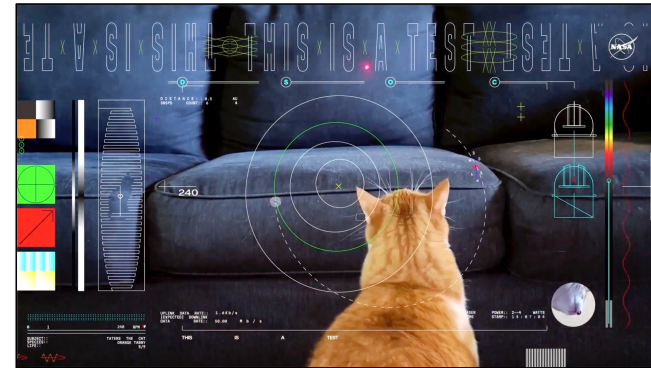
... and an even bigger radio dish on Earth.



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?

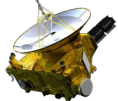
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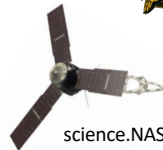
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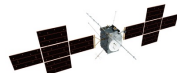
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26 Feb 2026