

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?

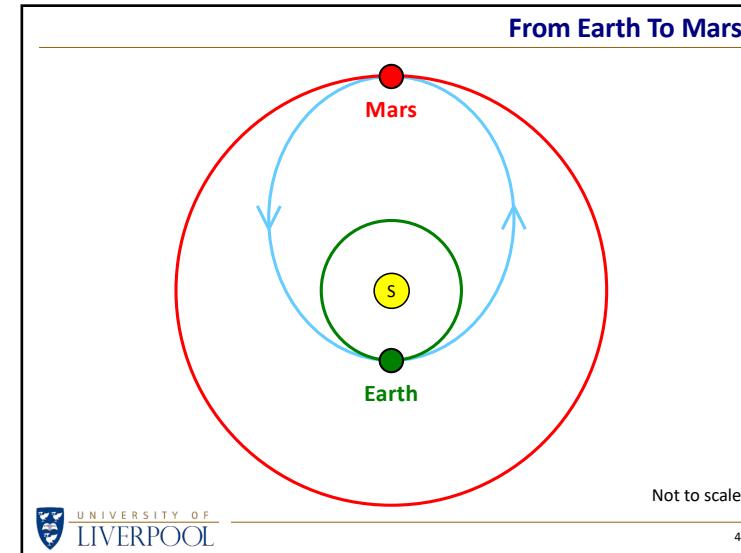


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70 Years of Spacecraft

Sputnik 1	Luna 10	Zond 7	Pioneer Venus 1	Genesis	PROCYON
Sputnik 2	Surveyor 1	Apollo 12	Pioneer Venus 2	CONTOUR	DSCOVR
Explorer 1	Explorer 33	Apollo 13	ISEE-3	Hayabusa	ExoMars
Vanguard 1	Apollo 14	Venera 7	Venera 11	Beagle 2	OSIRIS-REx
Luna 1	Pioneer 7	Zond 11	Venera 12	Spirit rover	Ingenuity
Pioneer 4	Zond 12	Zond 13	Venera 13	Opportunity rover	Quicksand
Luna 2	Surveyor 2	Luna 17	Venera 14	SMART-1	Parker Solar Probe
Luna 3	Luna 12	Apollo 14	Venera 15	Rosetta/Philae	BepiColombo
Pioneer 5	Lunar Orbiter 2	Salyut 1	Venera 16	MESSENGER	Chang'e 4
Venera 1	Luna 13	Mars 2	Vega 1	Mars Impact	Chandrayaan-1
Vostok 1	Lunar Orbiter 3	Mars 3	Vega 2	Mars Reconnaissance	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	Phobos 1	Interplanetary	Zhurong rover
Ranger 4	Mariner 5	Luna 19	Phobos 2	STEREO	Perseverance rover
Mariner 2	Surveyor 4	Luna 20	Phoenix	Phoenix	Chang'e 5
Ranger 5	Explorer 35	Pioneer 10	Magellan	SELENE	Lucy
Mars 1	Lunar Orbiter 5	Venera 8	Galleon	DART	DAVINCI
Luna 4	Surveyor 5	Apollo 16	Galileo	GOCE	CAPSTONE
Cosmos 21	Surveyor 6	Apollo 17	Chang'e 1	Chandrayaan-1	Danuri
Ranger 6	Apollo 4	Luna 21	Ulysses	Asteroid	Artemis 1
Zond 1	Pioneer 8	Yohkoh	Mars Observer	Solar Dynamics Obs	Hubble-R 1
Zond 2	Pioneer 11	Mariner 10	Wind	Akatsuki	JUICE
Ranger 7	Surveyor 7	Explorers 49	WIND	PICARD	Chandrayaan-3
Voskhod 1	Apollo 5	Mars 4	SOHO	Chang'e 2	Luna 25
Mariner 3	Zond 4	Mars 5	NEAR Shoemaker	Odyssey	Aditya-L1
Mariner 4	Luna 14	Mars 6	Global Surveyor	GRAM	SLIM
Zond 2	Zond 5	Mars 7	Mars 96	Fobos-Grunt	Poiche
Ranger 8	Apollo 7	Mariner 10	Mars Pathfinder	Yinghuo-1	Peregrine One
Voskhod 2	Pioneer 9	Luna 22	ACE	Curiosity rover	Novo-C Odysseus
Ranger 9	Zond 6	Luna 23	HiRISE	Vesta-1	DART
Luna 5	Apollo 8	Heos-3A	Marconi-Huygen	Odyssey	QB50
Luna 6	Venera 5	Venera 9	Lunar Prospector	IRIS	Quicksat-2
Zond 3	Venera 6	Venera 10	Nozomi	LADEE	Chang'e 6
Luna 7	Mariner 6	Viking 1	Deep Space 1	Hisat	Hera
Venera 2	Apollo 9	Viking 2	Mars Climate Orb	Mars Orbiter	Europa Clipper
Venera 3	Mariner 7	Luna 24	Mars Polar Lander	MAVEN	
Luna 8	Apollo 10	Voyager 2	Deep Space 2	Chang'e 3	
Pioneer 6	Luna 15	Voyager 1	Stardust	Chang'e 5-T1	
Luna 9	Apollo 11	2001 Mars Odyssey	Hayabusa2	Hayabusa	

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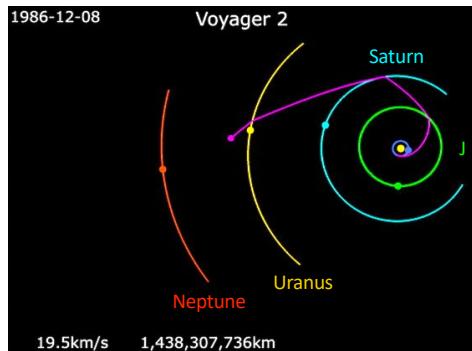
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Gravity Assists

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.

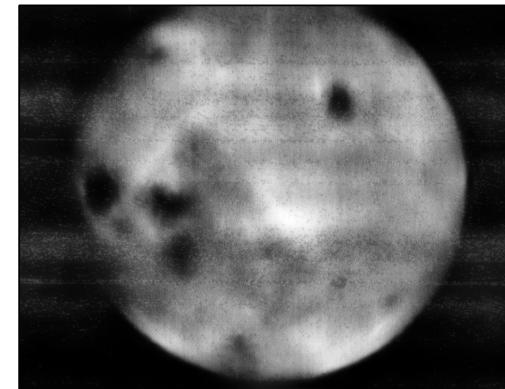


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Imaging Technology



Luna 3



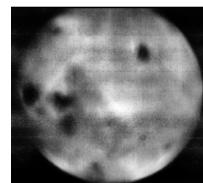
Far side of the Moon – Oct 1959



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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.



LRO 2009

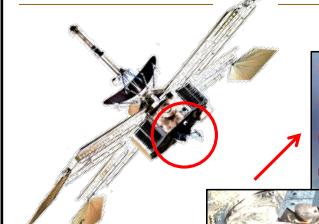
The signal from the photomultiplier was then **transmitted** to the Earth to allow an image to be constructed (like a fax machine).

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



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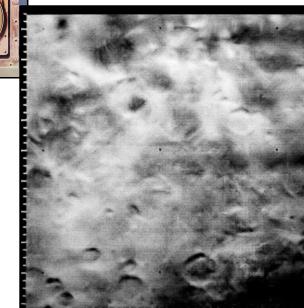
Imaging Technology



Mariner 4



World's first **digital** camera

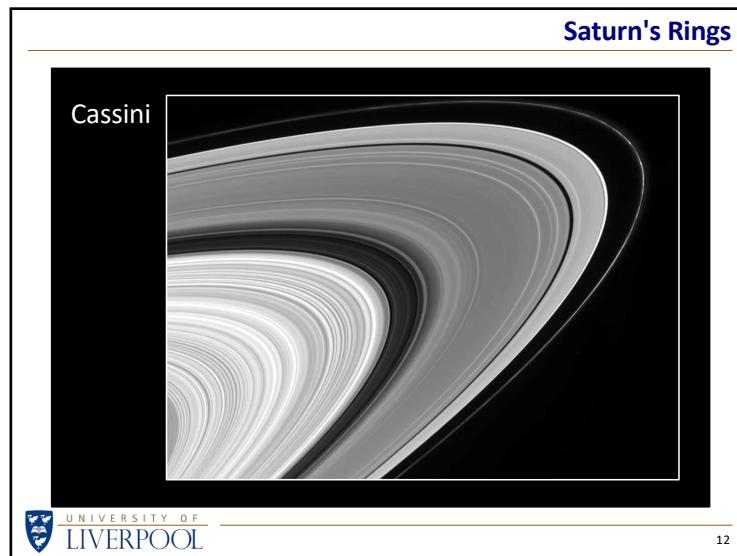
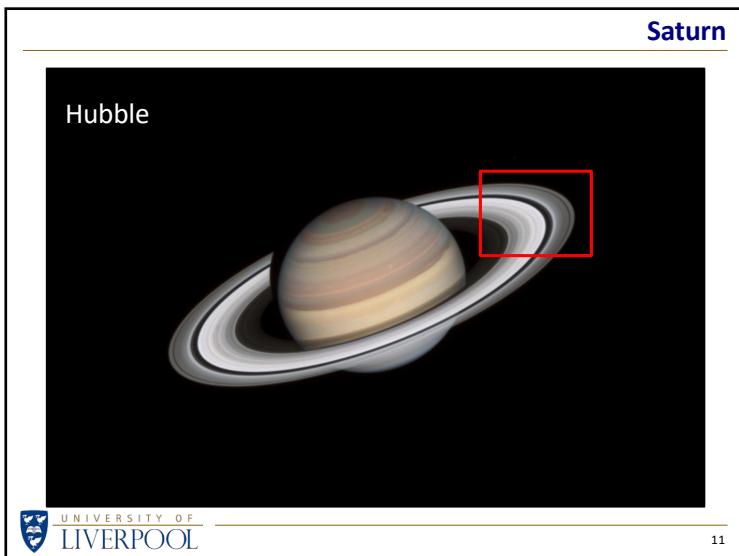
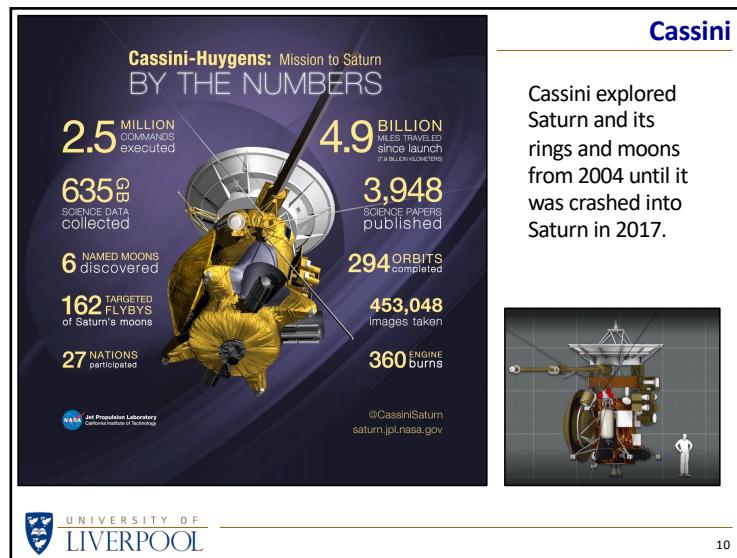
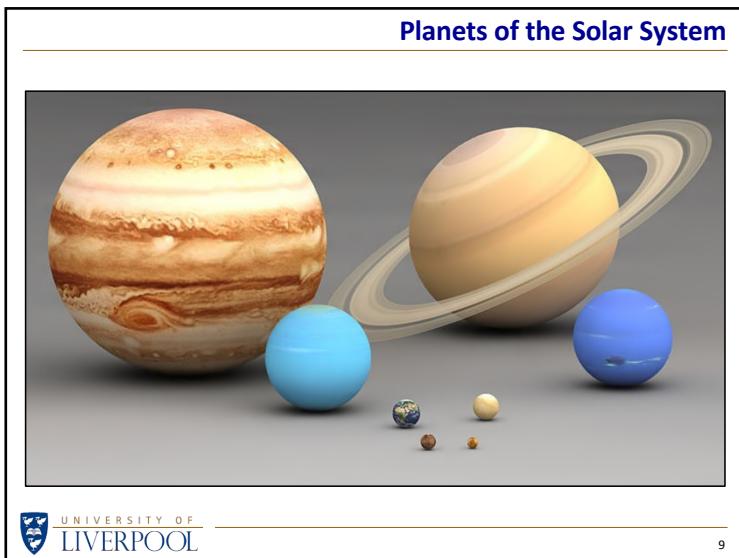


Mars – July 1965

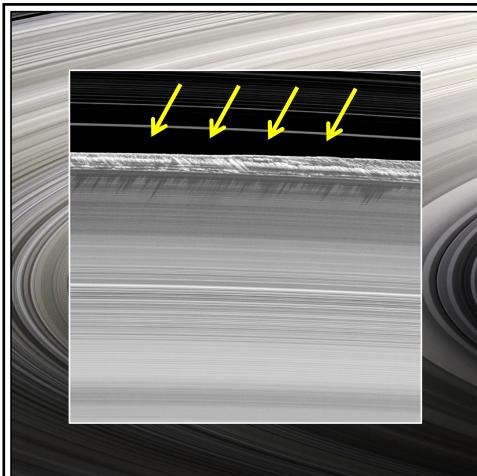


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Saturn's Rings

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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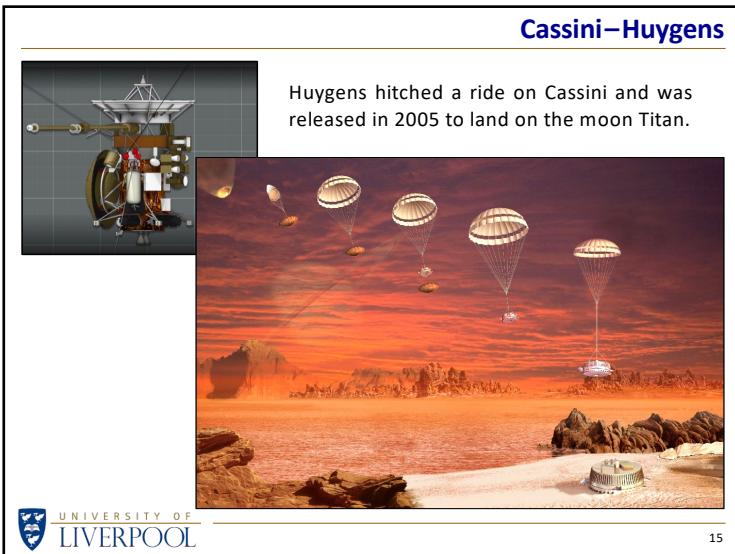


Saturn

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



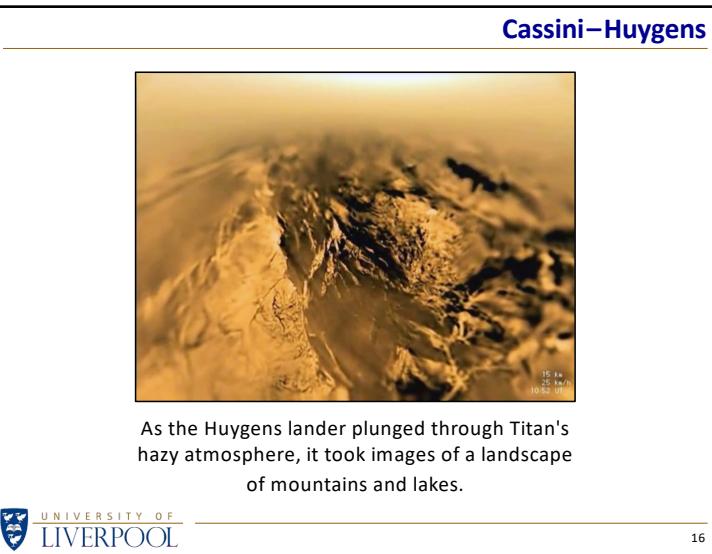
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Cassini–Huygens

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

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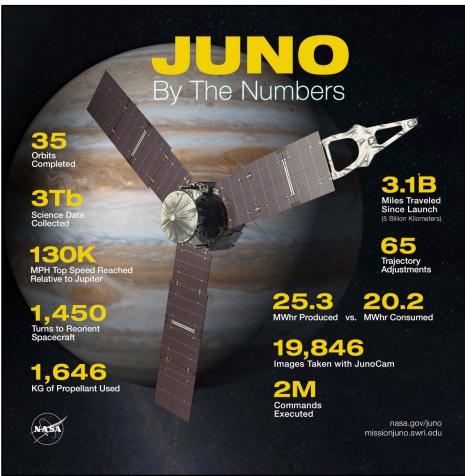


Cassini–Huygens

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.

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 missionjuno.swri.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.

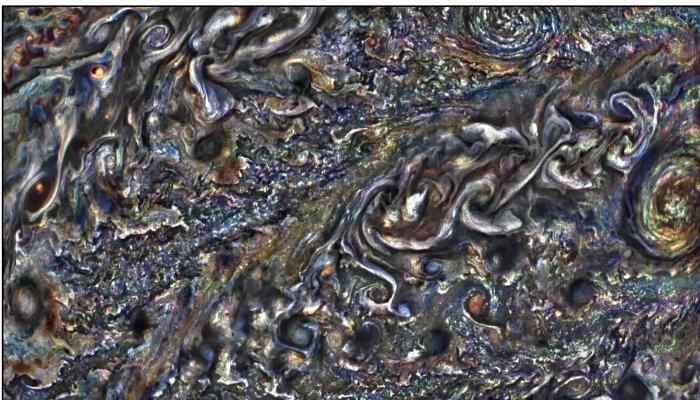
The dark spot is a deep vortex of swirling clouds, imaged when Juno passed only 15,000 km above the cloud tops.

NASA/JPL-Caltech/SWRI/MSSS
Stu Serafin/Sébastien Doran

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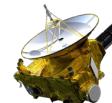
Storms On Jupiter



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Solar System

The Solar System is not just the Sun and 8 planets



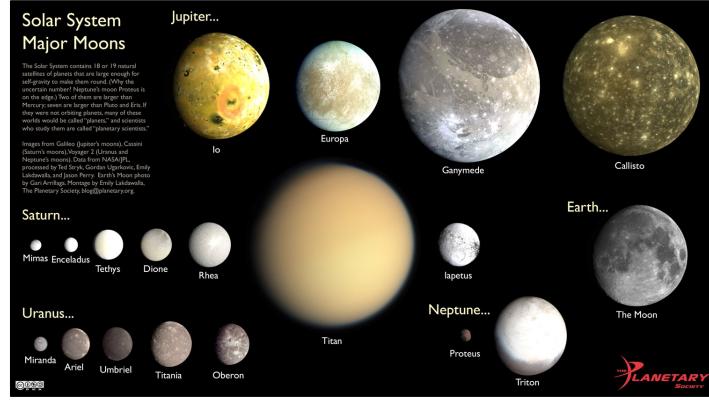
New Horizons is exploring beyond Pluto

There are also over 300 moons!



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300+ Moons



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Future Missions



Juice



Europa Clipper

Solar System Major Moons



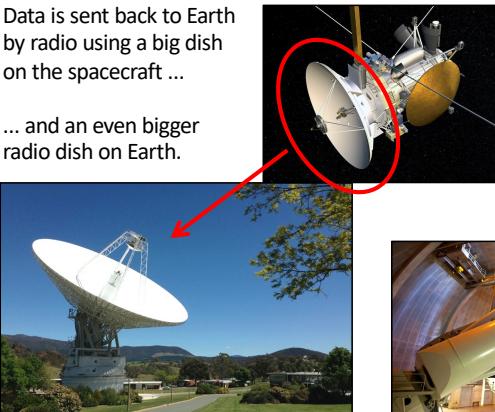
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Future Communications

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

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



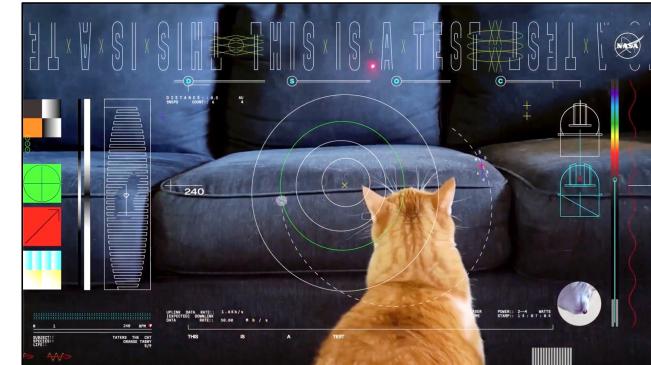
Lasers would provide faster transmission and need less power.



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Future Communications



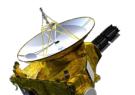
Laser data rates: 260 Mb/s at a distance of 50 million km
8 Mb/s at a distance of 400 million km

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Want To Know More?

ESA.int/Science_Exploration/Space_Science/BepiColombo 

science.NASA.gov/mission/new-horizons 

ESA.int/Science_Exploration/Space_Science/Juice 

science.NASA.gov/mission/cassini 

science.NASA.gov/mission/juno 

science.NASA.gov/mission/europa-clipper 

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