Exploring the Solar System: all about spacecraft/spaceflight

I. How can we explore the Solar System?
- types of space missions

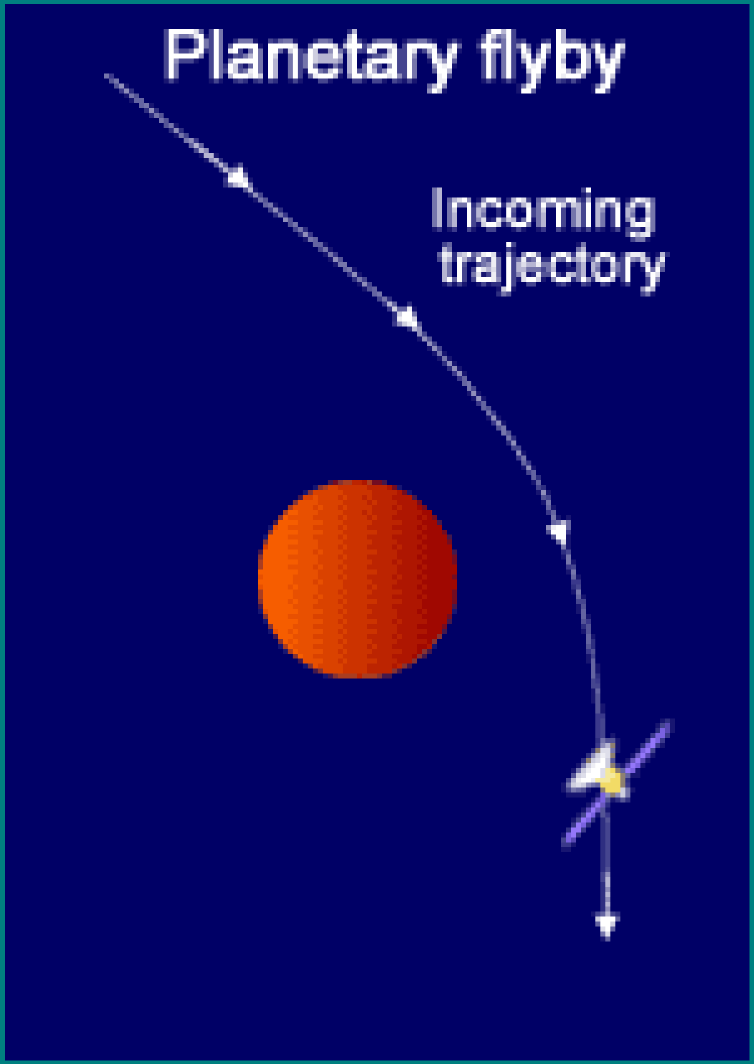
II. How do we get there?
- launch & orbits
- gravity assist
- fuel/propulsion

III. Onboard Systems
- everything but the kitchen sink…

1. Flyby Missions

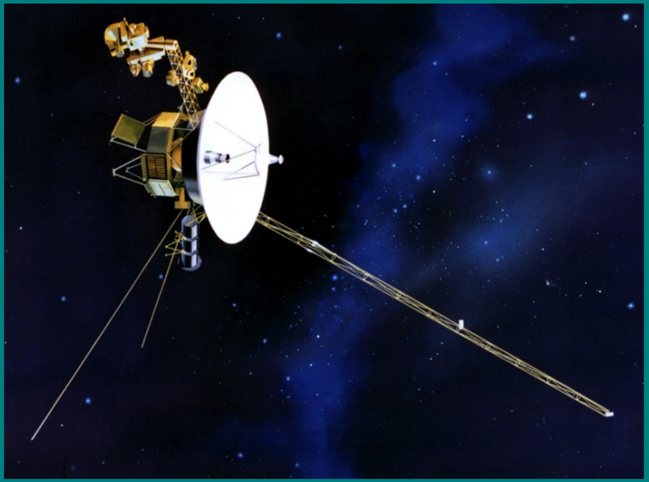
• usually the first phase of exploration
(remember Mars & Mariner 4?)

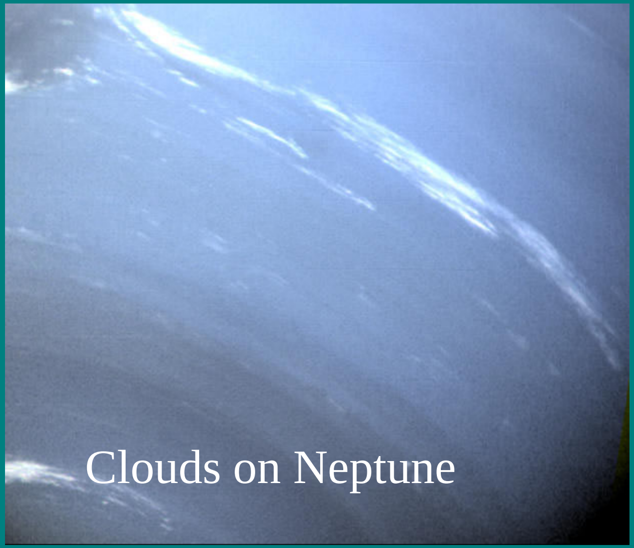
• spacecraft following continuous orbit
- around the Sun
- escape trajectory
(heading off into deep space)



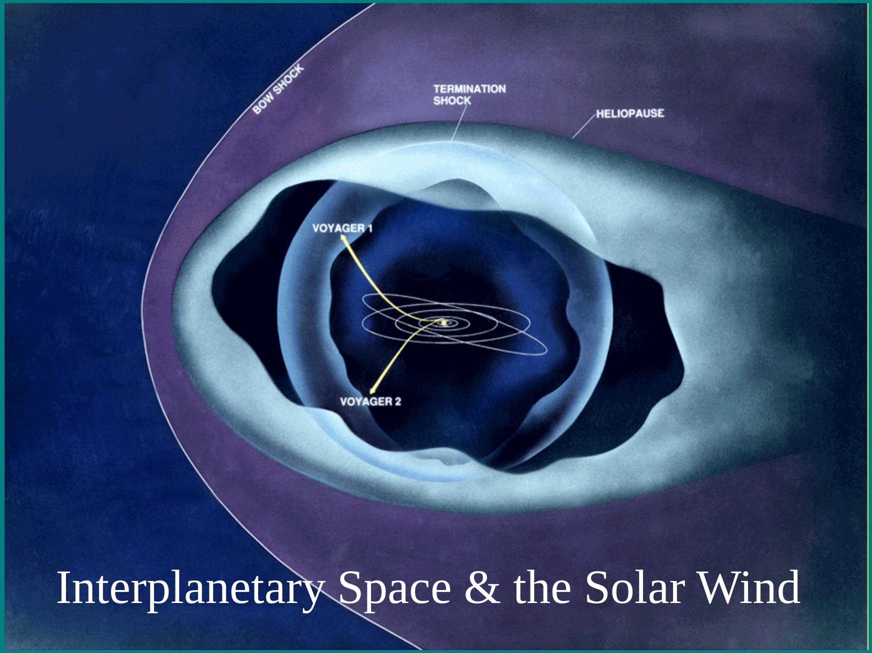
Famous Example: VOYAGER 2

- launch 1977 with VOYAGER 1
- flew by Jupiter in 1979
- Saturn in 1980/1981
- Uranus (V2) in 1986
- Neptune in 1989
- will continue to interstellar space
- study of interplanetary space particles (Van Allen)
- data expected until 2020





Clouds on Neptune



Interplanetary Space & the Solar Wind

Other Flyby examples:

Underway: Stardust Comet return mission

- launched in 1999
- interstellar dust collection
- asteroid Annefrank flyby
- Comet encounter (Jan 2004)
- Earth/sample return (Jan 2006)

Future flyby: Pluto-Kuiper Belt Mission

- to be launched in January 2006

- swing by Jupiter (gravity assist*)

- fly by Pluto & moon Charon in 2015

- then head into Kuiper Belt region
(tons of solar system debris)

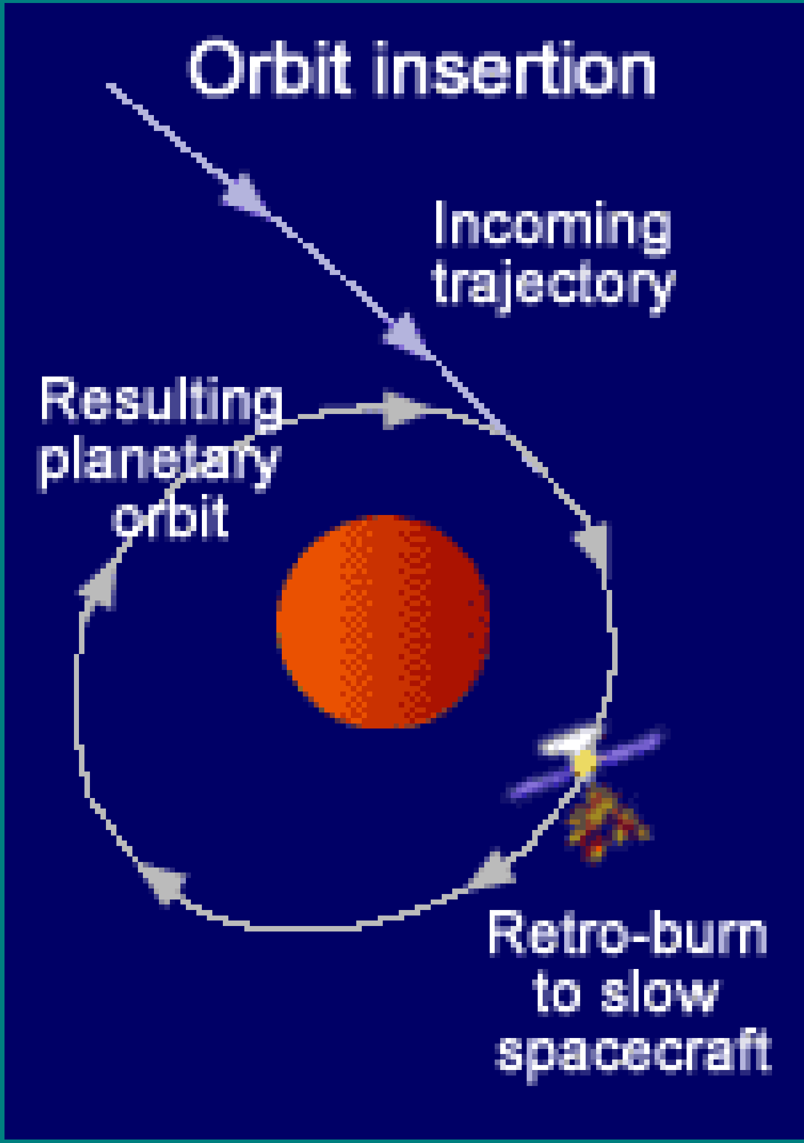
- to study objects that are like Pluto

2. Orbiter Spacecraft

• designed to travel to distant planet & enter into orbit around planet

• must carry substantial propulsion (fuel) capacity has to withstand:
- *staying in the 'dark' for periods of time*
- *extreme thermal variations*
- *staying out of touch with Earth for periods of time*

• usually the second phase of exploration



Famous Example: Galileo

- why would a mission to Jupiter be called Galileo?
- launched in 1989 aboard Atlantis Space Shuttle
- entered into Jupiter’s orbit in 1995
- highly successful study of Jupiter & its moons

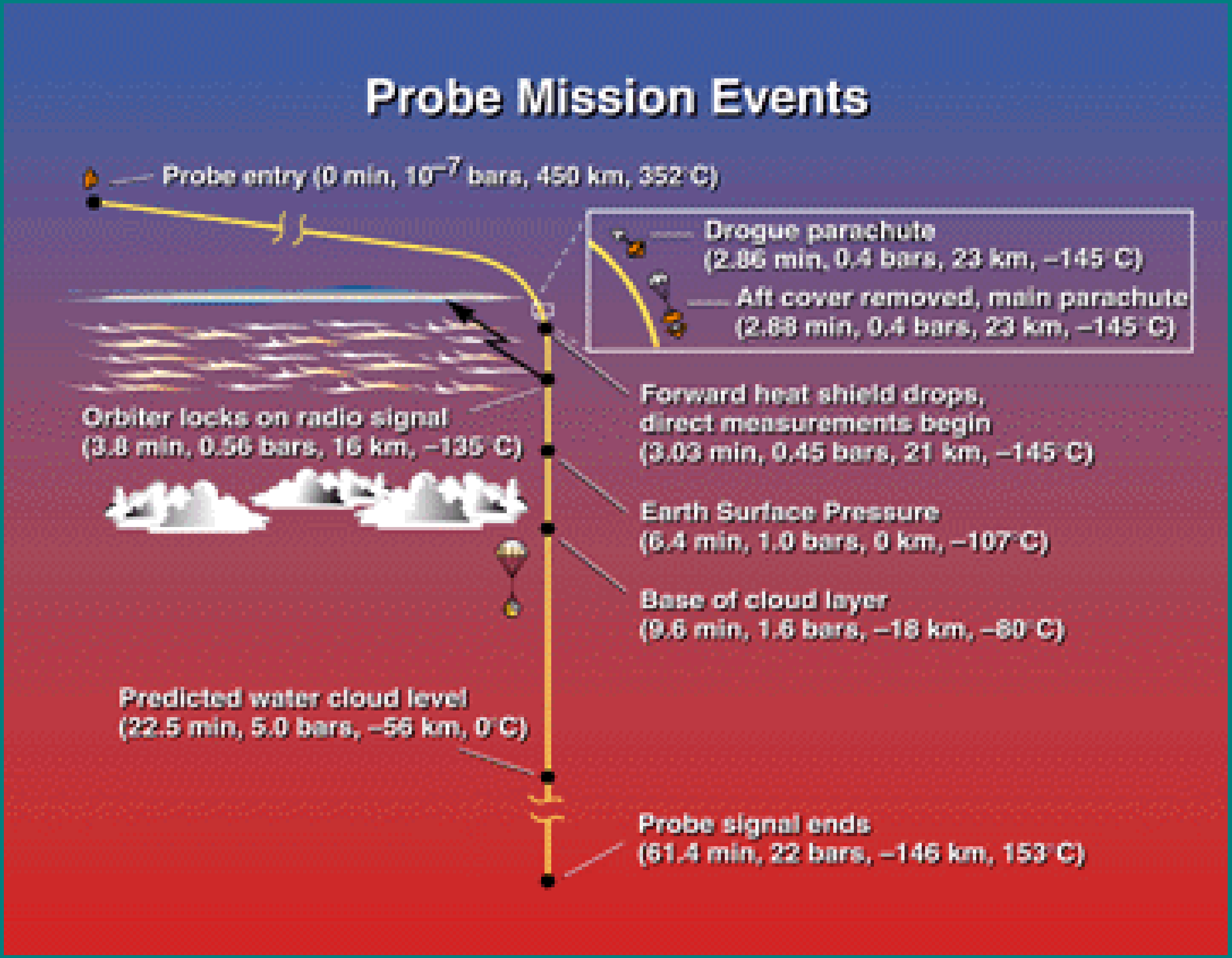
3. Atmospheric Spacecraft

- relatively short mission
- collect data about the atmosphere of a planet or planet’s moon
- usually piggy back on a bigger craft
- needs no propulsion of its own
- takes direct measurements of atmosphere
- usually is destroyed; rest of spacecraft continues its mission

Example:
Galileo’s atmospheric probe

Example: Galileo's atmospheric probe

- traveled with Galileo for nearly six years
- took five months from release to contact with atmosphere
- collected 1 hour's data IN Jupiter's atmosphere



4. Lander Spacecraft

- designed to reach surface of a planet/body
- survive long enough to transmit data back to Earth
- small, chemical experiments possible

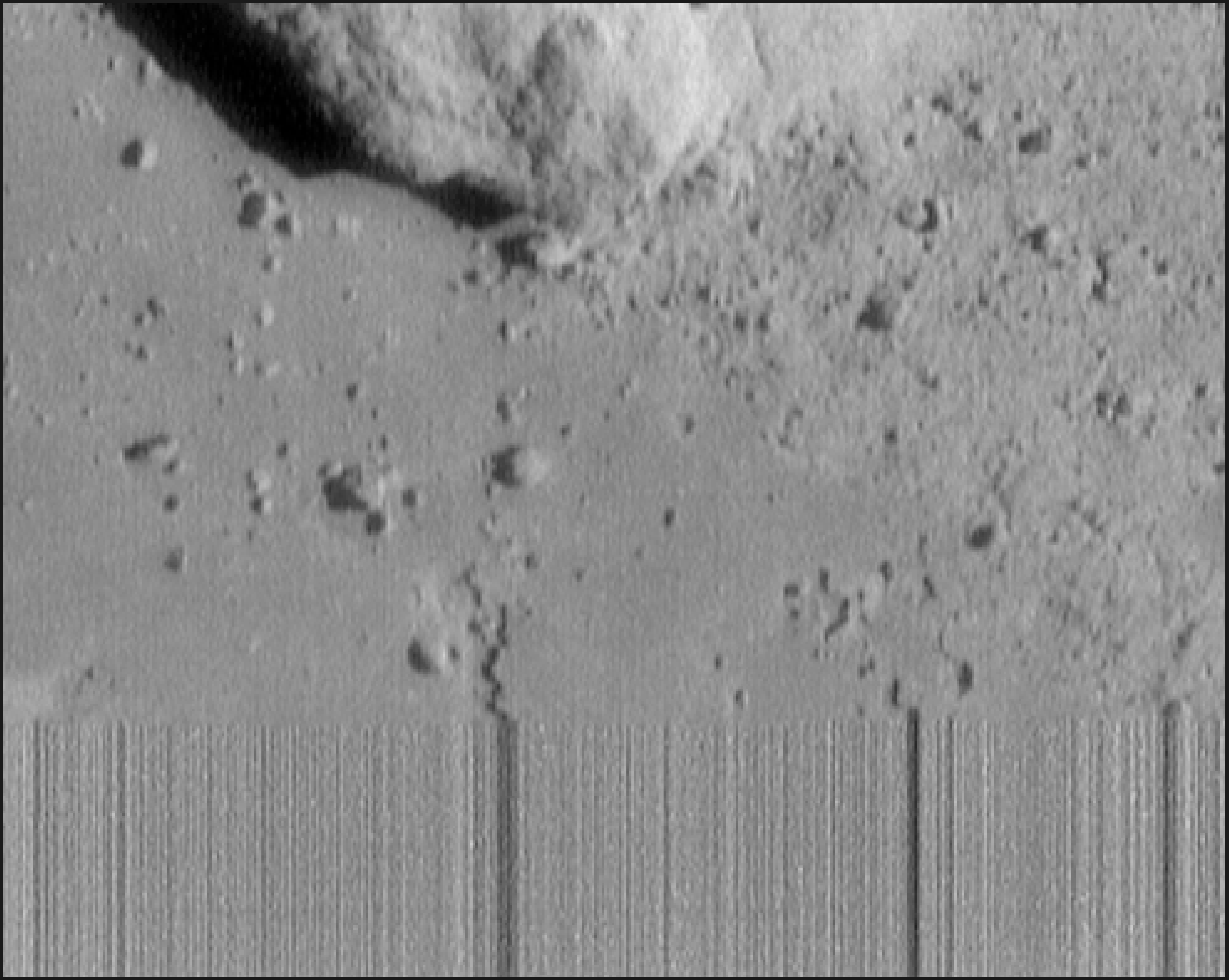
Many Successful Examples:

- Mars Viking Landers
- Venus Lander
- Moon Landers
  (with humans!)

Example: NEAR Asteroid Rendevous Mission

fly to a nearby asteroid: Eros – 1-2 AU orbit around Sun

Near-Earth Asteroid Eros ~ twice size of NYC



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5. Penetrator Spacecraft

- designed to penetrate the surface of a planet/body
- must survive the impact of many times the gravity on Earth
- measure properties of impacted surface

No Currently Successful Examples:

- Deep Space 2 (lost with Mars Polar Lander)

But more to come in future:

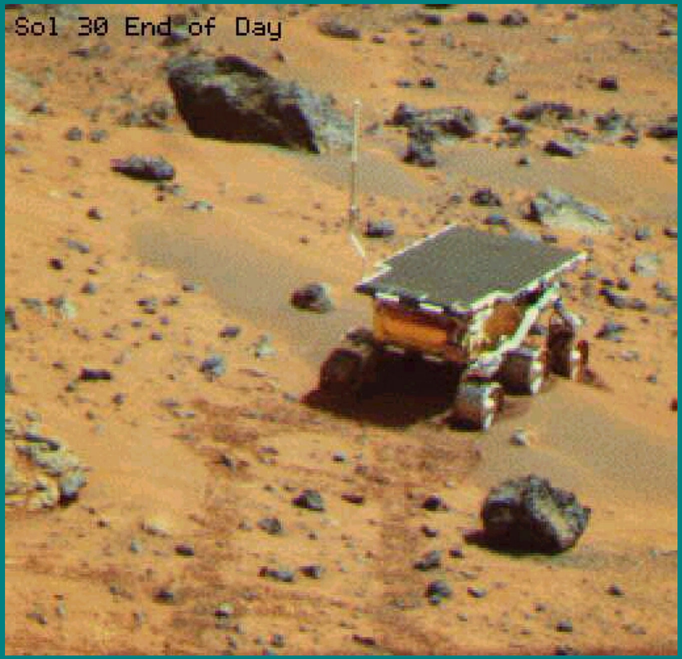
- “Ice Pick” Mission to Jupiter’s Moon Europa
- “Deep Impact” Mission to a Comet

A JPL proposal for a Europan ocean explorer

6. Rover Spacecraft

- electrically powered, mobile rovers
- mainly designed for exploration of Mars' surface
- purposes: taking/analyzing samples with possibility of return
- *Pathfinder* was test mission – now being heavily developed

Mars Pathfinder

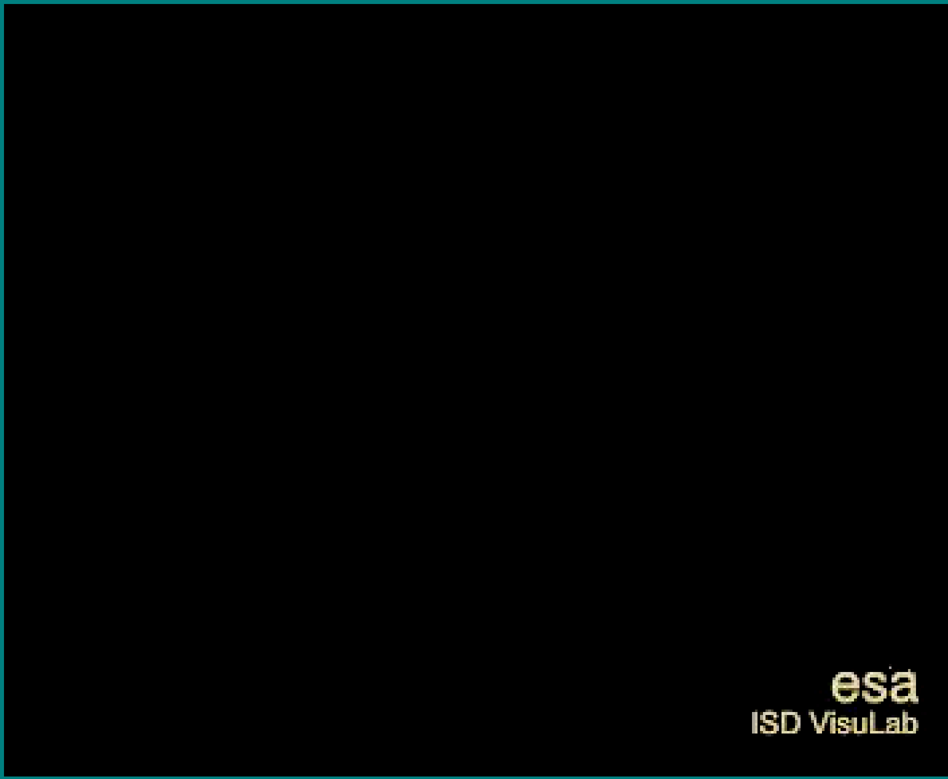


Mars Exploration Rovers

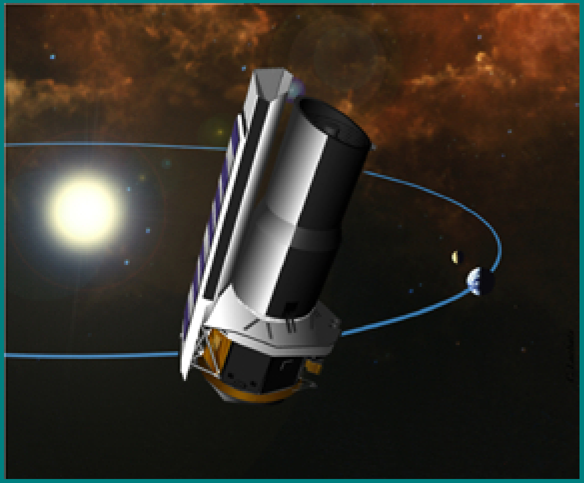
7. Observatory Spacecraft

- in Earth orbit (or at Lagrange points)
- NASA's "Great Observatories":
    - *Hubble (visible)*
    - *Chandra (X-ray)*
    - *SIRTF (infrared)*
    - *Compton (gamma-rays)*
- Large, complex scientific instruments
    - *up to 10-20 instruments on board*
- designed to last > 5-10 years

SOHO



SIRTF (near-IR)



Chandra (X-ray)

How do we get there?

using LEAST amount of fuel – saves big $$$ to be light

1. First must leave the Earth's surface

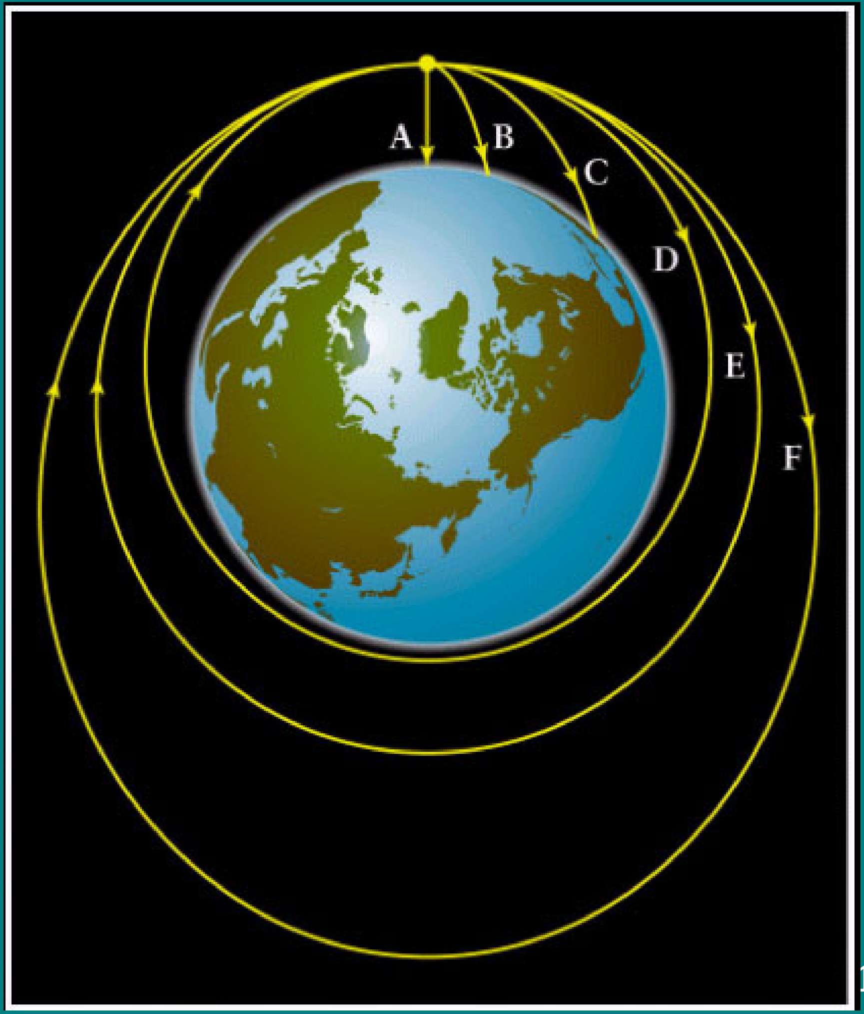
- must 'escape' into orbit

- gets an initial boost via rocket to go into Earth's orbit – needs an acceleration of 5 miles/sec

- during orbit, you sometimes need to adjust height of orbit by increasing/decreasing energy:

- practically: firing onboard rocket thrusters

- a speed of 19,000 miles/hr will keep craft in orbit around Earth



How do we get there?

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2. To get to an outer orbit: Mars

- spacecraft already in orbit (around Sun)

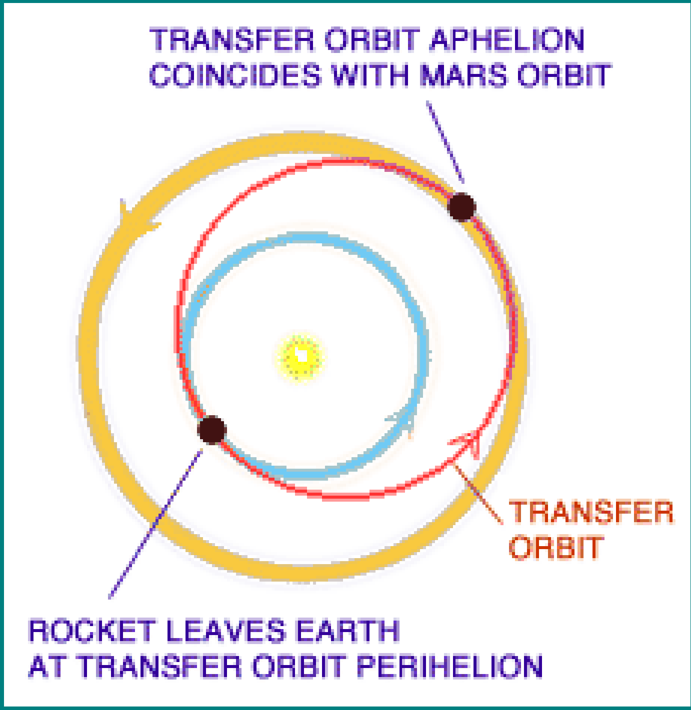
- need to adjust the orbit – boost via rocket – so that the spacecraft gets transferred from Earth's orbit around Sun to Mars' orbit around Sun

- but you want spacecraft to intercept Mars on Mars' orbit

- matter of timing: small window every 26 months

- to be captured by Mars – must decelerate

- to LAND on Mars – must decelerate further & use braking mechanism



How do we get there?

using LEAST amount of fuel – saves big $$$ to be light

3. To get to an inner orbit: Venus

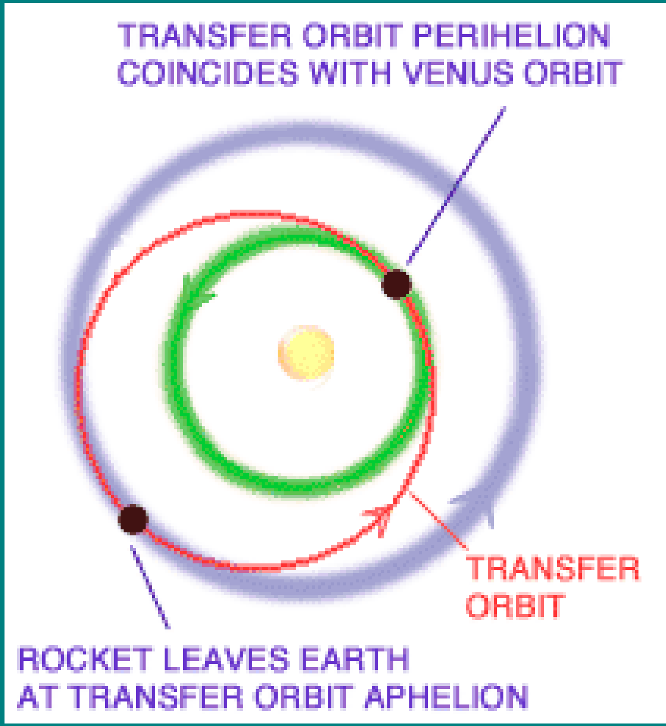
- spacecraft already in orbit (around Sun) on Earth

- need to adjust the orbit once off Earth to head inwards to Venus

- instead of SLOWING down (you'd fall to Earth), you use reverse motion in your solar orbit, effectively slowing down to land on Venus' orbit

- but you want spacecraft to intercept Venus on Venus' orbit

- matter of timing: small window every 19 months



How do we get there?

using LEAST amount of fuel – saves big $$$ to be light

4. Gravity Assist

- can use the law of gravity to help spacecraft propel themselves further out in the SS

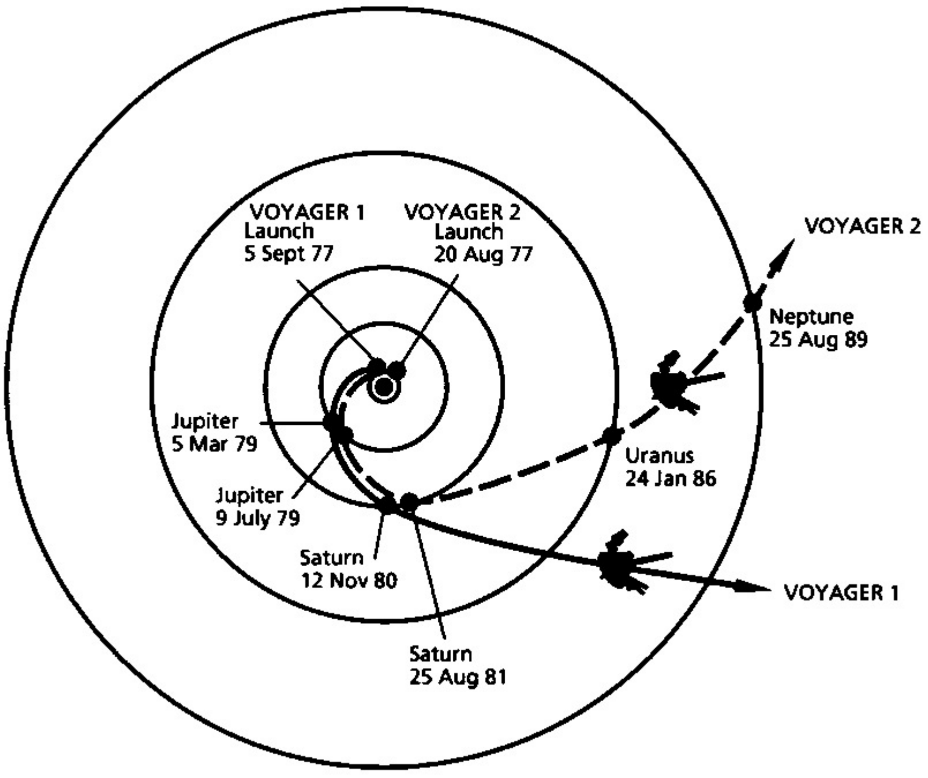
- Voyager: its trajectory was aimed at getting to Jupiter's orbit just after Jupiter

- Voyager was gravitationally attracted to Jupiter, and fell in towards Jupiter

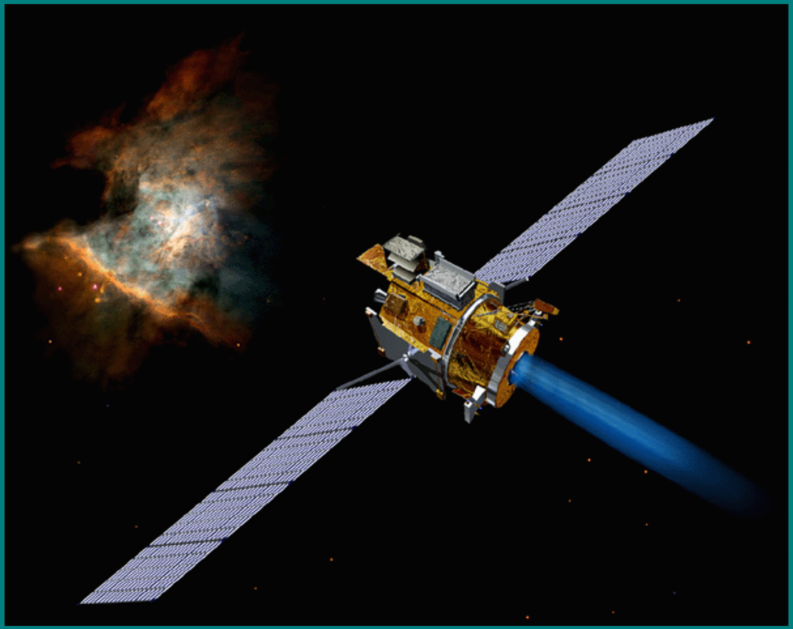
- Jupiter was "tugged on" by Voyager and its orbital energy decreased slightly

-then Voyager had more energy than was needed to stay in orbit around Jupiter, and was propelled outward!

- repeated at Saturn & Uranus



At what speeds are these things traveling through space?



The currently fastest spacecraft speeds are around **20 km per second** (72,000 km per/hr)

For example, *Voyager 1* is now moving outwards from the solar system at a speed of 16 km per second. At this rate, it would take 85,000 years to reach the nearest star -3,000 human generations!

Even assuming that we could reach a speed of 1/10th of the velocity of light, it would still take **a minimum of 40 years** or so to reach our nearest star.

How do we get there?

using LEAST amount of fuel – saves big $$$ to be light

5. Concerns about energy sources

- traditional energy boost: chemical thrusters

- most of energy is provided on launch – very costly! especially for large, heavy, complex instruments

- a few times per year spacecraft fires short bursts from its thrusters to make adjustments

- mostly free falling in orbit, coasting to destination

How do we get there?

using LEAST amount of fuel – saves big $$$ to be light

5. The Future: Ion Propulsion

- Xenon atoms are made of protons (+) and electrons (-)

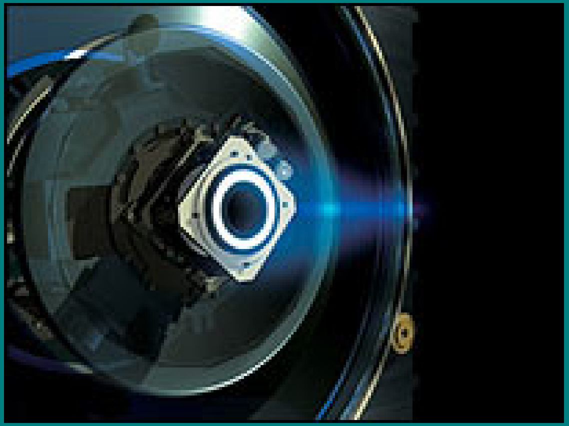
- bombard a gas with electrons (-) to change charge

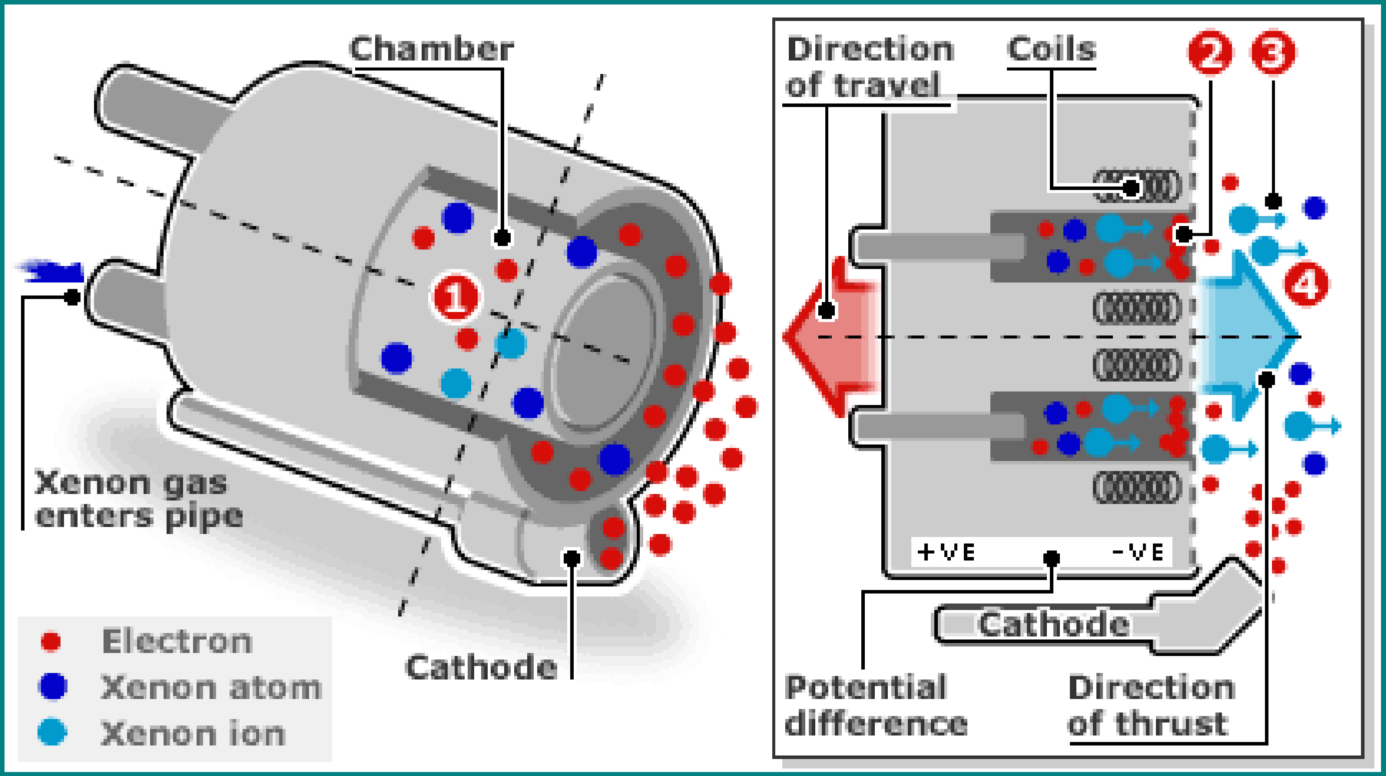
- creates a build up of IONS (+)

- use magnetic field to direct charged particles

- the IONS are accelerated out the back of craft

- this pushes the craft in the opposite direction



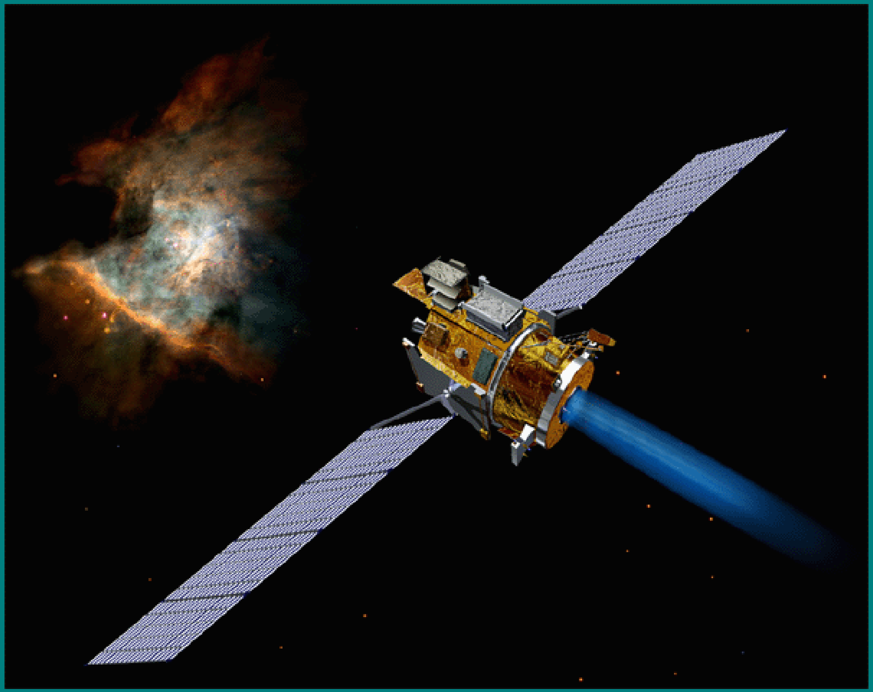


- to operate the ion system, use SOLAR panels
- sometimes called solar-electric propulsion
- can push a spacecraft up to 10x that of chemical propulsion
- very gentle – best for slow accelerations

HISTORY of ION PROPULSION

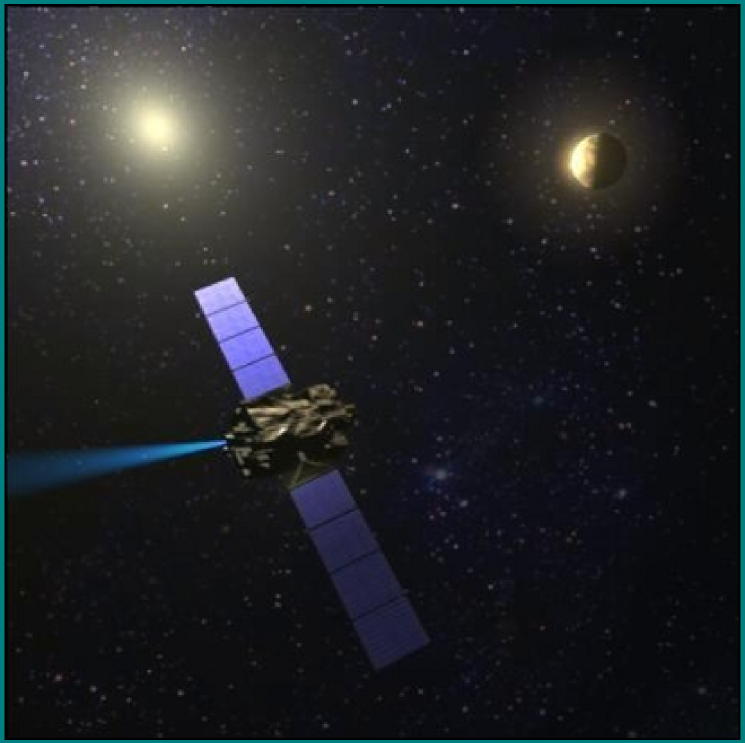
- first ion propulsion engine – built in 1960
- over 50 years in design/development at NASA
- very new technology
- has been used successfully on test mission:

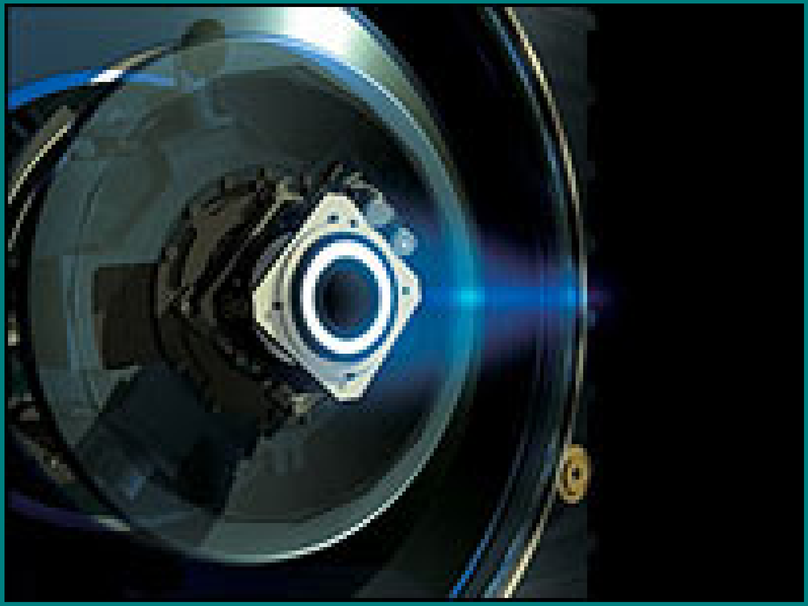
Deep Space 1



Europe's Lunar Explorer: Smart 1 Probe

- launched 27 September 2003 (Saturday)
- 2-2.5 year mission
- will study lunar geochemistry
- search for ice at south Lunar pole
- ***testing/proving of ion propulsion drives!***





LEO satellite
160 – 1600 km

MEO satellite
10,000 – 20,000 km

GEO satellite
35,786 km above Earth