# SMART-1
# A new technological step forward

Being in the forefront of the technological evolution requires a long-term plan. Space-related activities are needed too. To secure adequate preparation for the large future space research such as Bepi-Colombo and LISA, it is necessary to develop new technology. One such technology is an effective and reliable propulsion system for space probes. SMART-1 (Small Mission for Advanced Research and Technology) is the first of ESA's technological missions to test new technology in space. SMART-1 has the moon as a target and the main task is to test the electric propulsion. Additionally, the mission plans to test other techniques as well, and not least, provide substantially extensive information about our alleged neighbours in space.

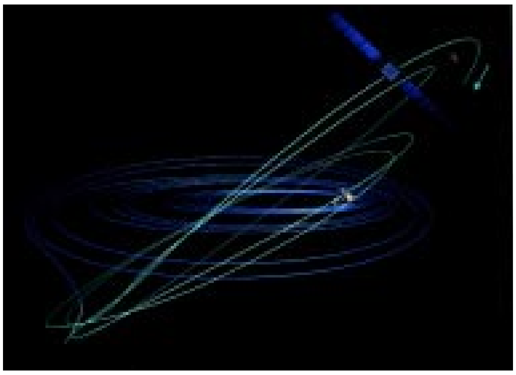
SMART-1 is to some extent very unlike previous missions to the moon. Previous spacecrafts have reached the moon in a matter of some days after launch; however, SMART-1 is going to spend 16-18 months on the journey. The effects from the sun and the moon's gravitation forces will move it slowly and steadily towards the moon in an environmental way. Not as a dead body, but as a very well equipped scientific laboratory which will spend the time travelling to provide the space community with new information, both about the technological experiments onboard, about the moon, and about the space between us and our neighbour.

### The road to the Moon

The principle for the ion engine that is going to run SMART-1 was discovered back in 1879, however, the effect is very weak, and the areas used on earth is limited. However, as a propulsion system for satellites the engine has proved itself very useful and might possibly make the basis for future missions to very distant celestial bodies.

Drawing electric power of 1350 watts from SMART-1's solar panels, the ion engine generates a thrust of 0.07 Newton, something that is equivalent to the weight of a postcard. By accelerating SMART-1 at 0.2 millimetres pr second, the incredibly gentle thrust could in theory fling the spacecraft right out of the solar system, if sustained for long enough. In practice, SMART-1 will use its ion engine intermittently over 16 months, fighting against the earth's attraction, to put itself into orbit around the moon. The launcher will put SMART-1 into an elliptical orbit around earth. Under the control of ESA's operation centre two days per week, repeated burns of the ion engine will change the ellipse into a circle and gradually expand it into a spiral.

The moon revolves the earth at a distance of 350-400 000 kilometres. When 200 000 kilometres from earth the spacecraft will begin to feel significant gravitational tugs from the moon. Mission controllers then have to inaugurate a new era of space navigation. For the very first time they will use the sustained thrust of electrical propulsion jointly with manoeuvres under gravity. The tug of the moon's gravity will at first help to widen the spiral orbit, in regular encounters called "lunar resonances". When the Smart-1 passes within 60 000 kilometres of the moon, the effect of gravity will be much more pronounced, in encounters known as "lunar swingbys".



**SMART-1 first orbits the Earth in ever-increasing ellipses. When it reaches the Moon, its orbit is altered by the Moon's gravitational field. It uses a number of these 'graviatational assists' to position itself for entering orbit around the Moon.**
Illustration by AEOS Medialab, ESA 2002.

A crucial stage in the journey, called "lunar capture", SMART-1 will pass through an invisible doorway in space at Lagrange point No. 1, or L1 for short. As first noted by the mathematician Joseph-Louis Lagrange in 1772, the gravitational effects of the moon and the earth are in balance at L1, 50 000 to 60 000 out from the moon at the earthward side. Beyond L1, SMART-1 will fly over the lunar North Pole, aiming at a point of closest approximation above the South Pole, thus achieving a wider polar orbit around the moon. During the weeks that follow its capture by the moon, SMART-1's ion engine will gradually reduce the size and duration of this orbit, to improve the view of the lunar surface.

## The spacecraft and the instruments.

SMART-1 spans 14 metres with its solar panels extended, and has a total mass of 370 kilograms, but otherwise everything for propulsion, communications, housekeeping and instrumentation fits into a cube just 1 metre across. Propulsion by an ion engine is not the only innovative technology on SMART-1. Its solar panels use an advanced type of gallium-arsenide solar cell in preference to the traditional silicon cells, and it will also test new communications and navigational techniques. Miniaturization is a red thread in the development and the scientific instruments only weigh 19 kilograms.

## SMART Experiments

**AMIE**
Asteroid Moon Imaging Experiment. Miniaturised CCD camera.

**LaserLink**
Demonstration of a deep-space laser link with ESA Optical Ground Station.

**OBAN**
Validation of On-Board Autonomous Navigation algorithm. Ground demonstration only.

**SPEDE**
Spacecraft Potential, Electron & Dust Experiment.

**EPDP**
Electric Propulsion Diagnostics Package for monitoring the EP; plasma environment characterisation.

**RSIS**
Radio-Science Investigation System monitors the Electric Propulsion, using KATE and AMIE.

**SIR**
Smart-1 IR Spectrometer. Miniaturised 256-chanel near IR (0.9-2.4 mm) grating spectrometer for lunar surface mineralogy studies.

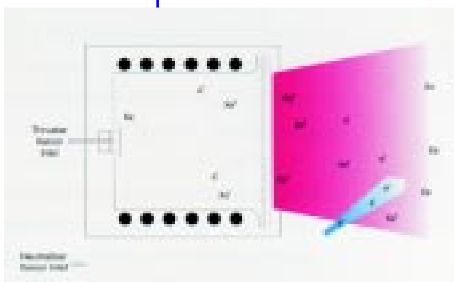
**D-CIXS/XSM**
Demonstration Compact Imaging X-ray Spectrometer for lunar rock-forming minerals via X-ray fluorescence.

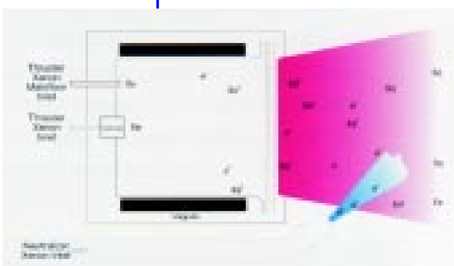
**KATE**
Ka-band TT&C Experiment, demonstrates X-band + Ka-band telecommunications from lunar orbit.

## Electric Propulsion

There are two ways in which a space probe can be sent to another celestial body. Either by means of brutal power, large consumption of fuel, large speed and short travel represented by the well-known chemical engines, or alternatively, by means of weak engine power, low consumption of fuel, but with long travel time represented among others by means of electric propulsion. The large consumption of fuel to bring space probes out of the Earth's gravitation field requires quite large launchers in order to secure adequate amounts of fuel for the transfer orbit. In the work to find more fuel-friendly propulsion systems, electric propulsion seems the most suitable and the most acknowledged technique today.

This is a technique ESA wishes to use in future missions such as Bepi-Colombo and LISA. As a part of the development of a final propulsion system for these missions, ESA wishes to try out the technique in a technical mission. The task for SMART-1 is therefore a test and verification of electric propulsion even if the probe tests other techniques and carries out scientific work, both on the way to the Moon and later in the final orbit.





**The working principles of two different types of electromagnetic thrusters.**
Figure: ESA.

Electric propulsion offers several advantages; it is safer and more efficient than chemical ones, and it requires much less propellant to produce the same overall effects. The propellant is ejected up to twenty times faster than classical thrusters and therefore the same overall effect. The only down side is that chemical engines can eject massive amounts of propellant, while electric thrusters work with very small flows, so they can push the spacecraft very gently compared to chemical systems. However, the engine can burn for months, even years, and for interplanetary missions the target can be reached more quickly than with chemical propulsion.

**Test firing of the ion engine in the laboratory.**
Photo ESA.

Today the technique is mainly used in accurate positioning of satellites, e.g. geostationary satellites. These types of thrusters can save more than 20% of the initial launch mass.