# NASA Facts

National Aeronautics and
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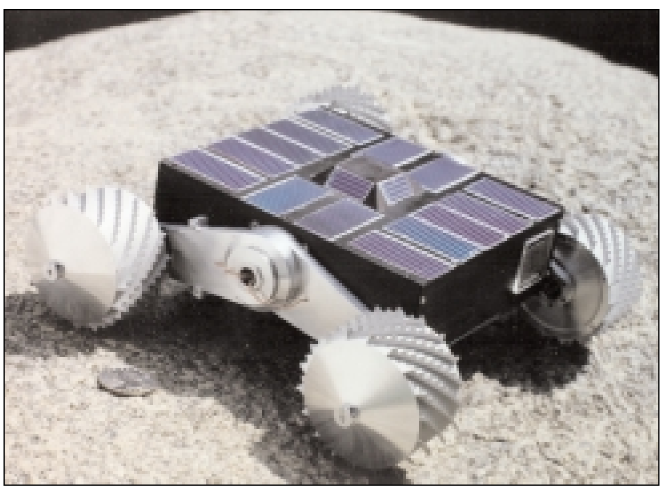
# MUSES-CN Asteroid Rover

The small near-Earth asteroid 1998 SF36 is the target of a Japanese spacecraft mission that will acquire a sample of the asteroid and return it to Earth for analysis. The spacecraft will carry a NASA-supplied miniature rover which will explore the surface and gather photos of the terrain.

The mission, called MUSES-C, is scheduled for launch from Kagoshima, Japan on a Japanese M5 rocket in November or December 2002. The MUSES-C mission is a collaboration between the Japanese Institute of Space and Astronautical Science (ISAS) and NASA.



The international effort represents the world's first asteroid sample return mission, and will also provide the first spaceflight demonstration of several new technologies. "MUSES-C" stands for Mu Space Engineering Spacecraft (the "C" signifies that it is the third in a series). It is part of a series of flight technology and science missions managed by (ISAS). NASA's Jet Propulsion Laboratory in Pasadena, California is managing the U.S. portion of the mission which is called MUSES-CN (N for NASA).

The MUSES-C spacecraft, sample-return vehicle and M5 launcher are provided by Japan's Institute of Space and Astronautical Science (ISAS). NASA, via the JPL MUSES-CN project, is providing the rover and various support services for the ISAS mission. The spacecraft, rover and sample-return vehicle will be combined as one package for flight to the asteroid.

**Asteroid Science**

Asteroids can vary in diameter from less than two kilometers (one mile) to nearly 1,000 kilometers (about 600 miles). Many of the asteroids we see today were once part of much larger asteroids that had metallic cores, stone-iron middle regions and stony surface regions. When these larger asteroids collided, the smaller asteroid fragments that we see today were born. As a result, many asteroids are currently classified as irons, stony-irons and stony.

Objects like 1998 SF36 are relatively unaltered since the planets of the inner solar system (including Earth) formed by the coalescing of millions of smaller asteroids. By studying the structure and chemical composition of primitive objects, scientists can discern clues as to Earth's initial chemical composition and the conditions under which it formed some 4.6 billion years ago.

Asteroid 1998 SF36, whose orbital period is about 1.5 years, will closely approach the Earth to within 4 million miles on March 29,2001 and to within 1.3 million miles on June 25, 2004. Extensive observing campaigns will be planned near these close approach times to determine this asteroid's approximate size, shape, rotation state, and some surface characteristics. The asteroid has been estimated to be wbetween .5 and 1.2 kn in diameter, according to calculations made from studying its albedo. Due to the presumed very faint gravity, one engineering challenge is designing the MUSES-C spacecraft and rover to safely perform their duties on the asteroid's surface.

**Mission Overview**

After launch, the MUSES-C spacecraft will use solar electric propulsion to travel to the asteroid – a trip that will take 17 months. Solar electric propulsion produces only a tiny amount of thrust, roughly equivalent to the pressure of a single sheet of paper held in the palm of the hand. Its magic lies in its staying power. This low thrust slowly builds up the spacecraft's velocity over time, bringing it from low to high speed and making it ideal for long missions. The actual thrust comes from electrically accelerating and expelling the positively charged atoms, called ions, which are fired out of four thrusters at more than 108,000 kilometers per hour (68,000 miles per hour). This produces a minute, but effective, thrust of only 120 millinewtons (27 thousandths of a pound) to drive the spacecraft forward.

The spacecraft will arrive at the asteroid in September 2005, and the solar electric propulsion system will be used to rendezvous with 1998 SF36. The spacecraft will hover about 20 kilometers above the surface and perform mapping and other measurements of the asteroid's surface. After about one month, the spacecraft will descend to the surface using small rocket engines for control.

Just before touchdown, the spacecraft will drop the U.S.-built MUSES-CN rover onto the surface. At the moment of touchdown the Japanese MUSES-C spacecraft will fire a small pellet into the asteroid, collecting ejecta thrown off through an inverted funnel and storing it in the sample-return capsule onboard. Plans call for a few different samples to be taken using this method and stored in a sample capsule for return to Earth.

The rover is referred to as a "nanorover" because of its extraordinarily small size, which takes advantage of robotics technologies under development at JPL. It will be the smallest rover ever to fly on a space mission. The diminutive robot fits in the palm of a hand and has a mass of about 1.2 kilogram (2.2 pounds). It is equipped with instruments that observe in both the visual and near-infrared wavelengths; in addition, it will provide information on the elemental composition of the asteroid's surface.

With minor modification, the MUSES-CN rover prototype is being designed to allow operation of nanorovers at targets other than 1998 SF36, such as comet nuclei, moons around other planets and on Mars.

The rover's task will be to move around the surface of the asteroid collecting images. The imaging system can measure surface texture, composition and morphology with spatial resolution better than 1 millimeter (1/25th of one inch). The rover will transmit these data to the spacecraft for relay back to Earth. The rover camera can be focused to take panoramic shots as well as microscopic images.

Solar cells will be placed on all sides of the rover so that even if it flips over on the asteroid's low-gravity surface, the rover will always have enough power to activate motors that will allow it to right itself. Wheel struts will allow the rover to position its chassis such that the camera can be pointed straight down at the surface or straight up at the sky. The rover's prime mission lasts one month.

The MUSES-C spacecraft will stay at 1998 SF36 for about three months before heading back to Earth. Shortly before reentering Earth's atmosphere in June 2007, the sample-return capsule will separate from the spacecraft. The spacecraft itself will be steered away from Earth to avoid an atmospheric reentry. The capsule will descend through Earth's atmosphere, deploy a parachute and land in a vast area in the western United States where it will be retrieved by the MUSES-C team. The samples will be sent to Japan for analysis, with NASA receiving its portion of the samples one year later.

**Science Team**

In June 1999, NASA selected the following science team for the MUSES-CN mission:

- Dr. Faith Vilas of the NASA Johnson Space Center will use the spacecraft's infrared spectrometer to determine the nature of the minerals on the surface of 1998 SF36 by comparing readings that the instrument takes with those obtained in the laboratory from meteorites and terrestrial rocks.
- Dr. David Tholen of the University of Hawaii will use the spacecraft camera to study the asteroid's rotation, and to estimate the asteroid's age, shape and size in addition to other properties such as density.
- Dr. Beth Clark of Cornell University will use the rover camera and infrared spectrometer to study the physical and light-scattering properties of the surface

of 1998 SF36. This will help tell the difference between data that reveals details of the asteroid's chemical composition from data that shows optical effects of the surface.

❑ Dr. Peter Smith of the University of Arizona will use the rover camera to study the surface characteristics of 1998 SF36 in order to understand how the surface and its structures has evolved over time.

❑ Dr. Andrew Cheng of Johns Hopkins University's Applied Physics Laboratory will use the spacecraft lidar instrument to determine the size, shape, mass and rotation of 1998 SF36.

❑ Dr. Michael Zolensky of the NASA Johnson Space Center will participate in the preliminary analysis of the asteroid samples returned to Earth by the MUSES-C spacecraft.

❑ The alpha X-ray spectrometer for the rover, which will be used to determine the chemical composition of many surface rocks, is being supplied by Dr. Thanasis Economou of the University of Chicago.

**Program**

In addition to providing the rover for the mission, the JPL MUSES-CN project will arrange for the testing of the MUSES-C reentry heat shield at NASA's Ames Research Center; arrange for supplemental tracking of the spacecraft by NASA's Deep Space Network; and assist in navigating the spacecraft. U.S. and Japanese scientists will collaborate on the investigations of the returned samples.

This collaboration between the United States and Japan allows the two nations to combine their expertise in achieving science and technology goals in a cost-constrained environment. The U.S. portion of the mission is about $30 million, while Japan is investing 18 billion yen, or about $150 million.

The Institute of Space and Astronautical Science manages the MUSES-C project for Japan's Ministry of Education, Science, Sports and Culture. Prof. Jun'ichiro Kawaguchi is the MUSES-C project manager, and Prof. Akira Fujiwara is the MUSES-C project scientist.

JPL is managing the U.S. contribution to the MUSES-C mission for NASA's Office of Space Science, Washington, DC. Ross M. Jones of JPL is the MUSES-CN project manager, and Dr. Donald K. Yeomans of JPL is the MUSES-CN project scientist. Brian H. Wilcox of JPL created and manages the MUSES-CN rover development.

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