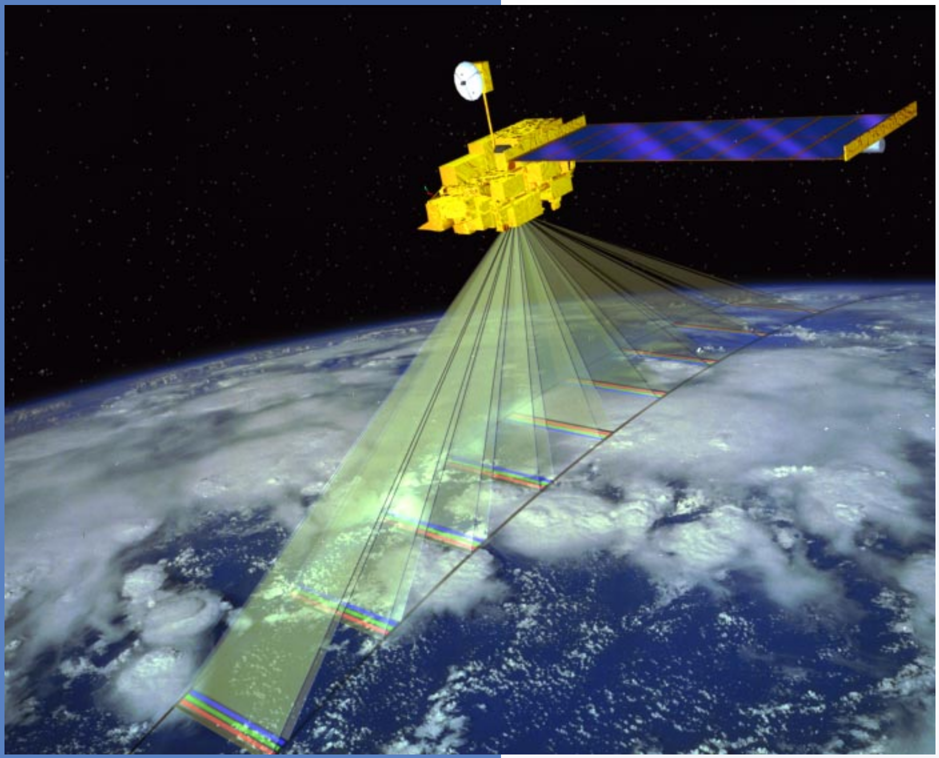
MISR

Multi-angle Imaging Spectro-Radiometer

If Earth were a movie screen, there would be no need for MISR. Movie screens are made of a material that reflects light nearly equally in all directions. So for people sitting in the right, left, and center sections of the theater, the movie looks equally sharp and bright.

But Earth is a more complicated place: its surface, the clouds, even tiny particles floating in the air, each reflect light differently when viewed at different angles. This matters to us because the light being reflected is sunlight, which carries the energy that heats our planet. The ways in which sunlight is scattered — by forests; deserts; snow- and ice-covered surfaces; cumulus, stratus, and cirrus clouds; smoke from forest fires; and soot and other by-products of industry — all affect Earth's climate.



Most satellite instruments look only straight down or toward the edge of the planet. To fully understand Earth's climate, and to determine how it may be changing, we need to know the amount of sunlight that is scattered in different directions under natural conditions. MISR is a new type of instrument that will view Earth with cameras pointed in nine different directions. As the instrument flies overhead, each piece of the planet's surface below will be successively imaged by all nine cameras, in each of four color bands (blue, green, red, and near-infrared).

MISR will fly on the National Aeronautics and Space Administration's (NASA's) first Earth Observing System (EOS) satellite — EOS AM-1 — together with four other instruments designed to study Earth from space. Launch is planned for 1999. The Jet Propulsion Laboratory (JPL) of the California Institute of Technology built the MISR instrument for NASA. JPL, in collaboration with the MISR science team, is also building the software to convert raw MISR data into information that Earth science researchers can use.

M I S R

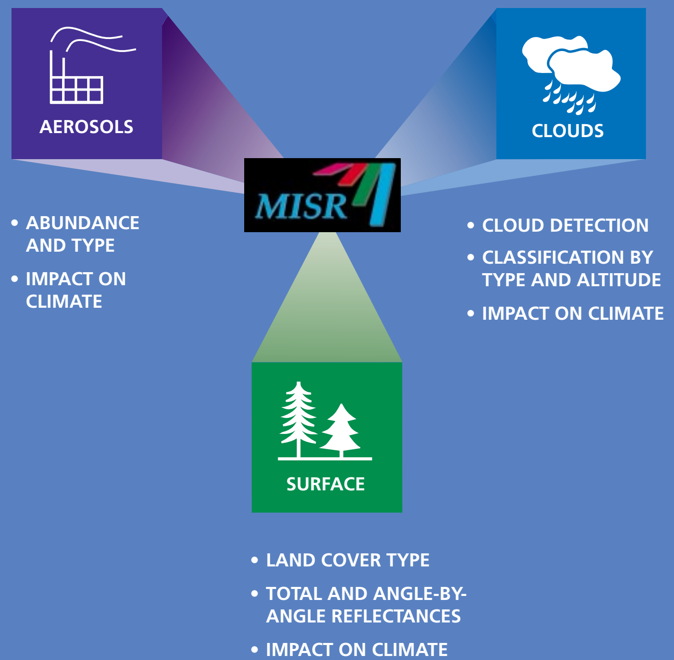
MISR can distinguish different types of clouds, atmospheric particles, and surfaces. Over time, MISR will monitor trends in

- The amount and types of aerosols (tiny particles floating in the air) — those formed by natural processes and by human activity.
- The amounts, types, and heights of clouds.
- The distribution of vegetation types and other land-surface cover.

Aerosols tend to cool the surface below them, because most aerosols are bright particles that reflect sunlight back to space, reducing the amount of sunlight that can be absorbed at the surface. The magnitude of this effect depends on the size and composition of the aerosols, and on the reflecting properties of the underlying surface. Aerosol cooling may partially offset the expected warming due to increases in the amount of atmospheric carbon dioxide from human activity. But key details about aerosol properties needed to calculate even their current effect on surface temperatures are not known. MISR data will make it possible to determine global aerosol amounts with unprecedented accuracy, and to estimate particle size and composition.

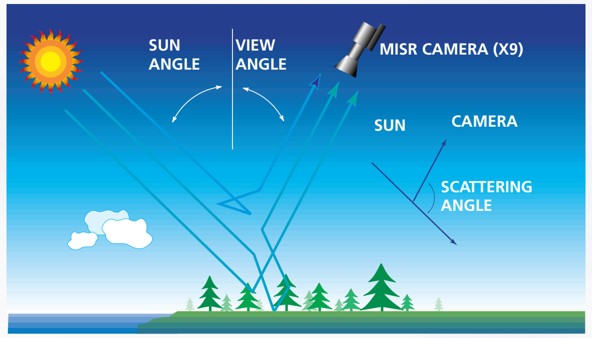
Because they are very common, clouds play a major role in controlling Earth's climate. Clouds may warm or cool the Earth, depending on their thickness and location. Since clouds are so variable, their effect on global climate is difficult to measure — it is currently the leading uncertainty in climate-prediction models. Stereo images from MISR will provide new data about cloud-top heights. The multiangle observations will also yield information about the structure of clouds, the properties of cloud particles, and the way clouds reflect incoming solar energy.

Earth's land surface is constantly changing. There are natural variations, such as the progression of seasons, as well as changes caused by human activities, such as deforestation and desertification in overgrazed regions. And because we care about climate, the amount and manner in which surfaces around the globe reflect sunlight matters to us too. MISR will characterize in detail the reflection properties of Earth's surface. From these observations, we will be able to tell where and how the surface is changing, as well as what effect these changes are likely to have on Earth's climate.



S c i e n c e

Viewing Geometry for a Satellite Camera Looking at Earth



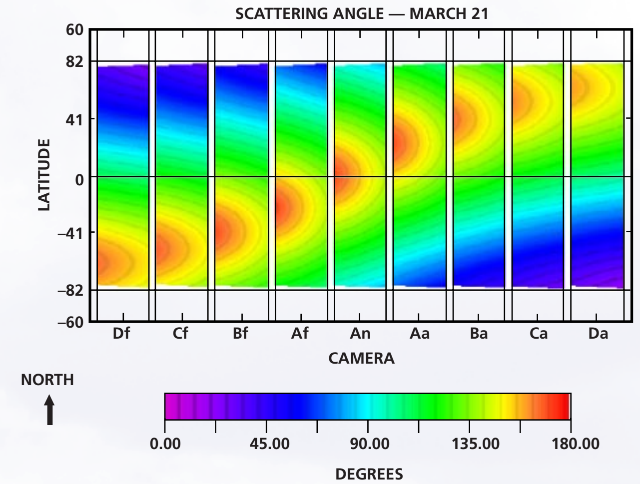
This figure shows how the positions of the Sun, surface, and atmosphere, and any one of the nine MISR cameras, are related. Remember that the true situation is three-dimensional. MISR views Earth at a number of angles simultaneously.

The Range of Scattering Angles Observed by the Nine MISR Cameras

The scattering angle is the angle between the direction of incoming light and the viewing direction. Most of the information about clouds, haze, and dust particles in the air, and much of what remote-sensing instruments can learn about the surface, comes from studying observations taken at different scattering angles.

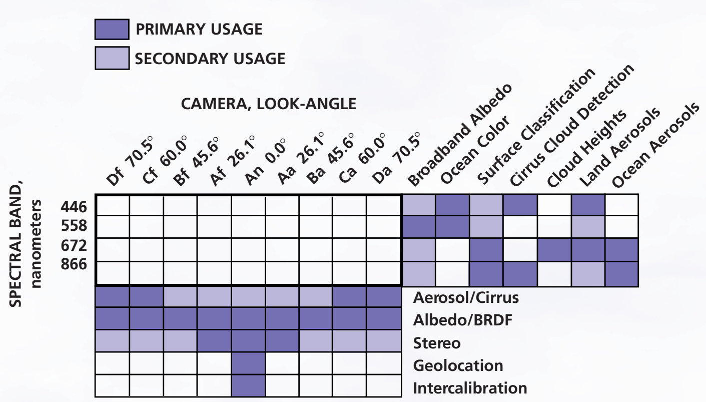
The scattering angle MISR observes is different for each camera, and also changes with the geographic latitude of the satellite (vertical axis in the figure) and the location across the MISR image (horizontal axis). Each swath is 360 kilometers (224 miles) wide. This illustration shows the situation for March 21 and the nominal EOS AM-1 satellite orbit. Imaging extends to 82 degrees latitude. The pattern remains nearly the same, but shifts poleward during the solstice seasons.

MISR is unique as a satellite instrument because it covers such a wide range of scattering angles.



How We Will Use Our Nine Cameras and Four Bands

This diagram illustrates the roles played by each of the nine cameras and four color bands (36 combinations) in MISR science. Each MISR camera corresponds to one labeled column. In the lower part of the figure, colored boxes indicate that the corresponding camera is used for the science objective to the right. For example, the "An" camera (which looks straight down) is needed to geolocate MISR images, and for "intercalibration" with other instruments. The terms "Albedo" and "BRDF" refer to ways that a surface reflects light.



Each of the MISR color bands corresponds to one of the labeled rows in the figure. On the right side, colored boxes indicate that the corresponding color band is needed for the science objective at the top. For example, the 672-nanometer (red) and 866-nanometer (near-infrared) bands are used to detect aerosols over the ocean, since the ocean surface is darkest in these bands, making bright aerosols easier to see.

The MISR Instrument

The MISR instrument is the size of a steamer trunk, and weighs 149 kilograms (328 pounds). To meet its scientific objectives, MISR will measure Earth's brightness in four color bands, at each of nine look angles spread out along the flight path in the forward and aft directions. The nine separate cameras within the instrument are arranged for compactness in the shape of a "V-9" engine. In the artist's rendition showing a cutaway view of the MISR instrument, the nine cameras appear as yellow cylinders. In this orientation, MISR would look down toward Earth.

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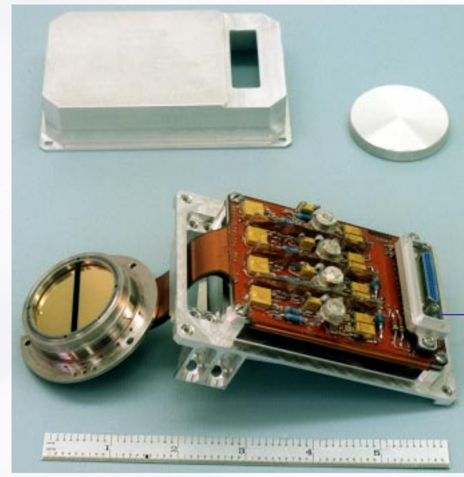
MISR will orbit the Earth about 705 kilometers (438 miles) above the ground. During a period of seven minutes, a 360-kilometer (224-mile) wide swath of Earth will successively come into the view of each of the nine cameras, as the instrument flies by. It takes nine days to cover the globe. MISR can see objects on the surface of Earth as small as 275 meters (902 feet), about the size of a major-league baseball stadium. (This is the "spatial resolution" of MISR.)

To improve the scientific value of the data, special attention has been paid to accurately measuring the instrument's sensitivity to light, which may change during its lifetime. This high absolute and relative radiometric calibration accuracy is achieved using onboard reflecting surfaces that, when commanded to move into position, will reflect sunlight into the cameras, and simultaneously into an additional set of light-detecting sensors designed to check the camera response.

MISR will fly together with four other instruments on NASA's EOS AM-1 satellite. Three of the instruments will measure quantities related to Earth's energy budget, covering aspects of both reflected sunlight and thermal energy emitted by Earth. When the satellite is on the day side of Earth, its orbit crosses the equator at about 10:30 A.M. local time. EOS AM-1 is scheduled for launch in 1999; the instruments are all designed to operate for at least six years.

Focal Plane Assembly



This is a detector from one of the MISR cameras (disk-shaped object with slit). The detector is attached to a rectangular "camera head" electronics package that is about 10 centimeters (4 inches) long. The cover for the electronics package can be seen in the background. This collection of parts is called the Focal Plane Assembly, since the detector belongs at the focus of the camera lens.

Beneath the detector slit are strips of light-sensitive, solid-state material. Each strip is divided into 1,504 light-sensitive spots called "pixels" that will produce line after line of a MISR image as the sweep of the satellite orbit carries MISR around the Earth. (For this reason, MISR is called a "push-broom" camera.) There are four closely spaced strips in each detector, one for each of the MISR color bands. Since there are nine cameras altogether, MISR produces 36 images simultaneously. (JPL-23831Ac)

Camera and Support Electronics

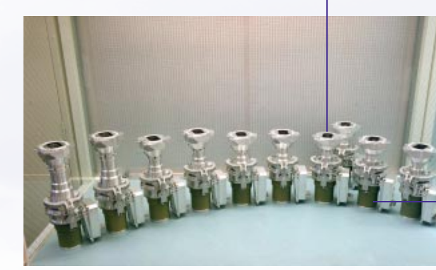
This is one of the nine MISR cameras, completely assembled, together with its support electronics. Each camera is a self-contained unit that was tested and calibrated independently before it was added to the MISR Optical Bench. The small rectangular box

attached to the side of the camera barrel, a part of the Focal Plane Assembly, is about 10 centimeters (4 inches) long. The camera in this image is one of the MISR "A" cameras, which have the shortest telescopes, and when mounted on the instrument, will look nearly directly down toward Earth. (JPL-28033Bc)

MISR Instrument Description

Parameter	Value
Camera View Zenith Angles at Earth's Surface	0.0 degrees (nadir) 26.1, 45.6, 60.0, and 70.5 degrees (both fore and aft of nadir)
Swath Width	360 kilometers (224 miles) (9-day global coverage)
Cross-Track × Along-Track Pixel Sampling (Commandable)	275 × 275 meters (902 × 902 feet) 550 × 550 meters (0.34 × 0.34 mile) 1.1 × 1.1 kilometers (0.68 × 0.68 mile) 275 × 1.1 kilometers (0.17 × 0.68 mile)
Spectral Bands (Solar spectrum weighted)	446.4, 557.5, 671.7, 866.4 nanometers
Spectral Bandwidths	41.9, 28.6, 21.9, 39.7 nanometers
Charge-Coupled Device Sensor Architecture	4 lines × 1504 active pixels (Each of 9 cameras)
Absolute Radiometric Uncertainty	3 percent (1 sigma) at maximum signal
Mass	149 kilograms (328 pounds)
Power (worst case)	83 watts (average); 131 watts (peak)
Data Rate	3.3 megabits per second (average)

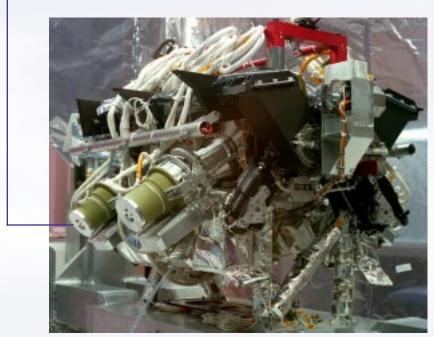
"Family Portrait"



Here are the nine MISR cameras (plus one "spare" camera) in 1996, before they were attached to the MISR instrument. The two cameras designed to look at the steepest angles, called the "D forward" and "D aft" cameras, have the longest telescopes. A spare camera was used to build AirMISR, an instrument designed to fly in an airplane to help interpret the data from the spacecraft instrument. (JPL-28033Ac)

Optical Bench

This is the "science part" of the MISR instrument. It includes the cameras and calibration equipment. The photograph was taken in October 1996, as MISR was being assembled. Subsequently, the parts



that supply power, communications, and onboard data processing were added. The entire package was then encased in a protective housing, which was covered with highly reflective thermal blankets. The Earth-viewing orientation is up in this photograph. (JPL-28109Ac)

THE MISR Validation Program

Currently, satellite instruments provide our best hope of making, at a reasonable cost, the routine global observations of aerosol, cloud, and surface properties needed to assess their climatic effects. But satellite instruments must rely on remote sensing — the study of light collected at a distance from the Earth's surface and lower atmosphere.

How will we know if we are interpreting the MISR measurements correctly? This is the goal of the MISR Validation Program.

One of the main tools in the Validation Program is an instrument called AirMISR, which was built largely of spare parts from the MISR instrument. AirMISR contains a single camera on a rotating mount so it can view Earth at multiple angles. It flies at a height of about 20 kilometers (over 65,000 feet), above the clouds that affect our weather, in the nose of a NASA high-altitude aircraft. To AirMISR, Earth looks much as it does from space. But unlike the satellite instrument, AirMISR can be cleaned and tested regularly in the laboratory. So, at times during the six-year MISR mission, AirMISR will fly under the path of its satellite sister, making measurements to check those from the satellite.

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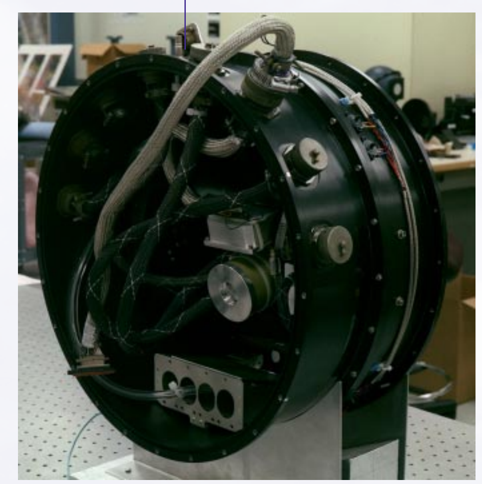
AirMISR was readied for flight in 1997. And since MISR is one of the first instruments designed to take multiangle images of Earth from space, AirMISR data are helping us develop methods to interpret multiangle observations even before the spacecraft version of MISR is launched.

Some of the most accurate measurements of atmospheric properties and surface characteristics can be made from the ground. Field measurements of sky brightness, aerosol properties, and ground reflectance are also part of the MISR Validation Program.

AirMISR Instrument and ER-2 Aircraft

AirMISR flies aboard the NASA high-altitude ER-2 aircraft. The photogaph above shows the instrument in its black cylindrical cover, mounted at the bottom of the aircraft just ahead of the cockpit, before an engineering test flight in April 1997. (P-48594)

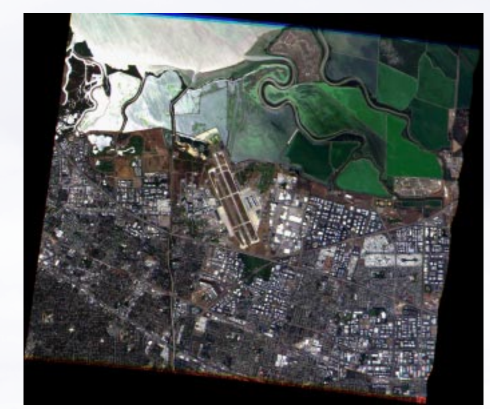
The image below is a close-up of AirMISR with the rear cover off, revealing internal cabling and the back of the camera. The cylinder is about 45 centimeters (18 inches) in diameter. (JPL-28762Ac)



These members of the MISR team are preparing to make field measurements at Lunar Lake, Nevada, early on the morning of June 5, 1996. They are working with a portable instrument that can measure light reflected by the surface in many color bands and at multiple view angles. In the course of the day, they carried parts of this instrument around the test site in a backpack, taking hundreds of surface measurements. (P-48455Ac)

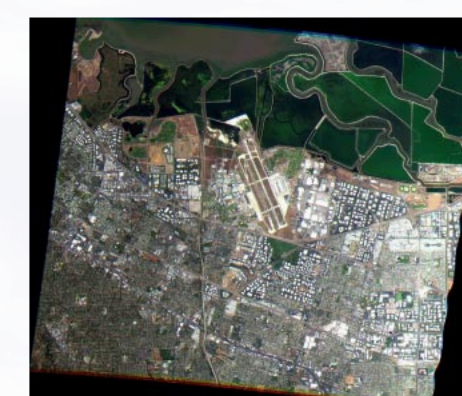
Sunset on a smoggy summer day in Los Angeles. You can see the tallest buildings in the downtown area poking up through the smog layer, and you may be able to just make out the Los Angeles River wending its way across East Los Angeles in the foreground. MISR will measure aerosol amounts globally, and will deduce some information about particle size, shape, and composition. (P48863A)

Views of Moffett Field, California, at Two Angles



These red/green/blue images of the area surrounding Moffett Field, California, were taken by the AirMISR instrument on August 25,1997. North is toward the top in the pictures, and the Sun is shining from approximately the south. For the image above, the camera was pointing 26.1 degrees forward of nadir, along the southward direction of flight. (P-49345Ac)

The image below was taken 26.1 degrees aft of nadir. Rivers and tidal areas are brighter in the image to the left, illustrating that these surfaces produce mirrorlike reflections. The images cover about 10 kilometers (6 miles) on a side, and show details as small as 8 meters (26 feet) in size. (P-49345Bc)



MISR

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The MISR instrument, covered with its protective gold blanket, is seen here as it was being tested in a simulated space environment at JPL in December 1996. The instrument will look much like this when it is flying in space; Earth would be toward the top of the picture. The black cover for the camera view ports is open, and for this test, a device placed over the instrument (curved metal object with cables at the top center of the box) provides a target for the cameras to image. Control equipment for the test electronics appears on the table in the foreground. (P-28315Ac)

For more information

Visit the MISR World Wide Web site:
http://www-misr.jpl.nasa.gov

The EOS project is managed by NASA Goddard Space Flight Center, Greenbelt, Maryland.

On the cover: MISR views Earth. This computer-generated image shows NASA's Earth-orbiting EOS AM-1 satellite with the MISR instrument on board. The direction of flight is toward the lower left. The actual location along Earth's surface to be imaged by each of MISR's nine cameras is illustrated here with a translucent surface. The background star field is also realistic. (P-49081)

Acknowledgments

Text: Ralph Kahn, MISR Science Team. Front cover image: Shigeru Suzuki and Eric DeJong, JPL Solar System Visualization Project. Photographs: P-48863A, P-48864A, P-48455Ac by Barbara Gaitley, MISR Team; P-48594 by Charles Sarture, MISR Team. Layout contribution: Lena Kahn. Editing: Marilyn Morgan, JPL Design Services; Design: Adriane Jach and Elsa King-Ko, JPL Design Services; Production: David Hinkle and Sophia Kim, JPL Design Services.

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JPL 400-732 6/98