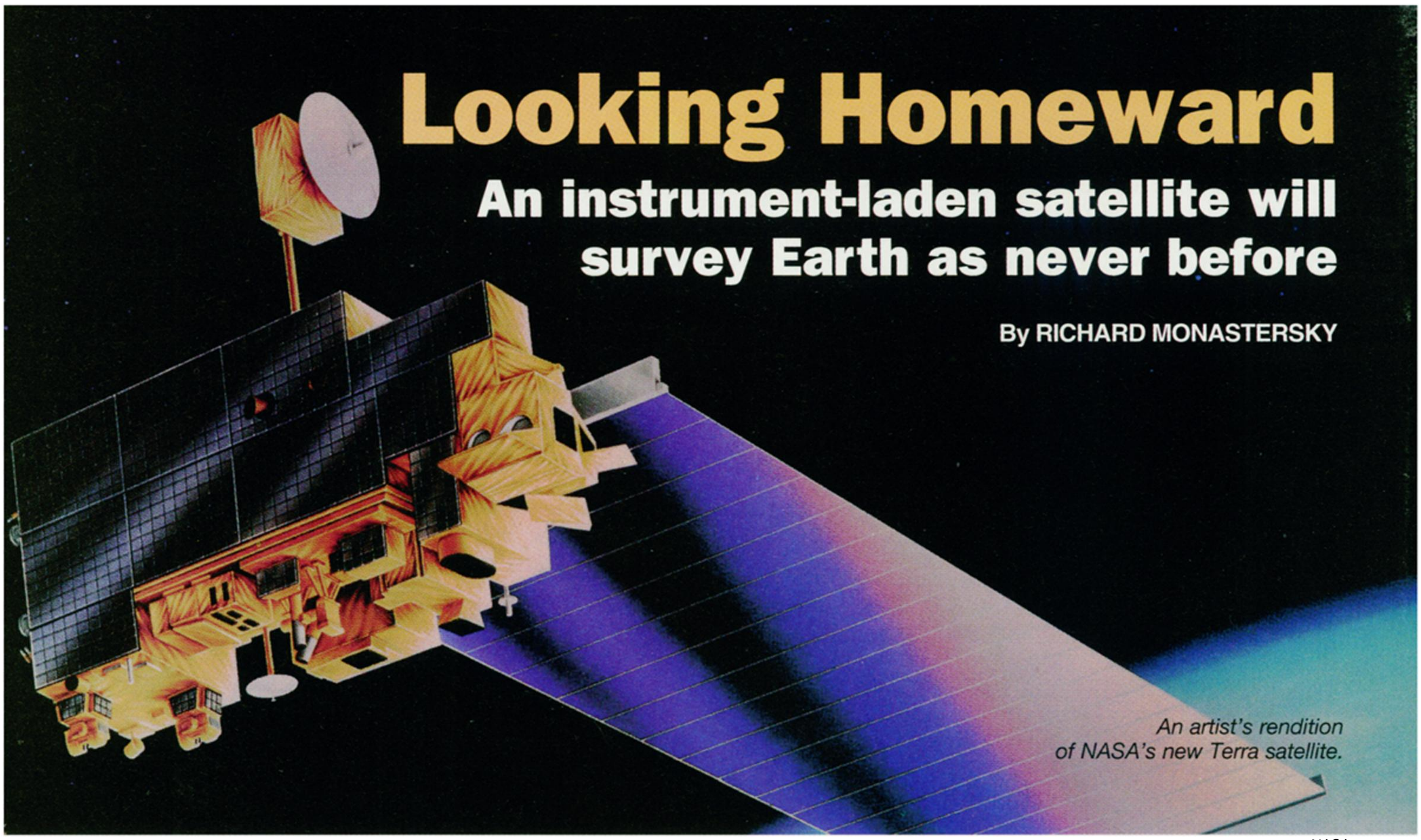

An artist's rendition of NASA's new Terra satellite.

NASA

Looking Homeward

An instrument-laden satellite will survey Earth as never before

By RICHARD MONASTERSKY

In a cavernous building just off the Pennsylvania Turnpike, a gleaming satellite called Terra rests like a princess on a bed of 400 springs, designed to smother all vibrations from the 18-wheelers speeding by. A team of technicians at the Lockheed Martin Missiles and Space facility has finished final tests on the spacecraft and is packing it up for a trip this week to the launch pad at Vandenberg Air Force Base in California.

If plans hold, NASA will launch Terra in 3 months. Once in orbit, the craft will train its five separate sensors on the big blue ball below that shelters nearly 6 billion people. As the cameras and telescopes begin sending back a flood of data from an altitude of 700 kilometers, they will usher in a new age in the study of Earth and its climate.

In glowing language, sometimes more reminiscent of politics than science, the space agency calls Terra "the flagship" of its Earth Observing System (EOS)—an 18-year-long program of unprecedented scope designed to explore the planet and assess its health.

"It's quite state-of-the-art in terms of capabilities, and it will give us new glasses to the environment," says Michael D. King, EOS senior project scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. "It will enable questions to be answered that haven't even been posed yet."

The launch of the satellite "marks the beginning of humankind's comprehensive monitoring of solar radiation, the atmosphere, the oceans, and the Earth's components from a single space-based platform," according to NASA. Terra and complementary future satellites, the agency says, will revolutionize climate-change models—the principal tools for forecasting temperatures and precipitation.

Earth scientists in general eagerly await the first data from Terra, yet the satellite has drawn criticism from many researchers who question this expensive, broad-brush approach to studying the planet. Some view the $1.2 billion craft as a bloated and blunt tool—more than a decade old in concept—that has eaten up too large a share of the federal budget for global-change research.

Last year, a report of the National Academy of Sciences held up Terra and its EOS sibling satellites as examples of how the federal government has lost a proper focus in studying global change.

The original plans for the EOS program emerged in the late 1980s, when NASA proposed sending up a fleet of titanic satellites to monitor all of Earth's vital signs over a period of 15 years. The first launch of the $15 billion to $30 billion program, originally scheduled for 1996, would have propelled a craft carrying 19 instruments into an orbit around both of Earth's poles.

NASA planned to build for launch in 1998 a second large polar-orbiting satellite with different sensors. European nations and Japan would each build craft to complement the U.S. platforms. Because the satellites had anticipated lifetimes of 5 years, NASA planned to send up identical replacements of each on at least two occasions to maintain a continuous vigil over the planet.

In the early 1990s, this grand—some would say grandiose—vision fell victim to U.S. budget deficits, which forced NASA to reduce the size of the polar orbiters and split up the instruments by placing them on different satellites. What emerged, after a series of critical reviews and redesigns, were plans for a trio of large—but no longer gigantic—platforms, which would be followed by a group of smaller, more focused missions.

As the first in the family, Terra was supposed to take off last year, but NASA delayed the launch after finding problems in the software system that controls the satellite.

Though smaller than originally planned, Terra is still the Swiss army knife of the satellite world. The 5.9-meter-long orbiter carries a bevy of cameras, telescopes, and other sensors designed to observe the shifting hues of Earth and its airy envelope.

At the leading edge of the 5-ton satellite rides an instrument called MODIS, for Moderate-resolution Imaging Spectroradiometer. The scanner senses visible light and infrared radiation at 36 different frequency bands, providing an unparalleled means of measuring such features as ocean plankton, vegetation on land, clouds in the atmosphere, and the temperature of the air.

"For a global sensor that sees the entire planet, we've never flown anything like this before," says King. Because MODIS has a wide field of view, it revisits each spot on the planet at least every 2 days.

Next in line comes ASTER, short for Advanced Spaceborne Thermal Emission and Reflection Radiometer. Built by Japan, this set of three telescopes has the sharpest vision of all the Terra instruments. It can provide stereo images with a resolution of 15 m for mapping landforms. Other data from ASTER report on clouds, sea ice, glaciers, and the temperature of Earth's surface. The instrument also gives information about what kinds of vegetation and rock cover the continents.

Amidships is a gaggle of nine cameras, collectively called MISR, for Multi-angle Imaging Spectro-Radiometer. Each camera stares in a different direction to measure vegetation, ground topography, and the types and heights of clouds.

MISR will also monitor changes in atmospheric aerosols—tiny droplets and particles that come from natural sources such as sea spray and from human-caused fires and pollution. Aerosols reflect sunlight and stimulate the growth of cloud particles, both of which can greatly influence Earth's climate. As such, aerosols have emerged as one of the major question marks in climate studies.

Canada contributed the fourth instrument, called MOPITT, for Measurements of Pollution in the Troposphere. The sensor gauges two crucial pollutants, carbon monoxide and methane, in the lowermost atmosphere.

The last set of scanners on Terra is CERES, for Clouds and the Earth's Radiant Energy System. Its two radiometers measure the amount of sunlight reflected off clouds and aerosols in the atmosphere as well as the amount of thermal radiation emitted from the ground and lower atmosphere.

Terra's array of instruments will help climate scientists address three primary areas of concern. By improving measurements of clouds, aerosols, methane, and atmospheric moisture, the satellite will provide a better measure of Earth's natural greenhouse effect and the extent to which humans have amplified the heat-trapping capacity of the atmosphere.

The second focus is on understanding how carbon dioxide shuttles among the oceans, atmosphere, and vegetation—a key to forecasting future shifts in climate. As a third objective, data from Terra will help scientists create maps of the land surface, a prerequisite for tracking changes caused by either nature or people.

The mapping measurements will dovetail with data collected by another satellite, called Landsat-7, scheduled for launch this week. The latest in a 25-year-long series of orbiters, Landsat-7 will provide extremely sharp images of Earth's surface that will reveal objects as small as a house.

Terra inaugurates the first phase of the EOS program, but its launch simultaneously signals the waning of the large-satellite era for climate science. NASA has plans to fly only two other comparably sized EOS polar orbiters. All the rest of the satellites will be trimmer craft holding just one or two instruments—in keeping with NASA Administrator Daniel S. Goldin's mantra "faster, better, cheaper."

The first of the two other large EOS satellites, a six-instrument, climate-sensing craft, is scheduled for launch in late 2000. Another orbiter will follow 2 years later with four sensors designed to measure atmospheric chemicals.

When EOS managers fashioned plans for these first three bulky satellites, they were responding to calls from researchers to attack the global-change problem on a broad front. The scientists wanted to gather as much information as possible over a long time span.

Although that approach has some merit, it was unrealistic and has harmed U.S. efforts to address the threat of climate change, according to the National Academy of Sciences. The academy's committee on global-change research and its board on sustainable development jointly issued a report last year critiquing the U.S. Global Change Research Program (USGCRP), which coordinates all federal studies of environmental change.

The philosophy of a broad attack, the report says, "has been a valuable and intellectually exciting goal, but it also has made the Program too diffuse and left it vulnerable. When budgets ceased to expand and began to contract, the Program was not well grounded or well integrated enough to scale back in a logical way."

Although NASA has put the EOS program on a crash diet by reducing the size of its satellites, the committee calls for a fundamental shift regarding EOS and the entire program.

"A data strategy is needed that emphasizes flexible and innovative systems—systems that are less costly than the current EOS core system, that appropriately reflect focused responsibility for data character, that provide open access to the scientific community and the public, and that rapidly track technological developments," says the report.

The academy committees also fault the USGCRP for permitting satellites to grab the lion's share of funding—61 percent in fiscal year 1998. Other important aspects of climate research are suffering, such as measurement systems that track conditions from the ground and from balloons, they say.

NASA

Room for two views. To get an example of how multiple images from the Terra satellite might appear, NASA put a stand-in for one of Terra's instruments on a high-flying aircraft. From an altitude of 20 kilometers, cameras collected these images of San Francisco Bay and the cities of Mountain View and Sunnyvale. The only difference: One image is from a camera pointing forward on the plane, the other, a camera pointing rearward. The differing light angles yield distinct colorations.

Another neglected area consists of so-called process studies, which are focused research efforts seeking to understand individual elements of the climate puzzle. Strikingly, the committees also report that the United States has lost the leadership position it once held in constructing computer models of the climate.

Some authors of the report make more pointed comments. "[Terra] is old technology. It gathers massive amounts of data without cutting the problem acutely with respect to diagnosing what is going on," says Harvard University atmospheric chemist James G. Anderson. "Scaling back and reducing EOS in scope isn't really the answer because you have to go after this from an entirely different point of view to solve the problem."

Instead of simply harvesting data, scientists need to pinpoint the most important questions and test individual hypotheses, Anderson says. As positive examples of focused federal research programs, he cites AIDS studies, the human genome project, efforts to understand stratospheric ozone loss, and investigations concerning El Niño.

"We cannot as a nation afford to run programs other than [in this] way," he says.

NASA has gotten the message from criticisms over the years and has responded to some by restructuring the EOS program. The agency will send up a series of small spacecraft designed to address particular problems, such as changes in solar radiation, ocean circulation, and polar ice sheets.

By all accounts, EOS as currently structured will fail to deliver in one important respect: It will not measure how the planet's climate is changing over the long term.

Although NASA originally regarded EOS as a monitoring mission, the redesigns of the early 1990s shifted the emphasis toward understanding how the many different facets of atmosphere, land, and ocean interact. Lost by the wayside were plans to track land temperatures, sea temperatures, cloud cover, and other critical indicators of the planet's health. Although debate concerning the planet's temperature has simmered since the 1980s (SN: 3/15/97, p. 156), the USGCRP lacks a coherent plan for determining how quickly the globe is warming.

"We as a country do not have a strategy for making long-term climate-relevant measurements," says Berrien Moore III, an EOS investigator from the University of New Hampshire in Durham. "And if we don't begin to put that strategy into place, then EOS really will not achieve what it should. . . . That would be a very grave error." Chairperson of the National Academy of Science's committee on global-change research, Moore played a substantial role in devising the original EOS plans that he now admits were "fundamentally flawed."

Despite the decade of criticisms leading up to this summer's launch and the lingering questions concerning the future, Moore and others agree that Terra will provide scientists with completely new ways of looking at Earth. By observing the same point simultaneously with so many instruments, it will enable researchers to examine the ties between different facets of climate, exploring such topics as how temperature affects tree growth and vice versa.

"It's a wonderful opportunity," says Inez Y. Fung, director of the Center for Atmospheric Sciences at the University of California, Berkeley, who formerly criticized the U.S. program.

Fung, now part of the EOS team, likens the Terra launch to sending a patient to the hospital for a full, and costly, examination. "Maybe this is our only chance to check Earth into the Mayo Clinic to get a thorough scan of everything we can," she says. □

Biomedicine

Genetic variation helps ward off AIDS

Diversity is good. That's not a politically correct conclusion but a medical one. Scientists have begun to study how people's genetic variation may slow the speed at which an HIV infection leads to AIDS (SN: 8/16/97, p. 103).

"A few years ago, we really didn't have any genes that we knew influenced the outcome of an infectious disease. Now, we have a handful," says Stephen J. O'Brien of the National Cancer Institute in Frederick, Md., a leader in the effort.

In the March 12 SCIENCE, O'Brien and his colleagues report that HIV-infected people with a limited repertoire of so-called HLA genes are likely to develop AIDS within 3 to 5 years rather than the usual 10 or so. The researchers also found a quicker progression to AIDS in people having either of two particular HLA genes, even if they have diversity within their HLA genes.

HLA genes encode proteins that help cells present pieces of invading viruses or bacteria as targets for the immune system to attack. Each of the dozen or so HLA genes that people carry comes in many slightly different forms, or alleles. Some of these genes have more than 100 alleles. People typically inherit different HLA alleles from each parent, but a mother and father occasionally pass on the same HLA allele. Those cases, known as HLA homozygosity, seem to pose a threat.

Scientists have long suspected that having a diverse set of HLA genes allows people to present a wider range of targets to their immune system, but finding proof was tough. O'Brien's group now has examined the variation among three HLA genes (*A*, *B*, and *C*) in nearly 500 HIV-infected people. Those with different forms of all three genes—adding up to six different HLA alleles—avoided AIDS on average for 10 to 12 years, and many stayed healthy even longer. "If you're optimally represented with HLA types, you'll have a better defense against a virus that changes a lot, like HIV," concludes O'Brien.

He's now studying why having at least one of the HLA alleles called *B*35* and *Cw*04*, even if the person isn't homozygous for it, makes one vulnerable to rapid AIDS progression. Since almost half of the population is homozygous at one of the three HLA genes or has a *B*35* or *Cw*04* allele, O'Brien says it's crucial to know how these genes influence HIV infections.

Identifying such genetic factors, he adds, should help in the evaluation of new AIDS drugs and vaccines. People who don't respond may have a vulnerable genome. —*J.T.*

Misplaced DNA generates problems

Autoimmune diseases largely remain a mystery. Infections or injuries often precede autoimmune attacks, but how can those events make the body attack its own tissues?

Misplaced DNA inside cells may lead them to rally the immune system to destroy normal tissues, suggests Leonard D. Kohn of the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md. In the March 2 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, he and his colleagues show that introducing DNA into a cell's cytoplasm—rather than the nucleus, where most genetic material resides—triggers changes that scientists had overlooked.

In response to the added DNA, the cell turns on genes usually employed only by specialty cells that display targets for the immune system to attack. Since viruses often introduce their DNA into a cell's cytoplasm, and damaged cells may have their DNA leak out of the nucleus, Kohn's finding may explain why infections and tissue injuries are associated with autoimmunity.

The results may also indicate why gene therapy has had little success. Viruses are often used to deliver the genes to the cytoplasm, and frequently the immune system later destroys the cells that have received the DNA. Scientists are studying compounds that may suppress the changes brought about by DNA in the cytoplasm, says Kohn. —*J.T.*